Upper Ohio Navigation Study, Pennsylvania
Draft Feasibility Report

Appendix B

PROJECT ECONOMICS

Fact Sheet: Update of Upper Ohio economics due to update of project costs from Oct 14 to Oct 15 price level for inclusion in Chief's Report

Dated 8 Aug 2016

The Civil Works Review Board (CWRB) approved the recommendation for construction of the Upper Ohio Navigation project in 2014. However the study team was instructed to make changes to assumptions affecting lock closure durations prior to release of the report for State and Agency Review. The changes were made by the team and reviewed and approved by Headquarters in June 2016. The construction costs and economics of the recommended project were then updated from an October 2014 price level to an October 2015 price level. The results of these updates are presented in this paper.

Construction costs at the October price levels increase from $2,320,082,000 to $2,648,471,000, a 9% increase. The economics were computed with the Oct 15 costs using four discount rates: the FY 11 rate of 4.125% used in the original study; the FY 14 rate of 3.5% used in report submitted to the CWRB, the current FY 16 rate of 3.125%, and the OMB preferred rate of 7.0%. The economics are lower with the October 2015 costs than the October 2014 price level because the 9% increase in costs exceeded the increase in benefits. Table 1 is a summary table showing the economics using costs at October 2015 price level and at October 2014 price level.

Table 1: Economics with Oct 15 costs (Ave Ann Values; thsds of dollars)				
	FY16 Discount Rate	FY14 Discount Rate	FY11 Discount Rate	OMB Discount Rate
	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 350.5	$ 341.5	$ 327.2	$ 272.3
Incremental costs over WOPC	$ 95.0	$ 103.3	$ 117.7	$ 192.0
Incremental net benefits	$ 255.5	$ 238.3	$ 209.5	$ 80.3
BCR	3.7	3.3	2.8	1.4
Note: Total Project First Cost at Oct 15 Price Level = $2,648,471,000				
Economics with Oct 14 costs (Ave Ann Values; thsds of dollars)				
	FY16 Discount Rate	FY14 Discount Rate	FY11 Discount Rate	OMB Discount Rate
	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 355.7	$ 346.6	$ 332.1	$ 276.3
Incremental costs over WOPC	$ 83.2	$ 90.5	$ 103.1	$ 168.2
Incremental net benefits	$ 272.5	$ 256.1	$ 229.0	$ 108.1
BCR	4.3	3.8	3.2	1.6
Note: Total Project First Cost at Oct 14 Price Level = $2,320,082,000				
Note: WOPC is without project condition; Increments are changes of 'with' recommended project condition over the without project condition.				

Fact Sheet: Update of Upper Ohio economics due to longer downtimes between failures and repairs

Dated 18 Apr 2016

1. Background: The consensus of the Civil Works Review Board (CWRB) and the independent external peer review (IEPR) members was that the downtimes between failure and repairs used in the study were based on overly optimistic assumptions that should be reconsidered. In response the project delivery team (PDT) developed alternative downtimes that were reviewed and approved for use by Headquarters. The effects on the economics of the use of the original and alternative durations are presented in Table ES-1. The original durations are referred to as the "short durations" and the alternative durations as the "long durations" in the table.

2. Revised economics: The economics were computed at four discount rates: the FY 11 rate of 4.125% used in the original study; the FY 14 rate of 3.5% used in report submitted to the CWRB, the current FY 16 rate of 3.125%, and the OMB preferred rate of 7.0%. In sum, the BCRs decrease as the discount rate increases. A full accounting of the original and updated values is given in Attachment 9 to the Economics Appendix. Table ES-1 is a summary table showing the values in the report submitted to the CWRB and the updated values from this evaluation that were used to replace the CWRB report values in a revised (2016) feasibility report.

Table ES-1: Certified costs at Oct 14 dollars; report submitted to CWRB; updated values

Short durations used in CWRB report				
Cost = $2,320,082,000	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 226.1	$ 220.1	$ 210.3	$ 171.1
Incremental costs over WOPC	$ 82.0	$ 89.2	$ 101.8	$ 166.4
Incremental net benefits	$ 144.1	$ 130.9	$ 108.5	$ 4.7
BCR	2.8	2.5	2.1	1.0
Long durations developed and evaluated in response to IEPR and CWRB comments				
Cost = $2,320,082,000	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 355.7	$ 346.6	$ 332.1	$ 276.3
Incremental costs over WOPC	$ 83.2	$ 90.5	$ 103.1	$ 168.2
Incremental net benefits	$ 272.5	$ 256.1	$ 229.0	$ 108.1
BCR	4.3	3.8	3.2	1.6

Fact Sheet: Update of Upper Ohio economics at Oct 2014 price level

Dated 26 Aug 2014

1. Costs: The total project cost (TPC) of the recommended plan in the report was $2.1 billion at the October 2013 price level. The TPC was recently updated and certified at October 2014 price levels at $2.3 billion, or 8.2% higher than the October 2013 estimate.

Table 1: Total Project Cost of Recommended Plan			
	Oct 2013	Oct 2014-certified	% change
Emsworth	$ 713,940,431	$ 737,141,000	3.2%
Dashields	$ 704,625,954	$ 800,691,000	13.6%
Montgomery	$ 725,120,760	$ 782,250,000	7.9%
Total	$ 2,143,687,146	$ 2,320,082,000	8.2%

2. Benefits: The benefits of the recommended plan were also updated to October 2014 price levels in order to provide up-to-date economics. The benefits decreased 3.5% due to a reduction in the savings of barge transportation compared to rail and truck.

Table 2: Benefits of Recommended Plan (millions of dollars)			
	Oct 2013	Oct 2014-certified	% change
Total	$ 569.4	$ 549.7	-3.5%

3. Economics: The economics of the tentatively recommended plan decreased from a benefit to cost ratio of 2.9 to 2.6 as shown in Table 3 at the fiscal year 2014 discount rate of 3.5%.

Table 3: Economics of recommended plan - Oct 2013 and Oct 2014 (Average annual values; millions of dollars)			
	Oct-13	Oct-14	Change
Incremental values	$ -	$ -	
Costs	$ 90.1	$ 97.5	8.2%
Benefits	$ 257.7	$ 248.7	-3.5%
Net benefits	$ 167.5	$ 151.2	-9.8%
BCR	$ 2.9	$ 2.6	-10.8%

Fact Sheet: Update of Upper Ohio economics to Oct 2013 price level

Dated 12 Feb 2014

1. Background: The costs used in the evaluation were at a venture level of detail and at October 2009 price levels with a base year of 2020. The evaluation resulted in the identification of a plan involving the construction of new 600’ x 110’ chambers to replace the existing 360’ x 56’ chambers and the maintenance of the old 600’ chambers as auxiliary chambers at all three projects as the national economic development (NED) plan. Based on a consideration of the economics and other planning criteria, this plan was selected as the tentatively recommended plan. The costs of this plan were then developed at a higher level of detail using M-CACES procedures and software. The initial M-CACES costs were expressed in Oct 2010 dollars and have seen been updated to Oct 2013 price levels to reflect inflation and some minor changes in construction costs. The venture level costs used in the study, the M-CACES at October 2010 price levels, and the M-CACES at October 2013 price levels are listed in Table 1. The base year has also been updated from 2020 to 2025.

Table 1: Total Project Cost – Venture Level and M-CACES Costs for Recommended Plan
(thsds of dollars)

Cost level	Venture	M-CACES	M-CACES
Price level	Oct 2009	Oct 2010	Oct 2013
Total project cost	$ 1,479,000	$ 1,923,641	$ 2,143,687

2. Results: The economics of the tentatively recommended plant decreased because the costs increased 45 percent from 2009 to 2013 while the transportation benefits increased only 22 percent. The economics are shown in Table 2 at the then official discount rate (4 1/8% at time of feasibility computations and 3 1/2 % in 2013) and at 7%, which is the rate preferred by OMB. The updated BCR is 2.9 at 3 1/2% and 1.2 at 7%.

Table 2: Economics using venture level and M-Caces costs
(Ave Ann Values; millions of dollars)

	Venture		**M-Caces@Oct-2013**	
	4 1/8%	7 %	3 1/2 %	7 %
Without				
Costs	$ -	$ -	$ -	$ -
Benefits	$ 249.6	$ 312.6	$ 311.7	$ 438.9
Recommended plan				
Costs	$ 64.9	$ 106.1	$ 90.1	$ 182.4
Benefits	$ 433.5	$ 462.2	$ 569.4	$ 650.2
Incremental values				
Costs	$ 64.9	$ 106.1	$ 90.1	$ 182.4
Benefits	$ 183.9	$ 149.6	$ 257.7	$ 211.2
Net benefits	$ 119.0	$ 43.5	$ 167.5	$ 28.8
BCR	2.8	1.4	2.9	1.2

Executive Summary

The proposed reinvestment in the upper Ohio navigation system was evaluated according to the general guidance for the economic evaluation of navigation projects outlined in Engineer Regulation (ER) 1105-2-100 dated 22 April 2000. The upper Ohio infrastructure is defined as Emsworth, Dashields and Montgomery (EDM) locks and dams. They are the oldest and smallest lock projects on the Ohio River, having been built prior to World War II. Two major problems associated with EDM are deteriorated structural condition leading to reduced service reliability, and insufficient auxiliary lock capacity when the main lock chamber is closed for maintenance or repair.

A total of five plans were evaluated representing different combinations of maintenance and lock construction. Benefits and costs are expressed at an FY 2009 price level and were discounted and annualized using the Fiscal Year 2011 interest rate of 4 1/8 %. The economics of the plans for the Mid Case forecast are listed in the following table. The benefits and costs are incremental to the without-project condition.

The plan that provides the greatest positive net benefits is designated as the National Economic Development (NED) plan. The NED plan for the upper Ohio is the immediate replacement of the existing auxiliary chambers with 600'x110' chambers at each project accompanied by reactive maintenance of the existing 600' locks (LMA 7).

Economic Feasibility of Alternative Plans
Average Annual Equivalent Values
Mid Case Traffic Forecast
(Millions of dollars; FY 09 price level; 4 1/8 %)

		Incremental			
Plan Description/Designation	Rank	Benefits	Costs	Net Benefits	BCR
600' Chamber & FAF Old (LMA 7)	1	183.8	64.9	118.9	2.8
Dual 600s w/ Lagged 2nd Lock (LMA 1)	2	184.2	70.4	113.8	2.6
800' Chamber & FAF Old (LMA 8)	3	178.8	76.5	102.3	2.3
Advance Maintenance (AMA)	4	114.7	38.1	76.6	3.0
1200' Chamber & FAF Old (LMA 9)	5	167.5	92.3	75.2	1.8

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ATTACHMENTS

1. Ohio River Navigation Investment Model (ORNIM)
2. Upper Ohio Feasibility Capacity Attachment
3. Traffic Demand Forecasts
4. Transportation Rate Analysis
5. External Costs of Diverted EDM Traffic
6. Procedures Used for Economic Update
7. Economic Update and Analysis (2014)
8. IEPR - revised economic tables; coal sourcing; economic updates; and equilibrium tables (2014)
9. Supplemental Report - Update of Economics in response to Reviews by IEPR Panel and CWRB (2016)

Section 1: INTRODUCTION

1.1 BACKGROUND

The Upper Ohio Navigation Study, Pennsylvania (Upper Ohio Study) is a planning study to consider and evaluate the feasibility of navigation improvements and ecosystem restoration opportunities on the upper Ohio River. The upper Ohio River infrastructure is defined as Emsworth, Dashields and Montgomery (EDM) locks and dams. They are the oldest and smallest lock projects on the Ohio River, having been built prior to World War II. Two major problems associated with EDM are deteriorated structural condition leading to reduced service reliability, and insufficient auxiliary lock capacity when the main lock chamber is closed for maintenance or repair.

Table 1-1 presents general lock and dam specifications for the facilities at EDM. The 600'x110' main chambers at EDM are one-half the length of the main chambers at the other 17 Ohio River facilities and the 360'x56' auxiliary chambers are smaller than the 600'x110' typical auxiliary chamber size on the rest of the Ohio River.

TABLE 1-1 - Upper Ohio Lock Specifications

Lock & Dam Project Name	River Mile	Year Operational			Year Rehabilitated			Chamber Size	
		Main	Aux	Dam	Main	Aux	Dam	Main	Aux
Emsworth	6.2	1921	1921	1922	1984	1984	1984	600x110	360x56
Dashields	13.3	1929	1929	1929	1990	1990	1990	600x110	360x56
Montgomery	31.7	1936	1936	1936	1989	1989	1989	600x110	360x56

1.2 PURPOSE

The purpose of this economic evaluation is to determine the economic feasibility of various alternative re-investment plans and to identify the National Economic Development (NED) plan. The focus of the current study is the current disposition and expected future performance of the three uppermost projects on the Ohio River. The study evaluates alternative plans that include different levels of operation and maintenance as well as planned improvements. The economics are positive if the benefits of a plan exceed its costs with the difference referred to as the net benefits. The alternative with the greatest positive net benefits is designated as the NED plan. The NED benefits are a major consideration in selecting the recommended plan.

1.3 GUIDANCE

The general guidance for the economic evaluation of navigation projects is Engineer Regulation (ER) 1105-2-100 entitled "Planning Guidance Notebook" and dated 22 April 2000. Specific guidance for projects with reliability related problems is provided in Engineering Pamphlet (EP) 1130-2-500 entitled "Partners and Support (Work Management Guidance and Procedures)" dated 27 Dec 1996. These two documents (**Table 1-2**) were the principle guides for performing the Upper Ohio economic analysis.

TABLE 1-2 - Guidance Documents for Economic Evaluation

Reference	Title	Date	Comment
ER 1105-2-100	Planning Guidance Notebook	22 April 00	General procedures for economic evaluations of inland navigation projects
EP 1130-2-500	Partners and Support	27 Dec 96	Specific guidance for reliability related problems.

1.4 STUDY AREA

The first step in the study evaluation was to define the study area. This was done by identifying the geographic limits that contain a significant portion of the docks, mines, and industrial facilities that ship or receive goods that are transported through the three upper Ohio projects. Based on an examination of traffic flows, the primary study area was defined as the area between the Huntington, WV in the south to the heads of navigation on the Allegheny and Monongahela Rivers in the north. The secondary study area is the entire Ohio River navigation system, of which the upper Ohio projects are an important link. Maps showing the primary and secondary study areas are provided as **Figures 1-1 and 1-2**.

FIGURE 1-1 - Map of Upper Ohio River Navigation System – Primary Study Area

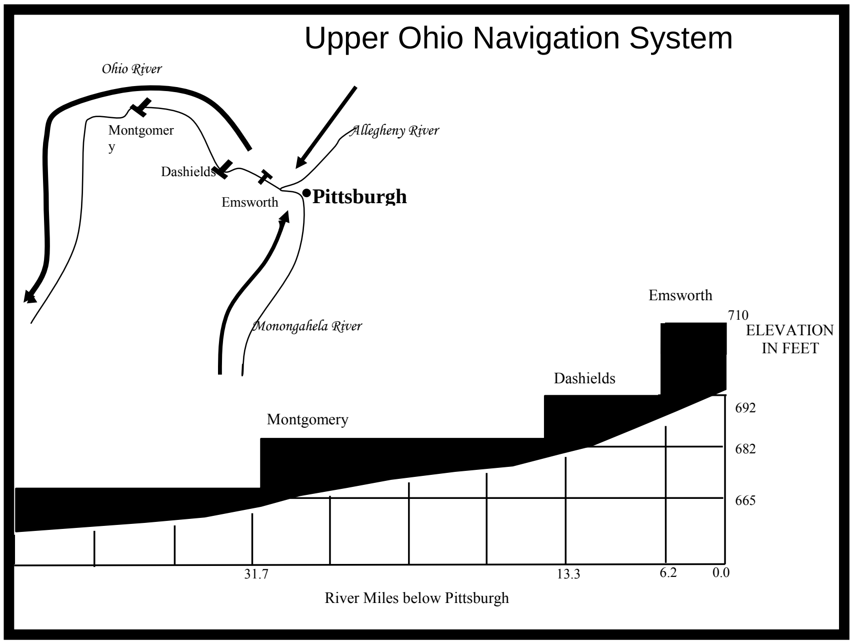
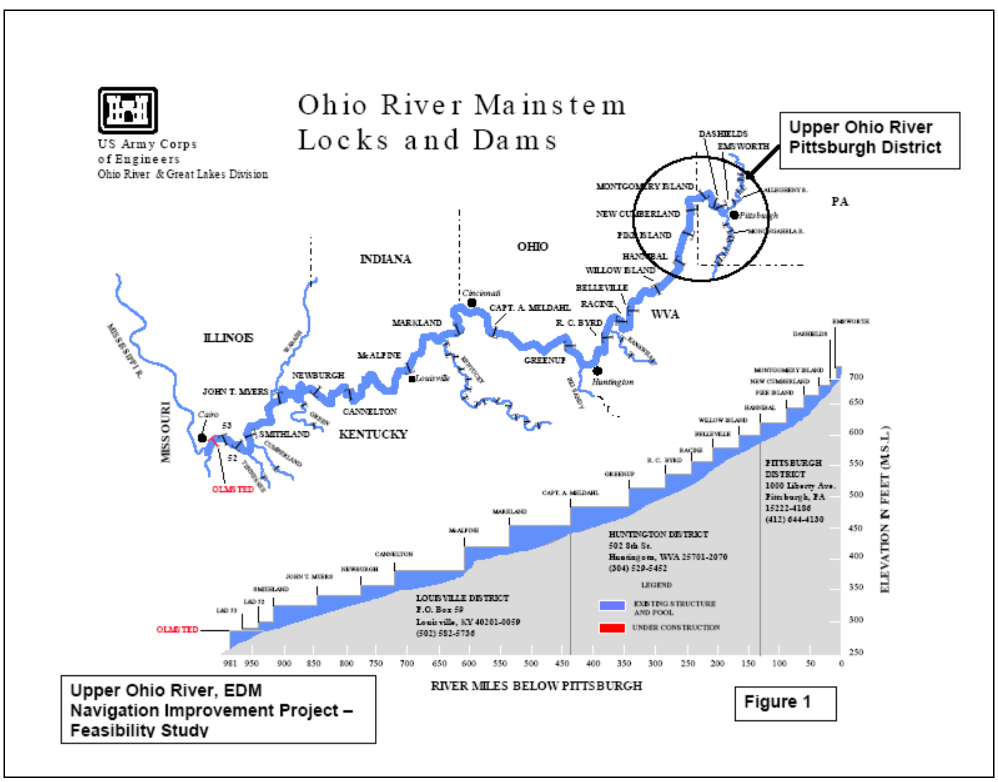


FIGURE 1-2 - Map of Ohio River Navigation System – Secondary Study Area



1.5 NAVIGATION PROJECTS

The Emsworth, Dashields, and Montgomery projects were evaluated as one integral subsystem for purposes of this study based on the close proximity of the projects and the high percentage of common traffic (**Table 1-3**). Over 91 percent of the traffic passes through all three projects and all three lie within 25.5 miles of one another.

TABLE 1-3 - Proximity of Projects and Commonality of Traffic

	Emsworth	Dashields	Montgomery	Average
2008 Tonnage in thousands	21,273	21,788	20,813	21,291
% Traffic Thru Other Projects:				
Emsworth thru	100%	97%	85%	94%
Dashields thru	97%	100%	86%	94%
Montgomery thru	85%	87%	100%	91%
Ohio River Mile	6.2	13.3	31.7	----
Distance in miles:				
Emsworth to	0.0	7.1	25.5	----
Dashields to	7.1	0.0	18.4	----

Source: COE Waterborne Commerce

Table 1-4 displays the commonality of 2006 EDM traffic to other selected Ohio River System (ORS) lock and dam projects.

TABLE 1-4 - Commonality of 2006 EDM Traffic With Selected ORS Projects

Project	Emsworth Traffic Thru	Other Project Traffic Thru Emsworth	Dashields Traffic Thru	Other Project Traffic Thru Dashields	Montgomery Traffic Thru	Other Project Traffic Thru Montgomery
Emsworth	100%	100%	97%	97%	85%	85%
Dashields	97%	97%	100%	100%	87%	86%
Montgomery	85%	85%	86%	87%	100%	100%
Allegheny L/D 2	5%	56%	5%	56%	3%	35%
Braddock	86%	92%	83%	89%	75%	80%
Charleroi	44%	71%	41%	66%	33%	53%
Gray's Landing	9%	40%	7%	29%	3%	12%
Winfield	8%	8%	7%	8%	8%	8%
Marmet	7%	9%	7%	9%	7%	9%
R.C. Byrd	55%	20%	55%	20%	62%	22%
Greenup	38%	11%	38%	11%	44%	13%
McAlpine	18%	7%	19%	7%	23%	8%
Myers	17%	5%	18%	5%	22%	6%
L/D 52	11%	2%	11%	2%	15%	3%
Kentucky/Barkley	7%	3%	7%	3%	7%	4%

SOURCE: COE Waterborne Commerce Statistics

The Emsworth, Dashields and Montgomery projects were constructed in the 1920s and 1930s. They were rehabilitated in the 1980s and have outlived their engineering design life. These navigation projects facilitate the transport of about 22 million tons of commodities annually and are vital links in the nation's freight transportation system. The greatest volumes of traffic consist of downbound steam coal produced in the Mon Valley coal fields, moving to power plants along the length of the Ohio River, with some moving as far as the Tennessee Valley. Another major flow is metallurgical coal moving upriver from the Kanawha Valley and Big Sandy area coal fields to coke plants in the Pittsburgh area. Coke is a vital ingredient in steel making. Steel moves downriver through EDM to distant markets within the US interior and to the Gulf Coast. Steel also moves upriver. A little comes from interior places but much of it – imported steel – comes from the Gulf Coast.

Table 1-5 displays EDM and Ohio River tonnage since 1970. Traffic has been fairly flat at EDM since peaking in the mid 1990s. Coal comprises 75 percent of EDM traffic. The restructuring of the regional steel industry is reflected in the relatively flat growth in overall traffic since 1975.

TABLE 1-5 - EDM and Ohio River Traffic since 1970
('000 tons)

Proj/River	1970	1974	1975	1980	1985	1990	1995	2000	2005	2008	Percent Change 1970-2008
Emsworth	24,076	24,707	22,094	21,202	17,246	23,068	23,075	22,335	21,178	21,273	-0.3%
Dashields	21,739	23,683	22,348	22,178	17,912	24,025	24,551	23,335	22,024	21,788	0.0%
Montgomery	19,697	22,111	20,759	21,799	19,012	25,447	25,515	25,974	23,142	20,813	0.1%
Ohio River	129,585	139,294	140,058	155,907	177,484	224,747	234,064	236,300	249,212	230,200	1.5%

Source: COE LPMS and WCSC data.

1.6 PROBLEMS AND OPPORTUNITIES

The primary problems associated with EDM are declining reliability and insufficient auxiliary capacity. Declining reliability stems from the deterioration of concrete and mechanical components that are necessary for lock operation. The small auxiliary chambers, additionally, do not provide sufficient capacity during main chamber closures. There are two major concerns with the physical condition of the lock wall concrete at EDM: 1) concrete deterioration below concrete overlays placed during major rehabilitations in the 1980s, and 2) questionable remaining effectiveness of metal anchors installed during those rehabilitations to prevent wall movements. Many mechanical components are either original equipment or utilize the same design as used during construction in the 1920s and 1930s. These mechanical components are subject to increasingly frequent breakdowns, and with many replacement parts no longer manufactured, are becoming very difficult and expensive to maintain. Reliability problems at EDM are necessitate closing the 600' x 110' main chambers for both scheduled and unscheduled maintenance, which in turn requires use of the very small 360' x

56’ auxiliary chambers to lock commercial traffic one barge at a time. Delay costs to navigation interests increase dramatically during main chamber closures. Table 1-6 displays total main chamber closure durations for repair or maintenance at EDM since 1986.

TABLE 1-6 - Main Chamber Closure Durations at EDM (Total Days)

Lock	1986-90	1991-95	1996-00	2001-05	2006-09
Emsworth	-	37.01	27.10	17.28	23.98
Dashields	133.29	-	3.76	3.70	29.54
Montgomery	45.33	-	40.16	30.01	-
Total	178.62	37.01	71.02	50.99	53.52

Addressing the numerous structural reliability problems associated with EDM provides the Corps an opportunity to work with stakeholders to improve the efficiency and safety of the upper Ohio navigation system while enhancing environmental sustainability through ecosystem restoration measures.

1.7 APPENDIX ORGANIZATION

The remainder of this appendix is organized into the following major topical sections: Section 2 describes the socio-economic, transportation and industrial characteristics of the study area. Section 3 describes the evaluation procedures. Section 4 describes the upper Ohio navigation system and the vessel fleet and performance characteristics of the upper Ohio River. Section 5 discusses historic traffic and projected traffic demands. Section 6 describes the system benefit evaluation process, including the system model used, major model inputs, and the results of model calibration. Section 7 identifies and evaluates the upper Ohio without-project condition. Section 8 identifies the alternative navigation improvement plans and Section 9evaluates these plans. Section 10 provides a sensitivity analysis for the NED plan.

Five attachments complement this appendix. Attachment 1 provides a thorough discussion on the economic system model used in the analysis. Attachment 2 discusses the tonnage-transit curves used in the economic analysis. Attachment 3 documents development of traffic demand forecast scenarios used in the analysis. Attachments 4 and 5 describe the transportation rates used in the analysis and the results of our efforts to estimate the external costs of diverted EDM traffic.

Section 2: STUDY AREA RESOURCES AND ECONOMY

2.1 INTRODUCTION

The focus of the Upper Ohio Navigation Study is the upper section of the Ohio River in the vicinity of Pittsburgh, Pa. The river is navigable due to dredging and the operation and maintenance of the Emsworth, Dashields and Montgomery locks and dam projects, which are located in the upper 31.7 miles of the 981-mile Ohio River. There are 17 lock and dams projects on the rest of the Ohio River for a total of 20.

The study area is centered on Pittsburgh, Pennsylvania, one of the nation's major metropolitan areas. Water and coal were the main contributors to the development of the Pittsburgh area as an industrialized urban complex and as the steel capital of the country. Coal production preceded steel production, and initially coal was distributed nationwide as a fuel for railroad locomotive car propulsion and other uses. Steel production followed coal production, and led to the establishment of Pittsburgh as a major steel producing center. The area's steel production capacity was relatively constant from the early twentieth century up to the 1980's, when market forces culminated in its near disappearance in the Pittsburgh area. Only two major raw steel producing plant remains in the Pittsburgh area.

With the demise of the local steel industry, the study area economy evolved into one principally dependent on services, particularly health care and education. The purpose of this appendix is to describe the changes in the area's economy and to assess how these changes affect the need for possible improvements to the area's navigation system.

2.2 RESOURCES

The study area contains extensive natural and man-made resources. Natural resources include coal, limestone and water. Man-made resources include rail, road, water, and air transportation systems, commercial and residential dwellings, bridges, dams, pipelines, electric grids and all the other structures and infrastructures of modern society. To varying degrees, all of these resources affect usage of the waterway system, some in a positive manner and some in a negative manner. These resources are discussed in this section, starting with population. To provide perspective, current demographic and economic values are compared to 1980 values, which reflect the era before the majority of the area's steel plants were closed.

2.2.1 Population

The population of the primary study area in 2008 was 3.1 million or about 10 percent of the basin total and about 1 percent of the national total. In both absolute and relative terms, the population of the study area has declined over at least the past three decades, as shown in

Table 2-1. As discussed in a later section, the decline is largely related to the demise of the area's steel-making capacity and the loss of steel industry and related jobs.

TABLE 2-1 - Population in Thousands

	U.S.	ORB	Study Area
1980	226,542	28,639	3,520
2008	304,060	32,533	3,119
Annualized % change	1.1%	0.5%	-0.4%
Source: http://www.census.gov/popest/counties/files/CO-EST2008-ALLDATA.csv http://www.census.gov/popest/archives/1980s/e8089co.xls			

2.2.2 Natural Resources

The natural resources of greatest significance to use of the region's waterway transportation system are the area's coal reserves and water supplies.

2.2.2.1 Coal Reserves

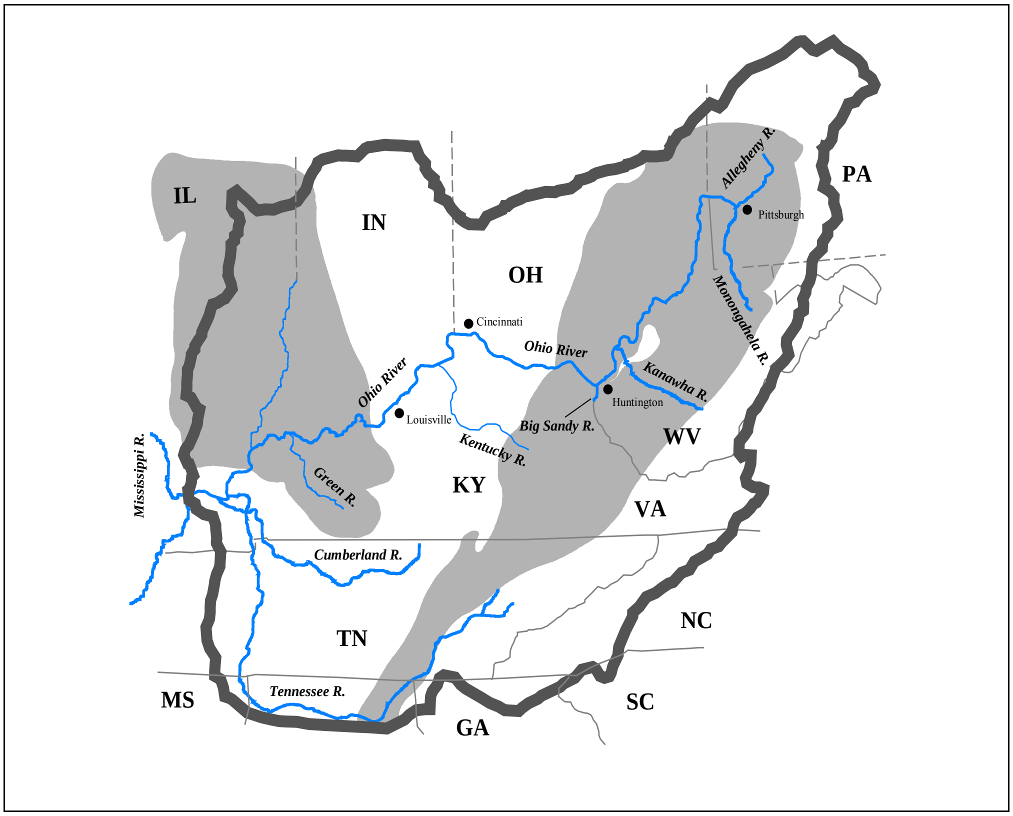
The study area includes most of the northern Appalachian coal fields that fueled over 100 years of economic growth and expansion both regionally and nationally. Coal reserves in the study area, region, and the nation are listed in **Table 2-2**. Both the study area and the basin contain significant reserves of coal. In fact, the Appalachian coals are included with the Powder River Basin deposits in the west and the Illinois Basin coals in the interior when discussing major U.S. coal deposits.

TABLE 2-2 - Coal Reserves in Billions of Tons

	U.S.	ORB	Study Area
Billion Tons	436.775	197.513	32.159
% of U.S.	100%	45%	7%
Source: Reserves data file provided by DOE. Last updated in 1977.			

A general overlay of coal deposits over the Ohio River Basin area is shown in **Figure 2-1**. Much of the coal field overlies the river system, particularly in the north where the study area is located.

FIGURE 2.1 - Ohio River Basin Coal Reserves



Despite over a century of mining, the area still contains large reserves of coal that are sufficient to meet the nation's expected needs for several centuries to come. At current production rates, the basin's reserves are sufficient to continue producing coal within the basin for the next 350 to 400 years.

2.2.2.2 Water Supply

Among the nation's rivers, the Ohio is second only to the lower Mississippi in terms of volume of flow. Rivers flowing out of the Appalachian Mountains and the Allegheny plateau (Monongahela, Allegheny, Kanawha, Cumberland, and Tennessee) contribute the greatest flow to the Ohio. However, its vast watershed is also drained by major streams like the Muskingum, the Scioto, the Little Miami, the Kentucky, the Green and the Wabash rivers. A system of reservoirs on these streams or their tributaries insures reliable flows for navigation and municipal and industrial water supply on the Ohio and its tributaries.

Withdrawals for municipal, agricultural, and industrial use for the nation, basin, and primary study area are shown in **Table 2-3**. The first project built on the Ohio River was constructed with the support of the Pittsburgh area steel industry for the principle reason of providing a reliable supply of water for the area's manufacturing plants.

TABLE 2-3 - Water Withdrawals from River System
(million gallons per day)

	U.S.	ORB	Study Area	EDM Pools
MGD	405,000	28,768	9,829	138
% of U.S.		7.10%	2.43%	0.03%
Source: unpublished Pittsburgh District report entitled "Water Intakes and Withdrawals from Navigation Pools within Ohio River Basin" dated Jan 2009.				

A detailed breakdown of withdrawals by navigation pool is provided in **Table 2-4**. Municipal withdrawals are highest in the Emsworth pool, which includes parts of the City of Pittsburgh, while industrial withdrawals are highest in the Montgomery pool, which includes several large electric generating plants. Within the basin as a whole, electric generating plants are the largest users of the waterway system for water supply, accounting for nearly 90 percent of total withdrawals. There are no records of withdrawals within the basin for irrigation purposes.

TABLE 2-4 - Water Withdrawals in Study Area by Type of User
(million gallons per day)

	Emsworth	Dashields	Montgomery	Total
Municipal	25.0	6.2	0	31.2
Industrial	25.1	0	81.9	107.0
Total	50.1	6.2	81.9	138.2
Source: unpublished Pittsburgh District report entitled "Water Intakes and Withdrawals from Navigation Pools within Ohio River Basin" dated Jan 2009.				

2.2.3 Man-Made Resources

The man-made resources of greatest significance to use of the region's waterway transportation system are the system itself and alternative transportation systems, the number and location of production facilities, the number and location of communities, and the number and location of other infrastructure, such as bridges.

2.2.4 Transportation Systems

The major transportation systems used to move solid bulk products are the inland navigation system, the highway system, and the railroad system. The region and study area are well served by all three systems.

2.2.4.1 Inland Navigation

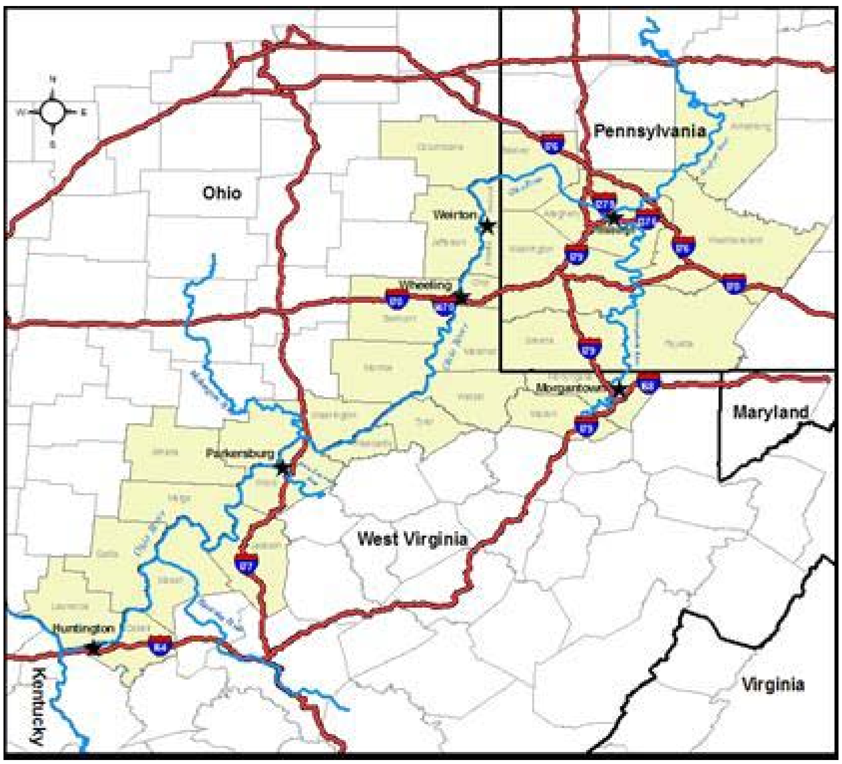
The inland navigation system extends throughout the Ohio River and Mississippi River Basins to the Gulf Coast from Florida to Texas, all of which can be reached by barges that move through the upper Ohio River projects (**Figure 2-2**).

FIGURE 2-2 - Inland Navigation System

2.2.4.2 Highways

The area is well served by roadways that not only connect municipalities, but also mining and other production sites. To illustrate the extensiveness of the roadway system without clutter, **Figure 2-3** below shows only the interstate system. Parts of five interstates are in the study area with two north-south and three east-west. These either straddle or bisect the Appalachian Mountains, which lie in the eastern portion of the study area.

FIGURE 2-3 - Highway System in Study Area



2.2.4.3 Railroads

The major commercial railroads in the study area are Norfolk Southern and Conrail (CSX). Combined, these systems serve or are in close proximity to every major municipal and industrial site in the area. To illustrate the coverage but without undue clutter, only the Norfolk Southern System is shown on **Figure 2.4**. The Norfolk Southern System is centered north-south on the Appalachian coal fields, rather than along the Atlantic Coast or in the Mississippi Basin. The railroad is heavily engaged in transporting coal to electric generating plants located throughout the eastern United States, as well as transporting imported and other goods to distributions points in the cities and elsewhere in the study area.

FIGURE 2.4 - Rail System in Study Area

2.2.5 Manufacturing Facilities

There are approximately 4,200 manufacturing facilities in the study area that employ over 150,000 workers, as shown in **Table 2.5**. The principle manufacturing facilities in terms of employment are for the generation of electricity and the manufacture of chemicals.

TABLE 2-5 - Number of Manufacturing Facilities in Study Area

River	Number	Employment
Allegheny	976	32,430
Monongahela	1,466	46,881
Ohio	1,762	73,578
Study Area Total	4,204	152,889
Source: Harris Directory		

2.2.6 Communities

Pittsburgh and Huntington have a combined population of about 350,000 or about one-third of the study area total. There are 20 other communities in the study area with populations that exceed 20,000, with most of these being located along the rivers. A summary of the number of communities and population by river and county is provided in **Table 2.6**.

TABLE 2-6 - Number of Large Communities in Study Area

River basin	Number	Population
Allegheny	3	103,506
Monongahela	9	253,460
Ohio	10	609,353
Study Area Total	22	966,319
Source: Census data.		

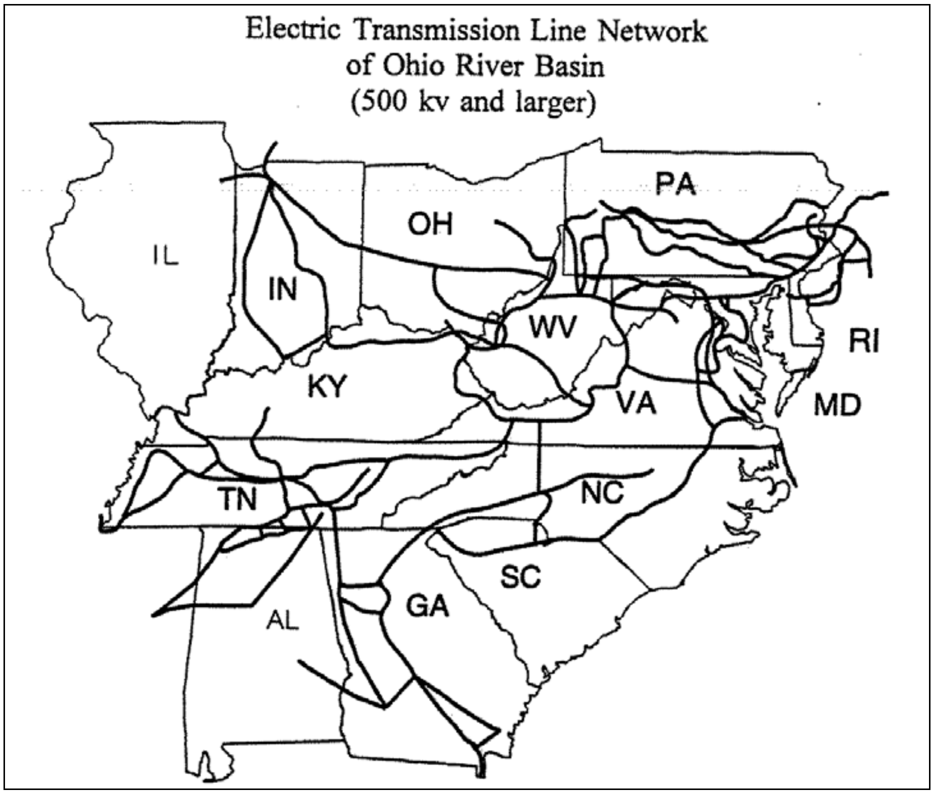
2.2.7 Infrastructure

The infrastructural systems of greatest importance to the navigation system are the regional interconnection electric transmission lines, bridges over the river, and docks along the river. The transmission lines allow the area to be a net exporter of electricity since it can generate the electricity at low cost within the basin and transmit the electricity to the Philadelphia, Washington D.C. and other urban areas along the East Coast. This is often referred to as shipping coal by wire. The electricity is largely generated at coal-fired plants located along the river system.

2.2.7.1 Regional Interconnection Transmission Lines

Infrastructure within the study area includes electric transmission lines, which deliver electricity from generating plants to consumers. The study area is a net exporter of electricity, with significant amounts of electricity delivered to consumers in the highly urbanized corridor along the Atlantic Coast from Washington DC to New York City. The major interconnecting transmission lines in the region are shown in **Figure 2.5**. The transmission lines run parallel to the river where the majority of the large generating plants are located and extend north, east, and south to the coastal population centers.

FIGURE 2.5 - Regional Electric Transmission Lines



2.2.7.2 Bridges

There are approximately 131 bridges in the study area; the number is an approximation because this only includes bridges over a navigable waterway; it does not include bridges over non-navigable portions of rivers that, for example, connect the mainland to islands (**Table 2.7**). The highest concentrations are in the Pittsburgh and Huntington/Charleston areas. Bridges are necessary transportation structures for railroads and roadways, but can be an impediment to navigation.

TABLE 2-7 - Number of Bridges in Study Area

River	Highway	Railroad	Total
Allegheny	19	7	26
Monongahela	29	12	41
Ohio	37	10	47
Kanawha	14	3	17
Study Area Total	99	32	131
Source: Counted from entries on Navigation Charts.			

2.3 ECONOMY

The area's economy developed in response to the regional advantages and natural resources of the area. The original regional advantage was the number and convergence of the area's rivers. Two large rivers, the Monongahela flowing north out of West Virginia and the Allegheny flowing south out of New York, join at what is now know as the City of Pittsburgh to form the Ohio River. In turn, the Ohio flows in a generally southwest direction which allowed westward expansion in the colonial period to be made by river rather than by foot. The natural advantages were accessible and abundant coal deposits and water supplies. The area became the nation's coal producing center which eventually led to its establishment as an iron and steel producing center.

Viewing total employment from 1980 to 2007, the study area increased albeit at a slower rate than regionally and nationally, as shown in **Table 2.8**. This time frame is shown because 1980 was the last decadal year before the collapse of the steel industry.

TABLE 2-8 - Total Employment in Study Area
(thousands)

	U.S.	ORB	Study Area
1980	114,231	8,070	1,570
2007	180,944	13,634	1,878
Annualized % change	1.7%	2.0%	0.7%
Source: Census data.			

Iron and steel production was the mainstay of the area's economy until the 1980's when eleven of the area's thirteen steel plants were closed and many were demolished. Manufacturing employment dropped precipitously despite an overall growth in jobs, as shown in **Table 2.9**. The decline in manufacturing employment was significantly higher than the comparable national and regional declines.

TABLE 2-9 - Manufacturing Employment in Study Area
(thousands)

	U.S.	ORB	Study Area
1980	20,781	1,886	355
2007	14,512	1,395	140
Annualized % change	-1.3%	-1.1%	-3.3%
Source: Regional Economic Information System, Bureau of Economic Analysis, U.S. Department of Commerce			

Employment in the education and health care sectors for the Pittsburgh Metropolitan Statistical Area, which roughly corresponds to the study area, is listed in **Table 2.10** for the years 1980 and 2007. The data illustrates that growth in these sectors is largely responsible for the overall growth in employment in recent years.

TABLE 2-10 - Health Care and Education Employment in the Study Area

	2001	2007	Annual Rate
Educational services	55,038	60,596	1.6%
Health care and social assistance	206,090	222,780	1.3%
Total employment	1,663,785	1,692,094	0.3%
Source: http://www.bea.gov/regional/reis/default.cfm?&selTable=CA25N&series=NAICS			

2.3.1 Coal Mining

Study area coal production increased at faster than the regional and national rates as shown in **Table 2.11**. In fact regional (East of the Mississippi) production has declined as production shifted west to the Powder River Basin of Wyoming and adjacent states. The reasons for the increase in study area output are large reserves, high energy content, low transportation costs, and the installation of scrubbers which neutralizes the high sulfur content of the coal.

TABLE 2-11 - Coal Production in the Study Area
(thousands of tons)

	U.S.	ORB	Study Area
1980	1,072,606	468,341	74,302
2007	1,146,635	446,852	94,400
Annualized % change	0.2%	-0.2%	0.9%
Source: extracted from DOE data base -http://www.eia.doe.gov/cneaf/coal/page/database.html			

Ten mines (**Table 2.12**) account for 73.7 million tons, or 78% of coal production in the study area. The Enlow Fork and Bailey mining complex in Greene County, PA. is the largest underground coal mining operation in the country. The complex distributes the mined coal by rail directly to consumers and indirectly via the Alicia dock at about the mid-point of the Monongahela River, where the rail coals are offloaded to barges for transportation to power plants on the Ohio River. This is a state-of-the-art operation with a capacity of about 6 million tons per year.

TABLE 2-12 - Top Ten Coal Mines in Study Area
(thousands of tons)

Rank	ST	County	Company	Mine	Tons
1	Pa	Greene	Consol Pa Coal Co	Enlow Fork Mine	11,222
2	Pa	Greene	Consol Pa Coal Co	Bailey Mine	9,827
3	WV	Marshall	McElroy Coal Company	McElroy Mine	9,667
4	Pa	Greene	Cumberland Coal Resources	Cumberland Mine	7,264
5	Oh	Monroe	American Energy Corporation	Century Mine	7,141
6	WV	Marion	Consolidation Coal Co	Loveridge No 22	6,642
7	WV	Harrison	Consol Energy Inc	Robinson Run No 95	6,502
8	Pa	Greene	Emerald Coal Resources LP	Emerald Mine No 1	5,674
9	Pa	Greene	Consolidation Coal Company	Blacksville No 2	5,150
10	Oh	Belmont	The Ohio Valley Coal Comp	Powhatan No 6 Mine	4,594
					73,686
Source: extracted from DOE data base -http://www.eia.doe.gov/cneaf/coal/page/database.html					

2.3.2 Electric Generating Plants

The principle use of coal mined in the area is in the generation of electricity. The study area contains an abundance of electric generating plants, which were sited in the area to take advantage of the abundance of both coal and water.

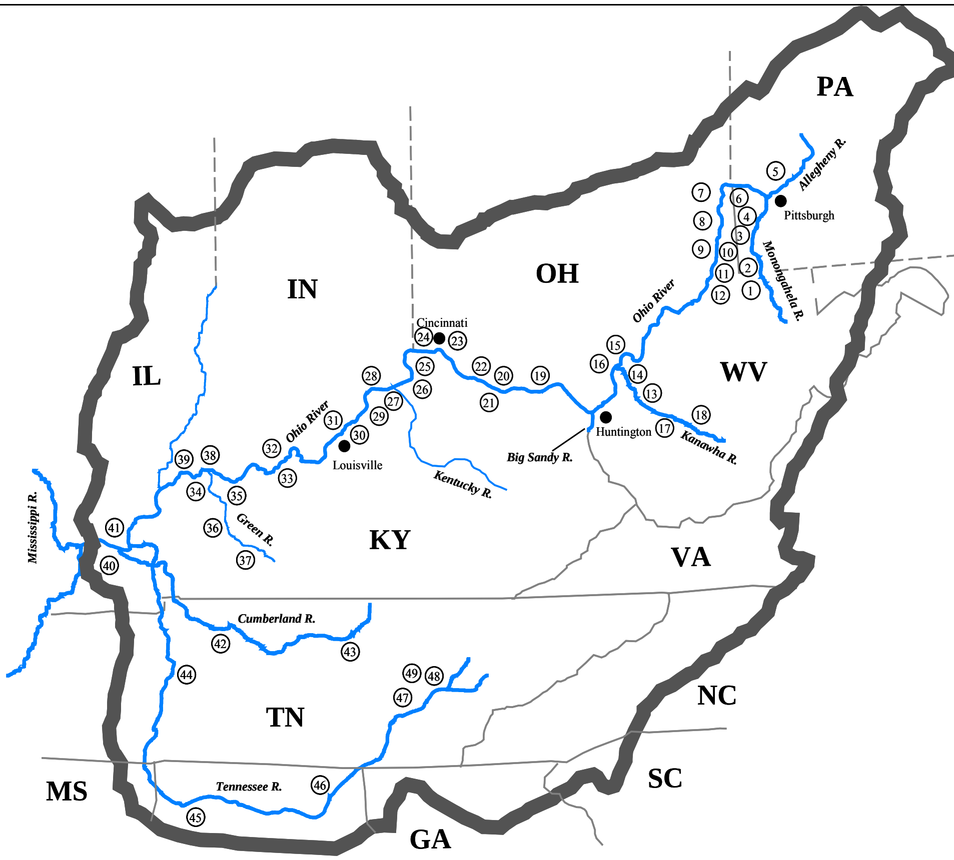
Summary statistics regarding waterside coal-fired electric generating plants in the study area are provided in **Table 2.13**. There are 18 plants and they consumed 65.1 million tons of coal in 2008.

TABLE 2-13 - Number of Coal-fired Electric Generating Plants in Study Area

Riverside	Number	Coal Consumption
Allegheny	1	1,156,298
Monongahela	4	7,649,158
Kanawha	2	8,997,028
Ohio	11	47,342,764
Study Area Total	18	65,145,248
Source: EIA923december2008.xls		

Figure 2.6 shows the name and location of all coal-fired electric generating plants in the Ohio River Basin. Eighteen of the forty-nine plants are in the study area.

FIGURE 2.6 - Location of Riverside Electric Generating Plants



Code	Plant	Code	Plant	Code	Plant
1	Fort Martin	18	Kanawha Rv	35	Wilson
2	Hatfield	19	Killen	36	Green River
3	Mitchell	20	Stuart	37	Paradise
4	Elrama	21	Spurlock	38	Warrick
5	Cheswick	22	Zimmer	39	Brown
6	Mansfield	23	Beckjord	40	Shawnee
7	Sammis	24	Miami Fort	41	Joppa
8	Cardinal	25	Tanners Crk	42	Cumberland
9	Burger	26	East Bend	43	Gallatin
10	Kammer	27	Ghent	44	Johnsonville
11	Mitchell	28	Clifty Crk	45	Colbert
12	Pleasants	29	Trimble	46	Widows Crk
13	Mountaineer	30	Mill Crk	47	Watts Bar
14	Sporn	31	Gallagher	48	Kingston
15	Gavin	32	Rockport	49	Bull Run
16	Kyger Creek	33	Coleman		
17	Amos	34	Reid		

Table 2.14 is a list of the waterside coal-fired plants in the study area. The 18 plants consumed 65 million tons of coal in 2008, which is an increase of 18% over the amount they consumed in 2001.

TABLE 2.14 - List of Waterside Coal-fired Electric Generating Plants on ORS

					Coal Consumption (Ktons)		
Name	Milepoint *	River	State	Electricity Generation (MWh in 2008)	2,001	2,008	% Differerence
Cheswick	15.4	Allegheny	PA	2,446,615	1,231,580	1,156,298	-6%
Amos	39.7	Kanawha	WV	16,150,263	5,891,270	6,621,648	12%
Kanawha Rv	78.3	Kanawha	WV	2,468,537	763,620	1,027,510	35%
Elrama	25.1	Monongahela	PA	1,141,624	1,171,990	546,965	-53%
Mitchell	29.5	Monongahela	PA	1,504,283	338,730	690,697	104%
Hatfield	79.0	Monongahela	PA	11,094,481	3,439,430	4,738,374	38%
Fort Martin	92.0	Monongahela	WV	6,798,071	2,037,710	3,020,992	48%
Mansfield	33.1	Ohio	PA	18,556,736	5,944,030	7,237,444	22%
Sammis	52.9	Ohio	OH	14,728,590	5,800,340	7,289,452	26%
Cardinal	76.2	Ohio	OH	10,386,166	3,751,460	4,314,916	15%
Burger	102.3	Ohio	OH	1,431,883	852,970	779,768	-9%
Kammer	111.1	Ohio	WV	3,115,279	1,786,550	1,396,561	-22%
Mitchell	112.3	Ohio	WV	11,162,745	3,213,290	4,430,130	38%
Pleasants	160.5	Ohio	WV	8,379,184	3,454,050	3,559,517	3%
Sporn	241.6	Ohio	WV	4,940,454	2,343,480	2,151,814	-8%
Mountaineer	243.4	Ohio	WV	9,818,558	2,756,070	4,107,544	49%
Gavin	258.5	Ohio	WV	21,102,131	7,367,770	8,543,550	16%
Kyger Creek	259.6	Ohio	OH	6,845,578	2,924,820	3,532,068	21%
Study area				152,071,178	55,071,161	65,147,256	18%
Rest of basin				224,959,917	94,877,789	115,110,689	21%
Total				377,031,095	149,948,950	180,257,945	20%

* Mile points indicate distance from source for the Ohio River and distance from the mouth for tributaries

2.3.3 Steel Producing Plants

Pittsburgh was nicknamed the steel city for the obvious reason that it contained the largest concentration of steel producing plants in the country, if not the world, for nearly 100 years. This era ended in the 1980s when the internationalization of previously largely separate national economies led to the closure of nearly all of the area's steel mills. A snap shot of the plants located on the lower 40 miles of the Monongahela River near Pittsburgh in 1945 and 2009 is provided in **Table 2.15** and illustrates the demise of the area's steel complex.

TABLE 2-15 - Steel Plants on Lower Mon River in 1945 and 2009
(steel capacity in thousands of tons)

Plant	1945	2009
Braddock	2,297	2,700
Clairton	805	-
Donora	877	-
Duquesne	2,140	-
Homestead	1,740	-
McKeesport	1,200	-
Munhall	3,507	-
	12,566	2,700

In addition to the Braddock plant, which is a USX facility, there is one other major raw steel producing plants in the study area (**Table 2.16**), the Wheeling plant owned by the Severstal corporation, which is a Russian corporation. While both plants have been upgraded on numerous occasions, they were originally constructed over 100 years ago. They tend to depend on the waterway system more as a source of water than for transportation purposes.

TABLE 2-16 - Waterside Steel Mills in Study Area

Company	Facility	River	River Mile	Capacity
USX	Braddock	Monongahela	11.3	2,700
Severstal	Wheeling	Ohio	87.5	4,200
				6,900

2.3.4 Coke Production

One hundred years ago all iron and steel producing operations required coke to create the heat to turn iron ore into a liquid and separate the iron from other materials. Today the U.S. has only a fraction of the steel productive capacity it had 50 years ago and only a fraction of the current steel production capacity require coal so that coke production has declined more precipitously than steel production. Coal consumption by coke plants has declined 87% since 1950 (**Table 2.17**).

TABLE 2-17 - U.S. Coal Usage to Make Coke (thousands of tons)

1950	1980	2008	% Change
104,014	66,657	23,566	-87%
Source: http://www.eia.doe.gov/emeu/aer/coal.html			

Coal is pre-processed in coke plants to remove impurities and other undesirable elements prior to use in a traditional steel plant. The process is accomplished in a series of ovens, which effectively bake out the impurities. By-products of the process include gases, which are often transported to adjacent plants for use as inputs in chemical processing. The coke itself is transported to steel plants where it is used to process iron ore into iron and thence into steel. A listing of the waterside coke plants in the basin is provided in **Table 2.18**. The coke plant at Clairton is the largest in the country. Its output goes to USX steel plants throughout the country. The Mountain State Carbon plant is located near the Wheeling steel plant with its output going to the Wheeling plant and other facilities owned by Severstal.

TABLE 2-18 - Waterside Coke Plants in Study Area

Company	Facility	River	River Mile	Capacity
USX	Clairton	Monongahela	20.1	4.5
Severstal	Mountain State Carbon	Ohio	69.0	1.0
Source: http://www.eia.doe.gov/emeu/aer/coal.html				

2.3.5 Recreational Facilities

The project area encompasses the City of Pittsburgh and sections of the Allegheny, Monongahela, and Ohio Rivers. Historically the Allegheny was considered the river for recreation, the Mon for manufacturing, and the Ohio for transportation. While the Ohio also has numerous marinas and launching ramps (**Table 2.19**), one-third of them are on the Beaver River, which is a tributary of the Ohio. These facilities depend on the existence of the pools created by the navigation projects.

TABLE 2-19 - Marinas in Study Area

River	Marinas	Ramps	Total
Allegheny	6	5	11
Mon	1	5	6
Ohio	20	9	29
Total	27	19	46
Source: Corps navigation charts.			

2.3.6 Economic Outlook

Recent projections were obtained from official Government sources regarding likely activity in the sectors of the economy that are linked to type and volume of traffic through the study area navigation projections. The principle source is the Energy Information Agency (EIA), which is the analytical branch of the Department of Energy (DOE). Other sources were the Census Bureau and the Department of Transportation (DOT). In the case of the DOT projections, they were published in 2002 during a period of economic expansion and rapid growth in international transportation. They are shown to illustrate the difficulty of forecasting the future versus projecting the future. Forecasts imply certitude of the future while projections provide a glimpse of the future given a continuation of certain trends.

2.3.7 Population Projections

Population projections by the U.S. Census Bureau show a continuation in the absolute loss of population in the study area over the next decade (**Table 2.20**).

TABLE 2-20 - Projections of Population (thousands)

	U.S.	ORB	Study Area
1980	226,542	28,639	3,520
2008	304,060	32,533	3,119
2020*	341,387	34,837	2,988
Annualized % change	1.1%	0.5%	-0.4%

*Georgia projections were only available to 2015
Source: http://www.census.gov/popest/counties/files/CO-EST2008-ALLDATA.csv
http://www.census.gov/popest/archives/1980s/e8089co.xls; Multiple state sources (State data centers and universities).

2.3.8 Transportation

Transportation projections by the U.S. Department of Transportation, circa 2002, were for continued robust growth via all transportation modes (**Table 2.21**). Given the descent of the economy into a deep recession, these projections are probably optimistic. Like most projections, they were based on existing conditions at the time and a continuation of trends up to that time. The trends did not continue and these growth rates are unlikely to materialize. They are presented to illustrate the difficulty of projecting the future and particularly of ignoring the implications of the projections, such as continued unlimited imports from China and other foreign nations.

TABLE 2-21 - Projections of Transportation by Mode

	1998	2020	
Air	9	26	4.9%
Highway	10,439	18,130	2.5%
Rail	1,954	2,894	1.8%
Water	1,082	1,487	1.5%
Total	13,484	22,537	2.4%
Source: USDOT, Freight News, October 2002			

2.3.9 Electricity Consumption and Production

Electricity consumption projections by the U.S. Department of Energy, circa 2008, are for continued growth in electricity consumption but with production of the electricity being led by 'green' energy sources (**Table 2.22**). Nonetheless, generation from coal-fired plants is second in importance with the rate of increase in production nearly matching the overall rate of growth in demand.

TABLE 2.22 - Projected Electricity Generation by Type of Generation

	2007	2030	% Annual Growth
Coal	2,002	2,367	0.7%
Petroleum	61	46	-1.2%
Natural Gas	814	881	0.3%
Nuclear	806	907	0.5%
Pumped Storage/Other 9/	4	1	-7.8%
Renewable Sources 10/	318	614	2.9%
Total Generation	4,006	4,816	0.8%
Source: http://www.eia.doe.gov/oiaf/aeo/supplement/supref.html			

2.3.10 Coal Production

Coal production forecasts developed by the Department of Energy as part of their "Annual Energy Outlook 2009" show an increase in U.S. production, a decrease in Appalachian production, and an increase in Northern Appalachian production (**Table 2.23**). These were the latest forecasts by DOE that were available when this document was prepared and reflect to a certain extent the move towards green energy and away from what is perceived as global warming coal-fired production. Despite this, the outlook for coal production in the study area is a relatively robust 1.9%, or twice the national average. This would appear to indicate that coal transportation by all modes, including waterway transportation, will continue to be significant in the study area.

TABLE 2-23 - Projections of Coal Production
(thousands of tons)

	2007	2030	Annualized rate of change
Northern Appalachia	132,285	194,015	1.9%
Appalachia	478,161	353,072	-1.5%
United States Total	1,146,635	1,340,563	0.8%
Source: AEO 2009; specifically the supplementary tables found at http://www.eia.doe.gov/oiaf/aeo/supplement/supref.html			

2.3.11 Employment Projections

Employment projections for the study area are listed in **Table 2.24**. Manufacturing is projected to continue to decline while “All others”, which includes education and health care, is projected to increase by 9.1%.

TABLE 2-24 - Projections of Employment by Sector in Pittsburgh MSA

	2006	2016	Percent Change
Mining	4,980	5,320	6.8%
Manufacturing	96,980	89,620	-7.6%
Wholesale & retail trade	175,640	175,840	0.1%
Government	61,760	62,440	1.1%
All others	781,300	852,220	9.1%
Total non-farm employment	1,173,180	1,239,270	5.6%
Source: Pennsylvania Center for Workforce Information, Long-Term Employment Projections: http://www.paworkstats.state.pa.us/gsipub/index.asp?docid=401			

2.4 Implications for Maintenance of Navigation System

The study area has changed significantly since the construction of the Ohio River Navigation System nearly one hundred years ago. What began as an area dominated by coal and steel production which used the system for water supply and transportation has evolved into an area whose economy is largely dependent on the provision of health care and education. The latter are obviously less dependent on the existence of a waterway transportation system than are steel and coal production. The question then becomes whether continued maintenance of the navigation system is warranted given the potentially large investment that will be needed to modernize the aged projects.

While the loss of high quantity and reliable water supplies from the three navigation pools could have significant adverse local economic impacts, particularly to the City of Pittsburgh and electric generating plants, national impacts are largely dependent on the navigation system created by the projects. In turn, the navigation impacts are largely dependent upon developments in the coal market, which in turn depend on developments in the electric generating industry. This is the area of highest uncertainty and volatility which could result in significant increases or decreases in the volume of barge traffic. Due to concerns over global warming, it is the objective of many decision makers in the area of electric generation to minimize the use of coal-fired plants and increase ‘green’ and gas-fired plants. The effects on barge transportation of coal could be negative and greatly diminish the utility of the waterborne transportation system. However, as is often stated, ‘hope is not a plan’. Many government and private entities have analyzed the situation in detail and are of generally in agreement that coal will continue to be a significant player in the electric generating market for two reasons: 1) it is cost competitive; and 2) it is reliable in the sense that it can produce electricity when needed, and not just when the wind blows or the sun shines. The 2009 forecasts by the Department of Energy are for an annual increase in electricity demands of 0.8 percent and an annual increase in coal-fired generation of 0.7 percent, or nearly the same. Specific projections of the location of additional coal-fired capacity is not readily available, but the recent pattern has been to construct additional capacity at or near existing capacity to minimize community opposition and to take advantage of existing transmission lines. This would mean that much of the additional capacity in the region would be located along the navigation system.

The DOE also forecasts an annual increase in Northern Appalachian coal production of 1.9 percent, which reflects the adequacy of the area’s coal deposits to not only sustain but increase their share of the steam coal market. It would appear, therefore, that increases in steam coal shipments on the Upper Ohio could reasonably range between 0.7% and 1.9% a year, given DOE forecasts of annual growth in coal-fired generation and Northern Appalachian coal production. Since steam coal accounts for about one-half of Upper Ohio tonnage, this equates to a growth rate of 0.35 percent and 0.95 percent annually even with no growth in other traffic. However, one reason for the projected growth in Northern Appalachian coal usage is increased demand from power plants installing scrubbing units. Scrubbing units also require significant volumes of lime/limestone in an amount equal to between 5 percent and 15 percent of coal consumption and the possible increase in traffic to between 0.5 percent and 1.0 percent annually. Of course there are a host of other factors that determine traffic levels and these were considered in the analysis documented in the addendum on traffic forecasts. The purpose of this appendix was to describe the study area and to consider how changes in the area affect the usage and importance of the navigation system. The data indicate that the waterway system remains an important element in the economy of the study area, despite the closure of the area’s steel industry and the disfavor of coal-fired electricity generation.

Section 3: EVALUATION PROCEDURE

The purpose of a U. S. Army Corps of Engineers planning analysis "*… is to estimate changes in national economic development that occur as a result of differences in project outputs with a plan, as opposed to national economic development without a plan*"[1]. This is accomplished through a federally mandated National Economic Development (NED) analysis which is "*… generally defined as an economic cost-benefit analysis for plan formulation, evaluation, and selection that is used to evaluate the federal interest in pursuing a prospective project plan.*"[2] NED benefits are defined as "*… increases in the net value of the national output of goods and services, expressed in monetary units …*"

For a navigation project investment, NED benefits are composed primarily of the reductions in transportation costs attributable to the improved waterway system. The reduction in transportation costs is achieved through increased efficiency of existing waterway movements, shifts of waterway and overland traffic to more efficient modes and routes, and shifts to more efficient origin-destination combinations. Further benefits accrue from induced (new output/production) traffic that is transported only because of the lower transportation cost deriving from an improved project, and from creating or enhancing the potential for other productive uses of the waterway, such as the generation of hydropower. National defense benefits can also be realized from regional and national growth, and from diversity in transportation modes. In many situations, lower emissions can be achieved by transporting goods on the waterway. The "*… basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities*"[3] remains the conceptual basis of NED benefits for inland navigation..

Traditionally, this primary benefit for barge transportation is calculated as the cost savings for barge shipment over the long-run least-costly all-overland alternative routing. This benefit estimation is referred to as the waterway transportation rate-savings, and it also accounts for any difference in transportation costs arising from loading, unloading, trans-loading, demurrage, and other activities involved in the ultimate point-to-point transportation of goods. A newer way to estimate this primary benefit is to define the movement willingness-to-pay for barge transportation with a demand curve (instead of the long-run least-costly all-overland rate) and then calculate a transportation surplus (consumer surplus). Either way, the primary benefit for federal investment in commercially-navigable waterways (benefits with a plan as opposed to benefits without a plan) ends up as a transportation cost reduction.

The primary guidance document that sets out principals and procedures for evaluating federal interest is the *Principles and Guidelines* (P&G)[4]. Corps guidance for implementing P&G is

[1] Planning Manual, IWR Report 96-R-21, U.S. Army Corps of Engineers, November 1996, page 56.
[2] National Economic Development Procedures Manual Overview, IWR Report 09-R-2, U.S. Army Corps of Engineers, June 2009, page 1.
[3] Planning Guidance Notebook, ER 1105-2-100, U.S. Army Corps of Engineers, 22 April 2000, page 6-55.
[4] "*Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*", U.S. Water Resources Council, March 10, 1983.

found in the *Planning Guidance Notebook*[5] with additional discussions of NED analysis documented in the *National Economic Development Procedures Overview Manual*[6]. For inland navigation analysis, the focus is on the evaluation and comparison of the existing waterway system with three basic alternative measures: 1) increase capacity (decrease transit times and thereby reduce delay costs); 2) increase reliability (replace or rehabilitate aging structures, thereby reduce the probability of structural failure and its consequences); and / or 3) reduce demand (e.g. congestion fees). The P&G provides general guidance for doing the benefit assessment, but leaves open opportunities to improve the analytical tools used as new data and computational capabilities are developed.

3.1 SYSTEM ANALYSIS

The inland waterway system is a network of locks and channel reaches. As a result, no navigation project stands in isolation from other projects in the system. The study area must extend to areas that would be directly, indirectly or cumulatively affected by the alternative plans. An improvement at one node (e.g. lock) in the system affects traffic levels past that node, and since that traffic can also transit other system nodes the performance at these other nodes changes, possibly affecting traffic levels unique to those nodes, and so on. The evaluation of inland navigation system equilibrium is a substantial computational problem given the mix of commodity flows, each transiting different locks and each having their own set of economic properties.

Since the 1970s, the Corps has been performing inland waterway cost-benefit analysis with a system level evaluation. Through the USACE Planning Center of Expertise for Inland Navigation (PCX-IN) located in the Navigation Planning Center in the Huntington District (CELRH-NC), the Great Lakes and Ohio River Division (LRD) of the Corps has adopted and continues to maintain a set of computerized analytical models for estimating the NED benefits of proposed improvements to the Ohio River inland navigation system. The primary models utilized in LRD are the Waterway Analysis Model (WAM) and the Ohio River Navigation Investment Model (ORNIM[7]). In general these models have been designed to help Corps planners achieve two goals: i) to operate and maintain the inland waterway network as efficiently as possible, and when necessary, ii) to select the best size, location, and timing of inland navigation waterway improvements.

While the upper Ohio River is a subsystem of the Ohio River System (ORS), around 16 percent of the upper Ohio traffic also transits the lowest project on the Ohio River (L/D 53). Insignificant amounts of Upper Ohio traffic move on the Tennessee, Cumberland, and Kanawha Rivers, and little moves above Maxwell on the Monongahela River. Still, the Upper

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[5] Planning Guidance Notebook, ER 1105-2-100, U.S. Army Corps of Engineers, 22 April 2000.

[6] National Economic Development Procedures Manual Overview, IWR Report 09-R-2, U.S. Army Corps of Engineers, June 2009.

[7] ORNIM was built by Oak Ridge National Laboratory (ORNL) in collaboration with the Navigation Planning Center of the Great Lakes and Ohio River Division (LRD). It is based on a long history of model development within the Corps beginning in the 1970s with the Tow Cost Model (TCM) and the Equilibrium Model (EQ).

Ohio evaluation is performed within the context of detailed modeling of the Ohio River Navigation System[8]. Origins and destinations are modeled outside the ORS, however, these areas are not described in any level of detail which assumes waterway transportation costs in these areas are constant through time and will not vary between an Upper Ohio with plan and without plan.

The LRD models employed in determining system benefits (and the incremental benefits between the with and without plans) requires four main classes of input data: i) data describing the navigation system, its condition, and performance characteristics, ii) data describing the waterway transportation costs characteristics (e.g. equipment usage and its costs), iii) data describing the waterway traffic patterns and forecasted demands (i.e. commodity origin destination), and iv) data describing the willingness-to-pay for barge transportation (i.e. the long-run least-costly all-overland rate or a movement demand curve).

Lock performance characteristics are defined with tonnage-transit curves developed with the WAM. The tonnage-transit curves are used by ORNIM to determine future transportation costs, equilibrium traffic levels, and benefits for the with and without plans. **Attachment 1, Ohio River Navigation Investment Model (ORNIM)** and **Attachment 2, Capacity Analysis**, provide full discussion of the ORNIM and WAM model.

3.2 ANALYSIS FRAMEWORK

To understand the inland navigation analysis framework, it is best to first understand the investment issues involved with inland navigation projects. The inland waterway transportation system is a mature transportation system and as a result, the investment options are focused on operational measures. The investment decisions are not whether to build a waterway transportation system, but whether and how to maintain or enhance the existing system (e.g. extended or new locks, channel improvements, replacement of key components, alternative maintenance policies, etc.). The objective is not to determine the value of the waterway transportation system, but to determine the value to changes in the waterway transportation system.

Navigation performance issues can arise as traffic levels increase (congestion) and / or the infrastructure degrades and becomes less reliable. At locks too small to efficiently handle higher traffic volumes (and / or changing fleet configurations) congestion leads to a degradation in service reflected in increased delays and higher transit times. Aging projects and heavy usage can also cause serious reliability issues necessitating disruptive maintenance outages and causing disruptive service failures (e.g. closures)[9]. Increased lock transit times, whether caused by traffic growth congestion or a lock outage, increases transportation costs

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[8] The Ohio River Navigation System is comprised of the Ohio River and its navigable tributaries – the Allegheny, Monongahela, Kanawha, Big Sandy, Green, Cumberland and Tennessee rivers.

[9] The most recent failure in LRD as of this writing occurred at Greenup Locks and Dam 27 January 2010. The anchorage supporting a lower main chamber miter gate broke, closing the main and auxiliary chambers.

for shipments transiting the lock, increasing trip cycles and ultimately requiring more equipment to move the same annual volume of traffic.

In the past, traffic growth congestion has been the primary focus of lock improvement studies. As adequate base capacity has been constructed in the Ohio River System (ORS), however, the system has aged and lock performance reliability threatens the systems capacity to move traffic. To over simplify, in the ORS most navigation projects consist of a main lock chamber and a smaller auxiliary chamber. The main chamber is typically of adequate size and capacity to handle current and expected forecasted demand. Due to traffic growth, however, the auxiliary chamber is now often inadequate to handle current traffic levels on its own. On a day-to-day basis, the auxiliary chamber is used to increase the efficiency of the project when queues develop by passing small vessels, freeing up the larger main chamber for passage of the larger vessels. The auxiliary chambers have always served as a backup to intermittent closures of the main chamber, however, main chamber closures lasting more than a couple of days can now result in large queues, high delay, and diversion of shipments often to already congested land transportation corridors. During main chamber closures, the typically-sized Ohio River tow capable of transiting a main chamber in one 60-minute lockage operation must move through the smaller auxiliary lock chamber in two lockage cuts lasting a total of about 150-minutes. With the processing time of each vessel is more than doubled, queues can develop rapidly and equipment is trapped in queue idling rather than moving.

In response to shifting demands and increased traffic levels in some areas of the system, along with consideration of the aging infrastructure and increasing reliability concerns, the Corps desires identification of investments to maintain and / or enhance service where economically justified. In light of recent lock failures it has become particularly imperative to avoid failures of major lock components (particularly in the main chambers) and the lengthy lock closures they invoke. In addition, in a budget constrained world, quantification and prioritization of investment options with consideration of risk becomes important in managing the system. These issues and concerns help frame the needed analysis framework as discussed below.

3.2.1 Sectoral, Spatial and Temporal Detail

Economic models vary in terms of sectoral, spatial, and temporal detail. At one extreme are spatially-detailed computable general equilibrium (CGE) models. A general equilibrium analysis (despite the abstraction from the real economy) attempts to explain the behavior of supply, demand, and prices in a whole economy with an equilibration of all prices. CGE models are appropriate for issues expected to have economy-wide effects or whose economic effects follow complex but tractable pathways. If economy-wide effects are not realistically associated with the project being considered, modelers must make informed tradeoffs among the three dimensions.

As noted, from a transportation perspective the needed investment decisions are on relatively small improvements (e.g. extended or new locks, channel improvements, replacement of key components, alternative maintenance policies, etc.); whether and how to maintain or enhance the existing system. The need does not exist to estimate the total benefits the nation would lose if a waterway system no longer existed. Given this focused objective, a spatially-detailed, partial-equilibrium model is sufficient. In a partial-equilibrium analysis, the determination of the equilibrium price-quantity of a good is simplified by just considering the price of that good and assuming that the prices of all other goods remain constant. In other words, the prices of all substitutes and complements (as well as consumer income levels) are constant.

3.2.2 Principals and Guidelines

As previously noted, the primary guidance for this framework is described in P&G (the latest regulatory successor to the *Green Book*[10]). Inland navigation investments are to be analyzed through a NED analysis following an incremental and iterative planning process[11] that "… *relies on the marginal analysis of benefits and costs for the formulation, evaluation, and selection of alternative plans that provide incremental changes in the net value of desired goods and services.*"[12] The alternative plan with the greatest net NED benefits is defined as the NED plan. NED analysis can be generally defined as an economic benefit-cost analysis (BCA). BCA is a well-established method for systematically organizing and comparing information between alternatives and aims to separate acceptable from unacceptable projects, and to rank the acceptable projects, to ensure that resources are invested wisely. Benefit-cost analysis remains the most important criterion in Corps planning studies[13].

To accomplish an incremental analysis, all alternatives must be measured against a common base. The future condition at the project (and in the system) without the investment(s) is referred to as the Without-Project Condition (WOPC) and the future condition with investment is referred to as the With-Project Condition (WPC). Identifying these future scenarios or conditions is central to the analysis framework. An economic analysis of these competing future conditions (over a 50-year analysis period) estimates the stream of benefits and costs associated with each respective future. The temporal aggregation of these cash flows necessitates discounting to complete the BCA.

NED benefits for a navigation project investment are composed primarily of the reductions in transportation costs attributable to the availability of the improved waterway system. These reductions in transportation costs are achieved by increasing the efficiency of existing waterway movements, by providing for shifts of waterway and overland traffic to more efficient modes and routes, and by providing for shifts to more efficient origin-destination combinations. Further benefits accrue from traffic that is transported only because of the lower transportation cost deriving from an improved project, and from creating or enhancing the potential for other productive uses of the waterway, such as the generation of hydropower. National defense benefits can also realized from regional and national growth,

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[10] Bureau of the Budget; the 1958 report, *Proposed Practices for Economic Analysis of River Basin Projects*" (known familiarly as "the Green Book"), issued by a subcommittee of the Federal Interagency River Basin Committee; Senate Document 97, approved by President Kennedy in May 1962; and the 1973 *Principles and Standards* (*P&S*) and the 1983 *Principles and Guidelines* (*P&G*), both issued by the federal Water Resources Council (WRC, 1973; 1983).

[11] The P&G six-step process for civil works project planning.

[12] National Economic Development Procedures Manual Overview, IWR Report 09-R-2, U.S. Army Corps of Engineers, June 2009, page 9.

[13] USACE. 2000. Planning Guidance Notebook. ER 1105-2-100, April 22, 2000.

and from diversity in transportation modes. In many situations lower emissions can be achieved by transportation of goods on the waterway. But, the conceptual basis for the "… *basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities.*"[14] These reductions in transportation costs can be classified as:

- **Cost-reduction benefits** for commodity movements having the same origin, destination and waterway routing that realize cost reductions because of a navigation improvement. This reduction represents an NED gain because resources will be released for productive use elsewhere in the economy. Examples for inland navigation are reductions in costs incurred from trip delays (e.g. reduction in lock congestion), reduction in costs associated with the use of larger or longer tows, and reduction in costs due to more efficient use of barges. Examples for deep draft navigation are reductions in costs associated with the use of larger vessels, with more efficient use of existing vessels, with more efficient use of larger vessels, with reductions in transit time, with lower cargo handling and tug assistance costs, and with reduced interest and storage costs.
- **Shift-of-mode benefits** for commodity movements having the same origin and destination that realize a cost savings by shifting from their current mode/routing to the improved waterway. In this case, benefits are the difference in costs of transport between the without-project condition (when rails, trucks or different waterways or ports are used) and the with-project condition (improved locks, waterways or channels). The economic benefit to the national economy is the savings in resources from not having to use a more costly mode or point of transport.
- **Shift-in-origin and / or destination benefits** that would provide benefits by either reducing the cost of transport if a new origin is used or by increasing net revenue of the producer, if a change in destination is realized. This benefit cannot exceed the reduction in transportation costs achieved by the project.
- **New movement benefits** are claimed when there are additional movements in a commodity or there are new commodities transported due to decreased transportation costs as a result of a navigation improvement. The new movement benefit is defined as the increase in producer and consumer surplus, thus the estimate is limited to increases in production and consumption due to lower transportation costs. Increases in shipments resulting from a shift in origin or destination are not included in the new movement benefits. This benefit cannot exceed the reduction in transportation costs achieved by the project.
- **Induced movement benefits** are the value of a delivered commodity less production and transportation costs when a commodity or additional quantities of a commodity are produced and consumed due to lower transportation costs. The benefit, in this case, is measured as the difference between the cost of transportation with the project and the maximum cost the shipper would be willing to pay.

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[14] "*Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*", U.S. Water Resources Council, March 10, 1983, page 49.

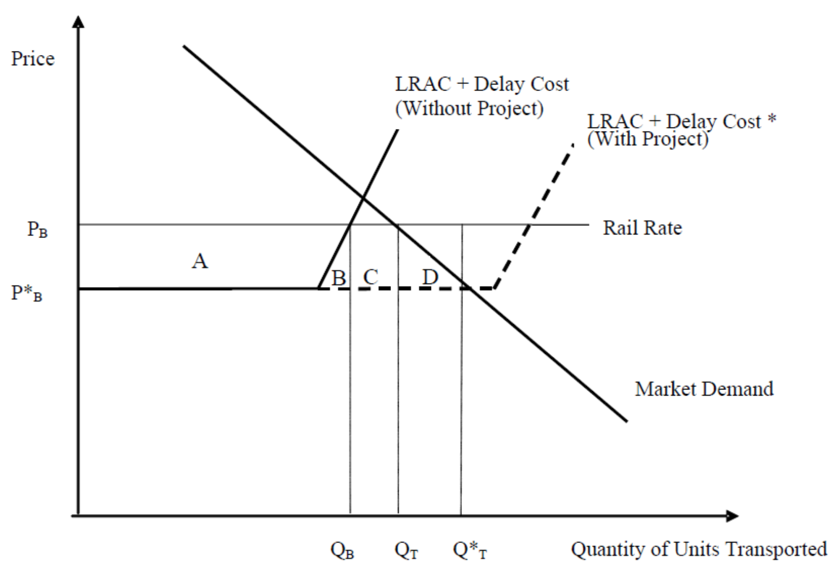
Basically, the economic analysis of waterway investments focuses on the evaluation and comparison of the costs and benefits of the existing waterway system with three basic alternative measures: 1) increase capacity (decrease transit times and thereby reduce delay costs); 2) increase reliability (replace or rehabilitate aging structures, thereby reduce the probability of structural failure and its consequences); and / or 3) reduce demand (e.g. congestion fees).

3.2.3 Theoretical Equilibrium and Incremental Benefit Framework

The P&G provides general guidance for doing benefit assessments and benefit-cost analysis, but it does not overly restrict or dictate how the assessments should be done. As discussed in IWR Report 09-R-2, National Economic Development Procedures Manual (dated June 2009), the cost reduction is the principal inland navigation benefit category and the other benefit categories reflect the different ways that cost reduction can give rise to non-marginal changes in the use of inland navigation.

IWR Report 09-R-2 also describes calculation of cost reduction, shift-of-mode, and new movement benefits through the hypothetical project example shown in **FIGURE 3.1**. This example depicts the calculation of benefits to shippers from expanding locks along a specific origin-destination route as a means to alleviate barge traffic congestion and associated passage delays at the locks. The vertical axis represents the unit prices (rates) for transport, and the horizontal axis shows the total quantity of commodity units transported in response to different rates.

FIGURE 3.1 - Benefits to Shippers from Lock Expansion



The downward sloping line shows shippers' total market (derived[15]) demand function for transporting a specific commodity from a given origin to a given destination. The slope of the demand function, or Market Demand for all available transportation methods, represents the response of the quantity of the commodity transported to changes in transportation rates. For simplicity, it is assumed that this market is served by only two transport modes (barge and rail), and there is no qualitative difference between the services they provide.

In the FIGURE 3.1 example, it is assumed that, because of the open access nature of the barge industry, competition forces barge rates to the level of the long-term average costs (LRAC) of providing barge transportation. Further, the example assumes that the long-run average cost function for barge transportation is horizontal over some initial range of shipments, reflecting constant marginal costs of moving that range of shipments by barge. However, the example also assumes that as the level of barge shipments increases beyond a certain point, increased barge traffic results in congestion and queuing delays at the locks on the system. The increasing waiting times for passage through the locks reflects diseconomies for barge transportation due to increasing factor input costs, which is represented in FIGURE 3.1 by the portion of the barge long-run average cost function that suddenly veers upwards and to the right. The difference between the horizontal and upward sloping sections of this function is the delay (congestion) cost.

In the without-project situation, the total quantity of units shipped is Q_T. Of this total, Q_B is shipped by barge at price P_B that approaches but remains slightly below the prevailing rail rate. Since barge rates are set equal to barge long-run average costs, the barge price for Q_B includes a lock delay cost that is imposed on all barge shippers. The remaining quantity transported ($Q_T – Q_B$) is carried by rail, since the prevailing rail rate is below the rate that barges would need to charge shippers to accommodate the increased delay cost if total barge shipments were to increase beyond Q_B. Expansion of the locks would increase total potential barge shipments to Q^*_T by eliminating delay costs for this level of shipment. This is illustrated by the horizontal section of the without-project average cost function and the extending dashed line. This represents the new long-run average cost function for barge shipment with lock expansion. The new average cost function eventually turns upward, reflecting that even with lock expansion, delay costs would reappear if barge shipments increased much beyond Q^*_T.

Estimation of the benefits of lock expansion begins with a prediction by planners of the amount of barge shipments that would result if the new lock capacity were fully utilized, which in this example is Q^*_T. At this new level of barge shipment, project benefits would be the sum of 1) *cost reduction benefits* for the level of barge shipments that existed in the without-project condition, 2) *shift of mode benefits* associated with the level of without-project shipments that were carried by rail, but with the project will now switch to barge, and 3) *new movement benefits* associated with any increase in total market shipments beyond the without-project level.

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[15] Shippers' demand for barge transportation services is derived from the demand for the commodities that barge carriers transport to buyers.

Cost reduction benefits are equal to the sum of areas A and B in FIGURE 3.1 and are calculated by multiplying existing barge shipments (Q_B) by the difference between the without-project barge rate (P_B) and the estimated with-project barge rate (P^*_B). Shift of mode benefits are equal to area C, and are calculated by multiplying the quantity previously carried by rail ($Q_T - Q_B$) by the difference between the prevailing rail rate and the with-project barge rate. Finally, new movement benefits are equal to area D.

3.3 MODELING FRAMEWORK

Since the inland navigation investments analyzed have long lives (and regulation requires a benefit-cost analysis assuming a 50-year investment life), benefits and costs must be estimated through time. These estimated life-cycle WOPC and WPC benefit and cost cash flows then serve as the basis for the benefit-cost analysis.

To accomplish a life-cycle analysis, ORNIM is designed to estimate and analyze the benefits of incremental improvements in a river system and then to compare the benefits against the costs. ORNIM operates within the supply and demand framework discussed, with inputs that describe the long-run average cost of water transportation (supply) and the movement level demand for water transportation. ORNIM determines WOPC and WPC movement demand equilibrium and incremental benefits, however, the analysis of an investment within a system is much more complex than the simple commodity origin-destination route used as an example in the previous section. Additionally there are other considerations beyond equilibrium and surplus calculations that must be factored into the investment decision. The modeling requires a movement from the theoretical model to an empirical model that appropriately addresses the empirical question at hand and does so in a way that provides the most useful insights for decision-making, given the resource constraints placed on the overall analysis. This section briefly describes the modeling framework used to apply the theoretical framework discussed. Additional discussion can be found in **Attachment 1, Ohio River Navigation Investment Model (ORNIM)**.

3.3.1 Life-Cycle Analysis Accounting

A benefit-cost analysis is sensitive to the life-cycle period being considered and to the handling and comparison of the life-cycle cash flows. This is especially true for inland navigation investments which are costly and have long payback periods. Before proceeding further, the planning period and cash flow analysis will be discussed.

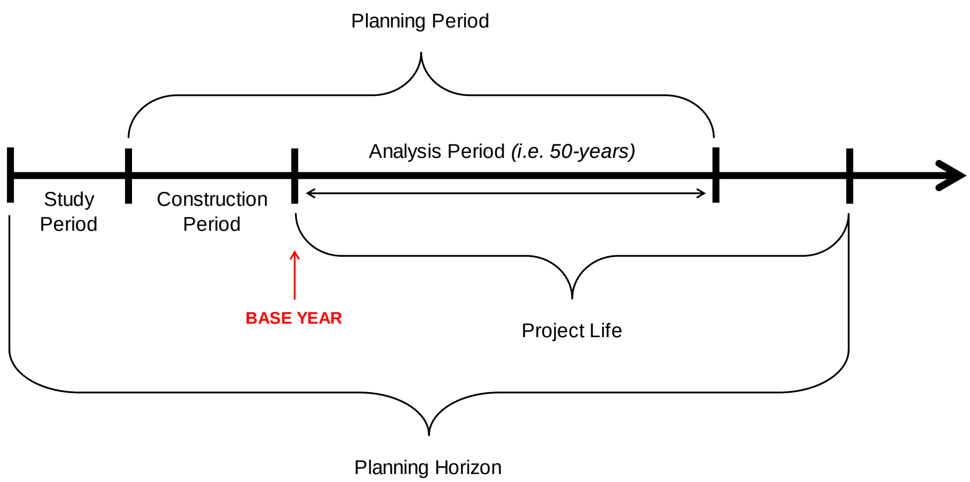
3.3.1.1 The Planning Period

Corps guidance requires that the period of analysis should be the same for each alternative plan, and include the time required for plan implementation plus the time period over which any alternative would have significant beneficial or adverse effects. In studies for which alternative plans have different implementation periods, Corps guidance says that a common "*base year*" should be established for calculating total NED benefits and costs, reflecting the year when the project is expected to be "*operational*."

Guidance also specifies that for inland navigation projects, the time period over which WPC alternatives have significant beneficial or adverse effects is 50 years. This is not to say that the project or alternative will only last 50 years (the actual life is often much longer), but that only 50-years worth of benefits can be considered to off-set the investment cost. The 50-year period is often referred to as the analysis period or project life (although regulated project life would be more appropriate).

The plan implementation period, however, must also be considered in the analysis. This does not mean the entire time leading up to the alternative completion including both the study and construction periods, but instead the period when costs are incurred that are to be compared against the project benefits (i.e. the construction period). Figure 0.2 displays the terminology that will be used in the remainder of this document.

FIGURE 3.2 - Planning Period



For the upper Ohio analysis the implementation (or construction period) was six years which was considered long enough to cover the longest alternative implementation. As a result, the planning period extended over 56-years. The first year of the construction period was set as 2012 (the first possible budget year), resulting in a base year of 2018 and a final analysis period year of 2068.

3.3.1.2 Compounding, Discounting, and Amortization

The life-cycle cash flows (whether benefits or costs) often fluctuate through time over the planning period. Project costs are incurred primarily at the time of construction while benefits accrue in varying amounts over the project life. Costs spent on construction today cannot be directly compared to the dollars in benefits that will be realized years from now. Even when inflation is not a concern, a rational person prefers one dollar now (a given level of consumption today) more highly than one dollar in the future (the same amount of consumption at some future point in time). Comparison of life-cycle benefits and costs is impossible without temporal aggregation of the cash flows; specifically compounding, discounting and amortization.

Compounding and discounting is the process of equating monetary values over time; measuring the "*time value*" of cash flows (benefits and costs) that occur in different time periods. Compounding defines past sums of money into a single equivalent value. Discounting defines future sums of money into a single equivalent value. This equivalent value is also known as a present value or present worth. Compounding and discounting requires the use of an interest rate which represents society's opportunity cost of current consumption. The same rate is used for both compounding and discounting.

The appropriate rate can be a matter of debate; however, Congress has resolved the dilemma for water resource agencies. The rate used in evaluating water resource projects is set annually, by law (Section 80 of PL 93-251), using a prescribed formula based on the cost of government borrowing. The rate is published each year by Corps Headquarters as an Economic Guidance Memorandum (EGM). The FY 2010 project evaluation and formulation rate is 4.375%; however, OMB prefers to use a "fixed" 7.0% rate. These compounding/discounting rates are typically referred to as the Federal discount rate and the OMB discount rate. The Federal discount rate is used for the formulation and selection of the NED plan. The NED plan is then summarized at the OMB discount rate for the Corps budgetary process.

The estimated benefit and cost cash flows expected to occur in time periods following the base year are to be discounted back to the base year using the prescribed interest rate. Since the implementation period for some plan may begin prior to the base year, any estimated NED benefits and costs for that plan expected to be realized before the base year are to be "compounded" forward to the base year. That is, for plan benefits or often known as "benefits during construction" and costs expected to be realized before the base year, the discounting procedure is applied in reverse, so that the interest rate serves to compound rather than discount those effects to the base year. The same prescribed interest rate is to be used for both compounding benefit and cost streams that occur prior to the base year, and for discounting benefit and costs streams that occur after the base year.

3.3.2 Waterway Equilibrium

To complete a life-cycle analysis of an incremental improvement to a river system, the WOPC and WPC movement demand equilibrium must first be determined. There are, however, two different types of equilibrium: shipper-based and social optimum equilibriums. In formulation of the NED a shipper-based equilibrium for the WOPC and WPC is assumed. The social optimal equilibrium is then estimated through a congestion fee analysis which is then compared against the WPC alternatives. Typically a congestion fee alternative will produce the highest benefit-cost ratio, but not the highest net benefit (which is the objective of the recommended NED plan).

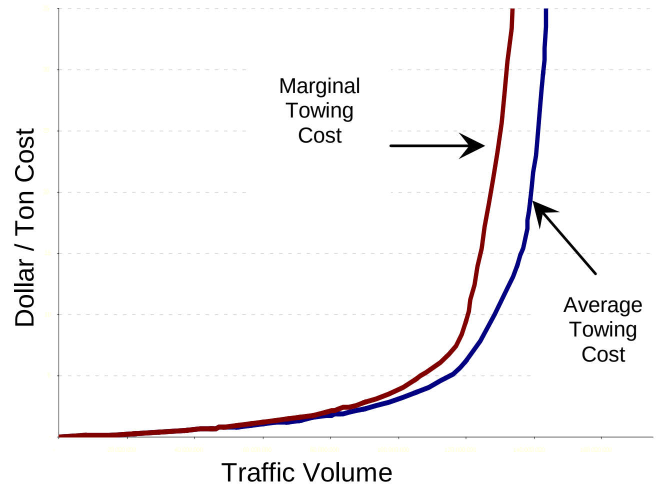
In the case of the Upper Ohio analysis, however, the congestion fee alternative is not appropriate as will be discussed later. The shipper-based and social optimum equilibriums can both be estimated with ORNIM and are briefly discussed in additional detail below.

3.3.2.1 Shipper-Based Equilibrium

In typical ORNIM equilibrium execution, individual shippers (i.e. movements) are assumed to make decisions based on their observed cost of moving on the waterway system; but they do not consider the additional congestion their shipments place on all other users of the waterway. As a result of this negative externality, the total use of the waterway exceeds the optimal level of use when considered from the perspective of society; a shipper-based equilibrium as opposed to a social-optimal equilibrium. The shipper-based equilibrium is reality while the social equilibrium minimizes transportation costs (considering all transportation modes).

In the equilibrium process ORNIM calculates a conditional cost curve for each movement which represents, for every level of traffic, the shipper cost of shipping commodities via the water routing. The costs include only those costs borne by the waterway carrier (e.g., equipment, labor, fuel, and supplies), and not those borne by the Federal Government in the operation and maintenance of the waterway system. Two waterway conditional cost curves are depicted in FIGURE 3.3 -- the average towing cost (ATC) curve and the marginal towing cost (MTC) curve. The ATC curve represents the average cost of shipping at different traffic levels. It rises because the average delay, and therefore the average cost, is higher at higher levels of traffic. The MTC curve represents the additional cost to the shipping industry of transporting an additional ton of cargo on the waterway. It increases at a faster rate than the ATC because the higher delays associated with higher levels of traffic are sustained by all shippers, not only the shipper who causes the delay. An additional tow entering the river system increases the delay costs for all tows sharing resources with the new tow (i.e. all tows transiting a shared lock). The external cost to society is the marginal congestion costs to all shippers resulting from this additional tow minus the average cost paid by the marginal tow.

FIGURE 3.3 - Conceptual Waterway Movement Conditional Cost Curves



As noted, in the shipper-based equilibrium shippers in the inland waterway operate in their own self-interest. Individual shippers will not restrict output to a social optimum, where the last increment of tonnage added to the system exhibits just enough marginal rate savings to offset the marginal towing costs (including induced delays); MTC=MRS. Instead, shippers tend to expand waterway volumes to the level at which their average towing costs equal their marginal rate-savings or demand (ATC = MRS). This occurs because each individual carrier pays only its own average cost for moving on the waterway system, not the true marginal costs, which include the costs imposed on all shippers. For example, in a congested lock situation, the addition of just a few more tows per day causes lock delays to increase exponentially because of the queuing effect. The additional tows do not pay for the total marginal increase in tow delay. Rather, the increased delay costs are spread among all tows using the congested lock, making each less efficient. For this reason, the ATC is used in the analysis and formulation of inland navigation projects.

3.3.2.2 Social Equilibrium (Congestion Fee Analysis)

A social-optimal equilibrium can be achieved by inducing private shippers to behave in a socially optimal way. The government can impose a tax or a congestion fee on shippers equal to the difference between the marginal social cost and the average private cost. These fees have both a temporal and spatial dimension and the difficulty is in determining the right mix of fees to mimic the marginal social cost. Movement tonnage demand forecasts, movement willingness-to-pay, and scheduled lock service disruptions also affect the optimal fees each year. As in the shipper-based equilibrium, spatially the exact origins and destinations of commodities affect the traffic levels by waterway segment and thus the optimal fees at individual locks.

The fees however can be determined by the relationship between the demand for traffic at each lock and the capacity of the lock. An initial implementation of an automated method of deriving congestion fees has been implemented in ORNIM (specifically WSDM) as an option in the equilibrium process. The procedure derives a fee (stated as $/ton) for each lock in the system. This approach provides an approximation to the theoretical ideal. The mechanics of this equilibrium can be found in **Attachment 1, Ohio River Navigation Investment Model (ORNIM)**.

3.3.3 Calculation of Transportation Surplus

As discussed in section 0, the benefits are transportation cost reductions. Another way to view the benefits is to compare the WOPC and WPC transportation benefits (i.e. transportation benefits increase when transportation costs decrease). In FIGURE 3.1 the transportation benefit is the area between the market demand curve and the LRAC (including delay cost) curve. There are however, two ways to define this market demand in ORNIM; inelastic and elastic. And there are actually two ways to define elastic demand; constant or piecewise-linear. For the Upper Ohio analysis, all movements were defined as piecewise-linear elastic. Additional information on the elastic movement definitions can be found in **Attachment 1, Ohio River Navigation Investment Model (ORNIM)**. The inelastic and elastic demands, and the calculation of waterway transportation savings, are briefly discussed below.

3.3.3.1 Inelastic Demand

For inelastic movement demand the transportation surplus (typically referred to as waterway transportation savings) is represented by a rectangle above the equilibrium waterway cost, under the inelastic willingness-to-pay (typically set at the least-costly all-overland rate), and between 0 and the equilibrium quantity. The transportation surplus is therefore:

$$TS_{inelastic} = (A - P^*)\, Q^* \qquad (1.0\text{-}1)$$

where:

TS = transportation surplus
A = the inelastic willingness-to-pay $/ton (least-cost all-overland alternative rate $/ton)
P^* = is the equilibrium water transportation rate (cost adjusted base water rate in $/ton)
Q^* = is the equilibrium quantity (tonnage)

3.3.3.2 Elastic Demand

If the demand is represented by a constant elastic demand function then the transportation surplus is calculated by an integral considering price as a function of quantity:

$$TS_{Q^*} = \int_0^{Q^*} \left(P - P^* \right) dQ = \int_0^{Q^*} \left(\left(\frac{Q}{\alpha} \right)^{\frac{1}{\varepsilon}} - \left(P^* \right) \right) dQ \qquad (1.0\text{-}2)$$

If we assume < -1, the integral is bounded and can be expressed in closed form:

$$TS_{(P^*,Q^*)} = \frac{-\alpha}{\varepsilon + 1}\left(P^*\right)^{\varepsilon + 1} \qquad (1.0\text{-}3)$$

(This form assumes the equilibrium point is on the demand curve)

However, if the elasticity is greater than -1 then the integral becomes unbounded if we try to integrate all the way to the vertical axis. To provide a reasonable way to compare benefits with elasticities between 0 and -1, ORNIM caps the cost for all constant elasticity demand curves at the value corresponding to one barge load of the commodity. Thus, instead of integrating from 0 to Q^*, the consumer surplus is calculated as the integral from Q_{min} to Q^* where Q_{min} is the single barge quantity. The surplus for the single barge $Q_{min}\,(P_{max} - P^*)$ is then added to the value of the integral. The details of the integration and an interesting linkage between the constant elasticity and the fixed demand functions is described in ADDENDUM 1D Calculation of Transportation Surplus.

If the demand is represented by a piecewise-linear demand function, then the calculation is relatively straightforward. The area under the curve is calculated by adding the areas under each of the segments. Each segment has a trapezoid shape; therefore, the area under a segment is:

$$TS_{(P^*,Q^*)} = \frac{1}{2}\left(\left(\left(P_i - P^*\right) + \left(P_{i+1} - P^*\right)\right)\left(Q_i - Q_{i+1}\right)\right) \qquad (1.0\text{-}4)$$

where:

P_i and Q_i are the (price, quantity) points that define the demand curve for the given movement & year

3.3.4 Benefit-Cost Analysis

Given the itemization of all the various cost categories over the life-cycle for both the WOPC and WPC, the benefit-cost analysis can be completed. Essentially the WPC WOPC costs foregone (benefits) can be compared against the WPC investment cost.

In the model, the various cost categories (waterway savings and system performance statistics) are itemized under four shipper-based equilibrium scenarios (Normal-operations, Scheduled-maintenance, Probabilistic without scheduled maintenance, and Probabilistic with scheduled maintenance). The non-probabilistic scenarios are itemized to allow incremental comparison against the probabilistic scenarios to enumerate risk effects. Additionally multiple forecast scenarios are summarized. The user then manually selects the NED plan from either the Probabilistic (without scheduled maintenance) scenario or the Probabilistic (with scheduled maintenance) scenario with consideration of the forecast scenario variation. Typically the Probabilistic (with scheduled maintenance) scenario is used with the results between the forecast scenarios averaged.

Note that the WOPC costs avoided under the WPC can be itemized as a benefit or they could be subtracted from the WPC investment cost which converts the benefit-cost analysis to a benefit-to-incremental-cost analysis. Either way the net benefits remain the same, however, the benefit-cost ratio will be higher under a benefit-to-incremental-cost analysis.

The net benefits are calculated by subtracting total economic costs from total economic benefits. Corps planning policy dictates selection of the NED plan as the plan that maximizes net NED benefits. The benefit-cost ratio (BCR) is calculated by dividing total economic benefits by total economic costs. Despite Corps formulation of investments by net benefits, prioritization of investments by the Office of Management and Budget (OMB) is often done using the BCR.

3.4 RISK AND UNCERTAINTY

Corps of Engineers guidelines as presented in the Principles and Guidelines have long recognized that uncertainty is inherent in all phases of the analysis of waterway investments. As such, this analysis provides information regarding the level of uncertainty associated with the values estimated for a number of critical inputs. These include traffic demand projections, lock performance descriptors (capacity and lock availability), and structural reliability. Estimating values for these inputs rests upon a large set of variables, many of which are unique to the input being estimated.

This study focuses its descriptions of uncertainty on the key determinants of economic feasibility--traffic demand projections, lock performance and structural reliability. In the case of traffic demand projections, alternative traffic forecast scenarios based upon competing sets of assumptions are presented and analyzed (**Attachment 3, Traffic Demand Forecasts**). Discrete event simulations based upon statistical analysis of tow operator behavior and actual lock operations are used to estimate traffic-delay or transit relationships at all locks (**Attachment 2, Capacity Analysis**). Lock availability and performance is further described through the use of hazard values and event trees, which is the key input into the Monte Carlo-type simulation which calculates expected future adverse impacts associated with a lock's structural reliability (**Attachment 1, Ohio River Navigation Investment Model**).

Section 4: UPPER OHIO VESSEL FLEET AND PERFORMANCE CHARACTERSITICS

4.1 INTRODUCTION

Tows moving on the inland waterway system are configured to operate as efficiently as possible along each waterway segment. Lock size and channel dimensions are critical in establishing the most efficient tow configuration. Currently, the upper Ohio fleet consists largely of jumbo barges, with six of these barges comprising a typical tow. This section describes the existing characteristics of barges and tows using upper Ohio locks and their performance in processing commercial traffic. Detailed discussions of the vessel fleet and lock utilization are presented in **Attachment 2 Capacity Analysis** of this economics appendix.

4.2 VESSEL FLEET

4.2.1 Introduction

The upper Ohio vessel fleet consists of different types of barges and towboats configured in tow sizes determined by market conditions consistent with lock sizes and channel dimensions.

4.2.2 Barge Fleet

Water transportation equipment has evolved over the years to take advantage of advances in towboats and to match lock sizes. In the distant past the towing industry developed the standard barge with dimensions of 175 feet by 26 feet, which could typically carry 1,069 tons of dry bulk cargo, such as coal or aggregates.

A single tow moving through the main locks at EDM could consist of 11 standard barges (4 across and three long, with a slot for the towboat) carrying 11,750 tons. The entire tow could pass through the 600 by 110 main locks at EDM without breaking the tow and double-locking. Larger tows of standard barges are possible, but they require breaking the tow and double locking when passing through EDM.

As 1,200 foot long locks were constructed downstream beginning in the 1950s, the towing industry adapted and developed the jumbo barge with dimensions of 195 feet in length by 35 feet in width, which is able to carry 1,669 tons (56 percent more than a standard barge).
On the rest of the Ohio River mainstem, the towing industry has adopted a maximum tow size of 15 jumbo barges (3 across and 5 long), which can carry 25,000 tons when fully loaded. This is 2.13 times the capacity of a tow consisting of eleven standard-sized barges, sized to

pass through the EDM locks. The use of jumbo barges increased the productivity of the water transportation system.

A tow of 15 jumbo barges has a length of 975-1,000 feet that can easily fit into the 1,200 foot lock chambers at the 17 other Ohio River projects, with 225 feet of length available for the tow boat and room to spare.

When a maximum tow of 15 jumbo barges encounters any of the EDM locks it must be broken apart and moved through the main locks in two parts, termed double locking. This adds to operating time and expense.

At times, when a main lock chamber at EDM is out of service for maintenance or repair, jumbo barges can only be moved one at a time through a 360 foot by 56 foot auxiliary chamber, thus causing very high delays to towboats and cargo.

An intermediate barge type was also developed, the so-called *stumbo*. It has the length of a jumbo barge – 195 feet – and the width of a standard barge – 26 feet – and can carry 1,121 tons of dry bulk cargo, about 5 percent more than a standard barge. Stumbo barges were sized to fit through 56 foot wide locks such as were present in the past on the Mon River and still exist on several other tributaries.

Jumbo barges predominate on the inland waterway system. Of the roughly 18,000 dry cargo barges currently in use, 96.4 percent are jumbo in size – 195 or 200 feet by 35 feet. The predominance of jumbo barges is shown in **Table 4-1**.

TABLE 4-1 - Dry Cargo Barge Fleet

Decade	Dry Cargo Barges Currently in Use				
Built	Standard	Stumbo	Jumbo	Total	Pct Jumbo
1960s	-	-	109	109	100.0%
1970s	40	112	2,121	2,273	93.3%
1980s	175	173	3,805	4,153	91.6%
1990s	71	49	6,874	6,994	98.3%
2000s	30	-	4,470	4,500	99.3%
Total Fleet	316	334	17,379	18,029	96.4%

Source: Probable Size of Future Barge Fleet at Emsworth, Dashields and Montgomery Locks, Linare Consulting, October 6, 2008.

The trend toward the use of jumbo barges was well established as long as four decades ago, yet it has increased over time. **Table 4-2** shows barge construction since 1991. Note that the vast majority of dry cargo barges built since 1991 (98.9 percent) have been jumbo barges. There have been no standard barges built since 2002 and no stumbo barges built since 2000.

TABLE 4-2 - Barge Construction Since 1991

Year Built	Dry Bulk Cargo				Liquid		Total
	Standard	Stumbo	Jumbo Open	Jumbo Covered	Jumbo Tank	Other Tank	
1991			309	143	48	29	529
1992	22		326	296	56	25	725
1993	12	15	137	283	16	29	492
1994			128	275	15	24	442
1995			118	387	14	70	589
1996			563	433	26	60	1,082
1997		30	301	1,198	12	35	1,576
1998			361	539	21	18	939
1999			336	515	25	55	931
2000	14	10	263	488	17	39	831
2001			175	434	14	32	655
2002	16		164	392		24	596
2003			110	107	11	52	280
2004			158	269	26	57	510
2005			185	34	55	54	328
2006			373	299	14	54	740
2007			353	493	28	57	931
Total	64	55	4,360	6,585	398	714	12,176

Source: Probable Size of Future Barge Fleet at Emsworth, Dashields and Montgomery Locks, Linare Consulting, October 6, 2008.

Trends in the types of barges in the barge fleet in recent years have shown a steady decline in the number of standard, stumbo open hopper and jumbo covered barges while there has been growth in the number of jumbo open hopper barges over the same period.

The U.S. Army Corps of Engineers conducted a study[16] to develop an effective and efficient plan for future operation and maintenance of the three upper Ohio navigation projects – Emsworth, Dashields and Montgomery (EDM). The plan is contingent on the fleet that passes through the projects in terms of the types of barges used and the size of the tows. The study investigated probable changes in the barge fleet that passes through these projects, and how this and possible changes in lock sizes would affect the size of tows at the projects.

A few findings are as follows: (i) only regional carriers in the Pittsburgh area use narrow (26' wide) barges – standards and stumbos. They are being phased out and will be fully retired in the next twenty years and replaced by jumbo (35' wide) barges. The result will be reduction in annual barge trips through the locks, without taking into account growth or decline in traffic volumes and (ii) there are multiple factors that affect the size of tows transiting the locks, with the two most important being the volume of shipments and the size of locks. Larger locks at EDM would result in larger tow sizes, but they would still be less than tow

[16] Probable Size of Future Barge Fleet at Emsworth, Dashields and Montgomery Locks, Linare Consulting, October 6, 2008.

sizes elsewhere on the Ohio River where shipment volumes are higher. This information was used in the development of future capacity estimates at EDM and is written up in more detail in **Attachment 2 Capacity Analysis**.

4.3 LOCK PERFORMANCE CHARACTERSITICS

Average lock performance characteristics for each lock from 2004 to 2009 are listed in **Table 4-3**. The number of empty barges indicates the level of backhaul opportunities. The percentage of empty barges is an important statistic when estimating lock capacity, where lock capacity is defined as an annual tonnage throughput based partially on fleet characteristics. Fifty-percent empty indicates the absence of backhaul opportunity with barges moving loaded in one direction and empty in the opposite direction. Upper Ohio projects show 38 percent empty barges indicating some backhaul opportunity. This is largely due to the fact that the upper Ohio projects tend to serve regions that are both production and consumption oriented so that greater opportunities exist for loaded backhauls.

4.3.1 Lock Transit Time

The time required for a tow to transit a lock has two components: processing time and delay time. Average processing and delay times from 2004 to 2009 for the upper Ohio projects are provided in **Table 4-8**. Processing time is the amount of time a lock is obligated to serve a particular tow. Delay time is the time a tow must wait to be served. Under normal operation, upper Ohio locks experience an average 30 minutes of "residual" delay; delay due to a tow arrival when the lock is in use. More variability is seen in average delay time compared to average processing time. Heavier use of the auxiliary chamber during main chamber closure accounts for most increases in processing time as single-cut tows configured for the main chamber require multiple cuts when using the auxiliary chamber. Higher than normal delays are generally attributable to a main chamber closure.

TABLE 4-3 - 2004-2009 Average Lock Performance Characteristics

River/Project	No. Tows	Number of Barges			Avg. Barges /Tow	Ktons	Avg. Tons /Tow	Avg. Time /Tow (min.)			Comm. Lockages	Avg. Lock Cuts/Tow
		Loaded	Empty	Total				Delay	Process	Total		
Emsworth	3,816	14,076	8,444	22,520	5.9	19,627	5,143	41.84	68.74	110.58	4,764	1.2
Dashields	3,634	14,781	9,156	23,937	6.6	20,361	5,604	30.38	66.19	96.57	4,618	1.3
Montgomery	3,652	13,866	8,147	22,013	6.0	20,112	5,507	40.57	71.03	111.59	4,561	1.2

Source: LPMS Data.

4.3.2 Lock Processing Time

Processing time encompasses the amount of time it takes to approach, enter, chamber, and exit the chamber. At smaller chambers where multiple cuts of the tow must be performed, chambering time includes all intermediate entries and exits. As a result, extra entry, exit, and chamber turnback times are experienced.

Processing times are also affected by site characteristics like hydraulic conditions, lift, number of valves, chamber size, and the location of arrival points. Tow sizes also affect processing times. Smaller tows can generally be processed faster.

Average processing time for a given lock chamber can vary from year to year depending on a number of factors. Most important are tow size, the share of the project's total tows locked through the smaller auxiliary, and the number of recreational boats relative to the number of tows. The larger the tow, the higher the average processing time since larger tows take longer to lock and in the event of a main chamber closure, would require multiple lockages to lock through the auxiliary chamber. The greater the number of recreation boats vis-à-vis tows, the shorter the average processing times because recreation vessels can lock through more quickly.

4.3.3 Lock Delay Time

Delays are recorded in the Lock Performance Monitoring System (LPMS) data when a tow reaches a lock's arrival point and must wait for service. Once the lock is available for service and the tow begins its approach, the period of delay ends. Delays are encountered for a variety of reasons including: weather, hydraulics, accidents, lock maintenance, and an existing queue of tows waiting to use the lock. Delays are a problem when a main chamber is closed for maintenance because at historic traffic levels tows arrive faster than they can be processed with the smaller auxiliary chamber. **Table 4-4** shows average tow delay during EDM main lock chamber closures.

4.4 LOCK OPERATIONS

4.4.1 Towing Operations

During normal operations, the main chamber is used for all tows and the auxiliary chamber is used by recreational traffic and other smaller vessels like lightboats. The maximum number of cuts allowed is a double cut through the main chamber and five-cuts through the auxiliary chamber. **Table 4-5** shows chamber utilization by vessel type averaged from 2004 to 2009.

TABLE 4-4 - Average Tow Delay During EDM Main Lock Chamber Closures *(Hours)*

Year	Project	Duration in Days	Number of Tows	Avg. Tow Delay (Hrs)
2007	Emsworth	4.3	58	12.2
2006	Dashields	7.5	60	7.2
2002	Montgomery	16.6	178	32.7
2002	Montgomery	10.7	130	33.6
2001	Emsworth	8.7	105	18.0
1999	Emsworth	5.5	81	9.2
1998	Emsworth	8.6	100	15.3
1997	Emsworth	6.9	84	14.1
1997	Dashields	33.3	385	22.5
1996	Emsworth	6.1	96	31.2
1995	Emsworth	7.1	100	17.8
1994	Emsworth	29.9	299	36.4
1989	Dashields	59.3	809	15.7
1988	Dashields	48.5	651	4.8
1988	Dashields	14.2	204	11.0
1986	Dashields	11.3	151	3.1
1986	Montgomery	45.3	570	24.3

Source: PCXIN in LRH.

TABLE 4-5 – Usage by Chamber, 2004-2009

	Main Chamber			Auxiliary Chamber			Both Chambers		
River/Project	Tows	Lt Boats	Rec Boats	Tows	Lt Boats	Rec Boats	Tows	Lt Boats	Rec Boats
Emsworth	3,109	36	37	707	686	1,222	3,816	722	1,258
Dashields	3,092	12	9	543	495	787	3,634	507	797
Montgomery	3,136	69	25	516	526	490	3,652	595	515

Source: COE LPMS Data.

4.4.2 Lock Operating Hours

All upper Ohio projects are operated year-round on a 24-hour basis except during periods when a chamber is closed due to weather or for inspection and maintenance/repair work.

4.4.3 Lockage Policy

Tows are normally locked through on a first-come/first-serve basis. EDM tows typically require two cuts and the use of a tow-haulage unit to extract the first cut. During periods when the main chamber is closed for maintenance/repair, lock masters implement n-up/n-down lockage policies and carriers implement a self-help program. This involves using the towboats in queue to extract the first cut of a two-cut lockage from the auxiliary chamber in order to speed up the lockage process. The program is planned in cooperation with the carriers and supervised by the lockmaster.

4.5 LOCK CAPACITY

Chamber dimensions, vessel fleet characteristics and lock processing time are the major factors that determine a project's capacity for annual tonnage throughput. Lock capacity in this study defined a future vessel fleet on the upper Ohio of all jumbo barges by 2028 as the Pittsburgh area standard and stumbo barges are being scrapped and not replaced. Lock capacity is defined as the level of tonnage where the tonnage-delay curve reaches its vertical asymptote and average tow delay increases without bound. Lock capacity analysis, developed using the Waterways Analysis Model (WAM), is more fully discussed in **Attachment 2, Capacity Analysis**. Despite sharing identical physical dimensions and similar fleets, the upper Ohio locks show some variation in capacities based upon differences in lock processing times. They have the lowest capacities on the Ohio River owing to their smaller size (**Table 4-6**). Their auxiliary capacity is far below the existing annual traffic of around 20 million tons.

TABLE 4-6 – Comparative Mainstem Lock Capacity (Million Tons)

Project	Main	Auxiliary	Both
Emsworth	**42.9**	**11.1**	**48.7**
Dashields	**48.1**	**14.3**	**51.5**
Montgomery	**43.2**	**11.5**	**50.3**
New Cumberland	78.5	44.5	132.9
Pike Island	99.5	47.9	151.2
Hannibal	103.1	52.4	152.1
Willow Island	107.5	54.2	155.1
Belleville	114.6	56.3	167.2
Racine	110.5	54.0	151.1
Byrd	116.3	55.5	151.0
Greenup	113.3	54.3	144.2
Meldahl	116.3	55.5	151.0
Markland	119.0	57.1	160.5
McAlpine	120.0	123.0	225.5
Cannelton	124.0	59.0	162.1
Newburgh	135.6	61.7	169.8
Myers	137.3	63.6	170.6
Smithland	143.4	132.9	264.4
Olmsted*	NA	NA	274.9

* under construction

4.6 TRANSPORTATION RATE SAVINGS

The transportation rate savings used in the upper Ohio economic analysis come from a study conducted by the Tennessee Valley Authority (TVA) under contract with the Navigation Planning Center (NC) housed in the Huntington District. The study provides a full range of transportation rates and supplemental costs for a sample of 2004 waterborne commodity movements which, in total or in part, were routed on the Ohio River Navigation System (ORS). All computations reflect rates and fees which were in effect in the third quarter 2007 (FY'08). Of the 1,552 sample movements, 205 went through Emsworth, Dashields, or Montgomery (EDM). The EDM movements captured 20.6 million tons of EDM traffic in 2004 – almost 86 percent of upper Ohio traffic.

The sample rate data was used to extrapolate rate savings data to the entire ORB. A full discussion of this can be found in **Attachment 4, Transportation Rate Analysis**. **Table 4-6** shows a sub-set of the ORB transportation rate savings as applied to the upper Ohio navigation system. The National Economic Development (NED) savings from waterway transportation are the basis by which the upper Ohio navigation system is valued and the basis by which economic justification for re-investment in the system is derived.

TABLE 4-7 – Upper Ohio NED Savings

		Average Per-Ton*		
Group	**Commodities**	**Water Rate**	**All-Land Rate**	**NED Saving**
1	Coal	$ 18.65	$ 24.03	$ 5.37
2	Petroleum Fuel Products	$ 16.87	$ 54.51	$ 37.64
3	Aggregates	$ 8.46	$ 15.56	$ 7.10
4	Food and Processed Food Products	$ 23.74	$ 52.27	$ 28.53
5	Chemicals	$ 40.48	$ 94.90	$ 54.42
6	Non-Metallic Minerals	$ 33.08	$ 49.47	$ 16.39
7	Ferrous Ores, I&S Products	$ 37.67	$ 69.96	$ 32.29
8	Manufactured Goods	$ 20.52	$ 55.15	$ 34.63
AVERAGE ALL COMMODITIES		**$ 18.88**	**$ 28.75**	**$ 9.87**

* All rates and rate differentials are weighted averages.

Section 5. HISTORIC AND PROJECTED UPPER OHIO TRAFFIC

5.1 GENERAL

This section discusses historic, existing and projected future traffic in the EDM reach, here defined as the Upper Ohio river segment extending from the confluence of the Allegheny and Monongahela rivers at Pittsburgh (the point) to the Montgomery Locks and Dam at river mile 31.7. This river reach comprises the mainstem navigation pools created by the Emsworth (mile 6.2), Dashields (mile 13.3) and Montgomery (mile 31.7) locks and dams, and is located entirely within the Pittsburgh Metropolitan Statistical Area. Historic developments that influenced the growth of traffic in this river reach are discussed. The methodology used in projecting future traffic demands is summarized along with the projection results. A more detailed discussion of the traffic demand forecasts used in this analysis can be found in Attachment 3.

5.2 EXISTING TRAFFIC

Commodity traffic in 2006 by major commodity group in the EDM reach along with data for Emsworth, Dashields, Montgomery, the Ohio River and the overall Ohio River System is shown in Table 5-1.

TABLE 5-1 – Commodity Traffic for EDM, the Ohio River and the ORS, 2006 (Thousand Tons)

	Emsworth	Dashields	Montgomery	EDM Reach	Ohio River	ORS
Coal & Coke	16,368	16,368	15,799	18,173	130,005	150,988
Petroleum Fuels	260	249	332	427	12,150	12,311
Crude Petroleum	7	7	7	7	625	647
Aggregates	1,308	1,404	582	2,420	39,900	44,886
Grains	0	0	0	0	11,464	11,562
Chemicals	660	671	824	824	9,597	10,641
Ores & Minerals	486	527	909	977	9,011	9,033
Iron & Steel	733	762	1,005	1,005	13,872	14,583
All Other	743	751	966	967	15,038	16,074
Total	20,564	20,738	20,425	24,801	241,662	270,726

SOURCE: COE Waterborne Commerce Statistics

In 2006, about 24.8 million tons of commodity traffic moved in the EDM reach, accounting for about 10.3 percent of traffic on the Ohio River and about 9.2 percent of traffic on the overall ORS. Emsworth, Dashields and Montgomery locks each handled a little in excess of 20 million tons of traffic, representing around 83 percent of Upper Ohio tonnage. Tonnage densities on the Upper Ohio are about evenly distributed throughout the river reach. Typically, about 85 percent of the traffic that actually locks through projects on the Upper Ohio is shared traffic among the three projects

The leading commodity group on the Upper Ohio in 2006 was coal, accounting for about 74 percent of total traffic. Aggregates was next in importance (10 percent), followed by iron and steel (4 percent), ores and minerals (4 percent), chemicals (3 percent) and petroleum fuels (2 percent). Collectively these six commodity groups accounted for more than 96 percent of traffic on the system. The bulk of the remaining tonnage on the Upper Ohio, classified as all other, was made up largely of lubricating oils and greases, asphalt, fabricated metal products, cement and lime.

5.3 HISTORIC TRAFFIC DEVELOPMENT

5.3.1 Historic Growth Factors.

Because of its traditional dominance in the area's economy, developments in the regional steel industry have been some of the most important factors affecting volumes and patterns of commodity traffic on the Upper Ohio River. A more recent factor has been the effect of environmental regulations on coal-fired electric utility plants. The lack of clear traffic growth trends since the 1950s is explained largely by the cyclical nature of the steel industry and its traditional dominance of the regional economy. The history of the steel industry is key to understanding the factors that have traditionally driven traffic growth/development on the Upper Ohio. More recent developments have produced some important changes that have reduced the dominance of the steel industry in the regional economy.

During the 1950s, the U.S. produced nearly half of the world's raw steel. Steel plants in the Monongahela Valley accounted for about one quarter of the nation's raw steel output and Pittsburgh was regarded as the center of U.S. production. Steel companies were vertically integrated, which meant that they not only produced steel, but also owned and controlled the raw material inputs, including the metallurgical coal reserves in the Monongahela, Kanawha and Big Sandy river basins. Captive metallurgical coal mines in these regions produced exclusively for the Pittsburgh area coking operations. Since the steel industry is a major consumer of electricity, even the region's steam coal demands were driven by the steel industry. River traffic volumes and flows were determined by the state of the region's steel industry.

After the 1950s, U.S. dominance in world steel production began to diminish to the extent that by 1970, U.S. production accounted for only about one fifth of world production. In the late 1970s and early 1980s, the integrated arm of the U.S. steel industry began a re-structuring process that resulted in the closure or consolidation of numerous obsolete and unprofitable plants. Despite intermittent periods of recovery and high demand, consolidation in the industry is a trend that persists to the present day. Eventually, U.S. raw steelmaking capacity was reduced from 160 million tons in 1977 to a level of about 112 million tons in 2006, at which point the U.S. was only the third-ranking steel producer, behind China and Japan. Overall industry employment was reduced from 452,000 in 1977 to 122,000 in 2006.

The decline in the U.S. integrated steel industry came about as a result of a long-term decline in domestic steel demand, increased import competition, intense intra-industry competition, and an increasingly non-competitive cost structure. The decline in steel demand is explained by increasing substitution of other materials (i.e. plastics and aluminum), the use of lighter-gauge steel and the decline in the rate of infrastructure construction. Direct steel imports, to say nothing of indirect steel imports in the form of appliances, machinery, and so forth, have risen from less than 3 percent of U.S. steel consumption in 1958 to more than one-third in 2006. Steel minimills, which relied mostly on scrap to produce steel in electric arc furnaces, have provided intense intra-indusry competition for integrated producers, rising from two percent of domestic output in 1960 to 43 percent in 2006. High labor costs, as well as a reluctance to adopt new technologies left the integrated sector at a competitive disadvantage both domestically and internationally.

The Pittsburgh area was severely impacted by industry restructuring in the integrated steel sector as companies closed and downsized facilities. In an effort to reduce the cost of transporting raw materials and finished products, integrated companies concentrated their operations in the Great Lakes region, closer to their primary source of iron ore and to their biggest customers - chiefly the motor vehicle and heavy equipment industries. As a result, the bulk of plant closings occurred in Ohio, Indiana and Pennsylvania, particularly the Pittsburgh area. Between 1982 and 1987, all or parts of 11 integrated steel plants in the Pittsburgh area, as well as some associated coking facilities, were closed. Other related sectors were affected as well, including steel industry suppliers and downstream basic steel recipients. Major waterborne coal movements that served area coking facilities were curtailed. Effects to the regional economy were both widespread and long-lasting, and led to an eventual re-structuring away from steel manufacturing to more of a service-based economy. Currently, only one integrated steel plant remains in operation in the Pittsburgh area, the J. Edgar Thompson Works in Braddock, Pennsylvania.

Restructuring in the industry, had a number of other important effects. As an additional cost-saving measure, major steel companies largely divested themselves of coal mines. Coal producers, no longer captive to steel companies, began to diversify into other markets, specifically the utility and export markets. With the closure of steel plants in the Pittsburgh area especially, electric utilities were left with excess generating capacity, since the steel plants were major customers. Coincidentally, baseload nuclear capacity came on line in the area, effectively reducing steam coal demands.

Besides the issues surrounding the integrated steel industry, the evolution of the environmental regulations governing electric power plant emissions has had a sizeable impact on Upper Ohio traffic. In the 1970s and 1980s, as the environmental regulations were developing, electric utilities began to favor low-sulfur coals, particularly Central Appalachian coals, either solely or in blends with higher sulfur coals, to meet their emission reduction targets. Since coal sources along the Upper Ohio and in the Monongahela Valley are generally high sulfur sources, this produced sizeable upbound traffic through the EDM reach to meet the needs of electric utilities on the Monongahela and Allegheny rivers. With the implementation of increasingly stringent environmental regulations, the widespread installation of scrubbers at electric utility plants and the gradual depletion of low sulfur Central Appalachian coals, the higher sulfur Northern Appalachian coals are increasingly in demand. This has produced increased downbound coal traffic through the EDM reach to meet the needs of scrubbed facilities, especially in the Middle and Lower Ohio valleys.

5.3.2 Historic Commodity Traffic

Table 5-2 shows annual commodity traffic at the Emsworth, Dashields and Montgomery projects compared to the Ohio River and the overall Ohio River System for the period 1970-2006. A similar time series for the Upper Ohio River segment is unavailable. Traditionally, the EDM reach has served as a conduit linking upstream producers with downstream consumers or downstream producers with upstream consumers. Most of the traffic utilizing this waterway segment is through traffic (two thirds in 2006) and 85 percent or more of the traffic through the Emsworth, Dashields and Montgomery locks is typically shared traffic.

Because so much of the traffic at the Upper Ohio locks is shared traffic, there exist many similarities at the locks in terms of overall traffic volumes and traffic patterns. Traffic through the Emsworth facility has ranged between 14.7 (1983) and 25.6 (1973) million tons. Traffic through Dashields has varied between 15.0 (1983) and 24.7 (2002) million tons, while traffic through Montgomery has ranged between and 16.0 (1983) and 28.3 (1993) million tons. Interestingly, the low-volume year (1983) at each facility coincides with the severe downturn in the region's (and nation's) steel industry. Clear trends in waterway traffic on the Upper Ohio are difficult to discern from the data in Table 5-2. Commodity traffic in this river reach has tended to mirror the cyclical nature of the region's steel industry. This stands in clear contrast to the relatively robust traffic growth on the Ohio River (1.7 percent) and the ORS (1.4 percent) over the 1970-2006 period.

Changes in Upper Ohio commodity traffic by major commodity group for selected years between 1990 and 2006 are displayed in Table 5-3. Although traffic volumes have fluctuated over the 16-year period, the 2006 traffic level in the EDM reach actually represented a decrease of about 2.7 million tons from 1990, diminishing from 27.4 to 24.8 million tons. The 2006 traffic levels represented an increase for four of the

TABLE 5-2 – Historic Traffic at EDM, the Ohio River and the ORS (Million Tons)

Year	Emsworth	Dashields	Montgomery	Ohio River	ORS
1970	19.6	20.2	17.4	129.6	163.9
1971	22.5	19.7	21.5	133.4	163.9
1972	23.7	21.9	21.7	138.9	171.7
1973	25.6	23.9	22.9	136.9	168.8
1974	24.7	23.7	22.1	139.3	170.2
1975	22.1	22.3	20.8	140.1	171.4
1976	23.7	24.6	23.4	148.4	178.1
1977	23.4	24.0	22.3	151.4	178.6
1978	21.8	22.0	21.6	152.6	177.6
1979	23.2	24.1	23.8	165.3	194.8
1980	20.0	21.0	20.4	174.9	200.5
1981	20.4	20.9	22.3	167.6	192.6
1982	16.5	16.8	18.2	150.7	174.0
1983	14.7	15.0	16.0	150.4	171.2
1984	20.3	21.2	22.2	174.7	202.2
1985	17.2	17.9	19.0	177.5	203.9
1986	17.6	18.6	20.1	195.6	223.8
1987	20.4	21.7	23.0	197.2	226.7
1988	19.8	21.1	22.8	192.6	225.9
1989	19.3	20.3	21.5	202.7	238.4
1990	22.4	23.9	25.7	225.7	260.3
1991	19.4	20.9	22.5	218.3	248.9
1992	22.7	24.1	26.0	226.4	257.7
1993	23.2	24.3	28.3	227.2	253.1
1994	23.5	24.6	27.3	236.7	267.0
1995	21.7	23.0	25.3	234.1	263.5
1996	23.5	24.5	27.3	237.7	267.2
1997	23.0	23.9	26.8	239.8	271.5
1998	23.3	24.4	26.8	242.0	274.5
1999	23.3	24.3	26.4	240.8	274.9
2000	21.9	22.4	25.2	236.5	271.8
2001	21.5	22.0	25.0	242.5	279.9
2002	23.8	24.7	27.3	243.1	279.1
2003	19.8	20.5	22.1	228.8	259.8
2004	18.9	19.6	20.6	239.0	269.9
2005	20.8	21.3	23.0	249.2	280.1
2006	20.6	20.7	20.4	241.5	270.7
Annual Growth (%) 1970-06	0.1	0.1	0.5	1.7	1.4

SOURCE: COE Waterborne Commerce Statistics

commodity groups, including coal and coke, crude petroleum, ores and minerals, and iron and steel. For five of the commodity groups, specifically petroleum fuels, aggregates, grains, chemicals and all other, the 2006 traffic level represented a reduction relative to 1990.

TABLE 5-3 – Historic EDM Reach Traffic by Commodity Group, 1990-2006 (Thousand Tons)

	1990	1995	2000	2004	2005	2006	Annual % Change
Coal & Coke	17,929	19,276	18,770	16,027	19,321	18,173	0.08
Petroleum Fuels	1,955	1,361	781	396	478	427	-9.1
Crude Petroleum	1	0	0	0	12	7	12.5
Aggregates	3,614	3,124	3,759	2,932	2,515	2,420	-2.5
Grains	10	8	2	0	0	0	-
Chemicals	1,009	1,030	977	796	773	824	-1.3
Ores & Minerals	616	803	988	1,406	1,161	977	2.9
Iron & Steel	844	1,233	1,201	1,254	1,097	1,005	1.1
All Other	1,492	1,373	1,529	1,153	990	967	-2.7
Total	27,469	28,207	28,007	23,964	26,346	24,801	-0.6

SOURCE: COE Waterborne Commerce Statistics

The coal and coke group, consisting of coal and a relatively small amount of petroleum coke, has traditionally dominated traffic in the EDM reach, accounting for 65-75 percent of traffic in the 1990-2006 time period. EDM reach coal and coke traffic serves the electric utility, metallurgical, industrial and export markets. Most of the coal and coke traffic in the EDM reach originates on the Monongahela River, with sizeable quantities also originating in the Middle Ohio, the Upper Ohio and the Kanawha rivers. The largest coal and coke recipients are the Upper Ohio, the Lower Ohio, the Monongahela and Middle Ohio rivers. The largest downstream recipients on the Ohio River are scrubbed electric utility plants. On the upstream side, the largest recipients on the Monongahela and Allegheny rivers are a coking facility and five electric generating facilities. Over the 1990-2006 period, most of the growth in receipt of EDM reach coal was accounted for by scrubbed electric utility plants on the Lower Ohio and the Tennessee and Cumberland rivers.

The petroleum fuels group, consisting of residual fuel oil, distillate fuel oil, gasoline, jet fuel and kerosene, accounted for only about 2-7 percent of total traffic in the EDM reach over the 1990-2006 period. The principle origin for petroleum fuels traffic in 2006 was the Upper Ohio, followed by the Middle Ohio and Lower Mississippi rivers. The principal destinations for petroleum fuels traffic in 2006 were the Upper Ohio and Monongahela rivers. Traffic in petroleum fuels diminished steadily over the 16-year period, largely because of increased reliance on pipeline movement in this region.

Crude petroleum movements are rare and quite small in the EDM reach, as they are elsewhere on the Ohio River System. When they do occur, they are typically movements from small regional oilfields to regional refineries.

Aggregates traffic in the EDM reach is made up of sand and gravel and crushed limestone destined for local construction activities, for use a flux stone in metals manufacturing, in cement manufacturing, and as sorbent material in scrubbers at coal-fired electric power plants. Aggregates traffic accounted for about 10-13 percent of total traffic in the EDM reach during the 1990-2006 period. The principal origins for aggregates traffic in 2006 were the Monongahela, Upper Ohio and Allegheny rivers. Origins for sand and gravel were frequently dredging sites. The principal destinations were the Upper Ohio, the Monongahela and Kanawha rivers. Reduced aggregates traffic in recent years reflects reduced needs for flux stone in metals manufacturing, as well as a leveling off of heavy construction activity in the Pittsburgh area .

Grain shipments in the EDM reach, which in the past have consisted of oats, rice, corn, soybeans and barley, are rare and small in volume when they do occur. No grain traffic moved in the EDM reach in 2006. Previous waterborne grain shipments moved to food/animal feed processors and occurred as an alternative to rail shipment. The principal origins for grains traffic were the Lower Mississippi, the Illinois Waterway and the Tennessee/Cumberland rivers. The principal destinations were the Allegheny, the Upper Ohio and the Monongahela rivers.

Chemicals traffic moving in the EDM reach includes movements of sodium hydroxide, alcohols, benzene and toluene, gum and wood chemicals and fertilizers. Typically, chemicals traffic comprises 3-4 percent of traffic in the EDM reach. Chemicals traffic transiting the EDM reach is typically used, directly or indirectly through downstream chemical producers, in various segments of the steel and glass industries. Another common usage is in fuel additives. The leading origins for EDM reach chemicals traffic are on the Lower Mississippi, the Upper Ohio and the Kanawha rivers. The primary destinations are the Upper Ohio, the Monongahela and the Allegheny rivers.

Ores and minerals traffic in the EDM reach includes movements of salt, gypsum, clay, bauxite and manganese. Ores and minerals typically account for 2-6 percent of total traffic in this river reach. The leading origins for ores and minerals traffic are the Gulf Coast, the Upper Ohio and the Lower Mississippi rivers. The leading destinations for this traffic are the Upper Ohio and Monongahela rivers. The growth in ores and minerals traffic in recent years is explained in large part by growth in artificial gypsum moving to wallboard plants. Artificial gypsum is a by-product of scrubbing at coal-fired electric generating facilities.

Iron and steel traffic in the EDM reach comprises movements of iron ore, pig iron, various iron and steel forms, ferroalloys and iron and steel scrap. Iron and steel normally accounts for about 3-5 percent of total traffic in the EDM reach. Upbound iron and steel traffic through the EDM reach generally comprises iron ore, scrap and iron and steel forms and alloys destined for the integrated mills, steel minimills and other steel manufacturers in the Pittsburgh area. Downstream traffic is generally scrap and iron and steel forms destined for steel minimills and steel manufacturers inside and outside the ORB. The leading origins for this traffic are the Monongahela, the Lower Mississippi and Upper Ohio rivers. The primary destinations are the Gulf Coast and the Lower Ohio and Upper Ohio rivers.

The final category, all other, is made up largely of lubricating oils and greases, asphalt, fabricated metal products, building cement and lime. These five groups accounted for about 88 percent of all other commodity traffic in 2006. Typically, this group accounts for around

4-5 percent of total traffic in the EDM reach. The leading origins for all other traffic are the Lower Mississippi, the Middle Ohio, and the Lower Ohio rivers. The leading destinations for all other traffic are the Upper Ohio and the Monongahela rivers.

5.4 COMMODITY SHIPPING PATTERNS

Table 5-4 shows Upper Ohio traffic by commodity group and direction of movement in 2006. Total traffic in the EDM reach in 2006 was about 24.8 million tons, consisting of inbound (terminating), outbound (originating), internal traffic and through (upbound and downbound) traffic. Nearly two-thirds of the traffic in the EDM reach was through traffic, with about 15 percent more traffic moving in an upbound direction than downbound (8.5 vs 7.5 million tons). Also in 2006, about 30 percent of the traffic on the Upper Ohio was inbound to or outbound from the EDM reach, with inbound traffic exceeding outbound by about 41 percent. Internal traffic on the Upper Ohio is quite small, consisting of less than 4 percent of total traffic.

TABLE 5-4 – EDM Reach Traffic by Direction of Movement, 2006 (Thousand Tons)

				Thru Traffic		
	Inbound	Outbound	Internal	Upbound	Downbund	Total
Coal & Coke	1,399	2,558	361	7,060	6,795	18,173
Petroleum Fuels	189	138	0	66	34	427
Crude Petroleum	0	0	0	7	0	7
Aggregates	1,376	318	534	135	56	2,420
Grains	0	0	0	0	0	0
Chemicals	416	10	0	368	30	824
Ores & Minerals	618	1	68	276	14	977
Iron & Steel	172	163	0	196	475	1,005
All Other	460	21	1	392	94	967
Total	4,631	3,210	964	8,499	7,497	24,801

SOURCE: COE Waterborne Commerce Statistics

Upbound traffic through the Upper Ohio, including both through traffic and traffic originating on the Upper Ohio, totaled about 10.3 million tons in 2006 and consisted largely of coal and coke (85 percent), chemicals (4 percent), ores and minerals (3 percent) and iron and steel (2 percent). A large majority of this traffic (78 percent) was destined for utility plants, coking facilities and other industrial facilities on the Monongahela River.

Downbound traffic through the Upper Ohio, again including both through traffic and traffic originating on the Upper Ohio, totaled about 9 million tons, consisting primarily of coal and coke (89 percent) and iron and steel (7 percent). A very large majority of this traffic originated at facilities on the Monongahela River. The coal traffic was destined in large part for scrubbed coal-fired electric generating facilities along the Ohio and tributary streams. The iron and steel traffic, which was mostly primary iron and steel products, was destined largely for metals manufacturers in the Ohio Valley.

Upper Ohio traffic was examined in terms of commodity movements between Bureau of Economic Analysis Economic Areas (EAs). The 2006 shipping and receiving Economic Areas for traffic using the EDM reach are shown in Table 5-5. Economic Areas are geographic regions defined by the Bureau of Economic Analysis, U.S. Department of Commerce. Economic Areas consist of a major city or Metropolitan Statistical Area that serves as a center for economic activity, and outlying areas that are economically related to the center. The Economic Areas cited correspond to the 2004 re-definition. The EDM reach is contained entirely within the Pittsburgh Economic Area (EA 129) as well as the Pittsburgh Metropolitan Statistical Area (38300).

Upper Ohio traffic moves from/to points as distant as Brownsville (McAllen, TX - EA 104), on the Gulf Intracoastal Waterway and Minneapolis, on the Upper Mississippi. The data in Table 5-5, however, indicate that more than half of the tonnage shipments (13.4 million tons) and nearly three quarters of the tonnage receipts (18.0 million tons) using the Upper Ohio originated/terminated in the Pittsburgh Economic Area.
Other important origin Economic Areas for Upper Ohio traffic include Charleston, WV (5.2 million tons); Columbus (2.2 million tons); Clarksburg, WV (1.4 million tons); New Orleans (0.7 million tons); Lafayette, LA (0.5 million tons); and Houston (0.4 million tons). Other major destination economic areas include Louisville (1.2 million tons); Columbus (0.9 million tons); Clarksburg, WV (0.9 million tons); Nashville (0.8 million tons); Cincinnati (0.7 million tons); and Charleston, WV (0.7 million tons).

5.5 LOCK TRAFFIC PATTERNS AND COMMONALITY OF TRAFFIC

Detailed listings of the 2006 directional distribution of commodity flows for the Emsworth, Dashields and Montgomery projects, as well as the overall EDM reach are displayed in Tables 5-6 and 5-7. From the data in Table 5-7, it is apparent that a majority of traffic (55-60 percent) at each of the facilities and on the EDM reach overall was upbound traffic. More than two-thirds of the upbound traffic was coal originating largely at locations on the Kanawha and Big Sandy rivers, as well as locations in the mid and upper Ohio River Valley. Most of this traffic was destined for coal-fired power plants, coking plants and other industrial facilities on the Monongahela River. Other important upbound traffic would include aggregates, much of which originates at a dredge site in the Montgomery pool; ores and minerals; and chemicals. These four commodity groups accounted for about 89 percent of upbound traffic on the Upper Ohio

TABLE 5-5 – EDM Reach, Shipments and Receipts by Economic Area, 2006 (Tons)

	Shipping/Receiving EA	Shipments	Receipts
11	Atlanta-Sandy Springs-Gainesville, GA-AL	0	39,311
15	Baton Rouge-Pierre Part, LA	332,271	2,167
16	Beaumont-Port Arthur, TX	41,564	0
19	Birmingham-Hoover-Cullman, AL	1,600	15,850
29	Charleston, WV	5,232,986	670,651
32	Chicago-Naperville-Michigan City, IL-IN-WI	9,944	16,982
33	Cincinnati-Middletown-Wilmington, OH-KY-IN	94,898	748,560
34	Clarksburg, WV + Morgantown, WV	1,353,048	942,236
35	Cleveland-Akron-Elyria, OH	131,659	0
40	Columbus-Marion-Chillicothe, OH	2,204,141	944,497
41	Corpus Christi-Kingsville, TX	3,336	0
54	Evansville, IN-KY	4,134	52,371
59	Fort Smith, AR-OK	0	20,561
75	Houston-Baytown-Huntsville, TX	434,451	135,565
76	Huntsville-Decatur, AL	31,437	0
80	Jackson-Yazoo City, MS	20,052	0
82	Jonesboro, AR	77,549	33,630
88	Knoxville-Sevierville-La Follette, TN	1,553	0
90	Lafayette-Acadiana, LA	468,577	0
91	Lake Charles-Jennings, LA	108,638	0
96	Little Rock-North Little Rock-Pine Bluff, AR	3,975	1,620
98	Louisville-Elizabethtown-Scottsburg, KY-IN	130,082	1,224,443
104	McAllen-Edinburg-Pharr, TX	0	69,150
105	Memphis, TN-MS-AR	7,133	33,001
109	Minneapolis-St. Paul-St. Cloud, MN-WI	0	3,187
112	Mobile-Daphne-Fairhope, AL	4,737	0
116	Nashville-Davidson--Murfreesboro--Columbia, TN	2,303	882,696
117	New Orleans-Metairie-Bogalusa, LA	687,462	199,088
122	Paducah, KY-IL	8,045	473,442
126	Peoria-Canton, IL	3,806	14,319
129	Pittsburgh-New Castle, PA	13,360,933	18,008,796
153	Shreveport-Bossier City-Minden, LA	1,244	0
160	St. Louis-St. Charles-Farmington, MO-IL	37,048	183,050
170	Tulsa-Bartlesville, OK	0	81,035
171	Tupelo, MS	2,477	4,875
	TOTALS	24,801,083	24,801,083

SOURCE: COE Waterborne Commerce Statistics

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Downbound traffic on the Upper Ohio in 2006 was dominated by coal (81 percent) destined largely for scrubbed coal-fired power plants in the upper and mid Ohio Valley. The other important downbound traffic consists of aggregates, most of which terminates in the Emsworth and Dashields pools; and iron and steel, which consists of primary iron and steel and scrap destined for downstream steel product producers, steel service centers and minimills. These three commodities comprised more than 97 percent of downbound traffic.

TABLE 5-6 – Upper Ohio Traffic by Direction of Movement, 2006 (Thousand Tons)

	Emsworth		Dashields		Montgomery		EDM Reach	
	Upbound	Downbound	Upbound	Downbound	Upbound	Downbund	Upbound	Downbound
Coal & Coke	8,929	7,439	8,929	7,439	7,816	7,983	9,187	8,986
Petroleum Fuels	212	48	180	70	255	77	350	77
Crude Petroleum	7	0	7	0	7	0	7	0
Aggregates	667	641	1,221	183	495	86	1,317	1,103
Grains	0	0	0	0	0	0	0	0
Chemicals	622	38	633	38	784	40	784	40
Ores & Minerals	471	15	512	15	894	15	894	83
Iron & Steel	258	475	258	504	368	637	368	637
All Other	644	100	651	100	851	115	853	115
Total	11,809	8,755	12,390	8,348	11,470	8,954	13,759	11,042

SOURCE: COE Waterborne Commerce Statistics

TABLE 5-7 – Upper Ohio Traffic by Direction of Movement, 2006 (Percent)

	Emsworth		Dashields		Montgomery		EDM Reach	
	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound
Coal & Coke	75.6	85.0	72.1	89.1	68.1	89.2	66.8	81.4
Petroleum Fuels	1.8	0.5	1.4	0.8	2.2	0.9	2.5	0.7
Crude Petroleum	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0
Aggregates	5.6	7.3	9.9	2.2	4.3	1.0	9.6	10.0
Grains	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemicals	5.3	0.4	5.1	0.4	6.8	0.5	5.7	0.4
Ores & Minerals	4.0	0.2	4.1	0.2	7.8	0.2	6.5	0.8
Iron & Steel	2.2	5.4	2.1	6.0	3.2	7.1	2.7	5.8
All Other	5.4	1.1	5.3	1.2	7.4	1.3	6.2	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SOURCE: COE Waterborne Commerce Statistics

Table 5-8 shows the commonality of Emsworth, Dashields and Montgomery traffic with each other and also with other selected projects on the Ohio River Navigation System for calendar year 2006. Since the EDM reach is basically a transit area for traffic moving to/from the Monongahela and Allegheny rivers and the Pittsburgh urban area, a large

TABLE 5-8 – Commonality of 2006 Traffic With Other Selected Projects (Percent)

Project	Emsworth traffic thru	Other project traffic thru Emsworth	Dashields traffic thru	Other project traffic thru Dashields	Montgomery traffic thru	Other project traffic thru
Emsworth	100%	100%	97%	97%	85%	85%
Dashields	97%	97%	100%	100%	87%	86%
Montgomery	85%	85%	86%	87%	100%	100%
Allegheny L/D 2	5%	56%	5%	56%	3%	35%
Monongahela L/D 2	86%	92%	83%	89%	75%	80%
Monongahela L/D 4	44%	71%	41%	66%	33%	53%
Gray's Landing	9%	40%	7%	29%	3%	12%
Winfield	8%	8%	7%	8%	8%	8%
Marmet	7%	9%	7%	9%	7%	9%
Byrd	55%	20%	55%	20%	62%	22%
Greenup	38%	11%	38%	11%	44%	13%
McAlpine	18%	7%	19%	7%	23%	8%
Myers	17%	5%	18%	5%	22%	6%
Kentucky/Barkley	7%	3%	7%	3%	7%	4%
L/D 52	11%	2%	11%	2%	15%	3%

SOURCE: COE Waterborne Commerce Statistics

majority of the traffic through the EDM projects is shared traffic. Total shared traffic at the EDM projects is about 17.4 million tons, with 9.9 million tons of shared traffic moving in an upstream direction and 7.5 million tons moving in a downstream direction. Moving in a downstream direction, the Emsworth project shares 97 percent of its traffic with Dashields and 85 percent of its traffic with Montgomery. In the upstream direction, the Montgomery project shares 87 percent of its traffic with Dashields and 85 percent of its traffic with Emsworth.

The near absence of internal traffic in the EDM reach means that large volumes of the traffic also passes through other projects on the inland navigation system. Table 5-8 shows that the strongest linkage for the EDM projects is to the Monongahela River, with 75-86 percent of the traffic transiting the EDM projects also transiting Monongahela Lock 2. The EDM projects also show a strong linkage to the Middle Ohio Valley, with 38-44 percent of the EDM project traffic also transiting the Greenup locks. Ties to the Tennessee-Cumberland system are considerably weaker, with only about 7 percent of EDM project traffic also passing the Kentucky/Barkley projects. The EDM projects show a surprisingly strong link to the Mississippi River, with 11-15 percent of project-level traffic also moving through Lock 52.

The issue of seasonality in traffic patterns is one that affects many of the inland waterways, but is not normally one that impacts the Upper Ohio reaches. Table 5-9 shows monthly tonnages through the Emsworth, Dashields and Montgomery facilities between January 2007

TABLE 5-9 - Monthly Distribution of Traffic Through the Upper Ohio Projects (Thousand Tons)

	2007			2008			2009		
	Emsworth	Dashields	Montgomery	Emsworth	Dashields	Montgomery	Emsworth	Dashields	Montgomery
Jan	1,517	1,509	1,436	1,748	1,741	1,753	1,693	1,644	1,560
Feb	1,327	1,335	1,264	1,678	1,658	1,494	1,465	1,494	1,539
Mar	1,480	1,486	1,567	1,696	1,658	1,483	1,263	1,228	1,292
Apr	1,535	1,569	1,569	1,832	1,886	1,736	1,294	1,393	1,212
May	1,714	1,905	1,831	1,925	2,010	1,917	1,398	1,441	1,331
Jun	1,564	1,641	1,588	1,912	1,982	1,897	1,501	1,633	1,512
Jul	1,571	1,678	1,573	1,668	1,709	1,702	989	1,079	1,154
Aug	1,720	1,776	1,647	1,962	2,012	1,957	1,490	1,622	1,579
Sep	1,745	1,858	1,642	1,778	1,802	1,687	1,417	1,571	1,478
Oct	1,849	1,989	1,789	1,697	1,810	1,734	823	1,004	1,107
Nov	1,764	1,813	1,758	1,783	1,866	1,800	1,245	1,317	1,435
Dec	1,614	1,611	1,615	1,594	1,655	1,653	1,110	1,107	1,191

SOURCE: LPMS

and December 2009. Navigation throughout the ORS is maintained on a year-round basis and traffic through the Upper Ohio projects is normally distributed evenly throughout the year.

5.6 PROJECTED TRAFFIC DEMAND

5.6.1 Introduction

The traffic demand forecasts presented here represent a comprehensive update of previous forecasts completed in the spring of 2003. New forecasts were prepared for all commodity groups under three forecast scenarios. Because of the dominance of utility steam coal on the system and the uncertainties surrounding the regulatory future, greater attention was devoted to the development of the coal traffic forecasts, in particular the utility steam coal. The current round of adjustments to the utility coal forecasts was necessitated by existing and likely future regulatory changes affecting the electric utility industry. Environmental issues are acknowledged by industry experts to be the dominant issues expected to affect future coal utilization and sourcing on the part of the electric utilities.

The traffic demand forecasts for the ORS are generally divided between coal and noncoal commodities. Coal, in this instance, includes all categories of coal and coke, meaning utility steam coal, coking coal, industrial coal, export coal and petroleum coke. Additionally, sorbent materials forecasts, which refers to the lime and limestone used in coal desulfurization, were developed in conjunction with the utility steam coal forecasts, since the usage of sorbent materials is associated with levels of coal consumption. All remaining commodities are categorized as noncoal and are forecast separately. The forecasting approaches used to generate the coal and noncoal forecasts are substantially different.

5.6.2 Coal Forecasts

It is generally agreed by industry experts that environmental regulations, both at the state and national levels, currently overwhelm all other issues related to the use of coal by the electric utilities. Since passage of the Clean Air Act, the electric utility industry has been confronted with increasingly stringent pollutant emission regulations, initially targeting principally sulfur dioxide and later focusing on nitrogen oxides, particulates and mercury. New regulations are now targeting carbon dioxide, presenting another set of unique challenges to the industry. The evolving environmental regulations have compelled the electric utilities to devote considerable effort to develop and update internally coordinated compliance strategies.

In order to deal with a broad range of issues affecting electricity generation, particularly the environmental issues, the current forecasting effort makes use of a linear programming approach through the use of the Greenmont Energy Model (GEM). The GEM is a detailed model of the electric utility and coal industries. The GEM was initially developed in 2005 by Greenmont Energy and has been continually updated since that time. The model has been used to prepare analyses for coal companies, utilities and government clients. An important client is the Department of Energy and its various labs. GEM has been used for analyses dealing with such issues as coal supply; regulatory planning; coal infrastructure; advanced technologies impact on coal-fired plants; coal/electricity forecasting; hurricane impacts on the coal and electric utility industries; and integrated gasification combined cycle (IGCC) competitiveness.

For every year in the specified forecasting horizon the GEM determines the least-cost means to produce required generation in a market context and within existing and expected future environmental constraints. The model deals with every unit at every power plant in the U.S. and Canada. The model forecasts generation requirements by type of generation, meaning nuclear, gas, coal and so forth, both nationally and regionally.

For coal-fired powerplants, the model determines level of dispatch as well as the least-cost strategies for the plants to comply with their emission reduction requirements under the environment regulations. These strategies may include actions such as fuel switching, adding clean-up equipment or allowance purchasing. For coal-fired power plants, the model determines the amount, type and sourcing of coal according to 104 separate supply regions. The model determines, as well, the amount and type of new generation capacity and retirement of existing units. On the coal supply side, the model determines fob coal mine prices as well as the amount of economically-justified mining capacity expansion for each cost level for each type of coal.

The GEM was run for High Case, Mid Case and Low Case scenarios for every year in a 64-year forecasting horizon. The High Case scenario assumed relatively high long-term economic growth coupled with low levels of nuclear plant development and high gas prices. The Mid Case scenario assumed moderate economic growth along with moderate growth in nuclear plant development. Both the High and Mid Case scenarios assume a reasonable evolution of existing environmental regulations relative to the electric utility industry. The Low Case scenario is founded on relatively low levels of economic growth with high levels of nuclear plant development. A key driver in the Low Case scenario is the assumption that the Waxman-Markey bill governing nationwide carbon dioxide emissions is implemented.

Coal consumption and sourcing by coal-fired plants are direct outputs of the GEM. Plant-level coal consumption and sourcing from GEM were used along with historical waterway sourcing patterns for utility steam coal from the Waterborne Commerce statistics to develop projected waterway flows. The sorbent material forecasts are developed based on plant-level coal consumption by coal type. Sorbent flows were developed using existing and expected future waterside sorbent material sources. Export coal, industrial coal, coking coal and industrial coke consumption are forecast separately and treated as inputs to the GEM. These forecasts were then used to develop indices that were then applied to a composite (2004-2006) of existing coal and coke movements in these categories.

5.6.3 Noncoal Forecasts

The forecast of noncoal commodities was generated using statistical time series techniques. For the purposes of this forecasting effort, the annual ORS dock-to-dock traffic data contained in the Waterborne Commerce Statistics (WCSC) was used. Commodity traffic is defined as ORS traffic if it uses all or part of the ORS in its routing[17]. In this instance a record in the WCSC data consists of an annual movement of a commodity (five-digit) between an origin dock and a destination dock by way of a particular waterway routing. In any given year, this traffic can total 10,000-12000 individual movements. Data for the 26-year period 1980-2006 were made available for this analysis. The data were grouped into 13 distinct commodity groupings based on common supply and demand characteristics.

As a part of the current forecasting effort, a number of forecasting techniques were considered and evaluated as to their usefulness. Ultimately, for the purposes of the current forecasting exercise, Box-Jenkins ARIMA models with additional explanatory variables were pursued because, given the number of variables to be forecast, the relatively limited numbers of observations, and the need for very long-run forecasts, these models were considered to be superior from a theoretical standpoint. Additionally, preliminary examinations using the Schwartz Information Criteria (SIC), the Akaike Information Criteria (AIC) and adjusted R2 measures to distinguish among the models suggested that this approach generated the best forecasts.

Within the Box-Jenkins framework, a variety of different approaches and data aggregations were made in an effort to improve the forecasting results. These included data aggregations for the entire ORS by commodity group, aggregations for origin-destination pairs by commodity and by geographic region and aggregations for destinations by commodity and by

[17] *All ORS traffic enters into the forecasting and system modeling because the modeling assesses the system effects of navigation improvements anywhere in the system. Since traffic is typically shared among multiple locks, improvements at one lock can have impacts at other locks as well as net system effects.*

geographic area. The output from this effort was the set of Mid Case traffic demand projections.

In addition to the Mid Case forecast, Low and High Case scenarios were also developed from the time series results. The High Case and Low Case forecasts were developed by reference to the Mid Case. Essentially, the High and Low cases represent modifications of the slope of the Mid Case forecast using its own standard error. The High and Low cases were developed by adding or deducting one standard error from the Mid Case result.

5.7 PROJECTION RESULTS

5.7.1 Total Traffic Demand

Total traffic demands for the ORS, the Ohio River main stem and the Upper Ohio reach as well as Emsworth, Dashields and Montgomery locks are displayed in Tables 5-9 and 5-10 . Traffic demand is the projected future traffic that could realize a cost savings if navigation system constraints are not considered. In other words, it is the traffic that could be expected to materialize in the absence of navigation system constraints. Figures 5-1 - 5-4 show historical and projected traffic for the Ohio River mainstem and the Upper Ohio projects under each scenario.

The Ohio River mainstem typically accounts for 85-90 percent of the traffic on the Ohio River System. Ohio River traffic trends, accordingly, are generally reflective of the overall system. For the Ohio River, the range in the forecasts for 2030 is between 272.7 million tons in the Low Case and 346.5 million tons in the High Case. By 2070, the range is between 277.5 and 432.2 million tons for these same scenarios. Annual growth rates for the 2006-2070 period range between 0.22 and 0.91 percent, compared to the historical (1980-2006) growth rate of 1.25 percent.

Forecast results for the Upper Ohio reach and the individual locks show substantially different patterns from the Ohio River and the overall system. Because of coal switching and interactions that arise in different scenarios, the rank ordering of the forecast scenarios at the locks is not necessarily the same as the Ohio River and ORS ordering in any given year. For the Upper Ohio reach, the range in the forecasts for 2030 is between 29.0 million tons in the Mid Case scenario

TABLE 5-9 – Projected Traffic Demands for the EDM Reach, Ohio River and ORS, 2006-2070 (Million Tons)

	EDM Reach			Ohio River			ORS		
	High	Base Case	Low	High	Base Case	Low	High	Base Case	Low
Actual									
1980	NA	NA	NA	174.9	174.9	174.9	200.5	200.5	200.5
2006	24.8	24.8	24.8	241.5	241.5	241.5	270.7	270.7	270.7
Projected									
2010	29.4	27.5	27.7	259.1	255.6	254.8	286.3	283.6	282.2
2020	32.1	32.0	34.1	319.4	301.8	279.2	351.5	334.4	300.9
2030	42.1	29.0	38.5	346.5	297.9	272.7	378.9	329.9	289.1
2040	54.8	39.5	36.3	400.0	327.5	254.3	436.7	360.2	268.1
2050	57.8	36.9	33.9	430.5	358.1	272.9	470.2	388.7	291.7
2060	54.7	38.3	32.2	434.3	381.1	283.7	479.4	413.3	298.8
2070	72.4	30.3	31.0	432.2	397.9	277.5	485.1	429.2	291.6
Annual Growth									
1990-06	-	-	-	1.25	1.25	1.25	1.16	1.16	1.16
2006-70	1.69	0.32	0.35	0.91	0.78	0.22	0.92	0.72	0.12

SOURCE: COE Waterborne Commerce Statistics; Planning Center for Expertise in Inland Navigation.

TABLE 5-10 – Projected Traffic Demands for EDM, 2006- 2070 (Million Tons)

	Emsworth			Dashields			Montgomery		
	High	Base Case	Low	High	Base Case	Low	High	Base Case	Low
Actual									
1980	20.0	20.0	20.0	21.0	21.0	21.0	20.4	20.4	20.4
2006	20.6	20.6	20.6	20.7	20.7	20.7	20.4	20.4	20.4
Projected									
2010	24.4	22.7	22.9	24.9	23.2	23.4	25.8	24.1	24.3
2020	25.6	24.6	26.8	26.3	25.2	27.4	28.1	28.1	30.5
2030	34.9	22.1	30.1	35.6	22.9	30.7	37.9	24.8	34.7
2040	45.2	31.2	27.3	46.0	32.0	28.1	50.2	34.9	32.0
2050	47.5	29.3	23.8	48.4	30.1	24.6	52.7	32.1	29.2
2060	43.3	29.9	22.5	44.4	30.9	23.4	49.3	33.1	27.1
2070	60.7	21.9	21.2	61.8	23.0	22.2	66.6	24.7	25.6
Annual Growth									
1980-06	0.11	0.11	0.11	-0.06	-0.06	-0.06	0.00	0.00	0.00
2006-70	1.70	0.10	0.05	1.72	0.16	0.11	1.86	0.30	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center for Expertise in Inland Navigation

FIGURE 5-1

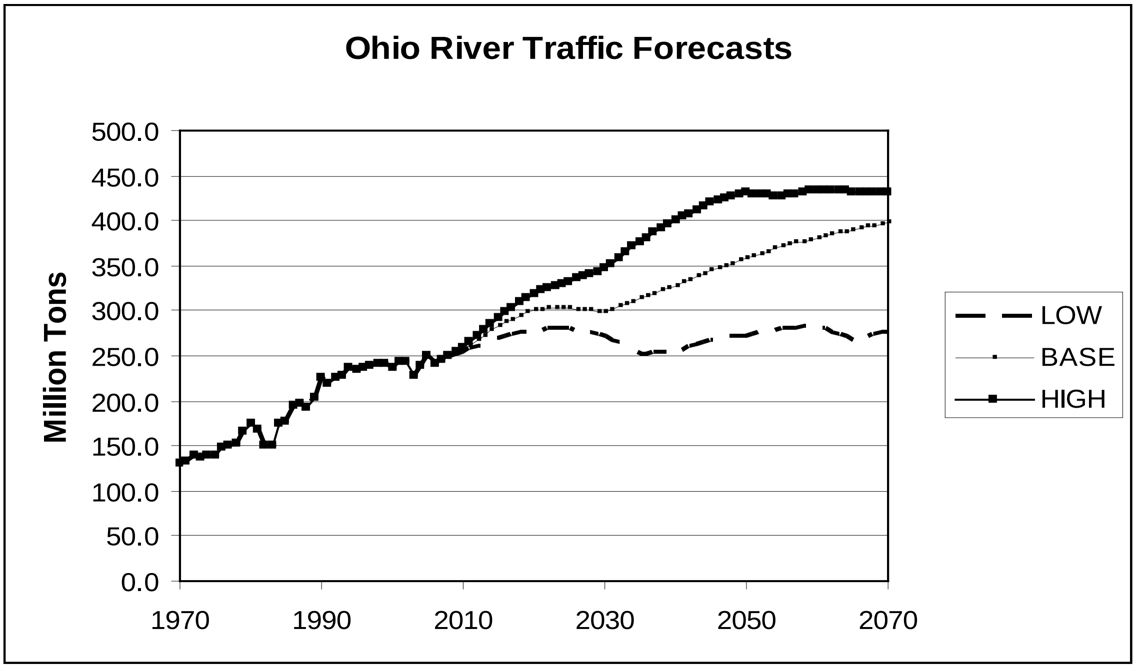


FIGURE 5-2

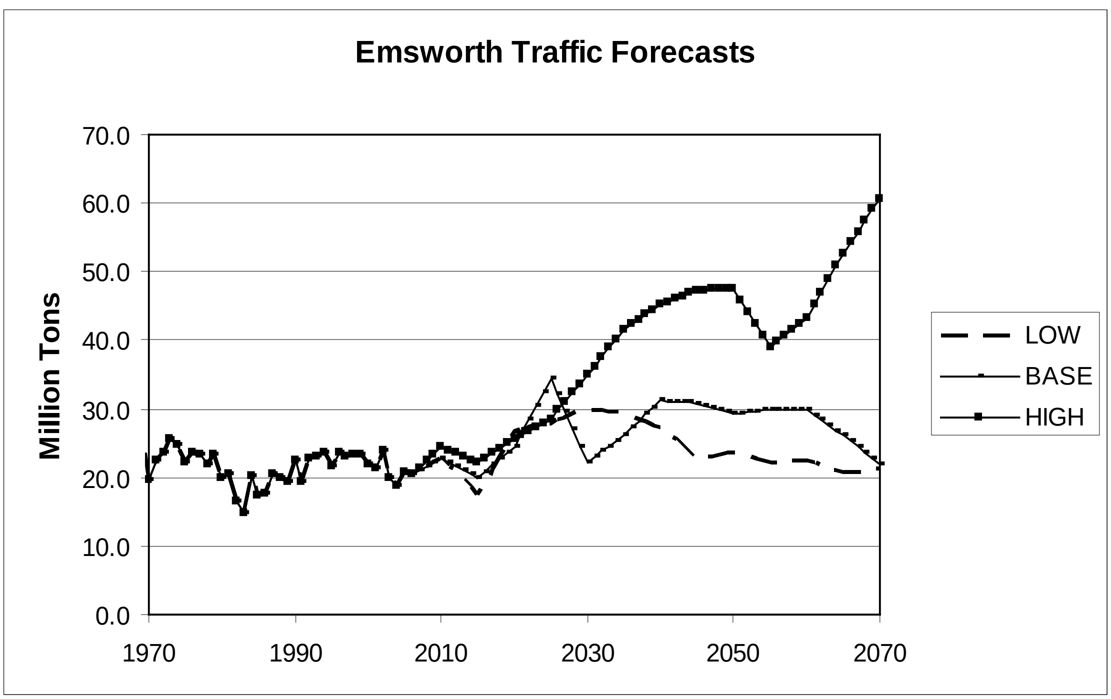


FIGURE 5-3

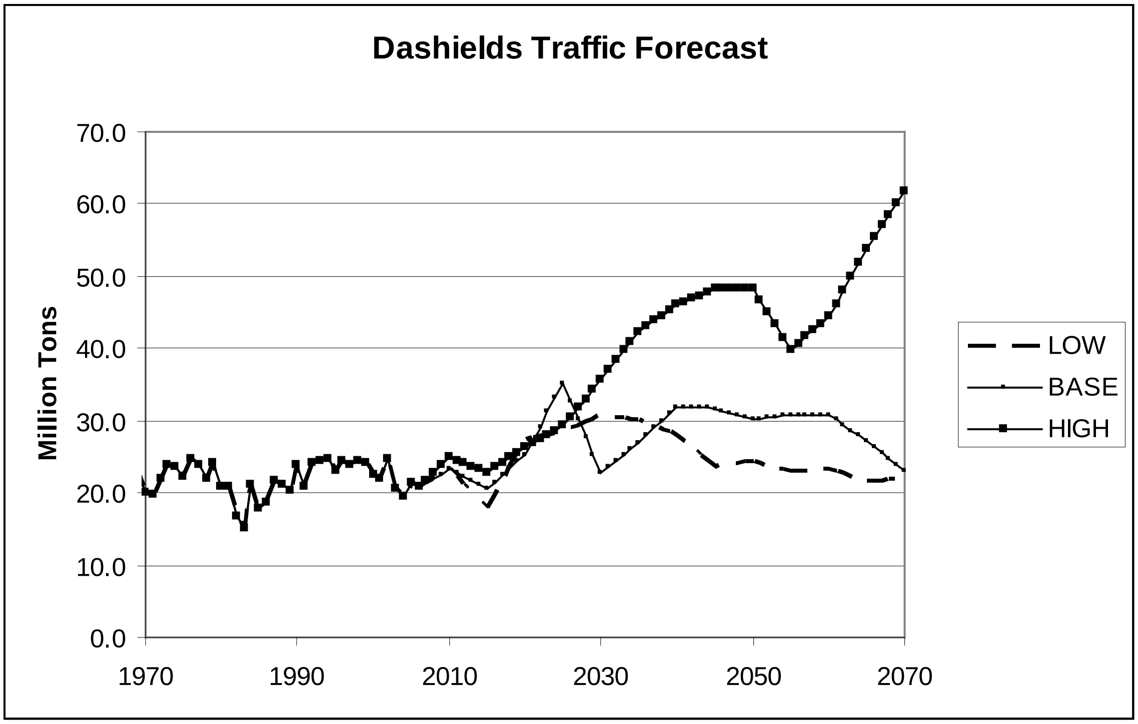
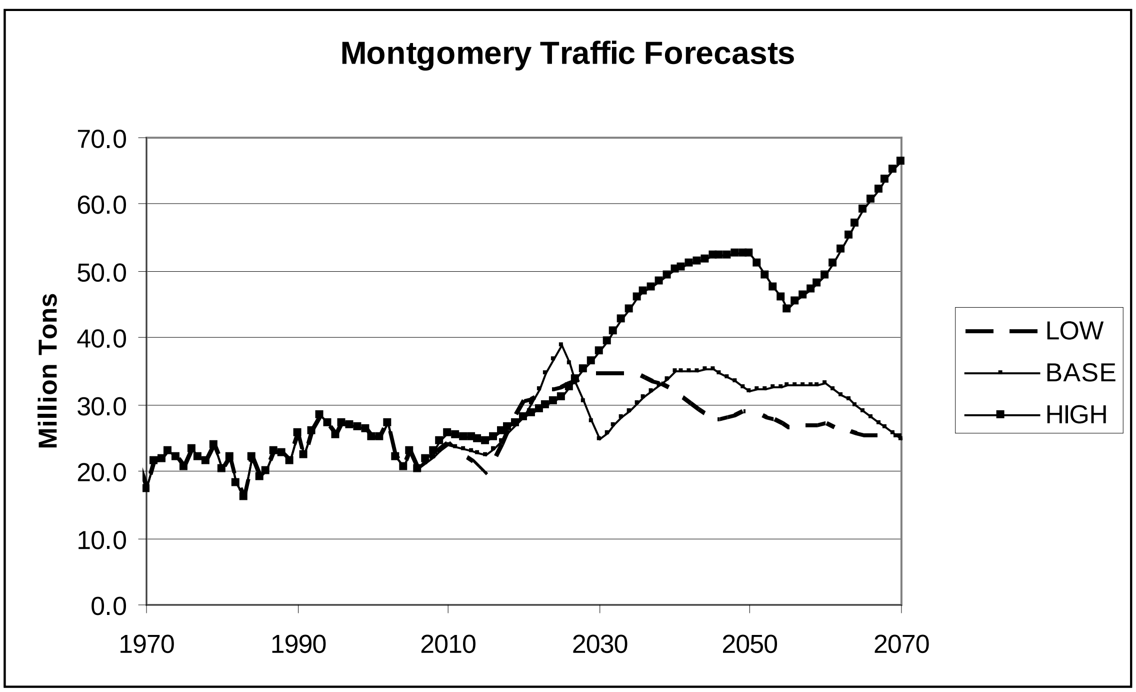


FIGURE 5-4



and 42.1 million tons in the High Case. By 2070, the range is between 30.3 million tons in the Mid Case and 72.4 million in the High Case. Annual growth rates for the 2006-2070 period range between 0.32 and 1.69 percent.

Given the level of commonality of traffic among the Emsworth, Dashields and Montgomery locks, the forecast patterns for the individual locks is largely similar to that of the Upper Ohio reach. It should be noted that historic traffic trends at the Upper Ohio projects are essentially flat, while the forecasts call for some level of mid-term growth (relative to the base year) in every forecast scenario. This is supported, in part, by DOE's outlook for Northern Appalachian coal production. Since the early 1970s, coal output in the Northern Appalachian producing region has been disadvantaged by the requirements of the Clean Air Act, given that coal from this region is generally in the medium-to-high sulfur range. As scrubbing becomes more and more widespread and as Central Appalachian low sulfur resources continue to diminish, DOE forecasts an increase in North Appalachian coal production amounting to about 1.5 percent per year between 2006 and 2030.

5.7.2 Traffic Demands by Commodity Group

Traffic demands by commodity group for the Upper Ohio reach along with Emsworth, Dashields and Montgomery locks are displayed in Tables 5-11 and 5-12. Coal continues to be a major component of traffic on the Upper Ohio as well as on the Ohio River and ORS. Coal traffic in 2006 totaled 18.2 million tons. The 2070 forecast for the Upper Ohio ranges between 57.7 million tons in the High Case and 17.8 million tons in the Low Case. These traffic levels represent annual growth ranges between 1.82 and –0.03 percent relative to 2006. Also over the 2006-2070 timeframe, coal traffic increases as a share of total traffic under the High Case scenario, but diminishes under the Low Case. Under the High Case, coal traffic increases from 73 percent of total traffic in 2006 to about 80 percent, while under the Low Case it diminishes to about 58 percent. The key driver in the High Case is the relatively low level of nuclear development, while in the Low Case it is the carbon dioxide emissions limitations.

The forecast for petroleum fuels on the Upper Ohio reach diminishes under every forecast scenario, which is likely reflective of the growing reliance on pipeline distribution throughout the ORB region. The forecast of crude petroleum remains small (>7,000 tons) and essentially flat under all scenarios. Petroleum fuels traffic in 2006 reached 427,000 tons. The range in the forecasts for 2070 is between 308,000 tons in the High Case Scenario and 162,000 tons in the Low Case Scenario, representing annual growth rates ranging between -0.51 and -1.51 percent respectively. Petroleum fuels diminishes as a share of total traffic under every scenario. In 2006, petroleum fuels was about 1.7 percent of total traffic. By 2070, petroleum fuels' share of total traffic is 0.4 percent in the High Case and 0.5 percent in the Low Case.

Aggregates traffic forecasts for the Upper Ohio increase under every scenario, reflecting expanding infrastructure investment as well as increased usage of limestone in coal

TABLE 5-11 – Projected Upper Ohio Traffic Demand by Commodity Group (Million Tons)

	Actual 2006	2010	2020	2030	2040	2050	2060	2070	Annual Growth 2006-70
High									
Coal & Coke	18173	21417	22959	32330	43822	45532	41222	57650	1.82
Petroleum Fuels	427	375	286	289	291	296	302	308	-0.51
Crude Petroleum	7	6	6	6	6	6	6	6	-0.14
Aggregates	2420	3224	3853	3774	4274	4775	5275	5824	1.38
Grains	0	0	0	0	0	0	0	0	-
Chemicals	898	902	962	1022	1082	1142	1202	1262	0.53
Ores & Minerals	977	1243	1449	1654	1860	2065	2271	2477	1.46
Iron & Steel	1005	1229	1598	1967	2336	2705	3074	3443	1.94
All Other	894	963	970	1070	1147	1242	1359	1466	0.78
Total	24800	29359	32083	42112	54819	57763	54711	72435	1.69
Base Case									
Coal & Coke	18173	20010	23336	19678	29033	25303	25472	16317	-0.17
Petroleum Fuels	427	342	268	259	254	249	244	239	-0.90
Crude Petroleum	7	6	6	6	6	6	6	6	-0.14
Aggregates	2420	2951	3550	3634	4075	4556	5126	5697	1.35
Grains	0	0	0	0	0	0	0	0	-
Chemicals	898	898	944	990	1036	1082	1127	1173	0.42
Ores & Minerals	977	1234	1408	1582	1756	1930	2104	2278	1.33
Iron & Steel	1005	1223	1571	1918	2266	2614	2962	3309	1.88
All Other	894	884	896	959	1026	1114	1213	1322	0.61
Total	24800	27548	31979	29027	39452	36853	38255	30342	0.32
Low									
Coal & Coke	18173	20020	25744	29666	26408	22916	20102	17803	-0.03
Petroleum Fuels	427	275	247	228	210	192	175	162	-1.51
Crude Petroleum	7	6	6	6	6	6	6	6	-0.14
Aggregates	2420	3211	3453	3462	3910	4457	5005	5552	1.31
Grains	0	0	0	0	0	0	0	0	-
Chemicals	898	894	924	955	986	1017	1048	1079	0.29
Ores & Minerals	977	1222	1358	1494	1629	1765	1901	2036	1.15
Iron & Steel	1005	1215	1538	1861	2184	2506	2829	3152	1.80
All Other	894	877	830	860	918	1008	1099	1190	0.45
Total	24800	27720	34100	38532	36250	33868	32165	30980	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center for Expertise in Inland Navigation

desulfurization. A total of 2.4 million tons of aggregates moved on the Upper Ohio reach in 2006. The 2070 forecasts range between 5.8 million tons in the High Case and 5.5 million tons in the Low Case. Annual growth rates are between 1.38 and 1.31 percent, respectively. Aggregates diminishes as a share of total traffic in the High Case, but increases in the Low Case. In 2006, aggregates traffic was about 9.8 percent of total traffic. In 2070, aggregates accounts for between 8.0 (High Case) and 17.9 (Low Case) percent of total traffic.

In the past, grains movements on the Upper Ohio reach have been occasional and quite small in volume. Accordingly, no grains traffic is forecast for the Upper Ohio reach under any of the forecast scenarios.

TABLE 5-12 – Projected EDM Traffic Demand by Commodity Group, 2006-2070 (Million Tons)

	Actual	2030			2070			Annual Growth (%), 2006-70		
	2006	High	Base Case	Low	High	Base Case	Low	High	Base	Low
Emsworth:										
Coal & Coke	16,368	29,618	17,178	25,436	53,138	14,748	14,495	1.86	-0.16	-0.19
Petroleum Fuels	205	69	66	63	107	99	90	-1.02	-1.12	-1.27
Crude Petroleum	7	6	6	6	6	6	6	-0.14	-0.14	-0.14
Aggregates	1,308	1,456	1,348	1,210	1,923	1,879	1,829	0.60	0.57	0.53
Grains	0	0	0	0	0	0	0	-	-	-
Chemicals	731	831	805	776	1,026	954	876	0.53	0.42	0.28
Ores & Minerals	486	829	795	754	1,273	1,180	1,067	1.52	1.40	1.24
Iron & Steel	732	1,368	1,334	1,294	2,395	2,302	2,192	1.87	1.81	1.73
All Other	664	688	594	515	859	760	684	0.40	0.21	0.05
Total	20,501	34,865	22,127	30,056	60,726	21,929	21,241	1.71	0.11	0.06
Dashields:										
Coal & Coke	16,368	29,616	17,177	25,435	53,136	14,747	14,493	1.86	-0.16	-0.19
Petroleum Fuels	249	229	206	183	254	202	146	0.03	-0.33	-0.83
Crude Petroleum	7	6	6	6	6	6	6	-0.14	-0.14	-0.14
Aggregates	1,404	1,847	1,734	1,591	2,583	2,525	2,459	0.96	0.92	0.88
Grains	0	0	0	0	0	0	0	-	-	-
Chemicals	744	848	821	792	1,046	973	894	0.53	0.42	0.29
Ores & Minerals	527	925	886	839	1,412	1,306	1,178	1.55	1.43	1.27
Iron & Steel	761	1,435	1,400	1,358	2,512	2,414	2,299	1.88	1.82	1.74
All Other	677	719	622	541	896	790	705	0.44	0.24	0.06
Total	20,738	35,624	22,852	30,745	61,843	22,963	22,181	1.72	0.16	0.11
Montgomery:										
Coal & Coke	15,799	30,848	18,155	28,390	56,142	14,922	16,530	2.00	-0.09	0.07
Petroleum Fuels	332	288	259	228	308	239	162	-0.12	-0.51	-1.12
Crude Petroleum	7	6	6	6	6	6	6	-0.14	-0.14	-0.14
Aggregates	582	1,177	1,114	1,035	1,700	1,661	1,616	1.69	1.65	1.61
Grains	0	0	0	0	0	0	0	-	-	-
Chemicals	898	1,022	990	955	1,262	1,173	1,079	0.53	0.42	0.29
Ores & Minerals	909	1,497	1,432	1,353	2,248	2,070	1,853	1.42	1.29	1.12
Iron & Steel	1,005	1,960	1,911	1,854	3,430	3,297	3,140	1.94	1.87	1.80
All Other	893	1,069	958	859	1,464	1,320	1,188	0.78	0.61	0.45
Total	20,424	37,868	24,825	34,680	66,559	24,688	25,575	1.86	0.30	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center of Expertise in Inland Navigation.

Various types of chemicals transit the EDM reach and are frequently destined for eventual use in some segment of the steel and glass industries or as fuel additives. Chemicals tonnage totaled 898,000 tons in 2006. Forecasts for 2070 range between 1.3 million tons in the High Case and 1.1 million in the Low Case. The resulting annual growth is between 0.53 and 0.29 percent for these same scenarios. As of 2006, chemicals traffic made up around 3.6 percent of total traffic through the EDM reach. For 2070, the range is between 1.7 (High Case) and 3.5 (Low Case) percent of total traffic.

Ores and minerals on the EDM reach consists principally of salt, gypsum, clay, bauxite and manganese. In 2006, the group totaled just under 1 million tons. By 2070, the forecasts range between 2.5 million tons in the High Case and 2.0 million tons in the Low Case, representing annual growth rates of 1.46 and 1.15 percent, respectively. In 2006, the ores and minerals traffic comprised about 3.6 percent of total traffic. By 2070, the range in the forecasts shows ores and minerals comprising between 3.4 (High Case) and 6.6 (Low Case) percent of the total.

Traffic in iron and steel in the EDM reach typically consists of iron ore, pig iron, various iron and steel forms, ferroalloys and iron and steel scrap. Totaling just over 1 million tons in 2006, the range in the forecasts for 2070 is between 3.4 million tons in the High Case and 3.1 million tons in the Low Case. The projected annual growth rates range between 1.94 to 1.80 percent under these scenarios. The 2006 EDM reach iron and steel tonnage was about 4.1 percent of the total, while the forecasts show that iron and steel tonnage will range from 4.8 percent in the High Case to 10.2 percent in the Low Case.

On the EDM reach, the all other category consists largely of lubricating oils and greases, asphalt, fabricated metal products, building cement and lime. For 2006, traffic in the all other category totaled 894,000 tons. The forecast for 2070 shows all other traffic ranging from 1.5 million tons in the High Case to 1.2 million tons in the Low Case, with annual growth rates ranging from 0.78 to 0.45 percent. All other traffic on the EDM reach in 2006 was about 3.6 percent of the total, while the 2070 forecasts show all other traffic ranging between 2.0 percent in the High Case and 3.8 percent in the Low Case.

Again, because of the high percentage of shared traffic at EDM, traffic and trends for the individual locks bear many similarities to the EDM reach.

5.8 SELECTION OF THE MOST LIKELY FUTURE SCENARIO

Utility steam coal traffic dominates the traffic picture on both the ORS and the EDM reach, accounting for about 47 percent of total 2006 traffic in the first instance and 40 percent in the second. As a result, future expectations for utility steam coal traffic largely define the most probable future forecast scenario. In developing the high and low case utility steam coal forecast scenarios, the contractor modeled a coincidence of factors that would be expected to produce plausible “best case” and “worst case” forecasts of steam coal consumption and waterborne coal traffic. For example, in the high case, it is assumed that high economic growth would coincide with low levels of nuclear plant development and high natural gas prices. In the low case, it is assumed that low economic growth would coincide with high levels of nuclear plant development and strict carbon dioxide emission reduction requirements as outlined in the Waxman-Markey bill. In reality, it is considered unlikely that such factors would coincide to produce high and low utility coal consumption and waterborne coal traffic. For this reason, the Mid Case, or alternatively, the “mid-level” forecast scenario for utility steam coal is considered to be the closest to a “most likely” future scenario. Other categories of coal and coke were treated similarly to the utility steam coal.
Concerning the noncoal commodities, the time series analysis produced a mid-level forecast that necessarily captured the long-term historic trend embedded in the commodity traffic data.

The high and low alternatives were then developed by altering the slopes of the Mid Case forecasts using the standard error of the estimate. Accordingly, the Mid Case or "mid-level" forecasts are considered to be the "most likely" future scenarios for the noncoal commodities.

Project economic analyses in Sections 8 and 9 are based largely on the "mid-level" forecast scenario. Economic analyses based on high and low alternative forecasts are handled as sensitivity analyses in Section 10.

Section 6: SYSTEM MODELING, INPUTS, CALIBRATION AND OUTPUTS

6.1 INTRODUCTION

The decentralized nature of Corps program execution resulted in the early development of several system models. The first model was developed by the North Central Division for the Illinois Waterway in the 1960s. In the early 1970s, with more complex studies on the horizon, a centralized research and development program was initiated within the Office of the Chief of Engineers called the Inland Navigation Systems Analysis (INSA) Coordination Group. In the mid-1970s the Waterway Analysis Model (WAM) and the Flotilla Model were developed[18]. The WAM is a tow-level discrete-event simulation model used to estimate lock performance under a given operating condition, with a defined fleet and for a specific traffic level. WAM was capable of modeling single, or multiple, navigation projects each with multiple lock chambers and was also modified in 1993 into a deep-draft version. The Flotilla Model was developed to calculate with and without-project economic impacts.

In 1977 the Transportation Systems Center of the U.S. Department of Transportation sponsored the expansion of the Flotilla Model into the Resource Requirements Model and a Post-Processor program. Additional modifications were made from 1979-80 under the direction of the CELRH-NC, and a third program, the Marginal Economic Analysis Model, was added. Collectively, these three programs (Resource Requirements Model, Post-Processor and the Marginal Economic Analysis Model) were known as the Tow Cost Model (TCM). Further modifications led to the development of the Equilibrium (EQ) Model in the mid-1980s, and the Marginal Economic Analysis Model was dropped. Collectively, the TCM and EQ Model were known as the Tow Cost / Equilibrium (TC/EQ) Models.

In the early-1990s structural reliability analytical techniques advanced, allowing for a more quantitative assessment of project maintenance requirements and the probability of unscheduled project closures. In the mid-1990s the TC/EQ Model suite was supplemented with the inclusion of the Life Cycle Lock Model (LCLM), which was developed to estimate the expected transportation impacts of unscheduled closures under both the without- and with-project conditions external to the TC/EQ. During this time period the WAM was also modified to capture re-scheduling effects observed during historic long-duration closure events.

In the mid to late-1990s, modernization and expansion of TC/EQ into the ORNIM began as engineering reliability data multiplied and the need to dynamically link the reliability analysis (LCLM) with a simultaneous investment optimization algorithm. ORNIM was built by Oak Ridge National Laboratory (ORNL) in collaboration with CELRH-NC / PCX-IN.

[18] These models were developed by Consolidated Analysis Centers (CACI), Inc. in SIMSCRIPT software which was developed in 1962 to support an Air Force RAND project and gave birth to CACI in 1964.

From 2005-2009 under the U.S. Army Engineer Institute of Water Resources (IWR) Navigation Economic Technologies (NETS) program empirically derived demand elasticity's were developed and ORNIM was expanded to equilibrate using downward-sloping movement-level demand curves.

6.2 THE LRD SYSTEM MODEL

Like its predecessors, ORNIM is an annual model which can be described as a spatially detailed partial equilibrium waterway transportation cost and equilibrium model. While it is not really designed to estimate the total benefits of a river system, or the benefits the nation would lose if the river system no longer existed (something like a computable general equilibrium model would be needed), it is appropriate to estimate the benefits of incremental improvements to river systems.

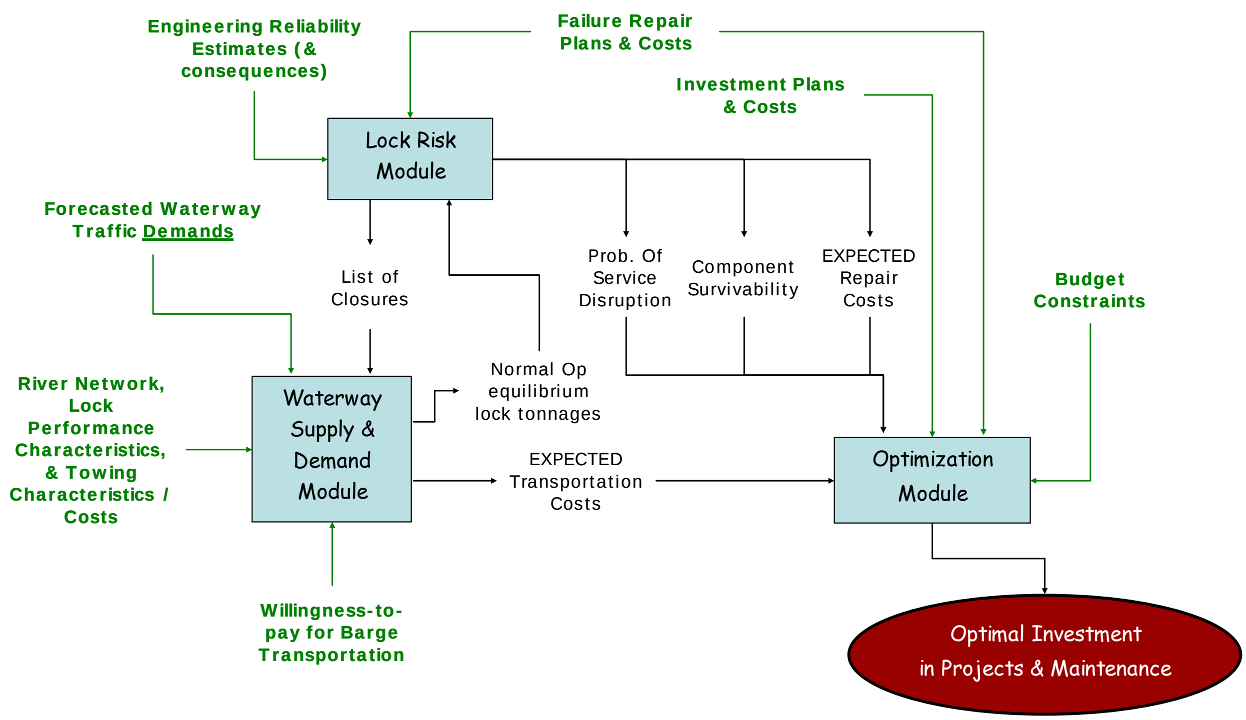
6.2.1 Model Development and Structure

Development of a model requires a number of design decisions and technology choices. ORNIM utilizes a relational database structure which allows flexibility in input and output structure, eliminating model code changes if analysis resolution (e.g. increasing the number of towboat classes considered) and / or assumptions change. Input, output, and execution data is stored in Microsoft Sequel (SQL) Server 2005 database with Microsoft Office 2003. The model is executed and model results analyzed in twenty C++ and C# executable programs using thirty dynamic-link libraries (the C++ code represents older original code that has yet to be converted to C#). The budget optimization feature utilizes CPLEX optimization software distributed by ILOG.

Simulation models fall into two basic categories: event-based and period-based. In an event-based model, a set of events that the model is concerned with are defined, and time moves forward in jumps, as each event takes place. Period-based models divide time into discrete periods of know length (e.g. years). All calculations are made for a given period, and then time is advanced to the next period. Both types of approaches have their advantages and disadvantages. In general, period-based models are easier to formulate and contain simpler calculations, but the assumptions required about averaging of data may be limiting. ORNIM is classified as a period-based model running on yearly time increments.

The ORNIM System is composed of three primary modules – the Lock Risk Model (LRM), the Waterway Supply and Demand Model (WSDM), and the Optimal Investment Module (Optimization). The general linkage of the model modules are shown in Figure 6.1.

FIGURE 6.1 - ORNIM Primary Modules



The LRM Module forecasts structural performance by simulating component-level engineering reliability data (hazard functions and event-trees) to determine life-cycle repair costs and service disruptions. The LRM summarizes the probabilities of reliability driven service disruptions (typically lock closures) for each lock for each component for each year, which are then used by the WSDM and Optimization modules to estimate expected transportation impacts resulting from the service disruptions.

The WSDM Module estimates equilibrium waterway traffic levels and transportation costs given a traffic demand forecast, movement willingness-to-pay, and waterway system performance characteristics. ORNIM's major economic assumptions are embedded within WSDM.

The Optimization Module organizes and analyzes the investment life-cycle benefit and cost streams and recommends optimally timed investments (what and when).

While there are three primary modules, the model is much more complex. The model structure is described in **Attachment 1, Ohio River Navigation Investment Model (ORNIM)** through nine separable modules.

6.2.2 Sectoral, Spatial, and Temporal Simplifying Assumptions

As noted, economic models vary in terms of sectoral, spatial, and temporal detail. Simplifying assumptions are made in empirical models because of data, time, computational, and resource limitations. The keys in making these simplifying assumptions are to clearly understand: (1) the theoretical model that serves as a starting point for the analysis; (2) how the simplifying assumptions deviate from the theoretical model; (3) the reasonableness of the assumptions as compared to what we know about real-world markets; and (4) the implications of the assumptions in terms of biasing and/or reducing the accuracy of the model's results (i.e. the estimation of WPC benefits). As a result, the fundamental sectoral assumption in the ORNIM model framework is to analyze inland navigation investments under a spatially-detailed barge transportation partial-equilibrium framework for reasons discussed in detail in **Attachment 1, Ohio River Navigation Investment Model (ORNIM)**. The spatial and temporal detail level in ORNIM is data driven (i.e. user specified) as discussed in the sections below.

6.2.2.1 Spatial Detail

The spatial detail is defined by the model user through the waterway transportation network, and through the aggregation level of the commodity groups and barge types. In the model a commodity origin-destination route and barge type defines the shipment which demands barge transportation. Spatial detail does not come without a cost. Since each and every movement (commodity origin-destination barge type) must be equilibrated with every other movement, each increment of detail increases computational time exponentially.

For the Upper Ohio analysis, the 622 5-digit WCSC commodity codes were aggregated into 9 commodity groups, the 5,928 docks serviced by ORS traffic were aggregated into 171 pick-up/drop-off nodes (with at least one node in each of the 56 navigation project pools), and the tens of thousands of unique barges were aggregated into 12 barge types. This results in 17,138 unique commodity origin-destination barge type movements in the model.

6.2.2.2 Temporal Detail

The model does not simulate individual waterway shipments (i.e. tow), but operates off a movement-level (an aggregation of shipments) cost in discrete time periods. Typically the model is utilized assuming yearly time periods. While the model's temporal detail is tied to a time period, the user can redefine the definition of a time period through the inputs. For example, instead of running the model as a yearly model over 50 years (i.e. 50-periods), the inputs could be aggregated to a quarterly level and 200 quarterly periods could be run to complete a 50-year life-cycle analysis. As with the spatial detail, increased detail significantly increases the computation time and too much granularity can complicate, if not invalidate, the theoretical framework (e.g. trip times spanning multiple periods).

For the Upper Ohio analysis, the model is run as a yearly model. A movement is defined as the annual volume of shipments for the commodity origin-destination barge type. There are 17,138 unique commodity origin-destination barge type movements defined in the Upper Ohio analysis, each of which are forecasted by year over the planning period.

6.2.2.3 Inter-Temporal Detail

Each time period in the model is independent of the other time periods, however, there is an inter-temporal effect interjected into the modeling process through user specification of infrastructure change and through the engineering reliability data.

Lock performance characteristics can be specified by the user to change through time. This allows for currently authorized projects (e.g. Olmsted) to come online and change the waterway system transportation characteristics at the appropriate time. Additionally, the analysis of the WPC alternatives requires the investment to be timed and the characteristics of the waterway system transportation to be adjusted accordingly at the correct times.

Lock performance can also change through time probabilistically through reliability. In this respect, the expected benefits and costs calculated in a given year is dependent upon the results in the previous years. With increasing service disruption through time, expected equilibrium traffic levels can decline as expected capacity declines. If, however, the user desires to model declining demand from increased reliability risk, this must be done through the forecasted demand input (i.e. a forecasted demand assuming decreased reliability).

6.2.3 Network and Movement Detail

Much of the model's spatial detail comes through the waterway transportation network definition. The transportation network not only defines the pick-up/drop-off nodes (171 of them in the Upper Ohio analysis) but it also defines constraint points in the system (bottlenecks). These constraint nodes can be any obstruction where vessel queuing can occur and congestion effects can be felt. While these constraint nodes can be areas such as bends or one-way channel sections, typically the constraint nodes modeled are the navigation projects. In the Upper Ohio study analysis 56 navigation projects are modeled.

In order to determine the impact of congestion effects on a movement's transportation costs (and ultimately the movement's equilibrium and surplus), the movement's trip time needs to be estimated. Distances between each model node (both pickup / drop-off nodes and the constraint nodes) are defined through the input data. Additionally, data on current speeds, channel depths, and equipment drag are input and utilized by a speed function (see **Attachment 1, Ohio River Navigation Investment Model (ORNIM), ADDENDUM 1B**) and combined with the trip distance to estimate line-haul trip time. Estimating the trip time at the constraint points is a different story.

6.2.3.1 Tonnage-Transit Curves

At the constraint points (i.e. locks), the transit times are characterized by a tonnage-transit curve. This tonnage-transit curve plots an average tow transit time against annual tonnage at the lock. The transit time not only includes the processing time to transfer to the next pool, but it also includes delay time from queuing resulting from the congestion effect. As utilization of the lock increases, the delay exponentially increases once persistent queuing starts.

Given a traffic level at the project, the average transit time is pulled from the tonnage-transit curve and applied to each movement transiting the project. All projects transited are polled for transit times along each movement's route and added to the movement's line-haul time to determine the movement's total transportation time.

The tonnage-transit curves are externally derived (typically through vessel-level simulation) and input into the model. Additional detail on the tonnage-transit curve development can be found in the **Attachment 2, Capacity Analysis**.

6.2.3.2 Movement Shipping-Plans

Congestion in the waterway transportation system does not affect all movements equally. In order to determine the impact of congestion effects on a movement's transportation costs, the shipping costs and characteristics of that movement must be known. The shipment characteristics are referred to as the "*shipping plan*". A shipping plan is needed for each of the 17,138 commodity origin-destination barge type movements in the model.

The shipping-plan drives the shipping cost and is stored in dollars per hour per ton. The shipping-plan includes specification of the shipment tow-size, the towboat class used, empty backhaul requirements, re-fleeting points, and tons per trip. Given the movement tonnage and the trip time, a movement cost can be calculated and then compared against the movement's willingness-to-pay.

The shipping plans could be specified by the user and given to the model through input; however, this data is not readily available and difficult to compile for large systems. Instead, the model develops a least-cost shipping plan for each movement which is then calibrated against observed data. This shipping-plan developer also allows re-specification of shipping-plans under increased congestion and for what-if scenarios (e.g. 1200' main chambers instead of existing 600' main chambers). Additional detail on the development of the movement shipping-plans can be found in **Attachment 1, Ohio River Navigation Investment Model (ORNIM), ADDENDUM 1B**.

6.2.3.3 Movement Level Willingness-to-Pay

Willingness-to-pay for barge transportation is needed to determine the equilibrium traffic level and to calculate the waterway transportation surplus (benefit). As discussed, the willingness-to-pay can be defined as either inelastic or elastic. The model allows either specification on a movement to movement basis. For the Upper Ohio analysis, all movements modeled were assigned a demand curve based on a study of demand elasticity on the Ohio River system[19]. Additional detail on the development of the movement demand curves can be found in **Attachment 1, Ohio River Navigation Investment Model (ORNIM), ADDENDUM 1C Ohio River System Willingness-to-Pay for Barge Transportation**.

When utilizing an elastic demand curve, an additional analysis setting/assumption must be specified; whether or not to allow the demand curve to be extrapolated beyond the forecasted demand point. The model can be run under either setting/assumption. The extrapolated demand curves are unbounded and problematic given their propensity to asymptotically approach the x-axis (i.e. infinite tonnage). Typically (and in this Upper Ohio analysis), the elastic demand curves are capped at the forecasted barge transportation demand.

6.3 MODEL INPUTS

The model inputs are described in the five attachments of this appendix with the engineering reliability data defined in the Engineering Appendix.

6.4 MODEL CALIBRATION AND VALIDATION

ORNIM, like any model, requires validation that it is capable of replicating observed shipper behavior and system operating characteristics. Waterborne Commerce Statistics Center (WCSC) data provides annual origin-to-destination barge flows by commodity; however, information on tow-size, towboat utilization, and empty return characteristics is not available for individual movements. These characteristics are recorded by the Lock Performance Monitoring System (LPMS) at each of the locks. LPMS data provides vessel fleet characteristics.

To determine movement equilibrium, and ultimately system equilibrium, movement shipping plans and the shipping plan cost characteristics must be known. WSDM not only contains movement equilibrium logic, but it also contains algorithms to determine the movement's least-cost shipping-plan. Given transportation constraint parameters, the model essentially creates and costs all allowable movement shipping plans and selects the least-cost shipping-plan for each movement. This process however, requires calibration.

ORNIM was calibrated to an average value of 2004-2006 LPMS data for the upper Ohio application. Calibration is a sequential process involving several iterative steps. At each step, certain static components of the model's waterway system towing and operating characteristics are adjusted or fine-tuned, the model is exercised, and specific results are compared with corresponding target values from LPMS data for the designated baseline or calibration year. The calibration process is designed to ensure that the relevant measures

[19] Kennith Train and Wesley W. Wilson, "*The Demand for Transportation in the Ohio River Basin*", supported by the Navigation technologies Program. August 2008.

match their corresponding target values as well as possible. A detailed discussion of the shipping plan cost calculation and shipping-plan selection can be found in **Attachment 1, Ohio River Navigation Investment Model (ORNIM), ADDENDUM 1B ORNIM Calibration**. A summary of the calibration targets is shown in Error! Reference source not found..

TABLE 6-1 - Calibration Results

	Tonnage			Number of Loaded Barges			Number of Empty Barges			Number of Tows			Towboat Class Average HP		
Navigation Lock Project	WCSC Input *	Model Output	Pct. Diff.	WCSC Input *	Model Output	Pct. Diff.	Estimated Target **	Model Output	Pct. Diff.	Estimated Target ***	Model Output	Pct. Diff.	LPMS **	Model Output	Pct. Diff.
OHIO RIVER															
LOCK & DAM 53 (OHIO)	81,613,688	81,613,688	0.0%	49,738	49,738	0.0%	21,360	21,363	0.0%	6,574	6,862	-4.4%	4,204	4,150	1.3%
LOCK & DAM 52 (OHIO)	95,648,485	95,648,485	0.0%	58,260	58,260	0.0%	30,746	30,749	0.0%	9,268	8,627	6.9%	3,728	3,700	0.8%
SMITHLAND L/D	82,477,322	82,477,322	0.0%	49,815	49,815	0.0%	25,634	25,636	0.0%	7,270	7,229	0.6%	4,081	4,028	1.3%
MYERS L/D	73,348,924	73,348,924	0.0%	44,607	44,607	0.0%	22,015	22,017	0.0%	5,991	5,994	-0.1%	4,386	4,320	1.5%
NEWBURGH L/D	69,589,809	69,589,809	0.0%	43,052	43,052	0.0%	25,096	25,098	0.0%	6,346	6,290	0.9%	4,144	4,084	1.4%
CANNELTON L/D	59,143,757	59,143,757	0.0%	36,733	36,733	0.0%	18,386	18,388	0.0%	5,162	5,211	-1.0%	4,055	3,974	2.0%
MCALPINE L/D	56,701,852	56,701,852	0.0%	34,419	34,419	0.0%	15,440	15,442	0.0%	5,275	4,932	6.5%	3,952	3,885	1.7%
MARKLAND L/D	54,041,630	54,041,630	0.0%	32,638	32,638	0.0%	12,990	12,991	0.0%	4,791	4,628	3.4%	4,064	3,964	2.5%
MELDAHL L/D	59,314,186	59,314,186	0.0%	34,887	34,887	0.0%	17,598	17,600	0.0%	5,030	5,418	-7.7%	3,993	3,862	3.3%
GREENUP L/D	71,566,262	71,566,262	0.0%	42,377	42,377	0.0%	25,063	25,065	0.0%	6,115	6,685	-9.3%	3,892	3,750	3.6%
R.C. BYRD L/D	60,811,235	60,811,235	0.0%	37,100	37,100	0.0%	17,810	17,812	0.0%	5,260	5,380	-2.3%	3,675	3,550	3.4%
RACINE L&D	54,801,938	54,801,938	0.0%	33,621	33,621	0.0%	17,175	17,177	0.0%	4,564	4,628	-1.4%	3,654	3,508	4.0%
BELLEVILLE L&D	54,221,170	54,221,170	0.0%	33,265	33,265	0.0%	17,177	17,179	0.0%	4,412	4,608	-4.5%	3,694	3,536	4.3%
WILLOW ISLAND L&D	51,011,845	51,011,845	0.0%	31,413	31,413	0.0%	16,450	16,452	0.0%	4,345	4,343	0.0%	3,643	3,479	4.5%
HANNIBAL L&D	53,836,241	53,836,241	0.0%	33,120	33,120	0.0%	18,490	18,492	0.0%	4,773	4,981	-4.4%	3,390	3,239	4.5%
PIKE ISLAND L&D	40,802,415	40,802,415	0.0%	25,773	25,773	0.0%	17,705	17,707	0.0%	4,679	4,964	-6.1%	3,137	3,037	3.2%
NEW CUMBERLAND L&D	33,296,680	33,296,680	0.0%	21,334	21,334	0.0%	14,793	14,795	0.0%	4,116	4,120	-0.1%	3,054	2,972	2.7%
MONTGOMERY L&D	21,829,002	21,829,002	0.0%	15,000	15,000	0.0%	8,541	8,542	0.0%	3,953	3,968	-0.4%	1,830	1,995	-9.0%
DASHIELDS L&D	20,923,289	20,923,289	0.0%	15,387	15,387	0.0%	9,051	9,052	0.0%	3,802	3,890	-2.3%	1,803	1,924	-6.7%
EMSWORTH L&D	19,998,867	19,998,867	0.0%	14,260	14,260	0.0%	8,069	8,070	0.0%	3,919	3,610	7.9%	1,784	1,890	-5.9%
MONONGAHELA RIVER															
MON LOCK & DAM 2 L&D	18,826,623	18,826,623	0.0%	13,447	13,447	0.0%	7,091	7,113	-0.3%	3,382	3,408	-0.8%	1,786	1,864	-4.4%
MON LOCK & DAM 3 L&D	12,614,903	12,614,903	0.0%	9,704	9,704	0.0%	7,400	7,400	0.0%	5,152	5,184	-0.6%	1,313	1,389	-5.8%
MON LOCK & DAM 4 L&D	10,820,928	10,820,928	0.0%	8,455	8,455	0.0%	7,693	7,693	0.0%	4,342	4,642	-6.9%	1,244	1,333	-7.1%
MAXWELL L&D	12,646,794	12,646,794	0.0%	11,100	11,100	0.0%	9,378	9,378	0.0%	3,374	4,065	-20.5%	1,224	1,293	-5.6%

** Averaged 2004-2006 WCSC data.*
*** Averaged 2004-2006 LPMS data.*
**** Sum of WCSC loaded barges plus estimated empty barges (using averaged 2004-2006 LPMS percent empty) divided by averaged 2004-2006 LPMS barges per tow.*

6.5 MODEL OUTPUTS

System performance statistics generated by ORNIM include life-cycle equilibrium tonnage, savings, and transit days. These statistics are generated for each alternative for three traffic forecast scenarios. Sections 7 and 8 describe and summarize system statistics for each of the maintenance / investment alternatives analyzed. Section 9 presents the recommended investment plan for the upper Ohio River projects.

Section 7: THE WITHOUT-PROJECT ANALYSIS

7.1 INTRODUCTION

The without-project condition (WOPC) is that future condition deemed most likely to exist in the absence of any proposed project(s) or any change in existing authority or public policy. By regulation, the Corps, as steward of the navigable inland waterways must make best use of the existing facilities for overall public interest concerns, including economic efficiency, safety and environmental impacts. Accurate description of the most likely WOPC is important because it is used as the baseline for comparing benefits, costs and net benefits of alternative investments.

7.1.1 WOPC Formulation

Formulation of the WOPC begins with the existing EDM locks and dams and their current performance and structural condition. It involves normal maintenance of the existing system in the absence of new investment. Any reasonably expected and economically justified nonstructural measure within Corps authority is assumed implemented at the appropriate time. The WOPC includes all operational measures which are routinely employed during periods of congestion. These include the use of helper boats and revised lockage policies to improve project performance and ensure the best use of the existing facilities during main chamber closures. The WOPC also includes all authorized improvements that are either under construction or are pending appropriation. The most likely WOPC will not include any proactive maintenance requiring a major investment decision, such as replacing a lock wall.

7.1.2 Reliability Assessment

The upper Ohio navigation study is a risk-based evaluation of the major maintenance and construction re-investment needs for the three upper most navigation locks on the Ohio River. With existing traffic levels, the upper Ohio locks experience high traffic delays when the main lock chamber must be closed for routine (scheduled) or emergency (unscheduled) repairs or accidents. Assessing structural reliability of lock components is critical in the without-project evaluation because the lock components are becoming increasingly unreliable with age and usage.

A complete evaluation of maintenance re-investment needs on the upper Ohio is not just influenced by structural condition but also by expected levels of traffic demand and auxiliary lock capacity. Engineering reliability modeling was not performed on the navigation dams at EDM due to recent major rehabilitation work done on each. The reliability analysis focused on lock components because maintenance closures of these structures adversely affect commercial navigation.

7.2 EXISTING CONDITION

As navigation projects age, component reliability worsens and maintenance requirements and unscheduled closures typically increase. Degradation of lock components can come from fatigue through utilization and age (e.g. cracking and corrosion). As lock components degrade, the question arises if and when they should be repaired or replaced.

Development of a WOPC begins with an assessment of existing condition, capacity, and demand; each a key input to the economic modeling. Lock reliability and capacity, traffic, and traffic delays are discussed for the upper Ohio projects. Ultimately, a lock's performance capability is limited by two factors: i) physical capacity and ii) structural reliability. The former is influenced by chamber dimensions, hydraulic conditions, vessel fleet characteristics, weather conditions, and accident frequencies; while the latter is affected by structural condition and intensity of maintenance efforts. The capability to process traffic in the face of traffic demand tests a lock's performance. Transit time and lock delay are used to measure lock performance. This section describes the existing condition of the upper Ohio in terms of project age and reliability, project capacity, and traffic demand and delay.

7.2.1 Project Age and Reliability

Lock performance is affected by lock availability for service. Availability is reduced due to random minor events like accidents, adverse weather, flow conditions, and maintenance-related closures. Maintenance-related closures, scheduled or unscheduled, are more likely to be lengthy closures that more dramatically affect lock performance than the random minor closure events which are of short duration. Age and level of use can act as an indicator of maintenance and rehabilitation needs. The locks at Emsworth, Dashields, and Montgomery are each over 80 years old. The locks were rehabilitated in the 1980s - new miter gates, culvert valves, and re-facing some of the lock concrete structures. These rehabilitations did not address all known structural issues. There are still serious concerns regarding the structural integrity and stability of the concrete structures at these three sites.

7.2.2 Project Capacity

Lock capacity is largely determined by lock chamber dimensions, approach conditions, and service availability. The upper Ohio projects each have a main chamber measuring 600' x 110' and an auxiliary lock measuring 360' x 56'. They are the lowest capacity locks on the Ohio River (**Table 7-1**). Modern fifteen barge tows must double-lock through the main chambers at EDM, while in the auxiliary chambers tows are limited to 5 barges and can only be locked through one barge at a time.

TABLE 7-1 - Ohio River Mainstem Locks Age, Chamber Dimension and Capacity 2008 Tonnage in Millions

Lock Project	Main Ch. Age	Chamber Dimension		Chamber Capacity (mtons)			2008 LPMS Tonnage
		Main	Auxiliary	Main	Auxiliary	Both	
OHIO RIVER							
LOCK & DAM 53 (OHIO)*	30	1200x110	600x110				77.8
LOCK & DAM 52 (OHIO)*	41	1200x110	600x110				89.7
SMITHLAND L/D	31	1200x110	1200x110	143.4	132.9	264.4	77.1
MYERS L/D	35	1200x110	600x110	137.3	63.6	170.6	69.5
NEWBURGH L/D	35	1200x110	600x110	135.6	61.7	169.0	71.2
CANNELTON L/D	39	1200x110	600x110	124.0	59.0	162.1	58.1
MCALPINE L/D	1	1200x110	1200x110	120.0	123.0	225.5	57.3
MARKLAND L/D	51	1200x110	600x110	119.0	57.0	160.5	53.2
MELDAHL L/D	48	1200x110	600x110	116.3	55.5	151.0	54.1
GREENUP L/D	51	1200x110	600x110	113.3	54.3	144.2	59.8
R.C. BYRD L/D	17	1200x110	600x110	116.3	55.5	151.0	52.3
RACINE L&D	43	1200x110	600x110	110.5	54.0	151.1	48.6
BELLEVILLE L&D	42	1200x110	600x110	114.6	56.3	167.2	46.9
WILLOW ISLAND L&D	38	1200x110	600x110	107.5	54.2	155.1	43.8
HANNIBAL L&D	38	1200x110	600x110	103.1	52.4	152.1	45.6
PIKE ISLAND L&D	45	1200x110	600x110	99.5	47.9	151.2	34.6
NEW CUMBERLAND L&D	51	1200x110	600x110	78.5	44.5	132.9	29.2
MONTGOMERY L&D	**74**	**600x110**	**360x56**	**43.2**	**11.5**	**50.3**	**20.8**
DASHIELDS L&D	**81**	**600x110**	**360x56**	**48.1**	**14.3**	**51.5**	**21.8**
EMSWORTH L&D	**89**	**600x110**	**360x56**	**42.9**	**11.1**	**48.7**	**21.3**
MONONGAHELA RIVER							
BRADDOCK L&D**	105	720x110	360x56			67.6	19.8
ELIZABETH L&D***	104	720x84	360x56				15.1
CHARLEROI L&D**	78	720x84	360x56			104.4	14.6
MAXWELL L&D	46	720x84	720x84			77.0	13.2

* scheduled for replacement by Olmsted L/D in 2014
** scheduled for new 800x110 chamber in 2025
*** scheduled for removal in 2025

Four non-structural measures to improve capacity are part of the existing upper Ohio navigation system and are included in the development of the WOPC. They are: i) helper-boats during a main chamber closure; ii) n-up and n-down lockage policy during main chamber closure; iii) re-scheduling of shipments during a long duration, scheduled main chamber closure; and iv) the use of a permanent tow haulage unit at the main chamber to extract the first cut of a two-cut lockage. The use of helper-boats, through an industry self-help program, effectively maximizes the capacity of the small 360’ x 56’ auxiliaries during a main chamber closure.[20] An n-up and n-down lockage policy, when queues exist in both directions, also effectively increases capacity during a main chamber closure. These practices, along with limiting tow sizes to five cuts during a main chamber closure on the upper Ohio, are reflected in the lock capacities reported in **Table 7-1**.

Some voluntary re-scheduling and other adjustments by industry occurs because of navigation notices mailed out six months to one year in advance of the scheduled closure. Industry re-scheduling during a closure serves to re-distribute tows on either side of the closure. Annual

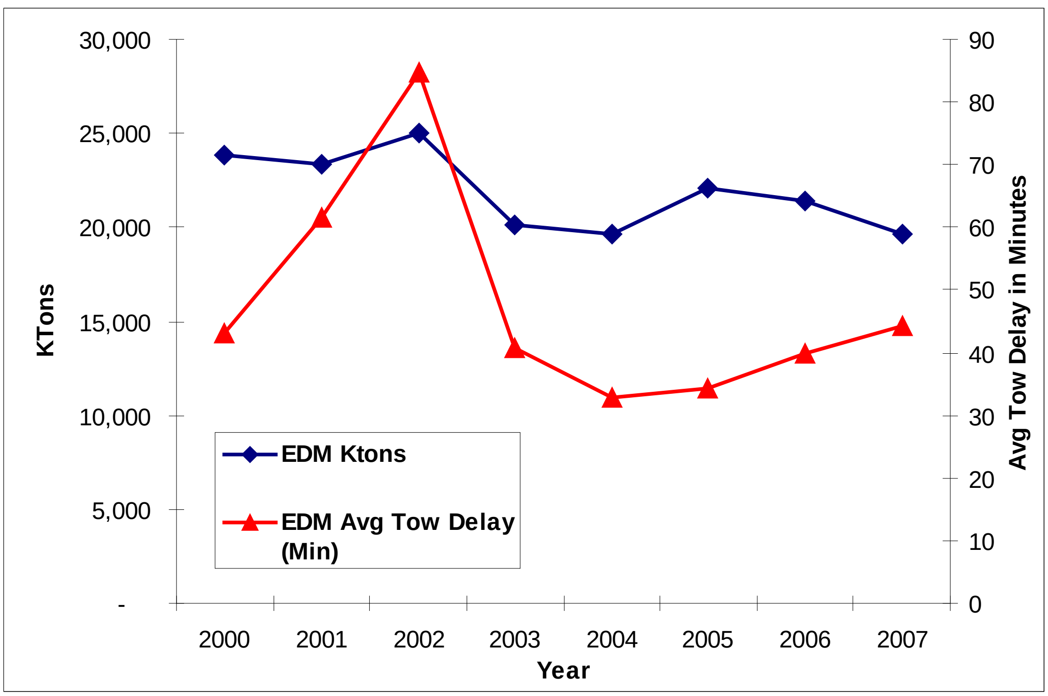
[20] The self-help program at EDM includes a restriction on tow sizes to 5 barges per tow.

throughput, or capacity is unaffected but average delay-per-tow during the closure is lower than it would be otherwise.

7.2.3 Traffic and Delays

Auxiliary chamber (360' x 56') capacity at EDM ranges between 11 and 14 million tons, well below the average annual tonnage of around 20 million tons. High delays are experienced at these projects when main chambers close for maintenance or repair. Delays are a function of project capacity, fleet utilization, reliability, and traffic. Delays during normal traffic operations (main chamber open) typically average 30 minutes at upper Ohio locks. But delays become severe during main chamber closures. **Figure 7-1** compares annual traffic and average tow delays at EDM.

FIGURE 7-1 - Annual Traffic and Average Tow Delays at EDM
(2000-2007)



7.3 MAINTENANCE AND OPERATIONAL MEASURES

Maintenance and its effect on the performance of aging locks is a key concern to sustainable navigation. The efficient operation of the existing locks and dams is an important consideration and this is especially true during times when the main chamber is closed for maintenance and all traffic is processed through the smaller auxiliary chamber.

Two different maintenance plans were developed and analyzed for the upper Ohio study. They include reactive maintenance and advanced maintenance or component replacement. Due to the poor structural condition of the middle lock walls at EDM, a rehabilitation maintenance plan was considered infeasible from an engineering standpoint. Rehabilitation of the middle walls would close both chambers to navigation. Also, advanced maintenance or component replacements at EDM would likely require an investment decision and surpass the $10.6 million major rehabilitation threshold. Because of this, advanced maintenance (component replacement) was not considered in the WOPC. Instead, a component replacement plan will be considered as a with-project alternative and will be evaluated by comparison to the WOPC like all other re-investment decisions. In the absence of new investment, a reactive maintenance plan where components are repaired or replaced "after they fail" is assumed to be the base maintenance plan for the WOPC and is the standard against which all other alternatives will be measured. Maintenance and investment costs, reactive maintenance, and operational measures associated with the WOPC are described in the following sub-sections.

7.3.1 Lock Maintenance and Investment Costs

Component level reliability evaluations were conducted on the upper Ohio projects to estimate probable project performance and maintenance requirements from 2012 to 2068. A detailed discussion of engineering reliability modeling is presented in the **Engineering Appendix**.

Reactive maintenance and each alternative investment analyzed contains normal (or routine) O&M costs, scheduled lock maintenance costs, scheduled dam maintenance costs, unscheduled lock repair costs, random minor costs, and scheduled lock improvement costs at each project throughout the study period. All Federal costs are described below:

- Normal O&M or routine operation costs are the annual fixed costs to operate the project with some incidental maintenance that doesn't impact traffic or component reliability. Corps normal O&M policy operates a project as efficiently as possible in the absence of any repair or maintenance that improves project reliability.[21]

- Scheduled Maintenance costs are related to periodic chamber inspections that close a chamber, including some relatively minor maintenance/repair costs. Scheduled maintenance procedures typically do not address the long-term failure probabilities (reliability) associated with fatigue/fracture and the end of useful design life and therefore it is assumed that scheduled maintenance does not have a significant effect on the overall reliability of the structures[22]. However, it is noted that scheduled maintenance does help keep the major features in working order and operating as

[21] Normal (or routine) O&M is a fixed-cost to operate the project and includes labor, utilities, mowing the grass, and basic project supplies.
[22] This is mainly due to the fact that we are looking at failure modes that are associated with fatigue and fracture of critical members (miter gates and valves in particular)

originally designed. The reliability analysis was carried out for the situation where the components are no longer cost effective to maintain.

- Scheduled Dam Maintenance costs are attributed to maintenance and rehabilitation of dam components (dam gates, operating machinery, concrete piers, etc.) This maintenance is critical to sustainable navigation but does not typically require a lock chamber closure because the repair fleet can tie up outside the river wall. Reliability modeling was not performed on dam components at Emsworth and Montgomery. At Emsworth, both the main and auxiliary channel dams are being repaired as part of an on-going major rehabilitation, including the stilling basins, gates, and dam abutments. After these repairs are made, currently scheduled for 2013, no failures of any dam component are anticipated throughout the analysis period. At Montgomery, a dam safety study is currently underway and any problems as confirmed by that study should be effectively repaired early in the study period, thereby reducing the chances of failure to an acceptably low value. Reliability analysis was conducted for Dashields dam components. The fixed crest dam section was determined to be reliable throughout the period of analysis for planning purposes, susceptible only to unforeseen and extremely unlikely erosive effects below the dam. The dam abutment was determined to be susceptible to failure but rehabilitation measures were not developed. There are no scheduled dam maintenance costs at EDM in this analysis.

- Unscheduled Lock Repair costs are estimated from reliability modeling that determines when to repair or replace major lock components over the year period of analysis. ORNIM is run to estimate unscheduled repair costs for each maintenance plan.

- Random Minor closures are separated into two categories. These are random minor closures that require maintenance and those that require no physical repair costs. The random minor closures with repair costs are intended to reflect lock closures for routine testing. This is typically for on-site personnel and not the large repair fleet. Random minor closures without repair costs are for things such as debris in lock, tow malfunctions, accidents, etc.

- Scheduled Lock Improvement costs include any future investment decisions that include economically justified individual lock component replacements and lock replacements. New investment decisions are treated as WPC alternatives and are compared to the WOPC. Scheduled lock improvements involving future investment decisions are discussed in Section 8 - Identification and Evaluation of Alternative Investment Plans.

7.3.2 Reactive Maintenance

Under reactive maintenance, components are fixed or replaced after they perform unsatisfactorily. The Engineering team developed reliability models for each of the lock components displayed in **Table 7-2.** The reliability models were used to calculate expected component failures through time, estimate the cost and type of repair required, and determine whether the failure caused a chamber closure. This information was used by ORNIM to calculate the unscheduled repair/replace costs and industry costs associated with an unanticipated lock closure. The reactive maintenance plan as developed in the WOPC, serves as a baseline against which to compare more proactive maintenance plans and structural improvement investments.

Under reactive maintenance, normal O&M is performed, along with scheduled periodic maintenance. Unscheduled lock repair and cost is estimated from the reliability data – hazard functions and event trees. Repairs to correct the failure are made at the time of failure and not deferred through a short-term repair. There are no scheduled lock improvements for the upper Ohio system in reactive maintenance. No lock rehabilitation occurs, though individual components may be replaced upon failure. There is no scheduled dam maintenance for the upper Ohio.

TABLE 7-2 - Upper Ohio Lock Components Reliability Analysis

Emsworth L/D		Dashields L/D	
Main	Auxiliary	Main	Auxiliary
Gates		Gates	
Gate Machinery	Gate Machinery	Gate Machinery	Gate Machinery
Hydraulic	Hydraulic	Hydraulic	Hydraulic
Mid Wall Fill Valves	River Fill Valves	Valve Machinery	Valve Machinery
Mid Wall MT Valves	River MT Valves		
Electrical	Electrical	Electrical	Electrical
Land Wall		Land Wall	Guard Wall
Guide Wall		Guide Wall	
Middle Wall	Middle Wall	Middle Wall	Middle Wall

Montgomery L/D	
Main	Auxiliary
Gates	
Gate Machinery	Gate Machinery
Hydraulic	Hydraulic
Valve Machinery	Valve Machinery
Electrical	Electrical
Land Wall	River Wall
Middle Wall	Middle Wall

7.3.3 Operational Measures Currently Implemented

During normal operation, with both chambers open, delay is not usually a problem and project capacity is sufficient to handle traffic efficiently at the upper Ohio projects throughout the 56-year period of analysis (2012-2068). During normal operation, tows are handled on a first-come-first-served basis.[23] When a main chamber must be closed, tows use the auxiliary chamber, where at the upper Ohio projects, traffic demand exceeds capacity and delays occur. During main chamber closures, a number of effective supply-side measures designed to improve efficiency and reduce delay are currently employed at the locks and are included in the base-level WOPC analysis. These include lockage sequencing, restricted tow size, and helper boats. Traffic management measures, such as Notices to Navigation Interests[24] are used to reduce lock congestion by providing waterway users advance notice of scheduled closures. Notices to Navigation Interests allow towing companies and their customers to reschedule traffic to the extent possible around scheduled main chamber outages. The operational effect of rescheduling shipments in response to scheduled closures is captured in future traffic-delay relationships in the analysis through the tonnage-transit curves developed by the WAM, but the additional costs incurred by shippers to reschedule around a closure are not included in this analysis. These operational and other measures are discussed below.

7.3.3.1 Notice to Navigation Interests: Industry Coordination

Two years before a scheduled closure, the Corps sends a notice to waterway users announcing its intent to close a lock and the expected dates of closure. The notice includes anticipated delays during the closure, expressed as significant or minor, and the operational policies to be in effect. Around six months before the scheduled closure, the Corps and affected towing companies meet to finalize procedures for operating during the closure. Even with low levels of delay expected, special accommodations, such as cut limits, are required because the auxiliary chambers are typically one-half the size of the main chambers. If major delays are expected, the announcement will also state that tows have priority in lockage over recreational craft. This is an effort to provide industry information to better manage traffic during a scheduled closure.

7.3.3.2 Lockage Sequencing : N-up, N-down Lockage Policy

This strategy (to minimize delays at locks that develop queues) involves locking a given number (N) of tows in the same direction, then allowing the same number to lock through from the opposite direction. Lock sequencing takes advantage of the efficiency of proceeding with several successive “turnback” style lockages rather than running tows through in alternate directions when queued on either side of the lock. Use of this strategy has been proven to lower delays over a first-come-first-served policy at virtually zero cost. This is a supply management measure that has the effect of increasing capacity during closure. Lock

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[23] FIFO – first-in-first-out
[24] Industry receives Notices to Navigation Interests from the Corps well in advance of a scheduled maintenance closure.

sequencing is modeled at all mainstem projects during any main chamber closure and an optimal n-up/n-down strategy is developed.

Typically, as queues develop above and below a project during a main chamber closure, a 3-up and 3-down lockage policy is used to most efficiently and equitably pass traffic. The actual n-up and n-down policy used depends on the queue sizes and is under the discretionary authority of the lock master.

7.3.3.3 Helper-Boats: Industry Self Help

The use of helper boats complements the n-up/n-down lockage policy. Helper boat operations are a collaborative effort between industry and the Corps. Due to traffic levels and fleet size, industry implements a helper boat policy any time a main chamber is closed on the Ohio. The industry “self help” operation significantly reduces lockage times for multi-cut lockages and typically works as follows: the last towboat to arrive at a congested project in the direction opposite of an on-going lockage operation will disconnect from its barges and move up to the lock, where it serves as a “helper boat” by assisting the tow locking through the project by extracting un-powered cuts of barges from the lock chamber. It will then move the barges to a re-fleeting site away from the project so that reconstruction of the tow does not interfere with lockage operations. Industry self help is provided to each tow until all barges have moved through the lock. To be effective, the policy requires tows queued in both directions above and below the project. This is another supply-side measure that enhances capacity during a closure and is modeled at each mainstem project during a main chamber closure.

7.3.3.4 Tow Haulage Units

Tow haulage units are relatively low-cost pieces of equipment that are used to expedite the two-cut lockage process at the main chambers on the upper Ohio. There are two principal types of tow haulage systems: permanent and portable. Permanent units consist of rail tracks located directly alongside the chamber on top of the walls and a moveable tie-down unit that moves on the rails. The un-powered barges are tied to the moveable tie-down unit by a cable, and the unit moves along the rails to pull the barges out of the chamber. Portable systems consist of two winches that are anchored atop the upstream and downstream guide walls. The winches “crank” the cable, pulling the barges out of the chamber. The second set of barges, which are powered by a towboat, can then lock through the chamber unassisted. Upon completion of the second lockage, the first and second cuts are reconnected along the guide wall.

Permanent tow-haulage systems are installed at the main chambers of Emsworth, Dashields, and Montgomery where the main chambers are 600’ in length compared to 1200’ at all other mainstem projects. Double lockages through these main chambers are a common occurrence even during normal times. Permanent tow haulage units are not considered appropriate at the 360’ x 56’ auxiliary chambers because these chambers can only lock one barge at a time and oftentimes (during main chamber closures) tows require two to five cuts. Portable units are considered sufficient at these small lock chambers.

7.3.3.5 Industry Adjustments During Main Chamber Closures

The towing industry also makes adjustments during main chamber closures to maintain as normal a delivery schedule as possible. Industry adjustments include reducing the number of empty barges, increasing barge loadings, shipping around closures, working off stockpiles, or shipping by other routings. These adjustments are accounted for in the LPMS data used to develop the closure related tonnage-transit curves.

7.3.3.6 Other Measures

Other measures intended to reduce commercial lockage delays include real-time lock reports on the Corps web page. Information contained in the lock reports is updated every few hours and includes the number of tows waiting in queue and river flow conditions at each facility. Coordination with industry is conducted on a regular basis, not just during those times prior to an extended main chamber closure. These low-cost measures have proven useful and are accepted by the navigation industry.

7.3.4 Operational Measures Not Currently Implemented

Price-related traffic demand management measures (i.e. congestion or lockage fees) are not currently used at EDM. Demand management measures at EDM will not address the problem which is condition and insufficient auxiliary capacity.

Using lock scheduling to reduce delays that occur during the normal operation of the upper Ohio is not currently practiced and has not been evaluated. A preliminary research effort into the physical practicality and economic feasibility of lock scheduling was conducted during the Ohio River Mainstem System Study (2006). Its findings were inconclusive and further funding for this effort has ceased. But again, lock scheduling would not address the problems at EDM.

7.4 BASE-LEVEL WOPC

Historically, LRD lock improvement studies have assumed unconstrained funding for major maintenance and major rehabilitation in developing the WOPC. LRD optimized the WOPC in navigation feasibility studies through a mixture of non-structural and structural measures like component replacement and chamber rehabilitation not requiring congressional authorization. The Corps has authority for major rehabilitations and advanced component replacements but recent history shows the Administration considers some component replacements and all major rehabilitation to be new starts and the Administration is not currently budgeting for new starts.

Therefore, for purposes of this analysis, any maintenance beyond fixing-after-failing is assumed to require an investment decision and is not included in the base-level WOPC. Proactive maintenance plans involving actions such as component replacement require an investment decision and therefore, in this analysis, will be treated as with-project alternatives along with other structural improvements.

Given recent funding levels and experience elsewhere on the Ohio (Markland and Greenup lock gate failures), a reactive maintenance future seems most likely. Accordingly, a base-level reactive maintenance WOPC will serve as the basis to compare more aggressive maintenance plans and structural improvement alternatives. The use of appropriate non-structural and operational measures and the assumption of authorized projects in-place are also part of the base-level WOPC.

The WOPC for the upper Ohio analysis includes the following authorized Ohio River improvements:

- Olmsted L/D – Olmsted L/D is modeled throughout the period of analysis[25]. Since this investment is under construction, no Federal costs are included.

- Myers auxiliary chamber extension – JT Myers auxiliary lock extension is under construction. JT Myers is included in the WOPC as a twin 1200' x 110' project beginning in 2012. Since this investment is under construction, no Federal costs are included.

- Greenup auxiliary chamber extension and main chamber rehabilitation – Greenup is included in the WOPC as a twin 1200' x 110' project with a rehabilitated main chamber beginning in 2012.

7.5 ECONOMICS OF THE WITHOUT-PROJECT CONDITION

The without-project reactive maintenance plan can be described in terms of its Federal costs and its associated cost impacts on navigation. ORNIM uses engineering reliability data to predict emergency repair/replacement closures on an average annual basis. These unscheduled closures reduce system capacity and cause navigation delays that reduce system transportation savings by increasing waterway costs.

7.5.1 System Costs - Reactive Maintenance

ORNIM was run to estimate expected annual Federal costs to operate and maintain EDM under a reactive maintenance or fix-as-fails scenario. The average annual expected Federal cost at EDM from 2012-2068 is $39.4 million. **Table 7-3** displays the expected annual Federal costs at EDM from reactive maintenance broken out into improvement costs, scheduled repair costs, unscheduled repair costs, random minor maintenance costs and normal O&M costs. There are no scheduled improvement plans at EDM under the reactive maintenance scenario. Scheduled repair costs include periodic maintenance inspections. Unscheduled repair costs utilize engineering reliability data. Random minor costs are taken

[25] Period of analysis is 2012-2068

from operations data, and normal O&M is the "fixed" cost of operating the project independent of the project passing traffic, i.e. overhead.

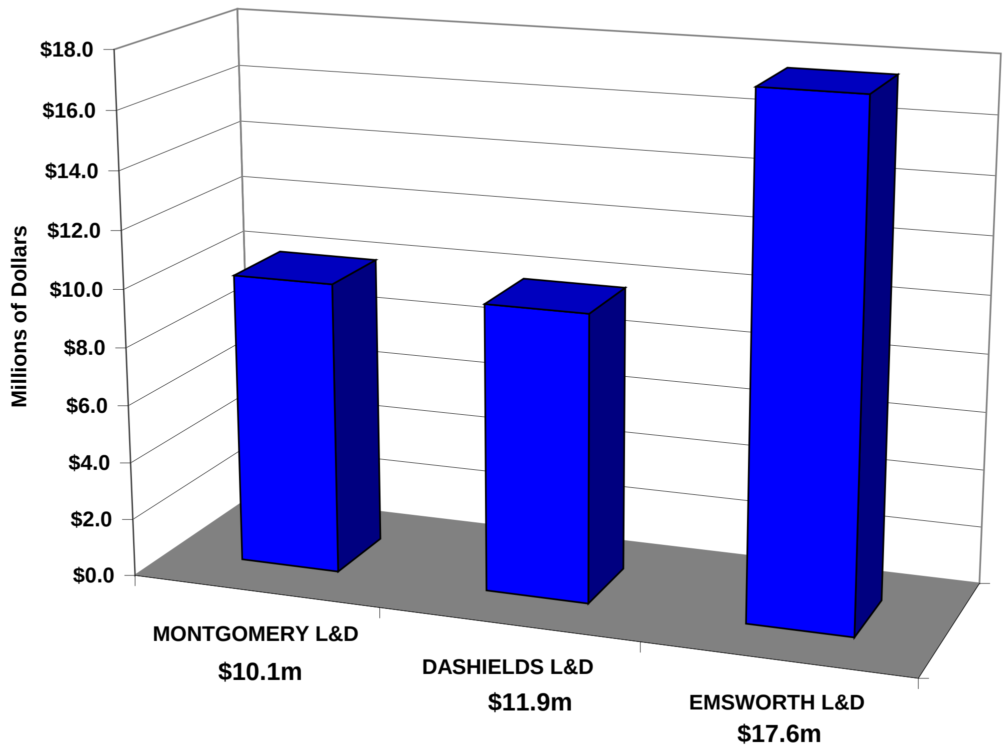
TABLE 7-3 - Annual Federal Costs at EDM Reactive Maintenance
(2012-2068, 4 1/8%, Million FY 09$)

Federal Costs	Reactive Maintenance	
Scheduled Lock Improvement	$	-.-
Scheduled Repair	$	8.4
Unscheduled Repair	$	22.2
Normal O&M	$	8.0
Random Minor	$	0.8
Total Costs	$	39.4

The Corps has a legal mandate to provide dependable, safe, and environmentally sustainable navigation on the Ohio River. In the long run, a reactive maintenance strategy will likely result in more frequent and longer duration scheduled and unscheduled closures. Such a maintenance strategy is not likely to provide the dependable, safe and environmentally sustainable navigation that our stakeholders deserve.

Figure 7-4 displays the average annual Federal costs for a reactive maintenance strategy by project. Emsworth is the most costly. Scheduled and unscheduled lock repair costs comprise 70 to 80 percent of the total annual Federal cost at these projects and represent potential cost savings that may be realized with a more proactive maintenance strategy.

FIGURE 7-4 - Average Annual Federal Costs - EDM Reactive Maintenance
(2012-2068, 4 1/8%, FY09$)

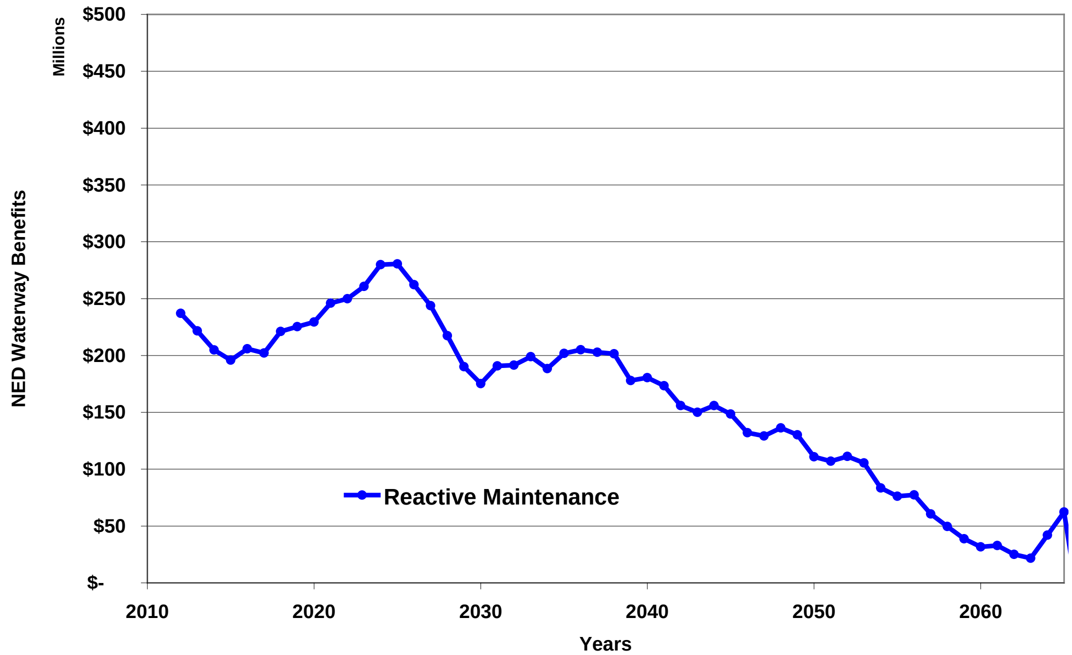


7.5.2 System Benefits - Reactive Maintenance

The primary benefit for Federal investment in the inland waterways is the collective transportation savings for barge shipment over the least-costly alternative routing. The benefit is referred to as the transportation surplus. Corps regulations recognize transportation savings or cost reduction as a national economic development (NED) benefit. NED benefits are calculated from equilibrium waterway traffic transportation savings net of any reduced transportation savings from congestion or delay due to scheduled or unscheduled repair closures.

Figure 7-5 displays upper Ohio NED waterway transportation savings for the reactive maintenance strategy. Annual savings are $249.6 million – using a 4.125 percent interest rate and a 2018 base year.

FIGURE 7-5 - NED Waterway Benefits – EDM Reactive Maintenance
(Mid Forecast)



7.5.3 System Economics – Reactive Maintenance

Table 7-4 summarizes average annual system waterway benefits and costs for a reactive maintenance strategy at EDM for the mid-forecast scenario. Total system benefits are equilibrium waterway transportation surplus net of any transportation losses from unscheduled repair closures and external costs of diverted traffic. Waterway transportation surplus is the consumer surplus (savings) realized by shippers under the normal operation of the waterway. Normal operation includes scheduled and random minor maintenance but does not include unscheduled closures. Unscheduled closures for repair result in transportation losses through congestion delay and the diversion of traffic to overland routes. The diverted traffic adds to overland congestion. The transportation losses and external costs from unscheduled closures are removed from the waterway transportation surplus to yield system waterway benefits.

Total system costs are the expected annual expenditures needed to maintain upper Ohio navigation infrastructure under the reactive maintenance strategy. These costs represent the costs to the Federal government to maintain, repair, or improve the waterway system under the reactive maintenance policy. Scheduled improvement costs are shared 50-50 with the Inland Waterways Trust Fund (IWTF). There are no scheduled improvement costs in reactive maintenance. Scheduled maintenance costs are what the Federal government pays for the periodic maintenance of EDM. Unscheduled repair costs are the Federal costs associated with the unscheduled repair of lock components. Normal O&M is the day-to-day recurring cost to staff and supply the project regardless of the project's ability to accommodate any traffic – things like on-site labor, utility costs, cutting grass, etc. Random minor costs mostly involve lock testing. Annual system benefits are $249.6 million. Annual system costs under reactive maintenance are estimated at $39.4 million. Annual net benefits are $210.2 million. This shows the expected value (benefit) of the existing upper Ohio infrastructure with a reactive maintenance strategy.

TABLE 7-4 - Reactive Maintenance –EDM
Mid Forecast
Average Annual Costs and Benefits
(2012-2068, 4 1/8%, Million FY09 $)

	Reactive Maintenance Mid - Forecast
Reactive Maintenance Benefits	
Waterway Transportation Surplus	$ 451.4
Transportation Losses from Unscheduled Closures	$-199.7
Externality Costs Incurred	$-2.1
Total System Benefits	**$ 249.6**
Reactive Maintenance Costs	
Scheduled Lock Improvements*	$ 0.0
Scheduled Lock Maintenance	$ 8.4
Unscheduled Lock Repair	$ 22.2
Normal O&M	$ 8.0
Random Minor	$ 0.8
Total System Costs	**$ 39.4**
Net Benefits	**$ 210.2**
BCR	**6.3**

* *Scheduled lock improvements are 50% cost shared with the Trust Fund*

Section 8: IDENTIFICATION OF ALTERNATIVE IMPROVEMENT PLANS

8.1 GENERAL

This section identifies and evaluates a more proactive maintenance strategy and alternative improvement plans that address the navigation problems and needs of the upper Ohio. The proactive maintenance strategy involves advanced maintenance where individual components can be replaced before failing. The alternative improvement plans considered include new 600', 800' and 1200' chambers to replace the auxiliary chambers and, under three of the alternatives, the main chambers at Emsworth, Dashields and Montgomery. Additionally, consideration was given to a nonstructural plan in the form of a congestion fee designed to divert marginal traffic and thereby increase total system benefits…Each of these plans requires an investment decision and therefore is considered to be a with-project alternative.

Evaluation of alternative improvement plans will ultimately identify an optimum mix of site-specific maintenance alternatives, non-structural improvements, and large-scale structural investments for each traffic forecast scenario.

8.2 OPTIMIZING COMPONENT MAINTENANCE

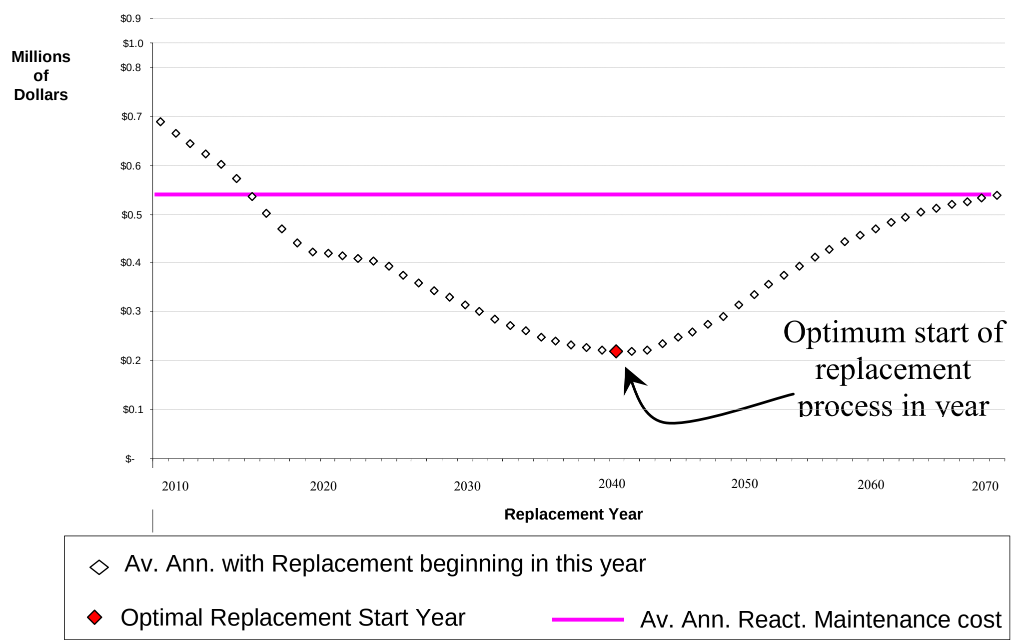
The ORNIM Lock Risk Module (LRM) simulates each year's expected repair costs and closure probabilities for each lock component analyzed. ORNIM's Optimization Module (OM) then calculates the annual expected equilibrium waterway savings (benefits) and total Federal reactive maintenance (RM) costs. This defines the expected net benefits for the reactive maintenance plan.

If the likelihood of a lock component's failure is high enough and a scheduled component replacement has less consequence (i.e. lower cost and shorter chamber closure duration) than an unscheduled replacement, it is better to replace a component before it fails. However, it is impossible to determine precisely when a failure will occur. The next best option is to estimate the expected annual reactive maintenance costs of repair and transportation impacts over the planning period and compare them to the cost of a proactive replacement. The least-cost alternative (reactive maintenance vs. replace in the 1st year vs. replace in the 2nd year, etc.) is the optimal maintenance plan for a component.

ORNIM compares the expected cost for the reactive maintenance plan with the costs for proactive component replacement in various years. If, for example, the component replacement cost in 2020 is being calculated, the expected reactive maintenance costs up through 2019 are accumulated, the probability of the components survival in 2020 is calculated and the expected up-front replacement cost is calculated[26]. This amortized cost stream with a 2020 replacement is compared to the amortized RM cost stream. The least-cost alternative is the optimal maintenance alternative.

Figure 8-1 uses a hypothetical set of main chamber miter gates to illustrate an average annual RM cost ($0.54 million) relative to average annual miter gate replacement costs for each year in the period of analysis. In this example, repair, replacement, and transportation costs can be minimized with a proactive miter gate replacement starting in 2040. All components were modeled this way. Optimum replacement timing represents the year the replacement process starts.

FIGURE 8-1 - Hypothetical Main Chamber Miter Gates
Reactive Maintenance vs. Component Replacement



Navigation projects are composed of many components. Determination of optimal replacement timing of each component is a critical step, but it may not indicate the best maintenance alternative for the project. Combining individual component replacements might offer savings in mobilization and de-mobilization costs and result in fewer chamber closures. Also, a large enough bundling of component replacements might eliminate enough collective reactive maintenance costs to be economically justified even if the up-front replacement of the individual components is not justified. This type of condition analysis of individual

[26] If the component's event tree contains a replacement of the component, there is a chance that the component is replaced before the scheduled up-front replacement date. In these simulations the scheduled replacement is canceled and replacement costs are not double counted.

components and bundled components is useful in formulating possible chamber rehabilitation. But, given the poor condition of the upper Ohio lock walls and their likely inclusion in any component bundle, engineering judgment ruled out chamber rehabilitation in favor of lock replacement as a viable with-project alternative.

8.3 ALTERNATIVES EVALUATED

8.3.1 Advanced Maintenance (Component Replacement)

The advanced maintenance strategy replaces a component before it fails. A planned, up-front component replacement can minimize the adverse navigation impacts of an unscheduled, emergency repair. To fully formulate advanced maintenance at a project, optimal individual component replacements must be determined. Optimal individual component replacements represent a piecemeal maintenance strategy which can be more efficient than reactive maintenance. It is considered a viable stand-alone alternative.

The engineering team evaluated up to fifteen lock components and component systems at Emsworth, Dashields, and Montgomery. Each component or component system was identified as critical enough to warrant detailed economic analysis. ORNIM was used to calculate the expected costs of reactive maintenance and repair and the additional transportation costs associated with the delays from the maintenance and repair closures. The amortized reactive maintenance costs are compared to up-front component replacement scenarios to determine if replacement is economically justified and if so, the optimal timing for the upfront replacement.

An advanced maintenance alternative combines reactive maintenance with economically justified component replacement. **Tables 8-1** and **8-2** show the year for beginning the recommended component replacement process and reactive maintenance (RM) schedules for the low and mid traffic forecast scenario. The gray shaded cells were not modeled in ORNIM for that project. RM in a cell represents reactive maintenance, which is the same thing as fixing the component after it fails, and the numbers in the cells represent the year which optimizes the start of a component replacement process.

It is clear from Tables 8-1 and 8-2 that component replacements at all three projects' main chambers are economically justified early on in the study period. At Emsworth, replacement of the land wall, guide wall and gates begin in 2014 and the middle wall, valves and gate machinery in 2015. At Dashields and Montgomery, replacement of the land walls begins in 2014 and the middle walls in 2015 under the low forecast scenario. The higher forecasts accelerate the replacement dates for some of the components.

TABLE 8-1 - Advanced Maintenance Scheduled Component Replacement

Low - Forecast Scenario

Chamber / Component	Upper Ohio Project		
	Emsworth	Dashields	Montgomery
MAIN			
Gates	2014	RM	2014
Gate Machinery	2015	2015	2015
Hydraulic	2014	2015	2014
Valve Machinery	-----	2015	2015
Mid Wall Fill Valves	2015	-----	-----
Mid Wall MT Valves	2015	-----	-----
Electrical	2015	2015	2015
Land Wall	**2014**	**2014**	**2014**
Guide Wall	**2014**	RM	-----
Middle Wall	**2015**	**2015**	**2015**
AUXILIARY			
Gate Machinery	RM	RM	RM
Hydraulic	RM	RM	RM
Valve Machinery	-----	RM	RM
River Fill Valves	2034	-----	-----
River MT Valves	2040	-----	-----
Electrical	RM	RM	RM
River Wall	-----	-----	RM
Guard Wall	-----	RM	-----

TABLE 8-2 - Advanced Maintenance Scheduled Component Replacement

Mid - Forecast Scenario

Chamber / Component	Upper Ohio Project		
	Emsworth	Dashields	Montgomery
MAIN			
Gates	2012	RM	2014
Gate Machinery	2015	2015	2015
Hydraulic	2012	2015	2012
Valve Machinery	-----	2015	2015
Mid Wall Fill Valves	2030	-----	-----
Mid Wall MT Valves	2014	-----	-----
Electrical	2012	2015	2012
Land Wall	**2014**	**2014**	**2014**
Guide Wall	**2013**	RM	-----
Middle Wall	**2015**	**2015**	**2015**
AUXILIARY			
Gate Machinery	RM	RM	RM
Hydraulic	RM	RM	RM
Valve Machinery	-----	RM	RM
River Fill Valves	2034	-----	-----
River MT Valves	2040	-----	-----
Electrical	RM	RM	RM
River Wall	-----	-----	RM
Guard Wall	-----	RM	-----

TABLE 8-3 - Advanced Maintenance
Scheduled Component Replacement
High - Forecast Scenario

Chamber / Component	Upper Ohio Project		
	Emsworth	Dashields	Montgomery
MAIN			
Gates	2023	RM	2021
Gate Machinery	2021	2021	2013
Hydraulic	2020	2022	2020
Valve Machinery	-----	2020	2019
Mid Wall Fill Valves	2022	-----	-----
Mid Wall MT Valves	RM	-----	-----
Electrical	2019	2012	2012
Land Wall	2016	2017	2016
Guide Wall	2014	2013	-----
Middle Wall	2012	2015	2014
AUXILIARY			
Gate Machinery	RM	RM	2068
Hydraulic	RM	RM	2064
Valve Machinery	-----	RM	2067
River Fill Valves	2035	-----	-----
River MT Valves	2040	-----	-----
Electrical	RM	RM	2029
River Wall	-----	-----	RM
Guard Wall	-----	2035	-----

8.3.2 Single Replacement Locks at EDM

The poor condition of the lock wall monoliths on the upper Ohio projects takes major rehabilitation out of the formulation process. Rehabilitation of the middle walls would close the river to navigation for up to two years. This is unacceptable to the Corps and to stakeholders. However, it is possible to construct a replacement lock in the footprint of the existing auxiliary chamber and avoid a total river closure. But during construction of a new lock there would be a risk of river closure with the existing 600' chamber. This risk could be monitored and communicated.

Alternatives involving construction of new 600', 800', or 1200' lock chambers riverward of the existing main chamber were developed and compared to reactive and advanced maintenance strategies at EDM. Lock sizes were selected by the engineering team. The 600', 800', and 1200' locks were each evaluated to optimize the chamber size to meet additional potential capacity needs at EDM given the forecast traffic demand scenarios. The upper Ohio projects are uniquely situated between 1200' chambers on the rest of the Ohio River and 720' chambers on the Monongahela River. In point of fact, the new 800' chambers on the Kanawha River are better suited to modern jumbo barge sizes than the Monongahela River's 720' chambers.

The alternatives entail replacing the smaller (360' x 56') auxiliary lock at each site with a 600'x110', 800'x110', or 1200'x110' chamber. The single replacement chamber projects were developed considering different options for the existing 600' chamber. One option was to maintain it in a reactive maintenance mode. Another option was to close it down after construction of the new chamber. A third option was to maintain it through reactive maintenance until such time as a catastrophic failure of a guide wall, middle wall or guard wall occurred.

The alternatives involving closure of the existing 600' locks at Emsworth, Dashields and Montgomery present a number of problems. The navigation projects downstream of EDM on the Ohio River as well as upstream on the lower Monongahela River have auxiliary chambers. When main chambers close in these river reaches, traffic diverts to the auxiliary chambers, although congestion and delays quickly become problematic at these smaller facilities. The alternatives involving closure of the existing 600' lock at EDM would leave waterway-dependent plants on the upstream side essentially cut off from the inland navigation system during lock shutdowns. Similarly, plants on the downstream side of EDM that rely on waterborne commodities originating in the Pittsburgh region (especially coal and primary metals products) would be cut off from those supplies. A related complication is the possibility of defacto limitations on overland capacity during lock shutdowns. Finally, operations personnel have pointed out that with an unexpected closure of single-lock facilities at any of the EDM projects, the repair fleet would be trapped upstream or downstream of the affected project which could complicate and ultimately prolong the shutdown.

In order to avoid the problems outlined above and maintain the dual-lock character of the Ohio River main stem projects, the above-mentioned alternatives involving the closure of the existing 600' lock were eliminated from consideration. With this caveat, ORNIM was run to determine optimal timing and combination of reactive maintenance, component replacement and new lock construction.

8.3.3 Two Replacement Locks at EDM

In addition to the single lock replacement plans, ORNIM was run to consider the economics of two new 600' chambers at EDM. Dual 800' and 1200' locks as well as 800' and 1200' locks with 600' auxiliaries were also considered early on but were eliminated because it became apparent that the alternatives calling for construction of new 600' locks with reactive maintenance of the existing 600' locks was superior (higher net benefits) to construction of new 800' or 1200' locks with reactive maintenance of the existing 600' locks under every forecast scenario. Because of this, construction of dual 800' or 1200' locks or 800' or 1200' locks with new 600' auxiliaries could not improve the relative economics of these plans versus a new 600' lock with reactive maintenance of the existing 600' lock. A new 600'x110' chamber riverward of the existing main chamber and a new 600'x110' chamber in the footprint of the existing main chamber were compared to single lock replacements (with various treatments of the existing main chamber, as indicated previously), advanced maintenance and reactive maintenance. This plan was considered to test the incremental benefit (if any) that would result from the installation of two new locks at each project.

A further refinement of the two-lock strategy was the construction sequencing. The first alternative evaluated was commencement of construction of the dual 600' chambers at EDM in 2012. The second alternative also called for commencement of construction of one of the new 600' lock chambers at EDM in 2012, with construction of the second locks at each project beginning 8 years later, in 2020. The third alternative involved a staggered construction sequence, with a new lock beginning construction at Emsworth in 2012, at Dashields in 2014 and at Montgomery in 2016, with construction of the second lock at each project beginning eight years after the first lock. Ultimately, the plan calling for construction of a new 600' lock chambers at EDM in 2012, with construction of the second locks at each project beginning 8 years later, in 2020 was found to have the highest net benefits among these three alternatives, and was therefore selected for inclusion in further analyses.

8.3.4 Congestion Fees

Under ordinary circumstances in navigation studies, a nonstructural with-project alternative to lock replacement in the form of a lock congestion fee is considered and evaluated. Since this measure would require additional congressional authorization, it is categorized as a with-project alternative. This alternative calls for the management of traffic demand at a lock through the imposition of a lockage fee. This fee is designed to influence the shipper with very marginal waterway savings to shift their traffic to an alternate overland mode, thereby reducing the amount of lock congestion and increasing the rate savings of the remaining shippers. The fee would thus serve as a device for rationing lock use to the movements with the highest marginal rate savings. The result would be to increase total rate savings net of delay costs for shippers that remain on the system. The congestion fee alternative typically includes the use of helper boats at a lock, when justified.

As the name implies, a congestion fee is designed to relieve congestion at a lock(s) by diverting the marginal movements and thereby increasing the sum of all benefits to remaining traffic. In the case of Emsworth, Dashields and Montgomery, traffic has remained essentially flat for more than 30 years and traffic has been well below project capacities. Congestion at these facilities has not been problematic except in instances of main chamber closures, when all traffic is forced to use the smaller auxiliary chambers. Furthermore, it is considered unlikely that future traffic will approach levels that would make congestion fees an attractive alternative.

Another, more salient issue is that the imposition of congestion fees does nothing to address the main chamber condition and reliability problems identified previously or the auxiliary lock capacity problem when the main chamber is down. In the final analysis, only structural alternatives are capable of addressing these problems. For these reasons, an evaluation of a congestion fee alternative to a structural plan was not undertaken

8.3.5 Analytical Issues

When analyzing system investment strategies where multiple investments can be timed differently, the specification of a base year as a project's earliest on-line year can be problematic (i.e. there are multiple on-line years). In the formulation and comparison between investment strategies, the planning parameters (planning period, base year, discount rate, and discounting method) are held constant. The base year is actually insignificant to the comparison as long as the planning period, discount rate, and the discounting method (e.g. end of year) are consistent. For the formulation of the upper Ohio alternatives, the planning period includes the implementation period and a 50-year analysis period. The first budgetable year, and the first possible construction year, was determined to be 2012. Initially, it was thought that all construction projects could be completed in 6 years, resulting in the specification of a base year 2018 and a planning period end year of 2068 (2018 plus 50-years). As it turned out, lock construction durations varied by alternative and location, and none was less than 8 years in duration.

For each new lock construction alternative except for the staggered twin 600' locks alternative, construction at each site was assumed to begin in 2012 (the first budgetable year). Construction completion and on-line years vary because of variation in lock sizes and because of staggering in the commencement of construction at the three lock sites. Once the recommended plan is finalized with construction timing, the cost and benefit cash flows for each location will be re-discounted with a base year set to the site's on-line year so that interest during construction (IDC) for each project can be determined.

Section 9. ECONOMICS OF THE ALTERNATIVE WITH-PROJECT IMPROVEMENT PLANS

9.0 GENERAL

The with-project alternatives can be described in terms of Federal costs and associated cost impacts on navigation. Under the with-project alternatives, normal O&M is performed along with scheduled periodic maintenance. Unscheduled lock repair costs are estimated from reliability modeling. Authorized lock improvement costs will be up-front component replacements and lock replacements.

Preliminary screening resulted in the identification of five alternative with-project improvement plans. In subsequent paragraphs, these plans are given a descriptive designation as well as short designations developed by the project delivery team to assure comparability between study documents. The short designations are displayed parenthetically following the descriptive designations.

9.1 ADVANCED MAINTENANCE (AMA)

9.1.1 System Costs – Advanced Maintenance (AMA)

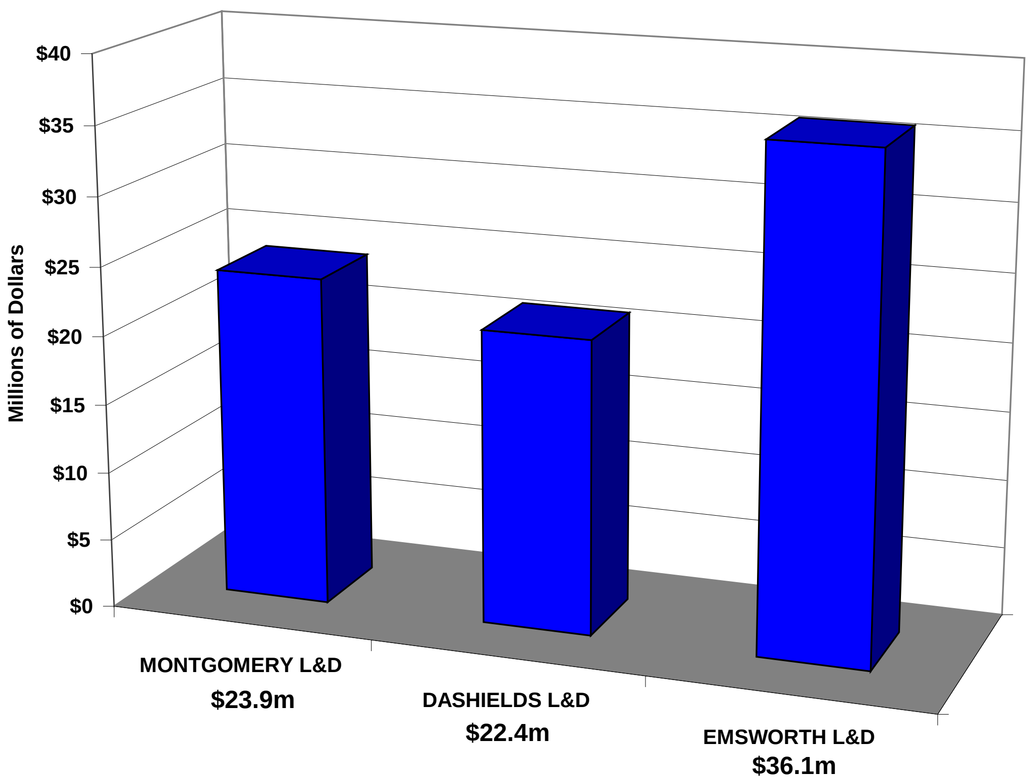
ORNIM was run to estimate expected annual Federal costs to operate and maintain EDM under an advanced maintenance scenario (AMA). The advanced maintenance scenario allows for component replacement when economically justified. The average annual expected Federal cost at EDM with an advanced maintenance strategy from 2012-2068 is $77.5 million. **Table 9-1** displays the expected annual Federal costs at EDM from advanced maintenance broken out into improvement costs, scheduled repair costs, unscheduled repair costs, random minor maintenance cost and normal O&M costs. A majority of component replacement activity occurs in 2014 and 2015 with middle walls being replaced in 2015.

TABLE 9-1 - Annual Federal Costs at EDM
Advanced Maintenance (AMA)– Component Replacement
(2012-2068, 4 1/8%, Millions FY 09$)

Federal Costs	Advanced Maintenance (AMA)
Scheduled Lock Improvement	$ 57.1
Scheduled Repair	$ 7.8
Unscheduled Repair	$ 3.8
Normal O&M	$ 8.0
Random Minor	$ 0.8
Total Costs	$ 77.5

Figure 9-1 displays the average annual Federal costs for the advanced maintenance strategy at EDM. The Federal costs include normal O&M, random minor maintenance, scheduled lock maintenance and unscheduled lock repair costs. The scheduled lock improvements are economically justified component replacements displayed in Tables 8-1 and 8.2. Again, Emsworth is the higher cost project. Unscheduled lock repair costs and scheduled lock maintenance costs are lower because of proactive component replacement efficiencies. High maintenance needs are seen on the upper Ohio projects where over 70 percent of the annual Federal costs over the next 50-60 years are economically justified component replacements.

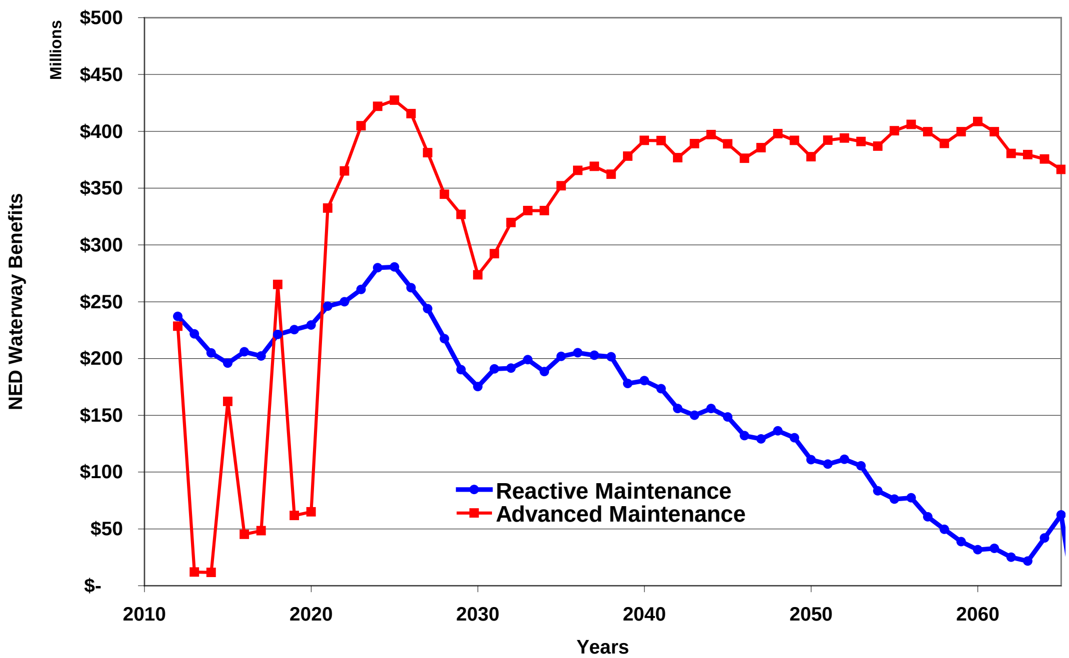
FIGURE 9-1 - Average Annual Federal Costs - EDM
Advanced Maintenance (AMA)– Component replacement
(2012-2068, 4 1/8%, FY 09$)



9.1.2 System Benefits – Advanced Maintenance (AMA)

System benefits are the equilibrium transportation savings net of any transportation losses caused by congestion delay or diversion due to scheduled improvement and unscheduled repair closures. **Figure 9-2** compares advanced and reactive maintenance benefits for the mid traffic forecast scenario. The deep reduction in advanced maintenance benefits early on in the study period results from overlapping partial and total river closures during wall replacements.

FIGURE 9-2 – NED Waterway Benefits – EDM
Advanced Maintenance (AMA)
(Mid Forecast)



9.1.3 System Economics – Advanced Maintenance (AMA)

Individual component replacement optimization was done at the project level in a system context. The simultaneous effect of multiple piecemeal component replacements at each project and between each project is captured by locking the recommended replacements for all projects and re-equilibrating the transportation system. Given the results of individual up front component replacement analysis, ORNIM was run to calculate the expected system component replacement costs under each traffic forecast scenario. **Table 9-2** summarizes annual system benefits and costs for an advanced maintenance strategy at EDM for the mid-forecast scenario. Table 9-2 shows both total system benefits and costs and incremental system benefits and costs. The incremental system benefits and costs are incremental with respect to the without-project condition. Although investment decisions are ordinarily made based on incremental system benefits and costs, total system benefits and costs are displayed at the request of HQ.

Advanced maintenance buys down risk with higher scheduled improvement costs that are 50 percent cost shared with the Trust Fund. Scheduled improvement costs for this alternative include justified up-front component replacements. Incremental annual benefits for advanced maintenance are $114.7 million, incremental annual costs are $38.1 million and the associated net benefits are $76. million.

TABLE 9-2 - Advanced Maintenance (AMA) – EDM
Mid Forecast
Average Annual Costs and Benefits
(2012-2068, 4 1/8%, Million FY09 $)

	Advanced Maintenance (AMA)-EDM System Economics Mid-Forecast
Advanced Maintenance Benefits	
Waterway Transportation Surplus	$ 388.0
Transportation Losses from Unscheduled Closures	$ -23.5
Externality Costs Incurred	$ -0.2
Total System Benefits	**$ 364.3**
Advanced Maintenance Costs	
Scheduled Lock Improvements	$ 57.1
Scheduled Lock Maintenance	$ 7.8
Unscheduled Lock Repair	$ 3.8
Normal O&M	$ 8.0
Random Minor	$ 0.8
Total System Costs	**$ 77.5**
Net Benefits	**$ 286.8**
BCR	**4.7**
Incremental Benefits	**114.7**
Incremental Costs	**38.1**
Incremental Net Benefits	**76.6**
BCR (Incremental)	**3.0**

9.2 NEW LOCK CHAMBERS AT EDM AND REACTIVE MAINTENANCE

New 600’ (LMA 7), 800’ (LMA 8), and 1200’ (LMA 9) lock chambers at EDM were modeled with the existing 600’ chambers maintained in a reactive maintenance (FAF) mode during and after construction. The new chambers would be constructed in the foot print of the existing 360’ auxiliary chambers. Putting the replacement locks in the footprint of the existing auxiliary chambers exposes the upper Ohio to the risk of a total river closure. Component reliability analysis indicates possible failure to occur at the existing 600’ chambers during construction of each new chamber - a construction period that could extend more than the planned six years.

9.2.1 System Costs – New Lock Chambers at EDM and Reactive Maintenance

ORNIM was run at all projects to estimate expected unscheduled repair/replace costs, component replacement costs and the construction of new lock chambers at EDM. **Table 9-3** shows expected annual Federal costs for the new lock at EDM alternative that maintains the existing 600' chamber in a reactive maintenance mode as a backup. Federal expenditures vary with lock size and range between $104.3 and $131.7 million a year. New lock construction at EDM buys down risk and lowers future unscheduled lock repair and scheduled maintenance costs relative to reactive maintenance.

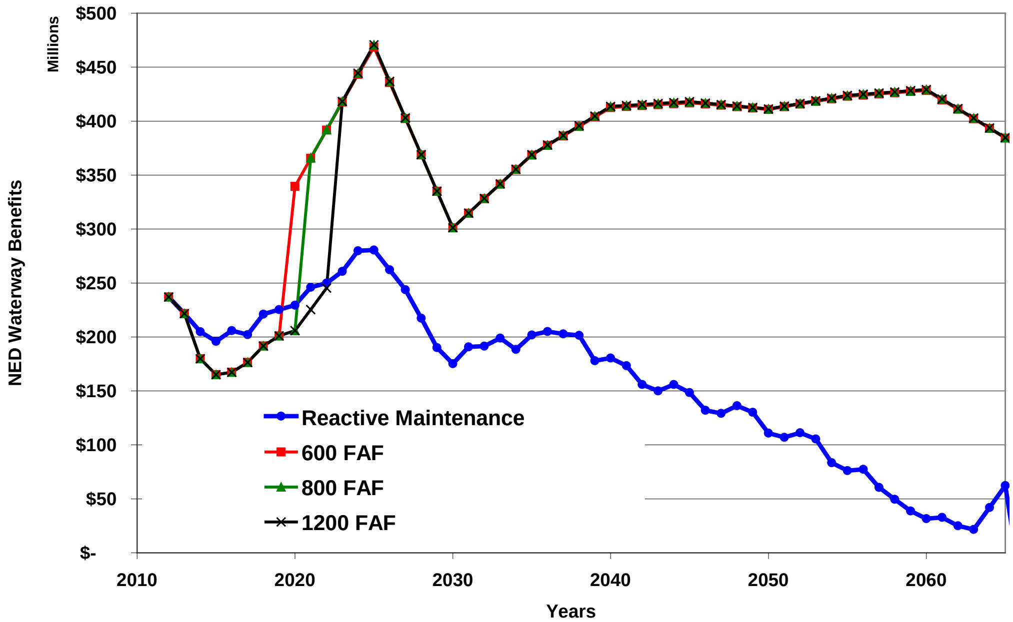
TABLE 9-3 - Annual Federal Costs at EDM
600' (LMA 7), 800' (LMA 8), and 1200' (LMA 9) Lock Replacements and FAF
(2012-2068, 4 1/8%, Millions FY 09$)

Federal Costs	600' (LMA 7)	800' (LMA 8)	1200' (LMA 9)
Authorized Lock Improvement	$ 72.2	$ 84.0	$ 100.1
Scheduled Repair	$ 4.7	$ 4.5	$ 4.2
Unscheduled Repair	$ 18.8	$ 18.8	$ 18.8
Normal O&M	$ 8.0	$ 8.0	$ 8.0
Random Minor	$ 0.6	$ 0.6	$ 0.6
Total Costs	$ 104.3	$ 115.9	$ 131.7

9.2.2 System Benefits – New Lock Chambers at EDM and Reactive Maintenance

System benefits are the equilibrium transportation savings net of any transportation losses caused by congestion delay or diversion due to scheduled improvement and unscheduled repair closures. **Figure 9-3** displays mid-forecast transportation benefits for the reactive maintenance strategy and for the new 600' (LMA 7), 800' (LMA 8), and 1200' (LMA 9) locks at EDM. The with-project alternatives show lower transportation savings during construction of the new lock. This is due to intermittent river closures when the existing 600' chamber closes for repair during construction of the new chamber.

FIGURE 9-3 Upper Ohio System New 600' (LMA 7), 800' (LMA 8), or 1200' (LMA 9) Locks at EDM with Reactive Maintenance - NED Waterway Benefits
(Mid Forecast)



9.2.3 System Statistics – New Lock Chambers at EDM and Reactive Maintenance

Table 9-4 summarizes mid forecast average annual system benefits and costs of constructing new 600' (LMA 7), 800' (LMA 8), and 1200' (LMA 9) locks at EDM while maintaining the existing 600' chambers. Incremental annual benefits range between $167.5 million with the 1200' lock, and $183.8 million with the 600' lock. Incremental annual costs range between $64.9 million with the 600' lock and $92.3 million with the 1200' lock. The resulting net benefits range from $75.2 million with the 1200' lock and $118.9 million with the 600'.

TABLE 9-4 - New 600' (LMA 7), 800' (LMA 8), or 1200' (LMA 9) Locks at EDM
Mid Forecast
Average Annual Costs and Benefits
(2012-2068, 4 1/8%, Million FY09 $)

Upper Ohio System – EDM	New Lock		
	600' (LMA 7)	800' (LMA 8)	1200' (LMA 9)
New Lock with FAF Benefits			
Waterway Transportation Surplus	$ 474.3	$ 474.4	$ 474.4
Transportation Losses from Unscheduled Closures	$-40.0	$-45.0	$-56.0
Externality Costs Incurred	$-0.9	$-1.0	$-1.3
Total System Benefits	**$ 433.4**	**$ 428.4**	**$ 417.1**
New Lock with FAF Costs			
Scheduled Lock Improvements	$ 72.2	$ 84.0	$ 100.1
Scheduled Lock Maintenance	$ 4.7	$ 4.5	$ 4.2
Unscheduled Lock Repair	$ 18.8	$ 18.8	$ 18.8
Normal O&M	$ 8.0	$ 8.0	$ 8.0
Random Minor	$ 0.6	$ 0.6	$ 0.6
Total System Costs	**$ 104.3**	**$ 115.9**	**$ 131.7**
Net Benefits	**$ 329.1**	**$ 312.5**	**$ 285.4**
BCR	**4.2**	**3.7**	**3.2**
Incremental Benefits	**183.8**	**178.8**	**167.5**
Incremental Costs	**64.9**	**76.5**	**92.3**
Incremental Net Benefits	**118.9**	**102.3**	**75.2**
BCR (Incremental)	**2.8**	**2.3**	**1.8**

9.3 NEW LOCK CHAMBER AND ADVANCED MAINTENANCE

The engineering reliability analysis indicates that an advanced maintenance strategy on the existing 600' chamber after construction of the new lock chamber would result in the complete replacement of the lock walls, gates, gate machinery, and hydraulic and electrical equipment – essentially a new chamber. This plan was not evaluated. Instead the formulation moved into twin chamber construction.

9.4 Dual 600' CHAMBERS AT EDM (LMA 1)

The dual 600'-chamber plan (LMA 1) for EDM calls for commencement of construction of one of the new 600' lock chambers at EDM beginning in 2012. The second lock chambers at each of the facilities would then begin construction eight years later, in 2020. Table 9-5 shows expected annual costs of $109.7 million for the two new 600' locks at EDM. Under this alternative, the dual-chamber character of the main stem Ohio is maintained, and the risk of a complete river shutdown, which is inherent with single-lock structures, is avoided.

TABLE 9-5 - Annual Federal Costs at EDM
Dual 600' Locks (LMA 1)
(2012-2068, 4 1/8%, Millions FY 09$

Federal Costs	Dual 600' Locks (LMA 1)
Lock Improvement	$ 92.8
Scheduled Repair	$ 1.2
Unscheduled Repair	$ 7.3
Normal O&M	$ 8.0
Random Minor	$ 0.4
Total Costs	$ 109.7

Table 9-6 summarizes the mid forecast annual benefits and costs of constructing dual 600' locks at EDM. As indicated previously, this plan calls for beginning construction of the first lock in 2012 followed by a second 600'lock in 2018. Incremental annual benefits for this alternative are $184.2 million and incremental annual costs are $70.4 million. The resulting incremental net benefits are $113.8 million.

TABLE 9-6 - Dual 600' Locks at EDM (LMA 1)
Mid Forecast
Annual Costs and Benefits
(2012-2068, 4 1/8%, Million FY09 $)

Upper Ohio System – EDM	Dual 600' Locks (LMA 1)
New Dual 600' Locks Benefits	
Waterway Transportation Savings	$474.3
Reduced Savings Unscheduled Closures	$-39.6
Externality Costs Incurred	$-0.9
Total System Benefits	**$433.8**
New Dual 600' Locks Costs	
Scheduled Lock Improvements	$92.8
Scheduled Lock Maintenance	$1.2
Unscheduled Lock Repair	$7.3
Normal O&M	$8.0
Random Minor	$0.4
Total System Costs	**$109.8**
Net Benefits	**$324.0**
BCR	**4.0**
Incremental Benefits	**$184.2**
Incremental Costs	**$70.4**
Incremental Net Benefits	**$113.8**
BCR (Incremental)	**2.6**

9.5 COMPARISON OF WITH-PROJECT ALTERNATIVE PLANS

Table 9-7 lists the incremental annual net benefits by rank for each investment plan evaluated under the mid case scenario. Net benefits are incremental with respect to those that would be realized under the without-project condition. From this array, the optimum investment plan, i.e. the plan that maximizes net benefits, calls for installation of a new 600' lock chamber with reactive maintenance of the existing 600'lock (LMA 7). This plan becomes the NED plan. All of the other plans, as well, would be economically justified since they result in positive incremental net benefits.

TABLE 9-7 - Incremental Annual Net Benefits by Plan
(2012-2068, 4 1/8%, Million FY09 $)

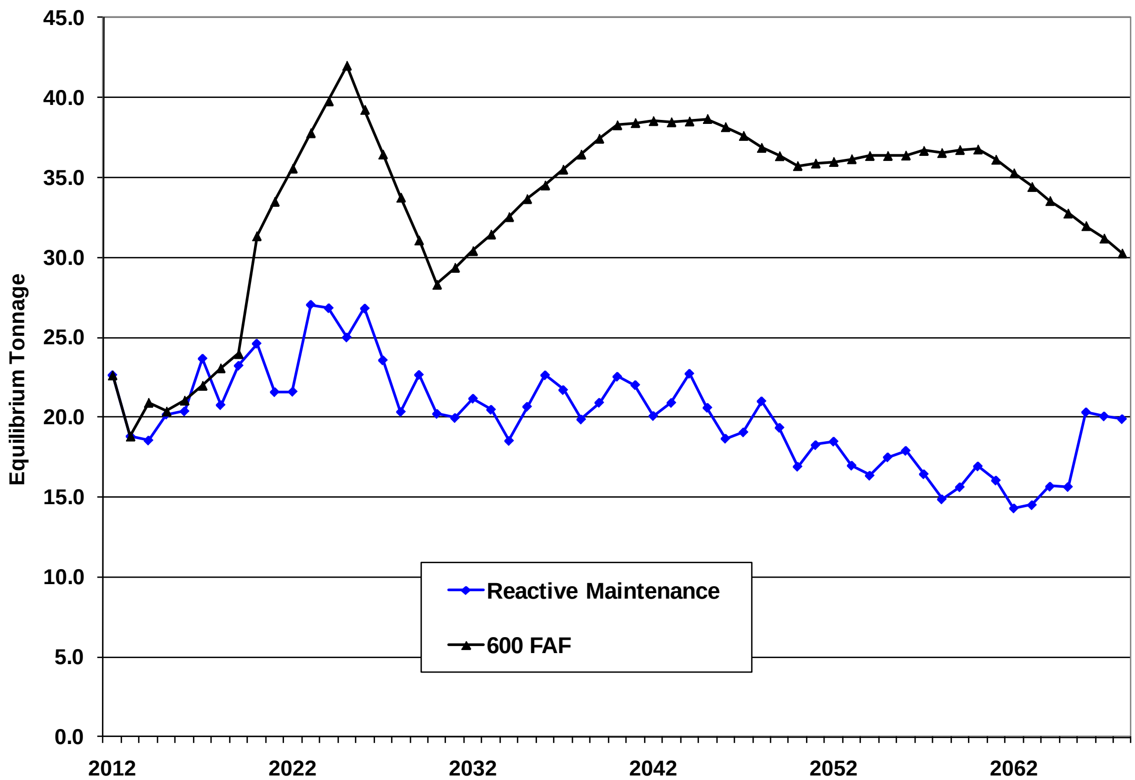
	Incremental Net Benefits/Ranking	
Plan Description/Designation	Rank	Mid Case
600' Chamber & FAF Old (LMA 7)	1	118.9
Dual 600s w/ Lagged 2nd Lock (LMA 1)	2	113.9
800' Chamber & FAF Old (LMA 8)	3	102.3
Advance Maintenance (AMA)	4	76.6
1200' Chamber & FAF Old (LMA 9)	5	75.2

9.6 ECONOMICS OF THE NED PLAN

9.6.1 Equilibrium System Traffic

Figure 9-4 displays equilibrium system traffic accommodated under reactive maintenance (WOPC) and under the NED plan which calls for new 600' chambers with reactive maintenance (FAF) of the old 600' locks (LMA 7). Gaps represent incremental diverted traffic between the plans. Under the NED plan, with the old 600' chambers open as auxiliaries, the upper Ohio would largely avoid periodic river closures.

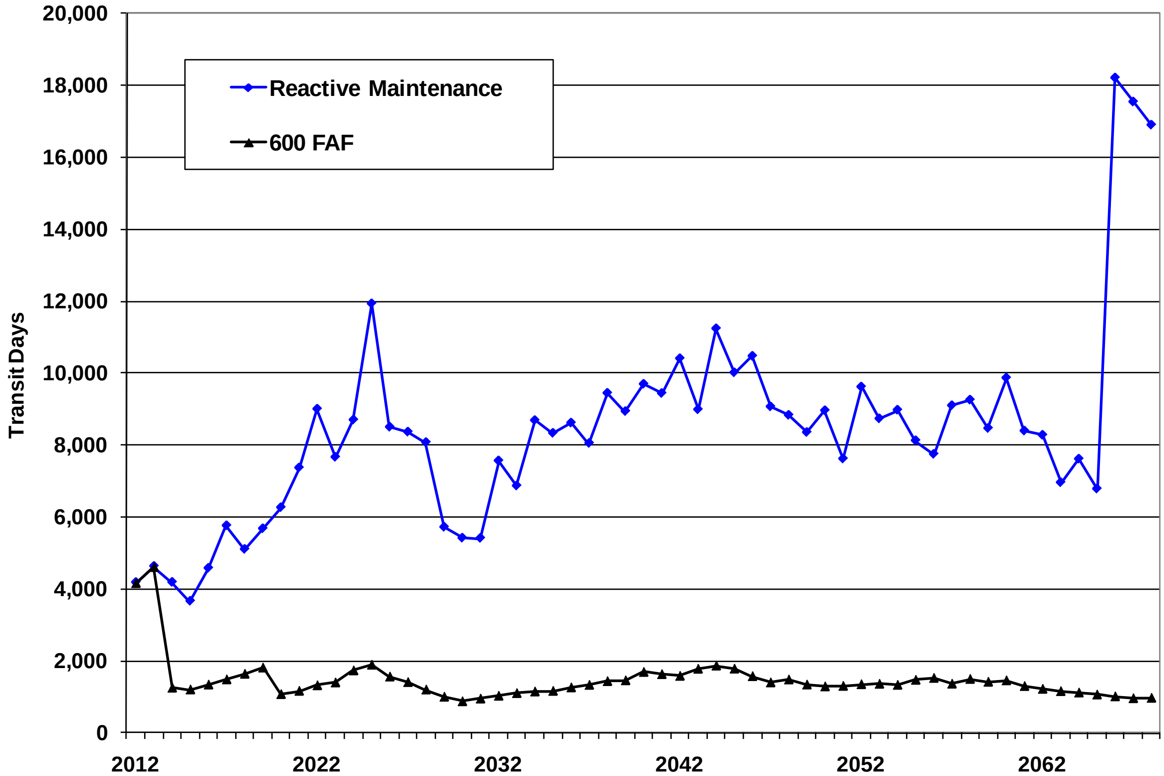
FIGURE 9-4
Equilibrium System Traffic – Mid Forecast
(Million Tons)



9.6.2 System Transit Days

Figure 9-5 compares system equilibrium traffic transit time for the modeled forecast traffic scenario between reactive maintenance and the NED plan calling for new 600' chambers and reactive maintenance of the old (LMA 7). NED plan benefits are derived from a more efficient transportation system because of improved reliability and increased capacity. Capacity increases with fewer closures at the new chambers.

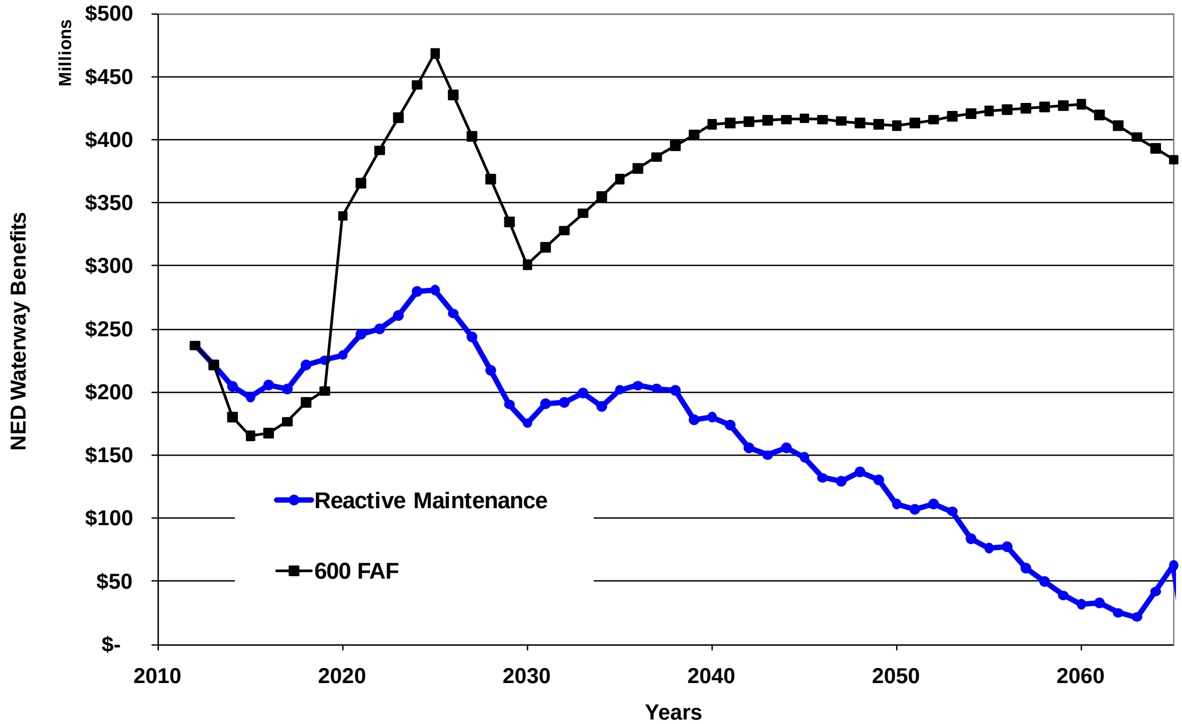
FIGURE 9-5
Transit Days to Accommodate Equilibrium Traffic – Mid Forecast



9.6.3 System Savings

Figure 9-6 displays the mid forecast traffic scenario system transportation savings for reactive maintenance (WOPC) and the NED plan , which includes new 600' chambers and reactive maintenance of the existing chambers (LMA 7). Equilibrium transportation savings represent system benefits in accordance with ER 1105-2-100. The gaps between reactive maintenance and the NED plan represent system benefits attributable to the new chambers. Again, because the NED plan continues to maintain the existing 600' chamber, the dis-savings associated with the river closures from future scheduled de-waterings of the new chamber are largely avoided.

FIGURE 9-6
Equilibrium System Savings – Mid Forecast
(Million Dollars)



9.6.4 Incremental Net Benefits

Table 9-8 presents the incremental annual benefits and costs, net benefits and BCRs for construction of the new 600'chamber with reactive maintenance of the existing 600' chamber (LMA 7). Incremental annual benefits are $183.9 and incremental costs are $64.9, producing a benefit-to-cost ratio of 2.8-to-1. Since this plan maximizes net benefits at $118.9, when compared to the other alternatives, this becomes the NED plan.

9.6.5 Investment Costs

Table 9-9 shows project first costs, interest during construction, and total investment costs for the NED plan. Interest during construction represents the interest cost incurred on Expenditures prior to the base year in the project economic life.

TABLE 9-8 - Incremental Annual Benefits and Costs Mid Forecast (2012-2068, 4 1/8%, Million FY09 $)

	Mid Forecast
Upper Ohio System – EDM	**600' FAF (LMA 7) (NED)**
Incremental Benefits over the WOPC	$ 183.8
Incremental Costs over the WOPC	$ 64.9
Incremental Net Benefit	**$ 118.9**
Incremental BCR	**2.8**

TABLE 9-9 - Summary of Investment Costs for the NED Plan (4 1/8%; Million FY09 $)

Item	Cost
First Costs -- New Construction	$1,479.0
IDC (new construction)	$75.8
Discounting of post-2017 work	-$27.3
Total Investment Costs	$1,527.5

Section 10: SENSITIVITY ANALYSES

10.1 INTRODUCTION

The preceding economic analyses were based largely on the results of the mid-level forecast scenario. The alternative plans for improving the existing Federal projects at EDM were evaluated, as well, using the high and low forecast scenarios. Also**,** In light of the uncertainty surrounding future market and navigation conditions, certain other analyses were considered for the purpose of testing the economic viability of the NED plan to changes in key variables. These included limiting the growth of traffic to the initial 20 years in the forecast period, no growth in commodity traffic beyond the 2007 level, use of the current OMB interest rate of 7 percent, the impact of price elasticity of demand estimates for waterway transportation and the use of the current fleet. In addition to these analyses, the NED plan was compared to a plan involving incremental additions of improved locks, i.e. a new 600'lock at Montgomery and then new 600' locks at Montgomery and Dashields. The results of these analyses are presented in this section.

10.2 HIGH AND LOW ALTERNATIVE FORECAST SCENARIOS

Table 10-1 lists the incremental annual net benefits by ranking for each investment plan evaluated under the low , mid and high case scenarios. Under low and mid-case scenarios, the optimum investment plan calls for installation of a new 600' lock chamber with reactive maintenance of the existing 600'lock (LMA 7). Under the high forecast scenario, the optimum investment plan is for installation of two new 600' locks at each facility, with the second locks beginning construction eight years after the beginning of construction on the first locks (LMA 1).

TABLE 10-1 - Incremental Annual Net Benefits by Plan and Scenario
(2012-2068, 4 1/8%, Million FY09 $)

Plan Description/Designation	Incremental Net Benefits/Ranking					
	Rank	Low Case	Rank	Mid Case	Rank	High Case
600' Chamber & FAF Old (LMA 7)	1	93.4	1	118.9	2	178.9
Dual 600s w/ Lagged 2nd Lock (LMA 1)	2	88.3	2	113.9	1	181.0
800' Chamber & FAF Old (LMA 8)	3	77.0	3	102.3	3	169.3
Advance Maintenance (AMA)	4	66.0	4	76.6	5	101.4
1200' Chamber & FAF Old (LMA 9)	5	51.1	5	75.2	4	143.9

Examination of Table 10-1 also indicates that advance maintenance (AMA) and the plans calling for new 800'(LMA 8) and 1200' (LMA 9) locks, both with reactive maintenance of the existing 600', would remain economically feasible regardless of forecast scenario.

10.3 NO GROWTH AND TWENTY-YEAR LIMITED GROWTH IN TRAFFIC DEMAND

In addition to the high, mid-level and low alternatives, two additional forecast scenarios were analyzed involving no growth in traffic demands beyond the 2007 level and a limitation on growth of traffic demand to the first 20 years of the period of analysis. Table 10.2 compares the results for the no growth and twenty year limited growth in traffic demand with the mid-forecast analysis. The results for no growth in traffic demand show that incremental benefits diminish by $87.6 million to $96.2 million. Incremental costs remain unchanged at $64.9 million and incremental net benefits diminish by $87.6 million to $31.3 million. With no growth in traffic demand, the NED plan remains economically justified with positive net benefits and a benefit-cost ratio of 1.5 to 1. Limiting the growth of traffic demand to the first

TABLE 10-2 – Comparison of Results with No Growth and 20-Year Limited Growth In Traffic Demands (Millions of FY09$; 4.125 percent)

	New 600' Lock and FAF Old (LMA 7)		
Upper Ohio System - EDM	No Growth	20-Year Limited Growth	Mid Forecast
Incremental Benefits over the WOPC (MM$)	96.2	153.7	183.8
Incremental Costs over the WOPC (MM$)	64.9	64.9	64.9
Incremental Net Benefit (MM$)	31.3	88.8	118.9
Incremental BCR	1.5	2.4	2.8

20 years of the period of analysis has the effect of weighting the initial years of the project economic life and de-emphasizing the latter years, which, by their nature involve greater uncertainty.

The results of the analyses for 20-year limited traffic demand growth compared to those for the mid-level forecast show incremental annual benefits diminishing by $31 million to $153.7

million. Incremental annual costs remain unchanged at $64.9 million. Incremental net benefits diminish by $31 million to a level of $88.8 million. Like the no growth scenario, with 20-year limited growth in traffic demand, the NED plan remains justified with positive net benefits and a BCR of 2.4 to 1.

10.4 ALTERNATIVE INTEREST RATE

The current analyses were conducted using the current Federal discount rate of 4.125 percent. In addition to the current Federal discount rate, an analysis was conducted using the interest rate that OMB typically requires for post authorization reporting, which is currently 7 percent.

The results of the analyses of the NED plan under the current interest rate of 4.125 percent and the OMB rate of 7 percent are presented in Table 10-3. Under the OMB interest rate, incremental annual benefits decrease by $34.2 million to $149.6 million. Incremental annual costs increase by $41.2 million to $106.1 million. Incremental net benefits diminish by $75.4 million to a level of $43.5 million. The NED plan remains justified with positive net benefits and a BCR of 1.4 to 1.

TABLE 10-3 – Comparison of Results Under Current Interest Rate with the OMB Rate (Millions of FY09 $)

	New 600' Lock and FAF Old (LMA 7)	
	OMB Rate	Current Rate
Upper Ohio System - EDM	7.00%	4.125%
Incremental Benefits over the WOPC (MM$)	149.6	183.8
Incremental Costs over the WOPC (MM$)	106.1	64.9
Incremental Net Benefit (MM$)	43.5	118.9
Incremental BCR	1.4	2.8

10.5 PRICE RESPONSIVE VERSUS FIXED QUANTITY MOVEMENT DEMAND

In the traditional navigation system analysis framework, individual origin-destination commodity movements are modeled with the assumption that the bulk of the individual movements are relatively unresponsive (price inelastic) to changes in waterway transportation costs that arise because of system constraints. The series of commodity movements, in this instance, forms a so-called fixed quantity demand curve. The traffic diversions that produce system equilibrium traffic are diversions of all or portions of the marginal movement, i.e. the lowest rate saver.

A more accurate analytical process reflects the fact that all of the origin-destination movements could potentially be responsive (price elastic) to changes in waterway transportation costs due to system constraints. This series of commodity movements forms a price responsive demand curve. Current navigation system analysis methods, including the analyses conducted for the Upper Ohio study, reflect price responsiveness on the part of the individual commodity movements.

A sensitivity test conducted for the current study compares results obtained for the alternative plans on the Upper Ohio using current methods based on price responsive movement demand with results generated using the traditional methods based on fixed quantity movement demand. Table 10-4 displays the results of this test. In this instance, incremental benefits increase by $40.1 million to $223.9 million with fixed quantity movement demand. Incremental costs remain unchanged. Incremental net benefits increase by $40.1 million to $159.0 million and the BCR increases to 3.5 to 1.

TABLE 10-4 – Comparison of Results Based on Fixed Quantity (inelastic) and Price Responsive (elastic) Movement Demand (Millions of FY09$)

	New 600' Lock and FAF Old (LMA 7)	
Upper Ohio System - EDM	Fixed Quantity (Inelastic)	Price Responsive (Elastic-Current)
Incremental Benefits over the WOPC (MM$)	223.9	183.8
Incremental Costs over the WOPC (MM$)	64.9	64.9
Incremental Net Benefit (MM$)	159.0	118.9
Incremental BCR	3.5	2.8

10.6 CHANGE IN FLEET ASSUMPTIONS

The term “fleet” refers to the towing equipment, meaning towboats and barges as well as the tow sizes and tow configurations used in inland navigation modeling. Tow sizes and tow configurations are usually selected by the model. Barge fleet assumptions are normally specified by the analyst. The upper Ohio is generally the only part of the ORS where narrow barges, i.e. standards and stumbos , continue to be used. As part of the Upper Ohio River Navigation Study, a study was conducted to determine the characteristics of the future barge fleet on this river segment. As a result of this study, it was determined that standard and stumbo barges would gradually be phased out in favor of jumbo barges.

In inland navigation system modeling, the normal procedure is to model both the WOPC and the alternative improvement plans using the future anticipated barge fleet. One of the required sensitivity tests is to model the WOPC and the alternative improvement plans using the current fleet. The results of this sensitivity test are displayed in Table 10.5. The change from current fleet to future fleet assumptions increases incremental benefits by $111.7 million to $184.7 million. Incremental costs decrease by $0.5 million to $64.9 million. Incremental net benefits increase by $112.2 million to $118.9 million and the BCR increases to 2.8 to 1.

TABLE 10-5 – Comparison of Results With Future and Current Fleets (Millions of FY09$

	New 600' Lock and FAF (LMA 7)	
Upper Ohio System - EDM	With Current Fleet	With Future Fleet
Incremental Benefits over the WOPC (MM$)	72.1	183.8
Incremental Costs over the WOPC (MM$)	65.4	64.9
Incremental Net Benefit (MM$)	6.7	118.9
Incremental BCR	1.1	2.8

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 1
Ohio River Navigation Investment Model (ORNIM) Version 5.1

April 2011

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1.1 INTRODUCTION

The purpose of a U. S. Army Corps of Engineers planning analysis "*… is to estimate changes in national economic development that occur as a result of differences in project outputs with a plan, as opposed to national economic development without a plan*"[1]. This is accomplished through a federally mandated National Economic Development (NED) analysis which is "*… generally defined as an economic cost-benefit analysis for plan formulation, evaluation, and selection that is used to evaluate the federal interest in pursuing a prospective project plan.*"[2] NED benefits are defined as "*… increases in the net value of the national output of goods and services, expressed in monetary units …*"

1.1.1 Inland Navigation Analysis

For a navigation project investment, NED benefits are composed primarily of the reductions in transportation costs attributable to the improved waterway system. The reduction in transportation costs are achieved through increased efficiency of existing waterway movements, shifts of waterway and overland traffic to more efficient modes and / or routes, and / or shifts to more efficient origin-destination combinations. Further benefits accrue from induced (new output / production) traffic that is transported only because of the lower transportation cost deriving from an improved project, and from creating or enhancing the potential for other productive uses of the waterway, such as the generation of hydropower. National defense benefits can also be realized from regional and national growth, and from diversity in transportation modes. In many situations lower emissions can be achieved by transportation of goods on the waterway. But, the conceptual basis for the "*… basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities*"[3].

Traditionally, this primary benefit for barge transportation is calculated as the cost savings for barge shipment over the long-run least- cost all-overland alternative routing. This benefit estimation is referred to as the waterway transportation rate-savings, and it also accounts for any difference in transportation costs arising from loading, unloading, trans-loading, demurrage, and other activities involved in the ultimate point - to - point transportation of goods. A newer way to estimate this primary benefit is to define the movement willingness-to-pay for barge transportation with a demand curve (instead of the long-run least-costly all-overland rate) and then calculate a transportation surplus (consumer surplus). Either way, the primary benefit for federal investment in commercially navigable waterways (benefits with a plan as opposed to benefits without a plan) ends up as a transportation cost reduction.

The primary guidance document that sets out principles and procedures for evaluating federal interest is the *Principles and Guidelines* (P&G)[4]. Corps guidance for implementing P&G is found in the *Planning Guidance Notebook*[5] with additional discussions of NED analysis documented in the *National Economics Development Procedures Overview Manual*[6]. For inland navigation analysis, the focus is on the evaluation and comparison of the existing waterway system with three basic alternative measures: 1) increase capacity (decrease transit times and thereby reducing delay costs); 2) increase reliability (replace or rehabilitate aging structures, thereby reduce the probability of structural failure and its consequences); and / or 3) reduce demand (e.g., congestion fees). The P&G provides general guidance for doing this benefit assessment, but leaves open opportunities to improve the analytical tools used as new data and computational capabilities become available.

The inland waterway system is a network of locks and open channel reaches. As a result, no navigation project stands in isolation from other projects in the system. The study area must extend to areas that would be directly, indirectly or cumulatively affected by the alternative plans. An improvement at one

[1] Planning Manual, IWR Report 96-R-21, U.S. Army Corps of Engineers, November 1996, page 56.
[2] National Economic Development Procedures Manual Overview, IWR Report 09-R-2, U.S. Army Corps of Engineers, June 2009, page 1.
[3] Planning Guidance Notebook, ER 1105-2-100, U.S. Army Corps of Engineers, 22 April 2000, page 6-55.
[4] "*Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*", U.S. Water Resources Council, March 10, 1983.
[5] Planning Guidance Notebook, ER 1105-2-100, U.S. Army Corps of Engineers, 22 April 2000.
[6] National Economic Development Procedures Manual Overview, IWR Report 09-R-2, U.S. Army Corps of Engineers, June 2009.

node (e.g., lock) in the system affects traffic levels past that node, and since that traffic can also transit other system nodes the performance at these other nodes change possibly affecting traffic levels unique to those nodes, and so on. The evaluation of inland navigation system equilibrium is a substantial computational problem given the mix of commodity flows, each transiting different locks and each having its own set of economic properties. Since the 1960s the Corps has been performing inland waterway cost-benefit analysis with a system level evaluation. Through the USACE Planning Center of Expertise for Inland Navigation (PCX-IN) located in the Navigation Planning Center in the Huntington District (CELRH-NC), the Great Lakes and Ohio River Division (LRD) of the Corps has adopted and continues to maintain a set of computerized analytical models for estimating the NED benefits of proposed improvements to the Ohio River inland navigation system. The primary modeling suite is the Ohio River Navigation Investment Model (ORNIM).

The purpose of this Appendix is to describe the theoretical foundations, use, logic, assumptions and operation of ORNIM version 5.1 used in the Upper Ohio Navigation Study. First, a brief introduction to transportation modeling is given, followed by a brief history of Corps inland navigation transportation modeling.

1.1.2 History of Corps Waterway System Modeling

The decentralized nature of Corps program execution resulted in the early development of several system models. The first model was developed by the North Central Division for the Illinois Waterway in the 1960s. In the early 1970s, with more complex studies on the horizon, a centralized research and development program was initiated within the Office of the Chief of Engineers called the Inland Navigation Systems Analysis (INSA) Coordination Group. In the mid-1970s the Waterway Analysis Model (WAM) and the Flotilla Model were developed[7]. The WAM is a tow-level discrete-event simulation model used to estimate lock performance under a given operating condition, with a defined fleet and for a specific traffic level. WAM was capable of modeling single, or multiple, navigation projects each with multiple lock chambers and was also modified in 1993 into a deep-draft version. The Flotilla Model was developed to calculate with and without-project economic impacts.

In 1977 the Transportation Systems Center of the U.S. Department of Transportation sponsored the expansion of the Flotilla Model into the Resource Requirements Model and a Post-Processor program. Additional modifications were made from 1979-80 under the direction of the CELRH-NC, and a third program, the Marginal Economic Analysis Model, was added. Collectively, these three programs (Resource Requirements Model, Post-Processor and the Marginal Economic Analysis Model) were known as the Tow Cost Model (TCM). Further modifications led to the development of the Equilibrium (EQ) Model in the mid-1980s, and the Marginal Economic Analysis Model was dropped. Collectively, the TCM and EQ Model were known as the Tow Cost / Equilibrium (TC/EQ) Models.

In the early-1990s structural reliability analytical techniques advanced, allowing for a more quantitative assessment of project maintenance requirements and the probability of unscheduled project closures. In the mid-1990s the TC/EQ Model suite was supplemented with the inclusion of the Life Cycle Lock Model (LCLM), which was developed to estimate the expected transportation impacts of unscheduled closures under both the without- and with-project conditions external to the TC/EQ. During this time period the WAM was also modified to capture re-scheduling effects observed during historic long-duration closure events.

In the mid to late-1990s, modernization and expansion of TC/EQ into the ORNIM began as engineering reliability data multiplied and the need to dynamically link the reliability analysis (LCLM) with a simultaneous investment optimization algorithm. ORNIM was built by Oak Ridge National Laboratory (ORNL) in collaboration with CELRH-NC / PCX-IN.

[7] These models were developed by Consolidated Analysis Centers (CACI), Inc. in SIMSCRIPT software which was developed in 1962 to support an Air Force RAND project and gave birth to CACI in 1964.

From 2005-2009 under the U.S. Army Engineer Institute of Water Resources (IWR) Navigation Economic Technologies (NETS) program empirically derived demand elasticities were developed and ORNIM was expanded to equilibrate using a downward sloping movement-level demand curves.

As are its predecessors, ORNIM is an annual model which can be described as a spatially detailed partial equilibrium model. While it is not really designed to estimate the total benefits of a river system, or the benefits the nation would lose if the river system no longer existed (something like a computable general equilibrium model would be needed), it is appropriate to estimate the benefits of incremental improvements to river systems.

ORNIM has also been described as a standard transportation planning model. Freight transportation supply and demand is part of a simultaneous decision process by multiple economic agents, with spatial and time dimensions. While the Four-Step Transportation Planning Model includes: 1) trip generation; 2) trip distribution; 3) mode choice; and 4) route assignment, ORNIM focuses on mode choice, or more specifically modal diversion from water shipment. In ORNIM trip generation and distribution is handled exogenously through inputs (i.e., waterway traffic demand forecast scenarios). Route assignment is handled in the model, but is typically not an issue in most waterway studies in the Ohio River System because the main multiple routes are via Kentucky or Barkley Locks. While there are other multiple route choices in the network, these are far enough removed from the areas of interest that they have little to no effect on the decisions made.

1.2 ANALYSIS FRAMEWORK

To understand the inland navigation analysis framework, it is best to first understand the investment issues involved with inland navigation projects. The inland waterway transportation system is a mature transportation system and, as a result, the investment options are focused on operational measures. The investment decisions are not whether to build a waterway transportation system, but whether and how to maintain or enhance the existing system (e.g., extended or new locks, channel improvements, replacement of key components, alternative maintenance policies, etc.). The objective is not to determine the value of the waterway transportation system, but to determine the value to changes in the waterway transportation system.

Navigation performance issues can arise as traffic levels increase (congestion) and the infrastructure can degrade and become less reliable. At locks too small to efficiently handle higher traffic volumes (or changing fleet configurations), congestion leads to a degradation in service reflected in increased delays and higher transit times. – Aging projects and heavy usage can also cause serious reliability issues necessitating disruptive maintenance outages and causing disruptive service failures (e.g., closures)[8]. Increased lock transit times, whether caused by traffic growth congestion or a lock outage, increases transportation costs for shipments transiting the lock, increasing trip cycles and ultimately requiring more equipment to move the same annual volume of traffic.

In the past, traffic growth congestion has been the primary focus of lock improvement studies. Though adequate base capacity has been constructed in the Ohio River System (ORS), however, the system has aged and lock performance reliability threatens the system's capacity to move traffic. To over simplify, in the ORS most navigation projects consist of a main lock chamber and a smaller auxiliary chamber. The main chamber is typically of adequate size and capacity to handle current and expected forecasted demand. Due to traffic growth, however, the auxiliary chamber is now often inadequate to handle current traffic levels on its own. On a day-to-day basis, the auxiliary chamber is used to increase the efficiency of the project when queues develop by passing small vessels, freeing up the larger main chamber for passage of the larger vessels. The auxiliary chambers have always served as a backup to intermittent closures of the main chamber, however, main chamber closures lasting more than a couple of days can now result in large queues, high delay, and diversion of shipments, often to already congested land transportation corridors. During main chamber closures, the typically-sized Ohio River tow capable of transiting a main chamber in one 60-minute lockage operation must move through the smaller auxiliary lock chamber in two lockage cuts lasting a total of about 150-minutes. With the processing time of each vessel is more than doubled, queues can develop rapidly and equipment is trapped in queue idling rather than moving.

In response to shifting demands and increased traffic levels in some areas of the system, along with consideration of the aging infrastructure and increasing reliability concerns, the Corps desires identification of investments to maintain or enhance service where economically justified. In light of recent lock failures it has become particularly imperative to avoid failures of major lock components (particularly in the main chambers) and the lengthy lock closures they invoke. In addition, in a budget constrained world, quantification and prioritization of investment options with consideration of risk becomes important in managing the system. These issues and concerns help frame the needed analysis framework as discussed below.

1.2.1 Sectorial, Spatial, and Temporal Detail

Economic models vary in terms of sectorial, spatial, and temporal detail. At one extreme are spatially-detailed computable general equilibrium (CGE) models. A general equilibrium analysis (despite the abstraction from the real economy) attempts to explain the behavior of supply, demand, and prices in a whole economy with an equilibration of all prices. CGE models are appropriate for issues expected to have economy-wide effects or whose economic effects follow complex but tractable pathways. If

[8] The most recent failure in LRD as of this writing occurred at Greenup Locks and Dam 27 January 2010. The anchorage supporting a lower main chamber miter gate broke, closing the main and auxiliary chambers.

economy-wide effects are not realistically associated with the project being considered, modelers must make informed tradeoffs among the three dimensions.

As noted, from a transportation perspective the needed investment decisions are on relatively small improvements (e.g., extended or new locks, channel improvements, replacement of key components, alternative maintenance policies, etc.); whether and how to maintain or enhance the existing system. The need does not exist to estimate the total benefits the nation would lose if a waterway system no longer existed. Given this focused objective, a spatially-detailed, partial-equilibrium model is sufficient. In a partial-equilibrium analysis, the determination of the equilibrium price-quantity of a good is simplified by just considering the price of that good and assuming that the prices of all other goods remain constant. In other words, the prices of all substitutes and complements (as well as consumer income levels) are constant.

1.2.2 Principles and Guidelines

As previously noted, the primary guidance for this framework is described in P&G (the latest regulatory successor to the *Green Book*[9]). Inland navigation investments are to be analyzed through a NED analysis following an incremental and iterative planning process[10] that "*… relies on the marginal analysis of benefits and costs for the formulation, evaluation, and selection of alternative plans that provide incremental changes in the net value of desired goods and services.*"[11] The alternative plan with the greatest net NED benefits is defined as the NED plan. NED analysis can be generally defined as an economic cost-benefit analysis (CBA). CBA is a well-established method for systematically organizing and comparing information between alternatives and aims to separate acceptable from unacceptable projects, and to rank the acceptable projects, to ensure that resources are invested wisely. Cost-benefit analysis remains the most important criterion in Corps planning studies[12].

To accomplish an incremental analysis, all alternatives must be measured against a common base.
The future condition at the project (and in the system) without the investment(s) is referred to as the Without-Project Condition (WOPC) and the future condition with investment is referred to as the With-Project Condition (WPC). Identifying these future scenarios or conditions is central to the analysis framework. An economic analysis of these competing future conditions (over a 50-year analysis period) estimates the stream of benefits and costs associated with each respective future. The temporal aggregation of these cash flows necessitates discounting to complete the CBA (see section 1.2.4.1.2).

NED benefits for a navigation project investment are composed primarily of the reductions in transportation costs attributable to the availability of the improved waterway system. These reductions in transportation costs are achieved by increasing the efficiency of existing waterway movements, by providing for shifts of waterway and overland traffic to more efficient modes and routes, and by providing for shifts to more efficient origin - destination combinations. Further benefits accrue from traffic that is transported only because of the lower transportation cost deriving from an improved project, and from creating or enhancing the potential for other productive uses of the waterway, such as the generation of hydropower. National defense benefits can also be realized from regional and national growth, and from diversity in transportation modes. In many situations lower emissions can be achieved by transportation of goods on the waterway. But, the conceptual basis for the "*… basic economic benefit of a navigation project is the reduction in the value of resources required to transport commodities.*"[13] These reductions in transportation costs can be classified as:

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[9] Bureau of the Budget; the 1958 report, *Proposed Practices for Economic Analysis of River Basin Projects*" (known familiarly as "the Green Book"), issued by a subcommittee of the Federal Interagency River Basin Committee; Senate Document 97, approved by President Kennedy in May 1962; and the 1973 *Principles and Standards* (*P&S*) and the 1983 *Principles and Guidelines* (*P&G*), both issued by the federal Water Resources Council (WRC, 1973; 1983).

[10] The P&G six-step process for civil works project planning.

[11] National Economic Development Procedures Manual Overview, IWR Report 09-R-2, U.S. Army Corps of Engineers, June 2009, page 9.

[12] USACE. 2000. Planning Guidance Notebook. ER 1105-2-100, April 22, 2000.

[13] "*Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*", U.S. Water Resources Council, March 10, 1983, page 49.

- **Cost-reduction benefits.** As defined by ER 1105-2-100 (page 3-5), cost-reduction benefits are "*… for commodities for the same origin and destination and the same mode of transit thus increasing the efficiency of current users. This reduction represents a NED gain because resources will be released for productive use elsewhere in the economy. Examples for inland navigation are reductions in costs incurred from trip delays (e.g., reduction in lock congestions), reduction in costs associated with the use of larger or longer tows, and reduction in costs due to more efficient use of barges.*" This can be calculated from the increase in consumer surplus for current users between the without-project and with-project conditions.

- **Shift-of-mode benefits.** As defined by ER 1105-2-100 (page 3-5), shift-of-mode benefits are "*…the difference in costs of mode transport between the without-project condition (when rail, trucks or different waterways or ports are used) and the with-project condition (improved locks, waterways or channels). The economic benefit to the national economy is the savings in resources from not having to use a more costly mode or point of transport.*" With a waterway improvement that shifts the supply curve rightward and lowers the price of water transportation, an increase (movement down the demand curve) in traffic will occur. This increase can come from either a general increase in the quantity demanded of transportation (i.e. similar to an income effect) or a "*shift-of-mode*" effect from the non-water transportation modes (i.e. a substitution effect). The partial waterway demand curve used by ORNIM, however, by itself cannot distinguish among the two. ORNIM instead calculates the increase in consumer surplus from the additional with-project condition waterway traffic and does not use the without-project condition alternative transport cost (although a least-cost all-overland rate is often used as a proxy for the movement's barge transportation willingness-to-pay). Given the use of a partial equilibrium framework using only a barge transportation demand curve in ORNIM, unmet waterway demand traffic is only known not to move on the waterway; it is not automatically assumed to move by land routing. As a result these benefits are best labeled as new movement benefits (as discussed below) even though shift-of-mode shipments might be involved. As a result, this increase in waterway transportation surplus generated from additional traffic between the without-project and with-project conditions contains benefits of both new movements and modal shifts. To avoid double counting, these benefits are all categorized as new movement benefits.

  Note, however, in ORNIM traffic diversions off the waterway as a result of unscheduled service disruption are assumed to move on a land routing (an assumed short-run response) and as a result, a recapture of these movements by elimination of unscheduled service disruption does result in a definable shift-of-mode benefits.

- **Shift-in-origin or destination benefits.** As defined by ER 1105-2-100 (page 3-5), shift-of-origin or destination benefits are benefits generated "*… by either reducing the cost of transport, if a new origin is used or by increasing net revenue of the producer, if a change in destination is realized. This benefit cannot exceed the reduction in transportation costs achieved by the project.*" ORNIM does not currently equilibrate shifts in origin or destination. This type of benefit can only be approximately through manipulation of exogenous inputs.

- **New movement benefits.** As defined by ER 1105-2-100 (page 3-5), new movement benefits "*… are claimed when there are additional movements in a commodity or there are new commodities transported due to decreased transportation costs. The new movement benefit is defined as the increase in producer and consumer surplus, thus the estimate is limited to increases in production and consumption due to lower transportation costs. Increases in shipments resulting from a shift in origin or destination are not included in the new movement benefits. This benefit cannot exceed the reduction in transportation costs achieved by the project.*" With a waterway improvement that shifts the supply curve rightward and lowers the price of water transportation, an increase (movement down the demand curve) in traffic will occur. This increase can come from either a general increase in the quantity demanded of transportation (i.e. similar to an income effect) or a "*shift-of-mode*" effect from the non-water transportation modes (i.e. a substitution effect). The partial waterway demand curve used by ORNIM, however, by itself cannot distinguish among the two. ORNIM calculates the increase in consumer surplus from the additional with-project condition waterway traffic. Given the use of a partial equilibrium framework using only a barge transportation demand curve in ORNIM, unmet waterway demand traffic is only known not to move on the waterway; it is not automatically assumed to move by land routing. As a result, this increase in waterway transportation surplus generated from additional traffic between the without-project and with-project conditions, while potentially containing shift-of-mode movements, is referred to as new movement benefits. As a result, this increase in waterway transportation surplus generated from additional traffic between the without-project and with-project conditions contains benefits of both new movements and modal shifts. To avoid double counting, these benefits are all categorized as new movement benefits.

- **Induced movement benefits.** As defined by ER 1105-2-100 (page 3-5), induced movement benefits "*… are the value of a delivered commodity less production and transportation costs when a commodity or additional quantities of a commodity are produced and consumed due to lower transportation costs. The benefit, in this case, is measured as the difference between the cost of transportation with the project and the maximum cost the shipper would be willing to pay.*" Induced movement benefits arise from induced demand. Induced demand is the increase in the derived transportation demand that arises because a producer sees a comparative advantage brought about by a waterway improvement that leads to increased output. Induced demand is a shift in the demand curve greater than the without-project condition base growth. It is exogenous to the ORNIM model and is externally estimated for a specific commodity flow and producer at a specific location.

A better understanding of the derivation of these benefit categories, or more accurately the dissection of the transportation cost reduction into these benefit categories, can be gained through a theoretical supply and demand discussion found in the next section (1.2.3).

Basically, the economic analysis of waterway investments focuses on the evaluation and comparison of the costs and benefits of the existing waterway system with three basic alternative measures: 1) increase capacity (decrease transit times and thereby reduce delay costs); 2) increase reliability (replace or rehabilitate aging structures, thereby reduce the probability of structural failure and its consequences); and 3) reduce demand (e.g., congestion fees).

P&G provides general guidance for doing benefit assessments and cost-benefit analysis, but it does not overly restrict or dictate how the assessments should be done. P&G leaves open for the analyst to improve their tools and assessments as new data become available, computational capabilities improve, or theory changes.

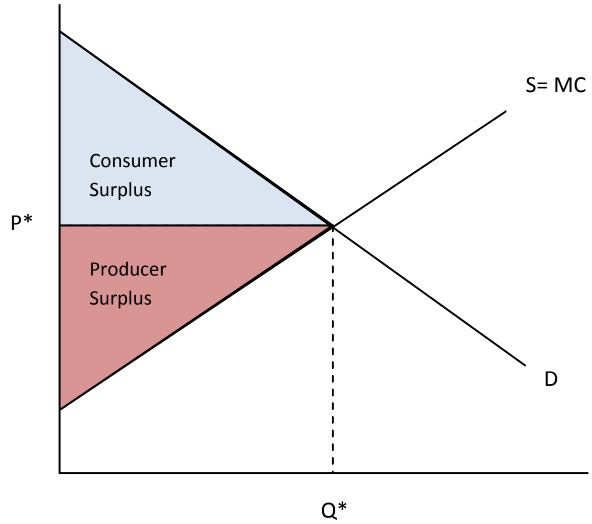
1.2.3 Theoretical Equilibrium and Incremental Benefit Framework

This section provides the economic foundation, or theoretical framework, for estimating benefits used in the modeling framework discussed in the next section (1.2.4). Transportation systems basically follow the same supply and demand theory as other industries and this theory will be used to frame the analysis of inland navigation capital investment below.

Supply and demand is a partial-equilibrium model of price determination in a market. A supply schedule (depicted graphically as a supply curve) represents the amount of a good that producers are willing and able to sell at various prices. Supply curves are typically represented as upward-sloping; as prices increase firms produce more goods as long as the cost of producing an extra unit (marginal cost) is less than the price received. The shape of the supply curve depends in part on the time horizon considered, since the timeframe affects the alternatives available to suppliers. In the short-run the supply curve is typically upward sloping because at some level of output, larger amounts of the variable production inputs are required to produce each additional unit given the fixed production technology. In the long-run, however, all factors of production are variable and a long-run supply curve can be horizontal, indicating that in the long-run marginal costs are constant with respect to output. In such a long-run case, technology and input prices determine the market price and not the level of output in the market. Since no resource is infinite, even in the long-run the supply schedule will eventually increase. A demand schedule (depicted graphically as a demand curve) represents the amount of goods that buyers are willing and able to purchase at various prices. Demand curves are typically represented as downward-sloping; as price decreases consumers will buy more and as price increases consumers buy less (the "*law of demand*").

Equilibrium in this supply and demand model is defined to the price-quantity pair where the quantity demanded is equal to the quantity supplied, represented by the intersection of the demand and supply curves as shown in FIGURE 1.2.1. In this welfare economics framework, the social surplus is defined as a consumer and producer surplus. Consumer surplus is the area below the demand curve and above the equilibrium price and represents the difference between the price consumers paid and the price they would be willing-to-pay. Producer surplus is the area above the supply curve and below the commodity price and represents the difference between the revenue producers receive for their good or service and the minimum amount they would accept to produce that level.

FIGURE 1.2.1 – Standard Supply Demand Equilibrium



For discussion of the analysis of inland navigation capital investment, however, this supply and demand analysis must be modified and expanded. Specifically, the discussion is on supply and demand of waterway (i.e., barge) transportation. First, however, the entire transportation system (barge included) will be discussed.

For the low-valued bulk commodities that dominate inland waterway transportation, the competitive land transportation modes are rail and truck. In reality, the competitive distinction is not so clear cut as most freight flows are actually multi-modal. For simplification in our theoretical discussions transportation will be generalized to waterway routed transportation (which may or may not include rail or truck legs depending on the ultimate origin and destination of the freight flow) versus the alternative all land-routed transportation. This results in a simplified 2x2 case that can be utilized to describe equilibrium under both the WOPC and WPC, calculation of surplus, and then the calculation of incremental surplus (i.e., WPC benefits). This hypothetical 2x2 case project example contains two markets (transportation supply and transportation demand), two transportation modes (water-routed and non-water or all land-routed), and, for additional simplification, represents a specific commodity origin-destination route where the water-routed and the alternative land-routed transportation are perfect substitutes. Under the assumption that the transportation routes are perfect substitutes, the supply curves for water-routing and land-routing can be added horizontally to derive the supply curve for total transportation. Also, the sum of all individual consumer demand schedules for the specific commodity origin-destination route results in the market (total) demand.

In reality of course, there are multiple commodities and multiple origin-destination routes (multiple buyer and supplier markets) operating in a transportation web. Despite these complexities in the aggregate transportation system, each commodity origin-destination route in the system operates under the 2x2 case logic.

1.2.3.1 Transportation Supply (long-run average cost)

As noted, a supply curve represents the amount of a good that producers are willing and able to sell at various prices and the shape of the supply curve depends in part on the time horizon considered. Given the long planning horizons for civil works projects, it is said that the long-run supply function is the relevant supply function for the analysis of the NED benefits and costs of project plans. Freight transportation supply (water and land modes), however, exhibits distinctive features that distinguishes it from other goods and services. The following sections provide additional clarification on the water-routed and land-routed supply schedules.

1.2.3.1.1 Water-Routed Transportation Supply

The complicating factor in the case of the water-routed transportation good is that (at least on the water line-haul portion of the freight movement) it requires a combination of private and public inputs; it cannot be totally supplied by commercial markets via price signals. In fact, a large part of the waterway transportation good is a collective or public good (i.e., channels and locks). As such, the supply schedule for waterway transportation (and thus the water-routed transportation supply schedule) is a function of the public transportation infrastructure, the private carrier resources and equipment, and the interaction of the two. Given that the public waterway transportation infrastructure cost represents the investment to be analyzed in an inland navigation study, the equilibrium sought in this analysis is between the demand for transportation and profit maximizing shipping agents given a specified transportation system (its characteristics and the cost to use it). As a result, in this discussion, the water-routed supply schedules should be thought of as a cost curve for carriers using the water-routed transportation system and not as the cost for supplying transportation capacity to shippers (which not only includes equipment capital and operating costs, but also includes infrastructure capital investment cost).

As noted, civil works projects have long planning horizons and thus it is said that the long-run supply function is relevant for NED benefit analysis. Under the long-run all factors of production are variable; however, for the waterway transportation supply (i.e., the water line-haul portion of the freight movement) we remove the waterway infrastructure capital investment for separate analysis. To isolate the cost increases in the cost curves to just waterway congestion effects, we also have to assume a long-run completely elastic (horizontal) supply of towing equipment. In other words, the cost of towing equipment is constant at all quantity levels at its long-run cost. In short, the waterway cost curve is a long-run cost curve with infrastructure capital investment fixed and towing equipment costs determined by technology and input prices.

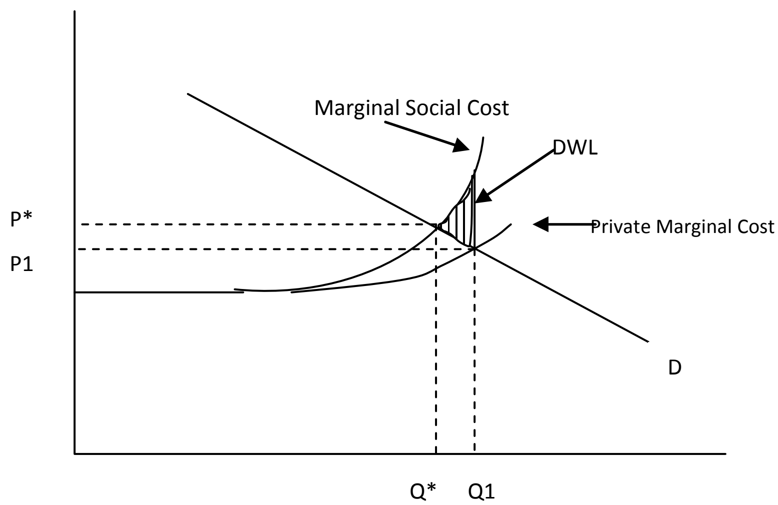
When an individual waterway user (carrier) decides whether to make a particular shipment, it compares the marginal cost of making the trip to the marginal revenue received. If the marginal cost of making the trip is less than or equal to the price received, it is worthwhile making the trip.

If we assume constant marginal costs of waterway line-haul transportation and no congestion, then industry supply is a horizontal line, and the marginal cost is equal to the average cost. Under congestion, however, if we assume constant marginal costs of waterway line-haul transportation, then marginal cost is flat only before the waterway becomes congested. Once the waterway becomes congested, the marginal cost of making an extra trip increases rapidly. An extra trip adds not only to the marginal cost of the particular trip considered (the marginal private cost), but also to all other waterway shipments due to the impact of delay on all other traffic. This implies that the total extra cost resulting from making another shipment (the marginal social cost) is higher than the cost to the individual carrier of making the shipment (the marginal private cost).

However, when making the trip, the individual carrier only considers the impact of the trip on its own costs (the marginal private cost) and not the full cost of making the shipment including the costs imposed on other users (the marginal social cost). Since an individual trip influences other shipments' traffic costs by imposing delay on all shipments traversing the same stretch of waterway, the average cost of making a shipment on the waterway increases. Because all individual carriers are willing to supply at the point where marginal private cost is equal to price, the industry supply curve becomes the sum of individual marginal private costs. However, the socially optimal quantity of waterway shipments would be where marginal social cost is equal to price.

FIGURE 1.2.2 shows this in detail. In the figure, once congestion sets in, the marginal social cost of extra traffic increases rapidly due to an increase in delay for the shipment considered and for all other shipments. However, the marginal cost to the carrier making the shipment (marginal private cost) goes up much less rapidly, because the delays are spread among all other shipments.

FIGURE 1.2.2 – Social versus Private Marginal Cost Curves



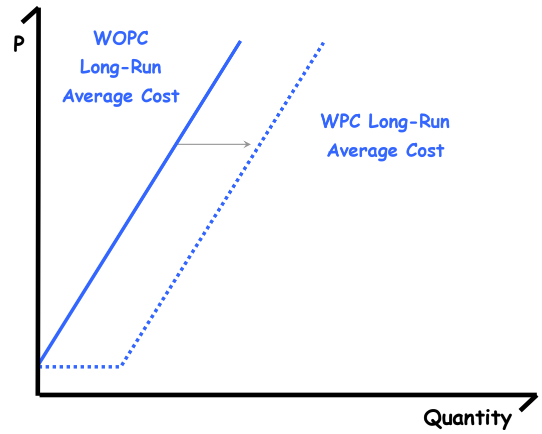
Without any congestion fees (and assuming a competitive water carrier industry), carriers will charge a price of P1 and shippers will ship a quantity of Q1 on the waterway. The social optimum, however, would be a price of P* and a quantity of Q* to be shipped on the waterway. There is a deadweight loss (DWL) that occurs from over shipment, since the marginal costs of making shipments beyond Q* are higher than the value placed on those shipments by society.

However, given the goal of analyzing investment decisions with the assumption that congestion user fees are not going to be charged, the model's assumption that equilibrium will be achieved at a price of P1 and a quantity of Q1 is appropriate. Private carriers will only consider the extra costs to themselves of making a particular shipment. Note that this means that the equilibrium achieved by ORNIM is not socially optimal. Deadweight loss results from excess use of the waterway. However, given the model's goal of identifying the benefits of waterway investment without any intention of charging optimal user fees, ignoring this deadweight loss is reasonable, since the change in overuse deadweight loss from investment is likely to be small.

The public portion of the waterway transportation capacity supply is non-excludable and once produced it is freely available to all potential users. Since equilibrium transportation price is determined by multiple profit maximizing shipping agents unconcerned with cost impacts they impose on others, the long-run cost curve is a long-run average cost curve instead of the long-run marginal cost curve.

To summarize, improving the waterway transportation infrastructure represents a shift in the entire long-run average cost curve (not a movement along the curve) as shown in FIGURE 1.2.3. Instead of increased transportation price causing an increase in transportation supply, in this discussion we should think of an increase in water-routed transportation utilization causing an increase in the long-run water-routed transportation price / cost (given specified waterway infrastructure investments). In other words, as utilization of the transportation system increases, there is congestion, which causes delays and increased trip times, which in turn increase the cost of transportation.

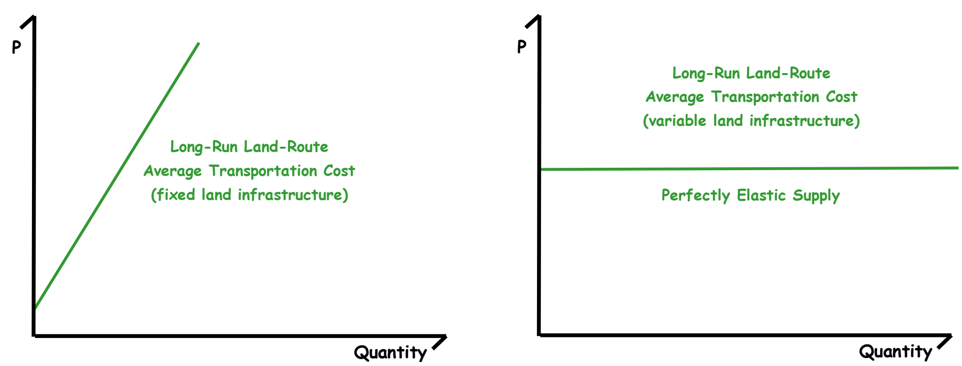
FIGURE 1.2.3 – Water Routed Long-Run Average Cost Curves



1.2.3.1.2 Land-Routed Transportation Supply

For the land transportation good (truck and rail), the private and public input split is not always as clear cut (e.g., track easement). Regardless of the private versus public label, there is a clear distinction between the transportation network infrastructure (e.g., track and roads) and equipment capital (e.g., trains, cars, trucks, and trailers). Similar to the water transportation good, the land transportation good should be thought of as a long-run average cost curve, however, in the discussions to follow it will be used first without and then with land transportation infrastructure capital costs (FIGURE 1.2.4). Without land transportation infrastructure capital costs included, as with the waterway long-run average cost curve, cost increases represent a congestion effect on the transportation mode. With land transportation infrastructure capital costs included the long-run costs assume all land transportation factors of production are variable and as a result technology and input prices determine the market price (transportation rate). In other words, congestion effects from increased demand will be eliminated through infrastructure capital investment and the cost curve is horizontal (perfectly elastic).

FIGURE 1.2.4 – Land Routed Long-Run Average Cost Curves



1.2.3.2 Transportation Demand

The characteristics of transportation demand are the same as for a standard demand curve. As noted, a demand curve represents the amount of goods (e.g., transportation) that buyers are willing and able to purchase at various prices; as price decreases consumers will buy more and as price increases consumers buy less (the "*law of demand*"). The sum of all individual consumer demand schedules results in the market (total) demand; the demand for land-routed and water-routed transportation can be summed to demand for transportation. As with a standard demand curve, the curve can be used to calculate consumer surplus. It should be noted, however, that demand for transportation services does not occur without first a demand for the goods being shipped.

1.2.3.2.1 Willingness-to-Pay

The downward sloping demand curve reflects consumer willingness-to-pay and an increase in consumption when price decreases. The downward sloping demand curve also indicates that the consumer values the first unit of a good consumed more than subsequent units. As a result the demand curve can be interpreted as a marginal benefit curve; as each additional unit is consumed less and less value is obtained. To determine the value from consuming a given quantity of goods, the marginal value of the first unit can be added to the marginal value of the second unit, and so on to the given quantity. Graphically one would calculate the area under the demand curve above the price paid. This benefit is also known as the consumer surplus (FIGURE 1.2.1).

1.2.3.2.2 Derived Demand for Transportation

The shipper's decision on the amount of waterway shipping to use is done within the context of the production decision for all factors used in the shippers output. In this sense the waterway demand is a derived demand from the production requirements. Other factors that typically would be considered are capital, labor, energy, raw materials and other transportation modes. Factor demands (including waterway demand) can be estimated from a firm's profit function or from its cost function. If the factor demands are estimated from the firm's profit function, input (waterway) demand is specified as a function of input prices (e.g. the price of waterway transport, the price rail transport, the price of labor, the price of raw materials) and the price of the shipper's output (e.g. coal or grain). When factor demands are estimated from the firm's cost function, demand is specified as a function of input prices and the amount of output the shipper plans to produce (e.g. tons of coal). With this derivation the derived demand for waterway shipping is shown to be a function of the prices of the other factors. In the ORNIM model a partial formulation of the derived demand is used in which the prices of the other factors are assumed to be constant and only the price of waterway shipping is variable.

The price or willingness-to-pay for a transportation service may include not only the rate but also the user's valuation of other characteristics specific to the mode. The concept of the price of waterway shipping In ORNIM is the rate the carrier charges (as computed from modeled shipping costs) plus the cost incurred due to a delay which reflects the value of time to the shipper.

1.2.3.3 Transportation Sector Equilibrium

As noted in a partial-equilibrium analysis, the determination of the equilibrium price-quantity of a good is simplified by just considering the price of that good and assuming that the prices of all other goods remain constant. Since the waterway transportation system is only a component of a larger national transportation system, this first section will discuss the theoretical framework under a partial-equilibrium framework with competition between the water and land transportation modes, or more specifically the water-routed and land-routed transportation alternatives. The next section (1.2.3.4) will then discuss the theoretical framework under a transportation sector partial equilibrium framework with an assumption of a perfectly (infinitely) elastic land transportation supply (i.e., land-routed transportation). The final section (1.2.3.5) will conclude with a discussion of the theoretical partial-equilibrium framework using only barge transportation demand.

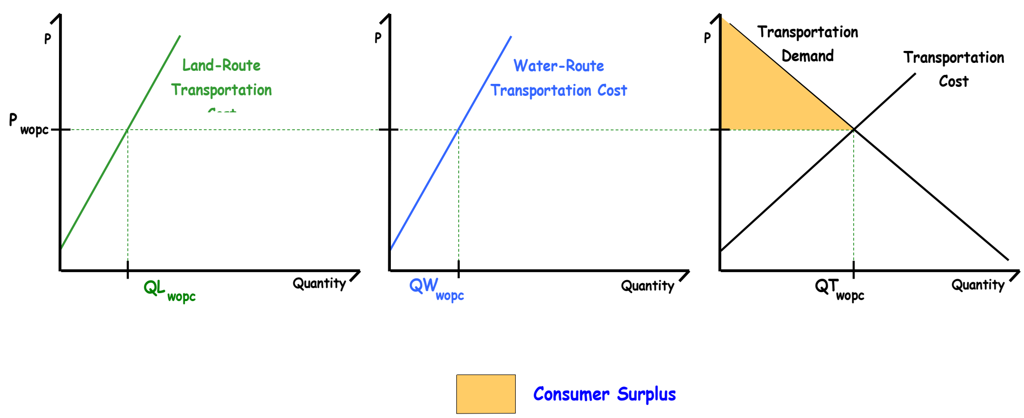
As previously noted, for simplification transportation will be generalized to water-routed and its alternative land-routed transportation modes for a specific commodity origin-destination route where the water-routed and the land-routed transportation are perfect substitutes. Since transportation demand is a derived demand, a general equilibrium framework could be expanded to include the commodity markets (e.g., coal) and even for the end products (e.g., electricity). This expansion is beyond this theoretical discussion, and it can be argued that the second order effects are minimal (e.g., transportation cost is minimal in the end product price).

1.2.3.3.1 WOPC Equilibrium

The hypothetical WOPC and WPC examples to follow depict the theoretical calculation of benefits from improvement of the waterway along a specific commodity origin-destination route. The vertical axis represents the unit prices (rates) for transportation, and the horizontal axis shows the total quantity of transportation utilizing transportation (e.g., commodity tonnage). For additional simplicity, it is assumed that this transportation market is served by only two transportation options (water-routed and land-routed transportation) and that there is no qualitative difference between the services they provide.

Assume there is some upward sloping cost curve for land-routed and water-routed transportation as shown in FIGURE 1.2.5. These cost curves should be thought of as long-run average costs with fixed water and land infrastructure; as the utilization increases on the transportation routes, the costs for using that transportation route increases as a result of congestion. The cost of land and water routed transportation can be added horizontally to derive the cost curve for total transportation. Since the land and water routings are assumed perfect substitutes, the demand curve for transportation can be found by horizontally summing individual movement demands (e.g., land-route and water-route transportation demand or individual shipments). The intersection of system transportation cost and the total transportation demand gives the without-project condition market equilibrium at P_{wopc} with an equilibrium system traffic level of QT_{wopc}. The system equilibrium price can then be traced back to the land-route and water-route cost curves to identify how much traffic is moving by each route (QL_{wopc} moving via land-route and QW_{wopc} moving via water-route).

FIGURE 1.2.5 – Transportation System Equilibrium – WOPC Benefits



When a competitive industry does not face congestion, the industry supply curve is the summation of individual firm marginal cost curves . The upward sloping marginal costs imply that each subsequent unit of output adds more to cost than the previous unit. Thus, when price is set equal to marginal cost of the last unit produced, the price received exceeds the resource costs of producing all previous units. The excess of price above the resource costs used to produce previous units is known as producer surplus, and it is a benefit to society.

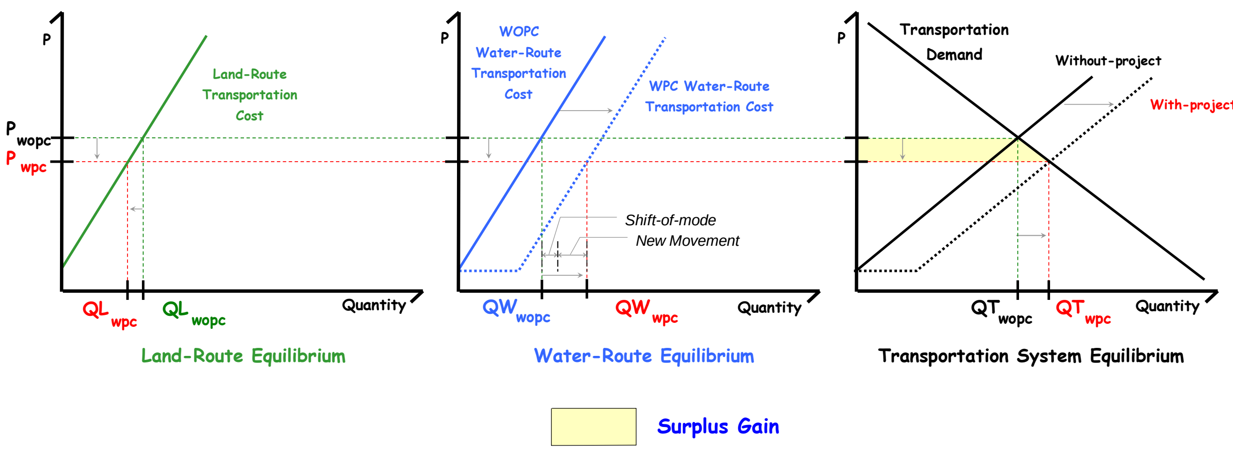
The total social welfare is the combination of consumer surplus (the amount consumers are willing to pay in excess of the price they have to pay) and producer surplus (the amount producers receive in excess of the costs of producing the good). The combination of the two (social welfare) is the value placed on the good by society in excess of the resource costs used to produce the good. In the case of congestion, the rising private marginal cost is reflective of all shipment costs increasing. Thus, it is average shipment cost for all competing shipments (i.e., those utilizing the same stretch of waterway). In this case, the price is set equal to average cost, and there is no producer surplus realized.

Thus, when there is congestion, supply is equal to private marginal cost, which is also equal to average cost for all competing shipments. If FIGURE 1.2.1 represents waterway transportation in the presence of congestion, then S=MC represents marginal private cost (not shown is the higher marginal social cost). Then, since marginal private cost is also equal to average cost for all competing shipments, the price received by water carriers is the same as their average costs and they do not receive any producer surplus. Thus, total social welfare is equal to consumer surplus.

1.2.3.3.2 WPC Equilibrium and Incremental Benefits

With an improvement to the waterway navigation system, the water-routed cost curve will shift to the right (assuming the navigation investment results in lower transportation costs for all levels of quantity supplied). This shift also results in a shift of the total transportation cost curve and results in a new system equilibrium at a lower equilibrium price P_{wpc} and a higher system equilibrium traffic level of QT_{wpc} as shown in FIGURE 1.2.6. The incremental benefit of the with-project condition comes from consumer surplus gain (i.e., WPC surplus minus WOPC surplus).

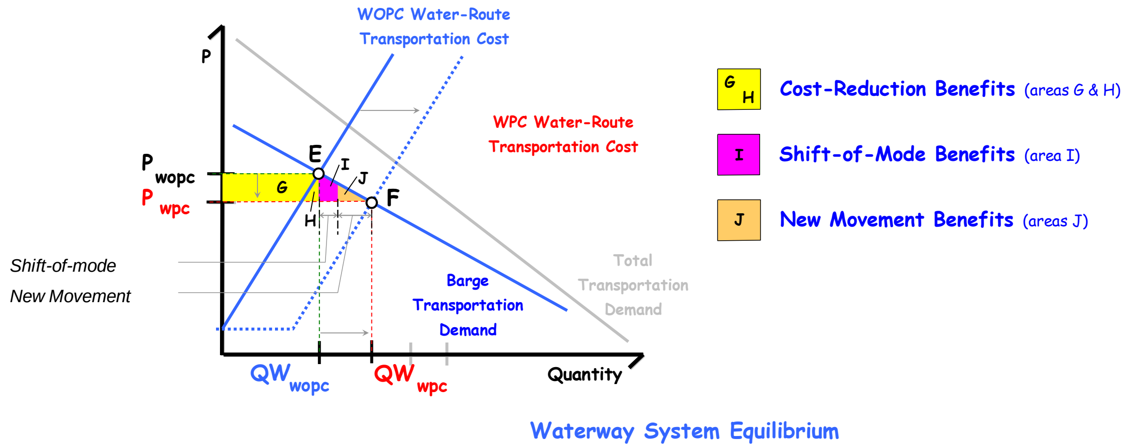
FIGURE 1.2.6 – Transportation System – Incremental WPC Benefits



While transportation system equilibrium traffic increases from QT_{wopc} to QT_{wpc} and water-routed transportation traffic increases from QW_{wopc} to QW_{wpc}, land-routed traffic actually decreases from QL_{wopc} to QL_{wpc} as water transportation becomes more cost competitive and captures some of the land only routed traffic. This shift of land-routed to water-routed traffic, however, only explains part of the water transportation gain. The rest of the water-routed traffic gain occurs from new movements induced by the lower system transportation costs.

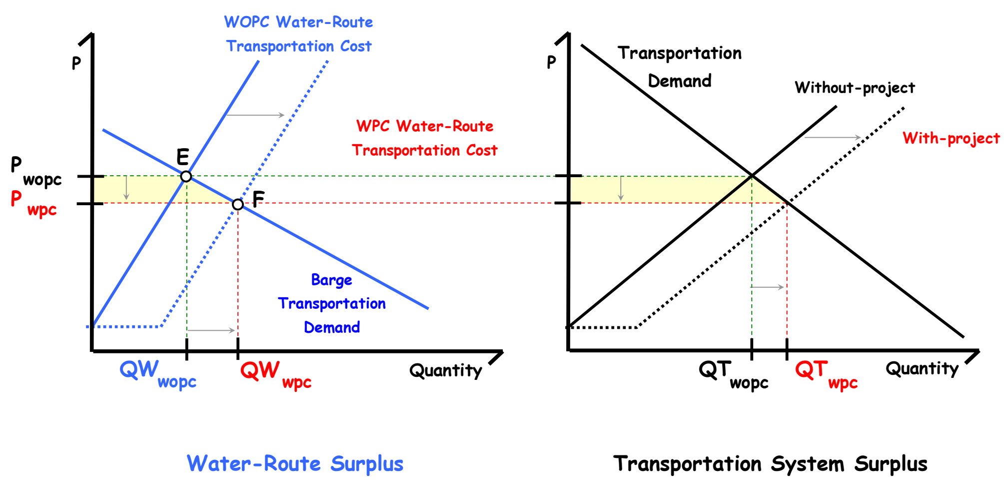
To determine the various benefit categories as defined in section 1.1.2 from a waterway transportation perspective (instead of a total transportation system perspective), we must look more closely at the center graph of FIGURE 1.2.6 as shown in FIGURE 1.2.7. Points E and F reveal the barge transportation demand curve which is derived from the interplay within the total transportation system. Areas G and H represent cost-reduction benefits to traffic existing under the WOPC and is a simple calculation of the price drop multiplied by the barge quantity. For the additional traffic moving by water in the WPC the benefits must be integrated under the derived barge demand curve (points E to F, willingness-to-pay or marginal benefit curve). The additional traffic is also a combination of shift-of-mode traffic captured from the land-route mode and new waterway movement traffic. The quantity of land traffic lost in the left most graph of FIGURE 1.2.6 is used to determine the shift-of-mode benefit area I in FIGURE 1.2.7. The remaining benefit, area J, represents the new movement benefit.

FIGURE 1.2.7 – Barge Transportation System – Incremental WPC Benefits



As shown in FIGURE 1.2.8, it is interesting to note that the total benefits in the waterway system (FIGURE 1.2.7) are significantly less than the total benefits for the transportation system (FIGURE 1.2.6). The benefits are greater for the complete transportation system because there is a cost-reduction benefit for the land mode as the equilibrium land transportation costs drop from reduced land congestion as traffic shifts to the waterway.

FIGURE 1.2.8 – Barge Transportation versus Total Transportation System Benefits



1.2.3.3.3 Cost-Benefit Analysis

Once the incremental WPC benefits are quantified, a similar incremental cost (WPC cost minus WOPC cost) can be calculated and used to complete a cost-benefit analysis of the investment. The net benefits are calculated by subtracting total economic costs from total economic benefits. Corps planning policy dictates selection of the NED plan as the plan that maximizes net NED benefits. The benefit-cost ratio (BCR) is calculated by dividing total economic benefits by total economic costs. Despite Corps formulation of investments by net benefits, prioritization of investments by the Office of Management and Budget (OMB) is often done using the BCR.

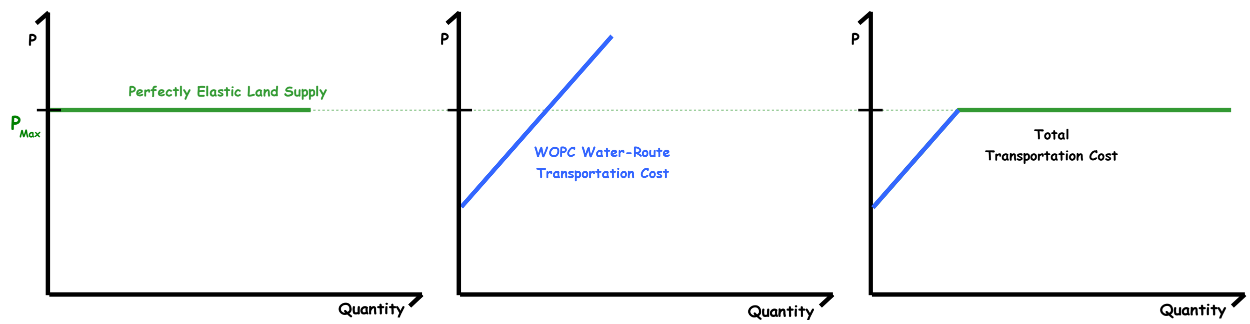
1.2.3.4 Transportation Equilibrium under Perfectly Elastic Land Supply

The Corps guidelines for estimating waterway benefits were established in the 1950's through a "*mutual understanding*" between the water resource agencies. The first such understanding was recorded in the Federal Inter-Agency River Basin Committee's *Proposed Practices for Economic Analysis of River Basin Projects* in May 1950 (U.S. Senate), and later revised in May 1958. In that report, referred to as the Green Book (because of the color of its cover), navigation benefits were identified as the difference between the total "*…cost of transportation by an alternative means and the non-project or associated cost of transportation by waterway*." In other words, guidance stipulates the conservative assumption of a perfectly elastic supply of land transportation.

In the previous discussion both the water-route and land-route cost curves represent a long-run average cost for using each transportation route with fixed infrastructure, and as a result, they reflect congestion effect costs along each route (as utilization increases, congestion and delays occur and operating costs to use the system increase). With a perfectly elastic supply of land transportation, congestion on the land transportation modes is constant. This in effect assumes that if and when land mode capacity constraints occur, the necessary capital investment in the transportation infrastructure will be made. In other words, all land transportation factors of production are variable and technology and input prices determine the market price or transportation rate (section 1.2.3.1.2). In the case of rail, the rail rate would include long-run rail infrastructure capital costs since railroads maintain their own track. In the case of trucking, the infrastructure capital costs of the roadway system are not included in the trucking rate, however, investment in the road system is assumed and this investment will keep trucking rates constant through time as road traffic increases.

Remember that it was conceded that most freight flows are multi-modal and that in our spatially-detailed partial-equilibrium framework transportation is generalized to water-route and non-water land-route transportation options which are perfect substitutes for one another. As before the cost of land-routed transportation and water-routed transportation can be added horizontally to derive the cost curve for total transportation (FIGURE 1.2.9). The water-routed transportation cost might contain some land transportation component that now becomes perfectly elastic (fixed), however for this example we assume the same WOPC water-route transportation curve as in the previous graphs. Assuming land-route and water-route transportation are perfect substitutes and that land transportation is perfectly elastic, the maximum transportation price is the land-route price of P_{max}.

FIGURE 1.2.9 – Conceptual Cost Curves



It should be noted that if technology or input prices change in the future, this horizontal land-route transportation supply cost curve can shift up or down through time, however, in most planning studies it is held constant unless there is good justification to deviate from observed data.

The effect of perfectly elastic land supply (perfectly elastic land-route transportation supply costs) on WOPC and WPC equilibrium is a function of the relationship between the land-route transportation price, the water-route transportation cost curve, and total transportation demand. Four situations can occur:

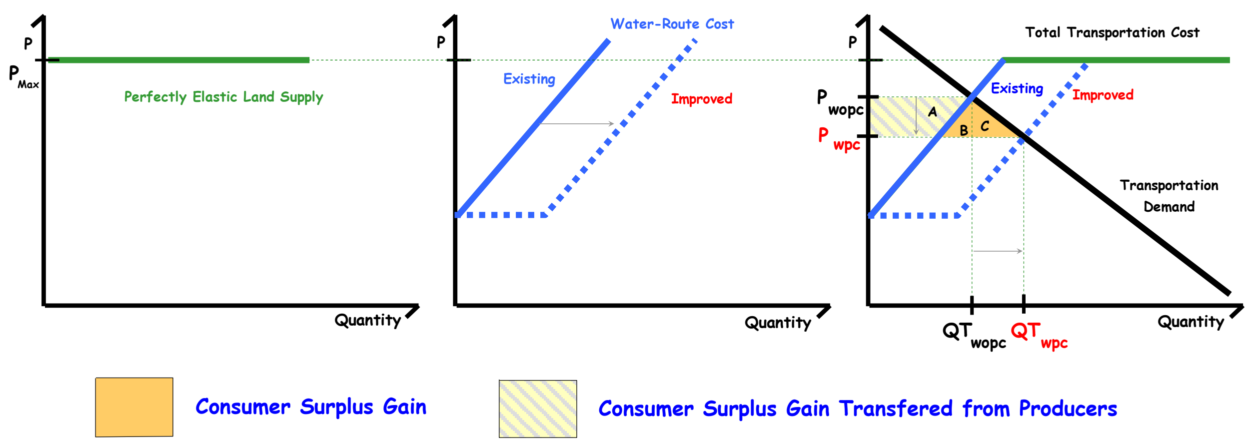
- Case 1) land-route transportation price is greater than all quantities of WOPC water-route transportation cost and all transportation demand is met by the water-route modes;
- Case 2) land-route transportation price is less than any quantity of water-route transportation cost and all demand is met by the land-route mode under the WOPC and WPC;
- Case 3) land-route transportation price is less than any quantity of WOPC water-route transportation cost, but not for all quantities of the WPC (improved) water-route system; or
- Case 4) demand is met with a combination of land-route and water-route transportation under the WOPC.

In a waterway system analysis there will most-likely be multiple movements in each one of these categories.

1.2.3.4.1 Case 1 Equilibrium and Incremental Benefits

In the first case, the land-route transportation price is greater than all quantities of WOPC water-route transportation cost and all demand is met by the water-route modes (FIGURE 1.2.10). A surplus (benefit) will occur with a waterway improvement and all the benefit gain is attributable to the waterway improvement and all traffic grain in the transportation system is to the water-route transportation. In this case the demand for barge transportation is equivalent to the total transportation demand, and the land price is actually immaterial in the determination of the incremental WPC benefits.

FIGURE 1.2.10 – System Equilibrium – Case 1

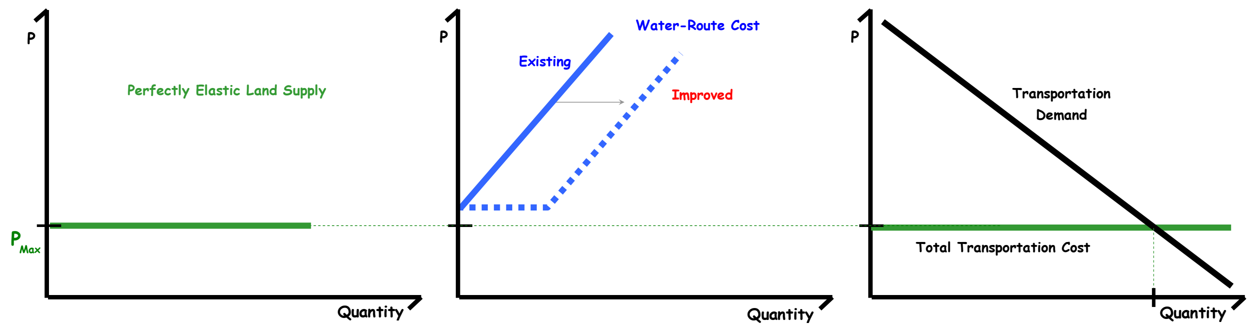


In Case 1 from a total transportation system perspective, one would classify the surplus benefits as cost-reduction (areas A and B) and new movement (area C) benefits. No traffic is shifted from land to water and there are no shift-of-mode benefits. To determine the various benefit categories (section 1.1.2) from a waterway transportation perspective (instead of a total transportation system perspective), we must look more closely at the center graph of FIGURE 1.2.10. In this case, however, since the land price is immaterial in the determination of equilibrium and the incremental benefits, the barge transportation demand curve is equal to the total transportation demand curve. As such, the calculation of the cost-reduction and new movement benefits are as previously described and shown in FIGURE 1.2.10.

1.2.3.4.2 Case 2 Equilibrium and Incremental Benefits

In the second case, where the land-route transportation supply price is less than all quantities of water-route transportation cost in the WOPC and under the improved WPC, all demand is met by the land-route transportation (FIGURE 1.2.11). In this case there is no surplus (benefit) generated by a waterway improvement (transportation price does not change).

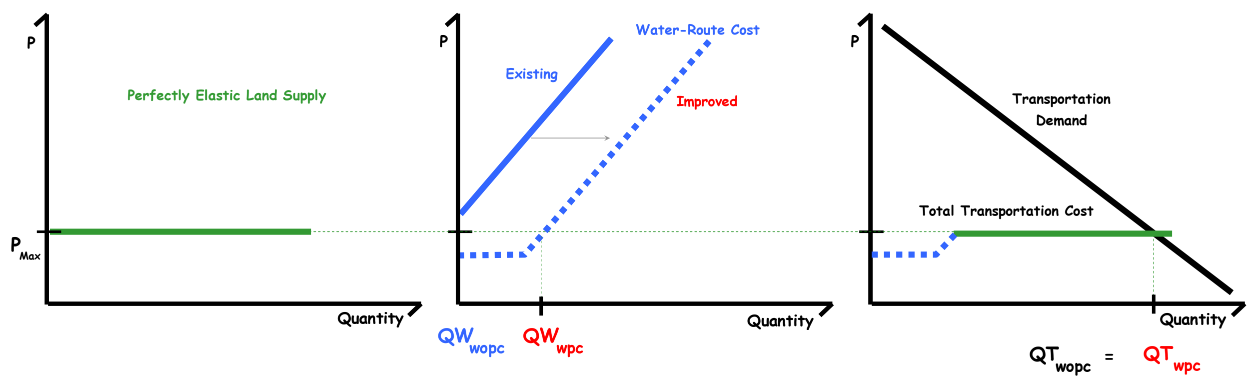
FIGURE 1.2.11 – System Equilibrium – Case 2



1.2.3.4.3 Case 3 Equilibrium and Incremental Benefits

In the third case, land-route transportation price is less than any quantity of WOPC water-route transportation cost, but not for all quantities of the water-route under the WPC (improved) waterway system. Thus water-route transportation is only used under the improved water transportation supply condition (FIGURE 1.2.12). The equilibrium quantity of transportation supply remains constant; however, some traffic is shifted from the land-route transportation to the water-route transportation. Despite the shift from one transportation route to the other, there is no surplus (benefit) realized for the users (shipper/carriers); the quantity shipped and the price of transportation between the WOPC and WPC remain the same.

FIGURE 1.2.12 – System Equilibrium – Case 3

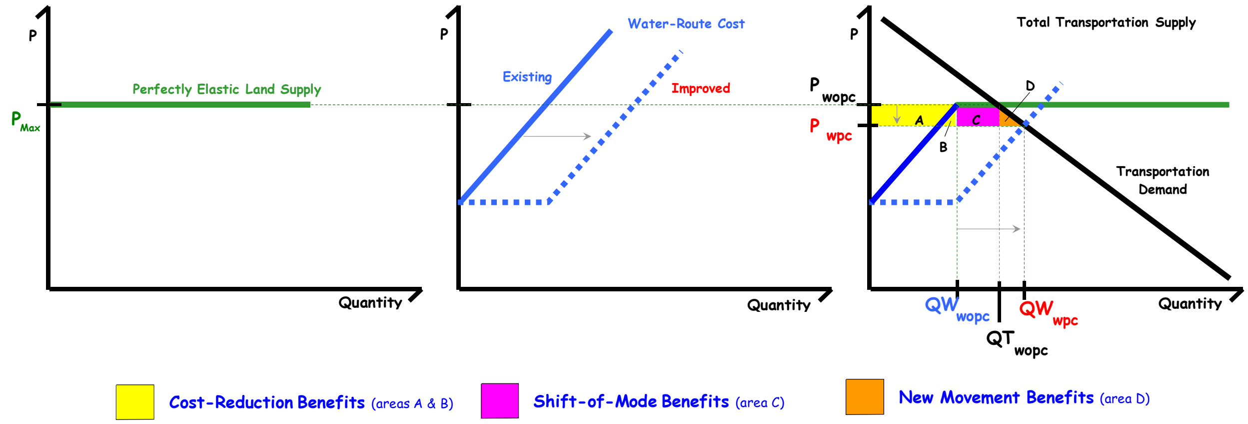


Despite there being no benefit for this shift-of-mode transfer of traffic from the land-route to the water-route, there will be congestion effects of this increased water-routed traffic, reducing the benefit gains of other movements in the waterway system in the WPC.

1.2.3.4.4 Case 4 Equilibrium and Incremental Benefits

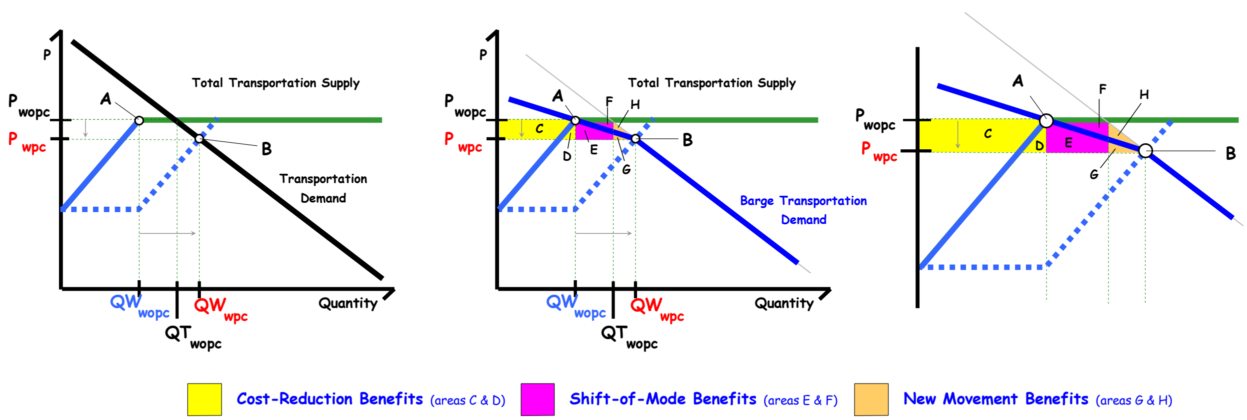
In the fourth case, under the WOPC there is a combination of land-route and water-route transportation being used to meet transportation demands (FIGURE 1.2.13). Under the WOPC, a total of QT_{wopc} is shipped with QW_{wopc} moving by water and $QT_{wopc} – QW_{wopc}$ moving by land. With an improvement to the waterway transportation system (and assuming a constant land transportation price), waterway transportation costs will decrease, shipment on the water-route will increase, and a surplus (benefit) will occur. All the benefit gain is attributable to the waterway improvement.

FIGURE 1.2.13 – System Equilibrium – Case 4



In Case 4 the incremental benefit of the with-project condition comes from a surplus gain. From a total transportation system perspective, one could classify the consumer surplus benefits as cost-reduction (areas A and B), shift-of-mode (area C), and new movement (area D) benefits. However, to determine the various benefit categories defined in section 1.1.2 from a waterway transportation perspective (instead of a total transportation system perspective); we must look more closely at the right graph of FIGURE 1.2.13, as shown in FIGURE 1.2.14. Points A and B reveal the barge transportation demand curve which is derived from the interplay within the total transportation system. Unlike Case 1 where the barge transportation demand curve was equivalent to the total transportation demand curve, in Case 4 it is separate.

FIGURE 1.2.14 – Barge Transportation System – Incremental WPC Benefits



Area C and area D (FIGURE 1.2.14) represent cost-reduction benefits to traffic existing under the WOPC and is a simple calculation of the price drop multiplied by the quantity and is the same as previously calculated in FIGURE 1.2.13. Area E (and not F) represents shift-of-mode benefits for traffic shifted from the perfectly elastic land transportation price to the lower water transportation price. Area G (and not H) represents new movement benefits. Both areas E and G must be integrated under the barge transportation demand curve (willingness-to-pay or marginal benefit curve). This estimate of shift-of-mode and new movement benefits is less than previously calculated (by areas F and H) since it is integrated under a lower barge transportation demand curve rather than the total transportation demand curve.

Additionally in FIGURE 1.2.14, if only the barge transportation demand curve is used, there is no way to calculate how much of the additional water-routed traffic comes from the land-routed traffic and how much is new movement traffic. As a result, areas E and G could only be characterized as shift-of-mode benefits.

It is also interesting to note that unlike the example with upward sloping land-route and water-route transportation supply (FIGURE 1.2.6 and FIGURE 1.2.7), with a perfectly elastic land transportation supply (fixed land-route transportation price) the total benefits in the waterway system are only slightly less than the total benefits for the transportation system (areas F and H of FIGURE 1.2.14). The huge land-route transportation cost-reduction benefits from reduced land-route congestion as traffic shifts to the water-route are eliminated when the land-route price is fixed.

In summary, use of the barge transportation demand curve for incremental benefit calculation can understate the benefits for Case 4 situations.

1.2.3.5 Barge Transportation Partial Equilibrium

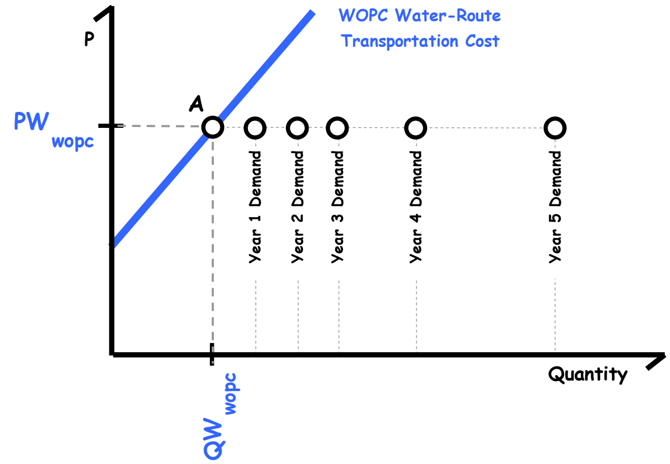
The benefits of waterway transportation improvements are measured by examining the barge partial equilibrium. Waterway and land transportation are not perfect substitutes, and different shippers are willing to pay different amounts to ship via each mode. The demand for barge transportation shows the amount shippers are willing to pay for various quantities of barge transportation. This barge transportation demand takes into account the availability of transportation alternatives and the differing characteristics (including price) of such alternatives. Some shippers may be willing to pay more for barge transportation than an alternative mode, while other shippers are willing to pay less for barge transportation than an alternative mode. Unless a shift in traffic to the waterway mode as a result of a waterway improvement leads to a change in the price of land transport, the entire benefits of a waterway improvement are captured by a gain in the social surplus for waterway shipments (i.e. the amount shippers are willing to pay for ***waterway transportation*** in excess of the costs of resources needed to produce that quantity of waterway transportation). As long as land transportation rates don't change as a result of the improvement, the land transportation rate is not needed to calculate the benefits of the waterway improvement. To understand the implications of barge transportation partial equilibrium analysis on incremental benefit estimation, the reader must understand how forecasted barge transportation demand is estimated and how barge transportation demand price responsiveness is specified.

1.2.3.5.1 Forecasting Demand for Barge Transportation

Given the long planning horizons for civil works projects, equilibrium and incremental benefits must be estimated for fifty or more years necessitating the forecasting of future demand, and more specifically the forecasting of future barge transportation demand. The examples so far represent the current (observed) commodity origin-destination route tonnage.

When discussing the forecasting of barge transportation demands we are not talking about the demand curve itself, but instead a particular point on the demand curve as it shifts to the right (or perhaps left in a declining industry). Barge transportation demand forecasts are basically developed by first identifying the commodity waterside origin-destination route movement, and then identifying the ultimate origin and destination of the freight flow. Then through surveys, econometrics, or modeling, a growth rate is developed and applied to the movement. This then assumes that the current transportation prices (all transportation modes) are in effect throughout the forecast horizon. In other words, the specific point on the demand curve we are forecasting through time is the point on the demand curve where the water-route transportation price (as well as the land-route transportation price) is fixed at its current price. In our example, point A in FIGURE 1.2.14 identifies the known (observed) WOPC (existing) level of barge traffic QW_{wopc}. Forecasted barge transportation demand for this commodity origin-destination might result in the demands shown in FIGURE 1.2.15; growth is slow in the first three years followed by a more rapid growth rates in years 4 and 5.

FIGURE 1.2.15 – Forecasted Barge Transportation Demand



1.2.3.5.2 Specification of Barge Transportation Demand Elasticity

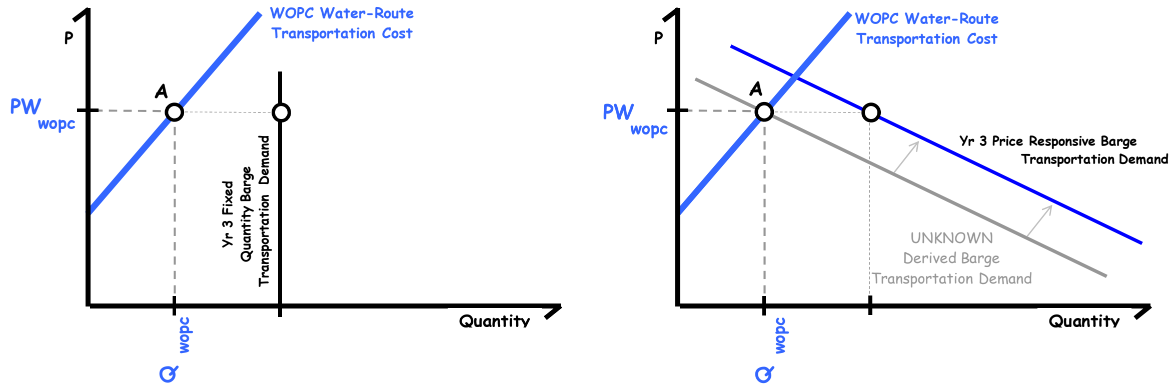
Elasticity is a measure of the "*sensitivity*" of one variable with another variable; the elasticity of a variable *x* with respect to a variable *y* (a one-to-one relationship between two variables):

$$\varepsilon_{x,y} = {}^{\%\Delta x}\!/_{\%\Delta y} \qquad (1.2\text{-}1)$$

Elasticity is a measurement of the slope of a demand curve, and as such the elasticity can vary depending upon the area of the demand curve being measured. Demand for barge transportation (variable *x*) can be related to any number of variables, such as the own-price elasticity of demand (e.g., quantity of barges demanded with respect to water transportation price) and cross-price elasticity of demand (e.g., quantity of barges demanded with respect to the alternative land price). Since non-water transportation costs are assumed fixed, our analysis is only concerned with own-price elasticity of demand for barge transportation. The question then becomes the sensitivity of the commodity origin-destination movement to waterway transportation price change. To over simplify, the movement can be defined as either fixed quantity or price responsive.

The specific commodity origin-destination route in our discussions is an aggregation of shipments of similar commodities moving between similar waterside docks over a specified period (e.g., year). For example, our movement might be coal shipments from pool A to a power plant in pool B. While the destination is a single power plant, the origin might consist of multiple waterside docks, each of which might collect coal from multiple mines. As a result, the willingness-to-pay for barge transportation for this movement might be better defined as a demand curve rather than a point as displayed in FIGURE 1.2.15. This determination is certainly dependent upon the characteristics of the commodity origin-destination and on the level of shipment aggregation in the movement. In our example coal movement from pool A to B, if the origin tonnage is derived from one dock and from one mine an fixed quantity demand specification would most-likely be appropriate, if the origin tonnage is derived from multiple mines resulting in a range of gathering costs at the origin waterside dock an price responsive demand curve specification would most-likely be appropriate. To summarize, this empirical question could result in our example commodity origin-destination route movement being specified as either fixed quantity or price responsive as shown in FIGURE 1.2.16.

FIGURE 1.2.16 – Fixed quantity Versus Price responsive Barge Transportation Demand

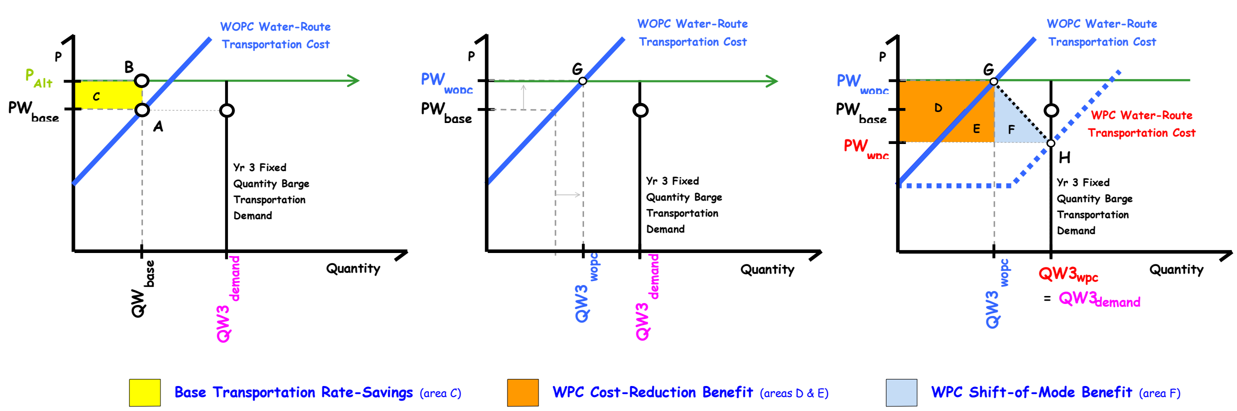


1.2.3.5.3 Fixed quantity Barge Transportation Demand Equilibrium

By definition, the price responsive barge transportation demand maps the willingness-to-pay and thus allows the determination of the equilibrium traffic level and calculation of the consumer (shipper/carrier) surplus. When a commodity origin-destination route is defined as a fixed quantity movement, additional information is needed to determine equilibrium and consumer surplus. A fixed quantity movement is not defined as perfectly or infinitely inelastic; there is a limit to the willingness-to-pay. The proxy for the fixed quantity willingness-to-pay limit is the least-costly all-overland rate. In short, fixed quantity barge transportation demand willingness-to-pay is capped by the least-costly all-overland rate (i.e., the land-route transportation price).

Using the left graph in FIGURE 1.2.16, say the least-costly all-overland rate is P_{Alt} (point B) as shown in FIGURE 1.2.17. Given the assumption that land-route transportation supply and costs are perfectly (infinitely) elastic through time, this least-costly all-overland rate serves as the willingness-to-pay for barge transportation for all forecasted years, including year 3 in this example. The forecasted demand in year 3 is $QW3_{demand}$, however, at equilibrium (point G FIGURE 1.2.17 middle graph) only $QW3_{wopc}$ is expected to move in the WOPC; the movement is split and the remaining demand tonnage ($QW3_{demand}$ - $QW3_{wopc}$) is assumed to move by the least-cost all-overland alternative routing. With an improvement in water transportation, water-routing costs are lowered to PW_{wpc} and diverted tonnage is shifted from the land-route to the water-route transportation up to $QW3_{wpc}$ which in this example equals $QW3_{demand}$ (FIGURE 1.2.17 right graph). As water-route transportation costs decrease, land-routed traffic is shifted to the water-route; however, this shift is bounded by the fixed quantity demand. As a result, there is only WPC shift-of-mode traffic and no new movement tonnage.

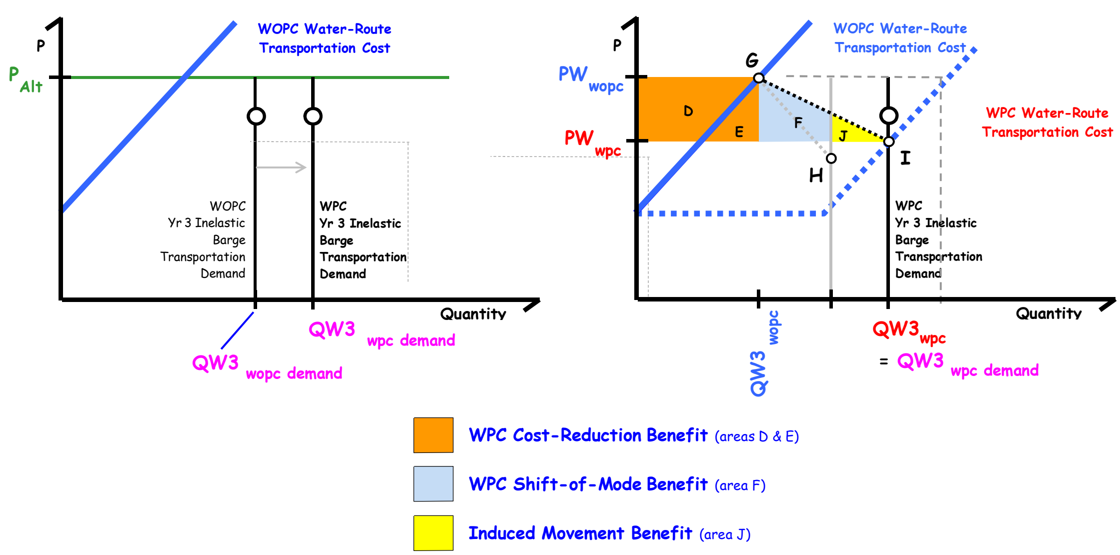
FIGURE 1.2.17 – Fixed quantity Barge Transportation Demand Equilibrium



Cost-reductions benefits are shown in areas D and E, while shift-of-mode benefits are area F of FIGURE 1.2.17. The cost-reduction benefits is a simple calculation of the price drop (PW_{wopc} - PW_{wpc}) multiplied by the WOPC quantity ($QW3_{wopc}$). The shift-of-mode benefits must be integrated under the demand curve (point G to H) and above PW_{wpc} over the shift-of-mode tonnage range ($QW3_{wopc}$ to $QW3_{wpc}$). Since tonnage moving on the waterway is capped by $QW3_{demand}$ and since any WOPC barge demand not met is assumed to move by the non-water route, traffic increase in the WPC can only be shift-of-mode. With an fixed quantity barge demand there can be no new movement traffic or benefits.

The creation of induced movement benefits requires a shifting of the fixed quantity demand curve to the right (induced demand) under the WPC only; there is an fixed quantity demand specified for the WOPC and a higher fixed quantity demand specified for the WPC. As shown in the left graph of FIGURE 1.2.18 an fixed quantity WPC demand (normal plus induced demand) is developed. WPC equilibrium with induced demand becomes $QW3_{wpc}$, which is greater than the equilibrium quantity without the induced demand (FIGURE 1.2.17). Given the higher traffic levels, the equilibrium water-route transportation cost (PW_{wpc}) is not as low as when induced traffic is not allowed. By comparison with FIGURE 1.2.17, with induced traffic cost-reduction and shift-of-mode benefits are lower since the equilibrium water-route transportation price is higher. The additional induced new movement benefit may or may not compensate for the lower cost-reduction and shift-of-mode benefits. As a result, total incremental benefits with the addition of induced movements may be lower than without the induced movements because the water-route transportation price is determined by multiple profit maximizing shipping agents unconcerned with cost impacts they impose on others.

FIGURE 1.2.18 – Fixed Quantity Barge Transportation Demand Induced Benefits

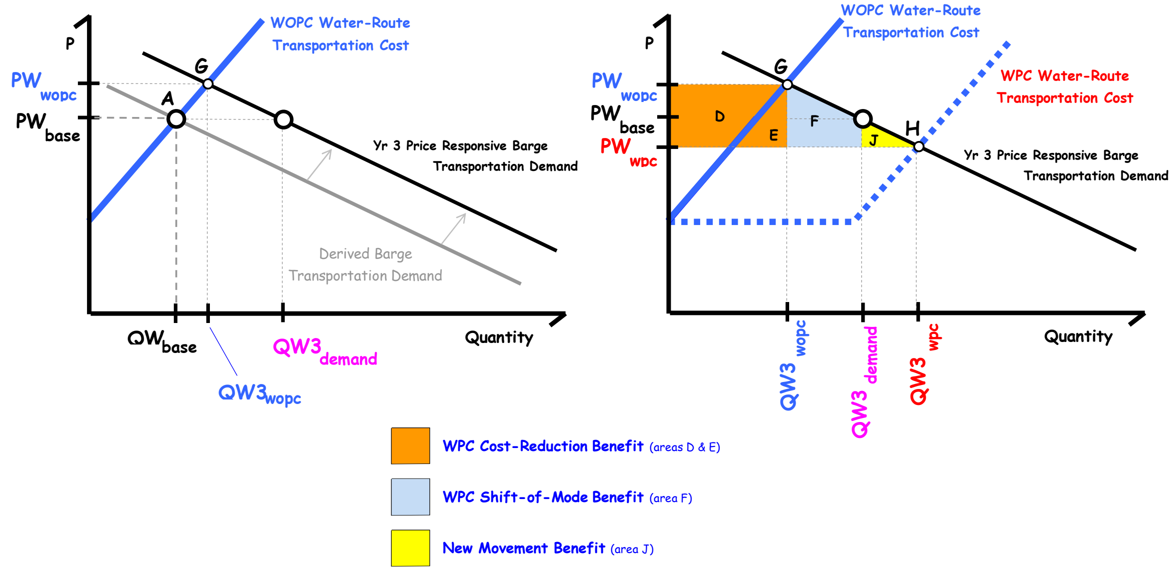


Demonstration of the shift-in-origin or destination benefit category in our hypothetical single origin-destination route example is rarely modeled and is difficult to demonstrate at such a theoretical level and will not be attempted.

1.2.3.5.4 Price Responsive Barge Transportation Demand Equilibrium

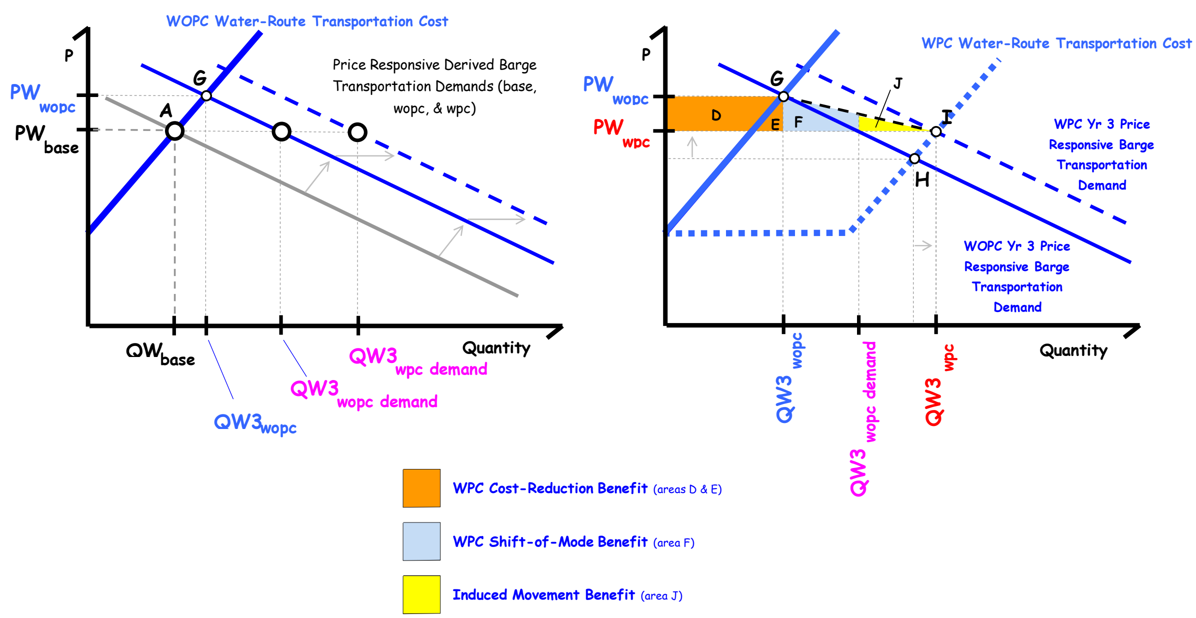
Using the right graph in FIGURE 1.2.16, the equilibrium process and the calculation of incremental benefits are shown in FIGURE 1.2.19. The forecasted demand in year 3 is $QW3_{demand}$, however, at equilibrium (point G FIGURE 1.2.19 left graph) only $QW3_{wopc}$ is expected to move by water in the WOPC; the movement is split and the remaining demand tonnage ($QW3_{demand}$ - $QW3_{wopc}$) is assumed to move by the least-cost all-overland alternative routing. With an improvement in water transportation (FIGURE 1.2.19 right graph), water-routing costs are lowered to PW_{wpc}, diverted tonnage is shifted from the land-route to the water-route transportation ($QW3_{demand}$ – $QW3_{wopc}$), and new movement tonnage is added ($QW3_{wpc}$ – $QW3_{demand}$). Unlike the fixed quantity movement case, the demand curve allows for new movement tonnage and benefits.

FIGURE 1.2.19 – Price Responsive Barge Transportation Demand Equilibrium



Cost-reductions benefits are shown in areas D and E, shift-of-mode benefits are area F, and new movement benefits are area J of FIGURE 1.2.19. The cost-reduction benefits is a simple calculation of the price drop (PW_{wopc} - PW_{wpc}) multiplied by the WOPC quantity ($QW3_{wopc}$). The shift-of-mode benefits must be integrated under the demand curve (point G to H) and above PW_{wpc} over the shift-of-mode tonnage range ($QW3_{wopc}$ to $QW3_{demand}$). The new movement benefits must be integrated under the demand curve (point G to H) and above PW_{wpc} over the new movement tonnage range ($QW3_{demand}$ to $QW3_{wpc}$).

FIGURE 1.2.20 – Price Responsive Barge Transportation Demand Induced Benefits



The creation of induced movement benefits requires a shifting of the price responsive demand curve to the right (induced demand) under the WPC only. As shown in the left graph of FIGURE 1.2.20 an price responsive WPC demand (normal plus induced demand) is developed. WPC equilibrium with induced demand becomes $QW3_{wpc}$, which is greater than the equilibrium quantity without the induced demand (FIGURE 1.2.19). Given the higher traffic levels, the equilibrium water-route transportation cost (PW_{wpc}) is not as low as when induced traffic is not allowed. By comparison with FIGURE 1.2.19, with induced traffic cost-reduction and shift-of-mode benefits are lower since the equilibrium water-route transportation price is higher. The additional induced new movement benefit may or may not compensate for the lower cost-reduction and shift-of-mode benefits. As a result, total incremental benefits with the addition of induced movements may be lower than without because the water-route transportation price is determined by multiple profit maximizing shipping agents unconcerned with cost impacts they impose on others.

1.2.4 Model Framework

Since the inland navigation investments analyzed have long lives (and regulation requires a cost-benefit analysis assuming a 50-year investment life), benefits (surplus) and costs must be estimated through time. These estimated life-cycle WOPC and WPC benefit and cost cash flows then serve as the basis for the cost-benefit analysis. To accomplish a life-cycle analysis, ORNIM is designed to estimate and analyze the benefits of incremental improvements in a river system and then to compare the benefits against the costs. ORNIM operates within the supply and demand framework discussed in section 1.2.1, with inputs that describe the long-run average cost of water transportation (supply) and the movement level demand for water transportation. ORNIM determines WOPC and WPC movement demand equilibrium and incremental benefits as discussed in section 1.2.3, however, the analysis of an investment within a system is much more complex than the simple commodity origin-destination route used as an example in the previous section (1.2.1). Additionally there are other considerations beyond equilibrium and surplus calculations that must be factored into the investment decision. The modeling requires a movement from the theoretical model to an empirical model that appropriately addresses the empirical question at hand and does so in a way that provides the most useful insights for decision-making, given the resource constraints placed on the overall analysis. This section describes the modeling framework used to apply the theoretical framework discussed. Section 1.3 will discuss the model structure.

1.2.4.1 Life-Cycle Analysis Accounting

A cost-benefit analysis is sensitive to the life-cycle period being considered and to the handling and comparison of the life-cycle cash flows. This is especially true for inland navigation investments which are costly and have long payback periods. Before proceeding further, the planning period and cash flow analysis are discussed in the following sections.

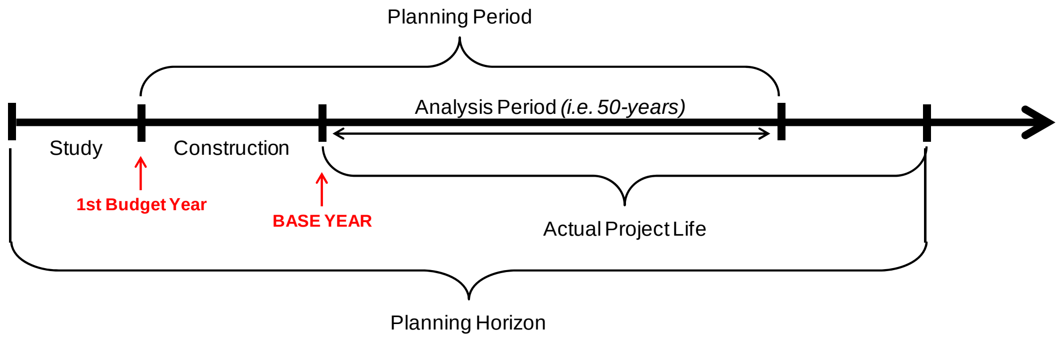
1.2.4.1.1 The Planning Period

Corps guidance requires that the period of analysis should be the same for each alternative plan, and include the time required for plan implementation plus the time period over which any alternative would have significant beneficial or adverse effects. In studies for which alternative plans have different implementation periods, Corps guidance says that a common “*base year*” should be established for calculating total NED benefits and costs, reflecting the year when the project is expected to be “*operational*.”

Guidance also specifies that for inland navigation projects, the time period over which WPC alternatives have significant beneficial or adverse effects is 50-years. This is not to say that the project or alternative will only last 50-years (the actual life is often much longer), but that only 50-years worth of benefits can be considered to off-set the investment cost. The 50-year period is often referred to as the analysis period or project life (although regulated project life would be more appropriate).
The plan implementation period, however, must also be considered in the analysis. This does not mean the entire time leading up to the alternative completion including both the study and construction periods, but instead the period when costs are incurred that are to be compared against the project benefits (i.e.,

the construction period). FIGURE 1.2.21 displays the terminology that will be used in the remainder of this document.

FIGURE 1.2.21 – Planning Period



For the Upper Ohio analysis the implementation (or construction period) was six years which was considered long enough to cover the longest alternative implementation. As a result, the planning period extended over 56-years. The first year of the construction period was set as 2012 (the first possible budget year), resulting in a base year of 2018 and a final analysis period year of 2067.

1.2.4.1.2 Compounding, Discounting, and Amortization

The life-cycle cash flows (whether benefits or costs) often fluctuate through time over the planning period. Project costs are incurred primarily at the time of construction while benefits accrue in varying amounts over the project life. Costs spent on construction today cannot be directly compared to the dollars in benefits that will be realized years from now. Even when inflation is not a concern, a rational person prefers one dollar now (a given level of consumption today) more highly than one dollar in the future (the same amount of consumption at some future point in time). Comparison of life-cycle benefits and costs is impossible without temporal aggregation of the cash flows; specifically compounding, discounting and amortization.

Compounding and discounting is the process of equating monetary values over time; in essence measuring the "*time value*" of cash flows (benefits and costs) that occur in different time periods. Compounding defines past sums of money into a single equivalent value. Discounting defines future sums of money into a single equivalent value. This equivalent value is also known as a present value or present worth. Compounding and discounting requires the use of an interest rate which represents society's opportunity cost of current consumption. The same rate is used for both compounding and discounting.

The appropriate rate can be a matter of debate; however, Congress has resolved the dilemma for water resource agencies. The rate used in evaluating water resource projects is set annually, by law (Section 80 of PL 93-251), using a prescribed formula based on the cost of government borrowing. The rate is published each year by Corps Headquarters as an Economic Guidance Memorandum (EGM). The FY 2010 project evaluation and formulation rate is 4.375%; however, OMB prefers a 7.0% rate. These compounding/discounting rates are typically just referred to as the Federal discount rate and the OMB discount rate. The Federal discount rate is used for formulation and selection of the NED plan. The NED plan is then summarized at the OMB discount rate for the Corps budgetary process.

The model calculates a present value for each cash flow category (e.g., benefits and costs) for each year in the planning period by the user defined compounding/discount rate according to the end of year discount method as shown in the equation below:

$$\text{Present Value} = PV = \sum_{y = Y^1}^{Y^N} \left(\frac{1}{\left(1 + i\right)} \right)^{y - Y^{Base} + 1} \times V_y \qquad (1.2\text{-}2)$$

where:

V_y = year y cash flow being equated
y = the year
Y^1 = the first year of the planning period
Y^{Base} = the base year for compounding/discounting
Y^N = the last year of the planning period
i = the compounding/discounting rate ($0 < i < 1$)

The present values for each cash flow category are then amortized and spread evenly over the regulated project life (i.e., analysis period) producing "*average annual equivalent*" values. The present values for each cash flow category are amortized over 50- years using the same compounding / discounting rate using end of period payments as shown in the equation below:

$$\text{Average Annual Equivalent} = AAE = PV \times \left(\frac{i}{1 - \left(\frac{1}{\left(1 + i\right)} \right)^{50}} \right) \qquad (1.2\text{-}3)$$

where:

PV = the cash flow present value
i = the compounding/discounting rate ($0 < i < 1$)

The estimated benefit and cost cash flows expected to occur in time periods following the base year are to be discounted back to the base year using the prescribed interest rate. Since the implementation period for some plan may begin prior to the base year, any estimated NED benefits and costs for that plan expected to be realized before the base year are to be "*compounded*" forward to the base year. That is, for plan benefits or often known as "*benefits during construction*" and costs expected to be realized before the base year, the discounting procedure is applied in reverse, so that the interest rate serves to compound rather than discount those effects to the base year. The same prescribed interest rate is to be used for both compounding benefit and cost streams that occur prior to the base year, and for discounting benefit and costs streams that occur after the base year.

1.2.4.1.3 Alternatives, RUNs, IPs, and Analysis Settings

"*The without project condition is the most likely condition expected to exist in the future in the absence of a project, including known changes in law or pubic policy.*"[14] The exact definition of what investment options (e.g., advanced maintenance, rehabilitation, replacement-in-kind) can be considered under the WOPC is always subject to debate and policy. While some investment options are within the Corps jurisdiction for implementation under the WOPC without Congressional action, excess funding is not

[14] ER 1105-2-100 Appendix D, Amendment #1 30 June 2004, page D-33.

available thus necessitating Congressional action as if the investment were a WPC option. The point here is that the WOPC often has to go through its own formulation and selection of the NED WOPC.

Regardless of where the user determines to divide the investment options between the WOPC and WPC, the model analyzes "*alternatives*" which are packaged into "*RUNs*" and "*Investment Plans*" for analysis assuming specified analysis settings / parameters. In a "*RUN*" the timing of investments are optimized. In an "*Investment Plan*" the life-cycle benefits and costs are calculated with the investments and investment timing specified. Typically the results from one or more "*RUNs*" (i.e., do this or that investment at this or that point in time) is used to define the "*Investment Plan*". These terms are more completely defined below:

- **Alternative** – the alternative is the investment itself. The alternative has a cost, a post implementation system and / or reliability and / or demand change, and possibly an implementation service disruption. An alternative can be the replacement of a single component (e.g., main chamber miter gates), a new lock (which essentially replaces multiple components), or a combination of investments across multiple navigation projects. An alternative can be defined as a single investment or as a package of multiple investments across multiple sites.
- **RUN** – the RUN analyzes an alternative or alternatives. The RUN specifies analysis parameters such as the planning period, base year, and discount rate. For each alternative listed in the RUN (through the AlternativeRunXRef table), the alternative is specified with an implementation range to be considered / analyzed, and may be specified as a "*must do*" alternative, meaning that it must be implemented within its implementation range. When an alternative is entered with an implementation range, the model will analyze implementation of that alternative in each year of the implementation range and compare the results against the no implementation scenario. Any alternatives listed as "*must do*" are automatically implemented in all of the analysis scenarios. The "*must do*" option allows for currently authorized projects (e.g., Olmsted, Greenup extension, etc.) to come online and change the waterway system transportation characteristics at the appropriate time. When multiple alternatives are specified with implementation ranges, the model will analyze the implementation permutations and again compare the results against the no implementation scenario. The RUN result specifies the optimal NED alternative, or alternatives, with implementation year(s) if economically justified over the no implementation scenario. RUNs are identified by a "*runID*".
- **Investment Plan (IP)** – the investment plan summarizes multiple runIDs. The investment plan also specifies the analysis parameters such as the planning period, base year, and discount rate. In short, the recommended investment implementations determined in the runID are specified in the investment plan as "*must dos*". The investment plan does no optimal timing and is used only to combine multiple investment options and re-equilibrate the system to ascertain the system effect of all the alternatives together in the system. To capture currently authorized projects (e.g., Greenup extension, Olmsted, etc.), a runID with only the authorized "*must do*" waterway system changes are included in the investment plan runID list. Investment plans are identified by a "*investmentPlanID*". An investment plan results in the creation of one investment permutation life-cycle equilibrium-scenario[15].

  With an investment plan, a "*no implementation scenario*" is not created for comparison like with a RUN. The comparisons between investment plans is done through a model post-processing utility where the user specifies which investment plan is to be considered the WOPC and which investment plans are to be considered WPC's.
- **Analysis Settings / Parameters (dataSetID)** – the RUN and IP require the specification of several additional settings / assumption prior to the determination of equilibrium and the life-cycle analysis over the planning period. While the RUN and IP definitions include the basic analysis parameters (e.g., planning period, base year, and discount rate), additional parameters are specified and stored under a "*dataSetID*" in three database tables. These other settings / assumptions include the

[15] One investment permutation life-cycle equilibrium-scenario calculated under four assumptions: 1) without scheduled service disruptions; 2) with scheduled service disruptions; 3) without probabilistic service disruptions; and 4) with probabilistic service disruptions. All four variations are run to allow a sensitivity check of each assumption.

forecasted demand scenario, the demand assumption (price responsive or fixed quantity), the fuel tax plan, the fee plan, and whether or not to allow shipping plan re-plan over the planning period. A complete listing of these settings / assumptions can be found in section 1.4.7.1.

For discussion purposes, the remainder of section 1.2.4 will refer to the "*investment option*" which will mean a single alternative with specified planning period and implementation date; a scheduled alternative. Modeling multiple alternatives at multiple sites at multiple times complicates the modeling framework discussion, but follows the same modeling process as the analysis of a single alternative.

1.2.4.1.4 The Fitness Metric

To facilitate rapid and efficient comparison of the RUN (runID) investment life-cycle equilibrium-scenario permutations, the analysis results can be, and are, reduced to a single metric; average annual net benefit (see section 1.2.4.4.4).

1.2.4.2 Sectorial, Spatial, and Temporal Simplifying Assumptions

As noted in section 1.2.1, economic models vary in terms of sectorial, spatial, and temporal detail. Simplifying assumptions are made in empirical models because of data, time, computational, and resource limitations. The keys in making these simplifying assumptions are to clearly understand: (1) the theoretical model that serves as a starting point for the analysis; (2) how the simplifying assumptions deviate from the theoretical model; (3) the reasonableness of the assumptions as compared to what we know about real-world markets; and (4) the implications of the assumptions in terms of biasing and/or reducing the accuracy of the model's results (i.e., the estimation of WPC benefits). These issues were discussed in the previous section (1.2.1). As a result, the fundamental sectorial assumption in the ORNIM model framework is to analyze inland navigation investments under a spatially-detailed barge transportation partial-equilibrium framework for reasons previously discussed. The spatial and temporal detail level in ORNIM is data driven (i.e., user specified) as discussed in the sections below.

1.2.4.2.1 Spatial Detail

The spatial detail is defined by the model user through the waterway transportation network, and through the aggregation level of the commodity groups and barge types. In the theoretical framework discussion, only a commodity origin-destination route movement was discussed. In the model a commodity origin-destination route and barge type defines the shipment which demands barge transportation. The barge type, however, drives the shipping characteristics (shipping plan) and thus is central in the cost characteristics of the movement and the congestion effect.

Hopper barges (used to transport dry bulk) are smaller and less costly than double skinned tanker barges (used to transport liquids such as chemicals). Tanker barges, because of their size and often because of the characteristics of their cargo, often move in small tows not enjoying economies of scale obtained from non-hazardous dry bulk commodities moving in large tows. Thus the trip hourly cost per ton of hazardous liquids is much higher than the hourly cost per ton for dry bulk. As congestion in the waterway system increases, waterway transportation costs increase much more rapidly for the tanker movement. To summarize, a waterway transportation system defined with only one barge type averaging the shipping and cost characteristics of tankers and hoppers, is much less spatially detailed than a waterway transportation system defined with four different sized tankers and eight different sized hopper barges (each with their own shipping characteristics and costs).

The spatial detail achieved through the commodity specification is self evident; modeling of each of the 622 5-digit WCSC commodity codes is much more spatially detailed than modeling commodities aggregated to nine group codes. The spatial detail achieved through the origin-destination level is also self evident; modeling of every waterway dock is much more spatially detailed than modeling one pickup / drop-off in each navigation pool. Spatial detail does not come without a cost. Since each and every movement (commodity origin-destination barge type) must be equilibrated with every other movement, each increment of detail increases computational time exponentially.

For the Upper Ohio analysis, the 622 5-digit WCSC commodity codes were aggregated into 9 commodity groups, the 5,928 docks serviced by ORS traffic were aggregated into 171 pick-up/drop-off nodes (with at least one node in each of the 56 navigation project pools), and the tens of thousands of unique barges were aggregated into 12 barge types. This results in 17,138 unique commodity origin-destination barge type movements in the model.

1.2.4.2.2 Temporal Detail

The model does not simulate individual waterway shipments (i.e., tow), but operates off a movement-level (an aggregation of shipments) cost in discrete time periods. Typically the model is utilized assuming yearly time periods. While the model's temporal detail is tied to a time period, the user can redefine the definition of a time period through the inputs. For example, instead of running the model as a yearly model over 50-years (i.e., 50-periods), the inputs could be aggregated to a quarterly level and 200 quarterly periods could be run to complete a 50-year life-cycle analysis. As with the spatial detail, increased detail significantly increases the computation time and too much granularity can complicate, if not invalidate, the theoretical framework (e.g., trip times spanning multiple periods).

For the Upper Ohio analysis, the model is run as a yearly model. A movement is defined as the annual volume of shipments for the commodity origin-destination barge type. There are 17,138 unique commodity origin-destination barge type movements defined in the Upper Ohio analysis, each of which are forecasted by year over the planning period.

1.2.4.2.3 Inter-Temporal Detail

Each time period in the model is independent of the other time periods, however, there is an inter-temporal effect interjected into the modeling process through user specification of infrastructure change and through the engineering reliability data (section 1.2.4.4.3.1).

Lock performance characteristics can be specified by the user to change through time. This allows for currently authorized projects (e.g., Olmsted) to come online and change the waterway system transportation characteristics at the appropriate time. Additionally, the analysis of the WPC alternatives requires the investment to be timed and the characteristics of the waterway system transportation to be adjusted accordingly at the correct times.

Lock performance can also change probabilistically through time through reliability. In this respect, the expected benefits and costs calculated in a given year are dependent upon the results in the previous years. With increasing service disruption through time, expected equilibrium traffic levels can decline as expected capacity declines. If however the user desires to model declining demand from increased reliability risk, this must be done through the forecasted demand input (i.e., a forecasted demand assuming decreased reliability).

1.2.4.3 Network and Movement Detail

Much of the model's spatial detail comes through the waterway transportation network definition. The transportation network not only defines the pick-up/drop-off nodes (171 of them in the Upper Ohio analysis) but it also defines constraint points in the system (bottlenecks). These constraint nodes can be any obstruction where vessel queuing can occur and congestion effects can be felt. While these constraint nodes can be areas such as bends or one-way channel sections, typically the constraint nodes modeled are the navigation projects. In the Upper Ohio study analysis 56 navigation projects are modeled.

In order to determine the impact of congestion effects on a movement's transportation costs (and ultimately the movement's equilibrium and surplus), the movement's trip time needs to be estimated. Distances between each model node (both pickup / drop-off nodes and the constraint nodes) are defined through the input data. Additionally data on current speeds, channel depths, and equipment drag are input and utilized by a speed function (see ADDENDUM 1B section 1B.4.13) and combined with the trip distance to estimate line-haul trip time. Estimating the trip time at the constraint points is a different story.

1.2.4.3.1 Tonnage-Transit Curves

At the constraint points (i.e., locks) the transit times are characterized by a tonnage-transit curve. This tonnage-transit curve plots an average tow transit time against annual tonnage at the lock. The transit time not only includes the processing time to transfer to the next pool, but it also includes delay time from queuing resulting from the congestion effect. As utilization of the lock increases the delay exponentially increases once persistent queuing starts.

Given a traffic level at the project, the average transit time is pulled from the tonnage-transit curve and applied to each movement transiting the project. All projects transited are polled for transit times along each movement's route and added to the movement's line-haul time to determine the movement's total transportation time.

The tonnage-transit curves are externally derived (typically through vessel level simulation) and input into the model. Additional detail on the tonnage-transit curve development can be found in the APPENDIX B Economics, ATTACHMENT 2 Capacity Analysis.

1.2.4.3.1.1 Normal Operations Tonnage-Transit Curves

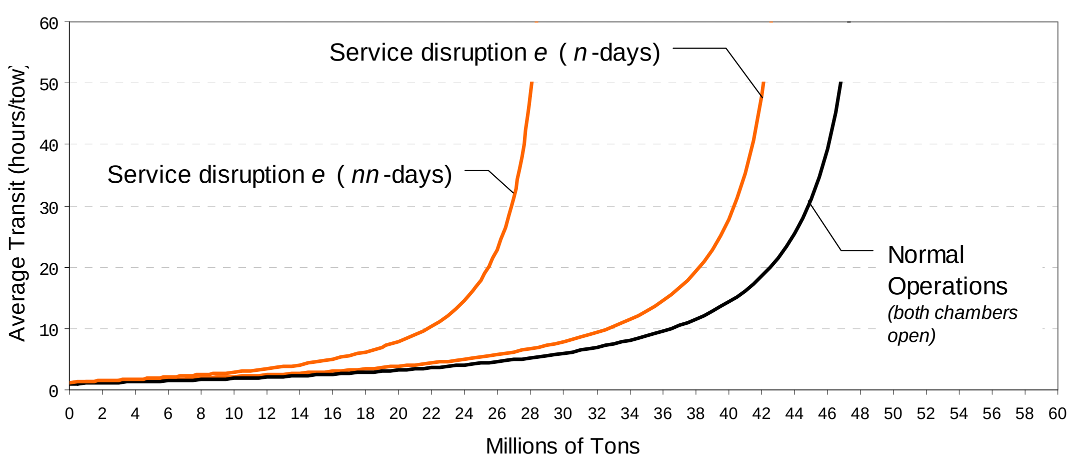
A normal operations tonnage-transit curve is typically created for each navigation project (lock) defined in the waterway transportation system network. This normal operation state reflects the project's full service capacity.

1.2.4.3.1.2 Service Disruption Tonnage-Transit Curves

As will be discussed in more detail later, lock capacity is not always consistent through time. Service disruptions at the locks (whether from scheduled maintenance or from failure events) reduce capacity. In order to factor these periods of decreased capacity into the analysis (specifically the transportation cost calculation) tonnage-transit curves are developed for each defined service disruption.

Service disruptions can range from hours to months and from a slowing of the lock processing time to a complete river closure. The service disruption definitions are determined by Corps engineering and operations staff. As with the normal operations tonnage-transit curves, the service disruption tonnage-transit curves are externally derived and input into the model. Additional detail on the tonnage-transit curve development can be found in ATTACHMENT 2 Capacity Analysis. Example normal operations and service disruption curves are shown in FIGURE 1.2.22.

FIGURE 1.2.22 – Example Tonnage-Transit Curves



1.2.4.3.1.3 Multiple Service Disruption Events

The service disruption tonnage-transit curves are developed for each defined service disruption at each navigation project. Within a year, however, a project can experience multiple service disruptions. Both the main and auxiliary chambers could be scheduled for maintenance in the same year. While components are assumed to fail no more than once a year, there are typically multiple components being modeled at each project (and multiple components in each chamber). While component failures are not assumed to occur during scheduled maintenance events, failures can occur during the rest of the year (e.g., a scheduled 14-day main chamber de-watering with an auxiliary chamber 30-day gate failure sometime during the rest of the year). When multiple service disruption events occur in a given year (whether scheduled, unscheduled, or a combination of scheduled and unscheduled events), the service disruptions are assumed to be spaced far enough apart for queues to dissipate before the next event occurs. This assumption reduces the number of tonnage-transit curves needed by eliminating the need for enumeration of curves for each possible service disruption combination-permutation.

For years with multiple service disruption events, the model combines the specified tonnage-transit curves to estimate the average tow transit times with occurrence of the multiple service disruption events. Essentially the relative effects of all the service disruptions are added:

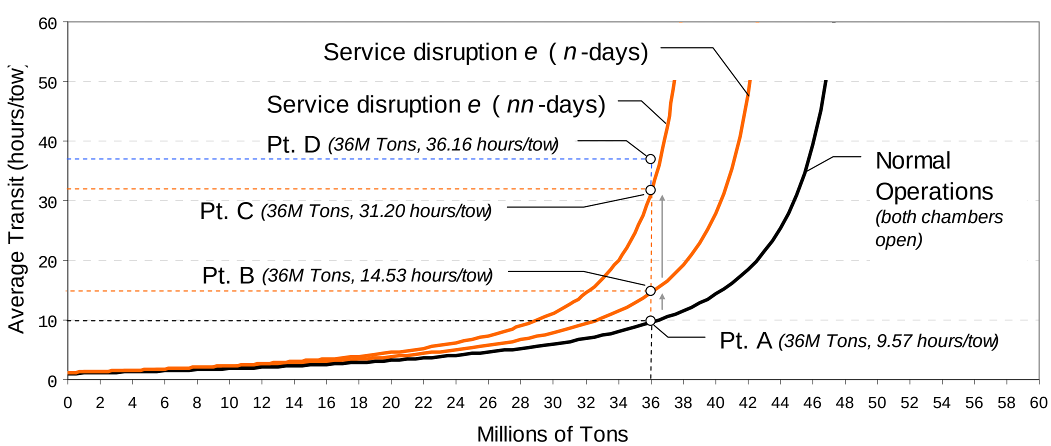
$$AvTT_{pT} = AvTT_{p0} + \sum_{event=1}^{E} \left(\Delta_{p\ event} \times N_{p\ event} \right) \qquad (1.2\text{-}4)$$

where:

$AvTT_{pT}$ = average tow transit time at project p
$AvTT_{p0}$ = normal operation average tow transit time at project p
event = service disruption event type
$\Delta_{p\ event}$ = change in average transit time at project p with *event*
$N_{p\ event}$ = number of *event* at project p

Visually, say that the subject lock in the specified year is moving 36 million tons in equilibrium at an average transit time of 9.57 hours per tow as shown in FIGURE 1.2.23. Say that the *n*-day service disruption event increases the average transit time to 14.53 hours per tow (point B) and the *nn*-day service disruption event increases the average transit time to 31.20 hours per tow (point C). The model estimates the average transit time as 36.16 hours per tow when both the *n*-day and *nn*-day events occur within the year (point D).

FIGURE 1.2.23 – Transit Time Calculation with Multiple Service Disruption Events



1.2.4.3.2 Movement Shipping-Plans

Congestion in the waterway transportation system does not affect all movements equally. In order to determine the impact of congestion effects on a movement's transportation costs, the shipping costs and characteristics of that movement must be known. The shipment characteristics are referred to as the "*shipping-plan*". A shipping-plan is needed for each of the 17,138 commodity origin-destination barge type movements in the model.

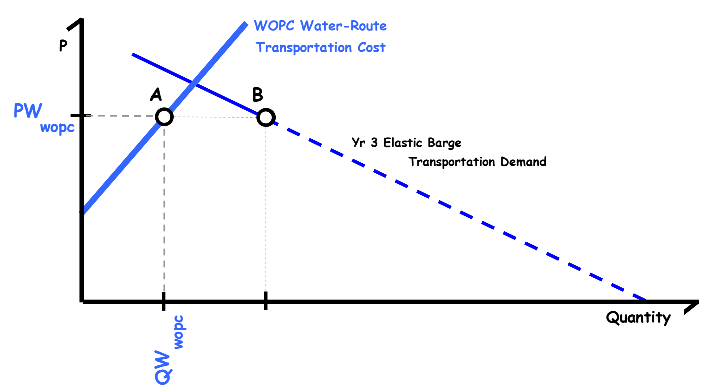
The shipping-plan drives the shipping cost and is stored in dollars per hour per ton. The shipping-plan includes specification of the shipment tow-size, the towboat class used, empty backhaul requirements, re-fleeting points, and tons per trip. Given the movement tonnage and the trip time, a movement cost can be calculated and then compared against the movement's willingness-to-pay.

The shipping plans could be specified by the user and given to the model through input; however, this data is not readily available and difficult to compile for large systems. Instead, the model develops a least-cost shipping plan for each movement which is then calibrated against observed data. This shipping-plan developer also allows re-specification of shipping-plans under increased congestion and for what-if scenarios (e.g., 1200' main chambers instead of existing 600' main chambers). Additional detail on the development of the movement shipping-plans can be found in section 1.3.1.1 and in ADDENDUM 1B section 1B.4.

1.2.4.3.3 Movement Level Willingness-to-Pay

As discussed in section 1.2.3.5, willingness-to-pay for barge transportation is needed to determine the equilibrium traffic level and to calculate the transportation surplus (benefit). As discussed, the willingness-to-pay can be defined as either fixed quantity or price responsive, and the model allows either specification on a movement to movement basis. For the Upper Ohio analysis, all movements in the model were assigned a demand curve (right graph in FIGURE 1.2.16) based on a study of demand elasticity on the Ohio River system[16]. Whether the fixed quantity or price responsive demand curve, the waterway transportation demand curve shows the relationship between the quantity shippers are willing to ship and the price (rate), while holding the rates of alternative modes constant, and the characteristics of waterway transportation and other modes constant. Additional detail on the development of the price responsive movement demand curves can be found in section 1.4.2.5, in ADDENDUM 1C Ohio River System Willingness-to-Pay for Barge Transportation, and in ADDENDUM 1D Demand Curve Inputs.

FIGURE 1.2.24 – Barge Transportation Demand Extrapolation



When utilizing an price responsive demand curve, an additional analysis setting / assumption must be specified. As discussed in sections 1.2.3.5.1 and 1.2.3.5.2, the demand elasticity is applied to a forecasted barge demand that assumes that the current transportation prices (all transportation modes)

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[16] Kennith Train and Wesley W. Wilson, "*The Demand for Transportation in the Ohio River Basin*", supported by the Navigation technologies Program. August 2008.

are in effect throughout the forecast horizon. The question then becomes whether to allow the demand curve to be extrapolated beyond the forecasted demand (point B in FIGURE 1.2.24). The model can be run under either setting / assumption. The extrapolated demand curves are unbounded and problematic given their propensity to asymptotically approach the x-axis (i.e., infinite tonnage).

Typically (and in this Upper Ohio analysis), the price responsive demand curves are capped at the forecasted barge transportation demand. Induced traffic is estimated externally and specified as a separate forecasted barge transportation demand to be used when infrastructure improvements are determined extensive enough to induce additional demand. This represents a shift in the demand curve (see FIGURE 1.2.20).

1.2.4.4 Waterway Transportation System Equilibrium

The example utilized in the theoretical discussions in section 1.2.1 above involved a specific commodity origin-destination route. In reality of course, in an inland navigation study there are multiple commodities and multiple origin-destination routes operating in a multi-lock waterway transportation system. As a result, equilibrium for each movement must be simultaneously computed with a complication that the waterway transportation cost a movement faces is an amalgamation of other movement shipping decisions along that movement's route. Despite this, the simplified 2x2 case (waterway transportation shipping costs and barge transportation demand) used to describe equilibrium (and the calculation of benefits) still applies at the individual movement level.

To accomplish the simultaneous equilibrium of all movements in the system, the model actually uses an iterative approach cycling through the movement list adjusting individual movement tonnages (and their congestion impact to the system) until the system equilibrium converges where all movements are in equilibrium. Each movement's trip time is estimated given the current congestion status of the system and then multiplied by the movement's shipping-plan hourly cost per ton and the number of trips to derive the new movement shipping cost. The movement's equilibrium decision, however, is based on price (the rate) and not it's cost since the barge transportation demand curves represent a price quantity relationship. The new movement price is based off the movement's new estimated cost by a movement "*cost-to-rate delta*" determined in the model's calibration process (ADDENDUM 1B ORNIM Calibration). In the calibration process the base-rate is compared and related to the model's estimated base movement cost. The delta represents an adjustment price (dollars per ton) needed to convert the model's movement cost estimate to the movement rate. The model's equilibrium process is discussed in detail in section 1.3.1.2.

As previously noted, ORNIM is an annual model, and as such equilibrium represents an annual snapshot. To complete a life-cycle cost-benefit analysis equilibrium must be estimated for each year over the planning period (50 plus years) for both the without-project condition and each with-project condition. Additional issues must also be considered (and adjustments made) to complete an analysis useful for decision-making. Namely, waterway transportation capacity is not always consistent through time. Changes in capacity can occur by design (e.g., new larger lock comes on-line) or from system maintenance / degradation. Service disruptions at the locks can cause periodic constraint points in the system which makes congestion effects and transportation costs much more severe, and can result in a diversion of traffic off the waterway. Service disruptions can occur from scheduled maintenance (infrastructure alternative specific) and probabilistically driven unscheduled events (risk). Service disruptions themselves can range from hours to months and from a slowing of the lock processing time to a complete river closure. System capacity and service disruptions vary between the investment options and must be considered.

Scheduled capacity changes and scheduled service disruptions are assumed known and the waterway price is assumed known in the equilibrium process. Unscheduled service disruptions by definition, however, are unknown and as a result are not considered in the equilibrium process, but are adjusted for after equilibrium is determined. Generally speaking, given a waterway system infrastructure configuration (including lock performance characteristics with scheduled maintenance service disruption information) and movement-level demands (including movement willingness-to-pay characteristics) the model determines the equilibrium traffic levels in the system, along with the equilibrium transportation costs, for each year over the study's analysis period. Next, these results are adjusted for engineering reliability (probability of unscheduled service disruption). Basically the equilibrium movement water transportation prices are increased by the probability of increased trip time cost caused by the risk of service disruptions. The following sections will discuss the analysis process, the development of the various equilibrium steps (or equilibrium scenarios), and the required equilibrium cost adjustments required to analyze an investment option (whether we are talking about an alternative or an investment plan analysis). For discussion, the following four life-cycle equilibriums will be used:

- Normal-operations equilibrium-scenario (aka "*no prob no scheduled*")
- Scheduled-maintenance equilibrium-scenario (aka "*no prob with scheduled*")
- Probabilistic adjusted normal-operations equilibrium-scenario (aka "*prob no scheduled*")
- Probabilistic adjusted scheduled-maintenance equilibrium-scenario (aka "*prob with scheduled*")

Since the waterway transportation equilibrium is directly tied to system capacity changes and service disruptions and its cost impacts to waterway transportation, it is best to simultaneously discuss the Federal costs to these capacity changes and service disruptions. Actually, for each of the four life-cycle equilibriums calculated, the model completes a cost-benefit analysis. The "*no prob no scheduled*" and "*no prob with scheduled*" results, however, are for quality checks and sensitivity analysis. The "*prob no scheduled*" is used to help formulate investment optimization and timing (removal of the scheduled service disruptions help smooth the timing optimization) and thus the specification of investment plans (IPs). The "*prob with scheduled*" results represents the definitive costs and benefits for the cost-benefit analysis.

1.2.4.4.1 System Equilibrium under Normal Operations

The first step in an investment option analysis is for the model to estimate the equilibrium traffic levels, waterway transportation costs, and waterway transportation surplus over the planning period assuming normal operations (i.e., no scheduled maintenance outages and no reliability issues; 24/7 operation). As shown in FIGURE 1.2.21, the planning period includes the implementation period and a 50-year analysis period; for the Upper Ohio analysis ranging 56-years from 2012 through 2067 with a base year of 2018. These normal operation results are not used in the cost-benefit analysis (per se), however, they are used for quality control and offer a way to determine the impact of scheduled maintenance discussed in the next section (1.2.4.4.2). These life-cycle equilibrium results will be referred to as the "*normal-operations equilibrium-scenario*".

It would appear that this normal-operations equilibrium-scenario assumes a constant waterway transportation capacity through time; however, this is not necessarily the case. While there are no service disruptions, scheduled capacity changes are assumed to take place. For example, the base normal operations WOPC would contain any authorized improvements (i.e., system capacity changes) in the system (e.g., Olmsted Locks and Dam online in year 2016). Additionally, if a with-project investment is scheduled, the capacity change would occur. The corresponding implementation service disruptions, and their effect on equilibrium, however, would not be factored into the calculations.

1.2.4.4.1.1 **Normal Operation Costs**

The model also contains user specified normal operations and maintenance (O&M) costs for each navigation project. These costs are normally constant through time and cover base operating costs like routine maintenance, salary, and utilities. These base operation costs, however, can change through time and between investment plan, and are therefore tracked and summarized by the model for the normal-operations equilibrium-scenario. For example, when a new project comes online its base operating costs might differ from the old project. For example, a two-for-three project replacement would most-likely reduce total operating costs at the three existing projects by a third.

Typically, O&M costs are only input for the navigation projects in the study area since the costs would be the same under the with and without-project conditions at all other projects. In this study, O&M costs were only tracked for the three Upper Ohio projects.

1.2.4.4.1.2 Improvement Costs

Investment costs for scheduled capacity changes (if applicable) are tabulated under this "*no prob no scheduled*" cost-benefit analysis. Scheduled maintenance costs are not included in these Federal cost calculations. Typically improvement costs are only input for the navigation projects in the study area since the costs would be the same under the with and without-project conditions at all other projects. In this study, improvement costs (if applicable) were only tracked for the three Upper Ohio projects.

1.2.4.4.2 System Equilibrium with Scheduled Service Disruption

The second step in an investment option analysis is for the model to estimate the equilibrium traffic levels, transportation costs (water and land), and waterway transportation surplus over the planning period with consideration of scheduled maintenance. Scheduled service disruptions are known and the waterway transportation price with the lower system capacity is assumed known by the shippers in the equilibrium process. Scheduled maintenance that involve a significant service disruption are developed well in advance, and the waterway transportation industry is notified up to two- years in advance through a "*Notice to Navigation*"[17]. With advanced notice, and a moderate service disruption, many of the slow moving low-value bulk commodities can often be re-scheduled around the event with minimal impact, relieving congestion during the actual event.

Each navigation project in the system has maintenance requirements that often require periodic service disruption (e.g., chamber dewatering for inspection). The maintenance needs vary between project based an assortment of factors (e.g., age, usage, weather, construction type, etc.) and can often vary between investment options considered at a single site. Typically the WOPC investment options at a project will contain more frequent and longer duration scheduled service disruptions compared to the WPC investment options (reflecting the lower reliability of maintaining older infrastructure). The maintenance requirements for an investment option are developed external to the model by Corps engineering and operations staff, and then supplied as input to the model. The model is given a scheduled maintenance schedule (or schedules) specific for the investment option (or options) considered. This maintenance schedule includes the scheduled service disruption date (year), level (e.g., half-speed, closed, etc.), duration (in days), and Federal cost by lock chamber.

Say for a specified investment option the maintenance schedule shows main chamber 15-day closure in year 2020 and 2030, and an auxiliary chamber 20-day closure event in year 2025 at Project A. Say also the maintenance schedule shows a 10-day main chamber half-speed event in year 2025 and an auxiliary chamber 10-day half-speed event in 2030 at Project B. Say the planning period is 2012-2067. For analysis of this investment option with consideration of scheduled maintenance, the model determines that the system is operating under the normal-operations equilibrium-scenario for all years except 2020, 2025, and 2030 (i.e., years 2012-2019, 2021-2024, 2026-2029, and 2031-2067). These normal-operations equilibrium-scenario results can be used in the investment option "*scheduled-maintenance equilibrium-scenario*" without re-running the equilibrium process. The model does, however, need to re-equilibrate years 2020, 2025, and 2030 with the specified system capacity constraints (i.e., scheduled service disruptions). For year 2020 a 15-day main chamber closure service disruption tonnage-transit curve at Project A is inserted into the system network and the system is re-equilibrated. For year 2025 two changes to the network are made. A 20-day auxiliary chamber closure service disruption tonnage-transit curve is inserted into the network for Project A and a 10-day main chamber half-speed service disruption tonnage-transit curve is inserted into the network for Project B. After the year 2025 network is re-built, the system is re-equilibrated. Similarly for year 2030, the appropriate service disruption tonnage-transit curves are inserted in the network and the system equilibrium is re-estimated.

[17] Typically each District releases a Notice to Navigation yearly specifying scheduled outages (service disruptions) for the next two years. Additional notices are released as schedules change or as unforeseen events occur.

These new equilibrium results for years 2020, 2025, and 2030 are then merged with the investment option's normal-operations equilibrium-scenario results to complete the life-cycle equilibrium results for the investment option's life-cycle "*scheduled-maintenance equilibrium-scenario*".

1.2.4.4.2.1 Normal Operation and Scheduled Maintenance Costs

Not only does the model contain user specified normal O&M costs for each navigation project; it also contains the scheduled maintenance costs. As the normal O&M varies through time and between investment options, so too the cyclical scheduled maintenance costs. These scheduled maintenance costs along with the normal O&M costs are therefore tracked and summarized by the model for the scheduled-maintenance equilibrium-scenario ("*no prob scheduled*"). As with the "*normal-operations equilibrium-scenario*" results, these scheduled-maintenance equilibrium-scenario results are not used in the cost-benefit analysis (per se), however, they are used for quality control and offer a way to determine the impact of scheduled maintenance discussed in the previous section (1.2.4.4.1).

1.2.4.4.2.2 Improvement Costs

As for the normal-operations equilibrium-scenario ("*no prob no scheduled*"), the scheduled-maintenance equilibrium-scenario ("*no prob scheduled*") tabulates the investment costs for scheduled capacity changes (if applicable). Again, typically improvement costs are only input for the navigation projects in the study area since the costs would be the same under the with and without-project conditions at all other projects. In this study, improvement costs (if applicable) were only tracked for the three Upper Ohio projects.

1.2.4.4.3 Adjustment for Unscheduled Service Disruption

As noted earlier, service disruptions can also occur from probabilistically driven events (risk). These are called unscheduled service disruptions. The third step in an investment option analysis is to adjust the investment option scheduled-maintenance equilibrium-scenario (section 1.2.4.4.2) over the planning period for probabilistically derived unscheduled service disruption. This may require adjustment of the equilibrium traffic levels and definitely requires adjustment of the transportation costs and waterway transportation surplus over the planning period.

Unscheduled service disruptions by definition are unplanned, and as a result the waterway transportation price under the lower system capacity is unknown by the shippers when their shipping decisions are made. With minimal (or perhaps no) notice, unscheduled service disruptions can result in severe transportation impacts. In addition, unscheduled service disruptions are defined probabilistically. As a result, the adjustment of equilibrium traffic levels, transportation costs, and waterway transportation surplus for unscheduled service disruptions is different than for scheduled service disruptions. While the resulting investment option's life-cycle "*probabilistic equilibrium-scenario*" contains scheduled maintenance service disruptions (along with its equilibrium traffic and cost adjustments), the incorporation of the probabilistic unscheduled events converts the result to expected values.

The following sections discuss the adjustment for probabilistically derived unscheduled service disruption. The model allows for each navigation project in the system to be defined with engineering derived reliability data which probabilistically defines the risk of unscheduled service disruption[18]. Basically, as discussed in detail below, each equilibrium movement's traffic level and transportation costs are adjusted by the probability and impact of unscheduled service disruptions.

1.2.4.4.3.1 Component Level Engineering Reliability Data

External to ORNIM, component level engineering reliability data is derived through engineering analytical methods where failure probabilities, failure levels, failure level probabilities, and failure consequences are developed and defined. This reliability data is specific to a "*component*" which can be defined at any structural or mechanical level as long as it's reliability is independent of other defined components. A

[18] Engineering reliability data does not consistently exist for all projects in the inland waterway system. In an analysis the user should take care to have consistent reliability data specification at all "critical" projects in the study area (see discussions in section 1B.2.8 in Addendum B Calibration. Typically, only projects considered for investment require specification of reliability directly into NIM and the specification of service disruption tonnage-transit curves. For other projects the reliability will be the same under both the without and with-project conditions, and a generalized reliability can be imbedded into "normal operations" tonnage-transit curve.

component might be defined as an entire lock chamber, a single gate leaf, a single monolith, or an entire wall. The definition of a component is determined in the engineering reliability analysis and is dependant upon engineering judgment and the planning formulation (investment) level desired. A brief description of the reliability data is given below, and additional discussion can be found in Engineering Appendix – Document GE, General Engineering Reference Data Appendix.

In the first portion of the engineering reliability analysis effort probabilities of unsatisfactory performance (PUP) are developed by year from the component's new state (i.e., when it was installed or rehabilitated; age 0) and then converted into a hazard function as shown in the example in TABLE 1.2.1 and FIGURE 1.2.25. In this example, the PUP is flat to demonstrate the difference between the PUP and its resultant hazard function. Even with a constant PUP through time the hazard function will eventually rise and level off at 100%. The hazard function as commonly used in reliability theory and insurance (where it is also called the "*force of mortality*") and is strictly defined as the *instantaneous* probability of failure or death, given no failure or death up until that time. As such, there becomes a point in time beyond which survivability becomes theoretically impossible.

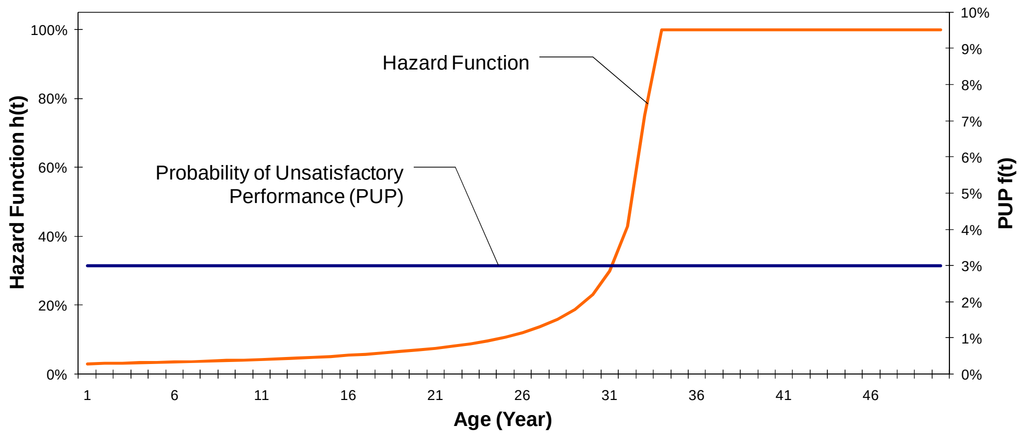
TABLE 1.2.1 – Calculation of Hazard Function from PUPs

	f(t)	**F(t)**	**R(t)**	***h(t)***
Age (Year)	**PUP / Year**	**Cummulative PUP**	**Cummulative Reliability**	**Hazard Function [R(t-1)-R(t)] / R(t-1)**
			1	
1	3.0000%	3.0%	97.0%	3.00000%
2	3.0000%	6.0%	94.0%	3.09278%
3	3.0000%	9.0%	91.0%	3.19149%
4	3.0000%	12.0%	88.0%	3.29670%
5	3.0000%	15.0%	85.0%	3.40909%
⋮	⋮	⋮	⋮	⋮
31	3.0000%	93.0%	7.0%	30.00000%
32	3.0000%	96.0%	4.0%	42.85714%
33	3.0000%	99.0%	1.0%	75.00000%
34	3.0000%	102.0%	-2.0%	100.00000%
35	3.0000%	105.0%	-5.0%	100.00000%
⋮	⋮	⋮	⋮	⋮
46	3.0000%	138.0%	-38.0%	100.00000%
47	3.0000%	141.0%	-41.0%	100.00000%
48	3.0000%	144.0%	-44.0%	100.00000%
49	3.0000%	147.0%	-47.0%	100.00000%
50	3.0000%	150.0%	-50.0%	100.00000%

The engineering reliability PUPs are developed either through an elicitation of experts (EOE) or mathematical modeling such as finite element analysis. The PUP will typically, but not always, gradually increase through time as the component degrades. This component degradation can be a result of age (e.g., corrosion) or can be the result of fatigue where expected future usage of the component become important. Typically, regardless of whether the component degrades by time, cycles, or a combination of both, the engineering reliability analysis will convert and tie the failure probabilities to the component's age (i.e. time).

For components such as lock chamber gates, to allow for a finer level of analysis that can take into account variation in forecasted traffic levels and thus variation in lockage cycles, ORNIM also allows the loading of PUPs with an additional tonnage level parameter. In this situation, the engineering reliability analysis will develop a low, medium, and high failure probability. The low probabilities are developed assuming flat traffic growth into the future, the high probabilities are developed assuming the maximum demand tonnage into the future, and the medium probabilities assume some traffic level in between these two extremes. In ORNIM (specifically the Lock Risk Module) the failure probability is estimated by interpolation between the failure probability curves at the specified age given the specified tonnage level being modeled.

FIGURE 1.2.25 – Component PUP and Hazard Function



While the hazard function is a good communication tool; the PUP is the appropriate probability to load and utilize in the ORNIM simulation to calculate life-cycle expected service disruption probabilities and costs[19]. To understand this, the failure levels, failure level probabilities, and most importantly the post-repair reliability adjustment must first be understood.

Beyond the development of the component failure probabilities, the second major portion of the engineering reliability effort is the definition of the failure levels, failure level probabilities, and failure consequences. This information is specified in an event-tree structure, however, while ORNIM will allow the definition of unlimited branches, the branching in the tree can only be two deep (a failure level and then a fix level). An example ORNIM event-tree is shown in the dashed section of FIGURE 1.2.26. In this figure it can be observed that the failure probability previously discussed represents the first branching (fail versus no fail) in a simulation of a component's reliability.

The fix level branches define: 1) the repair protocol (which may stretch over several years, e.g., emergency repair in year 1 with replacement in year 2); 2) the repair cost; 3) the service disruption type and duration; and 4) the reliability adjustment (if applicable).

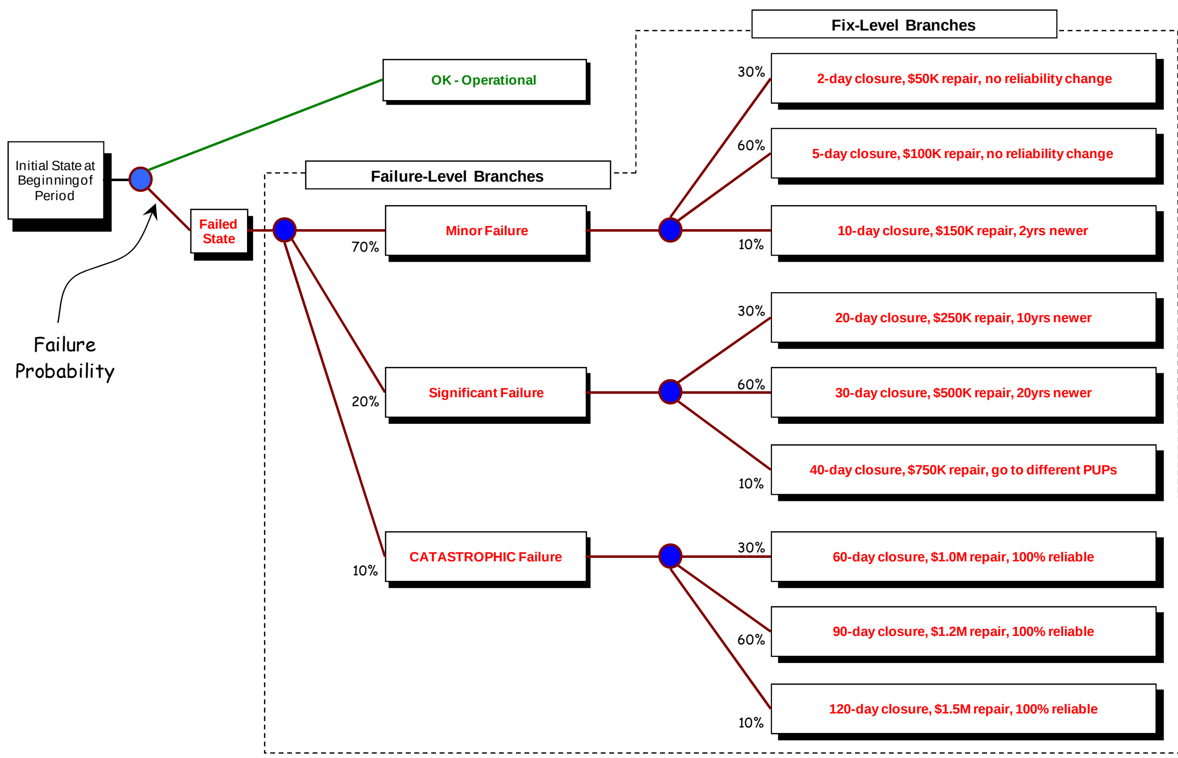
It is important to note that an event-tree represents only one time period (i.e., year). In effect, over the planning period or life-cycle, the event-tree is appended to itself year after year and as a result the event-tree must be allowed to morph or transform through time depending upon preceding events (failures). The ORNIM component event-tree allows the storage of the failure level branch probabilities by year, thus allowing the user to change the failure level branch weights through time. Typically the engineering reliability analysis concludes that the more severe failure level branches should become more heavily weighted through time. Of particular interest, however, is the reliability adjustment post failure-repair and its affect on transformation of failure probabilities through time.

Often after a repair the reliability of the component is improved. The post failure-repair of a minor failure may result in no change to the component's future reliability. The post failure-repair of a major failure may result in a significant rehabilitation of the component and may result in the component's reliability to "re-set" as *n*-years newer or as new (i.e., reset to age 0). The post failure-repair of a catastrophic failure may result in a replacement of the component where the engineering recommendation is to consider the component 100% reliable for the remainder of the planning period (life-cycle). The post failure-repair may

[19] Despite this, the model's original database table was named "*HazardFunction*" (section 1.4.5.4) and is yet to be changed.

even necessitate the use of a completely different failure probability curve and/or a completely different event-tree. This complexity demonstrates the need for simulation techniques to estimate the expected life-cycle impacts and costs.

FIGURE 1.2.26 – ORNIM Event-Tree Structure



ORNIM allows for this transformation of the event-tree and its failure probability curve through time through the planning period (life-cycle) simulation by a dynamic: 1) specification of the failure probability curve; 2) specification of the event-tree; 3) adjustment of the component's relative or reliability age (as opposed to its actual age); and 4) adjustment of the event-tree failure-level branch weights. If fact, with this dynamic failure probability and event-tree transformation the modeling constraint that components must be independent of one another can be somewhat circumvented by defining the interrelated components as sub-components under a component, and capturing the interrelationships between the sub-components by specifying new failure probability curves and event-trees off each event-tree branch. In other words, either the failure-level or repair-level branches (FIGURE 1.2.26) could be specified as a sub-component failure with the resulting post failure-repair failure probability curve and event-tree representing the risk of the remaining sub-components (assuming the interrelated effect).

These dynamic adjustments though the planning period demonstrates the need to load ORNIM with the PUP and not the hazard function (PUP assuming survival or no failure). In a life-cycle simulation, given whatever failure, repairs, and reliability re-sets might have occurred up to that simulated point in time in that particular simulation life-cycle iteration, the component may not have "*survived*", and hence the hazard function probability is inappropriate.

1.2.4.4.3.2 Chamber Level Engineering Random Minor Reliability Data

Engineering reliability can also be defined at a chamber level through a simple fixed probability. For example the existing chamber might be defined with a 4% probability of having a 3-day closure while a new replacement chamber might be defined with a 0.5% probability of having a 1-day closure. This unscheduled closure specification is reserved to what is referred to as random minor events (i.e., noise). In the tonnage-transit curve development, typically random service disruptions of 1-day or less are typically simulated. These events capture weather related events and short mechanical service disruptions. The engineering random minor events capture the reliability issues not directly captured with the components (e.g., components that didn't warrant full-blown reliability analysis).

1.2.4.4.3.3 Calculation of Expected Life-Cycle Repair Costs

The component engineering reliability data (PUPs and event-trees) are simulated through the analysis period and not through the complete planning period (FIGURE 1.2.21). This assumes survivability of all components to the decision point (i.e., base year). While there is risk during the study and construction periods, it is inappropriate to incorporate this risk in the planning decision since it could under estimate project benefits and skew the selection of the NED plan.

Simulation of the component's life-cycle is done in the model in a separate module from the equilibrium process (see section 1.3.3) and results in three primary outputs: life-cycle expected repair costs, probabilities of service disruptions, and survivability. The probabilities of service disruptions summarizes the probability of experiencing each service disruption (e.g., 10-day main chamber closure or 15-day half-speed chambering in the auxiliary chamber) in each year of the analysis period. The probabilities of service disruptions are then used to adjust the WOPC scheduled-maintenance equilibrium-scenario for reliability (unscheduled service disruption) as described in sections 1.2.4.4.3.5 through 1.2.4.4.3.12. Survivability summarized the probability of component survival through time. Survival is defined by whether the component is replaced as part of the repair.

1.2.4.4.3.4 River Closure Response Data

In the engineering reliability analysis of the Upper Ohio River projects there was determined a potential failure consequence of closure of both lock chambers, which would result in a complete river closure. The Upper Ohio River shippers were surveyed to ascertain their responses to various duration river closure situations. The river closure response was summarized for events less than 15-days, 15 to 60-days and greater than 60-days. The response summarized as either a: 1) wait / re-schedule; or 2) divert overland. With the divert overland response, a diversion transportation rate and a diversion externality cost[20] was also estimated for input into the model.

While this surveyed river closure response data was at a commodity dock-to-dock level, remember that the flow data is aggregated to a modeling movement level (section1.2.4.2.1). This then necessitated the aggregation of the diversion response, the diversion transportation rate, and the diversion externality cost. Since not all dock-to-dock movements aggregated to a modeling movement level contain the same river closure response, in the aggregation process a percentage of the model movement with a river closure diversion response is calculated. This movement river closure response diversion percentage is assumed constant for the movement through the analysis period[21].

It should be noted that the dock-to-dock mix of traffic can vary through time as different dock-to-dock flows grow and others decline, and thus the river closure diversion response percentage could vary. Since dock-to-dock growth rates vary between forecasted demand scenarios, the river closure diversion response percentage can also vary by forecast scenario. The sensitivity of this percentage through time and between forecast scenario is dependent upon whether multiple river closure responses (i.e., wait or divert) are aggregated in the model's movement level. In the Upper Ohio analysis and given the movement aggregation level, the assumption of a constant river closure diversion response percentage through time and between forecast scenarios is not considered significant. Under the movement level aggregation, 815 of the 879 (93%) movements containing a diversion response were completely diverted.

The aggregation of the diversion transportation rate and the diversion externality cost is more straightforward. These aggregations do not require weighting of the movement's diversion percentage

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[20] These externality costs should not and are not utilized in the model to determine investment viability, and are only estimated for informational purpose.

[21] The model's database design and code does allow for specification of the river closure diversion response percentage by year, however, the data was not available to specify these percentages by forecast scenario (making the yearly adjustments meaningless).

since they only apply to the tonnage diverted. The aggregation is only a tonnage weighting of the dock-to-dock flows aggregated.

1.2.4.4.3.5 Adjustment 1 – River Closure Response Traffic Adjustment

Given the investment option scheduled-maintenance equilibrium-scenario and the probabilities of service disruptions through time, years containing potential river closure events are isolated and equilibrium traffic indicating river closure response diversion is diverted. Given the probabilistic nature of service disruptions, the river closure event will most-likely have a potential of occurring in all years, except when the investment option contains an investment that eliminates the risk. This is of course dependent upon the alternative or alternatives in the investment options and on the engineering reliability data entered.

For each movement with a river closure diversion response percentage greater than 0%, the movement's equilibrium tonnage is multiplied by a diversion ratio to determine the amount of the annual equilibrium tonnage to divert from the system. The diversion ratio is different than the river closure diversion response percentage. Remember that the river closure event could be specified through the engineering reliability data as having any duration. The equilibrium tonnage should not be reduced by the movement's diversion percentage (which would assume a year long river closure), but by a diversion ratio that considers the duration of the river closure event. The diversion ratio is the diversion percentage of the movement times the closure period in days divided by 365.

$$RCRDTy_e = EqTy \times \frac{RCRDPct}{100} \times \frac{Days_e}{365} \qquad (1.2\text{-}5)$$

where:

$RCRDTy_e$ = the movement's expected diversion tonnage for year y given event e
e = the river closure service disruption event (defines level and duration)
$EqTy$ = the movement's equilibrium tonnage for year y
$RCRDPct$ = the movement's river closure response diversion percentage
$Days_e$ = the river closure duration in days for event e

Note that these calculations are done for all applicable years, for all applicable movements, and for all potential river closure duration events in each year. The expected river closure response diversion tonnage for the specified movement for a specified year y is then:

$$ERCRDT_y = \sum_{e=1}^{E} \left(RCRDTy_e \times \Pr oby_e \right) \qquad (1.2\text{-}6)$$

where:

$ERCRDT_y$ = the movement's expected diversion tonnage for year y
e = the river closure service disruption event (defines level and duration)
$RCRDTy_e$ = the movement's diversion tonnage calculated for the river closure event e in year y
$Proby_e$ = the probability of the event e in year y

The total expected river closure response diversion tonnage would be the summation of all expected movement diversions. This number is calculated and saved in the model output.

Similarly, the expected equilibrium tonnage for the specified movement for a specified year y is then:

$$EEqT_y = \sum_{e=1}^{E} \left[\left(EqT_y - RCRDTy_e \right) \times \Pr oby_e \right] \qquad (1.2\text{-}7)$$

where:

$EEqT_y$ = the movement's expected equilibrium tonnage for year *y*
e = the river closure service disruption event (defines level and duration)
EqT_y = the movement's scheduled-maintenance equilibrium-scenario tonnage for year *y*
$RCRDTy_e$ = the movement's diversion tonnage calculated for the river closure event *e* in year *y*
$Proby_e$ = the probability of the event *e* in year *y*

The total expected equilibrium tonnage would be the summation of all expected movement equilibrium tonnages. This number is calculated and saved in the model output.

1.2.4.4.3.6 Adjustment 2 – RCR Diversion Transportation Cost Calculation

For each movement identified as potentially diverting entirely or partially from the waterway to an overland routing in response to a river closure event, a river closure diversion transportation rate (in dollars per diverted ton) was calculated and loaded into the model. For the movement tonnage identified as river closure response diverted (as discussed in section 1.2.4.4.3.5), two cost calculations are made.

First, the diverted tonnage is multiplied by the river closure diversion transportation rate specific to that movement to derive the transportation costs for this diverted traffic. This river closure diversion transportation cost is then multiplied by the river closure event probability to derive the expected river closure diversion transportation cost for the movement. The expected diversion transportation cost for the specified movement for a specified year *y* is then:

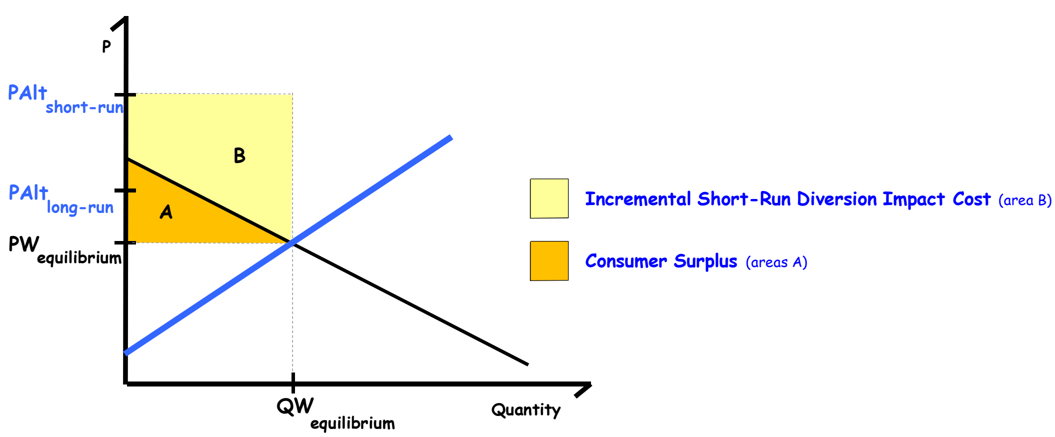
$$\text{ERCRDTC}_y = \sum_{e=1}^{E} \left(RCRDTy_e \times \begin{matrix} \textit{Diversion} \\ \textit{Rate} \end{matrix} \times Proby_e \right) \qquad (1.2\text{-}8)$$

where:

$ERCRDTC_y$ = the movement's expected diversion transportation cost for year *y*
e = the river closure service disruption event (defines level and duration)
$RCRDTy_e$ = the movement's diversion tonnage calculated for the river closure event *e* in year *y*
$Proby_e$ = the probability of the event *e* in year *y*

Second, only the incremental diversion cost is calculated as shown in FIGURE 1.2.27. The diverted tonnage consumer surplus (area A) is subtracted from the product of the diverted tonnage multiplied by the movement specific river closure diversion transportation rate minus it's waterway equilibrium rate. This river closure diversion transportation impact cost is then multiplied by the river closure event probability to derive the expected river closure diversion transportation impact cost for the movement.

FIGURE 1.2.27 – Transit Time Adjustment – no diversion (service disrupted lock)



The expected diversion transportation impact cost for the specified movement for a specified year *y* is then:

$$ERCRDTIC_y = \sum_{e=1}^{E}\left(\left(RCRDTy_e \times \left(\begin{matrix}Diversion\\Rate\end{matrix} - \begin{matrix}WW\\Equil.\\Rate\end{matrix}\right) - TS\right) \times Proby_e\right) \qquad (1.2\text{-}9)$$

where:

$ERCRDTIC_y$ = the movement's expected diversion transportation impact cost for year *y*
e = the river closure service disruption event (defines level and duration)
$RCRDTy_e$ = the movement's diversion tonnage calculated for the river closure event *e* in year *y*
TS = transportation or consumer surplus (see section 1.2.5)
$Proby_e$ = the probability of the event *e* in year *y*

Note that these calculations are done for all applicable years, for applicable movements, and for all potential river closure duration events in each year. The total expected river closure response diversion transportation cost and impact cost would be the summation over all years, movements, and events.

The diversion transportation cost (equation (1.2-8)) is calculated for information. The diversion transportation impact cost (equation (1.2-9)) is calculated for use in the cost-benefit analysis of an investment. This impact cost is used in the cost-benefit analysis because in the extreme short-run, elasticity of demand is much more inelastic than in the long-run and the impact of the unscheduled waterway service disruption on shippers is an understated by only counting the reduction in waterway transportation surplus. Numerous postmortem lock closure event studies document impacts in excess of shipment rate-savings. Addition of this incremental land transportation charge is a way to proxy the extra willingness-to-pay for shipping on the waterway in the extreme short-run.

1.2.4.4.3.7 Adjustment 3 – RCR Diversion Externality Cost Calculation

For each movement identified as potentially diverting entirely or partially from the waterway in response to a river closure event, a diversion externality cost (in dollars per diverted ton by year) for five land transportation externality categories were estimated and loaded into the model. The externality categories included: 1) truck induced road delay; 2) truck induced accidents; 3) truck emissions; 4) non-delay truck accident and emission; and 5) rail / barge emission. These estimates varied by year as land congestion was forecasted to increase (see Attachment 5 External Costs of Diverted EDM Traffic).

For the tonnage identified as river closure response diverted (as discussed in section 1.2.4.4.3.5), the tonnage is multiplied by each of the land transportation externality cost categories to derive the externality impacts for this diverted traffic. These land externality impacts are then multiplied by the river closure event probability to derive the expected land transportation externality costs.

As with the river closure diversion transportation cost, these diversion externality cost calculations are done for all applicable years and for all potential river closure duration events in each year. The expected diversion externality cost for a specified year *y* is then:

$$ERCRDEC_y = \sum_{e=1}^{E}\left[\sum_{ECat=1}^{5}\left(RCRDTy_e \times ECy_{ECat} \times \Pr oby_e\right)\right] \qquad (1.2\text{-}10)$$

where:

$ERCRDEC_y$ = the movement's expected diversion externality cost for year *y*
e = the river closure service disruption event (defines level and duration)
ECat = the externality category (1-5)
$RCRDTy_e$ = the movement's diversion tonnage calculated for the river closure event *e* in year *y*
ECy_{ECat} = the externality cost per ton for externality category *ECat* in year *y*
$Proby_e$ = the probability of the event *e* in year *y*

The total expected river closure response diversion externality cost would be the summation of all expected movement diversion externality costs. This number is calculated and saved (by cost type) in the model output.

Note that these externality costs are not utilized in the fitness metric and are not part of investment optimization. Beyond Corps' policy not advocating any of the externality categories as NED, the calculations at this time only address river closure diversions and not unscheduled over capacity diversions (section 1.2.4.4.3.8). It should also be noted that the exogenous calculation of the dollar values of externalities such as emissions and accidents are subject to a considerable amount of uncertainty and sensitive to the mode, routing, and time of day assumptions. As a result, these inputs and the resulting model calculations are much more uncertain than the other model calculations.

1.2.4.4.3.8 Adjustment 4 – Over Capacity Traffic Adjustment

For the river closure event, and for that matter any service disruption, the equilibrium traffic level at the lock may exceed the physical capacity in years that the event occur. The physical capacity may be exceeded even after the river closure response diverted traffic is removed. In unscheduled service disruption situations where the equilibrium traffic level exceeds the physical capacity of the lock, traffic (or additional traffic) must be removed (diverted) from the system.

Each tonnage-transit curve has an inherent capacity constraint for the total annual tonnage that can transit the lock. This is defined by the highest (tonnage, transit time) pair supplied as input and is assumed by the model to be the maximum working (physical) capacity of the lock. In these cases, the model removes tonnage from all equilibrium movements transiting the lock to achieve a total tonnage equal to the maximum working capacity of the lock. All movements transiting the lock (after the river closure response diverted traffic is removed) will be reduced by the same proportion to lower the traffic level to the maximum working capacity limit. The reduction ratio is calculated as:

$$\text{Over Capacity Reduction Ratio} = \frac{\text{Maximum Working Annual Capacity}}{\text{Lock Equilibrium Tonnage (after RCR traffic diversions)}} \qquad (1.2\text{-}11)$$

Given the investment option scheduled-maintenance equilibrium-scenario (adjusted for river closure response diversions) and the probabilities of service disruptions, years containing service disruptions are isolated and checked for an over capacity situation.

When an over capacity situation is encountered, each equilibrium movement has its equilibrium tonnage (after the river closure response diversion adjustment) multiplied by the over capacity reduction ratio to determine the adjusted equilibrium tonnage. Similarly, to determine the over capacity diverted tonnage, each equilibrium movement has its equilibrium tonnage (after the river closure response diversion adjustment) multiplied by 1 minus the over capacity reduction ratio:

$$OCDTy_e = EqTy' \times (1 - OCRR) \qquad (1.2\text{-}12)$$

where:

$OCDTy_e$ = the movement's expected diversion tonnage for year *y* given event *e*
e = the service disruption event (defines level and duration)
EqTy' = the movement's equilibrium tonnage for year *y* (after RCR adjustment)
OCRR = over capacity reduction ratio

Note that these calculations are done for all applicable years, for all applicable movements, and for all over capacity service disruption events in each year. The expected over capacity diversion tonnage for the specified movement for a specified year *y* is then:

$$EOCDT_y = \sum_{e=1}^{E} \left(OCDTy_e \times \Pr oby_e \right) \quad (1.2\text{-}13)$$

where:

$EOCDT_y$ = the movement's expected over capacity diversion tonnage for year *y*
e = the service disruption event (defines level and duration)
$OCDTy_e$ = the movement's over capacity diversion tonnage calculated for event *e* in year *y*
$Proby_e$ = the probability of the event *e* in year *y*

The total expected over capacity diversion tonnage would be the summation of all expected movement diversions. This number is calculated and saved in the model output.

Similarly, the expected equilibrium tonnage for the specified movement for a specified year *y* is then:

$$EEqT_y' = \sum_{e=1}^{E} \left[\left(EqT'_y - OCDTy_e \right) \times \Pr oby_e \right] \quad (1.2\text{-}14)$$

where:

$EEqT_y'$ = the movement's expected equilibrium tonnage for year *y*
e = the river closure service disruption event
EqT_y' = the movement's equilibrium tonnage (after RCR diversions) for year *y*
$OCDTy_e$ = the movement's over capacity diversion tonnage calculated for event *e* in year *y*
$Proby_e$ = the probability of the event *e* in year *y*

The total expected equilibrium tonnage would be the summation of all expected movement equilibrium tonnages. This number is calculated and saved in the model output.

1.2.4.4.3.9 Adjustment 5 – OC Diversion Transportation Cost Calculation

For the tonnage identified as over capacity diverted (as discussed in section 1.2.4.4.3.8), as with the river closure response diversion, two cost calculations are made.

First, the diverted tonnage is multiplied by the movement's base alternative rate (the least-costly all-overland rate) to derive the transportation costs for this diverted traffic. This over capacity diversion transportation cost is then multiplied by the river closure event probability to derive the expected over capacity diversion transportation cost. The expected diversion transportation cost for the specified movement for a specified year *y* is then:

$$EOCDTC_y = \sum_{e=1}^{E} \left(OCDTy_e \times \text{Base Alt. Rate} \times Proby_e \right) \quad (1.2\text{-}15)$$

where:

$EOCDTC_y$ = the movement's expected over capacity diversion transportation cost for year *y*
e = the river closure service disruption event (defines level and duration)
$OCDTy_e$ = the movement's over capacity diversion tonnage calculated for event *e* in year *y*
$Proby_e$ = the probability of the event *e* in year *y*

Second, the diverted tonnage is multiplied by the movement specific diversion transportation rate minus it's base alternative rate. This over capacity diversion transportation impact cost is then multiplied by the service disruption event probability to derive the expected over capacity diversion transportation impact cost for the movement. The expected diversion transportation impact cost for the specified movement for a specified year *y* is then:

$$EOCDTIC_y = \sum_{e=1}^{E} \left(OCDTy_e \times \left(\begin{matrix} Diversion \\ Rate \end{matrix} - \begin{matrix} Base \\ Alt. \\ Rate \end{matrix} \right) \times Proby_e \right) \qquad (1.2\text{-}16)$$

where:

$EOCDTIC_y$ = the movement's expected over capacity diversion transportation cost for year *y*
e = the river closure service disruption event (defines level and duration)
$OCDTy_e$ = the movement's over capacity diversion tonnage calculated for event *e* in year *y*
$Proby_e$ = the probability of the event *e* in year *y*

Note that these calculations are done for all applicable years, for applicable movements, and for all over capacity service disruption events in each year. The total expected over capacity diversion transportation cost and impact cost would be the summation over all years, movements, and events.

The diversion transportation cost (equation (1.2-15)) is calculated for information. The diversion transportation impact cost (equation (1.2-16)) is calculated for use in the cost-benefit analysis of an investment. This impact cost is used in the cost-benefit analysis because in the extreme short-run, elasticity of demand is much more inelastic than in the long-run and the impact of the unscheduled waterway service disruption on shippers is an understated by only counting the reduction in waterway transportation surplus. Numerous postmortem lock closure event studies document impacts in excess of shipment rate-savings. Addition of this incremental land transportation charge is a way to proxy the extra willingness-to-pay for shipping on the waterway in the extreme short-run.

1.2.4.4.3.10 **Adjustment 6 – Waterway Transportation Cost Recalculation, no diversion**

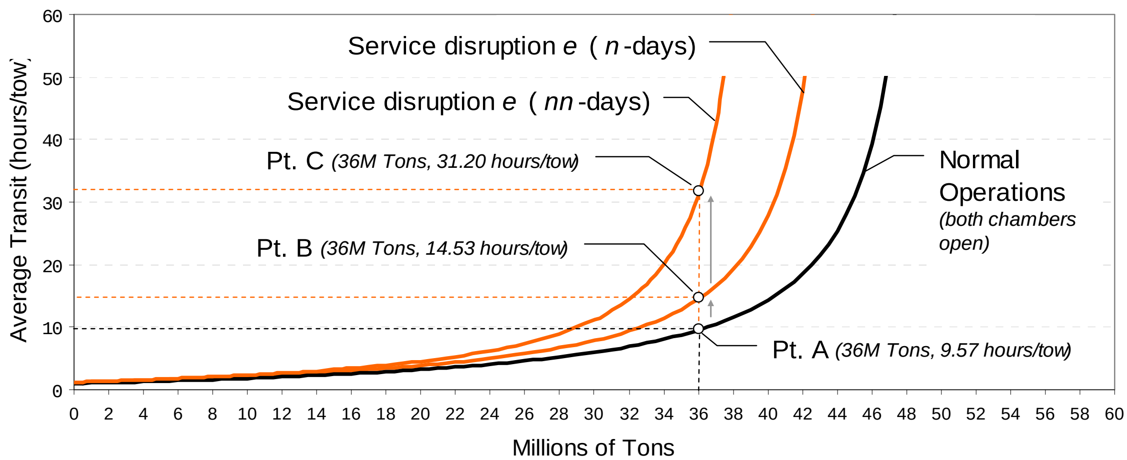
The recalculation of waterway transportation costs given a service disruption are done in two different ways depending upon the circumstance. With diverted equilibrium tonnage resulting from river closure response and / or over capacity situations, the calculation is more complex and will be discussed in the next section (1.2.4.4.3.11). Service disruption events without a diversion of waterway traffic will be described in this section.

Say for a specified year the investment option scheduled-maintenance equilibrium-scenario total traffic at the specified lock is 36 million tons with an average tow transit time of 9.57 hours per tow (point A FIGURE 1.2.28). Say in this year there is a *p*% chance of experiencing an *n*-day service disruption and a *q*% chance of experiencing an *nn*-day service disruption. Since none of the equilibrium traffic is diverted because of a river closure diversion response or an over capacity situation, the transportation cost increase only occurs at the lock where the service disruption occurs. For this lock a new average transit time is pulled from the *n-day* and *nn-day* tonnage-transit curves representing the two service disruption events.

In this example the average transit time for the 36 million tons increases from a normal operation average of 9.57 hours per tow to 14.53 hours per tow for service disruption of *n*-days (point B in FIGURE 1.2.28) and to 31.20 hours per tow for service disruption of *nn*-days. The increased trip times of 4.96 and 21.63 hours per tow are multiplied by the equilibriums average hourly transit cost (calculated from the lock's total transit time cost for the specified year divided by the transit hours in the year) and added to the system's waterway transportation costs.

Calculation of the expected waterway transportation costs cannot be done until the waterway transportation costs under the service disruption events with traffic diversion is calculated in the next section (1.2.4.4.3.11).

FIGURE 1.2.28 – Transit Time Adjustment – no diversion (service disrupted lock)



1.2.4.4.3.11 **Adjustment 7 – Waterway Transportation Cost Recalculation, with diversion**
Given the investment option scheduled-maintenance equilibrium-scenario and the probabilities of service disruptions through time, the previous steps may have diverted equilibrium tonnage as a result of river closure response or over capacity situations. For the river closure response diversion (if applicable), diversion externality costs have been calculated and saved (but not used in the fitness metric or in the investment plan cost-benefit analysis). Additionally, diversion transportation costs in excess of the long-run land rate have been calculated and saved for use in the fitness metric (section 1.2.4.1.4) and in the final investment plan cost-benefit analysis. Only the incremental land transportation rate is used here since the movement's consumer surplus (which is subtracted from the benefits) already accounts for the cost of diversion under a long-run alternative land rate. For the over capacity diversion (if applicable), given the assumption is that the diversion can be made at the long-run alternative land rate[22], no transportation cost for these over capacity diversions is calculated since the barge transportation consumer surplus already accounts for the diversion cost (in the long-run).

This diversion of traffic from the system, however, has a beneficial effect on the remaining traffic by reducing congestion at all the projects this diverted traffic use to transit. The simplified transportation cost adjustment described in section 1.2.4.4.3.10 cannot be used since the traffic mix at the affected locks will change and the equilibriums average hourly transit cost (calculated from the lock's total transit time cost for the specified year divided by the transit hours in the year) will no longer be applicable.

Instead, for each potential service disruption event that diverts traffic, the average transit time at each lock in the system is checked and reset where appropriate given the adjusted equilibrium movements. At the lock where the service disruption occurs, the new average transit time is pulled from the tonnage-transit curve developed assuming the specified service disruption, utilizing the lower adjusted traffic level. For all other projects in the system, their average transit times are still pulled from their normal-operations tonnage-transit curves. If the lock's adjusted traffic level is unchanged, the average transit time remains the same. If the lock's adjusted traffic level is now lower, a new (lower) average transit time is pulled from its normal-operations tonnage-transit curve.

Say for a specified year the investment option scheduled-maintenance equilibrium-scenario total traffic at Project A is 41 million tons with an average tow transit time of 16.2 hours per tow (point A FIGURE 1.2.29). Say in this year there is a *p*% chance of experiencing an *n*-day service disruption and a *q*% chance of experiencing an *nn*-day service disruption. Say that these two events (n-day and nn-day) do not result in a river closure traffic diversion response. In this example for the *n*-day event the average

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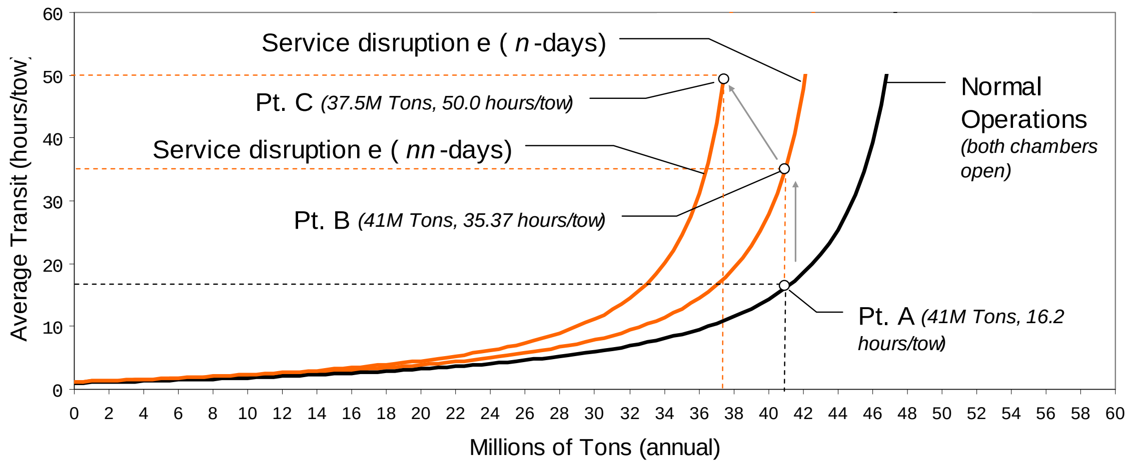
[22] This assumption is made primarily because unscheduled short-run land rates were only obtained for river closure events.

transit time for the 41 million tons increases from a normal operation average of 16.2 hours per tow to 35.37 hours per tow; point B in FIGURE 1.2.29. For the *nn*-day event, however, there is a capacity constraint. The nn-day tonnage-transit curve has a capacity limit of 37.5 million tons. In this situation, all movements transiting the lock (the 41 million tons) are proportionally reduced to equal the capacity limit of 37.5 million tons. For the *nn*-day event the movement traffic levels are adjusted and the average transit time for the lock is increased from a normal operation average of 16.2 hours per tow to 50.0 hours per tow; point C in FIGURE 1.2.29.

FIGURE 1.2.29 – Transit Time Adjustment – with capacity diversion (project A)



Say again for a specified year the investment option scheduled-maintenance equilibrium-scenario total traffic at Project A is 41 million tons with an average tow transit time of 16.2 hours per tow (point A FIGURE 1.2.30). Say in this year there is a *p*% chance of experiencing an *n*-day service disruption and a *q*% chance of experiencing an *nn*-day service disruption. Say that these two events (n-day and nn-day) do have a river closure traffic diversion response of 2 million tons. In this example for the *n*-day event the average transit time increases from an average of 16.2 hours per tow to 22.87 hours per tow (shifting to the n-day tonnage-transit curve and dropping annual traffic 2 million tons) resulting in point B in FIGURE 1.2.30. For the *nn*-day event, however, there is an additional capacity constraint. Again the nn-day tonnage-transit curve has a capacity limit of 37.5 million tons. In this situation, all movements transiting the lock after the river closure diversion response (i.e., 39 million tons) are proportionally reduced to equal the capacity limit of 37.5 million tons. For the *nn*-day event the movement traffic levels are adjusted and the average transit time for the lock is increased from a normal operation average of 16.2 hours per tow to 50.0 hours per tow; point C in FIGURE 1.2.30.

For service disruption events that cause traffic diversion, the diverted tonnage might have transited other projects in the system. Say there is only one other project in our network (Project B) and say with the n-day event only 1 million tons of the 2 million tons of diverted traffic transited this next project and say with the nn-day event 3 million tons of the 4.5 million tons of diverted traffic transited this next project. Say also that this next project has the same tonnage-transit characteristics; however, the investment option scheduled-maintenance equilibrium-scenario traffic is 46 million tons as shown in FIGURE 1.2.31. Under service disruption event n-days at Project A the model will reduce the average transit times for the 45 million tons of remaining traffic at Project B from 39.3 hours per tow to 31.0 hours per tow. Under service disruption nn-days at Project A the model will reduce the average transit times for the 43 million tons of remaining traffic at Project B from 39.3 hours per tow to 21.48 hours per tow.

FIGURE 1.2.30 – Transit Time Adjustment – with river closure diversion (project A)

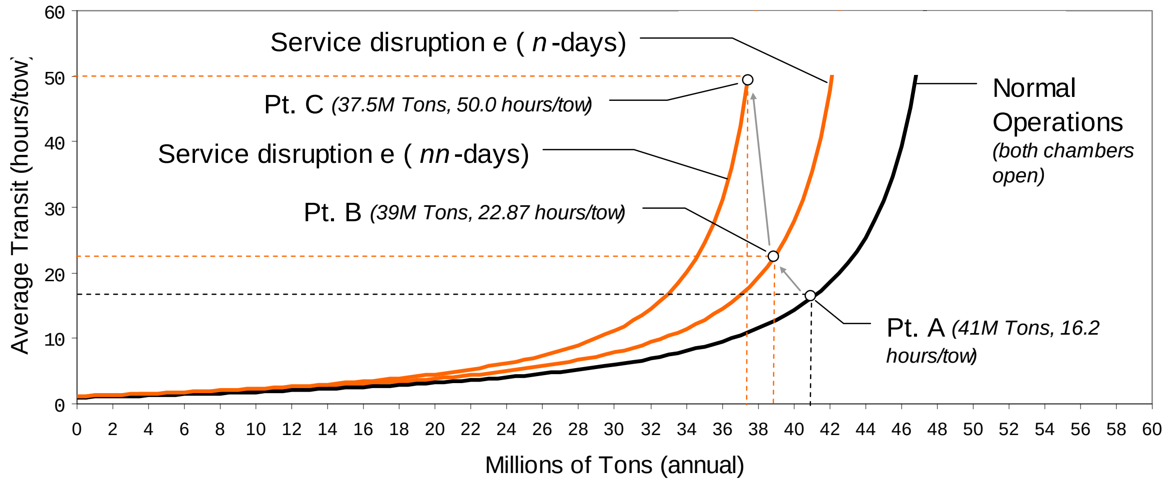
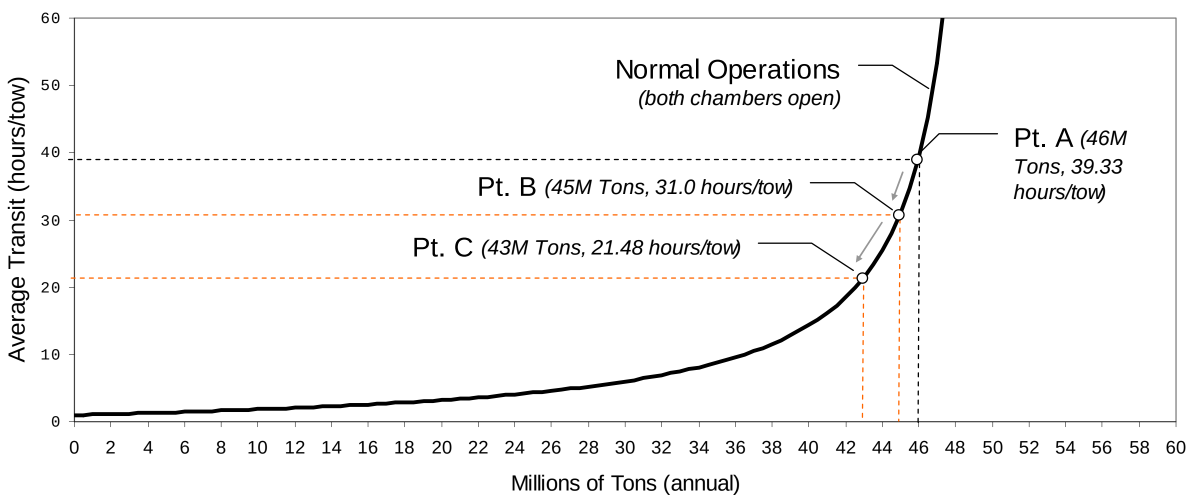


FIGURE 1.2.31 – Transit Time Adjustment – Project B given Project A Traffic Diversion



Given the adjusted traffic levels in the system and given the adjusted average transit times at each lock in the system (given the adjusted traffic levels); the transportation cost for each movement is then recalculated as:

$$WWTCy_{EqMvt'} = \left(\left(\sum_{\substack{\text{over all}\\ \text{locks}\\ \text{transited}}} \begin{pmatrix}\text{Lock Average}\\ \text{Transit Time}\\ \text{(hours)}\end{pmatrix} \times 2 \right) + \begin{matrix}\text{Trip Link}\\ \text{Travel Time}\\ \text{(hours)}\end{matrix} + \begin{matrix}\text{Trip}\\ \text{Refleeting Time}\\ \text{(hours)}\end{matrix} \right) \times \begin{matrix}\text{Movement}\\ \text{Number of}\\ \text{Trips}\end{matrix} \times \begin{matrix}\text{Movement}\\ \text{Hourly Tow}\\ \text{Cost}\end{matrix} \quad (1.2\text{-}17)$$

where:

$WWTCy_{EqMvt'}$ = waterway transportation cost (dollars) for adjusted equilibrium movement in year *y*.

The lock average transit time is multiplied by 2 because the lock is transited twice in a round trip. The lock transit times are changed at the lock experiencing the service disruption, and the lock transit times at the other locks are changed if the service disruption has diverted traffic lowering the utilization level of these other locks. If the movement experiences a service disruption diversion, the number of trips is also recalculated (lowered).

1.2.4.4.3.12 **Adjustment 8 – Expected Waterway Transportation Costs**

As with the other probabilistic service disruption estimates, an expected value is created by weighting the impacts of the event by the probability of each service disruption event. Given the waterway transportation cost estimates for each of the potential service disruptions and the probability of service disruption, an expected waterway transportation cost is calculated. The expected diversion transportation cost for the specified movement for a specified year *y* is then:

$$\text{Expected } WWTCy_{EqMvt'} = \sum_{event=1}^{E} \left(WWTCy_{EqMvt'} \times Proby_{event} \right) \qquad (1.2\text{-}18)$$

where:

$WWTCy_{EqMvt'}$ = waterway transportation cost (dollars) for adjusted equilibrium movement in year *y*

$Proby_{event}$ = probability of service disruption event in year *y.*

The total expected waterway transportation cost would be the summation of all expected movement waterway transportation costs. This number is calculated and saved in the model output.

1.2.4.4.4 Investment Option Fitness Metric

Given the adjustments to the scheduled-maintenance equilibrium scenario discussed in the above sections, a fitness metric can be calculated for the probabilistic adjusted normal-operations equilibrium-scenario (aka "*prob no scheduled*") or the probabilistic adjusted scheduled-maintenance equilibrium-scenario (aka "*prob with scheduled*"), depending on the user's specification (see TABLE 1.4.82). The probabilistic values for each equilibrium-scenario are converted to a present value and amortized into a single average annual net benefit fitness metric to facilitate comparison of the RUN (runID) investment life-cycle equilibrium-scenario permutations.

The fitness metric considers the benefits realized by the movements (as measured by their contributions to the consumer surplus) and the costs that are incurred. The fitness metric is calculated by starting with the expected waterway consumer surplus benefits in each year and subtracting from that the costs (or expected costs) that occur in the year. These benefits and costs differ slightly depending upon whether or not scheduled maintenance is included. The expected waterway consumer surplus is calculated without and with the impacts of scheduled maintenance. The costs are calculated without and with the scheduled maintenance costs as shown below:

- Probabilistic adjusted normal-operations equilibrium-scenario (aka "*prob no scheduled*")
  - Expected river closure response diversion transportation impact cost (section 1.2.4.4.3.6).
  - Expected over capacity diversion transportation impact cost (section 1.2.4.4.3.9).
  - Expected normal operations and maintenance cost.
  - Expected investment option cost (if applicable).
  - Expected unscheduled maintenance / repair / replacement costs.
  - Expected increased waterway transportation cost due to unexpected closures.

- Probabilistic adjusted scheduled-maintenance equilibrium-scenario (aka "*prob with scheduled*")
  - Expected river closure response diversion transportation impact cost (section 1.2.4.4.3.6).
  - Expected over capacity diversion transportation impact cost (section 1.2.4.4.3.9).
  - Expected normal operations and maintenance cost.
  - Expected investment option cost (if applicable).
  - Expected unscheduled maintenance / repair / replacement costs.
  - Expected increased waterway transportation cost due to unexpected closures.
  - Cyclical scheduled maintenance cost.

It should be noted that the benefits and all these cost categories are expected values (i.e., probabilistically derived) except for the cyclical scheduled maintenance cost. As discussed, equilibrium is defined in the system with consideration of known system capacity. Next this equilibrium is adjusted probabilistically for unscheduled service disruptions. The adjustments to the land transportation costs for unscheduled diversions are tabulated under separate categories for analysis and review purpose.

As previously discussed diversion transportation impact costs reflect land transportation costs in excess of the long-run alternative base rate. This impact cost is used in the net benefit calculation because in the extreme short-run, elasticity of demand is much more inelastic than in the long-run and the impact of the unscheduled waterway service disruption on shippers is an understated by only counting the reduction in waterway transportation surplus. Addition of this incremental land transportation charge is a way to proxy the extra willingness-to-pay for shipping on the waterway in the extreme short-run.

1.2.4.5 Investment Cost-Benefit Analysis

As noted earlier, the model analyzes "*alternatives*" (i.e. investment options) which are packaged into "*RUNs*" and "*Investment Plans*" (IPs). The cost-benefit analysis in each is the same and much of the model code is then same. The difference is that investment analysis through a RUN offers automated model execution of investment option combinations and permutations which can then be used to optimize investment and investment timing as will be discussed below. In short, RUNS help the user formulate IPs which are run to capture all the investment system effects and to complete the cost-benefit analysis. In other words, in a "*RUN*" the timing of investments are optimized and in an IP the life-cycle costs and benefits are calculated with the investments and investment timing specified. Typically the results from one or more "*RUNs*" (i.e., do this or that investment at this or that point in time) is used to define the definition of the IP.

1.2.4.5.1 Expected Investment Option Cost

One would think that the investment option, normal operation, and cyclical scheduled maintenance costs would be point estimates defined by the investment option (i.e., implement investment in year *y* and change the normal O&M and cyclical maintenance costs after implementation). These costs, however, are adjusted to account for survivability of the components being replaced. In the simplest case, say the investment option being analyzed is the replacement of a single component. Say the engineering reliability information indicates the potential of a catastrophic component failure resulting in a repair that replaces the component. As a result, there is a probabilistic chance that the component is replaced through failure prior to the scheduled replacement. When the component does not survive to the scheduled replacement date, the scheduled replacement cost is not incurred. The model captures this adjustment by tracking a survivability probability as it tracks the probability of service disruptions. If the investment option is scheduled for implementation in year 2020 for $10 million dollars and the survivability is only 10% in year 2020, the expected implementation cost of this investment option is only $1 million.

An alternative, and its investment options, is often defined as something more than a single component (e.g., bundled components / rehabilitation, or new lock). Say the alternative is a rehabilitation of the main chamber and that the main chamber consists of 3 components (each with defined reliability). As previously noted, the alternative has a cost, a post implementation system and / or reliability change, and possibly an implementation service disruption. The post implementation reliability change requires specification by component. In our example, each of the 3 main chamber components are specified with a reliability change ranging from no change in the reliability to deleting the component resulting in no future risk (100% reliable). In fact, implementation of an alternative can also create a new component which can generate future risk.

By specification in the alternative definition of which components are deleted and which components have their reliability increased, the model can then track a joint replacement probability of these components. Say that our investment option includes our main chamber rehabilitation example alternative. Say again the investment option is scheduled for implementation in year 2020 for $10 million dollars. If the probability of all three components catastrophically failing and being replaced by year 2020 is 10%, the expected implementation cost for this investment option is only $1 million.

1.2.4.5.1 RUN Output

Given the fitness metric (net benefit) summarization of the life-cycle costs and benefits for the various investment schemes and permutations, comparisons and investment optimization can be easily made through use of a model "*RUN*" specification. The optimization technique[23] relies on a complete enumeration of investment permutations which is quite CPU intensive. As a result, the investment search space in the specification of a "*RUN*" should be used resourcefully.

The RUN (runID) analyzes an alternative or alternatives over a user specified implementation range and selects the optimal investment option. Remember also that an alternative can range from replacement of a single component to a package of multiple investments across multiple sites. For each alternative listed in the RUN (through the AlternativeRunXRef table), the alternative is specified with an implementation range to be considered / analyzed, and may be specified as a "*must do*" alternative, meaning that it must be implemented within its implementation range (which may be fixed to a single year). When an alternative is entered with an implementation range, the model will analyze implementation of that alternative in each year of the implementation range and compare the results against the no implementation scenario. Any alternatives listed as "*must do*" are automatically implemented in all of the analysis scenarios. The "*must do*" option can allow for currently authorized projects (e.g., Olmsted, Greenup extension, etc.) to come online and change the waterway system transportation characteristics at the appropriate time.

When multiple alternatives are specified with implementation ranges, the model will analyze the implementation permutations and again compare the results against the no implementation scenario. The RUN result specifies the optimal NED alternative, or alternatives, with implementation year(s) if economically justified over the no implementation scenario.

Typically in an analysis, the user will define an alternative for each component replacement along with RUNs to analyze the replacement of each component in isolation of the other components. Next the user typically structures RUNs to allow individual component replacements to compete. Given the results of this component-level analysis, the user then defines additional alternatives for bundled component replacements, lock extensions, lock replacements, chamber rehabilitation, and so on. Then RUNs are structured to allow analysis of the additional alternatives in isolation and in competition with other alternatives. For discussion to describe the model's selection of the optimal investment option, in the following section we will use an alternative and the RUNs analyzing a single component replacement.

1.2.4.5.1.1 Single Alternative Optimization

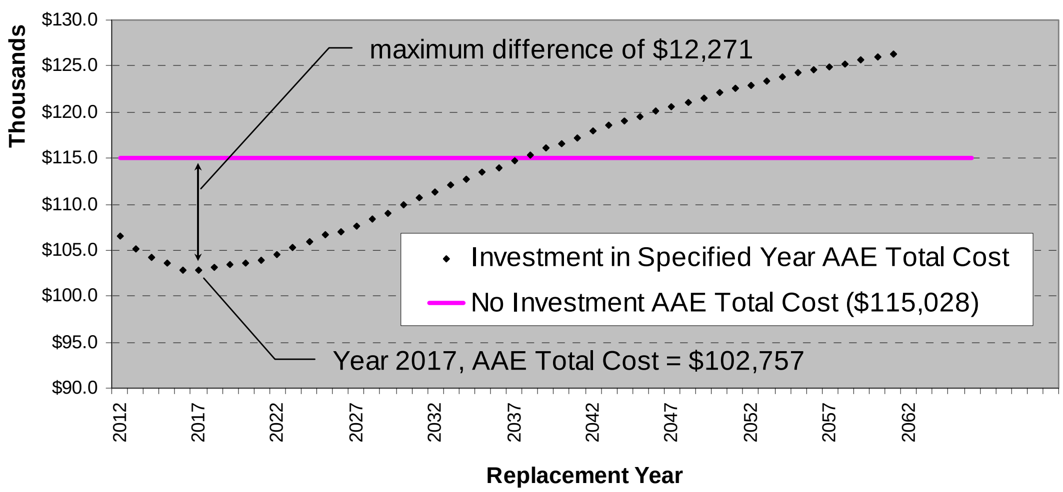
In our example, the RUN is set with one alternative (e.g., single component replacement) with an implementation period range equal to the planning period (e.g., 3 years construction plus 50 years analysis period). Additionally, the RUN is set-up to ignore scheduled maintenance. This is typically done for component level optimization analysis to make the timing analysis smoother (analysis with scheduled maintenance considered is usually not done until more complex and complete alternatives are being analyzed). Despite ignoring the scheduled service disruptions, the RUN is set-up to consider probabilistic service disruptions since this is a primary consideration in the economic viability of a component replacement.

[23] Genetic Algorithm techniques are being explored for implementation in the model.

One of the life-cycle probabilistic equilibrium-scenarios to be estimated out of the RUN optimization is for "*no investment*", which serves as a base from which to compare all potential investment timing. The cost and benefit cash flow streams for this no investment alternative are discounted and amortized. Next the cost and benefit cash flow streams for each replacement timing alternative (in this case 53, one for each potential replacement year over the planning period) are estimated, discounted, and amortized. The alternative with the highest fitness metric (net benefit) is the selected optimized alternative.

One of the output displays plots the average annual costs (as defined in section 1.2.4.4.4) for each alternative as shown in FIGURE 1.2.32. Here the no investment cost is represented by a horizontal line while each replacement timing alternative is represented by a diamond on the replacement year. In our example, the average annual no investment cost is $115,028 while the minimum cost alternative where the component is replaced in year 2017 is $102,757.

FIGURE 1.2.32 – Auto-Optimization – Alternative Timing Analysis



Minimum cost is equivalent to maximum fitness metric (net benefit) since minimum cost means minimum service disruption which will maximize water transportation consumer surplus. Investment option costs less than the no investment cost are economically justified. In the example, implementation of the alternative (component replacement) in years 2012 through 2037 are economically justified, however, it can be observed that not all replacement years are equal and that some offer a greater overall cost reduction which indicates a larger benefit to cost difference (i.e., greater net benefits and higher benefit-to-cost ratio). The model identifies the investment option that maximizes net benefits, and in this example the investment option with the implementation year of 2017 would be identified as the optimal investment option.

With the year 2017 implementation of the investment, costs are reduced an average annul of $102,757. This foregone cost, however, is not a benefit since this cost has imbedded within it the alternative cost and its interest during construction costs. All cost categories are tracked so a traditional cost-benefit layout can be generated through running of an IP (discussed in section 1.2.4.5.2).

1.2.4.5.1.2 **Multiple Alternative Optimization**

A similar optimization process (i.e., complete enumeration) is followed for RUNs specified with multiple alternatives. Each investment option (i.e., element of the alternative mix) is structured so that the implementation periods of the alternatives do not overlap. In short, multiple alternatives cannot be implemented in the same year. Remember however, that alternatives can be specified with multiple implementation years. So if an alternative has a 3-year implementation and its implementation is scheduled for years 1-3, the next alternative cannot be scheduled to start its implementation until year 4. If the user desires overlapping alternatives, a separate alternative is defined with the overlapping investments (e.g., component replacements).

1.2.4.5.2 Investment Plan Output

The investment plan analyzes a plan composed of multiple runIDs (which are optimized alternatives) and summarizes the results for development of a more typical cost-benefit layout. The investment plan does no optimal timing and is used only to combine multiple investment options and re-equilibrate the system to ascertain the system effect of all the alternatives together in the system. An investment plan is composed of one or more investment options (i.e., timed alternatives) and represents a formulated investment plan. The IP output consists of the yearly costs (see 1.2.4.4.4), waterway transportation surplus, and lock performance statistics. For each IP these cash flows are itemized, discounted, amortized, and summarized in two output EXCEL workbooks:

- IP-SystemStatistics*.xls – for a given IP this workbook contains system-level yearly statistics under all four equilibrium-scenarios (Normal-operations, Scheduled-maintenance, Probabilistic without scheduled maintenance, and Probabilistic with scheduled maintenance) and under all forecasted demand scenarios. Note that most of the statistics for the probabilistic equilibrium-scenarios are actually expected values. The statistics displayed include yearly (and amortized where appropriate):
  - Waterway system tonnages
    - Normal-operations equilibrium waterway system tonnage
    - Scheduled maintenance equilibrium waterway system tonnage
    - Probabilistic (WO sch.maint.) equilibrium waterway system tonnage
    - Probabilistic (with sch.maint.) equilibrium waterway system tonnage
  - Total system transit days
    - Normal-operations equilibrium waterway system transit days
    - Scheduled maintenance equilibrium waterway system transit days
    - Probabilistic (WO sch.maint.) equilibrium waterway system transit days
    - Probabilistic (with sch.maint.) equilibrium waterway system transit days
  - Waterway transit costs
    - Normal-operations equilibrium waterway system transit costs
    - Scheduled maintenance equilibrium waterway system transit costs
    - Probabilistic (WO sch.maint.) equilibrium waterway system transit costs
    - Probabilistic (with sch.maint.) equilibrium waterway system transit costs
  - Waterway transportation surplus
    - Normal-operations equilibrium waterway transportation surplus
    - Scheduled maintenance equilibrium waterway transportation surplus
    - Probabilistic (WO sch.maint.) equilibrium waterway transportation surplus
    - Probabilistic (with sch.maint.) equilibrium waterway transportation surplus
  - Waterway transportation base cost (identical for probabilistic scenarios)
    - Normal-operations equilibrium waterway transportation base cost
    - Scheduled maintenance equilibrium waterway transportation base cost
  - Waterway transportation equilibrium cost (identical for probabilistic scenarios)
    - Normal-operations equilibrium waterway transportation equilibrium cost
    - Scheduled maintenance equilibrium waterway transportation equilibrium cost
  - Land transportation equilibrium cost (identical for probabilistic scenarios)
    - Normal-operations waterway equilibrium land transportation equilibrium cost
    - Scheduled maintenance waterway equilibrium land transportation equilibrium cost
  - Land transportation expected river closure diversion transportation cost
    - Probabilistic (WO sch.maint.) equilibrium river closure diversion transportation cost
    - Probabilistic (with sch.maint.) equilibrium river closure diversion transportation cost

- Land transportation expected river closure diversion externality cost
  - Probabilistic (WO sch.maint.) equilibrium river closure diversion externality cost
  - Probabilistic (with sch.maint.) equilibrium river closure diversion externality cost
- Land transportation over capacity diversion transportation cost
  - Probabilistic (WO sch.maint.) equilibrium over capacity diversion transportation cost
  - Probabilistic (with sch.maint.) equilibrium over capacity diversion transportation cost
- System investment cost
  - Investment cost under normal-operations (same for sch.maint. scenario)
  - Investment cost under probabilistic scenarios (WO and with sch.maint.)
- Scheduled repair cost
  - Scheduled repair cost for scheduled maintenance equilibrium scenario
  - Scheduled repair cost for Probabilistic (with sch.maint.) equilibrium scenario
- Unscheduled repair cost
  - Unscheduled repair cost for Probabilistic (WO sch.maint.) equilibrium scenario
  - Unscheduled repair cost for Probabilistic (with sch.maint.) equilibrium scenario
- Random minor cost (same for all four equilibrium scenarios)

- IP-LockCostDetail*.xls – for a given IP this workbook contains lock-level yearly statistics under all four equilibrium-scenarios (Normal-operations, Scheduled-maintenance, Probabilistic without scheduled maintenance, and Probabilistic with scheduled maintenance) and under all specified forecasted demand scenarios. Note that most of the statistics for the probabilistic equilibrium-scenarios are actually expected values. The statistics displayed are yearly (and amortized where appropriate):
  - Lock tonnage
    - Normal-operations equilibrium lock tonnages
    - Scheduled maintenance equilibrium lock tonnages
    - Probabilistic (WO sch.maint.) equilibrium lock tonnages
    - Probabilistic (with sch.maint.) equilibrium lock tonnages
  - Lock transit time transportation costs
    - Normal-operations equilibrium lock transit time transportation costs
    - Scheduled maintenance equilibrium lock transit time transportation costs
    - Probabilistic (WO sch.maint.) equilibrium lock transit time transportation costs
    - Probabilistic (with sch.maint.) equilibrium lock transit time transportation costs
  - Lock scheduled repair costs (identical for probabilistic scenarios)
    - Normal-operations waterway equilibrium lock scheduled maintenance costs
    - Scheduled maintenance waterway equilibrium lock scheduled maintenance costs
  - Lock unscheduled repair costs
    - Probabilistic (WO sch.maint.) equilibrium lock unscheduled repair costs
    - Probabilistic (with sch.maint.) equilibrium lock unscheduled repair costs
  - Lock investment costs
    - Lock investment cost under normal-operations (same for sch.maint. scenario)
    - Lock investment cost under probabilistic scenarios (WO and with sch.maint.)
  - Lock operations costs
    - Lock operations cost under normal-operations (same for sch.maint. scenario)
    - Lock operations cost under probabilistic scenarios (WO and with sch.maint.)
  - Lock dam operations costs (same for all four equilibrium scenarios)
  - Lock random minor costs (same for all four equilibrium scenarios)

The comparisons between investment plans is done through a model post-processing utility where the user specifies which investment plan is to be considered to be the WOPC and which investment plans are to be considered WPC's (section 1.2.4.6). This allows flexibility in the definition of which IP is to be considered the WOPC. The IP comparison output consists of each IP's yearly costs, waterway transportation surplus, and lock performance statistics. For each IP these cash flows are itemized, discounted, amortized, and summarized in a single output EXCEL workbook:

- IP-IncrementalBC*.xls – for the specified IP's this workbook contains system-level yearly statistics under all four equilibrium-scenarios (Normal-operations, Scheduled-maintenance, Probabilistic without scheduled maintenance, and Probabilistic with scheduled maintenance) and under all forecasted demand scenarios. The statistics displayed include yearly (and amortized where appropriate) for each IP and incremental to the WOPC IP:
    - Waterway system tonnage (same as in IP-SystemStatistics workbook)
    - River closure diversion tonnage
        - Probabilistic (WO sch.maint.) equilibrium river closure diversion tonnage
        - Probabilistic (with sch.maint.) equilibrium river closure diversion tonnage
    - Over capacity diversion tonnage
        - Probabilistic (WO sch.maint.) equilibrium over capacity diversion tonnage
        - Probabilistic (with sch.maint.) equilibrium over capacity diversion tonnage
    - Total system transit days (same as in IP-SystemStatistics workbook)
    - Waterway transit costs (same as in IP-SystemStatistics workbook)
    - Waterway transportation surplus (same as in IP-SystemStatistics workbook)
    - Waterway transportation base cost (same as in IP-SystemStatistics workbook)
    - Waterway transportation equilibrium cost (same as in IP-SystemStatistics workbook)
    - Land transportation equilibrium cost (same as in IP-SystemStatistics workbook)
    - Land transportation expected river closure diversion transportation cost (same as in IP-SystemStatistics workbook)
    - Land transportation expected river closure diversion externality cost (same as in IP-SystemStatistics workbook)
    - Land transportation expected over capacity diversion transportation cost (same as in IP-SystemStatistics workbook)
    - System investment cost (same as in IP-SystemStatistics workbook)
    - Scheduled repair cost (same as in IP-SystemStatistics workbook)
    - Unscheduled repair cost (same as in IP-SystemStatistics workbook)
    - Random minor cost (same as in IP-SystemStatistics workbook)

1.2.4.6 Cost-Benefit Analysis

Given the itemization of the various cost categories in the IP-IncrementalBC output workbook, the WPC costs foregone (benefits) can be compared against the WPC investment cost. If investment costs occur under the WOPC the user must decide whether to itemize the costs foregone as a benefit or to subtract them from the WPC investment cost converting the cost-benefit analysis to a benefit-to-incremental-cost analysis. Either way the net benefits remain the same, however, the cost-benefit ratio will be higher under a benefit-to-incremental-cost analysis.

The various cost categories (and system performance statistics) are itemized under four equilibrium scenarios: Normal-operations, Scheduled-maintenance, Probabilistic without scheduled maintenance, and Probabilistic with scheduled maintenance. The non-probabilistic scenarios are itemized to allow incremental comparison against the probabilistic scenarios to enumerate risk effects. Remember also that multiple forecast scenarios are also summarized.

The user must manually select the NED plan from either the Probabilistic (without scheduled maintenance) scenario or the Probabilistic (with scheduled maintenance) scenario with consideration of the forecast scenarios. Typically the Probabilistic (with scheduled maintenance) scenario is used with the results between the forecast scenarios averaged.

1.2.5 Calculation of Transportation Surplus

The calculation of the transportation surplus for a price responsive movement is slightly different than for a fixed quantity movement, as discussed in the sections below.

1.2.5.1 Price responsive Movement Demand

If the demand is represented by a constant elastic demand function then the transportation surplus is calculated by an integral considering price as a function of quantity:

$$TS_{Q^*} = \int_0^{Q^*} \left(P - P^*\right) dQ = \int_0^{Q^*} \left(\left(\frac{Q}{\alpha}\right)^{\frac{1}{\varepsilon}} - \left(P^*\right)\right) dQ \qquad (1.2\text{-}19)$$

If we assume < -1, the integral is bounded and can be expressed in closed form:

$$TS_{(P^*,Q^*)} = \frac{-\alpha}{\varepsilon + 1}\left(P^*\right)^{\varepsilon + 1} \qquad (1.2\text{-}20)$$

(This form assumes the equilibrium point is on the demand curve)

However, if the elasticity is greater than -1 then the integral becomes unbounded if we try to integrate all the way to the vertical axis. To provide a reasonable way to compare benefits with elasticities between 0 and -1, ORNIM caps the cost for all constant elasticity demand curves with elasticities greater than -1 at the value corresponding to one barge load of the commodity. Thus, instead of integrating from 0 to Q^*, the consumer surplus is calculated as the integral from Q_{min} to Q^* where Q_{min} is the single barge quantity. The surplus for the single barge Q_{min} ($P_{max} - P^*$) is then added to the value of the integral. The details of the integration and an interesting linkage between the constant elasticity and the fixed demand functions is described in ADDENDUM 1D Calculation of Transportation Surplus.

If the demand is represented by a piecewise linear demand function, then the calculation is relatively straightforward. The area under the curve is calculated by adding the areas under each of the segments. Each segment has a trapezoid shape; therefore, the area under a segment is:

$$TS_{(P^*,Q^*)} = \frac{1}{2}\left(\left(\left(P_i - P^*\right) + \left(P_{i+1} - P^*\right)\right)\left(Q_i - Q_{i+1}\right)\right) \qquad (1.2\text{-}21)$$

where:

P_i and Q_i are the (price, quantity) points that define the demand curve for the given movement & year

1.2.5.2 Fixed quantity Movement Demand

For fixed quantity movement demand the transportation surplus is represented by a rectangle above the equilibrium waterway cost, under the fixed quantity willingness-to-pay (typically set at the least-costly all-overland rate), and between 0 and the equilibrium quantity. The transportation surplus is therefore:

$$TS_{fixed\ quantity} = (A - P^*)\ Q^* \quad (1.2\text{-}22)$$

where:

TS = transportation surplus
A = the fixed quantity willingness-to-pay $/ton (least-cost all-overland alternative rate $/ton)
P^* = is the equilibrium water transportation rate (cost adjusted base water rate in $/ton)
Q^* = is the equilibrium quantity (tonnage)

1.2.5.3 Expected Transportation Surplus

Transportation surplus is calculated under the following four assumption scenarios (and for each forecast scenario):

- Normal-operations equilibrium-scenario (aka "*no prob no scheduled*")
- Scheduled-maintenance equilibrium-scenario (aka "*no prob with scheduled*")
- Probabilistic adjusted normal-operations equilibrium-scenario (aka "*prob no scheduled*")
- Probabilistic adjusted scheduled-maintenance equilibrium-scenario (aka "*prob with scheduled*")

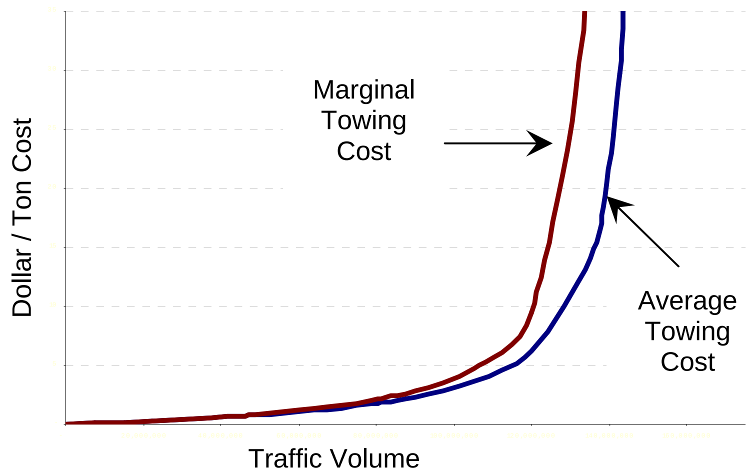
The "*no prob no scheduled*" and "*no prob with scheduled*" are point estimates while the "*prob no scheduled*" and "*prob with scheduled*" are probabilistically derived and are thus expected values. These expected transportation surplus calculations undergo adjustments similar to the transportation cost adjustments described in section 1.2.4.4.3. As previously noted, scheduled service disruptions are assumed known and the waterway price is assumed known in the equilibrium process. Unscheduled service disruptions by definition are unknown and as a result are not considered in the equilibrium process, but are adjusted for after equilibrium is determined. Generally speaking, given a waterway system infrastructure configuration (including lock performance characteristics with and without scheduled maintenance service disruption information) and movement-level demands (including movement willingness-to-pay characteristics) the model determines the equilibrium traffic levels in the system, along with the waterway transportation surplus, over the study's analysis period. Next, these results are adjusted for engineering reliability (probability of unscheduled service disruption). Basically the equilibrium movement water transportation surplus is decreased by: 1) the probability of increased trip time caused by the unscheduled service disruptions; and 2) the probability of change in transportation costs from diversion of traffic caused by the unscheduled service disruption.

1.2.6 Shipper-Based and Social Equilibrium

In typical ORNIM execution individual shippers (i.e., movements) make decisions based on their observed cost of moving on the waterway system; but they do not consider the additional congestion their shipments place on all other users of the waterway. As a result of this negative externality, the total use of the waterway exceeds the optimal level of use when considered from the perspective of society; a shipper-based equilibrium as opposed to a social-optimal equilibrium. The shipper-based equilibrium is reality and the social equilibrium minimizes transportation costs (considering all transportation modes). This social optimum can be estimated by ORNIM.

In the equilibrium process ORNIM calculates a conditional cost curve for each movement which represents, for every level of traffic, the shipper cost of shipping commodities via the water routing. The costs include only those costs borne by the waterway carrier (e.g., equipment, labor, fuel, and supplies), and not those borne by the Federal Government in the operation and maintenance of the waterway system. Two waterway conditional cost curves are depicted in FIGURE 1.2.33 -- the average towing cost (ATC) curve and the marginal towing cost (MTC) curve. The ATC curve represents the average cost of shipping at different traffic levels. It rises because the average delay, and therefore the average cost, is higher at higher levels of traffic. The MTC curve represents the additional cost to the shipping industry of transporting an additional ton of cargo on the waterway. It increases at a faster rate than the ATC because the higher delays associated with higher levels of traffic are sustained by all shippers, not only the shipper who causes the delay. An additional tow entering the river system increases the delay costs for all tows sharing resources with the new tow (i.e., all tows transiting a shared lock). The external cost to society is the marginal congestion costs to all shippers resulting from this additional tow minus the average cost paid by the marginal tow.

FIGURE 1.2.33 – Conceptual Waterway Movement Conditional Cost Curves



1.2.6.1 Shipper-Based Equilibrium

In the shipper-based equilibrium shippers in the inland waterway operate in their own self-interest. Individual shippers will not restrict output to a social optimum, where the last increment of tonnage added to the system exhibits just enough marginal rate savings to offset the marginal towing costs (including induced delays); MTC=MRS. Instead, shippers tend to expand waterway volumes to the level at which their average towing costs equal their marginal rate-savings or demand (ATC = MRS). This occurs because each individual carrier pays only its own average cost for moving on the waterway system, not the true marginal costs, which include the costs imposed on all shippers. For example, in a congested lock situation, the addition of just a few more tows per day causes lock delays to increase exponentially because of the queuing effect. The additional tows do not pay for the total marginal increase in tow delay. Rather, the increased delay costs are spread among all tows using the congested lock, making each less efficient. For this reason, the ATC is used in the analysis and formulation of inland navigation projects; however, a congestion fee alternative is typically included as an alternative in the formulation process. Typically a congestion fee alternative will produce the highest benefit-cost ratio, but not the highest net benefit (which is the objective of the recommended NED plan).

1.2.6.2 Congestion Fee Analysis

A social-optimal equilibrium can be achieved by inducing private behavior to behave in a socially optimal way. The government can impose a tax or a congestion fee on shippers equal to the difference between the marginal social cost and the average private cost. These fees have both a temporal and spatial dimension and the difficulty is in determining the right mix of fees to mimic the marginal social cost. Movement tonnage demand forecasts, movement willingness-to-pay, and scheduled lock service disruptions also affect the optimal fees each year. As in the shipper-based equilibrium, the exact origins and destinations of commodities affect the traffic levels by waterway segment and thus the optimal fees at individual locks.

The fees, however, can be determined by the relationship between the demand for traffic at each lock and the capacity of the lock. An initial implementation of an automated method of deriving congestion fees has been implemented in ORNIM (specifically WSDM) as an option in the equilibrium process. The procedure derives a fee (stated as $/ton) for each lock in the system. This approach provides an approximation to the theoretical ideal[24]. The mechanics of this equilibrium can be found in section 1.3.1.3.

1.2.6.3 Revenue Analysis

Through the model's costing algorithms any spatial or temporal fuel tax and processing fee (lockage fee, tonnage fee, or barge fee) can be analyzed to estimate equilibrium traffic levels and revenue generation. It should be noted, however, that only lock traffic movements are modeled and as such intra pool fuel tax revenues are not captured.

[24] The theoretical optimum fee would charge the shipper based on the commodities carried by the other shippers on the waterway. Thus, a coal movement sharing a lock with a chemical movement would be charged fees based on the delay cost imposed on the chemical barges. The chemical movement would be charged a different rate by ton for the delay imposed on the coal. This is not included in the current version of WSDM.

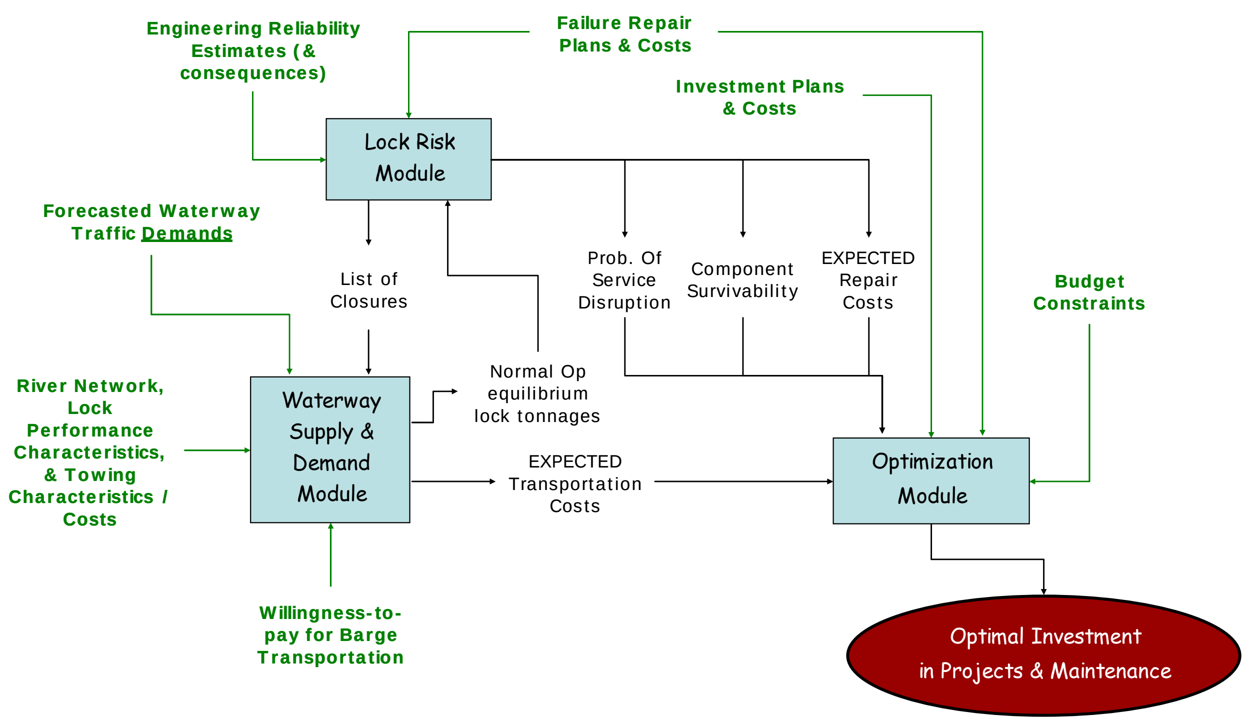
1.3 Model Structure

Development of a model requires a number of design decisions and technology choices. ORNIM utilizes a relational database structure[25] which allows flexibility in input and output structure, eliminating model code changes if analysis resolution (e.g., increasing the number of towboat classes considered) or assumptions change. Input, output, and execution data is stored in Microsoft Sequel (SQL) Server 2005 database with Microsoft Office 2003 used for output reports. The model is executed and model results analyzed in twenty C++ and C# executable programs using thirty dynamic-link libraries (the C++ code represents older original code that has yet to be converted to C#). The budget optimization feature utilizes CPLEX optimization software distributed by ILOG.

Simulation models fall into two basic categories: event-based and period-based. In an event-based model, a set of events that the model is concerned with are defined, and time moves forward in jumps, as each event takes place. Period-based models divide time into discrete periods of know length (e.g., years). All calculations are made for a given period, and then time is advanced to the next period. Both types of approaches have their advantages and disadvantages. In general, period-based models are easier to formulate and contain simpler calculations, but the assumptions required about averaging of data may be limiting. ORNIM is classified as a period-based model running on yearly time increments.

The ORNIM System is composed of three primary modules – the Lock Risk Model (LRM), the Waterway Supply and Demand Model (WSDM), and the Optimal Investment Module (Optimization). The general linkage of the model modules are shown in the FIGURE 1.3.1 below.

FIGURE 1.3.1 – ORNIM Primary Modules



The LRM Module forecasts structural performance by simulating component-level engineering reliability data (hazard functions and event-trees) to determine life-cycle repair costs and service disruptions. The

[25] Normalizing data removes redundant data; however, a completely relational database can generate such a large number of related tables that use (understanding) is hampered.

LRM summarizes the probabilities of reliability driven service disruptions (typically lock closures) for each lock for each component for each year, which are then used by the WSDM and Optimization modules to estimate expected transportation impacts resulting from the service disruptions.

The WSDM Module estimates equilibrium waterway traffic levels and transportation costs given a traffic demand forecast, movement willingness-to-pay, and waterway system performance characteristics. ORNIM's major economic assumptions are embedded within WSDM.

The Optimization Module organizes and analyzes the investment life-cycle benefit and cost streams and recommends optimally timed investments (what and when).

While there are three primary modules, the model is much more complex. The model structure is best described and understood through the following nine separable modules:

- Water Supply and Demand Module (WSDM)
    - o Calibration Sub-Module (Calibrate.exe)
    - o Equilibrium Sub-Module (WSDM.exe)
- Set-Up Component Alternatives and Runs Module
    - o Generate All Component Replacements Sub-Module (GenAllCompRep.exe)
    - o Generate Component Replacement Curve Sets Sub-Module (GenCompReplaceCurveSet.exe)
    - o Build Transit Time Curve Set Sub-Module (BuildTransitTimeCurveSet.exe)
    - o Copy Run Sub-Module (CopyRun.exe)
- Lock Risk Module (LRM.exe and runLRM.exe)
- Summarize Closures Module (SummClosures.exe)
- Optimization Module (ORNIMOptim.exe)
- Build Investment Plan Module (BuildInvestmentPlan.exe)
- Build Investment Plan Closures Module (BuildInvestmentPlanClosure.exe)
- Calculate Costs Module (CalculateCosts.exe)
- Output Utility Module

The reader should be wary that through the model's development and expansion, the naming convention of database tables, fieldnames, and processes is not always intuitive. For example the early engineering reliability work only estimated chamber closure events and hence the model was developed with "*closureID*" and "*ClosureType*" terminology. Given the refinement of the failure consequence into less than complete closure (e.g., half-speed chambering), in hindsight, a better term would be "*service disruption*".

1.3.1 Waterway Supply and Demand Module (WSDM)

The WSDM is the heart of ORNIM and a summary of its operation is required first. WSDM is a behavioral as well as a predictive model; it determines the least-cost barge transportation shipping plan (including route selection) and estimates equilibrium traffic levels given system performance (supply) and movement willingness-to-pay (demand) characteristics.

To determine movement equilibrium, and ultimately system equilibrium, movement shipping plans and the shipping plan cost characteristics must be known. WSDM not only contains movement equilibrium logic, but it also contains algorithms to determine the movement's least-cost shipping-plan. Given transportation constraint parameters, the model essentially creates and costs all allowable movement shipping plans and selects the least-cost shipping-plan for each movement. This process however, requires calibration. A detailed discussion of the shipping plan cost calculation and shipping-plan selection can be found in ADDENDUM 1B ORNIM Calibration. Below are general discussions of this WSDM calibration process followed by a discussion of the WSDM equilibrium process.

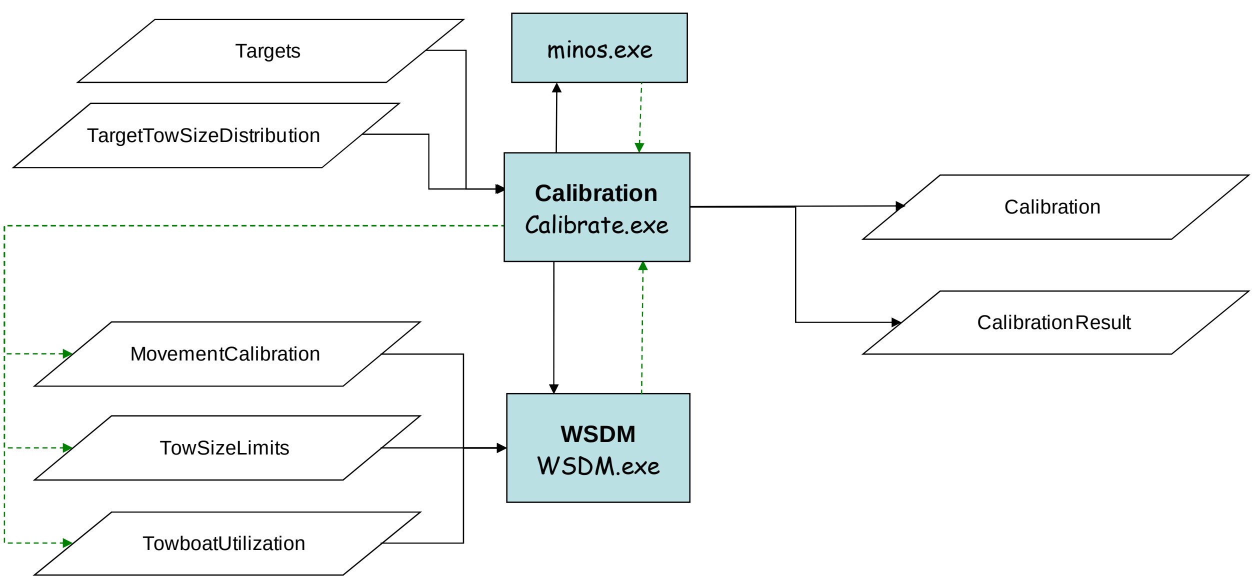
1.3.1.1 Calibration of the WSDM Shipping Plan

Looking at a historic year, Waterborne Commerce Statistics Center (WCSC) data gives the origin to destination barge flows by commodity. However, information on tow-size, towboat utilization and empty return characteristics are not readily available. To accurately assess the effects of increased shipping times in the waterway system, the complete cost characteristics of each movement is needed. In other words, the shipping plan needs to be determined; the barges need to be grouped into tows, assigned a towboat, potentially shipped to a re-fleeting point to be re-grouped and assigned another towboat for the remaining leg of the trip, and empty barge return shipping needs to be estimated and cost. As such the first task of WSDM is to develop least-cost waterway shipping plans for each movement modeled. WSDM determines the cost-effective tow configuration needed to transport at each annual port-to-port commodity movement on the waterway network honoring a set of towing and operating characteristics and to compute towing costs associated with these fleet requirements and traffic flows. Tow-size, towboat horsepower, re-fleeting, empty barge returns, and the number of tow trips per river segment are determined for each movement.

To validate that the model is capable of replicating observed shipper behavior and system operating characteristics, the model must be calibrated. This is a sequential process involving several iterative steps. At each step, certain static components of the model's waterway system description are adjusted or fine-tuned, the model is exercised, and specific results are compared with corresponding target values from the Lock Performance Monitoring System (LPMS) for the designated baseline or calibration year. The calibration process is designed to ensure that the relevant measures match their corresponding target values as well as possible.

The Calibration input and output database tables are shown in FIGURE 1.3.2. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010. Detailed discussion of the calibration process can be found in ADDENDUM 1B ORNIM Calibration.

FIGURE 1.3.2 – WSDM Calibration Sub-Module Inputs & Outputs



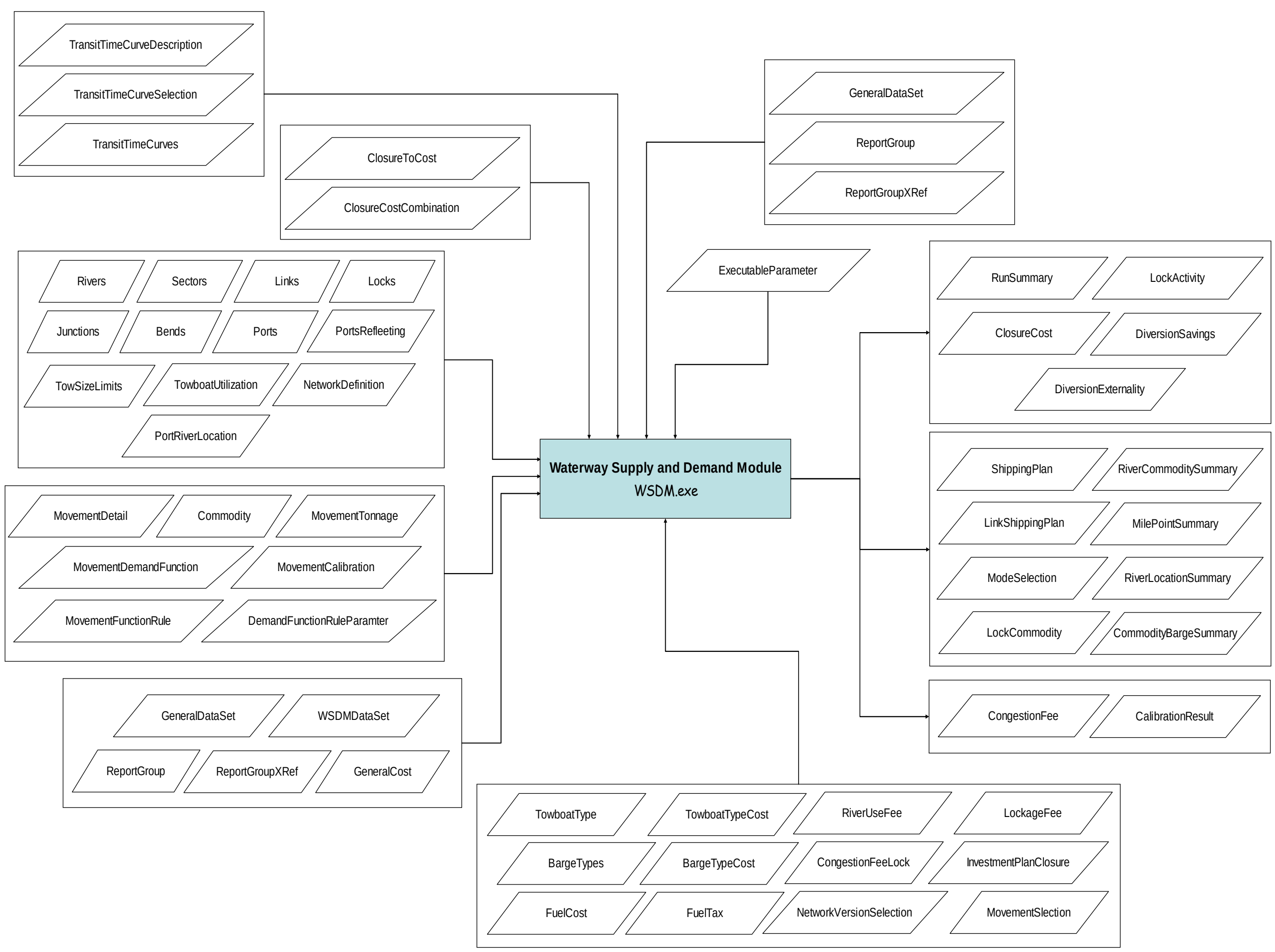
1.3.1.2 Shipper-Based Equilibrium Algorithm

Once each movement's shipping plan is determined and its cost characteristics are determined through the calibration process, WSDM can then determine future equilibrium traffic flows. Equilibrium is assumed to occur when every movement assigned to the waterway has a water routing cost-per-ton lower or equal to its willingness-to-pay for barge transportation, resulting in a positive waterway transportation surplus, while every movement not moving has a willingness-to-pay for barge transportation lower than the current water route cost-per-ton. This is a shipper-based equilibrium condition in which no single movement can improve its surplus by switching between water routing and non-water routing.

Determining the equilibrium traffic flows is a difficult problem requiring an iterative approach since the cost of shipping a movement by water depends on the aggregate traffic level at each lock on the movement's route. Exogenous data on a base-year waterway rate and the willingness-to-pay for barge transportation (including the forecasted demand) for each movement is used, in combination with the calibrated shipping-plans and the system performance characteristics (e.g., tonnage-transit curves), to determine system equilibrium.

The WSDM input and output database tables are shown in FIGURE 1.3.3 (discussion of the database tables can be found in section 1.4). Specification of the tables and table fields can be found in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010. The equilibrium iterative process and its convergence to the equilibrium solution is discussed in the sections below.

FIGURE 1.3.3 – WSDM Equilibrium Sub-Module Inputs & Outputs



1.3.1.2.1 Setting the Movement Cost-to-Rate Delta
A movement's equilibrium decision is based on price (the rate) and not cost per se since the barge transportation demand curves represent a price-quantity relationship. To convert the model's cost calculations in the equilibrium process to a price (or rate) the model uses a "*cost-to-rate delta*". The cost-to-rate deltas are determined in the model's calibration process (ADDENDUM 1B ORNIM Calibration), however, they are not stored in the database. Given the calibrated model parameters the base-rate is compared and related to the model's estimated base movement cost to create an adjustment price (dollars per ton) needed to convert the model's movement cost estimate to the movement rate. As a result the first step of WSDM is to recalculate the movement deltas and store the values in memory for use in the equilibrium process.

Regardless of the future network being analyzed (networkVersionID, see TABLE 1.4.3), the calibration network is used to re-set the cost-to-rate deltas.

1.3.1.2.2 Sorting the Movements
The first step of the equilibrium process it to sort the movement list by increasing base savings. Since the movements with the highest base rate-savings will most-likely be in the equilibrium solution set, these movements are loaded first onto the waterway. This allows for a quicker convergence to equilibrium. Note that base-savings is used as the sort criteria even when equilibrium is to be determined a price responsive demand.

1.3.1.2.3 Iteration through the Movement List
The second step of the equilibrium process is to iterate through the sorted movement list equilibrating movement-by-movement. Each movement is equilibrated given the present system equilibrium (i.e., the present equilibrium tonnages of all other movements) and the system performance statistics are updated if there is a change in the movement's equilibrium. The list is iterated through with each movement determining its equilibrium based on the system changes resulting from all previous movements' adjustments. This process is iterated until there are no equilibrium changes in an entire pass through the movement list.

1.3.1.2.3.1 STEP 1 – Initialize the Iteration
At the beginning of an iteration the sortID i is set to 1 (the first movement in the sorted list) and the change flag is set to "*NO*".

1.3.1.2.3.2 STEP 2 - Calculate the Movement's Conditional Cost Curve
The conditional cost curve (CCC) is then calculated for sortID_i movement. Calling this a cost curve is a little misleading; the CCC represents a quantity-price relationship. The CCC includes the movement fixed costs plus the movement's lock transit time costs (which are specific for the iteration) plus the movement's cost-to-rate delta. Detailed discussion of waterway transportation cost calculation can be found in ADDENDUM 1B ORNIM Calibration (section 1B.4). The difference in the equilibrium waterway transportation cost calculation and the calibration calculation is that the lock transit time is picked from the tonnage-transit curve rather than the calibration average transit time.

1.3.1.2.3.3 STEP 3 - Estimate the Movement's Equilibrium
Given the CCC the movement's equilibrium is dependent upon whether the movement is identified as price responsive or fixed quantity.

- Price responsive Demand – for a movement defined with a demand curve, the equilibrium quantity of movement i (Q_i) is set to the quantity of the intersection of the CCC and the demand curve for movement i. Remember that the price responsive demand curve can be specified to extend beyond the forecasted demand (point B in FIGURE 1.2.24). If the demand curve is bounded by the forecasted demand point (typical definition), Q_i will be set to no more than the forecasted demand point.
- Fixed quantity (fixed) Demand – for a movement defined with as fixed quantity, if the cost/ton for moving the entire annual demand by waterway is less than the fixed willingness-to-pay proxy (i.e., the

least-costly all-overland rate), the equilibrium quantity of movement *i* (Q_i) is set to the annual demand. If the cost/ton for moving the first ton of the annual demand by waterway is more than the fixed willingness-to-pay, the equilibrium quantity of movement *i* (Q_i) is set to zero. Otherwise, the intersection of the CCC and the fixed willingness-to-pay is calculated (i.e., the movement is split) and Q_i is set to the quantity at the intersection.

1.3.1.2.3.4 STEP 4 - Check for Over Capacity

For sortID$_i$ Q_i all locks transited by the movement are checked for over capacity. If Q_i results in a lock being over capacity, Q_i is reduced so that the lock tonnage is at capacity. Note that this over capacity check is for the normal operations and scheduled maintenance equilibrium scenarios, and not for the probabilistic equilibrium scenario which is an adjustment external to the equilibrium process (i.e., an expected value adjustment factoring in risk assuming a transportation cost change rather than a transportation decision).

1.3.1.2.3.5 STEP 5 - Set Change Flag

If Q_i has changed significantly (defined by a maximum tolerance value) set the change flag to "*YES*".

1.3.1.2.3.6 STEP 6 - Increment, Iterate, or Stop

If *i* is the last movement and change flag is "*NO*" the equilibrium process is stopped. If *i* is the last movement and change flag is "*YES*", go to step 1 and iterate through the list again. Otherwise increase *i* by one and go to step 2.

1.3.1.3 Social-Optimum Equilibrium Algorithm

When the user opts for the calculation of fees in WSDM, the cost function constructed in Step 2 (section 1.3.1.2.3.2) of the equilibrium process above is modified to include the individual cost and the cost of the additional delay imposed by the movement on all other movements transiting one of the same locks. Note that each movement has its own cost multiplier for delay time since each movement may have different holding costs for commodities and different temporal costs for the equipment used in its tow configuration. Thus, a movement will not move on the waterway unless it can afford to pay not only its own delay cost but also the cost of delay it imposes on all other movements.

Since the transit curves are represented by piecewise linear functions, the delay cost function is piecewise linear. At any combination of movements on the waterway, we can calculate the per ton cost for each movement. This is easiest to see by using a table to represent the cost and delay for a particular set of movements (TABLE 1.3.1).

TABLE 1.3.1 – Example Movement Costs and Locks Transited

LOCK	DELAY SLOPE	MOVEMENTS				
		1	2	3	4	5
1	d_1	c_1	c_2			
2	d_2		c_2	c_3	c_4	
3	d_3		c_2	c_3	c_4	
4	d_4				c_4	c_5

The d_i represents the slope of the transit curve at lock *i* at the current tonnage level (i.e., the increase in transit time per additional ton of traffic through the lock), x_j represents the current tonnage of movement *j* on the water, and c_j represents the cost/hour for delaying a ton of movement *j*. An extra ton of movement through lock *i* will create d_i extra hours of delay for each tow. Movement *j* is affected by the delay by a cost of c_j dollars per hour if there is a value in the j^{th} column for the lock. Note that not all movements transit all locks. For example, if we consider movement 4, it transits locks 2, 3 and 4 and therefore impacts movements 2, 3, and 5.

In general, the impact at lock *i* of an extra ton moving on the water is:

$$\sum_i d_i \;\; c_j \;\; x_j \qquad (1.3\text{-}1)$$

This is the fee with each movement *j* at level x_j . Since this fee value depends on the set of movements on the water at a given time, it must be recalculated whenever the mix of traffic changes, but the sum can be calculated as:

$$d_i \sum c_j \;\; x_j \qquad (1.3\text{-}2)$$

Since the c_j values are constant for each movement, the sum only changes as movements enter or leave the waterway. The d_i value changes as the tonnage level moves to a new segment of the piecewise linear delay curve. Thus, this value is easily updated during the equilibrium process. This provides the basis for creating a process which evolves the lockage fees during the equilibrium process.

1.3.1.3.1 Setting the Movement Cost-to-Rate Delta

As under the shipper-based equilibrium algorithm, the first step of WSDM is to recalculate the movement cost-to-rate deltas using the calibration network and store the values in memory for use in the equilibrium process.

1.3.1.3.2 Sorting the Movements

The first step of the equilibrium process it to sort the movement list by increasing base savings. Since the movements with the highest base rate-savings or largest surplus will most-likely be in the equilibrium solution set, these movements are loaded first onto the waterway. This allows for a quicker convergence to equilibrium. Note that base-savings is used as the sort criteria even when equilibrium is to be determined a price responsive demand. The equilibrium iterative process and its convergence to the equilibrium solution are discussed in the sections below.

1.3.1.3.3 Iteration through the Movement List

The second step of the equilibrium process is to iterate through the sorted movement list equilibrating movement-by-movement. Each movement is equilibrated given the present system equilibrium (i.e., the present equilibrium tonnages of all other movements) and the system performance statistics are updated if there is a change in the movement's equilibrium. The list is iterated through with each movement determining its equilibrium based on the system changes resulting from all previous movements' adjustments. This process is iterated until there are no equilibrium changes in an entire pass through the movement list.

1.3.1.3.3.1 STEP 1 – Initialize the Iteration

At the beginning of an iteration the sortID *i* is set to 1 (the first movement in the sorted list) and the change flag is set to "*NO*".

1.3.1.3.3.2 STEP 2a - Calculate the Movement's Conditional Cost Curve

The movement's conditional cost curve (CCC) is then calculated for sortID$_i$ movement including the cost of the additional delay imposed by the movement on all other movements transiting one of the same locks. Note that this movement cost is purely a trip cost and does not include lock fees (although it does include fuel tax). As previously noted, calling this a cost curve is a little misleading since the CCC represents a quantity-price relationship and included the movement's cost-to-rate delta.

1.3.1.3.3.3 STEP 2b - Calculate the Transportation Fees

Determine the locks transited by the movement and sum the fees. These fees (whether a per barge fee, a lockage fee, or a per ton fee) are added to the movement's CCC.

1.3.1.3.3.4 STEP 3 - Estimate the Movement's Equilibrium

Given the CCC the movement's equilibrium is dependent upon whether the movement is identified as price responsive or fixed quantity.

- Price responsive Demand – for a movement defined with a demand curve, the equilibrium quantity of movement *i* (Q_i) is set to the quantity of the intersection of the CCC and the demand curve for movement *i*. Remember that the price responsive demand curve can be specified to extend beyond the forecasted demand (point B in FIGURE 1.2.24). If the demand curve is bounded by the forecasted demand point (typical definition), Q_i will be set to no more than the forecasted demand point.
- Fixed quantity (fixed) Demand – for a movement defined as fixed quantity, if the cost/ton for moving the entire annual demand by waterway is less than the fixed willingness-to-pay proxy (i.e., the least-costly all-overland rate), the equilibrium quantity of movement *i* (Q_i) is set to the annual demand. If the cost/ton for moving the first ton of the annual demand by waterway is more than the fixed willingness-to-pay, the equilibrium quantity of movement *i* (Q_i) is set to zero. Otherwise, the intersection of the CCC and the fixed willingness-to-pay is calculated (i.e., the movement is split) and Q_i is set to the quantity at the intersection.

1.3.1.3.3.5 STEP 4 - Check for Over Capacity

For sortID_i Q_i all locks transited by the movement are checked for over capacity. If Q_i results in a lock being over capacity, Q_i is reduced so that the lock tonnage is at capacity. Note that this over capacity check is for the normal operations and scheduled maintenance equilibrium scenarios, and not for the probabilistic equilibrium scenario which is an adjustment external to the equilibrium process (i.e., an expected value adjustment factoring in risk assuming a transportation cost change rather than a transportation decision).

1.3.1.3.3.6 STEP 5 - Set Change Flag

If Q_i has changed significantly (defined by a maximum tolerance value) set the change flag to "*YES*".

1.3.1.3.3.7 STEP 6 - Increment, Iterate, or Stop

If *i* is the last movement and change flag is "*NO*" the equilibrium process is stopped. If *i* is the last movement and change flag is "*YES*", go to step 1 and iterate through the list again. Otherwise increase *i* by one and go to step 2.

1.3.1.3.4 WSDM Execution Parameter Settings

WSDM execution is controlled through eighteen specified parameters in the "*ExecutableParameter*" table as shown in TABLE 1.3.2.

TABLE 1.3.2 – WSDM Execution Parameters (ExecutableParameter Table Data)

Parameter			Variable	Default	
ID	Class	Name	Type	Value	Comments
1	networkID	Network ID	integer	0	
2	investmentPlanID	Investment Plan ID	integer	0	
3	forecastID	Forecast ID	integer	0	
4	lockageFeePlanID	Lockage Fee Plan ID	integer	0	
5	fuelTaxPlanID	Fuel Tax Plan ID	integer	-1	
6	demandFunctionPlanID	Demand Function Plan ID	integer	-1	
7	allowShippingReplan	Allow Shipping Plan Recalculation	Y/N	N	
8	calendarYear	Starting Year	integer	2005	starting year for the run
9	calendarYear	Ending Year	integer	2070	ending year for the run
10	allowTonnageInExcessOfForecast	Allow Tonnage in Excess of Forecast	Y/N	N	only used if running elasticity
11	outputModeSelection	Output mode selection	Y/N	N	
12	outputShippingPlans	Output shipping plan	Y/N	N	
13	outputCommodityBargeSummary	Output commodity barge summary	Y/N	N	
14	useHistoricalRoutings	Use Historical Routings	Y/N	N	
15	useMostLikelyHazardFunction	Use Most Likely Hazard Function	Y/N	Y	
16	calculateCongestionFees	Calculate Congestion Fees	Y/N	N	
17	congestionFeePlanID	Congestion Fee Plan ID	integer	-1	needed if calculating congestion fees
18	recalculateAllClosures	Recalculate All Closures	Y/N	N	

1.3.1.4 Equilibrium Variations

WSDM is equilibrated under two assumption scenarios (and for each forecast scenario):

- Normal-operations equilibrium-scenario (aka "*no prob no scheduled*")
- Scheduled-maintenance equilibrium-scenario (aka "*no prob with scheduled*")

As discussed in sections 1.2.4.4.3.10 and 1.2.4.4.3.11 there are waterway transportation cost adjustments that are different depending on whether or not traffic is diverted with the service disruption event. When there is no traffic diversion (i.e., only the transit time at the lock where the service disruption occurs, changes) the re-costing of the waterway transportation cost is straight forward and can be done (and is done) external to WSDM. When the service disruption diverts traffic, however, the re-costing has to be done within WSDM so that the tonnage levels (and transit times) at the other projects can be adjusted too.

First developing equilibrium traffic levels under the "*no prob no scheduled*" supplies information needed for the fatigue driven components in the LRM (see section 1.3.3.1), else for the fatigue based PUPs the most-likely PUP curve must be assumed. Development both equilibrium assumption scenarios allows for an incremental determination of the transportation impacts of engineering reliability and scheduled maintenance, and ultimately the impact on investment formulation and investment justification.

1.3.2 Component Replacement Alternatives and RUNs Module

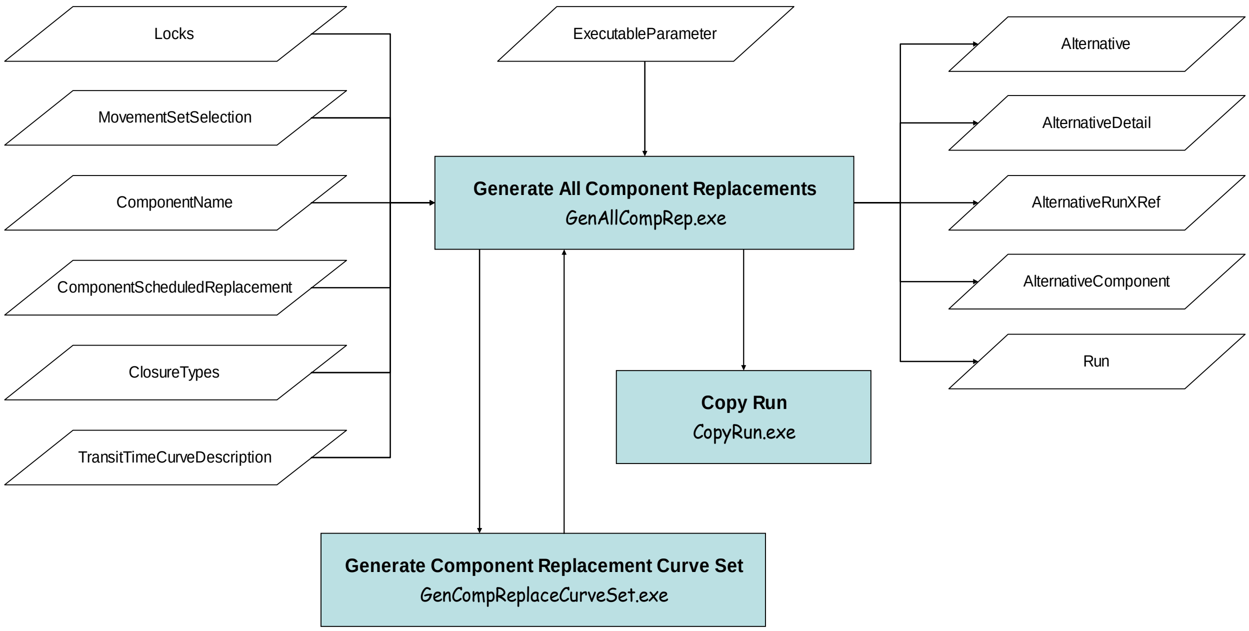
This module is really more of a user utility or analysis pre-processor. Remember from section 1.2.4.1.3 the definition and distinction of an Alternative and a RUN. Given that an inland navigation analysis will most-likely involve unreliable components defined with engineering reliability data (PUPs and event-trees), and given that at the most basic formulation level replacement of these individual components in isolation of investments is desired, the model contains a user utility that will set-up an Alternative and RUN to analyze component replacement for each component. After the component data, transit time curves, and component replacement costs have been loaded into the model, this "*Component Replacement Alternatives and RUNs*" module can be executed to create and load an Alternative and a RUN for each component replacement. Of course, this is more than just entering records into the "*Alternative*" and "*Run*" tables. This module actually contains four sub-modules as discussed in the following sections. The first two sub-modules are unique to the development of the component-level replacement alternatives; however, the last two sub-modules are more generic and are utilized elsewhere in the modeling process. Again, this user utility only sets up the component-level replacement alternatives. The more complex Alternatives and RUNs must be manually set-up by the user.

1.3.2.1.1 Generate All Component Replacements Sub-Module

The "*Generate All Component Replacements*" sub-module constructs an "Alternative" and a RUN for each component in the database. The "*Generate All Component Replacements*" sub-module input and output database tables are shown in FIGURE 1.3.4. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

Given a component's service disruption types (also known as closure types) and scheduled service disruptions at the project, this sub-module not only defines and populates the component level replacement alternative (defined in four tables) and its RUN, the sub-module also checks to see whether all the necessary tonnage-transit curves exist in the database. If additional combo tonnage-transit curves are needed, this sub-module executes the next "*Generate Component Replacement Curve Set*" sub-module. The "*Generate Component Replacement Curve Set*" sub-module execution is controlled through specified parameters in the "*ExecutableParameter*" table (i.e., "*networkID*" and "*runID*").

FIGURE 1.3.4 – Generate All Component Replacements Sub-Module Inputs & Outputs



1.3.2.1.1.1 Generate All Component Replacements Execution Parameter Settings

"*Generate All Component Replacements*" sub-module execution is controlled through four specified parameters in the "*ExecutableParameter*" table as shown in TABLE 1.3.3.

TABLE 1.3.3 – GenAllCompRep Execution Parameters (ExecutableParameter Table Data)

Parameter			Variable	Default	
ID	Class	Name	Type	Value	Comments
1	networkID	Network ID	integer	1	
2	runID	Base Run ID	integer	1	
3	calendarYear	Earliest Year	integer	2011	
4	calendarYear	Latest Year	integer	2070	

1.3.2.1.2 Generate Component Replacement Curve Sets Sub-Module

The full operations and service disruption tonnage-transit curves are generated external to the model and loaded as input (section 1.2.4.3.1). There is a need, however, to create combination curves representing multiple service disruption events, and this process is conducted in the model (as discussed in section 1.2.4.3.1.3). Prior to discussing the "*Generate Component Replacement Curve Set*" sub-module an understanding of the model's tonnage-transit curve management is needed.

1.3.2.1.2.1 Tonnage-Transit Curve Management (familyID, setID, and closureID)

To manage the numerous tonnage-transit curves utilized by the model, a hierarchical identification scheme is utilized. Early in the model development the term "*family of curves*" was coined to describe the full operation tonnage-transit curve and its related service disruption curves. While initially adequate, additional delineation was required. As a result, at the top level is the "*familyID*" which represents the navigation project. Next the curve set or "*setID*" represents variations within the family and the closure type or "*closureID*" represents variations within the curve set.

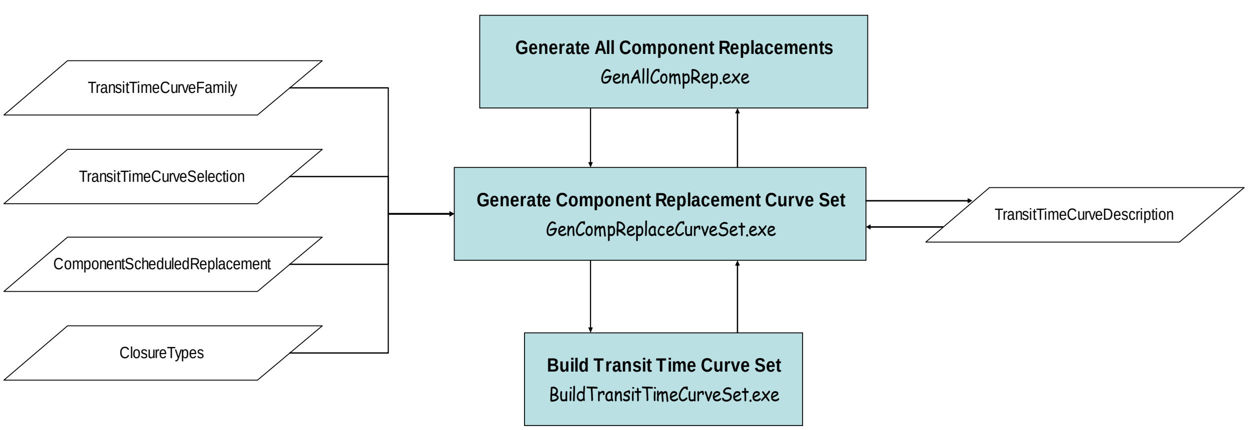
- **Tonnage-Transit Curve Family** – the "*familyID*" represents the navigation project and its operating assumptions. For example the existing 600' x 110' and 360' x 56' Emsworth Locks and Dam has a "*familyID*" and each new lock chamber alternative has a "*familyID*". Note that the operating assumption is also a factor in the "*familyID*" designation. For example a new 600' x 110' with the existing 600' x 110' Emsworth alternative has two different "*familyIDs*" where one "*familyID*" assumes normal operations of the existing 600' chamber and one "*familyID*" assumes the chamber is only utilized during closures of the new chamber.
- **Closure Type** – the "*closureID*" represents the service disruption type and duration. For a "*family of curves*" there is the full operation tonnage-transit curve along with a tonnage-transit curve for each "*closureID*" (e.g., 5-day main chamber closure, 15-day auxiliary chamber closure, and 10-day main chamber half-speed). A "*closureID*" of 1 indicates the full operation tonnage-transit curve.
- **Curve Set** – the "*setID*" represents variations within the "*familyID*" and evolved from a need to track service disruption events occurring during a construction year. Say the tonnage-transit curve family is for the existing 600' x 110' and 360' x 56' Emsworth Locks and Dam. Say the possible service disruptions ("*closureIDs*") for this project are a 5-day main chamber closure, a 15-day auxiliary chamber closure, and a 10-day main chamber half-speed. The "*family of curves*" would contain four tonnage-transit curves; a full operation and a curve for each of the three service disruption events. This "*family of curves*" would be stored under "*setID*" = 1.

  During a construction activity, the "full operation" tonnage-transit curve (that is, the tonnage-transit time curve without any probabilistic service disruptions) may be externally generated, or it may be the combination of the normal full operation tonnage-transit curve with, say, a 180-day main chamber closure. Other components not involved in the construction may fail, requiring the model to determine the effects of those service disruptions during the construction period. To facilitate the specification of this set of curves, the set would be given its own setID value, and the full operation curve would be stored under closureID of 1. Other service disruptions (the aforementioned 5-day main chamber closure, 15-day auxiliary chamber closure, etc.) would be stored under this same setID, using their corresponding closureID.

1.3.2.1.2.2 Determining the Needed Curve Sets

The "*Generate Component Replacement Curve Set*" sub-module input and output database tables are shown in FIGURE 1.3.5. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010. The function of this sub-module is to determine the specifics on the missing curve sets and to direct the "*Build Transit Time Curve Set*" sub-module (section 1.3.2.1.3) for their development.

FIGURE 1.3.5 – Generate Component Replacement Curve Sets Sub-Module Inputs & Outputs

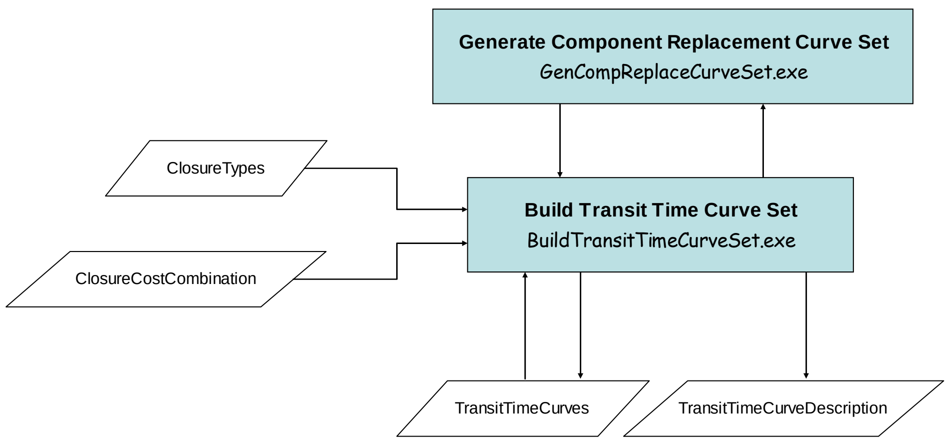


1.3.2.1.3 Build Transit Time Curves Sub-Module

Service disruption tonnage-transit curves are developed for each defined service disruption, however, within a year a project can experience multiple service disruptions. With a single component alternative and a single component RUN, within a year an unscheduled event might occur with a scheduled event. With a multiple component alternative or a RUN containing multiple alternatives, multiple unscheduled events might occur within the same year. As discussed in section 1.2.4.3.1.3, for these situations the model combines the specified tonnage-transit curves to estimate the average tow transit times with occurrence of the multiple service disruption events. The "*Build Transit Time Curve Set*" sub-module builds these combination curves.

The "*Build Transit Time Curve Set*" sub-module input and output database tables are shown in FIGURE 1.3.6. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

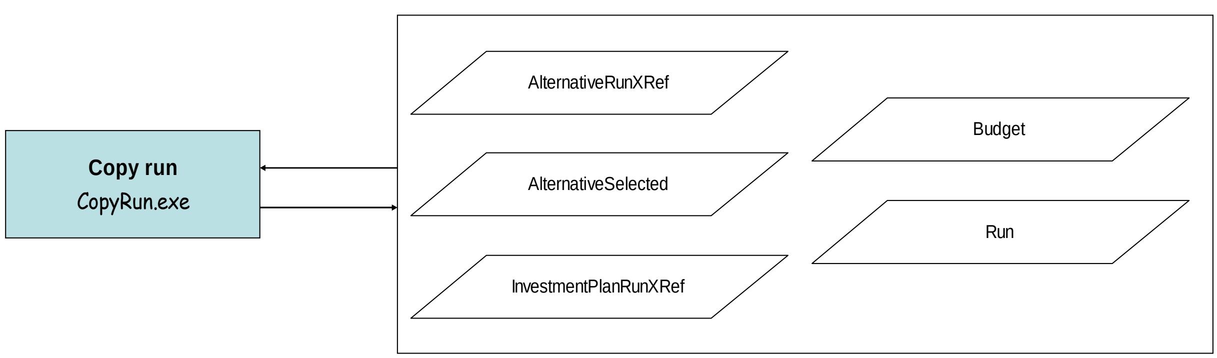
FIGURE 1.3.6 – Build Transit Time Curves Sub-Module Inputs & Outputs



1.3.2.1.4 Copy Run Sub-Module

The Copy Run input and output database tables are shown in FIGURE 1.3.7. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

FIGURE 1.3.7 – Copy Runs Sub-Module Inputs & Outputs



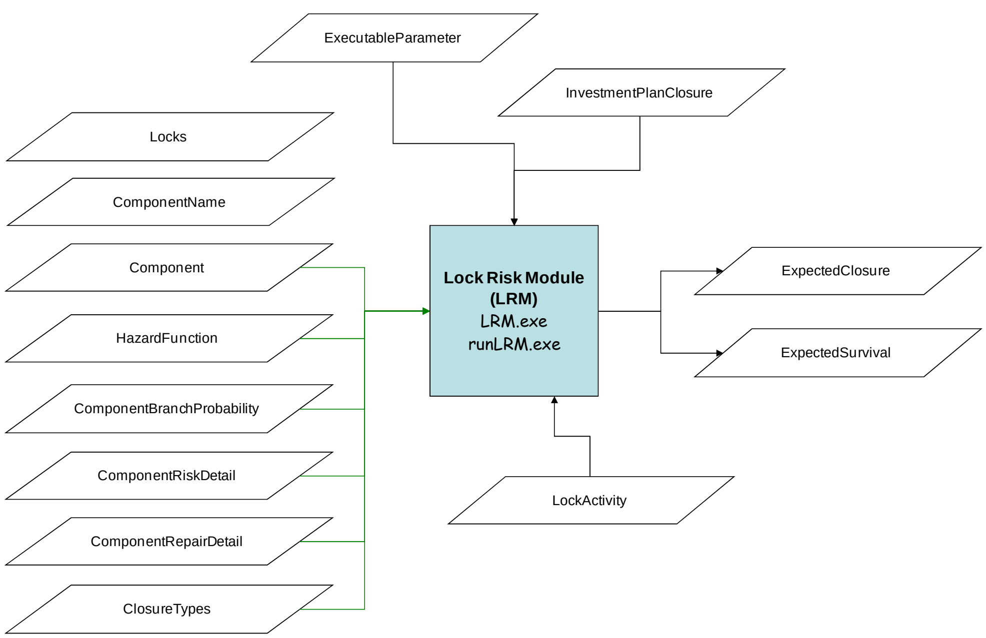
1.3.3 Lock Risk Module (LRM)

As a navigation project ages, maintenance requirements typically increase. Degradation can come from fatigue (utilization) or simply age (e.g., corrosion). As the different components of the project degrade, the question becomes if and when they should be rehabilitated or replaced. For some components it might be most economical to wait until the component fails before making a significant investment, for others it might be most economical to schedule and rehabilitate or replace the component before an unscheduled failure occurs. Since failure cannot be determined definitively, the timing of a scheduled rehabilitation or replacement can only be made through expected value calculations when expected risk exceeds the investment cost. The expected risk is a function of the probabilities and consequences of the do-nothing and the rehabilitation or replacement strategy.

Given the engineering reliability data (PUPs and event-trees) introduced in section 1.2.4.4.3.1, the LRM runs a Monte Carlo simulation of the component's life-cycle and collects statistics on the frequency of each service disruption and the average cost of repairs for each year of the analysis period. The LRM outputs estimate the probability of service disruption and repair cost for each specified component in each year of the analysis period[26]. The three primary outputs of the LRM are the life-cycle expected repair costs, probabilities of service disruptions, and survivability. The probabilities of service disruptions summarizes the probability of experiencing each service disruption (e.g., 10-day main chamber closure or 15-day half-speed chambering in the auxiliary chamber) in each year of the analysis period. The probabilities of service disruptions are then used to adjust the WOPC scheduled-maintenance equilibrium-scenario for reliability (unscheduled service disruption) as described in sections 1.2.4.4.3.5 through 1.2.4.4.3.12. Survivability summarizes the probability of component survival through time. Survival is defined by whether the component is replaced as part of the failure-repair.

The LRM input and output database tables are shown in FIGURE 1.3.8. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

FIGURE 1.3.8 – Lock Risk Module Inputs & Outputs



[26] Simulation of the analysis period and not the planning period assumes survivability of the component(s) to the decision point (i.e., base year).

The components are defined through the "*Locks*", "*Component*", and "*ComponentName*" tables. The reliability of the components are defined though additional tables discussed in the sections below. The primary inputs for a component to be analyzed by the LRM are the PUPs and the event-tree (including repair costs, post-repair reliability adjustment assumptions, and service disruption definitions) which were introduced in section 1.2.4.4.3.1.

1.3.3.1 Probabilities of Unsatisfactory Performance

Component degradation can result from age (time) or fatigue. Typically engineering reliability analysis will identify the predominate driver, and produce the PUPs accordingly. Typically engineering reliability PUPs are specified by time (component age), even when fatigue is the primary factor. The model does however; allow the loading of fatigue driven PUPs.

Fatigue driven PUPs by operating cycles which correlate to traffic levels. Since exact traffic levels in the future are not known, and the traffic levels at a project are also a function of constraint points elsewhere in the system, the traffic levels (operating cycles) are enveloped by three traffic levels: low, most-likely, and high. From these three future traffic level assumptions, three time-probability PUP curves are developed and loaded into the model (along with the underlying traffic level assumptions). The model will then interpolate between the curves to obtain a more accurate PUP given the full operation traffic levels at the project. The PUPs are loaded into the model through the "*HazardFunction*" table which allows specification of time or fatigue driven PUP curves.

The fatigue driven components generate a chicken or the egg causality dilemma; traffic levels drive the fatigue failures but the fatigue failures influence the traffic levels. When fatigue driven components are involved in the analysis, WSDM should be run under "*no prob no scheduled*" (see section 1.3.1.4) prior to running the LRM to develop the equilibrium tonnage levels to use in the LRM interpolation process.

1.3.3.2 Event-Trees

The PUPs only identifies the probability of failure and does not indicate the magnitude of the failure or the consequences; for this a consequence event-tree is developed (FIGURE 1.2.26). Actually the initial branch in the event tree (fail or not fail) is determined by the PUP. The event-tree then defines the probability of the severity (e.g., low, medium, high) of the failure and the intensity of the repair (e.g., low, medium, high) given that a failure has occurred. The distribution of severity probabilities can change over time reflecting the types of failures which typically occur at different points in a component's lifecycle. The intensity of the repair defines a protocol for repair that may stretch over several years (e.g., emergency repair in year 1 with replacement in year 2) and defines the cost and closure type for each year as well as the change to the component's reliability after the repair.

The first event-tree branching shown in FIGURE 1.2.26 is defined in the "*ComponentBranchProbability*" table. The second-level event-tree branching is defined in the "*ComponentRiskDetail*" table. The repair details (including the service disruption durations) off the second level branches are defined in the "*ComponentRepairDetail*" table.

1.3.3.3 Reliability Adjustment through Time

As failures and repairs occur in the LRM simulation, the reliability of the component is often changed going into the next time period. Minor failures generally require a minimal repair with a short-duration chamber service disruption. The probability of failure in the subsequent years might remain the same (the PUP curve is not changed). A moderate failure generally requires a larger repair with a longer duration service disruption. This repair might increase the reliability of the component, but not to the reliability of a new component. In this case, the PUP curve might be re-set to *n*-years earlier. For a catastrophic failure, a high repair cost with a long duration service disruption might be the consequence. In this case, the repair typically calls for a replacement of the component, in which case, the PUP curve is set to new or set to 100% reliable[27].

[27] While no component will be 100% reliable, once it is replaced as part of a new project / major rehabilitation / component replacement, it is often assumed to be reliable given regular maintenance. New components are assumed to be designed to current

Some component failure-repairs can necessitate the need for a different PUP curve rather than a re-setting on the existing PUP curve; some components can experience failures that transform future risk beyond the initial event-tree structure. The model also has the capability to branch to a different PUP function and event-tree (i.e., state) from any second-level branch.

To summarize, the failure-repair event can have no change to the component reliability, or the reliability change can: 1) make the component 100% reliable (no risk beyond the failure-repair); 2) reset the age of the component to new (age 0); 3) reset the age of the component *n*-years from the age at failure; or 4) switch to a different PUP curve (and event-tree).

1.3.3.4 LRM Execution Parameters

The LRM execution is controlled through eighteen parameters in the "*ExecutableParameter*" table shown in TABLE 1.3.4.

TABLE 1.3.4 – LRM Execution Parameters (ExecutableParameter Table Data)

Parameter			Variable	Default	
ID	Class	Name	Type	Value	Comments
1	networkID	network ID	integer	0	
2	investmentPlanID	investment plan ID	integer	0	
3	forecastID	forecast ID	integer		
4	lockID	lock ID	integer		
5	chamberID	chamber ID	integer	1	
6	componentID	component ID	integer	12	
7	useScheduledClosures	use scheduled closures	Y/N	Y	
8	calculateCongestionFees	calculate congestion fees	Y/N	N	
9	lockageFeePlanID	Lockage Fee Plan ID	integer	0	
10	fuelTaxPlanID	Fuel Tax Plan ID	integer	0	
11	demandFunctionPlanID	Demand Function Plan ID	integer	-1	
12	allowShippingReplan	Allow shipping plan recalculation	Y/N	N	
13	allowTonnageInExcessOfForecast	Allow tonnage in excess of Forecast	Y/N	N	
14	startYear	Start Year	integer	2005	
15	endYear	End Year	integer	2070	
16	useMostLikelyHazardFunction	Use Most Likely Hazard Function	Y/N	N	
17	iterations	Iterations	integer	250000	
18	randomNumberSeed	Random Number Seed	integer	12345	

Since the impacts of unscheduled service disruptions (and sometimes even their probability of occurrence) are sensitive to traffic levels, the LRM is actually run at two different points in the analysis process. The first time LRM is run it uses the normal operation equilibrium lock tonnages from WSDM. The LRM life-cycle repair costs and the service disruption probabilities are then used by the RUN in the Optimization Module to formulate investment plans. Traffic levels in the system, however, can be affected by the mix and timing of investments selected in the system level investment plan. The LRM is run again after the IP has been defined to more accurately estimate risk for the components defined with tonnage-probability curves.

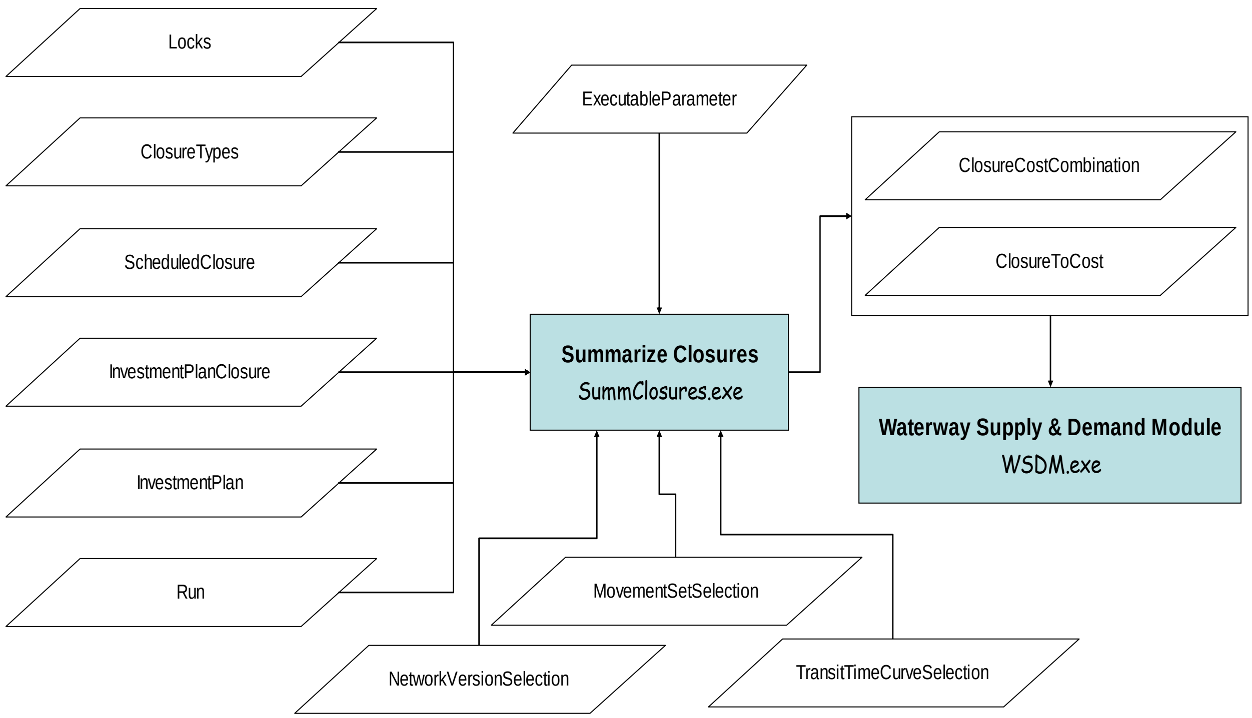
1.3.4 Summarize Closures Module

The objective of the "*Summarize Closures*" module is to determine the service disruption events that need to be costed for the Optimization Module. The Summarize Closures input and output database tables are shown in FIGURE 1.3.9. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

standards and with applicable standards and with applicable safety factors. A chance of significant failure is remote and would occur far into the future if at all.

The primary outputs from the "*Summarize Closures*" module are the "*ClosureCostCombination*" and "*ClosureToCost*" tables. The "*ClosureCostCombination*" is a translation table that changes a lock, family, set number, and closure string to an ID. The "*ClosureToCost*" stores which combinations are possibilities in each of the years. Data in these tables direct WSDM execution.

FIGURE 1.3.9 – Summarize Closures Module Inputs & Outputs



1.3.4.1 SummClosures Execution Parameters

The SummClosures execution is controlled through four parameters in the "*ExecutableParameter*" table shown in TABLE 1.3.5.

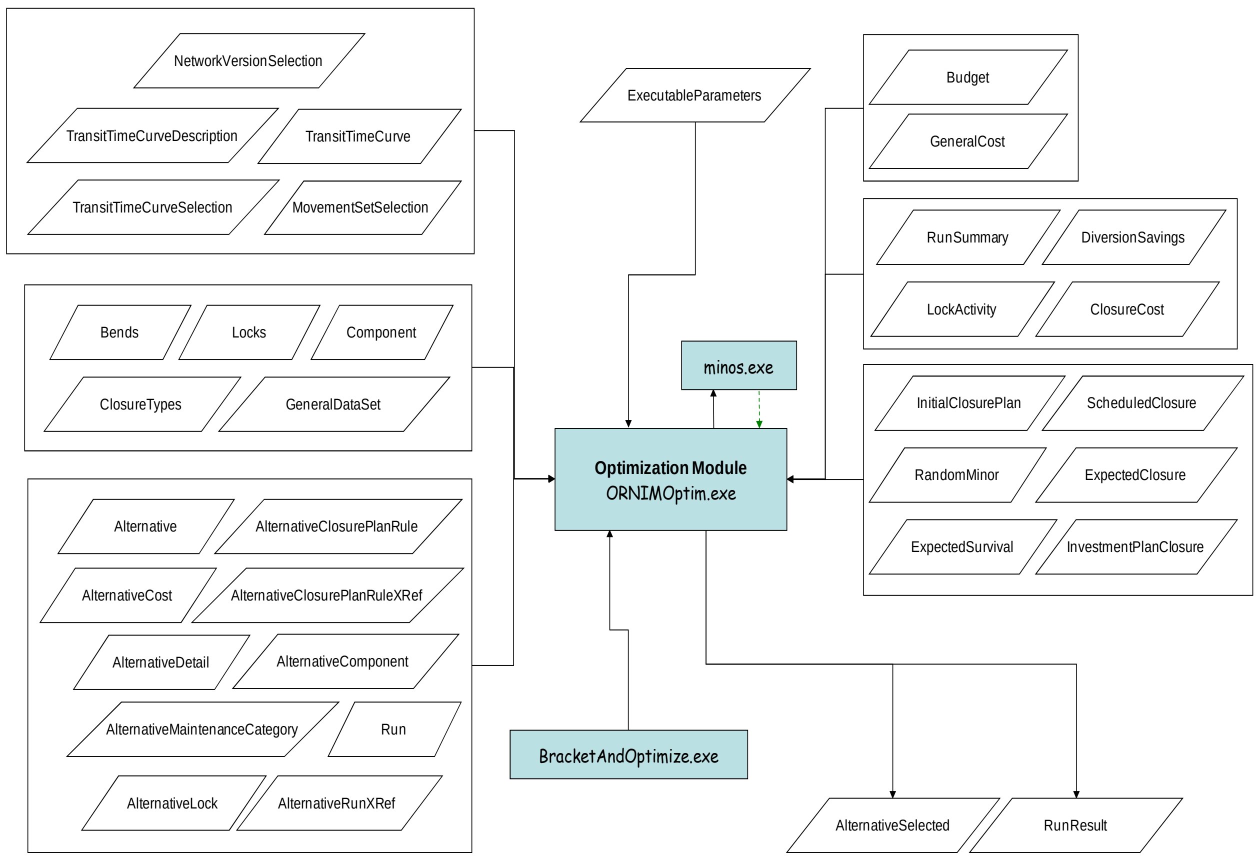
TABLE 1.3.5 – SummClosures Execution Parameters (ExecutableParameter Table Data)

Parameter			Variable	Default	
ID	Class	Name	Type	Value	Comments
1	networkID	Network ID	integer	0	
2	investmentPlanID	Investment Plan ID	integer	0	
3	runID	Starting Run ID	integer	0	
4	runID	Ending Run ID	integer	0	

1.3.5 Optimization Module

The Optimization Module input and output database tables are shown in FIGURE 1.3.10. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

FIGURE 1.3.10 – Optimization Module Input and Outputs



1.3.5.1 ORNIMOptim Execution Parameters

The ORNIMOptim execution is controlled through fourteen parameters in the "*ExecutableParameter*" table shown in TABLE 1.3.6.

TABLE 1.3.6 – ORNIMOptim Execution Parameters (ExecutableParameter Table Data)

Parameter			Variable	Default	
ID	Class	Name	Type	Value	Comments
1	networkID	Network ID	integer	0	
2	investmentPlanID	Investment Plan ID	integer	0	
3	forecastID	Forecast ID	integer	0	
4	runID	Run ID	integer	0	
5	calculateCongestionFees	Calculate Congestion Fees	Y/N	N	
6	lockageFeePlanID	Lock Fee Plan ID	integer	0	
7	fuelTaxPlanID	Fuel Tax Plan	integer	-1	
8	demandFunctionPlanID	Demand Function Plan	integer	-1	
9	allowShippingReplan	Allow Shipping Plan Recalculation	Y/N	N	
10	allowTonnageInExcessOfForecast	Allow Tonnage in Excess of Forecast	Y/N	N	
11	useMostLikelyHazardFunction	Use Most Likely Hazard Function	Y/N	N	
12	logfile	Logfile 1	text		
13	logfile	Logfile 2	text		
14	logfile	Logfile 3	text		

1.3.5.2 Budget Constrained Optimization

The description above describes the non-budget-constrained environment. That is, the analysis that allows for multiple large construction projects to proceed concurrently on the river system. ORNIM also has the capability to analyze the tradeoffs between alternatives in a budget-constrained environment. The budget could be an actual projected budget for USACE construction, or it could be a planning figure which models the reasonable level of effort which could be managed by the construction fleet and contracts during each year. If the unconstrained solution selects more activities in a short time period than the analyst feels is reasonable, using the budget-constrained option will force the system to spread the work out in an effective way. A true mathematical optimum cannot be claimed for this option, although the process does rely on optimization techniques. The overall process is a combination of heuristics and optimization techniques that attempts to find good combinations of alternatives.

In the budget-constrained option, the Optimization Module uses a simple heuristic to view the problem as a combination of budget allocation and optimal selection of alternatives. The procedure is best described through the following steps:

- The Optimization Module allocates the available budget for each year to the locks involved in alternatives.
- Each lock (or set of locks in the case of alternatives with activities at multiple locks) determines the optimal selection of alternatives given the annual budget constraint. The total cost of the alternative activities in each year must be less than or equal to the allocated budget. The lock (or lock group) then develops an optimal plan for Δ% more than the allocated budget and for Δ% less. (The value of Δ is set internally.) This provides three choices and three yearly cost streams and savings streams.
- The Optimization Module then collects the choices and cost streams from all of the locks and develops a simple integer program formulation. The integer program selects the set of choices (no more than one for each lock or lock group) that maximizes the total net savings and remains within the budget allocation. This process uses the CPLEX optimization software distributed by ILOG, an IBM company.
- The total cost is calculated for each year and subtracted from the budget. This provides a set of remaining un-allocated funds for each year.
- These funds are then allocated in turn to each lock (or lock group) to determine a new set of choices which would be optimal if the lock were allowed to use the residual funds.
- These new choices are added to the integer programming formulation and the problem is re-run through CPLEX. The optimization software selects the optimal combination of choices from the new selections.
- This process of allocating funds, developing choices for each lock and selecting the optimal set of choices continues until there is no longer a change in the optimal set of choices.

While there is no known globally optimal solution to compare with, this heuristic combination of allocating resources, solving sub-problems and optimally selecting sets of sub-problem solutions is a well-established technique. In the limited testing to date it appears to produce reasonable answers if the budget is sufficient to select at least the must-do alternatives. This technique has not thus far been used in operational tests[28].

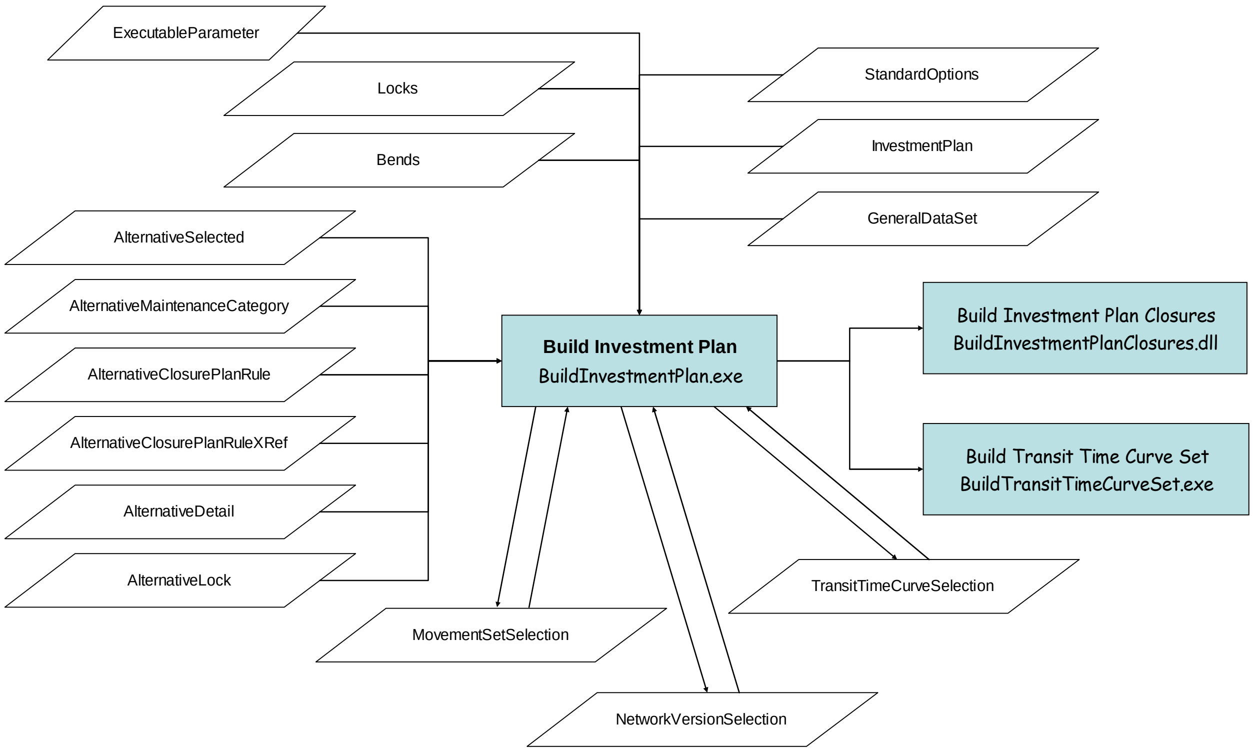
1.3.6 Build Investment Plan Module

The objective of the "*Build Investment Plan*" module is to determine the movement set, network version, and transit time curve set is in effect in each year of the investment plan. Additionally the program to build the investment plan's scheduled closure list (BuildInvestmentPlanClosures.dll) is called.

[28] Since the budget constraint has not been required operationally, the budget-constrained process including the links to CPLEX has not been used or tested recently. It is likely that some other changes and modifications have "broken" the process. This capability would likely need to be reworked and brought up to date with the rest of the software before it is used operationally. Also, the process has not been tested with large numbers of components and alternatives at many locks.

The "*Build Investment Plan*" module input and output database tables are shown in FIGURE 1.3.11. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

FIGURE 1.3.11 – Build Investment Plan Module Inputs & Outputs



1.3.6.1 BuildInvestmentPlan Execution Parameters

The BuildInvestmentPlan execution is controlled through ten parameters in the "*ExecutableParameter*" table shown in TABLE 1.3.7.

TABLE 1.3.7 – BuildInvestmentPlan Execution Parameters (ExecutableParameter Table Data)

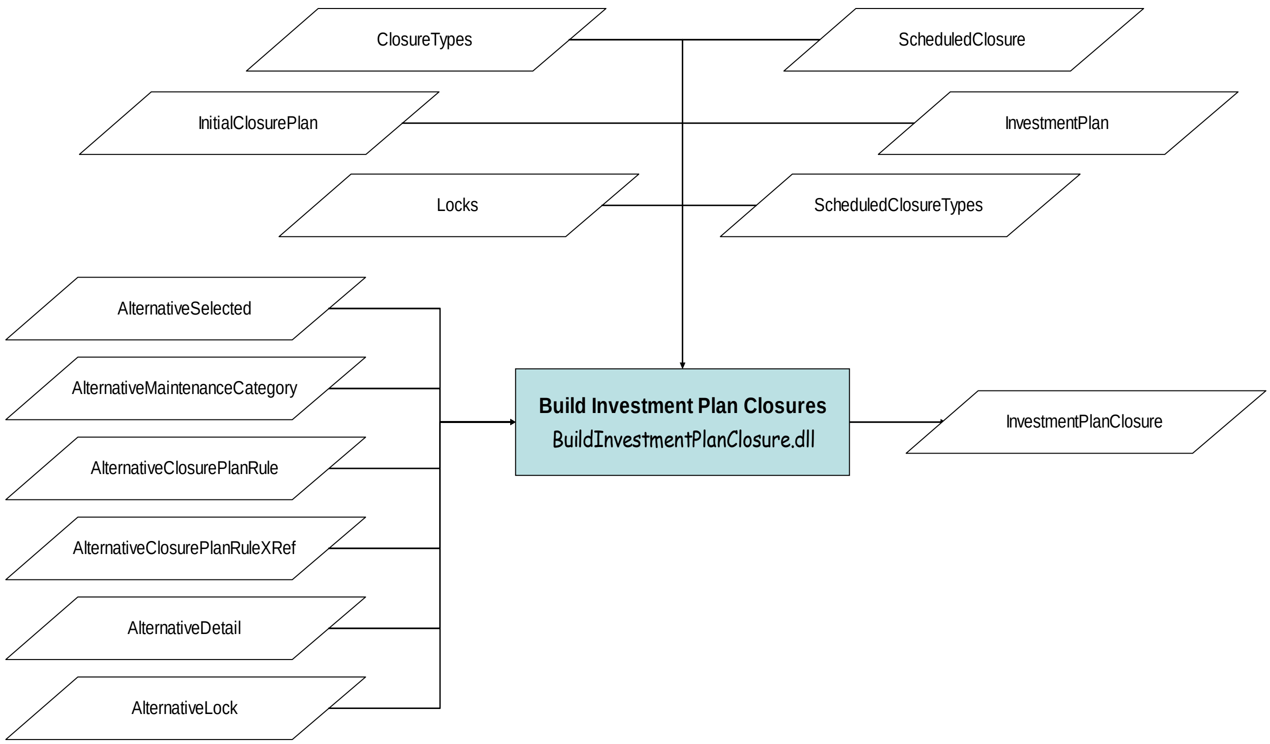
Parameter			Variable	Default	
ID	Class	Name	Type	Value	Comments
1	networkID	Network ID	integer	0	
2	investmentPlanID	New Investment Plan ID	integer	0	
3	forecastID	Forecast ID	integer	1	
4	calculateCongestionFees	Calculate Congestion Fees	Y/N	N	
5	lockageFeePlanID	Lockage Fee Plan ID	integer	0	
6	fuelTaxPlanID	Fuel Tax Plan ID	integer	0	
7	demandFunctionPlanID	Demand Function Plan ID	integer	-1	
8	allowShippingReplan	Allow Shipping Plan Recalculation	Y/N	N	
9	allowTonnageInExcessOfForecast	Allow Tonnage In Excess of Forecast	Y/N	N	
10	useMostLikelyHazardFunction	Use Most Likely Hazard Function	Y/N	Y	

1.3.7 Build Investment Plan Closures Module

The objective of the "*Build Investment Plan Closures*" module is to generate the set of closures (scheduled and improvement) for an investment plan, taking into account the existing scheduled closures, the modifications to the scheduled closures due to alternative implementation, and the closures associated with the alternatives.

The "*Build Investment Plan Closures*" module input and output database tables are shown in FIGURE 1.3.12. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

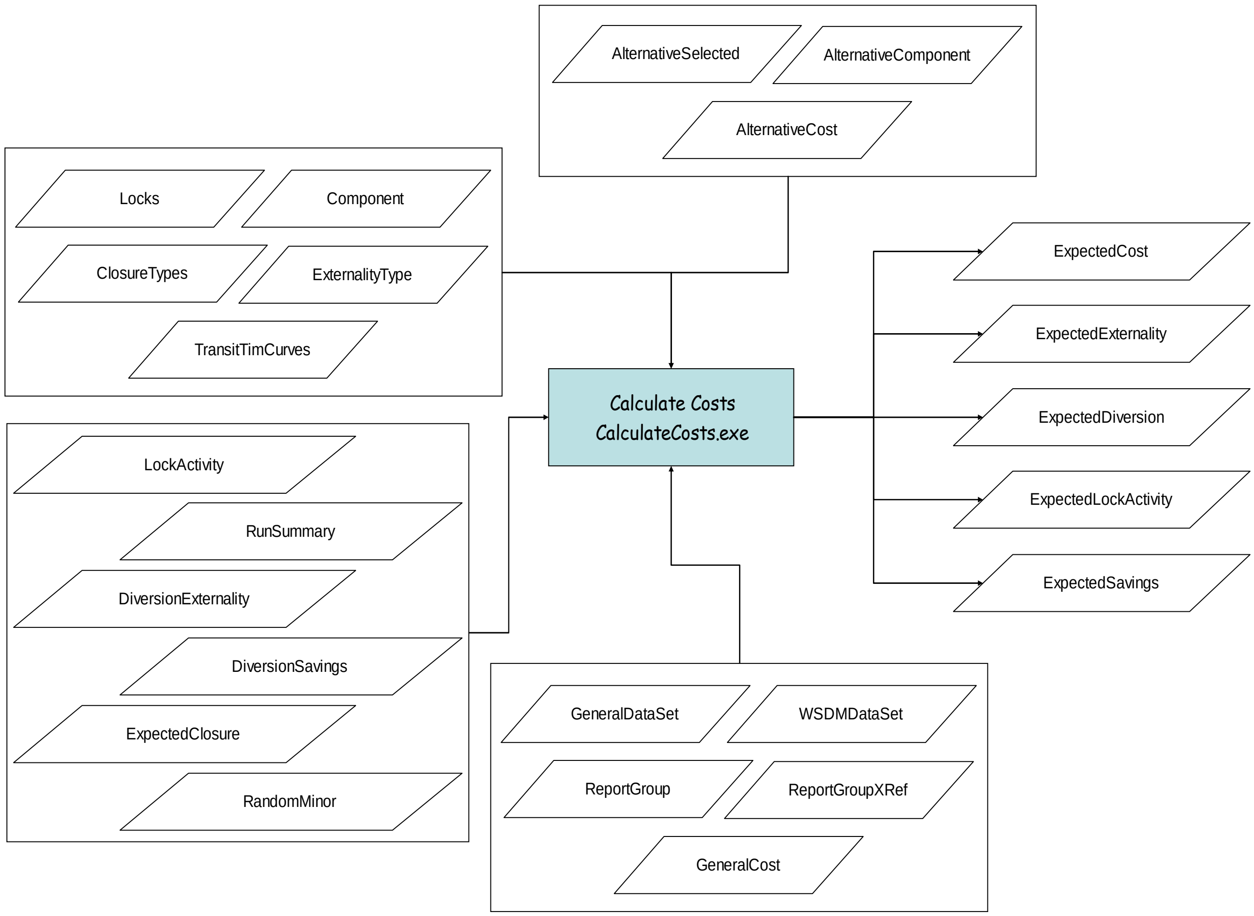
FIGURE 1.3.12 – Build Investment Plan Closures Module Inputs & Outputs



1.3.8 Calculate Costs Module

The objective of the "*Calculate Costs*" module is to compile the life-cycle cost (and waterway transportation surplus) dollar streams for an RUN or IP. The "*Calculate Costs*" module input and output database tables are shown in FIGURE 1.3.13. Additional discussion of the database tables can be found in section 1.4 with detailed specification of the ORNIM version 5.1 tables and table fields itemized in the ORNL Ohio River Navigation Investment Model 5.1 Data Management Document dated May 2010.

FIGURE 1.3.13 – Calculate Costs Module Inputs & Outputs



1.3.8.1 CalculateCosts Execution Parameters

The CalculateCosts execution is controlled through eighteen parameters in the "*ExecutableParameter*" table shown in TABLE 1.3.8.

TABLE 1.3.8 – CalculateCosts Execution Parameters (ExecutableParameter Table Data)

Parameter			Variable	Default	
ID	Class	Name	Type	Value	Comments
1	networkID	Network ID	integer	0	
2	investmentPlanID	Investment Plan ID	integer	0	
3	forecastID	Forecast ID	integer	1	
4	lockageFeePlanID	Lockage Fee Plan ID	integer	0	
5	fuelTaxPlanID	Fuel Tax Plan ID	integer	-1	
6	demandFunctionPlanID	Demand Function Plan ID	integer	-1	
7	calculateCongestionFees	Calculate Congestion Fees	Y/N	N	
8	allowShippingReplan	Allow Shipping Plan Recalculation	Y/N	N	
9	allowTonnageInExcessOfForecast	Allow Tonnage in Excess of Forecast	Y/N	N	
10	useMostLikelyHazardFunction	Use Most Likely Hazard Function	Y/N	N	

1.3.9 Output Utility Module

The objective of the "*Output Utility*" module is to generate the output workbooks for user review and analysis.

1.4 Model Inputs and Outputs

The development of accurate input data, and the appropriate aggregation and classification of the input data to adequately describe the inland waterway system, is essential for correct calibration and operation of the ORNIM. ORNIM is loaded with traffic flows in, out, or through the Ohio River System (ORS). There are two primary sources of inland waterway transportation flow data: Waterborne Commerce Statistical Center (WCSC) and Lock Performance Monitoring System (LPMS) data, each with their pros and cons. Analyzing the historic system data from these two data sources drives the specification and aggregation of the model's input data for use in the Upper Ohio River analysis.

Input, output, and execution data is stored in Microsoft Sequel (SQL) Server 2005 database with Microsoft Office 2003. The model's 129 database tables can be grouped into ten broad categories:

- system network / infrastructure / equipment characteristics (section 1.4.1);
- movement characteristics (section 1.4.2);
- system operating and budget assumptions (section 1.4.3);
- maintenance characteristics (section 1.4.4);
- reliability characteristics (section 1.4.5);
- investments to consider (section 1.4.6);
- analysis, execution, and summary parameters (section 1.4.7);
- Module outputs (section 1.4.8);
- Report Definitions (section 1.4.9); and
- Model bookkeeping (section 1.4.10).

In the model's 23 system network / infrastructure / equipment characteristics tables, the network is described with 171 pick-up/drop-off nodes, 56 navigation projects, 9 commodity types, 12 barge types, and 8 towboat types. In the 12 movement characteristics tables, historic and forecasted ORS traffic flows are described with 17,138 unique movement IDs. Each one of these movement IDs is defined not only with a unique origin-destination node pair, commodity type, and barge type, but also has its own base water rate, base least-cost all-overland rate, and demand elasticity. Detail on the aggregation of the network and movement data can be found in ADDENDUM 1B ORNIM Calibration. This section will focus on the data not covered in the calibration discussion (equilibrium data).

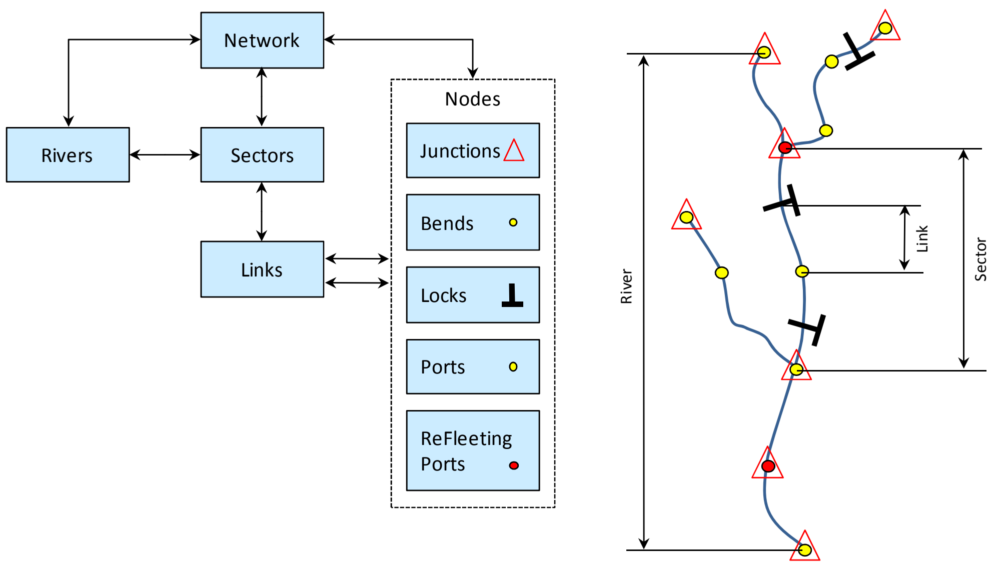
1.4.1 System Network / Infrastructure / Equipment Characteristics

Under this category of data are the input database tables describing: 1) the topology of the inland waterway network; 2) the characteristics of the system's constituent locks, ports, reaches, and other components that affect towing operations and costs; and 3) the characteristics and costs of towboat classes and barge types used for towing operations.

1.4.1.1 Transportation Network (System) Definition

System network data specifies the topology of the inland waterway network traversed by the movements and the characteristics of the locks, ports, bends and junctions for each river. FIGURE 1.4.1 provides a graphical view of the data relationships. The system has the ability to store multiple networks. The networks may be different waterway systems or different versions of the same waterway. The network is defined based on a set of nodes and links between the nodes. Nodes can be locks, ports, bends or junctions. Each node is associated with a latitude and longitude. Locks and bends represent the points that cause delay based on traffic levels. Each network is made up of one or more rivers. (The double-headed arrow in the diagram indicates that multiple entities are associated with a single entity on the other end of the arrow.) Each river is divided into sectors at junctions — the head and mouth of the river and points where tributaries enter the river. (For computational convenience the sectors are uniquely indexed and can be related directly back to the network.) Each sector is then divided into links between nodes. A link has an upstream node and a downstream node. Each link has data on length, depth (minimum and average), current speed, and coefficients for calculating tow speed.

FIGURE 1.4.1 – Relationships of the Network Entities

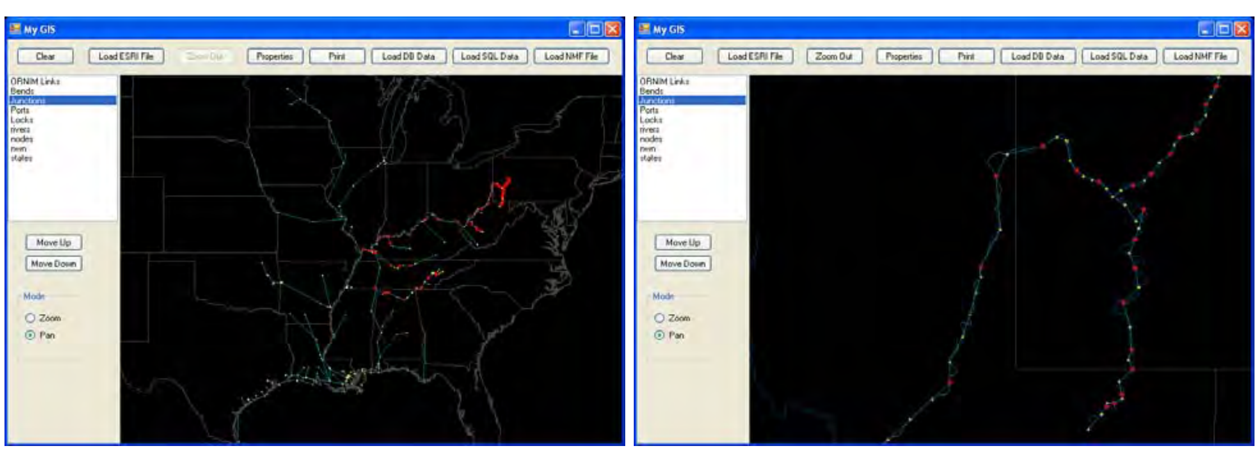


The network data provides the framework for much of the other ORNIM data. Locks and bends are related to their transit curves. Ports are related to movement origins and destinations. Port records also contain information on loading and unloading rates and re-fleeting times based on cargo type.

Note that the network nodes are associated with latitude and longitude points; however, the rest of the network is not associated directly with geographic locations. The links have lengths, but not a shape or path. Separate files are maintained for the geographic display of the network, but that is not a component of the WSDM module. Those displays are discussed in the User Interface chapter.

The network in the current database encompasses most of the inland waterway system, including much of the Gulf Intercoastal Waterway, over 12,000 miles of waterway. While much of the network detail is of little consequence to analysis of Upper Ohio River investment options, it was more efficient to maintain the network structure and update the inputs, rather than re-specifying the network from scratch (FIGURE 1.4.2).

FIGURE 1.4.2 – The Current ORNIM Waterway Network



1.4.1.1.1 NetworkDefinition and NetworkVersion Tables

ORNIM allows storage and analysis different networks for different river systems (TABLE 1.4.1), and allows for storage and analysis of variations of each network (TABLE 1.4.2).

TABLE 1.4.1 – NetworkDefinition Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkName		Network name
baseYear		Year for base cost (e.g. 9999 equals 2004-2006 average)
comments		Additional description if necessary

TABLE 1.4.2 – NetworkVersion Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Version ID (a variation of the network)
networkVersionName		Name
comments		Additional description if needed

The "*networkVersion*" is used to specify changes to the base network at a specified time in the planning period. These changes can occur from scheduled events such as a project already under construction being completed (e.g., Olmsted replacement of L/D 52 and 53) or from events being analyzed by the model (e.g., 2-for-3 replacement of the three Upper Ohio projects with two 1200' main chamber projects). Currently in the network for the Ohio River System the seven network versions shown in TABLE 1.4.3 are defined, however, only network versions 1, 5, and 6 are currently used at this time.

TABLE 1.4.3 – Network Versions (NetworkVersion Table Data)

networkID	networkVersion	networkVersionName	comments
1	0	Existing	ORMSS-SIP
1	1	UpperOHExisting	UpperOH Existing 2008 infrastructure calibrated to year 9999 (2004-2006 av)
1	2	UpperOHJumbo600	UpperOH w/ regulars & stumbos changed to jumbos assuming 600' locks at all 3 locks
1	3	UpperOHJumbo800	UpperOH w/ regulars & stumbos changed to jumbos assuming 800' locks at all 3 locks
1	4	UpperOHJumbo1200	UpperOH w/ regulars & stumbos changed to jumbos assuming 1200' locks at all 3 locks
1	5	UpperOH800	UpperOH assuming 800' locks at all three
1	6	UpperOH1200	UpperOH assuming 1200' locks at all three

1.4.1.1.2 NetworkVersionSelection Table

Since the applicable network version can change through time, the timing of the network version is specified in the "*NetworkVersionSelection*" table. For example, say "*networkVersion*" 1 represents the existing system and say no other projects (e.g., Olmsted) are coming online over the analysis period. The without-project condition would be analyzed over the analysis period using "*networkVersion*" 1. Say the with-project condition is replacement of all three Upper Ohio projects with 1200' main chambers, each coming online in different years. Say that given the high commonality of traffic between the three Upper Ohio River projects, shipping characteristics (i.e., tow-size) are not expected to change until all three 1200' main chambers are open. In this case, the with-project condition would use "*networkVersion*" 1 until the last 1200' chamber comes online, then "*networkVersion*" 6 (representing the system characteristics with all three 1200' main chambers on the Upper Ohio open) is used.

1.4.1.1.3 Rivers and RiverLocation Tables

A river in the model's waterway network (FIGURE 1.4.1) is a sequential string of sectors that represent the river. For "*networkID*" 1 101 rivers have been defined and stored in the "*Rivers*" table (TABLE 1.4.4). The primary use of the data stored in this table is to allow output data rollup for summary reports. The sixteen rivers that are in the ORS are shown in TABLE 1.4.5.

TABLE 1.4.4 – Rivers Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
riverID	Key	Unique river ID.
riverName		River name (description)
length		River length (miles).
Comments		Additional description if needed.

TABLE 1.4.5 – ORS Rivers (Rivers Table Data)

networkID	riverID	riverName	length
1	1	Monongahela	116.4
1	2	Allegheny	68.2
1	3	Ohio River	981.8
1	4	Kanawha	86.6
1	5	Green	87.3
1	6	Cumberland	358
1	7	Clinch	51.3
1	8	Tennessee	652.1
1	9	Ky/Brk Canal	1.5
1	23	Little Kanawha	4
1	24	Big Sandy	160.9
1	25	Kentucky	256.2
1	26	French Broad	2.7
1	27	Emory	5
1	28	Hiwassee	22
1	98	Licking River	0

1.4.1.1.4 Sectors Table

A sector in the model's waterway network (FIGURE 1.4.1) is a sequential string of links that represent that segment of the waterway system. For "*networkID*" 1 220 sectors have been defined and stored in the "*Sectors*" table. Data stored in this table is shown in TABLE 1.4.6. The current waterway fuel tax, however, is not applicable to all waterways. Under existing law (33 U.S.C. 1804), the fuel tax is collected on twenty-seven specified waterways. These fuel tax waterways are identified in the model through the "*collectFuelTax*" field in the "*Sectors*" table. Of the 220 sectors, twenty-two have been specified as non-tax waterways as shown in TABLE 1.4.7.

TABLE 1.4.6 – Sectors Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
sectorID	DB Key	Interger ID used as key in other database tables
sectorName		Text name used for output report labeling
riverID		Integer cross reference ID to the Rivers table
collectFuelTax		(TRUE or FALSE) does IWUB fuel tax apply to this water segment
waterwayCode		WCSC WTWY used for summary report generation

TABLE 1.4.7 – Non-Fuel Tax Waterways (Sectors Table Data)

networkID	sectorID	sectorName	riverID	collectFuelTax	waterwayCode
1	32	KY/Bark. Canal	9	FALSE	2377
1	61	Clinch River	7	FALSE	2375
1	62	Clinch split	7	FALSE	2375
1	63	Little Kanawha	23	FALSE	2346
1	64	Big Sandy	24	FALSE	2345
1	65	Kaskaskia River	13	FALSE	2305
1	71	Yazoo	15	FALSE	2010
1	72	Yazoo R.	15	FALSE	2009
1	115	French Broad	26	FALSE	2374
1	116	Emory	27	FALSE	2379
1	117	Hiwassee	28	FALSE	2376
1	119	Chicago North	30	FALSE	3746
1	120	Chicago Main	30	FALSE	3747
1	137	Intcoast wwy alt rou	46	FALSE	2053
1	146	Mobile Bay	51	FALSE	2000
1	191	Lake Pontchartrain	80	FALSE	2050
1	192	Lake Pontchartrain	80	FALSE	2050
1	194	Inner Harbor	82	FALSE	2052
1	195	Mississippi Gulf Out	83	FALSE	2060
1	217	Licking	98	FALSE	2340
1	219	Lake Michigan	100	FALSE	3701
1	220	Black (Wis)	101	FALSE	2322

1.4.1.1.5 Locks Table

ORNIM allows specification and storage of the navigation projects in the system network through the "*Locks*" table (TABLE 1.4.11). Primarily the table allows specification of a "*lockID*" for each project that can then be referenced as a key in other database tables where project specific data is stored (e.g., tonnage-transit curves). A text name and GIS coordinates are specified to facilitate report labeling and mapping. Additionally, for the auto shipping plan calibration programs (see ADDENDUM 1B ORNIM Calibration), a "*calibrationWeight*" field is specified for each lock in the system network. This lock calibration weight allows the calibration process to focus on projects important to the analysis (as specified by the user). For this Upper Ohio analysis, the twenty Ohio River and the four lower Monongahela River projects were set with lock calibration weights of 1.0, while the remaining thirty-two projects were set with a weight of 0.10. These settings were selected based on an analysis of Upper Ohio River traffic flow commonality as discussed in ADDENDUM 1B ORNIM Calibration.

TABLE 1.4.8 – Locks Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
lockID		Interger ID used as key in other database tables
lockName		Text name used for output report labeling
displayLockName		Text name used for output report labeling
lockGroup		Used to consolidate calibration statistics (i.e. Kentucky & Barkley L/Ds)
calibrationWeight		Used to identify primary projects for calibration
latitude		Latitude decimal degrees (used for display maps)
longitude		Longitude decimal degrees (used for display maps)
mainChamberLength		Main chamber length (ft) for output report labeling
mainChamberWidth		Main chamber width (ft) for output report labeling
auxChamberLength		Auxiliary chamber length (ft) for output report labeling
auxChamberWidth		Auxiliary chamber width (ft) for output report labeling

1.4.1.1.6 ChamberTypes Table

Locks are further delineated by a chamber type described in the "*ChamberTypes*" table (TABLE 1.4.9). The contents of this database table are shown in TABLE 1.4.10.

TABLE 1.4.9 – ChamberTypes Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
chamberID	DB Key	Chamber ID from ChamberTypes table.
chamberName		Chamber name.

TABLE 1.4.10 – Chamber Types (ChamberTypes Table Data)

networkID	chamberID	chamberName
1	1	Main
1	2	Auxilliary
1	3	Both

1.4.1.1.7 Bends Table

ORNIM allows specification and storage of the bends in the system network through the "*Bends*" table (TABLE 1.4.11). Primarily the table allows specification of a "*bendID*" for each bend that can then be referenced as a key in other database tables where bend specific data is stored. A text name and GIS coordinates are specified to facilitate report labeling and mapping.

TABLE 1.4.11 – Bends Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
bendID	Key	Unique bend ID
bendName		Bend name
latitude		Latitude decimal degrees coordinate used for display maps
longitude		Longitude decimal degrees coordinate used for display maps
comments		Additional description if needed.

1.4.1.1.8 Junctions Table

Junctions in the model's waterway network (FIGURE 1.4.1) define sector endpoints; the head and mouth of a river and points where tributaries enter the river. For networkID 1 213 junctions have been defined and stored in the "*Junctions*" table. Data stored in this table is shown in TABLE 1.4.12.

TABLE 1.4.12 – Junctions Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
junctionID	DB Key	Unique integer junction ID used as key in other database tables
junctionName		Text name used for output report labeling
latitude		Latitude decimal degrees coordinate used for display maps
longitude		Longitude decimal degrees coordinate used for display maps

1.4.1.1.9 Ports and PortsRefleeting Tables

Ports in the model's waterway network (FIGURE 1.4.1) define the traffic pickup and drop-off nodes in the link-node network. For "*networkID*" 1 171 ports have been defined and stored in the "*Ports*" table.

Data stored in this table is shown in TABLE 1.4.13. Additional discussion on the port parameters can be found in ADDENDUM 1B ORNIM Calibration.

TABLE 1.4.13 – Ports Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
portID	DB Key	Unique integer port ID used as key in other database tables
portName		Text name used for output report labeling
latitude		Latitude decimal degrees coordinate used for display maps
longitude		Longitude decimal degrees coordinate used for display maps
fleetTimePerTow		Time per tow to fleet barges to towboat
fleetTimePerBarge		Time per barge to fleet into tow (minutes)
loadRate1		Cargo handling class 1 load rate in minutes per ton
loadRate2		Cargo handling class 2 load rate in minutes per ton
loadRate3		Cargo handling class 3 load rate in minutes per ton
unloadRate1		Cargo handling class 1 unload rate in minutes per ton
unloadRate2		Cargo handling class 2 unload rate in minutes per ton
unloadRate3		Cargo handling class 3 unload rate in minutes per ton
portDelay1		Cargo handling class 1 port delay time in hours per tow
portDelay2		Cargo handling class 2 port delay time in hours per tow
portDelay3		Cargo handling class 3 port delay time in hours per tow
towboatWaitTime		Av. Hours barges wait for towboat pickup once loaded (hours)

These ports are not always the ultimate waterside origin and destination for the traffic flows; the movement might simply re-fleet (switch towboats or re-group into a different tow-size). The definition of which ports allow this re-fleeting operation is handled in a separate "*PortsRefleeting*" table as shown in TABLE 1.4.14. This is done in a separate table so that the assumptions regarding the re-fleeting points can be changed in an analysis without changing (or duplicating) the underlying port node definitions. As a result, the "*PortsRefleeting*" table contains a "*networkVersion*" ID while the "*Ports*" table does not.

TABLE 1.4.14 – PortsRefleeting Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
portID	DB Key	Movement portID (Ports table) where re-fleeting is considered

1.4.1.1.10 PortRiverLocation and RiverLocation Tables

Ports are cross-referenced to rivers through the "*RiverLocation*" table (TABLE 1.4.15) and "*PortRiverLocation*" table (TABLE 1.4.16).

TABLE 1.4.15 – RiverLocation Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
riverLocationID	Key	Unique river location ID.
riverLocationName		River location name.

TABLE 1.4.16 – PortRiverLocation Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
riverLocationID	Key	River location ID from RiverLocation table.
portID		Port ID from Ports table.

1.4.1.1.11 Links Table

Links in the model's waterway network (FIGURE 1.4.1) define the continuous stretches of waterway between the various types of nodes (e.g., ports and locks). For networkID 1 896 links have been defined and stored in the "*Links*" table. Data stored in this table is shown in TABLE 1.4.17.

TABLE 1.4.17 – Links Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
sectorID	DB Key	Sector ID (from Sectors table)
linkIndex	DB Key	Link ID (sequentially numbered 1,n within each Sector)
upNodeType		Upstream node type (B=bend , J= junction ,L=lock , or P=port)
upNodeID		Upstream node ID (note, node types B, J, L, and P can all be defined with the same node ID)
downNodeType		Downstream node type (B=bend , J= junction ,L=lock , or P=port)
downNodeID		Downstream node ID (note, node types B, J, L, and P can all be defined with the same node ID)
length		Length in miles of the river segment (link).
currentSpeed		Speed of current (mph).
avgDepth		Average depth of the link in feet (used in speed function).
minDepth		Minimum depth of the link in feet (used in barge loading calculation).
upSpeedCoefficient		Upbound speed coefficient (used in speed function).
downSpeedCoefficient		Downbound speed coefficient (used in speed function).

It can be noted that a node types ("*upNodeType*" and "*downNodeType*") are related to network nodes ("*upNodeID*" and "*downNodeID*") in this table since a node can be defined with multiple attributes. For example, the end of a river is often defined as a port where traffic can be loaded / unloaded and also as a junction representing the end of the sector. In this case, a port node and a junction node would be defined, and the distance between them would be set to 0. River junctions offer an additional example. At a river junction, often traffic can be picked up or dropped off (loaded, unloaded or re-fleeted) and three sectors merge. Most of the parameters defined in the "*Links*" table relate to the tow speed and trip time calculations discussed in ADDENDUM 1B ORNIM Calibration.

1.4.1.2 System Performance Characteristics

System performance of the lock and bend nodes are described through tonnage-transit curves relating an annual throughput with an average vessel transit time (where transit time includes both the processing and the delay time). Since this represents annual throughput, generally a lock tonnage-transit curve should not be defined unless all tonnage through the project is modeled.[29]

As discussed in section 1.3.2.1.2.1, to manage the numerous tonnage-transit curves utilized by the model, a hierarchical identification scheme of "*familyID*", "*setID*", and "*closureID*" is used. The data is

[29] A flat curve could be used (assuming the modeled movements have no significant impact on lock congestion) or a curve assuming non-modeled traffic is constant (assuming only the modeled movements impact congestion) could be utilized in cases where not all traffic through the lock is modeled.

managed in three database tables discussed in the follow sections. The "*closureID*" is handled in the "*ClosureTypes*" table to be discussed in section 1.4.5.3.

1.4.1.2.1 TransitTimeCurveFamily Table

Data on the tonnage-transit time curve families for the locks and bends are stored in the "*TransitTimeCurveFamily*" table (TABLE 1.4.18). This table sets the "*familyID*".

TABLE 1.4.18 – TransitTimeCurveFamily Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
nodeType	DB Key	Node type (B = bend, L = lock)
nodeID	DB Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
familyID	DB Key	Unique transit curve family ID.
name		Tonnage-transit curve family name.
comments		Additional description if needed.

1.4.1.2.2 TransitTimeCurveDescription Table

The description of each tonnage-transit time curve set is stored in the "*TransitTimeCurveDescription*" table (TABLE 1.4.19). This table sets the "*setNumber*" and whether or not there is additional specification of the tonnage-transit curve set down to the closure ("*closureID*") level.

TABLE 1.4.19 – TransitTimeCurveDescription Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
nodeType	Key	Node type (B = bend, L = lock)
nodeID	Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
setNumber	Key	Unique Tonnage-Transit curve set ID.
shortName		Tonnage-transit curve set name
comments		Additional description if needed.
allowClosures		Use closure curves, closureID > 1 (Y or N)

1.4.1.2.3 TransitTimeCurves Table

The data points for the tonnage-transit time curves are stored in the "*TransitTimeCurves*" table (TABLE 1.4.20).

TABLE 1.4.20 – TransitTimeCurves Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
nodeType	Key	Node type (B = bend, L = lock)
nodeID	Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
familyID	Key	Tonnage-Transit curve family ID from TransitTimeCurveFamily table.
setNumber	Key	Tonnage-Transit curve set ID from TransitTimeCurveDescription table.
closureID	Key	Service disruption ID from ClosureTypes table.
pointNumber	Key	Unique xy point ID.
tonnage		Annual tonnage at this point.
transitTime		Average vessel transit time (processing plus delay) at this point.
comments		Additional description if needed.

1.4.1.2.4 Calibration Targets

For the shipping-plan calibration process, historic system performance is also needed.

1.4.1.2.4.1 Targets Table

The "Targets" table (TABLE 1.4.21) contains the lock performance targets for the calibration process. These data are the actual lock activity levels in the calibration year (or an average of multiple years). Additional discussion of this database table and its contents can be found in ADDENDUM 1B ORNIM Calibration.

TABLE 1.4.21 – Targets Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
year	DB Key	Applicable year (9999 = 2004 through 2006 average)
lockID	DB Key	Lock ID (from Locks table)
lockName		Text name used for output report labeling
loadedBarges		Target # of loaded barges (WCSC)
emptyBarges		Target # of empty barges (est from WCSC loaded & LPMS % empty)
delayTime		Target av. tow delay time in min (LPMS av 2004-2006)
processingTime		Target av. tow processing time in min (LPMS av 2004-2006)
tonnage		Target tonnage (WCSC)
tows		Target # of tows (est from target loaded & empty barges, & LPMS barges per tow)
horsepower		Target av. Horsepower (LPMS)

1.4.1.2.4.2 TargetTowSizeDistribution Table

Additional detail on the historical distribution of tow-sizes at each lock is stored in the "TargetTowSizeDistribution" table (TABLE 1.4.22). Calibration of the shipping-plans to an average tow-size at each lock can result in hitting the average with an unrealistic underlying distribution. As a result, additional granularity on tow-sized was needed. Additional discussion of this database table and its contents can be found in ADDENDUM 1B ORNIM Calibration.

TABLE 1.4.22 – TargetTowSizeDistribution Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
lockID	DB Key	Lock ID (from Locks table)
year	DB Key	Applicable year (9999 = 2004 through 2006 average)
towSize	DB Key	Tow size in number of barges per tow (integer)
distribution		Proportion of tows of tow-size towSize (0-1.0)

1.4.1.3 Transportation Equipment Characteristics

Transportation equipment and its shipping characteristics are stored in four database tables discussed in the following two sections.

1.4.1.3.1 BargeTypes and BargeTypeCost Tables

ORNIM allows for a barge type (with unique cost and movement characteristics) to be specified on each movement. The 209 unique vessel type 4 (hopper) barge length-widths in the 2000-2007 ORS WCSC data were grouped into 7 hopper barge types, and the 286 unique vessel type 5 (tanker) barge length-widths were grouped into 5 tanker barge types (TABLE 1.4.23). Additional discussion on the development of these barge types can be found in ADDENDUM 1B ORNIM Calibration.

TABLE 1.4.23 – Barge Type Data

Barge Type	Handling Class *	Loading Capacity (tons)	Dimensions (ft) length	Dimensions (ft) beam	Draft (ft) Empty	Draft (ft) Loaded	Draft (ft) Maximum	Draft (ft) Clearance	Blocking Coefficient
Irregular Hopper	1	637	135	27	1.5	9.5	12	1	0.98
Regular Hopper	1	1,069	175	26	1.5	9.5	12	1	0.98
Stumbo	1	1,121	195	26	1.5	9.5	12	1	0.98
Jumbo Open Hopper	1	1,669	195	35	1.5	9.5	12	1	0.98
Jumbo Covered Hopper	1	1,764	195	35	1.5	9.5	12	1	0.98
Super Jumbo Hopper	1	2,106	245	35	1.5	9.5	12	1	0.98
Giant Hopper	1	3,329	260	52	1.5	9.5	12	1	0.98
Jumbo Tanker	3	1,454	195	35	1.5	9.5	12	1	0.98
147 ft Tanker	3	1,711	147	52	1.5	9.5	12	1	0.98
175 ft Tanker	3	2,317	175	54	1.5	9.5	12	1	0.98
264 ft Tanker	3	2,820	264	50	1.5	9.5	12	1	0.98
297 ft Tanker	3	3,295	297	54	1.5	9.5	12	1	0.98

** Handling class allows specification of different loading and unloading rates.*

For these twelve barge types, the latest Corps Economic Guidance Memorandum on shallow-draft vessel costs is EGM05-04[30] which has costs at a FY2004 price level. Previously this cost data was processed into the twelve barge types and eight towboat horsepower classes needed for loading into ORNIM. For this Upper Ohio analysis this FY2004 cost data was indexed to a FY2004-2006 price level, as shown in TABLE 1.4.24. The "*BargeTypes*" and the "*BargeTypeCost*" tables (TABLE 1.4.25 and TABLE 1.4.26) hold the data for the models.

TABLE 1.4.24 – Barge Cost Data (FY2004-2006 Price Level)

Cost Category	Barge Type: Deck (130x35)	Regular Open (175x26)	Stumbo Open (195x26)	Jumbo Open (195x35)	Jumbo Covered (195x35)	Super Jumbo (245x35)	Giant (260x52)	Jumbo (195x35)	147' (147x52)	175' (175x54)	264' (264x50)	297' (297x54)
FIXED COSTS:												
Replacement Cost	$ 196,682	$ 177,591	$ 197,886	$ 289,550	$ 332,965	$ 363,793	$ 579,098	$ 791,059	$ 870,495	$1,041,242	$1,384,476	$1,630,144
Utilization (days)	350	350	350	350	350	350	350	340	340	340	340	340
CRF 5.375% 20 yrs	$ 16,288	$ 14,707	$ 16,388	$ 23,979	$ 27,574	$ 30,127	$ 47,957	$ 65,510	$ 72,089	$ 86,229	$ 114,654	$ 134,998
Administration	$ 478	$ 2,616	$ 3,137	$ 4,226	$ 4,421	$ 4,226	$ 4,226	$ 9,022	$ 9,841	$ 11,602	$ 15,151	$ 10,006
Fixed Annual Capital Costs	$ 16,766	$ 17,323	$ 19,524	$ 28,204	$ 31,995	$ 34,353	$ 52,183	$ 74,532	$ 81,930	$ 97,831	$ 129,805	$ 145,004
VARIABLE COSTS:												
Maintenance & Repairs	$ 1,791	$ 2,145	$ 2,576	$ 3,466	$ 3,708	$ 4,356	$ 6,932	$ 15,390	$ 16,926	$ 20,226	$ 26,846	$ 31,554
Supplies	$ -	$ 228	$ 271	$ 365	$ 1,024	$ 459	$ 731	$ 545	$ 573	$ 633	$ 752	$ 836
Insurance	$ 673	$ 937	$ 1,125	$ 1,512	$ 1,248	$ 1,899	$ 3,025	$ 7,040	$ 8,301	$ 11,113	$ 17,111	$ 21,601
Other	$ 897	$ 239	$ 286	$ 387	$ 1,295	$ 485	$ 774	$ 6,667	$ 6,878	$ 7,324	$ 8,221	$ 8,864
Annual Variable Costs:	$ 3,361	$ 3,549	$ 4,258	$ 5,731	$ 7,276	$ 7,200	$ 11,462	$ 29,642	$ 32,679	$ 39,297	$ 52,930	$ 62,855
Total Annual Costs:	$ 20,127	$ 20,872	$ 23,783	$ 33,935	$ 39,271	$ 41,553	$ 63,645	$ 104,174	$ 114,608	$ 137,127	$ 182,734	$ 207,859
HOURLY COSTS:												
Hourly Fixed Costs:	$ 2.00	$ 2.06	$ 2.32	$ 3.36	$ 3.81	$ 4.09	$ 6.21	$ 9.13	$ 10.04	$ 11.99	$ 15.91	$ 17.77
Hourly Variable Costs:	$ 0.40	$ 0.42	$ 0.51	$ 0.68	$ 0.87	$ 0.86	$ 1.36	$ 3.63	$ 4.00	$ 4.82	$ 6.49	$ 7.70
Avg. Hourly Costs:	$ 2.40	$ 2.48	$ 2.83	$ 4.04	$ 4.68	$ 4.95	$ 7.58	$ 12.77	$ 14.05	$ 16.80	$ 22.39	$ 25.47

SOURCE: EGM05-06 FY 2004 Shallow Draft Vessel Costs indexed to CY 2004-2006 using averaged BLS CPI Inflation Calculator and averaged FY 2004-2006 Federal Discount Rate of 5.375%.

[30] *FY 2006 Shallow-draft vessel costs were completed but have yet to be finalized into an EGM.*

TABLE 1.4.25 – BargeTypes Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
bargeTypeID	DB Key	Unique barge ID used as key in other database tables
bargeTypeName		Text name used for output report labeling
handlingClassCode		
capacity		
length		Typical barge in class length in feet
beam		Typical barge in class width in feet
emptyDraft		Typical barge in class empty draft in feet
loadedDraft		Typical barge in class fully loaded draft in feet
maxDraft		
clearance		
blockCoefficient		ratio of volume to length, width, & draft.
availability		fraction of time available for hauling

TABLE 1.4.26 – BargeTypeCost Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
bargeTypeID	DB Key	Unique barge ID from BargeTypes table
beginYear		First year cost is to be applied
varOpCost		Variable operating cost per hour (dollars)
fixedCost		Fixed annual cost (dollars)

1.4.1.3.2 TowboatTypes and TowboatTypeCost Tables

The towboat class data discussed in ADDENDUM 1B ORNIM Calibration are loaded into the "*TowboatTypes*" table shown in TABLE 1.4.27. The towboat cost data discussed in ADDENDUM 1B ORNIM Calibration are loaded into the "*TowboatTypeCost*" table shown in TABLE 1.4.28. The "*beginYear*" field allows storage and use of different cost data, primarily for calibration to different years. Year "*9999*" was used to signify the 2004-2006 average.

TABLE 1.4.27 – TowboatTypes Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
towboatTypeID	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
towboatTypeName		Text name used for output report labeling
ratedHorsepower		Rated horsepower of the towboat class
horsepower		Nominal hp reflecting hp delivered to the prop.
maxTowSize		Maximum no. of barges that can be pushed by the towboat class
length		Overall vessel length (feet)
beam		Overall vessel width (feet)
draft		Overall vessel draft (feet)
blockCoeffieient		Ratio of the vol of the hull to the product of the vessel length, width, & draft.
opFuelRate		Operating (line-haul) fuel consumption rate (gallons per hour)
opFuelRateUpLoaded		Operating up-bound loaded barge(s) tow fuel consumption rate (gallons per hour)
opFuelRateDownLoaded		Operating down-bound loaded barge(s) tow fuel consumption rate (gallons per hour)
opFuelRateUpEmpty		Operating up-bound empty barge(s) tow fuel consumption rate (gallons per hour)
opFuelRateDownEmpty		Operating down-bound empty barge(s) tow fuel consumption rate (gallons per hour)
manFuelRate		Maneuvering fuel consumption rate (gallons per hour)
availability		Proportion of year equipment class is available for towing service
propDiameter		Propeller diameter (inches) used for NAVPAT file generation.
propPitch		Propeller pitch (degrees-) used for NAVPAT file generation.
percentageKort		Proportion of vessels in class with kort nozzles (0-1.0)
upboundLoadedRPM		Av. Up-bound loaded barge(s) tow propeller RPM
upboundEmptyRPM		Av. Up-bound empty barge(s) tow propeller RPM
downboundLoadedRPM		Av. Down-bound loaded barge(s) tow propeller RPM
downboundEmptyRPM		Av. Down-bound empty barge(s) tow propeller RPM

TABLE 1.4.28 – TowboatTypeCost Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
towboatTypeID	DB Key	Towboat Type ID (from BargeTypes table)
beginYear	DB Key	first year that the cost is in effect
laborCost		Labor cost ($/hour)
otherVarCost		Other variable costs ($/hour)
fixed Cost		Annual fixed costs

1.4.1.3.3 FuelCost Table

Fuel costs discussed in ADDENDUM 1B ORNIM Calibration are loaded into the "*FuelCost*" table as shown in TABLE 1.4.29. ORNIM allows storage and analysis different fuel costs by "*networkID*" by year. An average 2004 through 2006 No. 2 low sulfur diesel fuel price was used in the Upper Ohio analysis. The "*beginYear*" and "*endYear*" fields allow specification of fuel costs to a specific year or years. Year "*9999*" was used to signify the 2004-2006 average.

TABLE 1.4.29 – FuelCost Table Description

Database Field	DB Key	Description	Value
networkID	DB Key	River system network (1 = existing ORS)	1
beginYear	DB Key	first year that the price is in effect	9999
endYear		last year that the price is in effect	9999
fuelCost		cents per gallon fuel cost (no tax)	171.1639

1.4.1.3.4 TowSizeLimits Table

A component of the movement shipping plans is the movement tow-size(s). If movement tow-sizes were set based solely on the physical limitations of the river and equipment, WSDM would tend to produce shipping plans with larger tows than historically observed, since WSDM calculates the resources required to satisfy the demand on a least-cost basis. To account for other factors that play into the shipping plan tow-size, the model contains a barge type tow-size limit calibration parameter that is specified at a river segment level (rather than at the movement level) and stored in the "*TowSizeLimits*" table as shown in TABLE 1.4.30. When the model develops a shipping plan for a movement, it considers all the river segment restrictions in its route (i.e., the minimum of "*maxTowSize*" along the route), along with the towboat class specific characteristics (e.g., "*maxTowSize*" in TABLE 1.4.27).

TABLE 1.4.30 – TowSizeLimits Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
sectorID	DB Key	Sector ID (from Sectors table)
linkIndex	DB Key	Link ID (from Links table, 0 specifies Sector level specification)
bargeTypeID	DB Key	Barge Type ID (from BargeTypes table)
maxTowSize		Calibration maximum tow-size in/out/thru the link (number of barges per tow)
limitTowSize		Maximum tow-size in/out/thru the link (number of barges per tow)

As discussed, river segments in the model network are defined as rivers, sectors, nodes, and links (FIGURE 1.4.1). The tow-size limits and towboat class efficiency factors are specified at the link level, however, sector level setting can be specified. The "*linkIndex*" corresponds to the link ID specified in the "*Links*" table (TABLE 1.4.17). When "*linkIndex*" is set to zero, however, the parameters are used for all links within that sector except for any link specified records which will override any sector level specification.

While the river segment tow-size limits can be manually set and adjusted by the user, an automated calibration programs called the Sector Tow-size Limits Calibrator was developed (see ADDENDUM 1B ORNIM Calibration). The user, or the Sector Tow-size Limits Calibrator, adjusts the "*maxTowSize*" field in the "*TowSizeLimits*" table. The "*limitTowSize*" parameter provides an upper boundary for the "*maxTowSize*" field. The "*limitTowSize*" field is loaded by the user and was determined by calculating the maximum tow-size for the projects upstream and downstream from the river segment assuming a homogeneous barge type tow. For example, a river segment bounded by 1200' x 110' main chambers would have a "*limitTowSize*" for jumbo barges (195' x 35') of 17 barges per tow; 1,170' long by 105' wide in a knockout configuration with enough room for the towboat in the sixth row of barges.

The "*maxTowSize*" is calibrated by the model to observed data (i.e., 2004-2006 average targets). To develop shipping plan with a system containing larger lock chambers, these "maxTowSize" parameters are adjusted (see ADDENDUM 1B ORNIM Calibration).

1.4.1.3.5 TowboatUtilization Table

Not only is the tow-size a major component of the movement shipping plans, but also the towboat class utilized to move the barges. The towboat cost is the major cost component of the waterway shipment. If movement towboat types were set based solely on the physical capability of the equipment, WSDM would tend to produce tows with smallest towboat that could move the barges (i.e., the "*maxTowSize*" in the "*TowboatTypes*" table). This typically produces utilization of smaller towboats than historically observed, since WSDM calculates the resources required to satisfy the demand on a least-cost basis. To account for other factors that play into the shipping plan towboat class selection, the model contains a towboat efficiency calibration parameter that is specified at a river segment level (rather than at the movement level) and stored in the "*TowboatUtilization*" table as shown in TABLE 1.4.31. When the model develops a shipping plan for a movement, it considers all the towboat class specific characteristics including the maximum towboat tow-size and the towboat efficiency factor. Specifically the towboat efficiency factors for each river segment are multiplied by the towboat class maximum tow-size (TABLE 1.4.30) to develop the river segment tow-size limits by towboat class.

TABLE 1.4.31 – TowboatUtilization Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
sectorID	DB Key	Sector ID (from Sectors table)
linkIndex	DB Key	Link ID (from Links table, 0 specifies Sector level specification)
towboatTypeID	DB Key	Towboat Type ID (from TowboatTypes table)
capUtilFactor		proportion of the towboat's capability that can be utilized on the link

As discussed, river segments in the model network are defined as rivers, sectors, nodes, and links (FIGURE 1.4.1). Like the tow-size limits, the towboat class efficiency factors are specified at the link level, however, sector level setting can be specified. The "*linkIndex*" corresponds to the link ID specified in the "*Links*" table (TABLE 1.4.17). When "*linkIndex*" is set to zero, however, the parameters are used for all links within that sector except for any link specified records which will override any sector level specification.

While the river segment towboat efficiency limits can be manually set and adjusted by the user, an automated calibration programs called the Sector Towboat Efficiency Factor Calibrator was developed (see ADDENDUM 1B ORNIM Calibration). The user, or the Sector Towboat Efficiency Factor Calibrator, adjusts the "*capUtilFactor*" field in the "*TowboatUtilization*" table. The "*capUtilFactor*" parameter specifies the proportion of the towboat class capability that can be utilized on the specified link. For example, say the "*capUtilFactor*" is 0.50 on a given link for "*towboatTypeID*" 5 (3,400 BHP) which has a maximum tow-size of 14 barges per tow. As a result, with a "*capUtilFactor*" of 0.50 the towboat would only be allowed to move a tow with 7 or fewer barges through this link.

1.4.2 Movement Characteristics

Under this category of data are the input database tables describing shipment data specifying the origin, destination, commodity group, annual tonnage (historic and forecasted), barge type, barge loading, willingness-to-pay, river closure response, and river closure response externality cost of existing and projected port-to-port commodity movements.

Movement specification (i.e., origin, destination, commodity, barge type) is dictated by the network, commodity grouping, and barge type groupings. The aggregation of the WCSC flow data not only requires aggregation of the origin and destination nodes, commodity grouping, barge type, and tonnage, but also requires weighted averaging of the rate data. Aggregation of the 662 5-digit WCSC commodity codes, 395 WCSC barge types, and 129,876 ORS WCSC dock flows into 16,948 "*movementID*"s is documented in ADDENDUM 1B ORNIM Calibration.

1.4.2.1 CommodityTypes Table

The commodity types and costs discussed in ADDENDUM 1B ORNIM Calibration are loaded into the "*CommodityTypes*" table as shown in TABLE 1.4.32. The data are stored at a "*networkID*" level.

TABLE 1.4.32 – CommodityTypes Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
commodityID		Unique commodity ID
commodityName		Commodity Name
value		Commodity value in $/ton (for inventory holding cost calculation)
holdingCostFactor		Percent of commodity value to charge as holding cost
density		Commodity density in lbs per cubic foot
displayColor		Color to use for output graphs
comments		Additional description if needed

1.4.2.2 Movement Classification Tables

The movement data discussed in ADDENDUM 1B ORNIM Calibration is defined through multiple database tables. Not only does the model's database structure allow for storage and use of various waterway networks and various variations of each network, the model also allows for storage and use of various forecasted demand scenarios and various variations of each of the defined forecasted demand scenarios.

1.4.2.2.1 Forecast Table

The forecasted demand scenarios are defined in the "*Forecast*" table shown in TABLE 1.4.33. As shown in TABLE 1.4.34, the database contains definitions for eight forecast scenarios; the five older ORMSS-SIP forecast scenarios and the three updated forecast scenarios. The "*forecastID*" of 0 is used to identify historic (observed) data in the database. The annual tonnage is stored by calendar year, but in the case of the historic data a year "*9999*" was generated to store an average of 2004-2006 data.

TABLE 1.4.33 – Forecast Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
forecastID	DB Key	Unique forecasted demand ID
forecastName		Forecast name
comments		Additional user description if needed

TABLE 1.4.34 – Forecast Scenarios (Forecast Table Data)

networkID	forecastID	forecastName	comments
1	0	na (forecastID for historic/actual flows)	year 9999 represents 2004-2006 average
1	1	FY2003 Clear Skies Flat	ORMSS-SIP forecast scenario
1	2	FY2003 Clear Skies no Hg	ORMSS-SIP forecast scenario
1	3	FY2003 NAAQS Growth	ORMSS-SIP forecast scenario
1	4	FY2003 Utility Based (Coal Model)	ORMSS-SIP forecast scenario
1	5	FY2003 Utility Based High (Coal Model High)	ORMSS-SIP forecast scenario
1	6	FY2009 ORS Low (Oct 2009)	UpperOH forecast scenario
1	7	FY2009 ORS Base (Oct 2009)	UpperOH forecast scenario
1	8	FY2009 ORS High (Oct 2009)	UpperOH forecast scenario

1.4.2.2.2 MovementSet Table

To allow for additional delineation of the forecasted demand scenario, it is further defined by a "*movementSetID*" in the "*MovementSet*" table shown in TABLE 1.4.35. As shown in TABLE 1.4.36 the database defines four variations of each forecasted demand scenario (again, as in the "*Forecast*" table, "*movementSet*" 0 represents observed historic tonnages). There are two variations expressed: 1) routing through the Kentucky Lock and Barkley Lock routing options; and 2) induced movements. For the Upper Ohio Navigation Study analysis, "*movementSetID*" 0 and 2 are used.

TABLE 1.4.35 – MovementSet Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
movementSetID	DB Key	Unique movement set ID
movementSetName		Movement set name
comments		Additional user description if needed

ORS traffic has a routing option between the use of Kentucky and Barkley Locks. Often, if the primary study area has little traffic commonality with this area of the system (as in the case of the Upper Ohio River primary study area), the modeling is done with all Kentucky and Barkley traffic routed through Kentucky (with the Kentucky Lock tonnage-transit curve representing the capacity of both Kentucky and Barkley).

TABLE 1.4.36 – Movement Sets (MovementSet Table Data)

networkID	movementSetID	movementSetName	comments
1	0	Historic/Actual (KyBk routings)	
1	1	Base (KyBk routings)	base forecast with distinction between Ky & Barkley routings
1	2	Base (Ky only routings)	base forecast with Ky & Barkley routing through Ky.
1	3	Base + EDM Induced (KyBk routins)	base + induced with distinction between Ky & Barkley routings
1	4	Base + EDM Induced (Ky only routings)	base + induced with Ky & Barkley routing through Ky.

As discussed in section 1.2.3.5.4 (FIGURE 1.2.20), when induced traffic is considered the demand curves shifts to the right. Instead of creating a new forecasted demand scenario, a variation of the forecasted demand scenario with the induced demands added is specified through the "*movementSetID*".

1.4.2.3 MovementDetail and MovementBarge Tables

Much of the movement data discussed is stored in the "*MovementDetail*" table. The barge type and barge loading information is separated from the movement and placed in a separate "*MovementBarge*" table. This separation is done to allow changing of the movement barge type and loading assumptions by "*networkVersion*". As can be noted in TABLE 1.4.3, the model is set-up with network versions that not only allow for adjustment of tow-sizes in the system at user specified locations and under user specified investment options, but the network version also allows an assumption change in barge types. In the Upper Ohio region regular and stumbo barges are being replaced by jumbo barges. The "*MovementDetail*" table is shown in TABLE 1.4.37 and the "*MovementBarge*" table is shown in TABLE 1.4.38.

TABLE 1.4.37 – MovementDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
movementID		Unique movement ID
Origin		Movement origin portID (Ports table)
Destination		Movement destination portID (Ports table)
ForcedSec		Movement must be routed through this sectorID (Sectors table)
ForcedLk		Movement must be routed through this lockID (Locks table)
AvoidSec		Movement must not be routed through this sectorID (Sectors table)
Commodity		Movement commodityID group (CommodityTypes table)
WWLineHaul		Base waterway line-haul rate in dollars per ton
WWRate		Total base waterway rate in dollars per ton
AltRate		Base least-cost all-overland alternative rate in dollars per ton
WWExternality		Waterway externality cost in dollars per ton
AltExternality		Alternative routing externality cost in dollars per ton
Comment		Additional description if needed

TABLE 1.4.38 – MovementBarge Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion		River system network version (1 = existing UpperOH)
movementID		Unique movement ID
bargeTypeID		Movement bargeTypeID class (BargeTypes table)
tonsPerBarge		Movement average barge loading in tons

When setting up a network version with barge type changes, currently all movements must be listed in the "MovementBarge" table under the specified network version, regarless of whether the barge type specification varies from the base network version ("*networkVersion*" 1). This duplicates data. In the future the model will be modified to allow only specification of the changes under the new network version (similar to the new network version in the "*TowSizeLimits*" and "*TowboatUtilization*" tables).

1.4.2.4 MovementTonnage Table

The yearly tonnage data is stored in the "*MovementTonnage*" table under the "*networkID*", "*forecastID*", "*movementSetID*", "*movementID*" (called in this table just "*ID*"), and year. TABLE 1.4.39 shows the "*MovementTonnage*" database fields.

TABLE 1.4.39 – MovementTonnage Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
forecastID	DB Key	Unique movement set ID (defined in table Forecasts)
movementSetID	DB Key	Unique movement set ID (defined in table MovementSets)
ID	DB Key	Unique movement ID
year	DB Key	Year
cargoAmount		Annual tonnage (observed for historic, forecasted for future)

1.4.2.5 Movement Willingness-to-Pay

As noted in section 1.2.4.3.3, the model is capable of either modeling movements as fixed quantity or price responsive. For movements defined as fixed quantity, field "*AltRate*" of the "*MovementDetail*" table (TABLE 1.4.37) defines the movement's willingness-to-pay. For movements defined as price responsive, the willingness-to-pay is defined through four database tables discussed in the following sections. While only one fixed quantity willingness-to-pay value is allowed for each network movement (characterized by networkID and movementID), the model allows any number of price responsive demand curves to be specified for each movement. This was done to allow checking and sensitivity tests on various demand curve specifications.

While the demand curves can be defined uniquely to each movement, the demand curves developed for the ORS were only done at a commodity group level. In such a case, the demand curves do not have to be duplicated for each movement. The movement is linked to the demand curve through a "*demandFunctionRuleID*"; there is a "*demandFunctionRuleID*" for each commodity group. If each movement has a unique demand curve, then each demand curve is placed under its own "*demandFunctionRuleID*" and there are as many "*demandFunctionRuleID*"s as "*movementID*"s.

1.4.2.5.1 DemandFunctionPlan Table

There are also two different methods allowed to define the price responsive demand curve: constant elasticity and piecewise-linear. The "*DemandFunctionPlan*" table lists and names the demand function plans developed for each network (TABLE 1.4.40). As shown in TABLE 1.4.41, "*demandFunctionPlanID*" 0 is used to represent fixed quantity demand.

TABLE 1.4.40 – DemandFunctionPlan Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
demandFunctionPlanID	DB Key	Unique demand function plan ID
demandFunctionPlanName		Demand function plan name

TABLE 1.4.41 – Demand Function Plans (DemandFunctionPlan Table Data)

networkID	demandFunctionPlanID	demandFunctionPlanName
1	0	none (i.e. inelastic demand)
1	1	constant elasticity curves
1	2	piecewise-linear elasticity curves
1	3	piecewise-linear CONSTANT elasticity curves (test)

1.4.2.5.1.1 Constant Elasticity Definition

The constant elasticity movement definition assumes that there is a constant elasticity across all quantities and rates in a given year. Thus the demand curve will take the form of the function:

$$D_i\left(P\right) = \alpha P^{\varepsilon} \quad (1.4\text{-}1)$$

where:

P= waterway rate ($ / ton).

ε = elasticity (a negative number with an absolute value greater than 1).

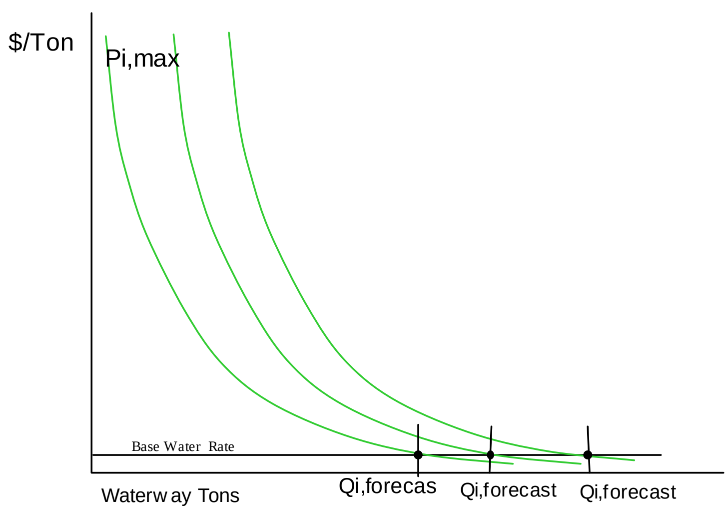
α = determined to produce the forecast demand at the base rate.

In general, the demand function looks like FIGURE 1.4.3. The location of a movement's demand curve for a specific year is determined by the forecast tonnage for that movement. Each movement is assigned a base rate derived from the TVA surveys of shippers. Even though they are derived in separate processes, it is assumed that all future forecasts are determined assuming this shipping rate (scaled to the appropriate base year) for the movement. Thus, the forecast tonnage for a year determines a (demand, price) point. The demand curve is constructed by setting the α value so the curve passes through that point.

$$\alpha = \frac{Q_{Forecast}}{P^{\varepsilon}_{Base}} \quad (1.4\text{-}2)$$

In the base year, the actual Waterborne Commerce tonnage is used with the base rate to determine the point for the base year demand curve. The cost of shipping the base year tonnage is estimated for each movement. This cost is compared to the survey-based rate and a delta is calculated. This delta is added to the calculated cost in each year to calibrate the cost function to the real world price. Thus, in the base year, the (base tonnage, base rate) point is on the demand curve and the cost curve for each movement, therefore, it is the equilibrium point[31].

FIGURE 1.4.3 – Constant Elasticity Demand Curves



1.4.2.5.1.2 Piecewise-Linear Demand Definition

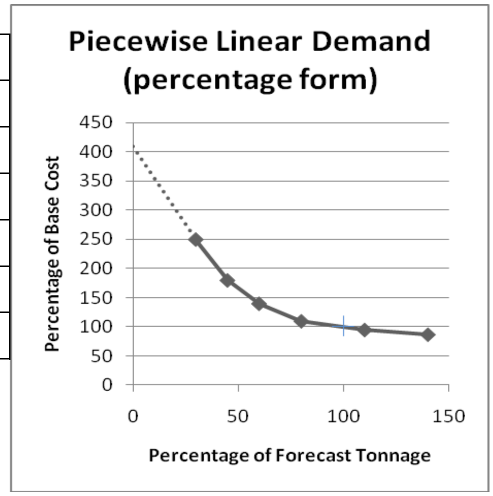
The second option for specifying the demand function is a piecewise linear approximation. This functional form allows a user to estimate any reasonable demand curve to whatever accuracy is

[31] Note that if all of the movements are price responsive, running equilibrium with a forecast equal to the base year tonnage and base year closures should produce the base tonnage at equilibrium.

appropriate by specifying a series of points defining the form of the curve (FIGURE 1.4.4). The points represent percentages of the forecast demand and the base price. This format allows the user to be in complete control of the demand function, however, it is incumbent upon the user to specify a curve that has a reasonable shape to allow the system to come to equilibrium. At a minimum, the curve should be decreasing in price as the quantity increases.

FIGURE 1.4.4 – Piecewise-Linear Demand Curves

Quantity	Price
30	250
45	180
60	140
80	110
100	100
110	95
140	87



If the points only define the demand function for part of the necessary range, the function is extended to intersect the vertical axis using the slope of the first segment. The function can also be extended toward the right using the slope of the last segment. The percentage form of the demand function is instantiated each year to form the annual demand function by specifying the forecast and base cost as the (100%, 100%) point. The rest of the curve is then defined relative to the forecast (FIGURE 1.4.4).

1.4.2.5.2 DemandFunctionRule Table

The "*DemandFunctionRule*" table (TABLE 1.4.42) is used to indentify the demand curve to be defined (either as a constant elasticity or as a piecewise-linear). As previously noted, there can be a one-to-one correspondence between the "*demandFunctionRuleID*" and the "*movementID*" when there is a demand curve defined for each movement. In the ORS, and for the Upper Ohio analysis, the price responsive demand curves (both constant elasticity or as a piecewise-linear) are defined at a commodity group level as shown in TABLE 1.4.43.

TABLE 1.4.42 – DemandFunctionRule Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
demandFunctionRuleID		Unique ID for the demand function
demandFunctionRuleName		Movement set name
demandFunctionType		Additional user description if needed

TABLE 1.4.43 – Demand Function Rule (DemandFunctionRule Table Data)

networkID	demandFunctionRuleID	demandFunctionRuleName	demandFunctionType
1	0	none (i.e. inelastic demand)	none
1	1	COAL constant e curve -2.20238452594811	constant elasticity
1	2	PETRO constant e curve -2.99397262186655	constant elasticity
1	3	CRUDE PETRO constant e curve -2.99397262186655	constant elasticity
1	4	AGGREGATES constant e curve -2.31859637814595	constant elasticity
1	5	GRAINS constant e curve -3.48577847107579	constant elasticity
1	6	CHEMICALS constant e curve -2.77137713868776	constant elasticity
1	7	ORES & MINERALS constant e curve -2.44860451815936	constant elasticity
1	8	IRON & STEEL constant e curve -2.410188166458	constant elasticity
1	9	OTHERS constant e curve -2.55828933200951	constant elasticity
1	11	COAL pw-linear	piecewise linear
1	12	PETRO pw-linear	piecewise linear
1	13	CRUDE PETRO pw-linear	piecewise linear
1	14	AGGREGATES pw-linear	piecewise linear
1	15	GRAINS pw-linear	piecewise linear
1	16	CHEMICALS pw-linear	piecewise linear
1	17	ORES & MINERALS pw-linear	piecewise linear
1	18	IRON & STEEL pw-linear	piecewise linear
1	19	OTHERS pw-linear	piecewise linear
1	21	COAL pw-linear (constant -2.20238452594811)	piecewise linear
1	22	PETRO pw-linear (constant -2.99397262186655)	piecewise linear
1	23	CRUDE PETRO pw-linear (constant -2.99397262186655)	piecewise linear
1	24	AGGREGATES pw-linear (constant -2.31859637814595)	piecewise linear
1	25	GRAINS pw-linear (constant -3.48577847107579)	piecewise linear
1	26	CHEMICALS pw-linear (constant -2.77137713868776)	piecewise linear
1	27	ORES & MINERALS pw-linear (constant -2.44860451815936)	piecewise linear
1	28	IRON & STEEL pw-linear (constant -2.410188166458)	piecewise linear
1	29	OTHERS pw-linear (constant -2.55828933200951)	piecewise linear

1.4.2.5.3 MovementDemandFunction Table

The "*demandFunctionRuleID*" is linked to the "*movementID*" through the "*MovementDemandFunction*" shown in TABLE 1.4.44. The model allows for respecification of the demand curve through time through the "*beginYear*" and "*endYear*" fields. This option was not used in the Upper Ohio Navigation Study.

TABLE 1.4.44 – MovementDemandFunction Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
demandFunctionPlanID	DB Key	Demand function plan ID from DemandFunctionPlan table.
ID	DB Key	movementID from MovementDetail table.
beginYear	DB Key	First year of demandFunctionRuleID
endYear		Last year of demandFunctionRuleID
demandFunctionRuleID		ID from DemandFunctionRule table.

1.4.2.5.4 DemandFunctionRuleParameter Table

The "DemandFunctionRuleParameter" table stores parameters that characterize the demand curve (i.e., the "*demandFunctionRuleID*").

TABLE 1.4.45 – DemandFunctionRuleParameter Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
demandFunctionRuleID	DB Key	ID from DemandFunctionRule table
parameterName	DB Key	Parameter name (x1 … xn or y1 …yn, or elasity for constant)
parameterValue		Proportion of demand (x) or base price (y), or elasticity value for constant

1.4.2.6 Movement River Closure Response

To allow flexibility in ORNIM for the user to define the river closure durations which define river closure responses, the river closure response data is stored in two tables. To allow flexibility in defining the river closure response externalities, two additional database tables are used. All four tables are discussed in the section below.

1.4.2.6.1 MovementResponse Table

The first table, "*MovementResponse*" (TABLE 1.4.46) defines a unique ID for a movement's river closure duration. The ID is simply called the "*responseID*", but a more descriptive name would be the "*riverClosureDurationID*". Since overland costs are assumed constant through time in ORNIM, the diversion rate is also stored in this table (field "*responseRate*").

TABLE 1.4.46 – MovementResponse Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
movementID	DB Key	Unique movement ID from MovementDetail table
minDaysClosed	DB Key	Lower boundry in days of river closure duration
maxDaysClosed		Upper boundry in days of river closure duration
responseID		Unique river closure duration ID
responseRate		Short-run diversion rate ($/ton)

1.4.2.6.2 MovementResponseDetail Table

The second table, "*MovementResponseDetail*" (TABLE 1.4.47) stores the percent of the model-level movement tonnage that is diverted. Since the response is either wait or divert, only one percentage needs stored. With a diversion percentage (field "*reductionFactor*") of 10%, the wait response is 90% (1.0 – 0.10).

TABLE 1.4.47 – MovementResponseDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
movementID	DB Key	Unique movement ID from MovementDetail table
responseID	DB Key	Unique river closure duration ID from MovementResponse table
beginCalendarYear	DB Key	Lower boundry for application of the reductionFactor
endCalendarYear		Upper boundry for application of the reductionFactor
reductionFactor		Percent of movement with divert response

Note field "*beginCalendarYear*" which allows the user to change the "*reductionFactor*" through time. This option was not utilized in the Upper Ohio analysis; the same "*reductionFactor*" was used for the entire analysis period (i.e., "*endCalendarYear*" = 9999).

1.4.2.6.3 ExternalityType Table

The first externality table, "*ExternalityType*" (TABLE 1.4.48) defines the number externality categories to track and assigns a unique ID to each.

TABLE 1.4.48 – ExternalityType Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
externalityTypeID	DB Key	Unique movement ID from MovementDetail table
externalityTypeName		Lower boundry in days of river closure duration

TABLE 1.4.49 – Externality Types (ExternalityTypes Table Data)

networkID	externalityTypeID	externalityTypeName
1	1	UTTRC Truck Delay Dollars
1	2	UTTRC Truck Accidents Dollars
1	3	UTTRC Truck Emissions Dollars
1	4	TVA Non Delay Truck-Accident & Emissions Dollars
1	5	TVA Rail & Barge emissions Dollars

1.4.2.6.4 MovementResponseDetailExternality Table

The second table, "*MovementResponseDetailExternality*" (TABLE 1.4.50) stores the defined externality cost by year. As discussed in ADDENDUM 1A Rate and River Closure Response Data, the externality cost data is only summarized at an externality type and year level. ORNIM, however, defines the externality costs at a movement level. As such, the data are assigned to the movement level based on year. While this duplicates data, it allows flexibility in the model if and when externality costs are defined at a movement level.

TABLE 1.4.50 – MovementResponseDetailExternality Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
movementID	DB Key	Unique movement ID from MovementDetail table
responseID	DB Key	Unique river closure duration ID from MovementResponse table
calendarYear	DB Key	year
externalityTypeID	DB Key	ID from ExternalityType table
externalityCost		dollars per ton cost

1.4.2.7 MovementCalibration Table

Not only are the system tow-size limits and towboat utilization characteristics important in the calculation of the movement's waterway transportation cost (through the shipping-plan specification), but the movement's barge loading and barge dedication are also important. The barge loading determines the number of barge trips and thus the number of tow trips required to transport the tonnage. The barge dedication determines the percentage of empty back-haul trips that must be factored into the movement's transportation cost.

Data on the movement barge loading and barge dedication factors are stored in the "*MovementCalibration*" table (TABLE 1.4.51). This is a unique input table in that it is adjusted by the calibration process (like the "*TowsizeLimits*" and "*TowboatUtilization*" tables are). The "*tonsPerBarge*" is calibrated (max loading given depth restrictions along its route) if a barge loading is not specified in the "MovementBarge" table. The "*dedicationFactor*" is calibrated using observed lock percent empty data (e.g., 2004-2006 average targets). Movement barge loadings are specified in the Upper Ohio analysis. Additional detail on the calibration of the barge dedication factors can be found in ADDENDUM 1B ORNIM Calibration.

TABLE 1.4.51 – MovementCalibration Table

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Version ID (a variation of the network) defined in NetworkVersion table
movementID	DB Key	Unique movement ID
year	DB Key	Year
tonsPerBarge		Barge loading if not specified in the MovementBarge table
dedicationFactor		Percent of loaded barges returning empty (i.e. dedicated to front flow)

1.4.3 System Operating and Budget Assumptions

Operation characteristics include information on the fixed costs for operating the system, the investment budget limits, and any fee/tax characteristics. Under this category of data are the input database tables describing: 1) system fixed costs; 2) fuel cost and taxes; 3) system fee/tax assumptions; and 4) budget constraints.

1.4.3.1 GeneralCost Table

Information on the costs associated with nodes, but not with particular components (e.g., normal O&M), are stored in the "*GeneralCost*" table (TABLE 1.4.52).

TABLE 1.4.52 – GeneralCost Table

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
nodeType	Key	Node type (B = bend, L = lock)
nodeID	Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
year	Key	Fiscal (or calendar) year.
costType	Key	C=cyclical, U=unscheduled, I=improvement, T=transit, M=random, O=operations
costCode	Key	GI, CG, OD=Op.Dam, OM=O&M, OR=Op.Rehab., TF=IWWTF.
cost		Dollars in specified year for specified cost code at specified node.
comments		Additional description if needed.

1.4.3.2 FuelTaxPlan and FuelTaxPlanYear Tables

In WRDA 1978 Congress passed the first excise tax on inland waterway users of $0.04 per gallon (taking effect Oct 1980) and rising to $0.10 per gallon in 1986[32]. WRDA 1986 then mandated that the tax increase to $0.20 per gallon by 1995[33]. Fuel taxes actually peaked over 1998 through 2004 at $0.253 per gallon with an additional Deficit Reduction Tax of $0.043 and a Leaking Underground Storage Tank (LUST) tax of $0.01 per gallon. Fuel tax has since dropped to the current $0.20 per gallon after the LUST tax expired 1 January 2005 and the deficit reduction tax expired 1 January 2007. Over the 2004 through 2006 period, the average fuel tax was 24.63 cents per gallon.

ORNIM allows storage and analysis different fuel taxes by year (tax plan) by networkID. In the "*FuelTaxPlan*" table (TABLE 1.4.53) the various tax plans are assigned an ID so that the yearly tax data can be stored in the "*FuelTaxPlanYear*" table. For this validation of the WSDM least-cost shipping plans,

[32] *Inland Waterways Revenue Act of 1978 (Public Law 95-502, October 21, 1978), Sections 203 and 204. Section 202 specifies the amount of tax and certain exemptions, and Section 206 specifies the waterways where the tax applies.*

[33] *Water Resources Development Act (WRDA) of 1986 (Public Law 99-662, November 17, 1986), Section 1405. Section 1404 amends the two sections in the earlier act to increase the amount of fuel tax and to add the Tennessee-Tombigbee Waterway to the waterways where the tax applies.*

the existing ORS network (i.e., networkVersion 1) is utilized and the existing tax law is defined and stored under fuelTaxPlanD 1. Data loaded into the "*FuelTaxPlanYear*" table is shown in TABLE 1.4.54.

TABLE 1.4.53 – FuelTaxPlan Table

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
fuelTaxPlanID		Fuel tax plan ID from FuelTaxPlan table.
fuelTaxPlanName		Description of the fuel tax plan.

TABLE 1.4.54 – FuelTaxPlanYear Table

Database Field	Description	Value
networkID	River system network (1 = existing ORS)	1
fuelTaxPlanID	Tax plan (1 = existing tax law)	1
beginYear	first year that the cost is in effect	9999
endYear	last year that the cost is in effect	9999
fuelTax	cents per gallon fuel tax	24.63333333

1.4.3.3 LockageFeePlan and LockageFee Tables

ORNIM allows storage and analysis different lockage fee plans by year. In the "*LockageFeePlan*" table (TABLE 1.4.55) the various lockage fee plans are assigned an ID so that the yearly fee tax data can be stored in the "*LockageFee*" table (TABLE 1.4.56).

TABLE 1.4.55 – LockageFeePlan Table

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
lockageFeePlanID		Unique lockage fee plan ID.
lockageFeePlanName		Description of the lockage fee plan.

TABLE 1.4.56 – LockageFee Table

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
lockageFeePlanID		Lockage fee plan ID (lockageFeePlanID) from LockageFeePlan table.
lockID		Lock ID from Locks table.
beginYear		First fiscal (calendar) year for the specified fee to be applied at the specified lock.
endYear		Last fiscal (calendar) year for the specified fee to be applied at the specified lock.
lockageFeePerTow		Fee per tow ($/tow).
lockageFeePerBarge		Fee per barge ($/barge).
comments		Additional description if needed.

1.4.3.4 RiverUserFee Table

ORNIM also allows storage of river fees by year. Unlike the fuel tax and lockage fee data structure, the river fee is not delineated with a river fee ID. This is because river fee analysis, to this point, has been a low priority. As a result the river fee data is stored in only one table, the "*RiverUserFee*" table (TABLE 1.4.57), without a river user fee plan ID.

TABLE 1.4.57 – RiverUserFee Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
riverID	Key	River ID from Rivers table.
beginYear	Key	First fiscal (calendar) year for the specified fee to be applied at the specified river.
endYear		Last fiscal (calendar) year for the specified fee to be applied at the specified river.
userFee		River tonnage user fee ($/kton mile) for specified river over specified years.
bargeMileFee		River barge-mile fee ($/barge/mile) on specified river over specified years.
comments		Additional description if needed.

1.4.3.5 CongestionFeeLock Table

Congestion fee data is stored differently than the fuel tax, lockage fee and river fee data. This is because of the automated optimal congestion fee equilibrium logic (see section 1.3.1.3). As a result, the "*CongestionFeeLock*" table (TABLE 1.4.58) does not store the fee, but instead stores fee limits to be used by the fee determination process. The user has the option to use or not use these limits. Bounding the fees limits the search space and speeds convergence to the optimal fee equilibrium.

TABLE 1.4.58 – CongestionFeeLock Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
lockID	Key	Lock ID from Locks table.
feePlanID	Key	Unique congestion fee plan ID.
useRange		Limit search to the specified min-max range (TRUE or FALSE).
useScheduledClosureLimit		Remove fee when specified max number of scheduled closure days is exceeded (TRUE or FALSE).
minimumFee		Minimum congestion fee ($/ton) to consider.
maximumFee		Maximum congestion fee ($/ton) to consider.
limitScheduledClosures		Max number of scheduled clousre days before fee is removed (days).

1.4.3.6 Budget Constraints

The budget available for repairs and improvement is stored in the "*Budget*" table (TABLE 1.4.59).

TABLE 1.4.59 – Budget Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
runID	DB Key	Run ID from Run table.
year	DB Key	Calendar Year
budget		Budget (dollars) for specified year.
comments		Additional description if needed.

1.4.4 Maintenance Characteristics

Under this category of data are the input database tables describing cyclical maintenance needs of the components and chambers. These cyclical maintenance cycles can shift as investments are implemented.

1.4.4.1 ScheduledClosureType Table

The scheduled closure types are given a "*scheduledClosureType*" code of long, moderate, short, or painting in the "*ScheduledClosureType*" table (TABLE 1.4.60)

TABLE 1.4.60 – ScheduledClosureType Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
scheduledClosureType	Key	Unique scheduled closure type ID (L, M, P, S)
scheduledClosureTypeName		Scheduled closure type name (e.g. long, moderate, painting, & short).

1.4.4.2 ScheduledClosure Table

Data on the cyclical scheduled closures for each lock are stored in the "*ScheduledClosure*" table (TABLE 1.4.61). A set of scheduled closures is indexed by maintenance plan ID. Maintenance plans are changed through alternatives. Since these cyclical maintenance cycles can shift as investments are implemented, the year field is defined with an offset rather than a calendar (or fiscal) year. The offset is from the "*startYear*" in the "*InitialClosurePlan*" table.

TABLE 1.4.61 – ScheduledClosure Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
lockID	Key	Lock ID from Locks table.
chamberID	Key	Chamber ID from ChamberTypes table.
closurePlanNumber	Key	Closure plan ID from ScheduledClosureType table.
year	Key	Year (1-n).
scheduledClosureType	Key	Scheduled closure type from ScheduledClosureType table.
comments		Additional description if needed.
closureNumber		Closure plan ID from ScheduledClosureType table.
maintenanceCategory		Maintenance category ID from AlternativeMaintenanceCategory table.
daysClosed		Number of days the specified chamber is closed for the specified closureID.
daysHalfSpeed		Number of days the specified chamber is operating at half-speed for the specified closureID.
cost		Dollars in specified year for specified maintenance category.

1.4.4.3 InitialClosurePlan Table

Information on the initial closure plan for each lock is stored in the "*InitialClosurePlan*" table (TABLE 1.4.62).

TABLE 1.4.62 – InitialClosurePlan Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
lockID	Key	Lock ID from Locks table.
chamberID	Key	Chamber ID from ChamberTypes table.
closureType	Key	Closure type ID from ClosureTypes table.
closurePlanNumber	Key	Unique cyclical clousre plan ID.
startYear		First fiscal (calendar) year to start the cyclical closure plan.
comments		Additional description if needed.

1.4.4.4 AdvancedMaintenance Table

Component advanced maintenance can be specified to occur when the component's PUP exceeds a user specified threshold value. Data for this feature is stored in the "*AdvancedMaintenance*" table (TABLE 1.4.63). This feature was not utilized in the Upper Ohio analysis.

TABLE 1.4.63 – AdvancedMaintenance Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
lockID		Lock ID from Locks table.
chamberID		Chamber ID from ChamberTypes table.
componentID		Component ID from Component table.
hazardRateThreshold		PUP threshold that triggers advanced maintenance action
daysClosed		Number of days the specified chamber is closed to implement the adv.maint. action.
daysHalfSpeed		Number of days the specified chamber is operating at half-speed to implement the adv.maint. action.
maxAllowableTimes		Max number of times the advanced maintenance action can be invoked.
maintenanceExtendsLife		Number of years "newer" the component becomes with the adv.maint. action (1-n).
cycleTime		Number of years (1-n) in the advanced maintenance cycle before re-implementation.
cost		Cost for implementing the advanced maintenance action.
comments		Additional description if needed.

1.4.5 Reliability Characteristics

Under this category of data are the input database tables describing engineering reliability of components and chambers. As discussed in sections 1.2.4.4.3.1 and 1.2.4.4.3.2, component level reliability is described through a PUP (also known as a hazard function) and event-tree while the chamber reliability is described with a simple fixed probability. Remember that the chamber level failures referred to as random minor events and are used to capture random short duration service disruption events not explicitly captured in the component level reliability analysis; it represents the reliability of components not explicitly going through the rigorous engineering reliability process. Discussion on the engineering reliability development can be found in APPENDIX B Engineering. The reliability data are stored in the model in the nine database tables discussed in the following sections.

1.4.5.1 Component and ComponentName Tables

Components that have engineering reliability data are defined through the "*Component*" and "*ComponentName*" tables (TABLE 1.4.64 and TABLE 1.4.65). The "*yearFailuresStart*" is set to the base year (FIGURE 1.2.21) so that the reliability is only simulated through the analysis period and not through the complete planning period. This assumes survivability of all components to the decision point (i.e., base year). While there is risk during the study and construction periods, it is inappropriate to incorporate this risk in the planning decision since it could under estimate project benefits and skew the selection of the NED plan.

TABLE 1.4.64 – Component Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
lockID		Lock ID from Locks table.
chamberID		Chamber ID from ChamberTypes table.
componentID		Unique component ID.
yearNew		Calendar year of age = 0.
yearFailuresStart		Year to start reading the PUP function.
initialStateID		State (or version) of the PUP and event-tree.
comments		Additional description if needed.

TABLE 1.4.65 – ComponentName Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
componentName		Component name
comments		Additional description if needed.

1.4.5.2 ComponentState Table

As mentioned in section 1.3.3, the model has the capability to branch to a different PUP function and event-tree from any of the second-level branches. These variations of a components reliability data (PUP and event-tree) are tracked through a "*stateID*" defined in the "*ComponentState*" table (TABLE 1.4.66).

TABLE 1.4.66 – ComponentState Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
lockID	DB Key	Lock ID from Locks table.
stateID	DB Key	Unique state (or version) ID of the PUP and evet-tree.
stateName		State ID name.

1.4.5.3 ClosureTypes Table

Specification of the service disruption event types is stored in the "*ClosureTypes*" table (TABLE 1.4.67).

TABLE 1.4.67 – ClosureTypes Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
closureID	DB Key	Unique service disruption ID
closureName		Service disruption name.
affectedChamber		Chamber ID from ChamberTypes table.
opSpeedLevel		Operating speed (1=1/2 speed, 2 = closed)
period		Service disruption duration (days)
comments		Additional description if needed.

1.4.5.4 HazardFunction Table

The engineering reliability PUP (also known as a hazard function) data are stored in the "*HazardFunction*" table (TABLE 1.4.68). This table is structured to hold period based PUPs, however, fatigue based PUPs can be stored and used as discussed in section 1.3.3.3. The PUPs need to be defined from the component's new state (i.e., when it was installed or rehabilitated). It is important to note that there is also a "*stateID*" specification which allows multiple PUPs to be defined for a component depending on its state of repair (i.e., the PUP curve can change through time).

TABLE 1.4.68 – HazardFunction Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
lockID	DB Key	Lock ID from Locks table.
stateID	DB Key	State (or version) ID from ComponentState table.
year	DB Key	Component age (1-100)
tonnageLevel	DB Key	Low, medium, or high (L, M, or H).
yearlyTonnage		Tonnage level for fatige driven components (enter 0 for time dependent)
probFailure		Failure probability (0-1.0)
comments		Additional description if needed.

1.4.5.5 Event-Trees

The engineering reliability component event-trees (FIGURE 1.2.26) display the consequences of component failures: probabilities of different failure levels, probabilities of different fix levels, service disruption type, service disruption duration, and post-repair reliability changes. Storage of these data in the model requires four tables as discussed in the following sections.

1.4.5.5.1 ComponentBranchProbability Table

The model allows two layers of branches, the first of which is referred to as the failure-level branch (FIGURE 1.2.26). This branch has the functionality of storing the branch probabilities by year, thus allowing the user to change the branch weights through time (provided they still sum to 1.0). The failure-level branch data is stored in the "*ComponentBranchProbability*" table (TABLE 1.4.69). Since the model has the capability to branch to a different PUP function and event-tree from any of the fix-level branches, the data also requires a "*stateID*" designation.

TABLE 1.4.69 – ComponentBranchProbability Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
lockID	DB Key	Lock ID from Locks table.
stateID	DB Key	State (or version) ID from ComponentState table.
yearTreeEffective		Calendar year prob becomes effective (can be superceeded by subsequent yr)
failureLevel		Branch level (0-n).
probability		Branch probability (0-1.0).
comments		Additional description if needed.

1.4.5.5.2 ComponentRiskDetail Table

The model allows two layers of branches, the second of which is referred to as the fix-level branch (FIGURE 1.2.26). This branch does not have the functionality of storing the branch probabilities by year like the failure level branch does. The fix-level branch data is stored in the "*ComponentRiskDetail*" table (TABLE 1.4.70). Since the model has the capability to branch to a different PUP function and event-tree from any of the fix-level branches, the data also requires a "*stateID*" designation.

TABLE 1.4.70 – ComponentRiskDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
lockID	DB Key	Lock ID from Locks table.
stateID	DB Key	State ID from ComponentState table
failureLevel	DB Key	Failure branch level from ComponentBranchProbability table.
fixLevel	DB Key	Branch level (0-n).
probability		Branch probability (0-1.0).
extendLife		Set-back PUP function n-years.
zeroOutHazardFunction		Is component 100% reliable post failure repair (Y or N)?
replaceComponent		Is component replaced (Y or N)?
newStateID		State ID after failure repair
comments		Additional description if needed.

1.4.5.5.3 ComponentRepairDetail Table

The repair action resulting from the fix-level branch is stored in the "*ComponentRepairDetail*" table (TABLE 1.4.71). The repair action defines a protocol for repair that may stretch over several years (e.g., emergency repair in year 1, replacement in year 2) and defines the cost and service disruption. The service disruption however is not defined with a "*closureTypeID*" from the "*ClosureTypes*" table, but instead is defined with a "*daysClosed*" and "*daysHalfSpeed*" fields.

TABLE 1.4.71 – ComponentRepairDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
lockID	DB Key	Lock ID from Locks table.
stateID	DB Key	State ID from ComponentState table
failureLevel	DB Key	Failure branch level from ComponentBranchProbability table.
fixLevel	DB Key	Fix branch level from ComponentRisk table.
yearIndex		Repair year (1-n).
repairChamberID		Repair chamber ID (from ChamerTypes table).
daysClosed		Days of service disruption (closure).
daysHalfSpeed		Days of service disruption (slowed processing)
repairCost		Repair cost (dollars)
comments		Additional description if needed.

1.4.5.6 RandomMinor Table

As discussed in section 1.2.4.4.3.2, engineering reliability can also be defined at a chamber level through a simple fixed probability. The random minor probabilities are input into the "*RandomMinor*" table shown in TABLE 1.4.72. Note that the data is specified by "*lockID*" and "*familyID*" so that the random minor assumptions can be changed when the project is changed. Note also that any "*closureID*" can be specified and remember that the "*closureID*" relates to a specific chamber.

TABLE 1.4.72 – RandomMinor Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
closureID	DB Key	Closure ID from ClosureTypes table.
lockID	DB Key	Lock ID from Locks table.
familyID	DB Key	Family ID from TransitTimeCurveFamily.
closureNumber	DB Key	Unique random minor ID
probability		Probability of occurrence
comments		Additional description if needed.
cost		Cost (dollars)

1.4.6 Investments to Consider

Under this category of data are the input database tables describing investments to be considered. As discussed in section 1.2.4.1.3, the model analyzes "*alternatives*" which are packaged into "*RUNs*" and "*Investment Plans*" for analysis assuming specified analysis settings and parameters.

1.4.6.1 Alternatives

The investment analyzed is referred to as an alternative in the model. The alternative has an implementation period, an implementation cost, possible post implementation system, reliability and demand changes, and possibly an implementation service disruption. An alternative can be the replacement of a single component (e.g., main chamber miter gates), a new lock (which essentially replaces multiple components), or a combination of investments across multiple navigation projects. An alternative can be defined as a single investment or as a package of multiple investments across multiple sites. The definition of an alternative is handled in nine database tables discussed below.

1.4.6.1.1 Alternative Table

Data on the basic information on the alternatives is stored in the "*Alternative*" table (TABLE 1.4.73). An "*alternativeID*" is assigned, the implementation duration is specified, and the post-implementation "*movementSetID*" and "*networkVersionID*" is specified. Remember that implementation of an investment can alter movement demand (i.e., induced demand) and the shipping characteristics (i.e., tow-sizes or barge types). The "*alternativeID*" is then used as a key to additional tables describing the alternatives. Remember that an alternative can include one or more investments, at the same or different times, at one or multiple sites.

TABLE 1.4.73 – Alternative Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
alternativeID	DB Key	Unigue alternative ID.
alternativeName		Alternative name.
alternativeType		Alternative type (C, R, K, or E)
duration		Implementation duration (years)
endMovementSetID		movementSetID from MovementSet table to use after implementation.
endNetworkVersion		networkVersionID from NetworkVersion table to use after implementation.
comments		Additional description if needed.

1.4.6.1.2 AlternativeComponent Table

Data on the components involved in an alternative.(i.e., "*alternativeID*") are stored in the "*AlternativeComponent*" table (TABLE 1.4.74). As can be observed in the table key, the alternative can reference multiple components over multiple years ("*yearOfAlternative*"). This allows for the tracking of multi-year investment plans. From this table the component level reliability change is defined. When the alternative is defined for a single component, the "cost" field is used. When the alternative is defined for an investment that impacts multiple components, any cost directly attributable to a component is stored in this table, while the investment costs related to the overall alternative are stored in the "*AlternativeCost*" table discussed below.

TABLE 1.4.74 – AlternativeComponent Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
alternativeID	DB Key	Unigue alternative ID.
lockID	DB Key	Lock ID from Locks table.
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
yearOfAlternative	DB Key	Implementation year (1-n)
costCode		GI=gen.Invest., CG=constr.gen., OD=Op.Dam, OM=O&M, OR=Op.Rehab., TF=IWWTF.
cost		Dollars in specified year for specified cost code.
addFlag		Whether the component is added (Y or N)
deleteFlag		Whether the component was deleted (Y or N)
replaceFlag		Whether the component is replaced (implies no further failures, factors into survivability).
yearNew		Calendar year of age = 0 (-1 if component is new).

1.4.6.1.3 AlternativeCost Table

Data on the costs associated with implementing a non-component-level alternative are stored in the "*AlternativeCost*" table (TABLE 1.4.75). The component-level implementation costs are handled in the "*AlternativeComponent*" table. Component-level alternatives are by definition part of a lock node. The more general alternative, however, can represent an investment at a lock or a bend. As such, this table additionally allows specification of the node type which then identifies the "*nodeID*" as a "*lockID*" or a "*bendID*". In short, the component-level alternatives are not listed in this table.

TABLE 1.4.75 – AlternativeCost Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
alternativeID	DB Key	Alternative ID from Alternative table.
nodeType	DB Key	Node type (B = bend, L = lock)
nodeID	DB Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
yearOfAlternative	DB Key	Implementation year (1-n)
costCode	DB Key	GI=gen.Invest., CG=constr.gen., OD=Op.Dam, OM=O&M, OR=Op.Rehab., TF=IWWTF.
cost		Dollars in specified year for specified cost code.
comments		Additional description if needed.

1.4.6.1.4 AlternativeDetail Table

Data on the details of the tonnage-transit time curve set used when an alternative is implemented.are stored in the "*AlternativeDetail*" table (TABLE 1.4.76). Both the component-level alternatives and the project-level alternatives are listed in this table. Similar to the "*AlternativeCost*" table, a node type and node ID are identified to cross-reference against the "*lockID*" or "*bendID*". By specifying a unique tonnage-transit curve set for each year of implementation, curves can be created with a construction service disruption sequence[34]. The tonnage-transit time curve family used after an alternative is implemented is discussed in the next section ("*AlternativeLock*").

[34] ORNIM has been used to analyze construction plans (e.g., what are the transportation cost impacts for a long service disruption during construction versus many shorter duration service disruptions which increase the construction costs).

TABLE 1.4.76 – AlternativeDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
alternativeID	DB Key	Alternative ID from Alternative table.
nodeType	DB Key	Node type (B = bend, L = lock)
nodeID	DB Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
yearOfAlternative	DB Key	Implementation year (1-n)
comments	DB Key	Additional description if needed.
setNumber		Tonnage-Transit curve set ID from TransitTimeCurveDescription table.

1.4.6.1.5 AlternativeLock Table

Data on the change in the tonnage-transit time curve family ID after an alternative is implemented are stored in the "*AlternativeLock*" table (TABLE 1.4.77). Typically the "startYear" is set at the "*duration*" in the "*Alternative*" table.

TABLE 1.4.77 – AlternativeLock Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
alternativeID	Key	Unique closure rule ID.
lockID	Key	Lock ID from Locks table.
startYear	Key	Implementation year (1-n) to switch to this new tonnage-transit curve family.
endFamilyID		Tonnage-transit curve family ID from TransitTimeCurveFamily table.

1.4.6.1.6 AlternativeClosurePlanRule Table

Data on the changes in scheduled closures that occur during the implementation of an alternative at a lock are stored in the "*AlternativeClosurePlanRule*" table (TABLE 1.4.78).

TABLE 1.4.78 – AlternativeClosurePlanRule Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
closureRuleID	DB Key	Unique closure rule ID.
chamberID	DB Key	Chamber ID from ChamberTypes table.
closurePlanNumber	DB Key	
closureType	DB Key	L = long, M = medium, S = short
startYearOffSet	DB Key	
action		C = cancel, D = defer, or S=switch (calc from end of construction)
endYearOffSet		(0-100)
useEndYearOffSet		Use the endYearOffSet (Y or N)
comments		Additional description if needed.

1.4.6.1.7 AlternativeClosurePlanRuleXRef Table

Data on which closure rule ("*closureRuleID*" from the "*AlternativeClosurePlanRule*" table) is in effect at a lock during an alternative is stored are the "*AlternativeClosurePlanRuleXRef*" table (TABLE 1.4.79).

TABLE 1.4.79 – AlternativeClosurePlanRuleXRef Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
alternativeID	Key	Alternative ID from Alternative table.
lockID	Key	Lock ID from Locks table.
closureRuleID	Key	Closure rule ID from AlternativeClosurePlanRule table.

1.4.6.1.8 AlternativeMaintenanceCategory Table

Data on how implementing an alternative modifies the maintenance plan at a lock are stored in the "*AlternativeMaintenanceCategory*" table (TABLE 1.4.80).

TABLE 1.4.80 – AlternativeMaintenanceCategory Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
alternativeID	Key	Alternative ID from Alternative table.
lockID	Key	Lock ID from Locks table.
chamberID	Key	Chamber ID from ChamberTypes table.
maintenanceCategory	Key	Unique maintenance category ID.
daysClosed		Number of days of closure.
absoluteDaysClosed		Whether the change to days closed is absolute (yes) or relative (no).
daysHalfSpeed		Number of days of half-speed.
absoluteDaysHalfSpeed		Whether the change to days half speed is absolute (yes) or relative (no).
cost		Cost (dollars).
absoluteCost		Whether the change to cost is absolute (yes) or relative (no).

1.4.6.2 ComponentScheduledReplacement Table

Data on the scheduled replacement of components are stored in the "*ComponentScheduledReplacement*" table (TABLE 1.4.81).

TABLE 1.4.81 – ComponentScheduledReplacement Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
lockID	DB Key	Lock ID from Locks table.
chamberID	DB Key	Chamber ID from ChamberTypes table.
componentID	DB Key	Component ID from Component table.
year	DB Key	Repair year (1-n).
cost		Repair cost (dollars)
daysClosed		Days of service disruption (closure).
daysHalfSpeed		Days of service disruption (slowed processing)

1.4.6.3 RUNS

As discussed in section 1.2.4.1.3, the RUN analyzes an alternative or alternatives. RUNs are defined through two database tables. The "*Run*" table defines a run ID and the analysis parameters such as the planning period, base year, and discount rate. The "*AlternativeRunXRef*" defines which alternatives are to be considered and how they are considered.

1.4.6.3.1 Run Table

Specification of a "*runID*" along with the basic data defining the RUN is stored in the "*Run*" table (TABLE 1.4.82). The "*runID*" is then used to cross-reference data in other tables. This table is also used to specify the analysis parameters such as the planning period, base year, and discount rate.

TABLE 1.4.82 – Run Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
runID	DB Key	Closure ID from ClosureTypes table.
runName		Lock ID from Locks table.
startYear		Family ID from TransitTimeCurveFamily.
endYear		Unique random minor ID
ignoreBudget		Ignore budget constraints in Budget table (Y or N)?
sequentialJustification		Sequential justification of alternatives (Y or N)?
useScheduledClosures		Consider scheduled closures in economic justification (Y or N)?
ignoreNonAlternativeComponents		Ignore the reliability of non-alternative components (Y or N)?
useRandomMinors		Use random minors in economic justification (Y or N)?
discountRate		Federal discount rate
discountMethod		Discount method (B, M, or E)
baseYearForDiscounting		Base year for discounting
comments		Additional description if needed.

1.4.6.3.2 AlternativeRunXRef Table

Data on the alternative or alternatives considered in a RUN are stored in the "*AlternativeRunXRef*" table (TABLE 1.4.83). The basic information on the alternatives (implementation duration, and the post-implementation "*movementSetID*" and "*networkVersionID*") is stored in the "*Alternative*" table (TABLE 1.4.73). For each alternative listed in the RUN, the alternative is either specified with an implementation range to be considered, and a possible designation as a "*must do*" alternative (one that must be implemnented).

TABLE 1.4.83 – AlternativeRunXRef Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
runID	Key	Run ID from the Run table.
alternativeID	Key	Alternative ID from Alternative table.
earliestYear		First possilbe calendar year for the alternative to start implementation.
latestYear		Last possible year for the alternative to start implementation.
mustDo		Automarically implement the alternative (Y or N).

Any alternatives listed as "*must do*" are forced to be implemented in all of the analysis scenarios.

The model will analyze implementation of that alternative in each year of the implementation range and compare the results against the no implementation scenario. When multiple alternatives are specified, the model will analyze the implementation permutations and again compare the results with the no implementation scenario.

1.4.6.4 Investment Plans (IPs)

As discussed in section 1.2.4.1.3, the investment plan summarizes the recommendations of one or more RUNs ("*runID*"s). In short, the recommended investment implementations determined in the runID are specified in the investment plan as "*must dos*". The investment plan does no optimal timing and is used only to combine multiple investment options and re-equilibrate the system to ascertain the system effect of all the alternatives together in the system.

The investment plans are defined through three tables. The "*InvestmentPlan*" table defines an investment plan ID and the analysis parameters such as the planning period, base year, and discount rate. The "*InvestmentPlanRunXRef*" defines which RUNs are to be included. The "*InvestmentPlanForecastXRef*" stores whether or not a specific IP and forecast has been analyzed at when the results were created.

1.4.6.4.1 InvestmentPlan Table

Specification of a "*investmentPlanID*" along with the basic data defining the investment plan (IP) is stored in the "*InvestmentPlan*" table (TABLE 1.4.84). The "*investmentPlanID*" is then used to cross-reference data in other tables. This table is also used to specify the analysis parameters such as the planning period, base year, and discount rate.

TABLE 1.4.84 – InvestmentPlan Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
investmentPlanID	Key	Unique investment plan ID.
unvestmentPlanName		Investment plan name
startYear		First fiscal (calendar) year of planning period.
endYear		Last fiscal (calendar) year of planning period.
baseInvestmentPlanID		The "basis" IP from which to measure incrementals (WOPC).
discountRate		Current FY Federal discount rate for PV and amortization.
discountMethod		PV and amortization method (B=beginning, M=middle, E=end).
comments		Additional description if needed.
baseYearForDiscounting		PV and amortization base fiscal (calendar) year.

1.4.6.4.2 InvestmentPlanRunXRef Table

Data on which RUNs are included in an investment plan ("*investmentPlanID*") are stored in the "*InvestmentPlanRunXRef*" table (TABLE 1.4.85). Specifically, the "*runID*" supplies the IP a pointer to the alternative ("*alternativeID*") and the implementation start year ("*startYear*") in the "*AlternativeSelected*" table.

TABLE 1.4.85 – InvestmentPlanRunXRef Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
investmentPlanID	Key	Investment plan ID from InvestmentPlan table.
runID	Key	Run ID from the Run table.

1.4.6.4.3 InvestmentPlanForecastXRef Table

Data on the status of an IP and forecast combination.analysis are stored in the "*InvestmentPlanForecastXRef*" table (TABLE 1.4.86).

TABLE 1.4.86 – InvestmentPlanForecastXRef Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
investmentPlanID	Key	Investment plan ID from InvestmentPlan table.
forecastID	Key	Forecast ID from Forecast table.
statisticsGenerated		Whether or not the statistics have been generated (TRUE or FALSE)
lastRun		Run date (mm/dd/yyyy hh:mm)

1.4.7 Analysis, Execution, and Summary Parameters

Several of the analysis parameter are specified for the RUN and the IP through their "*Run*" and "*InvestmentPlan*" tables when the "*RunID*" and "*investmentPlanID*" are defined. Specifically the start and end years of the planning period, the Federal discount rate, the discounting method, and the base year for discounting and amortization. There are however, numerous other analysis parameters that must be defined.

The additional analysis parameters needed are defined through a "*dataSetID*".

1.4.7.1 The Data Set ID

Additional parameters for the IP and WSDM are specified and stored under a "*dataSetID*" in two database tables. These other settings and assumptions include the forecasted demand scenario, the demand assumption (price responsive or fixed quantity), the fuel tax plan, the fee plan, and whether or not to allow shipping plan re-planning over the planning period.

1.4.7.1.1 GeneralDataSet Table

Translation from the "*dataSetID*" to the executables' result parameters is done through the "*GeneralDataSet*" table (TABLE 1.4.87).

TABLE 1.4.87 – GeneralDataSet Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
investmentPlanID		Investment plan ID from InvestmentPlan table.
forecastID		Forecast ID from Forecast table.
useScheduledClosures		Use scheduled closures (TRUE or FALSE).
calculateCongestionFees		Calculate congestion fees (TRUE or FALSE).
lockageFeePlanID		Lockage fee plan ID (lockageFeePlanID) from LockageFeePlan table.
fuelTaxPlanID		Fuel tax plan ID from FuelTaxPlan table.
demandFunctionPlanID		Demand function plan ID from DemandFunctionPlan table.
allowShippingReplan		Allow shipping-plan re-estimation (TRUE or FALSE).
allowTonnageInExcessOfForecast		If elastic demand, allow extrapolation beyond forecasted amount (TRUE or FALSE).
useMostLikelyHazardFunction		For fatigue driven components (i.e. mult-PUP curves) use the most-likely PUP (TRUE or FALSE).

1.4.7.1.2 WSDMDataSet Table

Translation from the "*dataSetID*" to the WSDM result parameters is done through the "*WSDMDataSet*" table (TABLE 1.4.88).

TABLE 1.4.88 – WSDMDataSet Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
investmentPlanID		Investment plan ID from InvestmentPlan table.
forecastID		Forecast ID from Forecast table.
useScheduledClosures		Use scheduled closures (TRUE or FALSE).
calculateCongestionFees		Calculate congestion fees (TRUE or FALSE).
lockageFeePlanID		Lockage fee plan ID (lockageFeePlanID) from LockageFeePlan table.
fuelTaxPlanID		Fuel tax plan ID from FuelTaxPlan table.
demandFunctionPlanID		Demand function plan ID from DemandFunctionPlan table.
allowShippingReplan		Allow shipping-plan re-estimation (TRUE or FALSE).
allowTonnageInExcessOfForecasts		If elastic demand, allow extrapolation beyond forecasted amount (TRUE or FALSE).
movementSetID		Movement set ID from MovementSet table.
networkVersion		Network version ID from NetworkVersion table.

1.4.7.2 ExecutableParameter Table

The LRM (section 1.3.3), WSDM (section 1.3.1), the Generate All Component Replacements module (section 1.3.2.1.1), the Summarize Closures module (section 1.3.4), the Build Investment Plan module (section 1.3.6), the Calculate Costs module (section 1.3.8), and the Optimization module (section 1.3.5) require execution parameters which are stored in the "*ExecutableParameter*" table (TABLE 1.4.89). The parameters, with the modules they are used in, are shown in TABLE 1.4.90. These entries in the table enable the analyst to run these modules from the user interface.

TABLE 1.4.89 – ExecutableParameter Table Description

Database Field	Key	Description
executableName	Key	Executable name.
parameterID	Key	Unique parameter ID by executable (executableName).
parameterClass		Parameter class.
parameterName		Parameter name.
variableType		User interface variable type (e.g. integer, text, Y/N, etc.)
defaultValue		Default parameter value unless otherwise specified.
isOptional		Whether or not the parameter is optional (True or False).
controlType		User interface control (e.g. check box, combo box etc.)
comments		Additional description if needed.

TABLE 1.4.90 – ExecutableParameter Parameters

Parameter (parameterClass)	Module
allowShippingReplan	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
allowTonnageInExcessOfForecast	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
calculateCongestionFees	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
calendarYear	GenAllCompRep, GenAllCompRep, RunLRM, RunLRM, WSDM, & WSDM
chamberID	LRM
componentID	LRM
congestionFeePlanID	WSDM
demandFunctionPlanID	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
endYear	LRM
forecastID	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
fuelTaxPlanID	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
investmentPlanID	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, SummClosures, & WSDM
iterations	LRM & RunLRM
lockageFeePlanID	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
lockID	LRM & RunLRM
logfile	ORNIMOptim
networkID	BuildInvestmentPlan, CalculateCosts, GenAllCompRep, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, SummClosures, & WSDM
outputCommodityBargeSummary	WSDM
outputModeSelection	WSDM
outputShippingPlans	WSDM
randomNumberSeed	LRM & RunLRM
recalculateAllClosures	WSDM
runID	GenAllCompRep, ORNIMOptim, RunAllAlternatives, RunAllAlternatives, SummClosures, & SummClosures
shouldBracket	RunAllAlternatives
startYear	LRM
useHistoricalRoutings	WSDM
useMostLikelyHazardFunction	BuildInvestmentPlan, CalculateCosts, LRM, ORNIMOptim, RunAllAlternatives, RunLRM, & WSDM
useScheduledClosures	LRM & RunLRM

1.4.7.3 Report Groups

The model's waterway transportation network can be extensive and the movement data can encompass part or all of the defined network. Often it becomes necessary to report on statistics for specified sections on the waterway transportation network. This is accomplished through a report group defined through two database tables discussed in the following sections. This is a specification of a group of locks that are of special interest (e.g., the Upper Ohio).

1.4.7.3.1 ReportGroup Table

The report group is assigned a "*reportGroupID*" through the "*ReportGroup*" table (TABLE 1.4.91). The data in this table is shown in TABLE 1.4.92. This table only assigns an ID and name, specific definition of the report group occurs in the ReportGroupXref table.

TABLE 1.4.91 – ReportGroup Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
reportGroupID	Key	Unique report group ID.
reportGroupName		Report group name (e.g. Upper Ohio)
comments		Additional description if needed.

TABLE 1.4.92 – Report Groups (ReportGroup Table Data)

networkID	reportGroupID	reportGroupName	comments
1	1	Ohio River Mainstem	Main stem projects only
1	2	Upper Ohio	Emsworth, Dashields, & Montgomery.

1.4.7.3.2 ReportGroupXRef Table

Identification of the locks of interest for each report group is accomplished in the "*ReportGroupXRef*" table (TABLE 1.4.93). The contents of this database table is shown in TABLE 1.4.94. As can be observed, the Upper Ohio report group ("*reportGroupID*" 2) is defined as the three Upper Ohio River projects (Emsworth, Dashields, and Montgomery).

TABLE 1.4.93 – ReportGroupXRef Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
reportGroupID	Key	Report group ID from ReportGroup table (e.g. Upper OH projects).
lockID	Key	Lock ID from Locks table.

TABLE 1.4.94 – Report Group Cross Reference (ReportGroupXRef Table Data)

networkID	reportGroupID	lockID
1	1	1
1	1	2
1	1	3
1	1	4
1	1	5
1	1	6
1	1	7
1	1	8
1	1	9
1	1	10
1	1	11
1	1	12
1	1	13
1	1	14
1	1	15
1	1	16
1	1	17
1	1	18
1	1	19
1	1	20

networkID	reportGroupID	lockID
1	2	18
1	2	19
1	2	20

1.4.8 Module Outputs

Under this category of data are the output database tables storing results from the various modules described in section 1.3.

1.4.8.1 Waterway Supply and Demand Module

As shown in FIGURE 1.3.2 and FIGURE 1.3.3 there are seventeen output tables from the Waterway Supply and Demand module. As discussed in section 1.3.1, WSDM is a behavioral as well as a predictive model and is utilized in a shipping-plan calibration and in determining future waterway system equilibrium.

Remember that system equilibrium is determined for: 1) "*no prob no scheduled*"; 2) "*no prob with scheduled*"; 3) "*prob no scheduled*"; and 4) "*prob with scheduled*". Remember also that these equilibria adjusted for probabilistic service disruptions are not complete adjustments, but only an adjustment for service disruption that diverts traffic. In fact, these probabilistic adjusted equilibria are not expected values, but a straight calculation given the service disruption. These results are probabilistically combined in the Optimization module.

In the WSDM shipping-plan calibration process two output tables are produced. In the WSDM equilibrium process the remaining fifteen output tables are produced, which can be further delineated into: 1) equilibrium; and 2) equilibrium adjusted (i.e., unscheduled service disruption traffic diversion).

1.4.8.1.1 WSDM Shipping-Plan Calibration Output

The two summary output tables produced from the WSDM shipping-plan calibration process (see section 1.3.1.1) are discussed in the following sections. Note however, that the calibration process also modifies the contents of the "*MovementCalibration*", "*TowsizeLimits*", and "*TowboatUtilization*" tables.

1.4.8.1.1.1 Calibration Table

Data on the calibration fitness "*offness*" values are stored in the "*Calibration*" table (TABLE 1.4.95). Discussion of the use of the "*offness*" values in the shipping-plan calibration process can be found in ADDENDUM 1B ORNIM Calibration.

TABLE 1.4.95 – Calibration Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
networkVersion	Key	Network version ID from NetworkVersion table.
calibrationYear	Key	Calendar (fiscal) year the shipping plans are calibrated to (e.g. 9999 = 2004-2006 av.)
offTargetTows		Sum of absolute differences in number of tows at specified locks with specified weights.
offTargetHorsepower		Sum of absolute differences in average horsepower at specified locks with specified weights.

1.4.8.1.1.2 CalibrationResult Table

Calibration result data on towboats and barges at each lock in the system are stored in the "*CalibrationResult*" table (TABLE 1.4.96). The table's key includes the "*networkVersion*" and "*calibrationYear*" so that the calibration results can be tracked for different network versions (e.g., the Upper Ohio with 1200' main chambers) and different calibration years (e.g., 2006 versus 9999).

TABLE 1.4.96 – CalibrationResult Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
networkVersion	Key	Network version ID from NetworkVersion table.
lockID	Key	Lock ID from Locks table.
calibrationYear	Key	Calendar (fiscal) year the shipping plans are calibrated to (e.g. 9999 = 2004-2006 av.)
resultType	Key	Statistic type (T = tow or towboat, B = barge).
resultID	Key	If resultType=T, resultID = towboatTypeID. If resultType=B, resultID = bargeTypeID.
result		The calibration result for the specified statistic.

1.4.8.1.2 WSDM Equilibrium Output

Outputs in this category include the "*no prob no scheduled*" and "*no prob with scheduled*" results. Remember that many of the settings (assumptions) are defined through the "*dataSetID*" discussed in the "*GeneralDataSet*" table (section 1.4.7.1.1).

1.4.8.1.2.1 RunSummary Table

Summary information on the WSDM no-unscheduled-service-disruption results is stored in the "*RunSummary*" table (TABLE 1.4.97).

TABLE 1.4.97 – RunSummary Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
reportGroupID	Key	Report group ID from ReportGroup table (e.g. Upper OH projects).
waterTonnage		Equilibrium system WW tonnage for specified year.
landTonnage		Equilibrium system land tonnage (demand - WW EQ tons) for specified year.
savings		WW trans.surplus for EQ tonnage in specified year (dollars).
transitTimeDays		Equilibrium WW system transit time (days).
landTransitCost		Equilibrium system land transportation cost (dollars).
waterTransitEquilibriumCost		Equilibrium system water transportation cost (dollars).
waterTransitBaseCost		Equilibrium WW tonnage base water transportation cost (dollars).
lockageFeeRevenue		Equil.WW revenues collected for all locks in the system for specified year (dollars).
fuelTaxRevenue		Equil.WW fuel tax revenues for specified year (dollars).
comments		Additional description if needed.
fuelTaxRevenueTransit		Equil.WW system fuel tax revenue during lock transit for specified year (dollars).
fuelTaxRevenueLineHaul		Equil.WW system fuel tax revenue for line-haul for specified year (dollars).
fuelTaxRevenueOther		Equil.WW system fuel tax revenue ?????? for specified year (dollars).

1.4.8.1.2.2 LockActivity Table

Data on the WSDM no-unscheduled-service-disruption activity at each lock are stored in the "*LockActivity*" table (TABLE 1.4.98).

TABLE 1.4.98 – LockActivity Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
lockID	Key	Lock ID from Locks table.
transitTime		Average transit time (processing plus delay) in hours / tow.
tonnage		Equilibrium annual system tonnage at specified lock in specified year.
savings		WW trans.surplus for EQ tonnage transiting the specified lock in specified year (dollars).
divertedTonnage		Lock demand tonnage diverted in equilibrium.
numLoadedTows		Equilibrium number of loaded tows at specified lock in specified year.
numEmptyTows		Equilibrium number of empty tows at specified lock in specified year.
avgTowSize		EQ average tow-size at specified lock in specified year.
avgTowLoad		EQ average tow loading (tons) at specified lock in specified year.
avgBargeLoad		EQ average barge loading (tons) at specified lock in specified year.
avgHorsepower		EQ average tow towboat HP at specified lock in specified year.
transitCost		EQ total WW transportation transit cost (dollars) at specified lock in specified year.
savings		WW trans.surplus for EQ tonnage transiting the specified lock in specified year (dollars).
~~savingsWExternalities~~		~~WW trans.surplus for EQ tonnage transiting the specified lock in specified year (dollars) with externalities.~~
capacity		Project (lockID) annual capacity.
lockageFeeRevenues		Revenues collected for specified lock in specified year (dollars).
comments		Additional description if needed.

1.4.8.1.2.3 LinkShippingPlan Table

Link-level shipping-plan data for the WSDM no-unscheduled-service-disruption results are stored in the "*LinkShippingPlan*" table (TABLE 1.4.99).

TABLE 1.4.99 – LinkShippingPlan Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
investmentPlanID	Key	Investment plan ID from InvestmentPlan table.
forecastID	Key	Forecast ID from Forecast table.
networkVersion	Key	Network version ID from NetworkVersion table.
movementSetID	Key	Movement set ID from MovementSet table.
movementID	Key	Movement ID from MovementDetail table.
sectorID	Key	Sector ID from Sectors table.
linkIndex	Key	Link ID from Links table (0 specifies Sector level specification).
loadStatus	Key	Loading status (F = full or loaded, E = empty).
towboatTypeID		Towboat class ID from TowboatTypes table.
numberBarges		Number of barges per tow on the leg (tow-size).
speed		Tow speed (mph) for the defined towboat class, tow-size, and link direction.
rpm		Propeller RPM.

1.4.8.1.2.4 MilePointSummary Table

Yearly river mile point summary data from the WSDM no-unscheduled-service-disruption results are stored in the "*MilePointSummary*" table (TABLE 1.4.100).

TABLE 1.4.100 – MilePointSummary Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
riverID	Key	River ID from Rivers table.
milepoint	Key	River milepoint.
dataType	Key	Data type (currently commodity)
dataIndex	Key	If commodity, dataIndex = commodityID
amount		Amount of specified data and data type at the specified milepoint.

1.4.8.1.2.5 LockCommodity Table

WSDM yearly lock results summarized by commodity for no-unscheduled-service-disruption are stored in the "*LockCommodity*" table (TABLE 1.4.101).

TABLE 1.4.101 – LockCommodity Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
lockID	Key	Lock ID from Locks table.
commodityID	Key	Commodity ID from CommodityTypes table.
tonnage		Equilibrium annual tonnage if useProbabilisticClosures = False, else expected annual tonnage.
divertedTonnage		Lock demand tonnage diverted in equilibrium.
savings		WW trans.surplus for EQ tonnage transiting the specified lock in specified year (dollars).
barges		Number of barges moving the specified commodity through the specified lock.
lockageFeeRevenue		Revenues collected for specified lock in specified year (dollars).
fuelTaxRevenueTransit		Fuel tax during transit for specified lock in specified year (dollars).

1.4.8.1.2.6 CommodityBargeSummary Table

Data on the yearly distribution of tonnage by commodity and barge type for a specified set of locks (reportGroupID) for the no-unscheduled-service-disruption results are stored in the "*CommodityBargeSummary*" table (TABLE 1.4.102).

TABLE 1.4.102 – CommodityBargeSummary Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
reportGroupID	Key	Report group ID from ReportGroup table (e.g. Upper OH projects).
bargeTypeID	Key	Unique barge ID from BargeTypes table
commodityID	Key	Commodity ID from CommodityTypes table.
tonnageOnRiver		Specified commodity tonnge in specified barge type through specified locks (reportGroupID).

1.4.8.1.2.7 CongestionFee Table

Information on the model optimized yearly congestion fees at the locks for an investment plan and forecast (assuming no-unscheduled-service-disruptions) are stored in the "*CongestionFee*" table (TABLE 1.4.103).

TABLE 1.4.103 – CongestionFee Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
lockID	Key	Lock ID from Locks table.
dataSetID	Key	Data set ID from the GeneralDataSet table.
feePlanID	Key	Lockage fee plan ID (lockageFeePlanID) from LockageFeePlan table.
year	Key	Fiscal (or calendar) year.
congestionFee		Model calculated fee (dollars per).

1.4.8.1.2.8 Optional ShippingPlan and ModeSelection Tables

These tables are optional (given their extensive size) and are used for QA/QC and debugging. Information on the towboat types and tow-sizes used in moving each individual movement (i.e., the shipping-plan) assuming no-unscheduled-service-disruption is stored in the "*ShippingPlan*" table (TABLE

1.4.104). Movement level data on how each movement is split between land and water routing assuming no-unscheduled-service-disruption are stored in the "*ModeSelection*" table (TABLE 1.4.105).

TABLE 1.4.104 – ShippingPlan Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
networkVersion	Key	Network version ID from NetworkVersion table.
movementSetID	Key	Movement set ID from MovementSet table.
movementID	Key	Movement ID from MovementDetail table.
leg	Key	WW shipping-plan leg (1-n).
loadStatus	Key	Loading status (F = full or loaded, E = empty).
startingPortID		Shipping-plan leg starting port ID from Ports table.
endingPortID		Shipping-plan leg ending port ID from Ports table.
towboatTypeID		Towboat class ID from TowboatTypes table.
bargeTypeID		Barge type ID from BargeTypes table.
numberBarges		Number of barges per tow on the leg (tow-size).

TABLE 1.4.105 – ModeSelection Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
movementID	Key	Movement ID from MovementDetail table.
landTonnage		Equilibrium land tonnage (demand - WW EQ tons) for specified mvt in specified year.
waterTonnage		Equilibrium WW tonnage for specified mvt in specified year.
savingsPerTon		Mvt EQ WW transportation surplus/ton (rate-savings if inelastic demand).
totalSavings		Mvt EQ WW transportation surplus (total rate-savings if inelastic demand).
waterDistance		Mvt water line-haul distance (miles).
lockageFeeRevenueGenerated		Lockage fees generated by the EQ mvt for specified year over entire route.
fuelTaxRevenueGenerated		Fuel taxes generated by the EQ mvt for specified year over entire route.
comments		Additional description if needed.
fuelTaxRevenueGeneratedTransit		Fuel taxes generated in lock transit by the EQ mvt for specified year over entire route.
fuelTaxRevenueGeneratedLineHaul		Fuel taxes generated in line-haul by the EQ mvt for specified year over entire route.
fuelTaxRevenueGeneratedOther		Fuel taxes generated in ????? by the EQ mvt for specified year over entire route.

1.4.8.1.2.9 RiverCommoditySummary and RiverLocationSummary Tables

WSDM yearly river results (summarized by commodity and assuming no-unscheduled-service-disruptions) are stored in the "*RiverCommoditySummary*" table (TABLE 1.4.106). WSDM yearly origin to destination river results (summarized by commodity and assuming no-unscheduled-service-disruptions) are stored in the "*RiverLocationSummary*" table (TABLE 1.4.107).

TABLE 1.4.106 – RiverCommoditySummary Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID		Data set ID from the GeneralDataSet table.
year		Fiscal (or calendar) year.
riverID		River ID from Rivers table.
commodityID		Commodity ID from CommodityTypes table.
originatingTonnage		WW tonnage of specified commodity originating on the specified river in the specified yr.
originatingLoadedBarges		Number of loaded barges of specified commodity originating on the specified river in the specified yr.
originatingEmptyBarges		Number of empty barges (commodityID=0) originating on the specified river in the specified yr.
originatingTows		Number of tows of specified commodity originating on the specified river in the specified yr.
tonnage		Equilibrium tonnage of specified commodity moving on the specified river in the specified yr.
tonMiles		Equilibrium tonmiles of specified commodity moving on the specified river in the specified yr.
bargeMiles		Equilibrium barge-miles of specified commodity moving on the specified river in the specified yr.
userFees		User fee revenues from specified commodity on specified river in specified year.
fuelTaxRevenue		Fuel tax revenues on specified river in specified year (dollars).
bargeMileFees		Barge-mile fee revenues from specified commodity on specified river in specified year.
fuelTaxRevenueLineHaul		Fuel tax during line-haul on specified river in specified year (dollars).
fuelTaxRevenueOther		Fuel tax during ???? on specified river in specified year (dollars).

TABLE 1.4.107 – RiverLocationSummary Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID		Data set ID from the GeneralDataSet table.
year		Fiscal (or calendar) year.
originRiverLocation		Origin river ID (riverLocationID) from RiverLocation table.
commodityID		Commodity ID from CommodityTypes table.
destinationRiverLocationID		Destination river ID (riverLocationID) from RiverLocation table.
forecastTonnage		Demand tonnage for specified river.
waterTonnage		Equilibrium WW tonnage for specified tonnage.
fuelTaxRevenue		Fuel tax revenues on specified river in specified year (dollars).
lockageFeeRevenue		Revenues collected for locks on specified river in specified year (dollars).
fuelTaxRevenueTransit		Fuel tax during transit for locks on specified river in specified year (dollars).
fuelTaxRevenueLineHaul		Fuel tax during line-haul on specified river in specified year (dollars).
fuelTaxRevenueOther		Fuel tax during ???? on specified river in specified year (dollars).

1.4.8.1.3 WSDM Closure-Combination Summary Output

For each closure-combination identified in the "*ClosureCostCombination*" table (section 1.4.8.4.1) the WSDM equilibrium results are adjusted and stored in the following tables. Remember that many of the settings (assumptions) are set through the "*dataSetID*" defined in the "*GeneralDataSet*" table (section 1.4.7.1.1).

1.4.8.1.3.1 ClosureCost Table

Data on the savings, tonnage, transit cost, and transit days associated with each closure-combination is stored in the "*ClosureCost*" table (TABLE 1.4.108). The associated savings, tonnage, transit cost and transit days are then calculated by WSDM and stored in this table.

TABLE 1.4.108 – ClosureCost Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
closureCostCombinationID	Key	Closure cost combination ID from ClosureCostCombination table.
transportationSavings		Adjusted WW EQ trans.surplus after the service disruption (closureCostCombinationID) adjustment.
tonnage		Adjusted WW EQ tonnage after the service disruption (closureCostCombinationID) adjustment.
totalTransitDays		Total system time in lock transit after adjustment (in days).
landTransitCost		Transportation cost of land movements after adjustment.
lockTonnage		Adjusted WW EQ tonnage at specified lock.
lockNumTows		Adjusted WW EQ number of tows at specified lock.
lockHourlyTowCost		Tow cost (in $/hour/tow) after adjustment.

1.4.8.1.3.2 DiversionSavings Table

Data on the effects of diversion off the waterway equilibrium traffic levels due to total river closures or capacity constraints are stored in the "*DiversionSavings-*" table (TABLE 1.4.109).

TABLE 1.4.109 – DiversionSavings Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
closureCostCombinationID	Key	Closure cost combination ID from ClosureCostCombination table.
closureID	Key	Service disruption ID from ClosureTypes table.
year	Key	Fiscal (or calendar) year.
transportationSavings		Adjusted WW EQ trans.surplus after the service disruption (closureCostCombinationID) adjustment.
tonnage		Adjusted WW EQ tonnage after the service disruption (closureCostCombinationID) adjustment.
transitTime		???
landTonnageClosureDiversion		Expected WW tonnage diversion from river closure response events
landTonnageCapacityDiversion		Expected WW tonnage diversion from over-capacity service disruptions
landTransitCostClosureDiversion		Expected land transportation costs for short-run river closure response traffic diversion.
landTransitCostCapacityDiversion		Expected land transportation costs for short-run over-capacity traffic diversion.
		Expected land transportation INCREMENTAL costs for SR river closure response traffic diversion.
		Expected land transportation INCREMENTAL costs for SR over-capacity traffic diversion.

1.4.8.1.3.3 DiversionExternality Table

Data on the externality costs arising from equilibrium diversions from unscheduled service disruptions (i.e., river closure response diversions caused by total river closures and diversions caused by capacity constraints) are stored in the "*DiversionExternality*" table (TABLE 1.4.110). Remember that not all probabilistic service disruption transportation costs adjustments can be done externally to WSDM (see section 1.2.4.4.3.11). When there is the potential for an unscheduled service disruption to divert traffic (i.e., equilibrium traffic is over the annual capacity with the service disruption, or the event is a river closure and the river closure response data indicate traffic diversion), WSDM must be used to recalculate the transit times at all locks in the system that experience the tonnage loss and then recalculate the waterway transportation costs for all movements transiting those locks.

TABLE 1.4.110 – DiversionExternality Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
year	Key	Fiscal (or calendar) year.
closureCostCombinationID	Key	Closure cost combination ID from ClosureCostCombination table.
closureID	Key	Service disruption ID from ClosureTypes table.
externalityTypeID	Key	Externality type ID from ExternalityType table.
externalityCost		WSDM EQ diversion externality cost (dollars).

1.4.8.2 Set-Up Component Alternatives and RUNs Module

As discussed in section 1.3.2, this module is really more of a user utility or analysis pre-processor. The output database tables of this module have been discussed in section 1.4.6.

1.4.8.3 Lock Risk Module

As shown in FIGURE 1.3.8 there are only two output tables from LRM.

1.4.8.3.1 ExpectedClosure Table

Data on the probability of a closure and the expected repair cost for each component at each age (out of LRM) are stored in the "*ExpectedClosure*" table (TABLE 1.4.111). Note that the "*averageRepairCost*" is an average cost for that component for the given "*closureID*", remembering that a given "*closureID*" might occur on multiple failure-level branches and that different repair costs can occur on each fix-level branch. The expected repair cost can be calculated by multiplying the "*averageRepairCost*" with the "*failureProbability*".

TABLE 1.4.111 – ExpectedClosure Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
chamberID	Key	Chamber ID from ChamberTypes table.
dataSetID	Key	Data set ID from the GeneralDataSet table.
lockID	Key	Lock ID from Locks table.
componentID	Key	Component ID from Component table.
closureID	Key	Service disruption ID from ClosureTypes table.
age	Key	Component age (1-n)
failureProbability		Probability (0.0-1.0)
averageRepairCost		Expected repair cost (dollars)

1.4.8.3.2 ExpectedSurvival Table

Data on the expectation of component survival (which is calculated by LRM) are stored in the "*ExpectedSurvival*" table (TABLE 1.4.112).

TABLE 1.4.112 – ExpectedSurvival Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
lockID	Key	Lock ID from Locks table.
chamberID	Key	Chamber ID from ChamberTypes table.
componentID	Key	Component ID from Component table.
age	Key	Component age (1-n).
survivalProbability		Probability (0.0-1.0)

1.4.8.4 Summarize Closures Module

The objective of the "*Summarize Closures*" module is to determine the service disruption events that need to be costed for the Optimization Module. As shown in FIGURE 1.3.9 there are two output tables from the "*Summarize Closures*" module.

1.4.8.4.1 ClosureCostCombination Table

Data on the combinations of closures that might occur in the same year at a specified node are stored in the "*ClosureCostCombination*" table (TABLE 1.4.113).

TABLE 1.4.113 – ClosureCostCombination Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
closureCostCombinationID	Key	Unique closure cost combination ID.
nodeType		Node type (B = bend, L = lock)
nodeID		Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
familyID		Tonnage-Transit curve family ID from TransitTimeCurveFamily table.
setNumber		Tonnage-Transit curve set ID from TransitTimeCurveDescription table.
closureString		Character string listing the closureID numbers.

1.4.8.4.2 ClosureToCost Table

Data on which combination of closures might occur in a particular year (out of Summarize Closures) are stored in the "*ClosureToCost*" table (TABLE 1.4.114).

TABLE 1.4.114 – ClosureToCost Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
closureCostCombinationID	Key	Closure cost combination ID from ClosureCostCombination table.
investmentPlanID	Key	Investment plan ID from InvestmentPlan table.
movementSetID	Key	Movement set ID from MovementSet table.
networkVersion	Key	Network version ID from NetworkVersion table.
useScheduledClosures	Key	Use scheduled closures (TRUE or FALSE).
year	Key	Fiscal (or calendar) year.

1.4.8.5 Optimization Module

As shown in FIGURE 1.3.10 there are only two output tables from the Optimization module.

1.4.8.5.1 AlternativeSelected Table

Data on which alternatives were selected for a given "*runID*" and when they should be implemented ("*startYear*") are stored in the "*AlternativeSelected*" table (TABLE 1.4.115).

TABLE 1.4.115 – AlternativeSelected Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
alternativeID	Key	Alternative ID from Alternative table.
dataSetID	Key	Data set ID from the GeneralDataSet table.
runID	Key	Run ID from the Run table.
startYear		Optimization selection of best first year of implementation for this alternative.
dateStored		Run date (mm/dd/yyyy hh:mm)
comments		Additional description if needed.

1.4.8.5.2 RunResult Table

Additional data on the alternatives selected from a RUN stored in the "*AlternativeSelected*" table is stored in the "*RunResult*" table (TABLE 1.4.116). Given the parameters specified in the "*dataSetID*", this table contains the amortized base and optimal repair and vessel lock transit costs.

TABLE 1.4.116 – RunResult Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
runID	Key	Run ID from the Run table.
baseRepairCost		Av.Ann. (using dataSetID settings) base repair cost.
baseTransitCost		Av.Ann. (using dataSetID settings) base vessel lock transit cost.
optimalRepairCost		Av.Ann. (using dataSetID settings) optimal (see AlternativeSelected) repair cost.
optimalTransitCost		Av.Ann. (using dataSetID settings) optimal (see AlternativeSelected) vessel lock transit cost.
dateLastRun		Run date (mm/dd/yyyy hh:mm)

1.4.8.6 Build Investment Plan Module

The objective of the "*Build Investment Plan*" module is to determine the movement set, network version, and transit time curve set is in effect in each year of the investment plan. As shown in FIGURE 1.3.11 there are three output tables where data are placed.

1.4.8.6.1 MovementSetSelection Table

Data on which movement sets are in effect by year for an investment plan and forecast are stored in the "*MovementSetSelection*" table (TABLE 1.4.117). Note that the forecast information is stored under the "*dataSetID*".

TABLE 1.4.117 – MovementSetSelection Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
startYear	Key	First fiscal (calendar) year for the specified movementSetID.
endYear		Last fiscal (calendar) year for the specified movementSetID.
movementSetID		Movement set ID from MovementSet table.
comments		Additional description if needed.

1.4.8.6.2 NetworkVersionSelection Table

Data on which network versions are in effect by year for an investment plan and forecast are stored in the "*NetworkVersionSelection*" table (TABLE 1.4.118). Note that the forecast information is stored under the "*dataSetID*".

TABLE 1.4.118 – NetworkVersionSelection Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
startYear	Key	First fiscal (calendar) year for the specified networkVersionID.
endYear		Last fiscal (calendar) year for the specified networkVersionID.
networkVersion		Network version ID from NetworkVersion table.
comments		Additional description if needed.

1.4.8.6.3 TransitTimeCurveSelection Table

Data on which transit time curve set are in effect by year for an investment plan and forecast are stored in the "*TransitTimeCurveSelection*" table (TABLE 1.4.119).

TABLE 1.4.119 – TransitTimeCurveSelection Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
nodeType	Key	Node type (B = bend, L = lock)
nodeID	Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
beginYear	Key	First fiscal (calendar) year for the specified tonnage-transit curve family & set.
endYear		Last fiscal (calendar) year for the specified tonnage-transit curve family & set.
familyID		Tonnage-Transit curve family ID from TransitTimeCurveFamily table.
setNumber		Tonnage-Transit curve set ID from TransitTimeCurveDescription table.
comments		Additional description if needed.

1.4.8.7 Build Investment Plan Closures Module

The objective of the "*Build Investment Plan Closures*" module is to generate the set of closures (scheduled and improvement) for an investment plan, taking into account the existing scheduled closures, the modifications to the scheduled closures due to alternative implementation, and the closures associated with the alternatives. As shown in FIGURE 1.3.12 there is only one output table from the "*Build Investment Plan Closures*" module.

1.4.8.7.1 InvestmentPlanClosure Table

Data on the scheduled and alternative closures included in an investment plan are stored in the "*InvestmentPlanClosure*" table (TABLE 1.4.120).

TABLE 1.4.120 – InvestmentPlanClosure Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
lockID	Key	Lock ID from Locks table.
year	Key	Fiscal (or calendar) year.
closureID	Key	Service disruption ID from ClosureTypes table.
scheduledClosureType	Key	Scheduled closure type from ScheduledClosureType table.
maintenanceCategory	Key	Maintenance category ID from AlternativeMaintenanceCategory table.
occurences		Number of occurences within the specified year.
cost		Dollars in specified year for specified maintenance category.

1.4.8.8 Calculate Costs Module

The objective of the "*Calculate Costs*" module is to compile the life-cycle cost (and waterway transportation surplus) dollar streams for an IP. As shown in FIGURE 1.3.13 there are five output tables from the "*Calculate Costs*" module.

1.4.8.8.1 System Level Statistics

1.4.8.8.1.1 ExpectedSavings Table

Data on the system transportation surplus, tonnage, and transit days (with and without probabilistic service disruption) are stored in the "*ExpectedSavings*" table (TABLE 1.4.121). Note that this table includes both the probabilistic and non-probabilistic results; "*prob*" and "*no prob*".

TABLE 1.4.121 – ExpectedSavings Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
dataSetID	DB Key	Data set ID from the GeneralDataSet table.
reportGroupID	DB Key	Report group ID from ReportGroup table (e.g. Upper OH projects).
year	DB Key	Fiscal (or calendar) year.
useProbabilisticClosures	DB Key	Whether probablistic closures were used (True or False).
expectedSavings		Equilibrium trans.surplus if useProbabilisticClosures = False, else expected trans.surplus.
expectedTonnage		Equilibrium tonnage if useProbabilisticClosures = False, else expected tonnge.
expectedTransitDays		Equilibrium transit days if useProbabilisticClosures = False, else expected transit days.

1.4.8.8.2 *Node and Lock Level Statistics*

1.4.8.8.2.1 ExpectedLockActivity Table

Data on the activity levels at the locks (with and without probabilistic service disruption) for the IP and forecast are stored in the "*ExpectedLockActivity*" table (TABLE 1.4.122). Note that this table includes both the probabilistic and non-probabilistic results; "*prob*" and "*no prob*".

TABLE 1.4.122 – ExpectedLockActivity Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
lockID	Key	Lock ID from Locks table.
year	Key	Fiscal (or calendar) year.
useProbabilisticClosures	Key	Whether probablistic closures were used (True or False).
transitTime		Average transit time (processing plus delay) in hours / tow.
tonnage		Equilibrium annual tonnage if useProbabilisticClosures = False, else expected annual tonnage.
capacity		Project (lockID) annual capacity.

1.4.8.8.2.2 ExpectedCost Table

Data on the expected yearly Federal costs by node, cost type, and cost code, for the IP and forecast are stored in the "*ExpectedCost*" table (TABLE 1.4.123).

TABLE 1.4.123 – ExpectedCost Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID	Key	Data set ID from the GeneralDataSet table.
nodeType	Key	Node type (B = bend, L = lock)
nodeID	Key	Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
year	Key	Fiscal (or calendar) year.
costType	Key	C=cyclical, U=unscheduled, I=improvement, T=transit, M=random, O=operations
costCode	Key	GI, CG, OD=Op.Dam, OM=O&M, OR=Op.Rehab., TF=IWWTF.
useProbabilisticClosures	Key	Whether probablistic closures were used (True or False).
cost		Dollars in specified year for specified cost code.

1.4.8.8.2.3 ExpectedDiversion Table

Data on the expected yearly tonnage diversion and transit costs by node for the IP and forecast are stored in the "*ExpectedDiversion*" table (TABLE 1.4.124).

TABLE 1.4.124 – ExpectedDiversion Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID		Data set ID from the GeneralDataSet table.
nodeType		Node type (B = bend, L = lock)
year		Fiscal (or calendar) year.
nodeID		Node ID (if nodeType = L, nodeID=lockID. If nodeType=B, nodeID=bendID)
landTonnageClosureDiversion		Expected WW tonnage diversion from river closure response events
landTonnageCapacityDiversion		Expected WW tonnage diversion from over-capacity service disruptions
landTransitCostClosureDiversion		Expected lock transit costs with river closure response traffic diversion.
landTransitCostCapacityDiversion		Expected lock transit costs with over-capacity service disruptions traffic diversion.

1.4.8.8.2.4 ExpectedExternality Table

Data on the expected yearly externality costs by lock and externality type, for the IP and forecast are stored in the "*ExpectedExternality*" table (TABLE 1.4.125). Since externality costs are triggered by river closures, and in the Upper Ohio analysis river closure only occur from unscheduled events, there are no externality costs when "*useProbabilisticClosures*" equals FALSE.

TABLE 1.4.125 – ExpectedExternality Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID		Data set ID from the GeneralDataSet table.
lockID		Lock ID from Locks table.
year		Fiscal (or calendar) year.
useProbabilisticClosures		Whether probablistic closures were used (True or False).
externalityTypeID		Externality type ID from ExternalityType table.
cost		Dollars in specified year for specified externality type.

1.4.8.8.2.5 ExpectedUnexpectedClosure Table

Data on the expected repair costs by the probabilistic closure types for an investment plan and forecast are stored in the "*ExpectedUnexpectedClosure*" table (TABLE 1.4.126).

TABLE 1.4.126 – ExpectedUnexpectedClosure Table Description

Database Field		Description
networkID	Key	River system network (1 = existing ORS)
dataSetID		Data set ID from the GeneralDataSet table.
lockID		Lock ID from Locks table.
chamberID		Chamber ID from ChamberTypes table.
componentID		Component ID from Component table.
closureID		Service disruption ID from ClosureTypes table.
yearOfFailure		Fiscal (or calendar) year.
failureProbability		Probability (0.0-1.0).
averageRepairCost		Expected repair costs for specified component closure type.

1.4.9 Report Definitions

The model currently has sixteen reports available through the model's interface. These reports are defined and controlled through the three tables described below.

1.4.9.1 Report Table

Data on the available reports are stored in the "*Report*" table (TABLE 1.4.127). This table assigns a unique "*reportID*" which is used to relate the report to data in other tables. The available reports are shown in TABLE 1.4.128.

TABLE 1.4.127 – Report Table Description

Database Field	Key	Description
reportID	Key	Unique report ID.
reportClass		Report class (DB, IP, LRM, Optim, or WSDM)
reportName		Report name.

TABLE 1.4.128 – Reports (Report Table Data)

reportID	reportClass	reportName
3	DB	Database Table Export
11	IP	Investment Plan Summary
13	IP	Investment Plan Lock Cost Detail
14	IP	Investment Plan System Statistics
15	IP	Investment Plan Cost Benefit Comparison
7	LRM	Component Reliability
9	LRM	Component Reliability for Lock
10	Optim	Component Replacement Comparison
12	Optim	Run Summary
16	Optim	Component Replacements by Forecast
1	WSDM	Revenue Generated
2	WSDM	Comparison of Revenue
4	WSDM	Comparison of WSDM Runs
5	WSDM	River Location Summary
6	WSDM	Multi-Year WSDM Comparison
8	WSDM	Calibration Comparison
99	WSDM	Test Report

1.4.9.2 ReportParameter Table

Information on the parameters needed to produce the reports is stored in the "*ReportParameter*" table (TABLE 1.4.129).

TABLE 1.4.129 – ReportParameter Table Description

Database Field	Key	Description
reportID	Key	Report ID from Report table.
parameterID	Key	Unique parameter ID.
parameterClass		The parameter (i.e. database fieldname).
parameterName		Description of the parameter
controlType		UI control type.

1.4.10 Model Bookkeeping

Execution management is handles through the following tables.

1.4.10.1 StandardOptions Table

The standard values, by network ID, for executable parameters are stored in the "*StandardOptions*" table (TABLE 1.4.130).

TABLE 1.4.130 – StandardOptions Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
useScheduledClosures		Use scheduled closures (TRUE or FALSE).
calculateCongestionFees		Calculate congestion fees (TRUE or FALSE).
lockageFeePlanID		Lockage fee plan ID (lockageFeePlanID) from LockageFeePlan table.
fuelTaxPlanID		Fuel tax plan ID from FuelTaxPlan table.
demandFunctionPlanID		Demand function plan ID from DemandFunctionPlan table.
allowShippingReplan		Allow shipping-plan re-estimation (TRUE or FALSE).
allowTonnageInExcessOfForecast		If elastic demand, allow extrapolation beyond forecasted amount (TRUE or FALSE).
useMostLikelyHazardFunction		For fatigue driven components (i.e. mult-PUP curves) use the most-likely PUP (TRUE or FALSE).
useHistoricRoutings		Use historic WW routing (TRUE or FALSE).
startYear		First fiscal (calendar) of the planning period.
endYear		Last fiscal (calendar) year of the planning period.
discountRate		Interest rate for discounting and amortization (i.e. the current Federal discount rate for water projects).
discountMethod		Discounting method (B=beginning, M=middle, and E=end of period).
baseYearForDiscounting		Analysis base year (for discounting and amortization of cash flows).

1.4.10.2 Job Table

The execution of jobs executing modules is done through the "*Jobs*" table (TABLE 1.4.131).

TABLE 1.4.131 – Job Table Description

Database Field	Description
networkID	River system network (1 = existing ORS)
jobID	Unique job ID (1-n).
jobName	Job name.
executableName	Executable name (i.e. module).
queueDate	Date (mm/dd/yyyy hh:mm)
priority	Priority (TRUE or FALSE). Priority jobs run before non-priority jobs.
userName	User submitting the job.
started	Date (mm/dd/yyyy hh:mm)
completed	Date (mm/dd/yyyy hh:mm)
machineName	Machine executing the job.
startDate	Date (mm/dd/yyyy hh:mm)
completionDate	Date (mm/dd/yyyy hh:mm)
comments	Additional description if needed.

1.4.10.3 JobParameter Table

The parameters specified for each job ID (executable) are stored in the "*JobParameter*" table (TABLE 1.4.132).

TABLE 1.4.132 – JobParameter Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
jobID	Key	Job ID from Job table.
parameterID		Parameter ID from ExecutableParameter table.
parameterValue		Parameter value for specified parameter ID.

1.4.10.4 JobDependency Table

Information on which jobs must be processed prior to a jobs execution is controlled through the "*JobDependency*" table (TABLE 1.4.133).

TABLE 1.4.133 – JobDependency Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
jobID	Key	Job ID from Job table.
predecessorJobID		Job ID that must complete before this job begins.

1.4.10.5 ProgramStatus Table

Information on processes that are currently running, or have aborted with an error, is stored in the "*ProgramStatus*" table (TABLE 1.4.134).

TABLE 1.4.134 – ProgramStatus Table Description

Database Field	Description
startDate	Date (mm/dd/yyyy hh:mm)
module	Module running.
parameters	Parameter settings of specified module.
processID	Process ID.

1.4.10.6 ErrorMessageLog Table

Execution error messages are logged into the "*ErrorMessageLog*" table (TABLE 1.4.135).

TABLE 1.4.135 – ErrorMessageLog Table Description

Database Field	Description
date	Error date (mm/dd/yyyy hh:mm)
module	Module where the error occurs.
parameters	Parameter settings of specified module at time of error.
message	Description of error encountered.
severity	Error severity (1-n where 1 is fatal).

1.4.10.7 JobInterruption Table

The "*JobInterruption*" table (TABLE 1.4.136) is used to interrupt jobs without corrupting data.

TABLE 1.4.136 – JobInterruption Table Description

Database Field	Key	Description
networkID	Key	River system network (1 = existing ORS)
jobID	Key	Job ID from Job table.
interruptRequestDate		Date (mm/dd/yyyy hh:mm)
userName		User submitting the interrupt request.

1.5 Model and Analysis Assumptions

1.5.1 Sectorial, Spatial, and Simplifying Assumptions

- Incremental changes to the waterway transportation system can be analyzed under a spatially-detailed barge transportation partial-equilibrium framework.
- The level of resolution for movements is at the annual tonnage of a commodity from one port complex to another via a particular barge type. This ignores the effects of seasonality in traffic or waterway closures. Note that the user can define a movement for any commodity-origin-destination-barge combination.
- Transit time (processing and delay) at each lock is calculated as an average number of hours per tow based on the total annual tonnage at the locks transited. All movements are assumed to experience the same average lock transit times. There is no seasonal variation.

1.5.2 Demand Assumptions

- It is assumed that technology is fixed at the time of the analysis. Forecast scenarios, however, can contain assumptions regarding technology advancement for certain industries which may affect the demand patterns for commodities.
- Waterway forecasted demand (whether fixed quantity or price responsive) represents future waterway traffic given fixed technology, current water transportation cost and current land transportation cost. Unmet waterway demand is assumed to be transported overland at the long-run least-costly all-overland rate.
- The supply of land transportation for individual movements is perfectly elastic at the given long-run least-costly all-overland rate.
- For fixed demand movements, the willingness-to-pay for barge transportation is assumed fixed through time (unaffected by demand or land congestion). The proxy for the fixed demand willingness-to-pay is typically set as the least-costly all-overland transportation rate, noting that this is an input value supplied by the user.
- For price responsive demand movements, we have sufficient exogenous information to allow a unique demand curve to be calculated. The exogenous forecasted tonnage for each movement for each year corresponds to the given long-run least-costly all-overland rate, which establishes one point on each demand curve.

1.5.3 Equilibrium Assumptions

- Shippers' decisions on waterway movements are determined by an economic equilibrium based on the cost of waterway transportation and a price-demand relationship (demand function) assigned to the movement.
- Shippers have complete knowledge of waterway transportation prices and incorporate the cost of scheduled lock closures into their shipping decision. Shippers do not estimate or consider expected costs for unplanned closures (i.e., they are not risk adverse).
- While the waterway routing rate includes fees for accessorial charges and charges for other modes of transportation from the ultimate origin to the ultimate destination (feeder legs), only congestion changes on the waterway leg are considered in the equilibrium process. All land transportation costs/rates are assumed constant through time.
- Individual shippers will not restrict waterway usage to the social optimal level, but will continue to expand waterway volumes to the level at which their average towing costs equal their marginal rate-savings (ATC = MRS). This occurs because each individual carrier pays only its own

average cost for moving on the waterway system, not the true marginal costs, which include the costs imposed on all shippers.

- Each movement is considered to be continuously divisible (i.e., tonnage values are not limited to discrete barge loads or full tow configurations).
- Shippers respond in the same way to a change in inventory carrying costs resulting from increased transit time as they do to increased transportation costs. A linear relationship exists between the cost of time (holding) and operating costs defined by the holding cost factor.
- Equilibrium in a year is independent of preceding year equilibrium (i.e., movements can change transportation mode each year). Note that scheduled and unscheduled service disruption is not independent from one year to the next and that equilibrium is a function of scheduled service disruption.
- Given the partial equilibrium model framework using only the barge transportation demand curves, unmet waterway demand traffic is only known not to move on the waterway; it is not automatically assumed to move by land routing.

1.5.4 Unscheduled Service Disruption Shipper Response Assumptions

- Except for unscheduled over capacity diversions and river closure response diversions, equilibrium traffic will be assumed to move on the waterway at a higher unscheduled service disruption lock transit time.
- Movement river closure diversion response percentage is assumed constant through time and among forecast scenarios. River closure response diverted traffic moves at a user specified diversion spot rate (not the long-run least-costly all-overland rate). Since the waterway consumer surplus already takes into account the long-run alternative land rate, only the incremental impacts are utilized in the model investment optimization and cost-benefit analysis.
- Unscheduled service disruption over capacity tonnage diversion is assumed to move at the long-run least-costly all-overland rate if at all (and not at the river closure response diversion rate). Since diversion spot rates were only generated for river closure diversion, and given that the waterway consumer surplus already takes into account the long-run alternative land rate, there are no assumed incremental impacts for unscheduled over capacity diversion in the model investment optimization and cost-benefit analysis. Similar to the long-run equilibrium solution (section 1.5.3), it is assumed that all that is really known is that the traffic does not move on water; it is not automatically assumed to move by land routing.

1.5.5 Reliability Assumptions

Lock chamber component reliability can be defined for any navigation project defined in the "*Locks*" table (section 1.4.1.1.5). For the Upper Ohio Navigation Study analysis, detailed engineering reliability data (PUPs and event-trees) were only entered for Emsworth, Dashields, and Montgomery. Detail on the engineering reliability data for these components at these locks can be found in APPENDIX B Engineering. Dated engineering reliability data exists for the other main stem Ohio navigation projects from the Ohio Mainstem Study System Investment Plan (May 2006)[35]; however, these data were not input or modeled. This simplifying assumption (i.e., full operation at all other ORS navigation projects) was made under the logic that these intermittent service disruptions elsewhere in the system would be the same under the WOPC and each WPC, and as a result would cancel in the incremental analysis between the WOPC and WPC.

Generalized reliability assumptions are:

- Survivability of all components should be assumed to the decision point (i.e., base year).

[35] The engineering reliability data for this study was done in the late 1990's.

- Components are assumed independent and fail independently of each other. Note however, that with event-tree state change option the user can lump components into a model-level component and thus model joint components.
- Components can only fail once in a year, however, multiple reliability closures from different components are allowed to occur in a year.
- When multiple reliability closures (from different components) occur in a given year, the closures are assumed to be spaced far enough apart for queues to dissipate before the next closure occurs.
- When multiple scheduled closures occur in a given year, the closures are assumed to be spaced far enough apart for queues to dissipate to normal levels before the next closure occurs.

1.5.6 Authorized ORS Improvements

The system that exists today (less the investment options analyzed) is not necessarily the system that will exist over the planning period. This future system should be modeled with and without the Upper Ohio investment alternatives. There are ORS infrastructure investments that have been authorized, and many already under construction, which are scheduled to be completed (come on-line) before or during the analysis period. This section describes those infrastructure changes and the modeling parameters assumed. To summarize, all currently authorized ORS projects are assumed complete and on-line for the entire Upper Ohio Navigation study analysis period. Descriptions of each of the authorized ORS improvements follow (from greatest to least Upper Ohio traffic commonality).

1.5.6.1 Lower Monongahela Locks and Dams

WRDA92 authorized a new twin 720'x 84' project (Charleroi) to replace L/D 3 (Elizabeth) and L/D 4 (Charleroi) on the Monongahela River. Construction began in 1995 with an upgrade to L/D 2 (Braddock). Currently only one chamber at L/D 4 is operational. According to the PY 2011 budget submission, the completion date is indeterminate given the current budget climate. Some Pittsburgh District sources estimate a project completion as early as 2016 (provided funding). The last phase of the project is removal of L/D 3 after dredging is completed. At completion of the project the transit time for L/D 3 is set to zero and L/D 4 is changed from a 720'x 56' with a 360'x 56' auxiliary to a twin 720'x 84' project.

For simplification in this analysis and given the uncertainty in a project completion date, in project is assumed complete in year 2012 (L/D 3 transit time is set to zero and L/D 4 is changed to a twin 720'x 84' facility). A significant amount of historic Upper Ohio traffic transits the three Lower Monongahela River projects; 69% transits Locks and Dam 2 diminishing to 32% at Locks and Dam 4. Given the high commonality of traffic and the potential for the Lower Monongahela to choke off Upper Ohio River traffic, a sensitivity test of the recommended NED plan without completion of the Lower Monongahela might be of interest.

1.5.6.2 Greenup Locks and Dam

Greenup Locks and Dam is authorized for an auxiliary chamber extension (110' x 600' to a 110' x 1200'). The current estimate is to have the chamber extension on-line by year 2015 (based on PY 2011 budget submission).

Historically 39% of the Upper Ohio traffic transits Greenup Locks and Dam. For simplification in this analysis, in year 2012 (instead of year 2015) the capacity of Greenup Locks and Dam is changed to a twin 110' x 1200' project. Since this investment is authorized and assumed in the WOPC and WPC's (i.e., all runs and investment plans), no federal costs or closures are modeled. As noted, however, a sensitivity test of the recommended NED plan will be performed with the project not completed (or any of the other scheduled ORS upgrades except for Chickamauga).

1.5.6.3 J. T. Myers Locks and Dam

J. T. Myers Locks and Dam is authorized for an auxiliary chamber extension (110’ x 600’ to a 110’ x 1200’). The current estimate is to have the chamber extension on-line by year 2018 (based on PY 2011 budget submission).

Historically only 19% of the Upper Ohio traffic transits Myers Locks and Dam. For simplification in this analysis, in year 2012 (instead of year 2018) the capacity of J. T. Myers Locks and Dam is changed to a twin 110’ x 1200’ project. Since this investment is authorized and assumed in the WOPC and WPC’s (i.e., all runs and investment plans), no federal costs or closures are modeled. As noted, however, a sensitivity test of the recommended NED plan will be performed with the project not completed (or any of the other scheduled ORS upgrades except for Chickamauga).

1.5.6.4 Olmsted Locks and Dam

Olmsted Locks and Dam (twin 1200’ x 600’ chambers) is authorized to replace Locks and Dams 52 and 53. Construction began in 1993, but completion is not expected until year 2016 (based on PY 2011 budget submission).

Historically only 16% of the Upper Ohio traffic transits the lower Ohio River (L/D 52 and 53). For simplification in this analysis, in year 2012 (instead of year 2016) L/D 52 is removed (i.e., transit time is set to zero) and L/D 53 is changed from a 1200’x 600’ with a 600’x 110’ auxiliary to a twin 1200’x 110’ chamber facility (i.e., Olmsted). Since this investment is authorized and assumed in the WOPC and WPC’s (i.e., all runs and investment plans), no federal costs or closures are modeled. As noted, however, a sensitivity test of the recommended NED plan will be performed with the project not completed (or any of the other scheduled ORS upgrades except for Chickamauga).

1.5.6.5 Markland Locks and Dam

Markland Locks and Dam is currently undergoing a rehabilitation (replacement of the main chamber gates and valves). The current estimate is to complete this work in year 2011 (based on PY 2011 budget submission). Since this investment is authorized and assumed in the WOPC and WPC’s (i.e., all runs and investment plans), and outside the planning period, no federal costs or closures are modeled. As noted, however, a sensitivity test of the recommended NED plan will be performed with the project not completed (or any of the other scheduled ORS upgrades except for Chickamauga).

1.5.6.6 Kentucky Lock and Dam

Kentucky Lock and Dam is a single lock facility (single 600’ x 110’) and a second chamber measuring 1200’x 110’ was authorized in WRDA96. Construction began in 1998 with an original completion expected in 2007. The current estimate is to have the new lock online in year 2016 (based on PY 2011 budget submission).

Historically only 3% of the Upper Ohio traffic transits Kentucky Lock and Dam (and none transits through Barkley Lock and Dam). The construction at Kentucky Lock has insignificant direct impact on Upper Ohio traffic. For simplification in this analysis, in year 2012 (instead of year 2016) the capacity of Kentucky Lock is changed to a 1200’x 110’ with a 600’x 110’ auxiliary project. Since this investment is authorized and assumed in the WOPC and WPC’s (i.e., all runs and investment plans), no federal costs or closures are modeled. As noted, however, a sensitivity test of the recommended NED plan will be performed with the project not completed (or any of the other scheduled ORS upgrades except for Chickamauga).

1.5.6.7 Chickamauga Lock and Dam

The existing 360’x 60’ is authorized for replacement with a single 600’x 110’ chamber. Original completion was scheduled for year 2010. The current estimate is to have the new lock online in year 2014 (based on PY 2011 budget submission).

Historically none of the Upper Ohio traffic transits Chickamauga Lock and Dam. The construction at Chickamauga Lock has no direct impact on Upper Ohio traffic. For simplification in this analysis, in year 2012 (instead of year 2014) the capacity of Chickamauga Lock is changed to a 600’x 110’ project. Since this investment is authorized and assumed in the WOPC and WPC's (i.e., all runs and investment plans), no federal costs or closures are modeled.

1.6 Model Analysis Reports

Analysis output EXCEL workbooks are produced through execution of available reports (see section ----).

1.6.1 Module Analysis Outputs

Currently in the report menu there are two LRM analysis output reports (TABLE 1.6.1).

1.6.1.1 Lock Risk Module Analysis Reports

Currently in the report menu there are two LRM analysis output reports (TABLE 1.6.1).

TABLE 1.6.1 – LRM Reports

reportID	reportClass	reportName
7	LRM	Component Reliability
9	LRM	Component Reliability for Lock

1.6.1.2 Waterway Supply and Demand Module Analysis Reports

Currently in the report menu there are six WSDM analysis output reports (TABLE 1.6.2).

TABLE 1.6.2 – WSDM Reports

reportID	reportClass	reportName
1	WSDM	Revenue Generated
2	WSDM	Comparison of Revenue
4	WSDM	Comparison of WSDM Runs
5	WSDM	River Location Summary
6	WSDM	Multi-Year WSDM Comparison
8	WSDM	Calibration Comparison

1.6.1.3 Optimization Module Analysis Reports

Currently in the report menu there are three Optimization module analysis output reports (TABLE 1.6.3). These reports are the RUN ("*runID*") reports.

TABLE 1.6.3 – Optimization Module Reports

reportID	reportClass	reportName
10	Optim	Component Replacement Comparison
12	Optim	Run Summary
16	Optim	Component Replacements by Forecast

1.6.1 Investment Plan Analysis Reports

Currently in the report menu there are four IP analysis reports (TABLE 1.6.4). The system statistics workbook displays yearly results for the defined system (i.e., report group), while the lock detail workbook displays yearly statistics by lock.

TABLE 1.6.4 – Investment Plan Reports

reportID	reportClass	reportName
11	IP	Investment Plan Summary
13	IP	Investment Plan Lock Cost Detail
14	IP	Investment Plan System Statistics
15	IP	Investment Plan Cost Benefit Comparison

1.6.1.1 IP System Summary Workbook

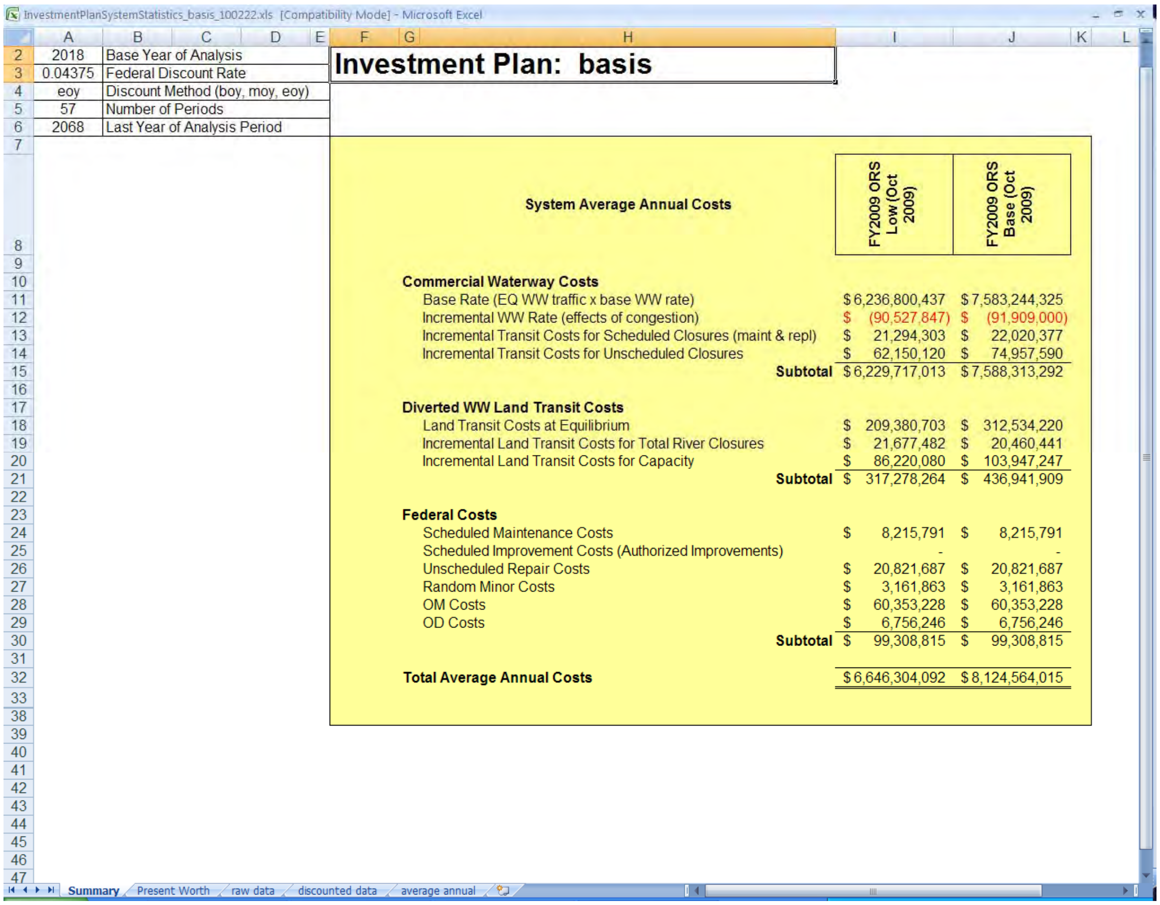
The IP Summary workbook (FIGURE 1.6.1) contains …

FIGURE 1.6.1 – IP System Summary Workbook

1.6.1.2 IP System Statistics Workbook

The IP Systems Statistics workbook (FIGURE 1.6.2) contains a "Summary" sheet with four backup tabs. The "*Present Worth*" sheet contains the yearly discounting factors for the specified discount rate, discount method, planning period, and base year. The "*raw data*" sheet contains the yearly cash flows for the various categories by forecasted demand scenario and by: 1) "*no prob no scheduled*"; 2) "*no prob with scheduled*"; 3) "*prob no scheduled*"; and 4) "*prob with scheduled*". The "*discounted data*" sheet is identical to the "*raw data*" tab except all the cash numbers have been converted to present worth using the factors in the "*Present Worth*" tab. The "*average annual*" sheet then performs the amortization of the total present worth values from the "*Present Worth*" tab.

FIGURE 1.6.2 – IP System Statistics Workbook



2018	Base Year of Analysis
0.04375	Federal Discount Rate
eoy	Discount Method (boy, moy, eoy)
57	Number of Periods
2068	Last Year of Analysis Period

Investment Plan: basis

System Average Annual Costs	FY2009 ORS Low (Oct 2009)	FY2009 ORS Base (Oct 2009)
Commercial Waterway Costs		
Base Rate (EQ WW traffic x base WW rate)	$ 6,236,800,437	$ 7,583,244,325
Incremental WW Rate (effects of congestion)	$ (90,527,847)	$ (91,909,000)
Incremental Transit Costs for Scheduled Closures (maint & repl)	$ 21,294,303	$ 22,020,377
Incremental Transit Costs for Unscheduled Closures	$ 62,150,120	$ 74,957,590
Subtotal	$ 6,229,717,013	$ 7,588,313,292
Diverted WW Land Transit Costs		
Land Transit Costs at Equilibrium	$ 209,380,703	$ 312,534,220
Incremental Land Transit Costs for Total River Closures	$ 21,677,482	$ 20,460,441
Incremental Land Transit Costs for Capacity	$ 86,220,080	$ 103,947,247
Subtotal	$ 317,278,264	$ 436,941,909
Federal Costs		
Scheduled Maintenance Costs	$ 8,215,791	$ 8,215,791
Scheduled Improvement Costs (Authorized Improvements)	-	-
Unscheduled Repair Costs	$ 20,821,687	$ 20,821,687
Random Minor Costs	$ 3,161,863	$ 3,161,863
OM Costs	$ 60,353,228	$ 60,353,228
OD Costs	$ 6,756,246	$ 6,756,246
Subtotal	$ 99,308,815	$ 99,308,815
Total Average Annual Costs	$ 6,646,304,092	$ 8,124,564,015

As can be noted in FIGURE 1.6.2, the results for the multiple forecast demand scenarios are displayed by column. Note also that an IP Systems Statistics workbook can be produced for each defined report group or "*reportGroupID*" (see section 1.4.7.3). In the "*raw data*" sheet the cash flow categories are shown in TABLE 1.6.5.

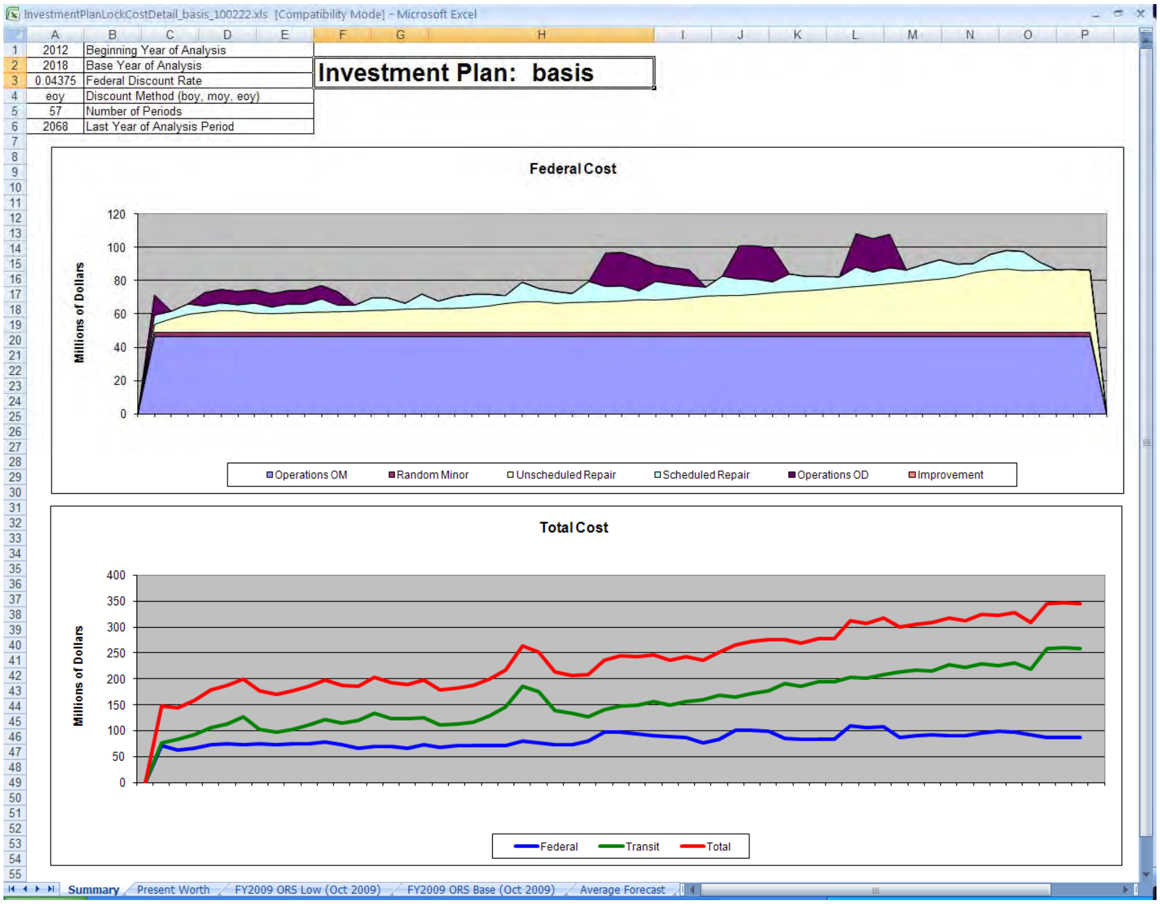
TABLE 1.6.5 – Categories in the IP System Statistics Workbook

System Cash Flows (in dollars) for the Report Group	Other Statistics for the Report Group
WW transportation surplus	Tonnage (in millions of tons)
Land Transportation Equilibrium Cost	Transit days (in days)
Land Transportation Closure Diversion Cost	Tonnage Diverted for Closure (in millions of tons)
Land Transportation Capacity Diversion Cost	Tonnage Diverted for Capacity (in millions of tons)
Water Transportation Base Cost	
Water Transportation Equilibrium cost	
Transit Cost	
Improvement Cost	
Scheduled Repair Cost	
Unscheduled Repair Cost	
Random Minor Cost	
Normal O&M Cost	
Normal O&D Cost	
Externality Cost for UTTRC Truck Delay Dollars	
Externality Cost for UTTRC Truck Accidents Dollars	
Externality Cost for UTTRC Truck Emissions Dollars	
Externality Cost for TVA Non Delay Truck-Accident & Emissions Dollars	
Externality Cost for TVA Rail & Barge emissions Dollars	

1.6.1.3 IP Lock Detail Workbook

The IP Lock Detail workbook (FIGURE 1.6.3) contains

FIGURE 1.6.3 – IP Lock Detail Workbook



1.6.1.4 IP Incremental Cost-Benefit Workbook

The IP Incremental Cost-Benefit workbook contains eight sheets which will incrementally compare a user defined WOPC (aka basis) against any number of user specified WPC's for any number of user specified forecast scenarios. The layout in the "*Summary*" sheet is shown in FIGURE 1.6.4 with major sections labeled. This was the first summary laid out, a more report friendly formulation layout occurs in the "*rpt*" sheet shown in FIGURE 1.6.5.

FIGURE 1.6.4 – IP Incremental Cost-Benefit Workbook Summary Sheet

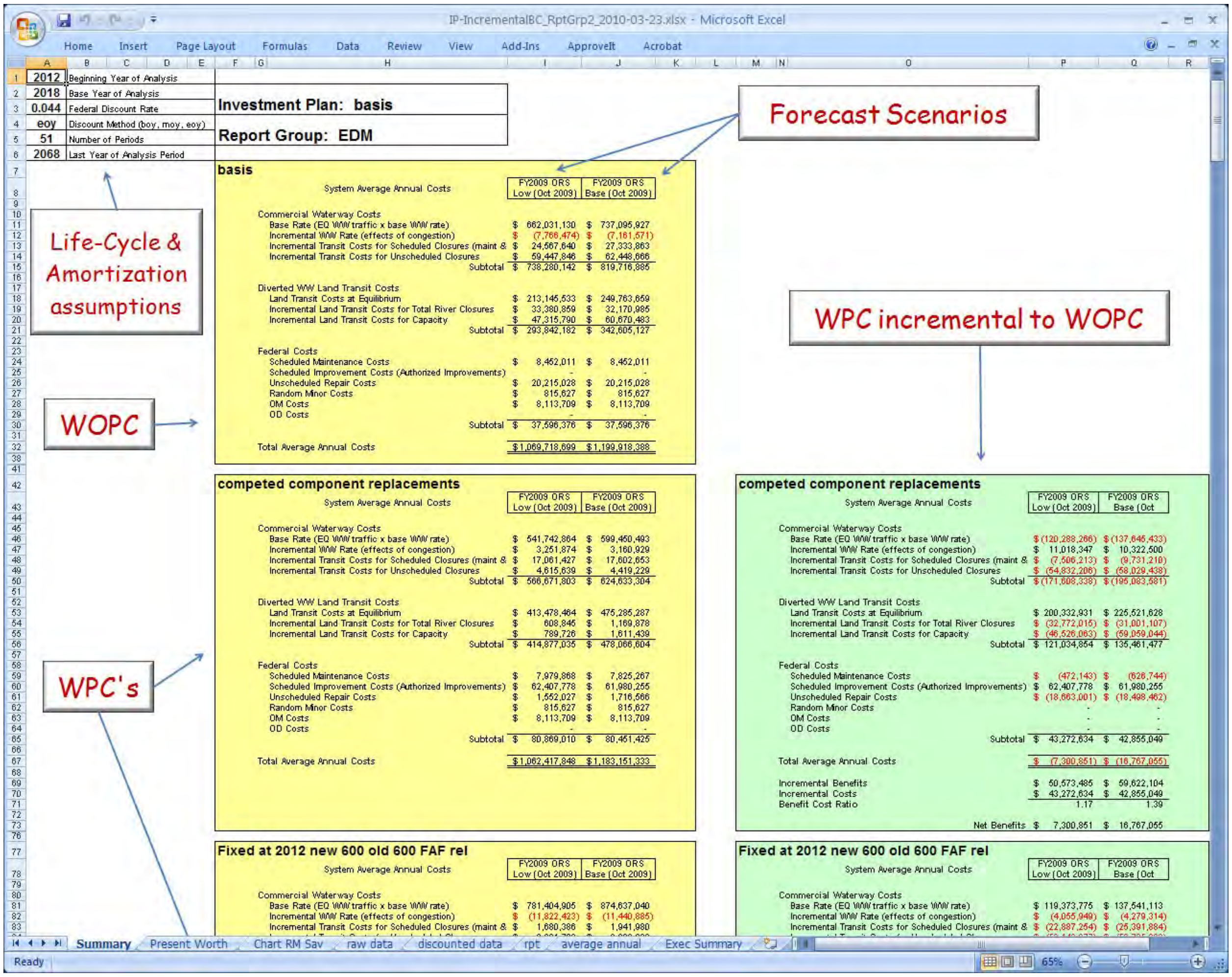


FIGURE 1.6.5 – IP Incremental Cost-Benefit Workbook rpt Sheet

Benefits	Reactive Maintenance			Advanced Maintenance			New 600' and FAF			New 800' and FAF			New 1200' and FA	
	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base
Transportation Savings	$405.9	$455.1	$0.0	$336.8	$375.0	$0.0	$425.8	$478.2	$0.0	$425.8	$478.3	$0.0	$425.8	$478.2
Reduced Surplus from Unsch Closures	($59.4)	($62.4)	$0.0	($4.6)	($4.4)	$0.0	($6.6)	($7.2)	$0.0	($7.1)	($7.4)	$0.0	($8.6)	($8.8)
Land trans costs Incurred from Unsch diversions	($80.7)	($92.8)	$0.0	($1.4)	($2.8)	$0.0	($31.6)	($33.9)	$0.0	($36.0)	($38.8)	$0.0	($44.7)	($48.6)
Externality Costs Incurred	($1.7)	($1.4)	$0.0	($0.0)	($0.0)	$0.0	($0.8)	($0.9)	$0.0	($0.9)	($1.1)	$0.0	($1.2)	($1.3)
Total System Benefits	$264.1	$298.4	$0.0	$330.8	$367.7	$0.0	$386.7	$436.3	$0.0	$381.8	$431.0	$0.0	$371.3	$419.4
Incremental Benefits														
Transportation Savings	na	na	na	($69.2)	($80.1)	na	$19.8	$23.1	na	$19.9	$23.2	na	$19.8	$23.1
Reduced Surplus from Unsch Closures	na	na	na	$54.8	$58.0	na	$52.8	$55.3	na	$52.3	$55.1	na	$50.9	$53.6
Land trans costs Incurred from Unsch diversions	na	na	na	$79.3	$90.1	na	$49.1	$59.0	na	$44.7	$54.0	na	$36.0	$44.2
Externality Costs Incurred	na	na	na	$1.7	$1.4	na	$0.9	$0.5	na	$0.7	$0.4	na	$0.5	$0.1
Total Incremental Benefits	na	na	na	$66.6	$69.3	na	$122.6	$137.9	na	$117.7	$132.6	na	$107.2	$121.0

Costs	Reactive Maintenance			Advanced Maintenance			New 600' and FAF			New 800' and FAF			New 1200' and FA	
	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base
Improvement Cost	$0.0	$0.0	$0.0	$62.4	$62.0	$0.0	$75.9	$75.9	$0.0	$87.7	$87.7	$0.0	$104.3	$104.3
Scheduled Repair Cost	$8.5	$8.5	$0.0	$8.0	$7.8	$0.0	$4.7	$4.7	$0.0	$4.5	$4.5	$0.0	$4.1	$4.1
Unscheduled Repair Cost	$20.2	$20.2	$0.0	$1.6	$1.7	$0.0	$18.1	$18.1	$0.0	$18.0	$18.0	$0.0	$18.0	$18.0
Random Minor Cost	$0.8	$0.8	$0.0	$0.8	$0.8	$0.0	$0.6	$0.6	$0.0	$0.6	$0.6	$0.0	$0.6	$0.6
Normal O&M Cost	$8.1	$8.1	$0.0	$8.1	$8.1	$0.0	$8.1	$8.1	$0.0	$8.1	$8.1	$0.0	$8.1	$8.1
Total System Costs	$37.6	$37.6	$0.0	$80.9	$80.5	$0.0	$107.4	$107.4	$0.0	$119.0	$119.0	$0.0	$135.2	$135.2
Incremental Costs														
Improvement Cost	na	na	na	$62.4	$62.0	na	$75.9	$75.9	na	$87.7	$87.7	na	$104.3	$104.3
Scheduled Repair Cost	na	na	na	($0.5)	($0.6)	na	($3.7)	($3.7)	na	($4.0)	($4.0)	na	($4.3)	($4.3)
Unscheduled Repair Cost	na	na	na	($18.7)	($18.5)	na	($2.2)	($2.2)	na	($2.2)	($2.2)	na	($2.2)	($2.2)
Random Minor Cost	na	na	na	$0.0	$0.0	na	($0.2)	($0.2)	na	($0.2)	($0.2)	na	($0.2)	($0.2)
Normal O&M Cost	na	na	na	$0.0	$0.0	na	$0.0	$0.0	na	$0.0	$0.0	na	$0.0	$0.0
	na	na	na	$43.3	$42.9	na	$69.8	$69.8	na	$81.4	$81.4	na	$97.6	$97.6

Net Benefits	Reactive Maintenance			Advanced Maintenance			New 600' and FAF			New 800' and FAF			New 1200' and FA	
	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base	High	Low	Base
Total Net Benefits	$226.5	$260.8	na	$249.9	$287.3	na	$279.4	$328.9	na	$262.8	$312.0	na	$236.1	$284.2
Total BCR	**7.0**	**7.9**	na	**4.1**	**4.6**	na	**3.6**	**4.1**	na	**3.2**	**3.6**	na	**2.7**	**3.1**
Incrementals														
Incremental Net Benefits	na	na	na	$23.4	$26.5	na	$52.8	$68.1	na	$36.3	$51.3	na	$9.6	$23.4
Incremental BCR	na	na	na	**1.5**	**1.6**	na	**1.8**	**2.0**	na	**1.4**	**1.6**	na	**1.1**	**1.2**

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 1
Ohio River Navigation Investment Model (ORNIM) Version 5.1

Rate and River Closure Response Input
Addendum A

February 2011

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1A.1 INTRODUCTION

The Ohio River Navigation Investment Model (ORNIM) Waterway Supply and Demand Module (WSDM) estimates equilibrium system traffic levels from a bottom-up movement level analysis given movement-level waterway demands and their corresponding willingness-to-pay for barge transportation. The model allows two basic methods for specification of the movement level willingness-to-pay, and as a result, two basic methods for the determination of system equilibrium through the use of either an: 1) elastic; or 2) inelastic movement level demand. In fact ORNIM is capable of equilibrating the system consisting of a mix of elastic and inelastic movements. Transportation rate data only needed when an inelastic movement-level demand is defined.

Transportation rate data is derived for a sample of existing waterway flows, rate estimating equations are developed, and then rates for the un-sampled movement flows are estimated. The focus of this attachment is on the application of the rate equations to the un-samples population and on the aggregation of the rate data to the model movement.

1A.2 HISTORIC AND FORECASTED MOVEMENT DATA

Historic 1990 through 2007 Ohio River System (ORS) Waterborne Commerce Statistical Center (WCSC) data is stored for by the Navigation Planning Center (LRH-NC) at an annual, location-dock to location-dock, 5-digit WCSC commodity code, vessel type, barge length-width, and routing (i.e. Kentucky Lock, Barkley Lock and / or Tennessee-Tombigbee). From this base historic database forecasted demands are developed and added. Next, base rates, base least-cost all-overland rates, and river closure responses are attached. In this documentation, these databases will be referred to as the "*dock-level*" databases. From this "*dock-level*" historic and forecasted demand database, the ORNIM modeling movements are aggregated and loaded into the model. Maintaining this "*dock-level*" data at such an un-aggregated level, allows flexibility in aggregating the data to any network granularity level.

1A.3 RATES

The transportation rate data used in the Upper Ohio analysis come from a Tennessee Valley Authority Water Management Support analysis titled "*Transportation Rate Analysis: Ohio River System National Economic Development*" dated July 2008. A sample of 1,552 movements from the 2004 ORS WCSC movement database (aggregated to annul, location-dock to location-dock, and 5-digit WCSC commodity group) were rated given their water routing and at a least-costly all-overland routing.

Because many of the sample movements have off-river origins and / or destinations, a full accounting of all transportation costs for waterborne movements also requires the calculation of railroad and / or motor carrier rates for movement to / from the nearest appropriate port facility. Additionally, all calculations reflect the loading and unloading costs at origin and destination, all transfer costs to or from barge, and any probable storage costs. Reported rates for both the existing water movement routing and the least-cost all-overland alternative routing are based on the actual identified location of shipment ultimate origins and destinations.

1A.3.1 Application of the Rated Sample

Sampled rates are applied directly to matching location-dock and 5-digit WCSC commodity code records in the database file. When matched, the rate sample reference number was also attached to the record, else the data field was left blank. As shown in TABLE 1A.3.1, 85.8% of the system tonnage in 2004 is covered in the sample. Also shown are the sample tonnage and rate-savings per ton statistics from the TVA report which vary slightly from the statistics pulled from the newer less aggregated database. So discrepancy occurs because of 5-digit WCSC commodity code grouping aggregation, but most occurs from differenced in the sample tonnages (i.e. the model database shows 269.9 million tons for the movements compared to only 231.4 million tons in the TVA file).

TABLE 1A.3.1 – Sample Rate Summary Statistics

Database								TVA Rate File	
Record Count	Rated Count	Commodity	Total 2004 Tons	Sample Tonnage	Tonnage Percent	Rate-Savings (FY2008 price level) Total	Rate-Savings (FY2008 price level) Per Ton	Tonnage	Rate-Savings Per Ton
19,553	1,431	Coal	145,256,328	140,285,886	96.6%	$ 1,159,527,353	$ 8.27	140,238,442	$ 8.16
24,518	1,399	Petroleum	16,977,193	11,930,355	70.3%	$ 335,453,781	$ 28.12	11,855,739	$ 28.75
327	9	CrudePetro	42,671	27,388	64.2%	$ 376,843	$ 13.76	27,388	na
16,780	867	Aggregates	48,032,516	42,425,866	88.3%	$ 481,992,208	$ 11.36	42,025,987	$ 11.25
18,443	381	Grains	16,556,509	8,502,588	51.4%	$ 129,388,552	$ 15.22	8,524,689	$ 15.08
18,594	638	Chemicals	11,499,905	6,134,453	53.3%	$ 316,682,833	$ 51.62	5,909,635	$ 50.32
5,622	149	Ores & Min	7,406,300	5,584,144	75.4%	$ 168,789,229	$ 30.23	5,476,531	$ 30.03
16,414	274	Iron/Steel	15,288,459	10,087,191	66.0%	$ 345,195,050	$ 34.22	10,194,089	$ 33.77
8,681	224	Others	8,883,522	6,669,011	75.1%	$ 171,065,584	$ 25.65	7,169,240	$ 26.12
128,932	5,372		269,943,403	231,646,882	85.8%	$ 3,108,471,433	$ 13.42	231,421,740	$ 13.32

In the sample, 5.1% of year 2004 tonnage was rated as movements with a negative rate-saving (i.e. the existing water routing rate was greater than the least-cost all-overland rate) as shown in TABLE 1A.3.2. Additional detail on the negative rate-savings sampled can be found documented in ATTACHMENT 4 Transportation Rate Analysis.

TABLE 1A.3.2 – Negative Base Rate-Saver Statistics

	Sample Movement Rate-Savings (FY2008 price level)							
	Sampled Movements with Positive Rate-Savings			Sampled Movements with Negative Rate-Savings			All Sampled Movements	
Commodity	Tonnage	Total Savings	Per Ton	Tonnage	Total Savings	Per Ton	Total Savings	Per Ton
Coal	128,900,806	$ 1,174,386,571	$ 9.11	11,385,080	$ (14,859,218)	$ (1.31)	$ 1,159,527,353	$ 8.27
Petroleum	11,881,735	$ 347,825,361	$ 29.27	48,620	$ (12,371,580)	$ (254.45)	$ 335,453,781	$ 28.12
Crude Petro	26,922	$ 401,676	$ 14.92	466	$ (24,833)	$ (53.29)	$ 376,843	$ 13.76
Aggregates	42,114,561	$ 483,027,630	$ 11.47	311,305	$ (1,035,422)	$ (3.33)	$ 481,992,208	$ 11.36
Grains	8,502,588	$ 129,388,552	$ 15.22		$ -	$ -	$ 129,388,552	$ 15.22
Chemicals	6,130,173	$ 318,793,122	$ 52.00	4,280	$ (2,110,289)	$ (493.06)	$ 316,682,833	$ 51.62
Ores & Min	5,583,556	$ 168,802,487	$ 30.23	588	$ (13,258)	$ (22.55)	$ 168,789,229	$ 30.23
Iron / Steel	9,985,646	$ 345,477,914	$ 34.60	101,545	$ (282,864)	$ (2.79)	$ 345,195,050	$ 34.22
Others	6,665,573	$ 171,305,538	$ 25.70	3,438	$ (239,954)	$ (69.79)	$ 171,065,584	$ 25.65
	219,791,560	$ 3,139,408,851	$ 14.28	11,855,322	$ (30,937,419)	$ (2.61)	$ 3,108,471,433	$ 13.42

1A.3.2 Rate Estimation of the Un-Sampled Movements

For the non-sampled flows, rating equations (1) and (2) below are applied. TABLE 1A.3.1 displays the rating equation parameters used for each commodity group. Additional detail on the sampled rates and the development of the rating equations is documented in ATTACHMENT 4 Transportation Rate Analysis.

$$\text{Water Routed Rate per} = \left(\frac{(\text{Ton-Miles} \times \text{Mi.}\alpha) + \text{Mi.}\beta}{\text{Tonnage}} \right) + \text{WW assessorials} + \text{WW legs} \qquad (1.3\text{-}1)$$

$$\text{Land Routed Rate per} = \left(\frac{(\text{Ton-Miles} \times \text{Alt.}\alpha) + \text{Alt.}\beta}{\text{Tonnage}} \right) + \text{Alt. assessorials} + \text{Alt. legs} \qquad (1.3\text{-}2)$$

TABLE 1A.3.3 – Rate Equation Parameters

	Commodity Group							
	1	2 / 3	4	5	6	7	8	9
Parameter	Coal	Petroleum & Crude Petro	Aggregates	Grains	Chemicals	Ores & Min	Iron / Steel	Others
Mi Alpha	0.695000	0.689500	0.742800	0.649600	0.770300	0.730200	0.682500	0.525900
Mi Beta	73.557	22.757	11.991	197.13	40.084	-14.369	-30.697	50.877
WW ass	$3.67	$2.30	$2.36	$5.82	$2.06	$5.10	$6.72	$3.73
WW leg	$7.42	$0.06	$0.13	$9.15	$0.53	$0.43	$0.81	$0.45
WW Alpha	0.018300	0.015200	0.015200	0.012100	0.025500	0.016100	0.012800	0.019800
WW Beta	172,176	445,321	134,320	255	125,979	-	80,826	144,964
Alt ass	$2.85	$4.72	$2.53	$5.97	$4.71	$5.31	$6.16	$4.15
Alt leg	$2.48	$0.33	$1.11	$7.10	$0.00	$0.00	$0.09	$0.00
Alt Alpha	0.025866	0.069500	0.052500	0.035700	0.076500	0.058000	0.053100	0.063500
Alt Beta	2,349,200	954,709	550,074	-	525,238	-	359,926	1,297,356

1A.3.2.1 Movement Calculation Tonnage

In applying the rate equations to the un-sampled movements, it needs to be realized that not all movements in the database have tonnage in the year 2004. Since the tonnage amount is a critical component of the rate estimating equation, the question then becomes what tonnage amount to use in the equation if tonnage does not exist in the year 2004. If a 2004 tonnage exists for a movement in the database, this 2004 tonnage serves as the "*calculation tonnage*". For movements that have no tonnage in year 2004, the following process was utilized to estimate the movement calculation tonnage.

First, tonnages for 2005-2007 are checked and the tonnage amount not equal to zero closest in time to year 2004 is selected (e.g. if there is zero tons in 2005 and tonnage in 2006 and 2007, the tonnage for 2006 is assumed). If there is no tonnages in years 2004-2007, tonnages for 2003 back to 1990 are checked and the first year with tonnage greater than zero is assumed. If there is no tonnage for the movement for 1990-2007, the movement is obviously a new forecasted or induced movement. The forecast tonnages are then checked from 2010 through 2070 and the first year tonnage is greater than zero is assumed.

1A.3.2.2 Rate Equation Calculation Tonnage

Initially the un-sampled movement rates (and rating equations) were calculated using either the 2004 movement tonnage level in the base database or the movement calculation tonnage as described in the section above. This however proved problematic since the "*dock-level*" database is largely un-aggregated (i.e. 5-digit WCSC commodity code, vessel type, length, and width, and routing), and as a result for any particular movement in the database the 2004 tonnage levels can be quite small; down to a single barge load. To counter this effect, a "*rate equation calculation tonnage*" was developed by aggregating tonnage to a location-dock and 5-digit WCSC commodity code level, and then using this tonnage for all movements in the database having the same location-dock to location-dock and 5-digit commodity code. In short, this eliminated the vessel type, barge dimension, and routing split from the movement. Despite this aggregation of the calculation tonnage, this too proved problematic from small tonnages entering into the rate equations. As shown in TABLE 1A.3.4 the rating equations still resulted in huge rate-savings for the un-sampled movements (e.g. sampled coal movements average a rate-savings of $8.27 per ton, while the calculated non-sampled coal average rate-savings is $303.00 per ton). This occurs because the rating equations produce high rates for low tonnage movements, especially for the least-costly all-overland rate (FIGURE 1A.3.1), resulting in huge rate-savings per ton.

Next, instead of a rate equation calculation tonnage from an aggregated location-dock and 5-digit WCSC commodity code level, a larger Port Equivalent (PE) and 1-digit 1-9 commodity code tonnage was used, resulting in the rates shown in TABLE 1A.3.5. Although much better, the rating equations still resulted in huge rate-savings for the un-sampled movements (e.g. sampled coal movements average a rate-savings of $8.27 per ton, while the calculated non-sampled coal average rate-savings is $130.25 per ton, down from $303.00 per ton).

TABLE 1A.3.4 – Equation Results Using Location-Dock & 5-Digit Commodity Code Tonnage

						Rate-Savings (FY2008 price level)					
						Sampled Movements		Calculated Rates *		All Movements	
Record Count	Rated Count	Commodity	Total 2004 Tons	Sample Tonnage	Tonnage Percent	Total	Per Ton	Total	Per Ton	Total	Per Ton
19,553	1,431	Coal	145,256,328	140,285,886	96.6%	$ 1,159,527,353	$ 8.27	$ 1,506,019,263	$ 303.00	$ 2,665,546,616	$ 18.35
24,518	1,399	Petroleum	16,977,193	11,930,355	70.3%	$ 335,453,781	$ 28.12	$ 588,451,001	$ 116.60	$ 923,904,782	$ 54.42
327	9	Crude Petro	42,671	27,388	64.2%	$ 376,843	$ 13.76	$ 3,036,084	$ 198.66	$ 3,412,927	$ 79.98
16,780	867	Aggregates	48,032,516	42,425,866	88.3%	$ 481,992,208	$ 11.36	$ 445,169,073	$ 79.40	$ 927,161,280	$ 19.30
18,443	381	Grains	16,556,509	8,502,588	51.4%	$ 129,388,552	$ 15.22	$ 123,982,105	$ 15.39	$ 253,370,657	$ 15.30
18,594	638	Chemicals	11,499,905	6,134,453	53.3%	$ 316,682,833	$ 51.62	$ 733,645,165	$ 136.74	$ 1,050,327,997	$ 91.33
5,622	149	Ores & Min	7,406,300	5,584,144	75.4%	$ 168,789,229	$ 30.23	$ 65,098,140	$ 35.73	$ 233,887,369	$ 31.58
16,414	274	Iron / Steel	15,288,459	10,087,191	66.0%	$ 345,195,050	$ 34.22	$ 482,903,246	$ 92.84	$ 828,098,295	$ 54.16
8,681	224	Others	8,883,522	6,669,011	75.1%	$ 171,065,584	$ 25.65	$ 624,746,363	$ 282.11	$ 795,811,947	$ 89.58
128,932	5,372		269,943,403	231,646,882	85.8%	$ 3,108,471,433	$ 13.42	$ 4,573,050,440	$ 119.41	$ 7,681,521,870	$ 28.46

** Statistics calculated using actual 2004 movement tonnage (and not using the "calculation tonnage").*

FIGURE 1A.3.1 – Coal Per Ton Rates and Rate-Savings by Tonnage and Mileage

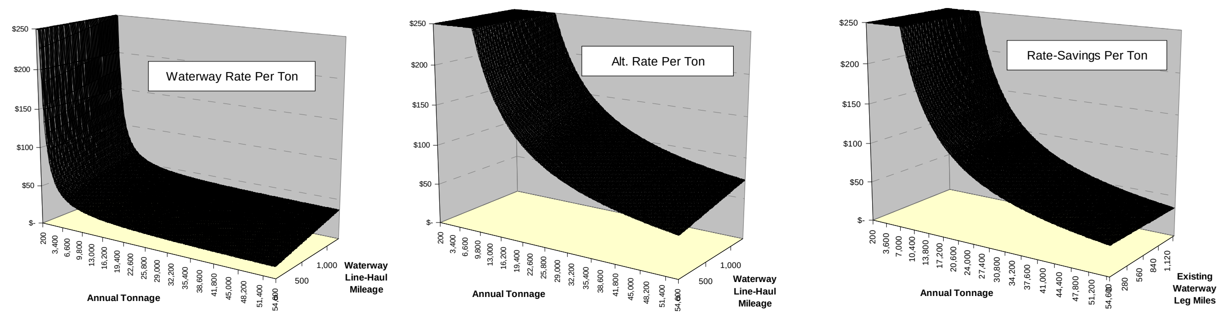


TABLE 1A.3.5 – Equation Results Using PE & 1-Digit Commodity Code Tonnage

						Rate-Savings (FY2008 price level)					
						Sampled Movements		Calculated Rates *		All Movements	
Record Count	Rated Count	Commodity	Total 2004 Tons	Sample Tonnage	Tonnage Percent	Total	Per Ton	Total	Per Ton	Total	Per Ton
19,553	1,431	Coal	145,256,328	140,285,886	96.6%	$ 1,159,527,353	$ 8.27	$ 647,377,395	$ 130.25	$ 1,806,904,748	$ 12.44
24,518	1,399	Petroleum	16,977,193	11,930,355	70.3%	$ 335,453,781	$ 28.12	$ 336,474,235	$ 66.67	$ 671,928,016	$ 39.58
327	9	Crude Petro	42,671	27,388	64.2%	$ 376,843	$ 13.76	$ 2,302,667	$ 150.67	$ 2,679,511	$ 62.79
16,780	867	Aggregates	48,032,516	42,425,866	88.3%	$ 481,992,208	$ 11.36	$ 193,540,292	$ 34.52	$ 675,532,499	$ 14.06
18,443	381	Grains	16,556,509	8,502,588	51.4%	$ 129,388,552	$ 15.22	$ 124,102,711	$ 15.41	$ 253,491,263	$ 15.31
18,594	638	Chemicals	11,499,905	6,134,453	53.3%	$ 316,682,833	$ 51.62	$ 421,324,848	$ 78.53	$ 738,007,681	$ 64.18
5,622	149	Ores & Min	7,406,300	5,584,144	75.4%	$ 168,789,229	$ 30.23	$ 65,057,494	$ 35.70	$ 233,846,723	$ 31.57
16,414	274	Iron / Steel	15,288,459	10,087,191	66.0%	$ 345,195,050	$ 34.22	$ 255,482,372	$ 49.12	$ 600,677,422	$ 39.29
8,681	224	Others	8,883,522	6,669,011	75.1%	$ 171,065,584	$ 25.65	$ 326,009,385	$ 147.22	$ 497,074,969	$ 55.95
128,932	5,372		269,943,403	231,646,882	85.8%	$ 3,108,471,433	$ 13.42	$ 2,371,671,399	$ 61.93	$ 5,480,142,832	$ 20.30

** Statistics calculated using actual 2004 movement tonnage (and not using the "calculation tonnage").*

Even with the use of PE and 1-digit commodity grouping level calculation tonnage, there were still small tonnage movements causing the calculation rates to result in huge rate-savings. In the final attempt to apply the rate equations to the un-sampled movements, if the PE and 1-digit 1-9 commodity code calculation tonnage was less than the sample average tonnage, the sample average tonnage was then used. For example, for coal the sample covered 140,238,442 tons which were applied to 1,411 records in the 1990-2007 database, or an average of 99,389 tons per movement. If a rated coal movement PE-PE-C calculation tonnage was less than 99,389 tons, then 99,389 tons was used as the calculation tonnage in the rating equation. This method results in the rates shown in TABLE 1A.3.6.

TABLE 1A.3.6 – Equation Results Using PE & 1-Digit Commodity Code with Tonnage Floor

Record Count	Rated Count	Commodity	Total 2004 Tons	Sample Tonnage	Tonnage Percent	Rate-Savings (FY2008 price level): Sampled Movements Total	Sampled Movements Per Ton	Calculated Rates * Total	Calculated Rates * Per Ton	All Movements Total	All Movements Per Ton
19,553	1,431	Coal	145,256,328	140,285,886	96.6%	$ 1,159,527,353	$ 8.27	$ 61,767,668	$ 12.43	$ 1,221,295,021	$ 8.41
24,518	1,399	Petroleum	16,977,193	11,930,355	70.3%	$ 335,453,781	$ 28.12	$ 290,677,093	$ 57.60	$ 626,130,874	$ 36.88
327	9	Crude Petro	42,671	27,388	64.2%	$ 376,843	$ 13.76	$ 2,020,855	$ 132.23	$ 2,397,698	$ 56.19
16,780	867	Aggregates	48,032,516	42,425,866	88.3%	$ 481,992,208	$ 11.36	$ 106,321,012	$ 18.96	$ 588,313,219	$ 12.25
18,443	381	Grains	16,556,509	8,502,588	51.4%	$ 129,388,552	$ 15.22	$ 124,154,701	$ 15.42	$ 253,543,253	$ 15.31
18,594	638	Chemicals	11,499,905	6,134,453	53.3%	$ 316,682,833	$ 51.62	$ 338,251,905	$ 63.04	$ 654,934,738	$ 56.95
5,622	149	Ores & Min	7,406,300	5,584,144	75.4%	$ 168,789,229	$ 30.23	$ 65,057,494	$ 35.70	$ 233,846,723	$ 31.57
16,414	274	Iron / Steel	15,288,459	10,087,191	66.0%	$ 345,195,050	$ 34.22	$ 158,261,275	$ 30.43	$ 503,456,325	$ 32.93
8,681	224	Others	8,883,522	6,669,011	75.1%	$ 171,065,584	$ 25.65	$ 104,638,452	$ 47.25	$ 275,704,036	$ 31.04
128,932	5,372		269,943,403	231,646,882	85.8%	$ 3,108,471,433	$ 13.42	$ 1,251,150,455	$ 32.67	$ 4,359,621,887	$ 16.15

** Statistics calculated using actual 2004 movement tonnage (and not using the "calculation tonnage").*

While a calculation tonnage is only needed for the non-sample movements, a calculation tonnage was also set for the sample movements, the need of which will become evident in section 1A.6.2.

1A.4 RIVER CLOSURE RESPONSE

The three navigation projects considered in the Upper Ohio River analysis have potential failure modes which could completely close transportation on the river. In a traditional / typical navigation analysis long duration service disruptions are never complete; only one of two chambers is closed. While annual expected average tow delays during these service disruptions can be large, and the physical capacity of the remaining chamber may necessitate some diversion, it is assumed the scheduled waterway traffic will plateau during the disruption and then rebound once the project becomes fully operational as postponed shipments are re-scheduled. With a complete river closure, the ability to ship critical tonnage through the limited capacity of the project during the service disruption while re-scheduling un-critical shipments is not an option. As a result, to capture the potential for such an event on the Upper Ohio, it became necessary to estimate which Upper Ohio movements would not wait out a complete river closure and at what river closure duration would the tonnage divert.

The Upper Ohio River closure shipper response used in the Upper Ohio analysis come from a Tennessee Valley Authority Water Management Support analysis titled "*Transportation Rate Analysis: Ohio River System EDM Regional Economic Development*" dated July 2008. The sample of 1,552 movements from the 2004 ORS WCSC movement database (aggregated to annul, location-dock to location-dock, and 5-digit WCSC commodity group) used in the rate analysis included all 205 Upper Ohio River movements. All 205 Upper Ohio River movements were surveyed for a river closure (any one of the Upper Ohio River projects is closed) for less than 60-days and 61 through 180-days. As with the rate analysis, since many movements utilize multiple transportation modes from ultimate origin to ultimate destination, a full accounting of all transportation costs including loading / unloading, transfer, and any storage costs, is performed.

The survey indicated that all movements (that hadn't already ceased to move) would wait out a river closure duration of 14-days or less. As a result, the river closure responses could be divided into three duration ranges: less than 14-days, 15 through 60-days, and 61 through 180-days. Four shipper responses were identified: wait, divert, re-source via water around the closure, or shut down. The responses are summarized in TABLE 1A.4.1. With the divert and re-source via water around the closure responses, the alternative diversion rate was estimated.

TABLE 1A.4.1 – Upper Ohio Movement River Closure Response Sample

	Upper Ohio River Closure Duration Response								
	1 through 14-days			15 through 60-days			61 through 180-days		
Response	Count	2004 Tonnage	Pct. Of Tons	Count	2004 Tonnage	Pct. Of Tons	Count	2004 Tonnage	Pct. Of Tons
Dock closed prior to 2007	21	1,823,983	8.9%	21	1,823,983	8.9%	21	1,823,983	8.9%
O/D's wait for lock to open	184	18,691,317	91.1%	7	226,480	1.1%	6	206,269	1.0%
O/D's shut down with closure	0	-	0.0%	7	673,573	3.3%	12	991,508	4.8%
Divert	0	-	0.0%	168	17,507,720	85.3%	135	13,790,785	67.2%
Re-sourced	0	-	0.0%	2	283,544	1.4%	31	3,702,755	18.0%
TOTAL	205	20,515,300		205	20,515,300		205	20,515,300	

1A.4.1 Application of the River Closure Response Sample

At this time, unfortunately, ORNIM can only handle a wait or divert river closure response. Fortunately as shown, these are the primary river closure responses. A re-source via water around the river closure, while doable, would require extensive model modification. A shut-down response (eliminate the demand from the closure event forward) is impossible given the current ORNIM structure. Traffic forecasted demand is an input to ORNIM and adjustment of forecasted demand would have to be simulated given the probabilistic nature of the river closure events. Adjustment of the forecasted demand in ORNIM would convert the model application into a simulation which would be improbable from a CPU perspective given the necessity to estimate equilibrium probabilistically. The only realistic application of the shut-down response would be to adjust the traffic demand forecasts before input into ORNIM. This would necessitate al least a doubling of the traffic demand forecasts since a forecasted demand with and without the river closure events would be required. If multiple components generate the river closure events, there would need to be a forecasted traffic forecasted demand for each component combination, in fact each component permutation.

The sampled river closure responses were applied directly to matching dock-level movement records based on the rate sample reference number. Since the base rates (and the rate sample reference number) were matched by location-dock and 5-digit WCSC commodity code, the river closure response in effect was matched by location-dock and 5-digit WCSC commodity code. This, however, was not a direct application of the sample results. First the "*dock closed prior to 2007*" data was thrown out (it was of no use). Second, since only the wait and divert river closure responses could be used by ORNIM, the following adjustments were made to the remaining sample data:

- If the 15-60 and 61-180 day river closure duration responses were both specified as re-sourced, the sample response and its alternative rates were thrown out (i.e. assumed a wait response).
- If the 15-60 day river closure duration response was divert and the 61-180 day river closure duration response was re-source, the 61-180 day response was assumed to be a divert response utilizing the 15-60 day diversion rates.
- The 61-180 day river closure duration response was assumed for a 181-365 day response (since the longer duration river closure was not anticipated when the survey was conducted).

Of the 15,221 dock-level Upper Ohio movement records in the historic and forecasted demand database, only 548 were directly matched to the river closure response sample. While only 3.6% of the database records, this represented 75% of the year 2004 tonnage. Note that 13,872 of the 15,221 records have zero tonnage in year 2004, so actually 40.7% of the 2004 records were matched. This still appears low considering all the Upper Ohio movements were apparently sampled in the survey. The majority of the discrepancy occurs because the TVA sample database only showed 20.5 million tons (TABLE 1A.4.1) of Upper Ohio River traffic while the historic and forecasted demand database contains 23.5 million tons. Second, the TVA sample did not collect a response for 8.9% of the 2004 Upper Ohio tonnage since the origin and/or destination dock was closed by 2007.

1A.4.2 Estimation of the Un-Sampled Movements

For the remaining 14,671 dock-level Upper Ohio movement records in the database that could not be directly matched to a sampled river closure response, a method needed to be developed to estimate their response.

First the river closure responses were aggregated into:1) a location dock to location dock level by the 1-9 commodity group codes; and 2) a PE to PE level by the 1-9 commodity group codes. As with the direct application of the sample to matching dock-level records, the "*dock closed prior to 2007*" sample records and the sample records with a re-source respond in both the 15-60 and 61-180 day river closure duration were thrown out; this amounted to 23 of the 205 sample records. The response rate for the remaining sample records were averaged according to the sample file tonnage weight (TVA 2004 movement tonnages) except when the responses being aggregated were not consistent (e.g. the 15-60 response was wait in one record but divert in another). For simplification these sample observations were thrown out. This amounted to an additional 14 recorded with the location dock level aggregation and 34 records with the PE level aggregation being thrown out.

Second, for each of the remaining 14,671 dock-level Upper Ohio movement records in the database that could not be directly matched to a sampled river closure response, a match was first queried in the location dock level aggregated file and next in the PE level aggregated file. As shown in TABLE 1A.4.2, only a few dock-level records could be assigned at from this aggregated sample lookup method. As a result, 12,173 (21.3% of the database 2004 Upper Ohio traffic) could not be assigned a river closure response from the sample. For these movements, a "*wait*" response was assumed for the 15-60, 61-180, and 181-365 river closure durations (noting that the sample predicts a wait response on all movements for river closure durations less than 15-days).

TABLE 1A.4.2 – River Closure Response Dock-Level Application

Database	Record Count	2004 Tonnage	Pct. Of Tons
Records matched with Survey Response	548	17,527,738	74.8%
Records assigned from LOC-NC level	859	363,862	1.6%
Records assigned from PE-NC level	1,641	576,868	2.5%
Records not assigned, assumed "wait"	12,173	4,985,513	21.3%
TOTALS	15,221	23,453,981	

1A.5 RIVER CLOSURE RESPONSE EXTERNALITY COSTS

The Upper Ohio River closure shipper response externality cost used in the Upper Ohio analysis come from a Tennessee Valley Authority Water Management Support analysis titled "*Transportation Rate Analysis: Ohio River EDM Social Costs*" dated July 2008. The sample of 1,552 movements from the 2004 ORS WCSC movement database (aggregated to annul, location-dock to location-dock, and 5-digit WCSC commodity group) used in the rate analysis included all 205 Upper Ohio River movements. All 205 Upper Ohio River movements were surveyed for a river closure response (any one of the Upper Ohio River projects is closed) of less than 60-days and 61 through 180-days. Movements identified as diverting from the existing waterway routing were routed. In addition to this short-term routing cost, an externality cost (in dollar per diverted ton, through the analysis period) for five externality categories was calculated. The externality categories included: 1) truck induced road delay; 2) truck induced accidents; 3) truck emissions; 4) non-delay truck accident and emission; and 5) rail / barge emission.

The river closure response diversion externality costs were then summarized by dollar per ton by externality type and year. There was no summarization to individual dock-level movements or commodity. Since there was no dock level or commodity type variation, there was no need to apply this data to the dock-level database. ORNIM, however, does store the river closure response externality costs by movement, which will be discussed in sections 1A.6.3.3 below.

1A.6 MODEL INPUT DATA SPECIFICATION AND AGGREGATION

As discussed in the sections above, rates, river closure response, and river closure response externality costs are applied in an annual, location-dock to location-dock, 5-digit WCSC commodity code, vessel type, barge length-width, and routing database. From this base historic and forecasted demand database, the ORNIM modeling movements are aggregated and loaded into the model. Maintaining this data at such an un-aggregated level, allows flexibility in aggregating the data to any network granularity level.

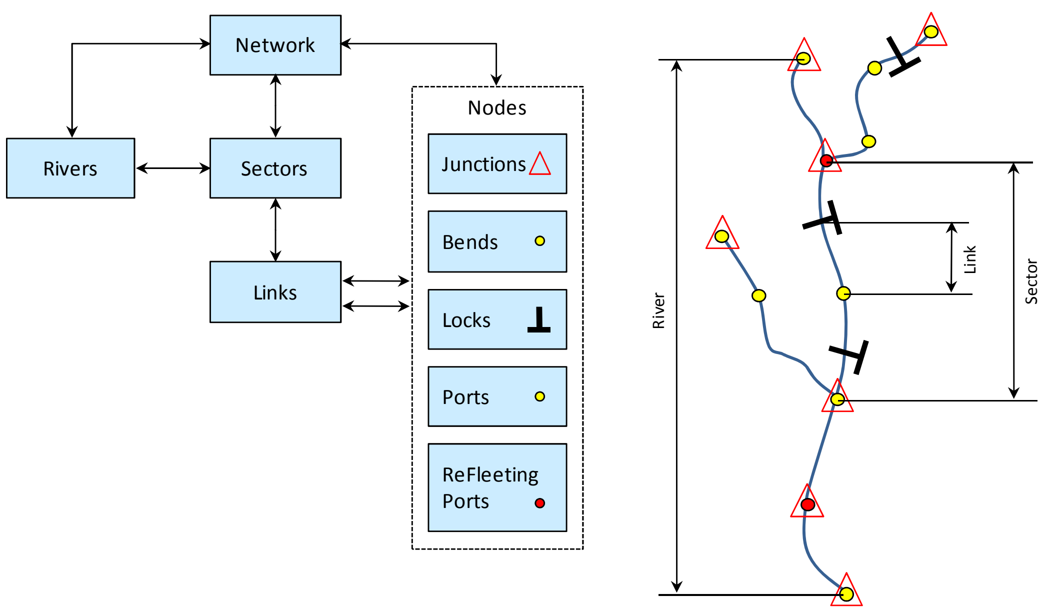
1A.6.1 Modeling Level

Modeling requires simplification of the real world. While the "*dock-level*" database discussed in the sections above is an aggregation of flow data to an annual level, ORNIM requires a further aggregation to the system internally defined in the model. While ORNIM is data driven (e.g. the level of aggregation is user defined), for the Upper Ohio analysis the waterway system is defined with 171 pick-up / drop-off nodes, nine commodity groupings, twelve barge types, and eight towboat types. Aggregation of the movement database involves aggregation of the location-docks, 5-digit WCSC commodity codes, and equipment, as discussed below.

1A.6.1.1 Model Network

The topology of the inland waterway system is defined in ORNIM through a network which describes the characteristics of the transportation system's constituent ports, reaches, locks, and other components that affect towing operations and costs. From FIGURE 1A.6.1 (a graphical view of the network data relationships) it can be observed that the model ports are an aggregation of the location-docks. In the ORS network there is at least one loading / unloading node in each navigation pool. In longer pools where traffic pickup / drop-off are diverse, multiple nodes exist.

FIGURE 1A.6.1 – Waterway Network Entities



1A.6.1.2 Model Commodity Groups

For modeling, the 662 WCSC data commodity classes have also been aggregated into nine major commodity groups reflecting major types of commodities with similar shipping characteristics and patterns.

1A.6.1.3 Model Barges

ORNIM allows for a barge type to be specified on each movement. Barge types clustered into primarily twelve barge types between the nine commodity groups. The 209 unique vessel type 4 (hopper) barge length-widths were grouped into 7 tanker barge types and the 286 unique vessel type 5 (tanker) barge length-widths were grouped into 5 tanker barge types.

1A.6.2 Data Aggregation to Model Level

The model's movement specification (i.e. origin, destination, commodity, barge type) is dictated by the network, commodity grouping, and barge type groupings discussed above (towboat type is not relevant). The aggregation of this flow data not only requires aggregation of the origin / destination nodes (5,928 docks to 171 model nodes), commodity codes (662 5-digit codes to 9 1-digit codes), barge types, and tonnage, but also requires aggregation or averaging of the rate data. Additionally, ORNIM does not accept intra-pool flows (i.e. movements that don't transit at least one lock). As a result, all non-lock flows are eliminated.

1A.6.2.1 Tonnage Weighting the Rate Data

The aggregation of the rate data to the model-level nodes are sensitive to the weights (i.e. tonnage) used. The "*rate equation calculation tonnage*" discussed in section 1A.3.2.2 was used for this tonnage weighting process; specifically the PE and 1-digit commodity grouping level calculation tonnage with a sample average tonnage minimum. Even though the "*rate equation calculation tonnage*" was only needed for the rate equations used on the non-sampled movements, a calculation tonnage was also assigned to each rated movement for a consistent weighting method when aggregating to the model level system. For the same reasons a calculation tonnage was needed for the rate equations (small, if not zero, tonnage at the "*dock-level*" movement database), a calculation tonnage was needed in the aggregation process.

The initial aggregation proved problematic. The rate sample negative base rate-savers got amplified from 5.1% of year 2004 tonnage from "*dock-level*" movements to 22.7% of the year 2004 tonnage from "*model-level*" movements. This also means that in the ORNIM inelastic equilibrium process a substantial portion of system demand will immediately divert even with just a slight increase in system congestion. Since the development of a different tonnage weighting scheme that might produce a closer model-level match to the dock-level data proved difficult, the process described in the section below was applied.

1A.6.2.2 Negative Rate-Savings and the Willingness-to-Pay

While some movements might ship inefficiently, the majority of negative rate-savers exist because rate data does not always capture a movement's true willingness-to-pay. For example, while the water routing rate might exceed the least-cost all-overland rate, the FOB commodity price might be less, resulting in a lower delivered price. Since the objective of ORNIM is to determine equilibrium traffic levels and estimate system transportation benefits (surplus) through the use of movement-level willingness-to-pay (whether through an elastic demand curve or an inelastic rate comparison). In short, the rate data is used as a proxy for willingness-to-pay. Since the sampled negative rate-saver tonnage is moving, by definition there is a positive willingness-to-pay, and the rates are obviously not an adequate proxy for the movement's willingness-to-pay. The movement's willingness-to-pay might in fact be small, but most-likely not negative.

Additionally, ORNIM diverts traffic in its inelastic demand equilibrium process by eroding movement base rate-savings. When a movement erodes to a negative rate-savings, the tonnage is diverted from the waterway. The movement base rate-savings is eroded by increased congestion on the waterway system increasing the waterway transportation costs (and hence the waterway rate). Since waterway congestion is typically always greater in the future, a zero base rate-savings is essentially the same as a negative base rate-savings; as soon as there is a slight water transportation cost increase, the tonnage diverts. The difference occurs in situations where the water transportation system is improved better than the base rate condition (e.g. construction of larger lock chambers). In a situation where larger lock chambers are constructed, zero base rate-savers will more likely move in equilibrium than if they were defined with a large negative base rate-savings. The term "*more likely*" is used here because effect of increased traffic at the new lock, as well as increased congestion elsewhere in the system, might not allow water transportation costs to reduce lower than the base case for the questionable movements.

Given the intent of the rate analysis to supply a proxy for movement willingness-to-pay, and given inelastic equilibrium diversion at a zero rate-savings, in the aggregation of the "*dock-level*" rate data to the "*model-level*" movement, negative base rate-savers were aggregated assuming a zero rate-savings. This is slightly different than throwing the movements out as outliers from the rate averaging. By averaging the negative base rate-savers with a zero base rate-savings, they pull the model-level rate average toward zero, but never pulls the model-level rate into a negative base rate-savings situation. Only 0.9% of model-level movement base year tonnage consisted of dock-level movements that were all negative base rate-savers. In the averaging of the rates for these all negative movements, the model-level base rate-savings averaged to zero. To be more specific, the model-level data (or for that matter the dock-level data) is not stored with a rate-savings, but rather the existing base water rate and the least-cost all-overland rate (which results, when subtracted, the base rate-savings).

As shown in TABLE 1A.6.1, dropping non-lock records from the database reduced the total record count from 128,932 to 122,818 (a 4.7% reduction). The lock only 2004 dock-level movements are then aggregated to 3,503 model level movements. Dropping the non-lock records from the database reduced the total year 2004 tonnage from 269.9 million to 241.1 million tons (a 10.7% reduction). What's most interesting is the change in the rate-savings. The average year 2004 rate-savings for all movements is $16.15 per ton (TABLE 1A.3.6), but when the non-lock traffic is removed, the average rate-savings increases slightly to $17.23 per ton. This is reasonable given lower rate-saving movements tend to be shorter haul movements, which are more likely not to traverse a lock.

TABLE 1A.6.1 – Rate Summary – Dock-Level versus Model-Level Aggregation

Commodity Group	Database Record Counts			Year 2004 Tonnage			Rate-Savings (FY2008 price level)			
	dock-level			dock-level			Base Database (Lock Only)		Model Level	
	Total	Lock Traf. Only	model-level	Total	Lock Traf. Only	model-level	Total	Per Ton	Total	Per Ton
Coal	19,553	18,603	672	145,256,328	135,107,853	135,107,853	$ 1,160,162,500	$ 8.59	$ 551,555,270	$ 4.08
Petroleum	24,518	23,694	560	16,977,193	16,260,416	16,260,416	$ 607,593,923	$ 37.37	$ 592,157,727	$ 36.42
Crude Petro	327	312	4	42,671	40,256	40,256	$ 1,982,874	$ 49.26	$ 2,534,839	$ 62.97
Aggregates	16,780	15,083	418	48,032,516	34,544,397	34,544,397	$ 520,332,222	$ 15.06	$ 466,312,017	$ 13.50
Grains	18,443	16,839	262	16,556,509	12,883,615	12,883,615	$ 215,962,447	$ 16.76	$ 209,911,225	$ 16.29
Chemicals	18,594	17,901	632	11,499,905	11,039,524	11,039,524	$ 640,489,477	$ 58.02	$ 618,027,829	$ 55.98
Ores & Min	5,622	5,585	168	7,406,300	7,289,177	7,289,177	$ 233,209,936	$ 31.99	$ 253,808,810	$ 34.82
Iron / Steel	16,414	16,334	472	15,288,459	15,206,938	15,206,938	$ 502,868,609	$ 33.07	$ 462,598,500	$ 30.42
Others	8,681	8,467	315	8,883,522	8,759,981	8,759,981	$ 272,098,550	$ 31.06	$ 242,909,168	$ 27.73
	128,932	122,818	3,503	269,943,403	241,132,157	241,132,157	$ 4,154,700,538	$ 17.23	$ 3,399,815,386	$ 14.10

Next, when the lock only dock-level movements are aggregated to model-level movements (and negative rate-savers are adjusted as discussed), the average rate-savings drops to $14.10 per ton.

1A.6.2.3 Aggregation of the River Closure Response

The dock-level river closure responses do not easily collapse to the model movement level. Even with simplification of the response to only wait or divert at each river closure duration range, most movements at the model level consisted of both responses. Instead of duplicating the movements in the model so both responses could be applied, response percentages of the model-level movement were developed. Say 50 dock-level movements aggregate into one model-level movement, but 30 of the movements have a wait response for the 61-180 day duration river closure and 20 movements have a divert response. Say the 30 movements having the wait response accounts for 90% of the aggregated model-level movement tonnage. In this case, for the 61-180 day duration river closure, a 90% wait and 10% divert response is recorded for the model-level movement.

1A.6.3 ORNIM Movement Data

ORNIM data is stored in Microsoft Sequel Server database tables. Movement rates, river closure response, and river closure response diversion externality costs are stored in the five database tables discussed in the sections below.

1A.6.3.1 Movement Detail Table

The rates along with other general movement characteristics are stored in the "*MovementDetail*" table shown in TABLE 1A.6.2. Note that the routing externality cost in this table is different than the river closure response externality cost discussed in section 1A.5, and were not used in the Upper Ohio analysis. These routing externality costs represent a long-run routing cost and not the short-run river closure diversion externality costs which are stored in a different table as discussed in sections 1A.6.3.3 below.

TABLE 1A.6.2 – MovementDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
ID		Unique movement ID
Origin		Movement origin portID (Ports table)
Destination		Movement destination portID (Ports table)
ForcedSec		Movement must be routed through this sectorID (Sectors table)
ForcedLk		Movement must be routed through this lockID (Locks table)
AvoidSec		Movement must not be routed through this sectorID (Sectors table)
TonsPerBarge		Movement average barge loading in tons
Commodity		Movement commodityID group (CommodityTypes table)
BargeType		Movement bargeTypeID class (BargeTypes table)
WWLineHaul		Base waterway line-haul rate in dollars per ton
WWRate		Total base waterway rate in dollars per ton
AltRate		Base least-cost all-overland alternative rate in dollars per ton
WWExternality		Waterway externality cost in dollars per ton
AltExternality		Alternative routing externality cost in dollars per ton

1A.6.3.2 Movement River Closure Response Tables

To allow flexibility in ORNIM for the user to define the river closure durations to which to define river closure responses, storing the river closure response data in the model required two tables. The first table, "*MovementResponse*" (TABLE 1A.6.3) defines a unique ID a river closure duration. The ID is simply called the "*responseID*", but a more descriptive name would be the "*riverClosureDurationID*". Since overland costs are assumed constant through time in ORNIM, the diversion rate is also stored in this table (field "*responseRate*").

TABLE 1A.6.3 – MovementResponse Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
movementID	DB Key	Unique movement ID
minDaysClosed	DB Key	Lower boundry in days of river closure duration
maxDaysClosed		Upper boundry in days of river closure duration
responseID		Unique river closure duration ID
responseRate		River closure diversion rate ($/ton)

The second table, "*MovementResponseDetail*" (TABLE 1A.6.4) stores the percent of the model-level movement tonnage that is diverted (see section 1A.6.2.3). Since the response is either wait or divert, only one percentage needs stored. With a diversion percentage (field "*reductionFactor*") of 10%, the wait response is 90% (1.0 – 0.10).

TABLE 1A.6.4 – MovementResponseDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
movementID	DB Key	Unique movement ID
responseID	DB Key	Unique river closure duration ID from MovementResponse table
beginCalendarYear	DB Key	Lower boundry for application of the reductionFactor
endCalendarYear		Upper boundry for application of the reductionFactor
reductionFactor		Percent of movement with divert response

Note field "*beginCalendarYear*" which allows the user to change the "*reductionFactor*" through time. This option was not utilized in the Upper Ohio analysis; the same "*reductionFactor*" was used for the entire analysis period (i.e. "*endCalendarYear*" = 9999).

1A.6.3.3 Externality Tables

To allow flexibility in ORNIM for the user to define the river closure response externalities to track, two database tables were needed. The first table, "*ExternalityType*" (TABLE 1A.6.5) defines the number externality categories to track and assigns a unique ID to each.

TABLE 1A.6.5 – ExternalityType Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
externalityTypeID	DB Key	Unique movement ID
externalityTypeName		Lower boundry in days of river closure duration

The second table, "*MovementResponseDetailExternality*" (TABLE 1A.6.6) stores the defined externality cost by year. As discussed in section 1A.5 the externality cost data is only summarized at an externality type and year level. ORNIM, however, defines the externality costs at a movement level. As such, the data is assigned to the movement level based on year. While this duplicated data, it allows flexibility in the model if and when externality costs are defined at a movement level.

TABLE 1A.6.6 – MovementResponseDetailExternality Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
movementID	DB Key	Unique movement ID
responseID	DB Key	Unique river closure duration ID from MovementResponse table
calendarYear	DB Key	year
externalityTypeID	DB Key	ID from ExternalityType table
externalityCost		dollars per ton cost

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 1
Ohio River Navigation Investment Model (ORNIM) Version 5.1

Calibration
Addendum B

February 2011

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1B.1 INTRODUCTION

A critical step in analysis is the determination of whether the model used is an accurate representation of the actual system being studied, that is, whether the model is valid. Conclusions from results derived from non-valid models are of doubtful value. The process of establishing a model's validity and credibility ranges from the development of the conceptual model through the model output analysis. Three primary steps in this process are model specification, verification and validation.

- Specification includes the theoretical framework of the conceptual model along with the application through the model's framework. Specification is also the determination of input data grouping and aggregation to describe the system being modeled (in this case the aggregation of the waterway system data).
- Verification is the determination that proper data has been loaded and that the model's code performs as intended.
- Validation is the determination of whether the model develops an accurate representation of the system under study. Validation often requires calibration, where the description of the system being modeled is fine-tuned to most accurately replicate observed behavior in the system.

The Ohio River Navigation Investment Model (ORNIM) Waterway Supply and Demand Module (WSDM) is a fleet sizing and costing model with enhancements which bridge the gap between towing industry operating characteristics and shipping costs and the physical and operational characteristics of the waterway system. WSDM actually serves two tasks: 1) develop and cost the least-cost movement shipping plans; and 2) estimate equilibrium system traffic levels from a bottom-up movement level analysis. The cost characteristics of the shipping plans are needed in the equilibrium traffic process. The focus of this addendum is on the specification, verification, and validation of the WSDM least-cost shipping plans. Specification of the model's equilibrium process is covered in the main attachment (ATTACHMENT 1 ORNIM).

By using detailed data describing the waterways network, the equipment used for towing operations, and the commodity flow volumes and patterns, the model (WSDM) calculates the resources (i.e., number of towboats, trip time, and fuel consumption) required to satisfy the demand on a least-cost basis. Specifically, this means that the shipping characteristics or shipping plan (tow-size, towboat type, re-fleeting points if applicable and empty barge returns if applicable) must be determined for each movement. The model then provides the analyst with the ability to estimate the effects of differences in the cost characteristics associated with different traffic levels and different waterway system definitions; WSDM is a predictive as well as a behavioral model. Before attempts are made to forecast future behavior and system operating characteristics, however, the analyst and reviewers must first be convinced that the model is capable of replicating known shipper behavior and system performance characteristics.

Looking at a historic year, Waterborne Commerce Statistics Center (WCSC) data gives the origin to destination loaded barge flows by commodity, however, information on tow-size, towboat utilization and empty return characteristics[1] are not available at a movement origin to destination level. As a result, a major function of WSDM is to determine the movement level origin to destination shipping plans. To validate that the model is developing accurate shipping plans and is capable of replicating observed shipper behavior and system operating characteristics, the model usually needs to be calibrated. This is a sequential process involving several iterative steps. At each step, certain static components of the model's waterway system description are adjusted or fine-tuned, the model is exercised, and specific results are compared with corresponding target values. The target values are specified by navigation lock project and are often derived from the Lock Performance Monitoring System (LPMS) data for the designated baseline or calibration year(s). The calibration process is designed to ensure that the relevant measures match their corresponding target values as well as possible.

This ADDENDUM discusses the model's input specification and data aggregation, model verification steps, and model validation with intention of supporting model credibility for estimating movement shipping

[1] WCSC does track empty barge flows, however, it is not reliable.

plans and ultimately to support the model's credibility for use in Upper Ohio River Navigation Study. The model was calibrated and validated against an average of 2004 through 2006 WCSC and LPMS data. These calibration and validation targets were selected primarily because the rate data was developed using the shipping characteristics for this time period, and this averaging also allows for a smoothing of the data to avoid individual year irregularities. This ADDENDUM also discusses the process and results of modification of the model's tow-size limit parameters for the development of shipping plans under an 800' and 1,200' Upper Ohio system.

1B.2 MODEL INPUT DATA SPECIFICATION AND AGGREGATION

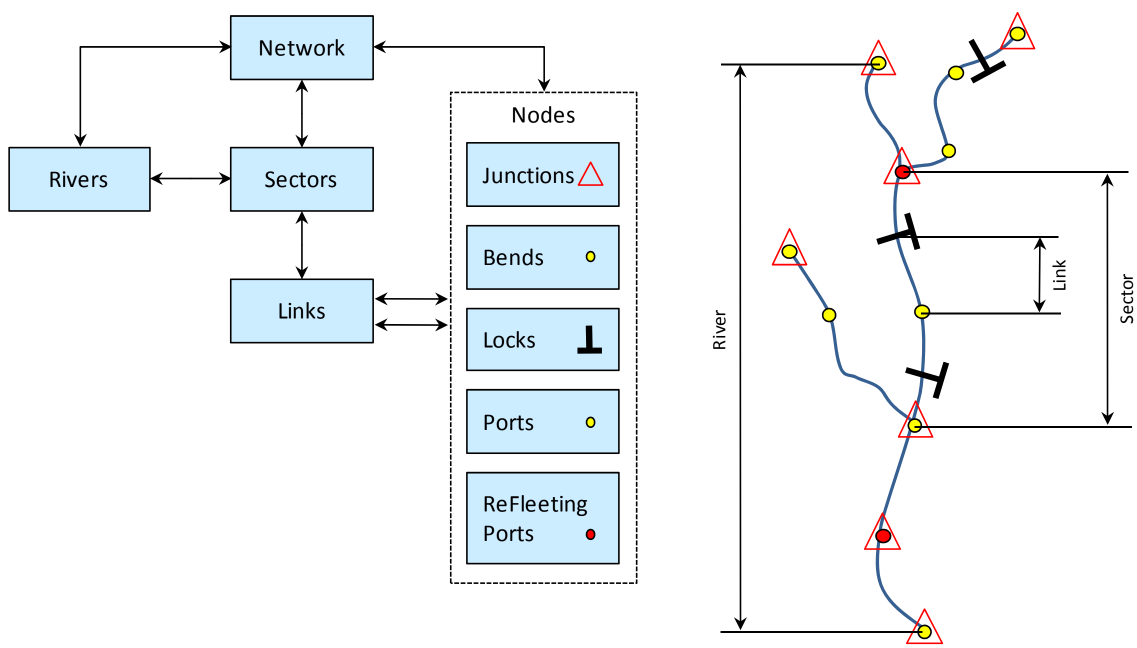
The development of accurate input data, and the appropriate aggregation and classification of the input data to adequately describe the inland waterway system, is essential for correct calibration and operation of ORNIM. A large part the model's validity and credibility necessitates an adequate number of barge, towboat, port, and commodity classes to represent the existing and future transportation systems.

In previous Ohio River System (ORS) investment analyses, and in this Upper Ohio River Navigation Study analysis, the Ohio River Navigation Investment Model (ORNIM) is loaded with traffic flows in, out, or through the ORS. There are two primary sources of inland waterway transportation flow data: Waterborne Commerce Statistical Center (WCSC) and Lock Performance Monitoring System (LPMS) data, each with their pros and cons. Analyzing the historic system data from these two data sources drives the specification and aggregation of the model's input data for use in the Upper Ohio River Navigation Study analysis.

1B.2.1 Waterway Network Specification

The topology of the inland waterway system is defined in ORNIM through a network which describes the characteristics of the transportation system's constituent ports, reaches, locks, and other components that affect towing operations and costs. The network is defined based on a set of nodes and links between the nodes, that is, a link-node network. Specifically this link-node network is defined with rivers, sectors, nodes, and links which define continuous stretches of waterway between the various types of nodes. FIGURE 1B.2.1 provides a graphical view of the network data relationships.

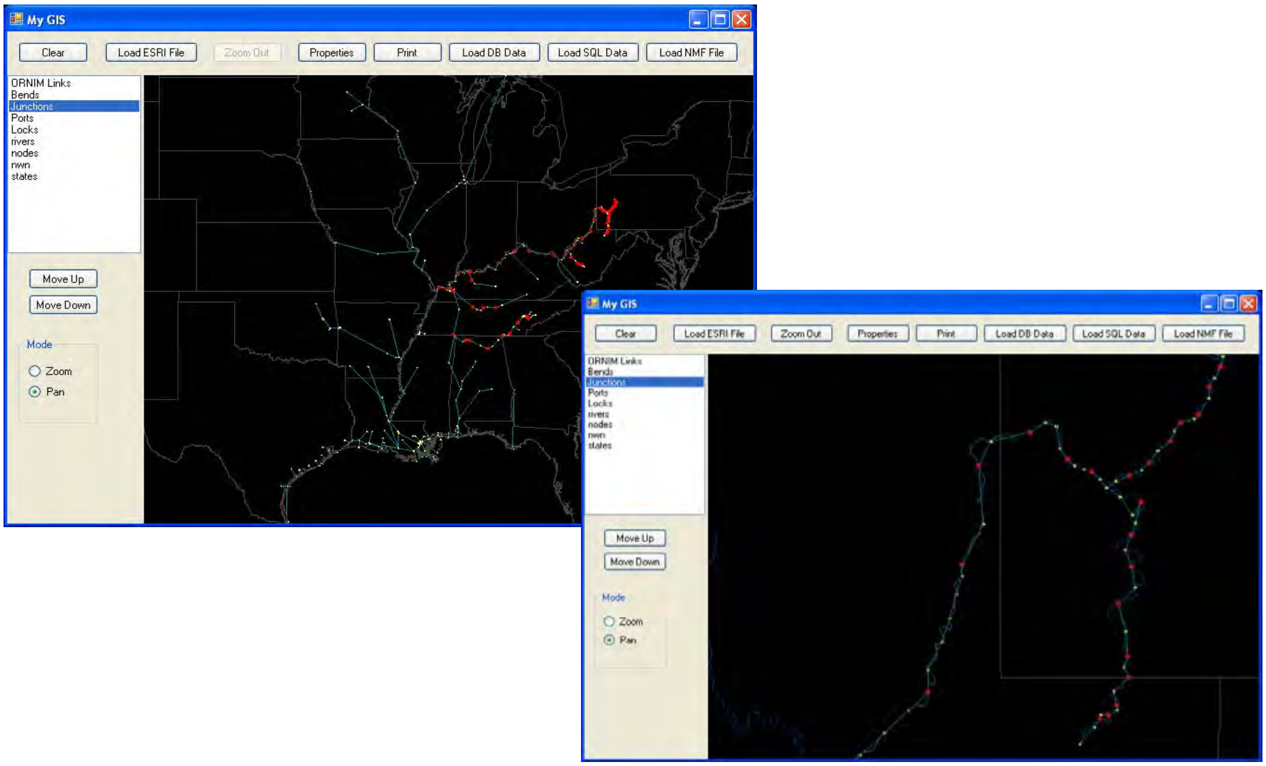
FIGURE 1B.2.1 – Waterway Network Entities



As part of the Ohio River Mainstem System Study, ORNIM's network was loaded with the 56 navigation projects in the ORS that process commercial traffic and loading and unloading nodes necessary to describe ORS traffic flows (which often move outside the ORS). Navigation projects outside the ORS, however, were not included since a complete traffic set moving through these projects was not modeled. Additionally the loading and unloading node granularity is thin outside the ORS given the distance and isolation of these areas of the waterway system with the ORS movements.

The network in the current database encompasses most of the inland waterway system, including much of the Gulf Intercoastal Waterway; it contains over 12,000 miles of waterway. While much of the network detail is of little consequence to analysis of Upper Ohio River investment options, it was more efficient to maintain the network structure and update the inputs, rather than re-specifying the network from scratch (FIGURE 1B.2.2).

FIGURE 1B.2.2 – The Current ORNIM Waterway Network



1B.2.1.1 Port Node Specification, Aggregation, and Characteristics

In the ORS there is at least one loading and unloading node in each navigation pool. In longer pools where traffic pickups and drop-offs are diverse, multiple nodes exist (e.g., Montgomery L/D's 22.7 mile pool contains three nodes). The location of the loading and unloading node within a navigation pool is a tonnage weighted centroid.

In the model's identification of the least-cost shipping plans, time in port whether loading, unloading, fleeting, or re-fleeting is considered. The model allows specification of component times shown in TABLE 1B.2.1 for each port, however, in the current database, all ports are currently specified with the values shown. Barge types are designated as carrying one of three handling classes. Each handling class can have its own loading rate, unloading rate, and port delay time. In the Upper Ohio Navigation Study analysis and in this calibration, only handling class 1 and 3 are utilized, where handling class 1 is for dry bulk and handling class 3 is for liquid. In previous studies, handling class 2 was used for hazardous commodities.

TABLE 1B.2.1 – Port Characteristics

Characteristic	Time *
Average Towboat Wait Time	4.4 hours per tow
Fleeting / Re-fleeting Time Per Tow	20 minutes per tow
Fleeting / Re-fleeting Time Per Barge	5 minutes per barge
Loading Rates	
Handling Class 1	0.13 minutes per ton
Handling Class 2	1.5 minutes per ton
Handling Class 3	0.27 minutes per ton
Unloading Rates	
Handling Class 1	0.22 minutes per ton
Handling Class 2	0.93 minutes per ton
Handling Class 3	0.39 minutes per ton
Port Delay	
Handling Class 1	0 hours per tow
Handling Class 2	0 hours per tow
Handling Class 3	0 hours per tow

** Ports can be specified individually, but all ports currently set with these values.*

As an example, say a 15 barge jumbo tow of dry bulk commodity with an average barge loading of 1,450 tons is being shipped. Origin port time will be calculated as 53.108 hours as shown below:

0.000	hours port delay
47.125	hours loading (15 barges x 1,450 tons/barge x 0.13 minutes/ton)
4.400	hours (waiting for a towboat)
1.583	hours fleeting (15 barges x 5 min/barge + 20 minutes)
53.108	hours at origin port

Similarly the destination port time will be calculated as 81.333 hours as shown below:

0.000	hours port delay
79.750	hours unloading (15 barges x 1,450 tons/barge x 0.22 minutes/ton)
79.750	hours at destination port

The hours at the port, however, should not be confused with the hours of equipment utilization. The model assumes: 1) sequential loading / unloading of the barges; 2) empty barges arrive as needed for loading; 3) towboat wait time starts once all barges are loaded and ready for fleeting; 4) the towboat is immediately released at the destination; and 5) barges are released once empty. As a result, at the origin and destination, each piece of equipment is cost for different times.

In this example, at the origin the first barge will be cost for 53.108 hours (port delay, loading, waiting for 14 other barges to load, waiting for towboat pickup, and fleeting), the second barge will be cost for 49.966 hours (port delay, loading, waiting for 13 other barges to load, waiting for towboat pickup, and fleeting), the third barge will be cost for 46.825 hours (port delay, loading, waiting for 12 other barges to load, waiting for towboat pickup, and fleeting), and so on. At the origin the towboat will only be cost for 1.583 hours (fleeting time).

In this example, at the destination the first barge emptied will be cost for 5.317 hours (port wait and unloading time), the second barge emptied will be cost for 10.633 hours (port wait, unloading time for previous barges and unloading time for the current barge), and so on. The last barge emptied will be cost for 79.750 hours. The towboat will be cost for 0 hours at the destination.

In summary, while total time in port (origin and destination) is 132.858 hours; each piece of equipment is cost with its unique utilization time. At the origin the towboat cost equation at the origin is simply the fleeting time (in this case 1.583 hours) multiplied by the hourly cost for the selected towboat class. The barge cost equation at the origin is:

$$\left[\left[\frac{\left[\dfrac{\text{no. of barges} \times (\text{no. of barges} + 1)}{2} \right] \times \text{barge loading in tons} \times \text{loading rate in minutes per ton}}{\text{60 minutes per hour}} \right] + \text{port wait time in hours} + \text{towboat wait time in hours} + \text{fleeting time in hours} \right] \times \text{Hourly barge cost} \qquad (1B.2\text{-}1)$$

Where fleeting time is number of barges x min./barge fleeting time + min./tow

At the destination the towboat cost always zero (even with a port delay time). The barge cost equation at the destination is:

$$\left[\left[\frac{\left[\dfrac{\text{no. of barges} \times (\text{no. of barges} + 1)}{2} \right] \times \text{barge loading in tons} \times \text{unloading rate in minutes per ton}}{\text{60 minutes per hour}} \right] + \text{port wait time in hours} \right] \times \text{Hourly barge cost} \qquad (1B.2\text{-}2)$$

In a re-fleeting situation where the shipping plan is upsized and/or downsized in route, the calculation is fairly similar. Say this shipment trip moves from a major river to a tributary river. At the mouth of the tributary the 15-barge tow is broke into three 5 barge tows for the remainder of the trip. As at the origin port, the towboat wait time starts once all barges are loaded and ready for fleeting, which at a re-fleeting point means that the towboat wait time begins when the tow arrives since all the barges are already loaded. This essentially assumes that the re-fleeting of the single tow into three tows is done simultaneously. There is no unloading and re-loading at the re-fleeting point meaning there is no unloading and re-loading time and as a result no port delay time. The re-fleeting time for a single 5 barge tow will be calculated as 5.150 hours as shown below:

4.400	hours (waiting for a towboat)
0.750	hours fleeting (5 barges x 5 min/barge + 20 minutes)
5.150	hours at the re-fleeting port for one 5-barge tow

Each of the three new towboats (a smaller towboat than used to initially move the 15-barge tow) will be cost for re-fleeting (in this case 0.75 hours/tow). Each of the 15 barges will be cost for 5.150 hours.

1B.2.1.2 Navigation Project Characteristics

Navigation projects are constraint points in the system and the transit times past these areas are represented by a tonnage-transit curves relating an average tow transit time to an annual aggregate traffic level at the project. In the verification, calibration, and validation of the model's movement shipping plans, these tonnage-transit curves are not used. Instead, the model uses the observed transit time in the "*Targets*" database table (section 1B.2.10.7.1) as input for its calculations (see section 1B.2.10). Validation of the project tonnage-transit curves are done as part of project level capacity analyses and not part of this model verification, calibration, and validation. No further discussions of the navigation project characteristics are needed in this document.

1B.2.1.3 Other System Constraint Points

A model node can be any constraint area in the waterway transportation system that affects towing operations and costs (e.g., bends). Other than navigation projects, no other significant constraint points are modeled. The lower Cumberland River has significant constraints, however, Kentucky Lock offers an alternate route and there is very little Upper Ohio River traffic in common with the Tennessee or Cumberland Rivers.

1B.2.1.4 Re-Fleeting Areas

Any loading and unloading node can be specified as a re-fleeting port which allows the shipping plan to change enroute. In comparing shipping plan options, the model considers upsizing and downsizing tows at the re-fleeting points. For example loaded barges might be shuttled down a small tributary river in a small tow-size with a low horsepower towboat to the river's confluence to a major river. At the tributary mouth, the barges are combined with other barges to form a larger tow utilizing a larger horsepower towboat for the remainder of the trip. Despite the use of a higher cost towboat, with economies of scale the cost per ton for the commodity is less. The lock on the tributary would see smaller tow-sizes and smaller towboats than the lock on the major river despite 100% commonality of tonnage between the locks.

Re-fleeting ports are typically always specified at river junctions where river characteristics change. In the Upper Ohio River area a re-fleeting port is specified at Pittsburgh. The next river junction re-fleeting port is at the mouth of the Kanawha River[2]. Re-fleeting ports are also located between navigation projects where the main chamber size varies. In the Upper Ohio River area re-fleeting options are allowed:

- below Montgomery Locks and Dam (between the Upper Ohio 600' x 110' main chambers and the 1200' x 110' main chambers downstream);
- below Monongahela Locks and Dam 3 (between L/D 3 720' x 56' and L/D 2 720' x 110');
- below Maxwell Locks and Dam (between Maxwell L/D 720' x 84' and L/D 3 720' x 56'); and
- below Morgantown Locks and Dam (between Morgantown L/D 600' x 84 and Point Marion L/D 720' x 84').

1B.2.2 Commodity Group Specification, Aggregation, and Costs

For modeling, the 662 WCSC data commodity classes have been grouped into nine major groups reflecting major types of commodities with similar shipping characteristics and patterns. The WCSC 5-digit and 4-digit commodity codes under each of the nine groups are shown in TABLE 1B.2.2 through TABLE 1B.2.10.

TABLE 1B.2.2 – COAL Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Coal (model ID # 1)
WCSC 5-digit	32100, 32210, 32220, 32230, 32500
WCSC 4-digit	1121, 2920

2 The re-fleeting port for the Kanawha River is at the mouth of the river, meaning that traffic passing the Kanawha River on the Ohio River are not considered for re-fleeting; only traffic moving between the Kanawha and Ohio Rivers are allowed a re-fleeting option.

TABLE 1B.2.3 – PETROLEUM Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Petroleum (model ID # 2)
WCSC 5-digit	33411, 33412, 33419, 33421, 33429, 33430, 33440, 33450, 33510, 33521-33525, 33530, 33540, 33590, 34000
WCSC 4-digit	2811, 2817, 2911-2918, 2920, 2921, 2991

TABLE 1B.2.4 – CRUDE PETROLEUM Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Crude Petroleum (model ID # 3)
WCSC 5-digit	33300
WCSC 4-digit	1311

TABLE 1B.2.5 – AGGREGATES Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Aggregates (model ID # 4)
WCSC 5-digit	27230, 27310, 27322-27324, 27330, 27340, 27350, 27910, 27920, 29115
WCSC 4-digit	931, 1411, 1412, 1442, 1471, 1494, 1499, 4029, 4118

TABLE 1B.2.6 – GRAINS Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Grains (model ID # 5)
WCSC 5-digit	4100, 4200, 4300, 4400, 4510, 4520, 4530, 4600, 4700, 4800, 5461, 8110, 8120, 8130, 8140, 8150, 8190, 22210, 22220, 22230, 22240, 22250, 22260, 22270, 22310, 22320, 22340, 22350, 22370, 22390
WCSC 4-digit	102-107, 111, 112, 119, 122, 2041, 2042, 2049

TABLE 1B.2.7 – CHEMICALS Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Chemicals (model ID # 6)
WCSC 5-digit	23200, 27210, 27220, 27240, 51111-51114, 51119, 51121-51127, 51129, 51131-51140, 51211-51217, 51219, 51221-51225, 51229, 51231, 51235, 51241-51244, 51299, 51371-51379, 51381-51385, 51389, 51391-51396, 51451-51455, 51461-51465, 51467, 51471, 51473, 51479, 51481-51486, 51489, 51541-51544, 51549, 51550, 51561-51563, 51569, 51571-51580, 51612-51617, 51621-51629, 51631, 51639, 51691, 51692, 51699, 52210, 52221-52229, 52231-52239, 52241, 52242, 52251-52257, 52261-52269, 52310, 52321, 52322, 52329, 52331, 52332, 52339, 52341-52345, 52349, 52351, 52352, 52359, 52361-52365, 52371-52375, 52379, 52381-52384, 52389, 52431, 52432, 52491-52495, 52499, 52511, 52513, 52515, 52517, 52519, 52591, 52595, 53100, 53200,
WCSC 4-digit	1479, 1493, 1911, 2810-2813, 2816-2819, 2821, 2822, 2831, 2841, 2851, 2861, 2871-2873, 2876, 2879, 2891

TABLE 1B.2.8 – ORES & MINERALS Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Ores and Mineral (model ID # 7)
WCSC 5-digit	27410, 27420, 27700, 27820, 27830, 27840, 27850, 27891-27899, 28300, 28400, 28500, 28600, 28740, 28750,
WCSC 4-digit	1021, 1051, 1061, 1091, 1451, 1491, 1492, 1499, 4012

TABLE 1B.2.9 – IRON & STEEL Commodity Group Classification

Commodity Code Scheme	Commodity Codes in Iron and Steel (model ID # 8)
WCSC 5-digit	28100, 28200, 67090, 67120, 67130, 67140, 67150, 67200, 67300, 67400, 67500, 67600, 67700, 67800, 67900
WCSC 4-digit	1011, 3311, 3314-3319, 4011

TABLE 1B.2.10 – OTHERS Commodity Group Classification

Commodity Code Scheme	Commodity Codes in All Others (model ID # 9)
WCSC 5-digit	10, 15, 20, 30, 40, 51, 52, 55, 100, 1100, 1200, 1600, 1700, 2210, 2220, 2230, 2240, 2300, 2400, 2500, 3400, 3500, 3600, 3700, 4590, 5410, 5420, 5440, 5450, 5469, 5470, 5480, 5600, 5710, 5720, 5730, 5740, 5750, 5760, 5770, 5790, 5800, 5900, 6110, 6120, 6150, 6160, 6190, 6210, 6220, 7100, 7200, 7300, 7400, 7500, 9100, 9811-9814, 9840, 9850, 9860, 9891-9894, 9898, 9899, 11101, 11102, 11200, 12100, 12200, 21110, 21120, 21140, 21160, 21170, 21191, 21199, 21200, 23100, 24400, 24500, 24610, 24620, 24700, 24810, 24820, 24830, 24840, 24850, 24890, 25090, 25110, 25120, 25130, 25140, 25150, 25160, 25190, 26100, 26300, 26400, 26500, 26600, 64130, 64140, 64150, 64160, 64170, 64190, 64200, 65110, 65120, 65130, 65140, 65150, 65160, 65170, 65180, 65190, 65200, 65300, 65400, 65500, 65600, 65700, 65800, 65900, 66110, 66120, 66130, 66181-66183, 66200, 66310, 66320, 66330, 66350, 66370, 66380, 66390, 66400, 66500, 66600, 66700, 68100, 68200, 68300, 68400, 68500, 68600, 68700, 68900, 69000, 71100, 71200, 71300, 71400, 71600, 71800, 72000, 73100, 73300, 73500, 73710, 73720, 73730, 73740, 74120, 74130, 74140, 74150, 74170, 74180, 74190, 74200, 74300, 74400, 74500, 74600, 74700, 74800, 74900, 75000, 76000, 77000, 78100, 78200, 78300, 78400, 78510, 78520, 78530, 78610, 78620, 78630, 78680, 79100, 79200, 79300, 81000, 82000, 83000, 84000, 85110, 85120, 85130, 85140, 85150, 85170, 85190, 87000, 88000, 89100, 89200, 89300, 89400, 89500, 89600, 89700, 89800, 89900, 90000, 99910,
WCSC 4-digit	101, 121, 129, 131-134, 141, 151, 161, 191, 841, 861, 911, 912, 1911, 2011, 2012, 2014, 2015, 2021, 2022, 2031, 2034, 2039, 2061, 2062, 2081, 2091, 2092, 2094, 2095, 2099, 2111, 2211, 2212, 2311, 2411, 2413, 2414, 2416, 2421, 2431, 2491, 2511, 2611, 2621, 2631, 2691, 2711, 2823, 2951, 3011, 3111, 3211, 3241, 3251, 3271, 3281, 3291, 3312, 3321-3324, 3411, 3511, 3611, 3711, 3721, 3731, 3791, 3811, 3911, 4022, 4024, 4029, 4111, 4112, 4114-4117, 4119, 9999

For specification of the shipping plan, the model requires cost data in order to determine the least-cost equipment utilization required to satisfy the demand. In this cost calculation the model considers an inventory holding cost. However, this cost plays very little into the model's selection of the shipping plan. This is primarily because the variation in inventory holding costs between shipping plans is minimal. Commodities transported on the inland waterway are predominately bulk low-value commodities and the costs of the equipment, primarily the towboat, outweigh the inventory holding costs. The inventory cost is calculated as 8% of the commodity value annually. For example a 1,500 ton jumbo barge loaded with a commodity valued at $100 / ton would have an inventory holding cost of $12,000 annually, or $1.37 / hour (compared with a towboat costing $500 / hour). Additionally, since the inventory holding cost is based on the time in the barge, the only difference in this time between shipping plans comes from variations in the towboat type and tow-size speed calculations and in re-fleeting time. The commodity values used in the inventory holding cost calculation are shown in TABLE 1B.2.11. The commodity values are dated, however, a contract is underway to update these values. As noted, these values will play very little in calibration and validation of the movement shipping plans.

TABLE 1B.2.11 – Commodity Group Values

Commodity Group	Value $ / ton (1997 price level)	Holding Cost Factor	Density (lbs / cu.ft.)
1	$ 28.59	0.08	62.4
2	$ 238.42	0.08	58.0
3	$ 238.42	0.08	58.0
4	$ 10.31	0.08	58.0
5	$ 164.79	0.08	56.0
6	$ 346.68	0.08	58.0
7	$ 96.64	0.08	57.0
8	$ 357.15	0.08	53.0
9	$ 194.66	0.08	53.0

Additionally, there is a commodity density factor assigned to each commodity group. This density factor is used in an equation to determine the barge loading for each movement if a barge loading is not specified as input (see section 1B.5.1). The factor, expressed in pounds per cubic foot, relates the average density and loading characteristics of cargo in the commodity group to the density of water (62.4 pounds per cubic foot). The value specified is not the commodity density factor for the commodity itself, but represents a value used in calculating barge capacity. The capacity of a barge is a function of the density of the medium (water) displaced by the barge. This displacement depends on how high the cargo can be piled on the barge or on how tightly it can be packed to fully utilize the barge's usable draft. As a result, most bulk commodities should be specified with a density factor equal to the density of water (62.4 pounds per cubic foot). A slightly lower density factor is used for extremely light commodities or commodities with inefficient packing.

As will be discussed in section 1B.5.1, movement barge loadings are calculated externally and supplied as input to the model in the Upper Ohio Navigation Study analysis. As a result, the commodity density factors are not used.

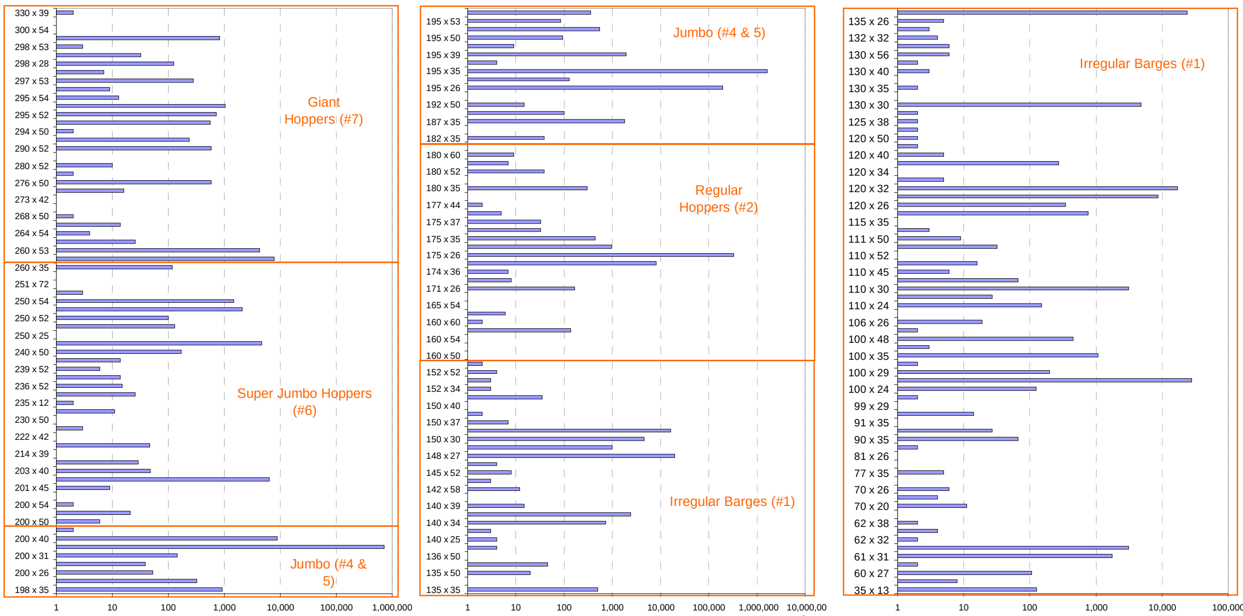
1B.2.3 Barge Type Specification and Aggregation

ORNIM allows for a barge type (with its own cost and movement characteristics) to be specified on each movement. In past efforts the reported WCSC barge trips by commodity group, vessel type (hopper or tanker), length, and width were used to develop distributions of barge dimension by commodity and river in order to determine the modeling barge types. Barge types clustered into primarily twelve barge types between the nine commodity groups. Although LPMS barge types are generalized, loaded barge counts by navigation project were developed and then compared against LPMS statistics.

For the current effort, 2000-2007 ORS WCSC data were summarized to verify the barge groupings remained valid. The 209 unique vessel type 4 (hopper) barge length-widths were grouped into 7 hopper barge types as displayed in FIGURE 1B.2.3. The 286 unique vessel type 5 (tanker) barge length-widths were grouped into 5 tanker barge types as displayed in FIGURE 1B.2.4.

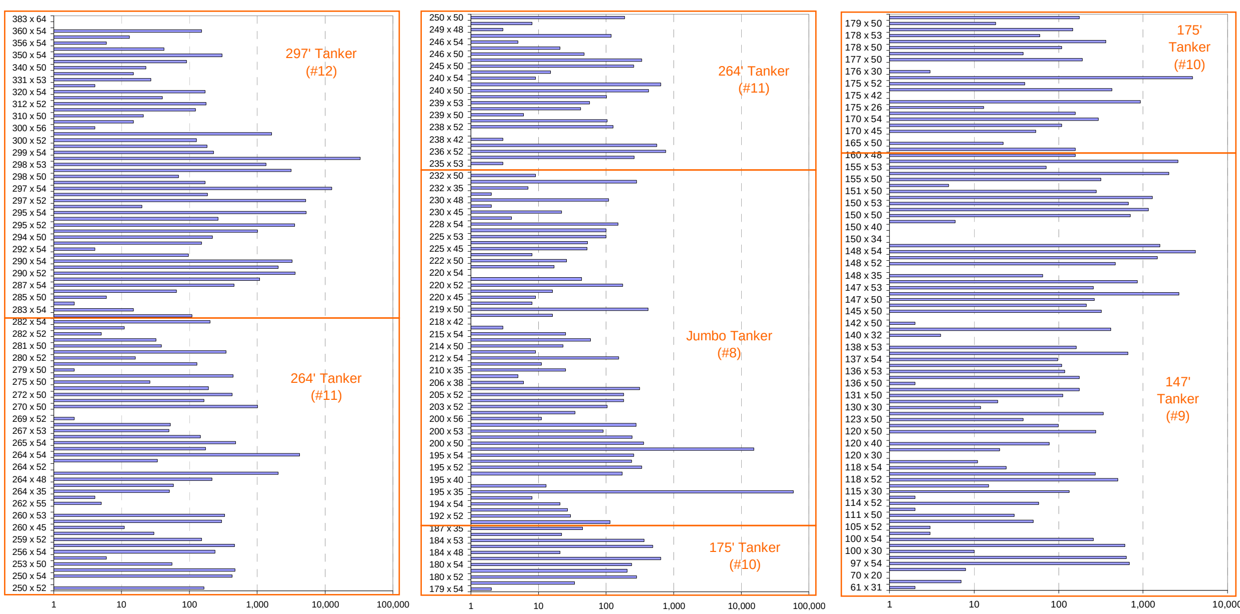
For these twelve barge types the summary data shown in TABLE 1B.2.12 were loaded into the model. The barge capacity, draft, and clearance data are a remnant of the barge loading calculations which are not currently used (since movement barge loading is summarized from the historic data). The blocking coefficient is used to calculate tow speed. Note that all barge types are set with the same blocking coefficient. The handling class allows specification of the loading and unloading rates at the loading and unloading ports (see section 1B.2.1.1).

FIGURE 1B.2.3 – ORS Barge Dimension Distribution Vessel Type 4 (Hoppers) 2000-2007



SOURCE: WCSC ORS data. Logarithmic scale.

FIGURE 1B.2.4 – ORS Barge Dimension Distribution Vessel Type 5 (Tankers) 2000-2007



SOURCE: WCSC ORS data. Logarithmic scale.

TABLE 1B.2.12 – Barge Type Data

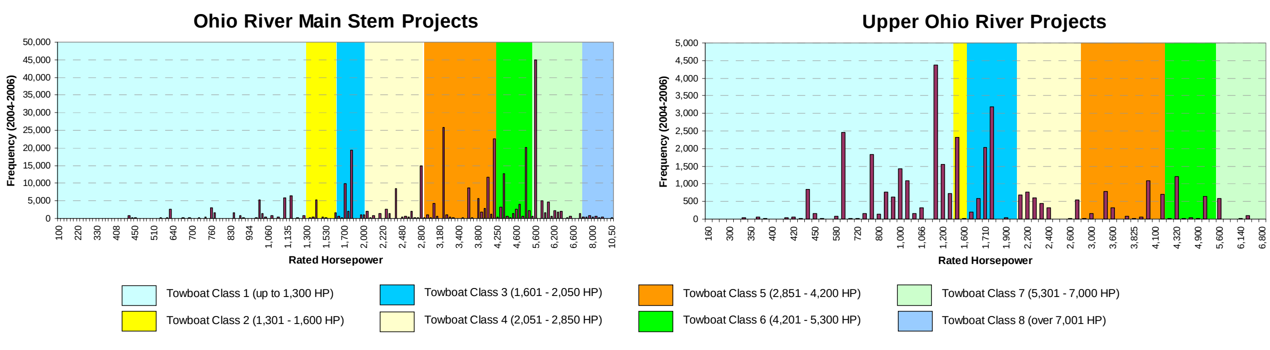
Barge Type	Handling Class *	Loading Capacity (tons)	Dimensions (ft) length	Dimensions (ft) beam	Draft (ft) Empty	Draft (ft) Loaded	Draft (ft) Maximum	Draft (ft) Clearance	Blocking Coefficient
Irregular Hopper	1	637	135	27	1.5	9.5	12	1	0.98
Regular Hopper	1	1,069	175	26	1.5	9.5	12	1	0.98
Stumbo	1	1,121	195	26	1.5	9.5	12	1	0.98
Jumbo Open Hopper	1	1,669	195	35	1.5	9.5	12	1	0.98
Jumbo Covered Hopper	1	1,764	195	35	1.5	9.5	12	1	0.98
Super Jumbo Hopper	1	2,106	245	35	1.5	9.5	12	1	0.98
Giant Hopper	1	3,329	260	52	1.5	9.5	12	1	0.98
Jumbo Tanker	3	1,454	195	35	1.5	9.5	12	1	0.98
147 ft Tanker	3	1,711	147	52	1.5	9.5	12	1	0.98
175 ft Tanker	3	2,317	175	54	1.5	9.5	12	1	0.98
264 ft Tanker	3	2,820	264	50	1.5	9.5	12	1	0.98
297 ft Tanker	3	3,295	297	54	1.5	9.5	12	1	0.98

** Handling class allows specification of different loading and unloading rates.*

1B.2.4 Towboat Class Specification and Aggregation

A major component in the model's calculation of waterway transportation costs is towboat cost. The towboat fleet is summarized into a user specified number of towboat classes, each with its own cost and usage characteristics. In the ORS, traditionally eight towboat classes have been used to describe the ORS towboat fleet. For the current effort, 2000-2006 ORS LPMS data were summarized to verify the towboat classes remained valid. As shown in FIGURE 1B.2.5, a finer granularity on small horsepower towboats is perhaps warranted in the Upper Ohio River region. Increasing the number of towboat classes would also increase model execution time. The need for increasing the granularity of the small horsepower classes would be more driven on cost variability between the small horsepower towboats and anticipated with-project fleet usage. Since there are minimal costs associated with operating a towboat, the cost variability between 500 – 1,300 horsepower is most likely minimal. In addition, under the with-project conditions considered in the Upper Ohio Navigation Study analysis, the towboat fleet usage will either remain constant, or shift toward the finer granularity higher horsepower towboat classes. As a result, the number of towboat classes was not increased.

FIGURE 1B.2.5 – Towboat Horsepower Frequency Distribution 2004-2006



SOURCE: LPMS, Coast Guard PSix, WCSC Master Vessel, and Inland River Record data.

For these eight towboat classes the summary data shown in TABLE 1B.2.13 were loaded into the model (also see sections 1B.2.9.1.10 and 1B.2.9.1.11). The dimensions, draft, blocking coefficient, and shaft horsepower are used in the speed calculation(s)[3]. The fuel consumption rates are used to calculate trip

[3] *There are actually two different speed functions coded in the model. Currently the original TCM calculation is used because the newer Maynord calculations are too CPU intensive.*

fuel consumption and hence trip fuel costs. The maximum tow-size limits the number of barges allowed in the shipping plan for each towboat class.

TABLE 1B.2.13 – Towboat Class Data

Towboat Type (rated HP)	Shaft Horse-power	Dimensions (ft)			Blocking Coefficient	Fuel Consumption Rates (gallons per hour)					Maximum Tow-size (# barges)
						Operating / Line-Haul Rates					
						Loaded Tow		Empty Tow		Maneuvering Rate	
		length	beam	draft		Up	Down	Up	Down		
1200 BHP Towboat	1,020	82	24	5.7	0.75	43.0	43.0	43.0	43.0	25.0	4
1400 BHP Towboat	1,190	98	29	7.2	0.75	50.0	50.0	50.0	50.0	29.0	6
1800 BHP Towboat	1,530	115	30	8	0.75	64.0	64.0	64.0	64.0	37.0	9
2300 BHP Towboat	2,185	131	31	8	0.75	91.0	91.0	91.0	91.0	53.0	11
3400 BHP Towboat	3,230	141	35	7.8	0.75	135.0	135.0	135.0	135.0	79.0	14
5000 BHP Towboat	4,750	146	38	7.9	0.75	198.0	198.0	198.0	198.0	115.0	15
5600 BHP Towboat	5,320	162	42	8	0.75	222.0	222.0	222.0	222.0	129.0	25
8400 BHP Towboat	7,980	170	45	8.9	0.75	333.0	333.0	333.0	333.0	194.0	30

1B.2.5 Equipment Costs

For comparison and selection of the least-cost movement shipping plans, the model requires cost data. As such, the equipment costs are critical in the model's determination of towboat type, tow-sizes, re-fleeting points, and ultimately the number of tow trips to move the tonnage. The latest Corps Economic Guidance Memorandum on shallow-draft vessel costs is EGM05-04[4] which has costs at a FY2004 price level. Previously this cost data was processed into the twelve barge types and eight towboat horsepower classes needed for loading into ORNIM. For this calibration effort this FY2004 cost data was indexed to a FY2004-2006 price level, as shown in TABLE 1B.2.14 and TABLE 1B.2.15, and discussed in the sections to follow.

TABLE 1B.2.14 – Barge Cost Data (FY2004-2006 Price Level)

Cost Category	Barge Type											
	Deck (130x35)	Regular Open (175x26)	Stumbo Open (195x26)	Jumbo Open (195x35)	Jumbo Covered (195x35)	Super Jumbo (245x35)	Giant (260x52)	Jumbo (195x35)	147' (147x52)	175' (175x54)	264' (264x50)	297' (297x54)
FIXED COSTS:												
Replacement Cost	$ 196,682	$ 177,591	$ 197,886	$ 289,550	$ 332,965	$ 363,793	$ 579,098	$ 791,059	$ 870,495	$1,041,242	$1,384,476	$1,630,144
Utilization (days)	350	350	350	350	350	350	350	340	340	340	340	340
CRF 5.375% 20 yrs	$ 16,288	$ 14,707	$ 16,388	$ 23,979	$ 27,574	$ 30,127	$ 47,957	$ 65,510	$ 72,089	$ 86,229	$ 114,654	$ 134,998
Administration	$ 478	$ 2,616	$ 3,137	$ 4,226	$ 4,421	$ 4,226	$ 4,226	$ 9,022	$ 9,841	$ 11,602	$ 15,151	$ 10,006
Fixed Annual Capital Costs	$ 16,766	$ 17,323	$ 19,524	$ 28,204	$ 31,995	$ 34,353	$ 52,183	$ 74,532	$ 81,930	$ 97,831	$ 129,805	$ 145,004
VARIABLE COSTS:												
Maintenance & Repairs	$ 1,791	$ 2,145	$ 2,576	$ 3,466	$ 3,708	$ 4,356	$ 6,932	$ 15,390	$ 16,926	$ 20,226	$ 26,846	$ 31,554
Supplies	$ -	$ 228	$ 271	$ 365	$ 1,024	$ 459	$ 731	$ 545	$ 573	$ 633	$ 752	$ 836
Insurance	$ 673	$ 937	$ 1,125	$ 1,512	$ 1,248	$ 1,899	$ 3,025	$ 7,040	$ 8,301	$ 11,113	$ 17,111	$ 21,601
Other	$ 897	$ 239	$ 286	$ 387	$ 1,295	$ 485	$ 774	$ 6,667	$ 6,878	$ 7,324	$ 8,221	$ 8,864
Annual Variable Costs:	$ 3,361	$ 3,549	$ 4,258	$ 5,731	$ 7,276	$ 7,200	$ 11,462	$ 29,642	$ 32,679	$ 39,297	$ 52,930	$ 62,855
Total Annual Costs:	$ 20,127	$ 20,872	$ 23,783	$ 33,935	$ 39,271	$ 41,553	$ 63,645	$ 104,174	$ 114,608	$ 137,127	$ 182,734	$ 207,859
HOURLY COSTS:												
Hourly Fixed Costs:	$ 2.00	$ 2.06	$ 2.32	$ 3.36	$ 3.81	$ 4.09	$ 6.21	$ 9.13	$ 10.04	$ 11.99	$ 15.91	$ 17.77
Hourly Variable Costs:	$ 0.40	$ 0.42	$ 0.51	$ 0.68	$ 0.87	$ 0.86	$ 1.36	$ 3.63	$ 4.00	$ 4.82	$ 6.49	$ 7.70
Avg. Hourly Costs:	$ 2.40	$ 2.48	$ 2.83	$ 4.04	$ 4.68	$ 4.95	$ 7.58	$ 12.77	$ 14.05	$ 16.80	$ 22.39	$ 25.47

SOURCE: EGM05-06 FY 2004 Shallow Draft Vessel Costs indexed to CY 2004-2006 using averaged BLS CPI Inflation Calculator and averaged FY 2004-2006 Federal Discount Rate of 5.375%.

The fuel costs shown in TABLE 1B.2.15 are for information only. The annual fuel costs are calculated based on one gallon per horsepower per day. The hourly fuel costs are based on fuel consumption equations defined in the EGM. Neither fuel consumption equation is used in ORNIM. Instead, ORNIM

[4] *FY 2006 Shallow-draft vessel costs were completed but have yet to be finalized into an EGM.*

calculates fuel consumption on a movement basis using the fuel consumption rates shown in TABLE 1B.2.13 and based on movement trip time (differentiated between maneuvering and line-haul time).

1B.2.5.1 Equipment Base Cost

Here the base costs refer to the basic fixed and variable costs such as equipment replacement cost, wages, maintenance, etc. To adjust the costs a 2004-2006 indexed was averaged using the BLS CPI Inflation Calculator. The Inflation Calculator showed an index of 1.0672 from 2004 to 2006, an index of 1.0339 from 2004 to 2005, and by definition the index for 2004 to 2004 is 1.000 (i.e. 2004 required no indexing). As a result, the index applied to the FY2004 costs to estimate the costs at an average 2004-2006 price level was 1.0337; a 3.37% escalation in cost.

1B.2.5.2 Equipment Capital Return

Equipment capitalization and return on investment are calculated with an interest rate (typically the project evaluation and formulation Federal Discount rate. E.G. EGM 09-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2009) amortized over the equipment life (i.e., 20-years). To adjust the capitalization and return on investment costs to a 2004-2006 price level, an averaged FY2004-2006 Federal Discount Rate was used. With discount rates of 5.625%, 5.375%, and 5.125% for FY 2004, FY2005, and FY2006, the average Federal Discount Rate used was 5.375%.

TABLE 1B.2.15 – Towboat Cost Data (FY2004-2006 Price Level)

	Towboat Horsepower							
Cost Category	1200	1400	1800	2300	3400	5000	5600	8400
FIXED COSTS:								
Replacement Cost	$ 1,321,793	$ 1,687,253	$ 2,174,533	$ 2,661,812	$ 3,636,371	$ 5,768,219	$ 6,560,048	$ 10,275,555
Utilization (days)	340	340	340	340	340	340	340	340
Crew Size	5	5	6	6	7	8	9	10
CRF 5.375% 20 yrs	$ 109,463	$ 139,728	$ 180,081	$ 220,434	$ 301,141	$ 477,687	$ 543,262	$ 850,956
Administration	$ 75,047	$ 80,554	$ 87,893	$ 95,231	$ 109,908	$ 142,017	$ 153,942	$ 209,901
Fixed Annual Capital Costs:	$ 184,509	$ 220,282	$ 267,974	$ 315,665	$ 411,049	$ 619,704	$ 697,204	$ 1,060,857
VARIABLE COSTS:								
Wages	$ 302,050	$ 328,392	$ 363,517	$ 398,596	$ 468,887	$ 622,553	$ 679,628	$ 947,446
Fringe Benefits	$ 71,539	$ 77,778	$ 86,097	$ 94,416	$ 111,054	$ 147,447	$ 160,964	$ 224,395
Food & Subsistence	$ 15,896	$ 17,285	$ 19,133	$ 20,982	$ 24,679	$ 32,766	$ 35,771	$ 49,865
Trans. (to and from vessel)	$ 7,950	$ 8,642	$ 9,567	$ 10,491	$ 12,340	$ 16,383	$ 17,886	$ 28,282
Maintenance and Repairs	$ 120,824	$ 126,764	$ 134,682	$ 142,604	$ 158,441	$ 193,089	$ 205,958	$ 295,056
Supplies	$ 38,755	$ 40,660	$ 43,201	$ 45,739	$ 50,821	$ 61,936	$ 66,064	$ 94,641
Insurance	$ 45,595	$ 47,837	$ 50,824	$ 53,812	$ 59,790	$ 72,864	$ 77,721	$ 111,342
Other	$ 22,796	$ 23,917	$ 25,410	$ 26,908	$ 29,895	$ 36,432	$ 38,861	$ 55,671
Annual Variable Costs:	$ 625,405	$ 671,274	$ 732,431	$ 793,546	$ 915,907	$ 1,183,472	$ 1,282,853	$ 1,806,698
Total Annual Costs (less fuel)	$ 809,915	$ 891,556	$ 1,000,405	$ 1,109,212	$ 1,326,956	$ 1,803,176	$ 1,980,057	$ 2,867,555
Annual Fuel Costs ($1.712 / gal)	$ 698,349	$ 814,740	$ 1,047,523	$ 1,338,502	$ 1,978,655	$ 2,909,786	$ 3,258,960	$ 4,888,441
Annual Fuel (Waterway)Tax ($0.2 / gal)	$ 81,600	$ 95,200	$ 122,400	$ 156,400	$ 231,200	$ 340,000	$ 380,800	$ 571,200
Deficit Reduction Tax ($0.043 / gal)	$ 17,544	$ 20,468	$ 26,316	$ 33,626	$ 49,708	$ 73,100	$ 81,872	$ 122,808
Total Annual Costs (with fuel)	$ 1,607,407	$ 1,821,964	$ 2,196,644	$ 2,637,739	$ 3,586,518	$ 5,126,062	$ 5,701,689	$ 8,450,004
per hour --->	$ 196.99	$ 223.28	$ 269.20	$ 323.25	$ 439.52	$ 628.19	$ 698.74	$ 1,035.54
HOURLY COSTS (340 days):								
Hourly fixed costs	$ 22.61	$ 27.00	$ 32.84	$ 38.68	$ 50.37	$ 75.94	$ 85.44	$ 130.01
Variable costs, Labour	$ 48.71	$ 52.95	$ 58.62	$ 64.28	$ 75.61	$ 100.39	$ 109.59	$ 153.18
Other	$ 27.94	$ 29.31	$ 31.14	$ 32.97	$ 36.64	$ 44.65	$ 47.62	$ 68.22
Avg. Hourly Costs less fuel	$ 99.25	$ 109.26	$ 122.60	$ 135.93	$ 162.62	$ 220.98	$ 242.65	$ 351.42
Hourly fuel costs	$ 97.81	$ 114.11	$ 146.72	$ 187.47	$ 277.13	$ 407.54	$ 456.45	$ 615.71
Avg. Hourly Cost	$ 197.06	$ 223.37	$ 269.31	$ 323.40	$ 439.75	$ 628.52	$ 699.10	$ 967.13

SOURCE: EGM05-06 FY 2004 Shallow Draft Vessel Costs indexed to CY 04-06 using averaged BLS CPI Inflation Calculator, averaged FY04-06 Federal Discount Rate of 5.375% and averaged EIA FY04-06 No.2 low sulfur diesel fuel cost.

1B.2.5.3 Towboat Fuel Cost

Price data were obtained from the United States Department of Energy (USDOE) Energy Information Administration. To derive a 2004-2006 average fuel cost, monthly U.S. No. 2 low sulfur diesel fuel prices[5] for Other End Users by All Sellers were averaged from October 2003 through September 2006. The average fuel price for this period was $1.7116 per gallon. Adding the $0.20 per gallon waterway fuel tax and the $0.043 per gallon deficit reduction tax yielded a total fuel price of $1.9546 per gallon. A complication in calculation of movement fuel cost is that the waterway fuel tax is not applicable to all waterways, and as a result an additional database table is needed to specify on which waterway segments to collect fuel tax on (see section 1B.2.9.1.4).

1B.2.5.4 Model Input

While the cost data shown in TABLE 1B.2.14 and TABLE 1B.2.15 are quite detailed, only a total fixed annual and total hourly variable cost are needed for each equipment type or class. Cost data entered into the database are shown in TABLE 1B.2.16. It should be noted that the fuel costs are not entered. ORNIM calculates fuel consumption and fuel cost on a movement basis based on a calculated movement trip time (differentiated between maneuvering and line-haul), the fuel consumption rates shown in TABLE 1B.2.13, the user specified fuel cost (i.e. $1.7116 / gallon), and user specified fuel taxes (i.e. $0.20 / gallon waterway fuel tax and $0.043 / gallon deficit reduction tax).

TABLE 1B.2.16 – Equipment Cost Data

Barge Type	Cost: Variable Operating ($ / hour)	Cost: Fixed Annual (000's)
Irregular Hopper	$ 0.400	$ 16.766
Regular Hopper	$ 0.423	$ 17.323
Stumbo	$ 0.507	$ 19.524
Jumbo Open Hopper	$ 0.682	$ 28.204
Jumbo Covered Hopper	$ 0.866	$ 31.995
Super Jumbo Hopper	$ 0.857	$ 34.353
Giant Hopper	$ 1.364	$ 52.183
Jumbo Tanker	$ 3.633	$ 74.532
147 ft Tanker	$ 4.005	$ 81.930
175 ft Tanker	$ 4.816	$ 97.831
264 ft Tanker	$ 6.486	$ 129.805
297 ft Tanker	$ 7.703	$ 145.004

Towboat Class	Cost: Hourly Costs: Labor Cost	Cost: Hourly Costs: Other Variable	Cost: Fixed Annual (000's)
1200 BHP Towboat	$ 48.705	$ 27.937	$ 184.509
1400 BHP Towboat	$ 52.953	$ 29.311	$ 220.282
1800 BHP Towboat	$ 58.617	$ 31.142	$ 267.974
2300 BHP Towboat	$ 64.275	$ 32.973	$ 315.665
3400 BHP Towboat	$ 75.608	$ 36.636	$ 411.049
5000 BHP Towboat	$ 100.386	$ 44.647	$ 619.704
5600 BHP Towboat	$ 109.589	$ 47.623	$ 697.204
8400 BHP Towboat	$ 153.185	$ 68.224	$ 1,060.857

1B.2.6 Movement Specification

Movement specification (i.e., origin, destination, commodity, barge type) is dictated by the network, commodity grouping, and barge type groupings discussed above. For the Upper Ohio analysis utilizing 1990-2007 WCSC data and the ORMSS-SIP five traffic forecast scenarios, 16,948 unique movements were needed to define the un-aggregated dock to dock ORS flows to the aggregated model network. A total of 3,480 movements of these flows transit one or more of the Upper Ohio River projects.

WCSC data which serve as the source of the model's movement data exist at a very detailed dock to dock, barge dimension, 5-digit commodity code level. The aggregation of this flow data not only requires aggregation of the origin and destination nodes, commodity groupings, barge types, and tonnages, but also requires weighted averaging of the rate data. Details of the data summarized and loaded into the model are discussed in Section 1B.2.9.2.

[5] *Conversion to ultra-low sulfur diesel (ULSD-15 ppm sulfur content) is expected to happen in 2010 after Exxon/Baton Rouge phases out their low sulfur production.*

1B.2.7 Movement Barge Loading Specification

As the movement specification is dictated by the network, commodity grouping, and barge type groupings, the movement barge loading specification is dictated by the movement specification discussed above (i.e., which location-dock to location-dock 5-digit commodity code shipments are included in each modeled movement). The model determines the number of loaded barges in the system by dividing each movement's annual tonnage by each movement's average barge loading. The average barge loading for each movement can either be calculated internally to the model or it can be calculated externally and specified as an input.

ORNIM's barge loading calculation, and calibration, is discussed in section 1B.5.1, however, for the Upper Ohio analysis the barge loadings were calculated externally to the model and supplied as an input. Since channel depths and barge loadings were not expected to change through the analysis period, or between the without and with-project conditions, externally calculating the barge loadings was the most straight forward and accurate method.

As the historic 1990-2007 WCSC data are aggregated from their detailed dock to dock levels to the model's network (section 1B.2.6), an average barge loading can also be tabulated. WCSC data include a "*trip*" field which is defined as the "*number of trips represented by one record*". The trip field is essentially equivalent to the number of barges, and the movement tonnage can be divided by the movement number of trips to determine an average barge loading. Potentially distorting this barge loading average are partial trips which are coded as zero trips.

Specification of movement barge loading was a two-step process. First, for each movement record, the sum of 1990 through 2007 tonnage was divided by the sum of 1990 through 2007 number of trips. Second, this observed average loading was compared against an ORS barge type average loading shown in TABLE 1B.2.17. If the observed average barge loading was outside of a specified range, the average barge loading for the movement was reset to the system average barge loading. For a tributary movement the acceptable average barge loading range was set from 10% to 150% of the system average barge loading. For example, say the system average jumbo barge loading is 1,618 tons. If the movement moved all or partially on a tributary and the observed average barge loading was less than 162 tons (0.10 x 1618) or more than 2,427 tons (1.50 x 1618), the average loading was re-set to 1,618 tons. For a non-tributary movement the acceptable average barge loading range was set from 80% to 200% of the system average barge loading. The distinction between tributary and non-tributary movements is due to lighter loading variability for movements transiting the smaller and shallower tributary sections and heavier loadings on the main stem Ohio.

TABLE 1B.2.17 – ORS Average Barge Loading by Barge Type

Barge ID	Barge Type Name	Typical Dimension (ft)	Coal	Petroleum	Crude Petroleum	Aggregates	Grains	Chemicals	Ores & Minerals	Iron & Steel	All Others
1	Irregular Barges	varies	934	578	*na*	453	1,276	739	507	428	284
2	Regular Hopper Barges	175' x 26'	960	938	*na*	1,070	1,562	1,562	800	974	789
3	Stumbo Hopper Barges	195' x 26'	1,106	1,103	*na*	1,025	*na*	1,126	1,040	1,073	1,074
4	Jumbo Open Hopper Barges		1,618	1,597	*na*	1,413	1,579	1,521	1,568	1,492	1,430
5	Jumbo Covered Hopper Barges		1,618	1,597	*na*	1,413	1,579	1,521	1,568	1,492	1,430
6	Super Jumbo Hopper Barges		2,143	1,443	*na*	2,202	1,727	1,955	1,662	1,619	2,026
7	Giant Hopper Barges		3,129	3,285	*na*	2,832	1,889	3,239	3,445	3,324	2,836
8	Jumbo Tanker Barges		1,543	1,363	1,554	1,656	1,547	1,409	1,619	1,496	1,388
9	147' Tanker Barges		*na*	1,521	1,250	1,241	*na*	1,645	*na*	*na*	1,420
10	175' Tanker Barges		*na*	1,850	1,814	1,502	*na*	1,542	767	*na*	1,413
11	264' Tanker Barges		*na*	2,430	2,797	486	1,315	2,280	*na*	*na*	1,933
12	297' Tanker Barges		*na*	3,044	2,751	*na*	1,570	3,061	3,217	*na*	3,081

SOURCE: 1990-2007 ORS WCSC data.

1B.2.8 Commonality of Upper Ohio Traffic Throughout the System

Determination of the areas of the Ohio River System that have the most in common with Upper Ohio traffic allows focus of model verification, calibration, and validation to areas that matter. There are two perspectives for quantifying the commonality of Upper Ohio traffic with the other river segments and navigation projects: 1) the amount or percentage of Upper Ohio traffic reaching these areas; and 2) the amount or percentage of Upper Ohio traffic transiting these areas. In other words, the distinction is the importance of these other areas to the Upper Ohio traffic versus the importance of Upper Ohio traffic to these other areas.

The majority of Upper Ohio River traffic is localized to the Ohio and Lower Monongahela Rivers as shown in TABLE 1B.2.18. For model verification, calibration, and validation the remaining sections will focus on the Ohio River and lower four projects on the Monongahela River.

TABLE 1B.2.18 – Upper Ohio Commonality of Traffic Throughout the System

River / Navigation Lock Project	Upper Ohio Tonnage			River / Navigation Lock Project	Upper Ohio Tonnage		
		Percentage				Percentage	
	Tonnage	Through	Of		Tonnage	Through	Of
OHIO RIVER				ALLEGHENY RIVER			
LOCK & DAM 53 (OHIO)	3,963,949	16%	5%	LOCK & DAM 2 SITE	1,042,448	4%	57%
LOCK & DAM 52 (OHIO)	3,973,472	16%	4%	LOCK & DAM 3 SITE	1,027,106	4%	57%
SMITHLAND L/D	4,704,867	19%	6%	LOCK & DAM 4 SITE	359,725	2%	37%
MYERS L/D	4,737,685	19%	6%	LOCK & DAM 5 SITE	124,552	1%	39%
NEWBURGH L/D	4,817,141	20%	7%	LOCK & DAM 6 SITE	33,031	0%	100%
CANNELTON L/D	4,861,945	20%	8%	LOCK & DAM 7 SITE	27,928	0%	100%
MCALPINE L/D	5,086,721	21%	9%	LOCK & DAM 8 SITE	-	*na*	*na*
MARKLAND L/D	6,161,907	25%	11%	LOCK & DAM 9 SITE	-	*na*	*na*
MELDAHL L/D	7,189,310	29%	12%				
GREENUP L/D	9,624,801	39%	13%	KANAWHA RIVER			
R.C. BYRD L/D	13,572,740	55%	22%	WINFIELD L/D	1,799,855	7%	9%
RACINE L&D	16,220,044	66%	30%	MARMET L&D	1,727,096	7%	11%
BELLEVILLE L&D	16,380,255	67%	30%	LONDON L&D	124,055	1%	9%
WILLOW ISLAND L&D	16,404,638	67%	32%				
HANNIBAL L&D	16,984,153	69%	32%	GREEN RIVER			
PIKE ISLAND L&D	19,371,647	79%	47%	GREEN RIVER L&D 1	1,538	0%	0%
NEW CUMBERLAND L&D	19,728,979	80%	59%	GREEN RIVER L&D 2	-	*na*	*na*
MONTGOMERY L&D	21,829,000	89%	100%				
DASHIELDS L&D	20,923,286	85%	100%	TENNESSEE & CUMBERLAND RIVERS			
EMSWORTH L&D	19,998,864	82%	100%	KENTUCKY L&D	660,516	3%	2%
				BARKLEY L&D	50,925	0%	3%
MONONGAHELA RIVER				CHEATHAM L&D	20,650	0%	0%
MON LOCK & DAM 2 L&D	16,882,226	69%	90%	OLD HICKORY L&D	-	*na*	*na*
MON LOCK & DAM 3 L&D	10,109,062	41%	80%	CORDELL HULL L&D	-	*na*	*na*
MON LOCK & DAM 4 L&D	7,923,603	32%	73%	PICKWICK L&D	85,268	0%	1%
MAXWELL L&D	5,409,969	22%	43%	WILSON L&D	69,038	0%	1%
GRAYS LANDING L&D	1,195,130	5%	30%	WHEELER L&D	69,038	0%	1%
POINT MARION L&D	1,180,543	5%	31%	GUNTERSVILLE L&D	38,863	0%	1%
MORGANTOWN L&D	170,631	1%	68%	NICKAJACK L&D	29,152	0%	1%
HILDEBRAND L&D	131,119	1%	62%	CHICKAMAUGA L&D	4,389	0%	0%
OPEKISKA L&D	131,119	1%	62%	WATTS BAR L&D	4,389	0%	0%
				MELTON HILL L&D	-	*na*	*na*
				FORT LOUDON L&D	467	0%	0%

SOURCE: 2004-2006 WCSC data.

1B.2.9 Loading the ORNIM Input Files

ORNIM data are stored in Microsoft Sequel Server database tables which can be grouped into six broad categories: 1) system network, infrastructure, and equipment characteristics; 2) movement characteristics; 3) system tax and fee characteristics; 4) reliability characteristics; 5) investment options; and 6) analysis summaries. This section is not a complete itemization of all model input, but only the loading of input pertinent to: 1) specification, verification, and validation of the WSDM least-cost shipping plans; and 2) adjustment of the calibrated shipping plans for future lock size and barge fleet changes.

1B.2.9.1 System Network, Infrastructure, and Equipment Characteristics

This category of data includes database tables describing: 1) the topology of the inland waterway network; 2) the characteristics of the system's constituent locks, ports, reaches, and other components that affect towing operations and costs; and 3) the characteristics and costs of towboat classes and barge types used for towing operations. The following eleven tables are used in the specification, verification, and validation of the WSDM least-cost shipping plans.

1B.2.9.1.1 NetworkDefinition and NetworkVersion Tables

ORNIM allows storage and analysis different networks for different river systems (TABLE 1B.2.19), and allows for storage and analysis of variations of each network (TABLE 1B.2.20).

TABLE 1B.2.19 – NetworkDefinition Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
networkName		Network name
baseYear		Year for base cost (e.g. 9999 equals 2004-2006 average)
comments		Additional description if necessary

TABLE 1B.2.20 – NetworkVersion Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Version ID (a variation of the network)
networkVersionName		Name
comments		Additional description if needed

The "*networkVersion*" is used to specify changes to the base network at a specified time in the planning period. These changes can occur from scheduled events such as a project already under construction being completed (e.g., Olmsted replacement of L/D 52 and 53) or from events being analyzed by the model (e.g., 2-for-3 replacement of the three Upper Ohio projects with two 1200' main chamber projects). Currently in the model the seven network versions shown in TABLE 1B.2.21 are defined, however, only network versions 1, 5, and 6 are currently used. Verification, calibration, and validation occurs using "*networkVersion*" 1. The use of network versions 5 and 6 will be covered in section 1B.6.1.

TABLE 1B.2.21 – Network Versions (NetworkVersion Table Data)

networkID	networkVersion	networkVersionName	comments
1	0	Existing	ORMSS-SIP
1	1	UpperOHExisting	UpperOH Existing 2008 infrastructure calibrated to year 9999 (2004-2006 av)
1	2	UpperOHJumbo600	UpperOH w/ regulars & stumbos changed to jumbos assuming 600' locks at all 3 locks
1	3	UpperOHJumbo800	UpperOH w/ regulars & stumbos changed to jumbos assuming 800' locks at all 3 locks
1	4	UpperOHJumbo1200	UpperOH w/ regulars & stumbos changed to jumbos assuming 1200' locks at all 3 locks
1	5	UpperOH800	UpperOH assuming 800' locks at all three
1	6	UpperOH1200	UpperOH assuming 1200' locks at all three

1B.2.9.1.2 NetworkVersionSelection Table

Since the applicable network version can change through time, the timing of the network version is specified in the "*NetworkVersionSelection*" table. For example, say "*networkVersion*" 1 represents the existing system and say no other projects (e.g., Olmsted) are coming online over the analysis period. The without-project condition would be analyzed over the analysis period using "*networkVersion*" 1. Say the with-project condition is replacement of all three Upper Ohio projects with 1200' main chambers, each coming online in different years. Say that given the high commonality of traffic between the three Upper Ohio River projects, shipping characteristics (i.e., tow-size) are not expected to change until all three 1200' main chambers are open. In this case, the with-project condition would use "*networkVersion*" 1 until the last 1200' chamber comes online, then "*networkVersion*" 6 (representing the system characteristics with all three 1200' main chambers on the Upper Ohio open) is used.

Again, in this verification, calibration, and validation exercise the model is exercised against a specific time period (in this case, an average of 2004 through 2006) and only one network version ("*networkVersion*" 1) is utilized.

1B.2.9.1.3 Rivers Table

A river in the model's waterway network (FIGURE 1B.2.1) is a sequential string of sectors that represent the river. For "*networkID*" 1 101 rivers have been defined and stored in the "*Rivers*" table. The primary use of the data stored in this table is to allow output data rollup for summary reports. The sixteen rivers that are in the ORS are shown in TABLE 1B.2.22.

TABLE 1B.2.22 – ORS Rivers

networkID	riverID	riverName	length
1	1	Monongahela	116.4
1	2	Allegheny	68.2
1	3	Ohio River	981.8
1	4	Kanawha	86.6
1	5	Green	87.3
1	6	Cumberland	358
1	7	Clinch	51.3
1	8	Tennessee	652.1
1	9	Ky/Brk Canal	1.5
1	23	Little Kanawha	4
1	24	Big Sandy	160.9
1	25	Kentucky	256.2
1	26	French Broad	2.7
1	27	Emory	5
1	28	Hiwassee	22
1	98	Licking River	0

1B.2.9.1.4 Sectors Table

A sector in the model's waterway network (FIGURE 1B.2.1) is a sequential string of links that represent that segment of the waterway system. For "*networkID*" 1 220 sectors have been defined and stored in the "*Sectors*" table. Data stored in this table are shown in TABLE 1B.2.23. As discussed in section 1B.2.5.3 the current waterway fuel tax is not applicable to all waterways. Under existing law (33 U.S.C. 1804), the fuel tax is collected on twenty-seven specified waterways. These fuel tax waterways are identified in the model through the "*collectFuelTax*" field in the "*Sectors*" table. Of the 220 sectors, twenty-two have been specified as non-tax waterways as shown in TABLE 1B.2.24.

TABLE 1B.2.23 – Sectors Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
sectorID	DB Key	Interger ID used as key in other database tables
sectorName		Text name used for output report labeling
riverID		Integer cross reference ID to the Rivers table
collectFuelTax		(TRUE or FALSE) does IWUB fuel tax apply to this water segment
waterwayCode		WCSC WTWY used for summary report generation

TABLE 1B.2.24 – Non-Fuel Tax Waterways

networkID	sectorID	sectorName	riverID	collectFuelTax	waterwayCode
1	32	KY/Bark. Canal	9	FALSE	2377
1	61	Clinch River	7	FALSE	2375
1	62	Clinch split	7	FALSE	2375
1	63	Little Kanawha	23	FALSE	2346
1	64	Big Sandy	24	FALSE	2345
1	65	Kaskaskia River	13	FALSE	2305
1	71	Yazoo	15	FALSE	2010
1	72	Yazoo R.	15	FALSE	2009
1	115	French Broad	26	FALSE	2374
1	116	Emory	27	FALSE	2379
1	117	Hiwassee	28	FALSE	2376
1	119	Chicago North	30	FALSE	3746
1	120	Chicago Main	30	FALSE	3747
1	137	Intcoast wwy alt rou	46	FALSE	2053
1	146	Mobile Bay	51	FALSE	2000
1	191	Lake Pontchartrain	80	FALSE	2050
1	192	Lake Pontchartrain	80	FALSE	2050
1	194	Inner Harbor	82	FALSE	2052
1	195	Mississippi Gulf Out	83	FALSE	2060
1	217	Licking	98	FALSE	2340
1	219	Lake Michigan	100	FALSE	3701
1	220	Black (Wis)	101	FALSE	2322

1B.2.9.1.5 Locks Table

ORNIM allows specification and storage of the navigation projects in the system network through the "*Locks*" table. Data stored in this table are shown in TABLE 1B.2.25. Primarily the table allows specification of a "*lockID*" for each project that can then be referenced as a key in other database tables where project specific data is stored. A text name and GIS coordinates are specified to facilitate report labeling and mapping. Additionally, for the auto shipping plan calibration programs (section 1B.5.3.5), a "*calibrationWeight*" field is specified for each lock in the system network. This lock calibration weight allows the calibration process to focus on projects important to the analysis (as specified by the user). For this Upper Ohio analysis, the twenty Ohio River and the four lower Monongahela River projects were set with lock calibration weights of 1.0, while the remaining thirty-two projects were set with a weight of 0.10. These settings were selected based on an analysis of Upper Ohio River traffic flow commonality as discussed in section 1B.2.8.

TABLE 1B.2.25 – Locks Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
lockID	DB Key	Interger ID used as key in other database tables
lockName		Text name used for output report labeling
displayLockName		Text name used for output report labeling
lockGroup		Used to consolidate calibration statistics (i.e. Kentucky & Barkley L/Ds)
calibrationWeight		Used to identify primary projects for calibration
latitude		Latitude decimal degrees (used for display maps)
longitude		Longitude decimal degrees (used for display maps)
mainChamberLength		Main chamber length (ft) for output report labeling
mainChamberWidth		Main chamber width (ft) for output report labeling
auxChamberLength		Auxiliary chamber length (ft) for output report labeling
auxChamberWidth		Auxiliary chamber width (ft) for output report labeling

1B.2.9.1.6 Junctions Table

Junctions in the model's waterway network (FIGURE 1B.2.1) define sector endpoints, that is, the head and mouth of a river and points where tributaries enter the river. For networkID 1 213 junctions have been defined and stored in the "*Junctions*" table. Data stored in this table are shown in TABLE 1B.2.26.

TABLE 1B.2.26 – Junction Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
junctionID	DB Key	Unique integer junction ID used as key in other database tables
junctionName		Text name used for output report labeling
latitude		Latitude decimal degrees coordinate used for display maps
longitude		Longitude decimal degrees coordinate used for display maps

1B.2.9.1.7 Ports and PortsRefleeting Tables

Ports in the model's waterway network (FIGURE 1B.2.1) define the traffic pickup and drop-off nodes in the link-node network. For "*networkID*" 1 171 ports have been defined and stored in the "*Ports*" table. Data stored in this table are shown in TABLE 1B.2.27. Additional discussion on the port parameters can be found in section 1B.2.1.1.

TABLE 1B.2.27 – Ports Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
portID	DB Key	Unique integer port ID used as key in other database tables
portName		Text name used for output report labeling
latitude		Latitude decimal degrees coordinate used for display maps
longitude		Longitude decimal degrees coordinate used for display maps
fleetTimePerTow		Time per tow to fleet barges to towboat
fleetTimePerBarge		Time per barge to fleet into tow (minutes)
loadRate1		Cargo handling class 1 load rate in minutes per ton
loadRate2		Cargo handling class 2 load rate in minutes per ton
loadRate3		Cargo handling class 3 load rate in minutes per ton
unloadRate1		Cargo handling class 1 unload rate in minutes per ton
unloadRate2		Cargo handling class 2 unload rate in minutes per ton
unloadRate3		Cargo handling class 3 unload rate in minutes per ton
portDelay1		Cargo handling class 1 port delay time in hours per tow
portDelay2		Cargo handling class 2 port delay time in hours per tow
portDelay3		Cargo handling class 3 port delay time in hours per tow
towboatWaitTime		Av. Hours barges wait for towboat pickup once loaded (hours)

These traffic pickup and drop-off nodes are not always the ultimate waterside origin and destination for the traffic flows; the movement might simply re-fleet (switch towboats or re-group into a different tow-size). The definition of which ports allow this re-fleeting operation is handled in a separate "*PortsRefleeting*" table as shown in TABLE 1B.2.28. This is done in a separate table so that the assumptions regarding the re-fleeting points can be changed in an analysis without changing (or duplicating) the underlying port node definitions. As a result, the "*PortsRefleeting*" table contains a "*networkVersion*" ID while the "*Ports*" table does not.

TABLE 1B.2.28 – PortsRefleeting Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion		Network version (1 = existing, 2 = 1200' UpperOH main chambers)
portID		Movement portID (Ports table) where re-fleeting is considered

1B.2.9.1.8 Links Table

Links in the model's waterway network (FIGURE 1B.2.1) define the continuous stretches of waterway between the various types of nodes (e.g., ports and locks). For networkID 1 896 links have been defined and stored in the "*Links*" table. Data stored in this table are shown in TABLE 1B.2.29.

TABLE 1B.2.29 – Links Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
sectorID		Sector ID (from Sectors table)
linkIndex		Link ID (sequentially numbered 1,n within each Sector)
upNodeType		Upstream node type (B=bend , J= junction ,L=lock , or P=port)
upNodeID		Upstream node ID (note, node types B, J, L, and P can all be defined with the same node ID)
downNodeType		Downstream node type (B=bend , J= junction ,L=lock , or P=port)
downNodeID		Downstream node ID (note, node types B, J, L, and P can all be defined with the same node ID)
length		Length in miles of the river segment (link).
currentSpeed		Speed of current (mph).
avgDepth		Average depth of the link in feet (used in speed function).
minDepth		Minimum depth of the link in feet (used in barge loading calculation).
upSpeedCoefficient		Upbound speed coefficient (used in speed function).
downSpeedCoefficient		Downbound speed coefficient (used in speed function).

It can be noted that a node types ("*upNodeType*" and "*downNodeType*") are related to network nodes ("*upNodeID*" and "*downNodeID*") in this table since a node can be defined with multiple attributes. For example, the end of a river is often defined as a port where traffic can be loaded or unloaded and also as a junction representing the end of the sector. In this case, a port node and a junction node would be defined, and the distance between them would be set to 0. River junctions offer an additional example. At a river junction, often traffic can be picked up or dropped off (loaded, unloaded, or re-fleeted) and three sectors merge.

Most of the parameters defined in the "*Links*" table relate to the tow speed and trip time calculations discussed in section 1B.4, which ultimately influence the shipping plan selection.

1B.2.9.1.9 BargeTypes and BargeTypeCost Tables

The "*BargeTypes*" and the "*BargeTypeCost*" tables (TABLE 1B.2.30 and TABLE 1B.2.31) hold the data discussed in section 1B.2.3 (TABLE 1B.2.12).

1B.2.9.1.10 TowboatType and TowboatTypeCost Tables

The towboat class data presented in TABLE 1B.2.13 are loaded into the "*TowboatType*" table shown in TABLE 1B.2.32. The towboat cost data presented in TABLE 1B.2.15 are loaded into the "*TowboatTypeCost*" table shown in TABLE 1B.2.33. The "*beginYear*" field allows storage and use of different cost data, primarily for calibration to different years. Year "*9999*" was used to signify the 2004-2006 average.

TABLE 1B.2.30 – BargeTypes Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
bargeTypeID		Unique barge ID used as key in other database tables
bargeTypeName		Text name used for output report labeling
handlingClassCode		
capacity		
length		Typical barge in class length in feet
beam		Typical barge in class width in feet
emptyDraft		Typical barge in class empty draft in feet
loadedDraft		Typical barge in class fully loaded draft in feet
maxDraft		
clearance		
blockCoefficient		ratio of volume to length, width, & draft.
availability		fraction of time available for hauling

TABLE 1B.2.31 – BargeTypeCost Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
bargeTypeID		Unique barge ID from BargeTypes table
beginYear		First year cost is to be applied
varOpCost		Variable operating cost per hour (dollars)
fixedCost		Fixed annual cost (dollars)

TABLE 1B.2.32 – TowboatType Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
towboatTypeID		Network version (1 = existing, 2 = 1200' UpperOH main chambers)
towboatTypeName		Text name used for output report labeling
ratedHorsepower		Rated horsepower of the towboat class
horsepower		Nominal hp reflecting hp delivered to the prop.
maxTowSize		Maximum no. of barges that can be pushed by the towboat class
length		Overall vessel length (feet)
beam		Overall vessel width (feet)
draft		Overall vessel draft (feet)
blockCoeffieient		Ratio of the vol of the hull to the product of the vessel length, width, & draft.
opFuelRate		Operating (line-haul) fuel consumption rate (gallons per hour)
opFuelRateUpLoaded		Operating up-bound loaded barge(s) tow fuel consumption rate (gallons per hour)
opFuelRateDownLoaded		Operating down-bound loaded barge(s) tow fuel consumption rate (gallons per hour)
opFuelRateUpEmpty		Operating up-bound empty barge(s) tow fuel consumption rate (gallons per hour)
opFuelRateDownEmpty		Operating down-bound empty barge(s) tow fuel consumption rate (gallons per hour)
manFuelRate		Maneuvering fuel consumption rate (gallons per hour)
availability		Proportion of year equipment class is available for towing service
propDiameter		Propeller diameter (inches) used for NAVPAT file generation.
propPitch		Propeller pitch (degrees-) used for NAVPAT file generation.
percentageKort		Proportion of vessels in class with kort nozzles (0-1.0)
upboundLoadedRPM		Av. Up-bound loaded barge(s) tow propeller RPM
upboundEmptyRPM		Av. Up-bound empty barge(s) tow propeller RPM
downboundLoadedRPM		Av. Down-bound loaded barge(s) tow propeller RPM
downboundEmptyRPM		Av. Down-bound empty barge(s) tow propeller RPM

TABLE 1B.2.33 – TowboatTypeCost Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
towboatTypeID	DB Key	Towboat Type ID (from BargeTypes table)
beginYear	DB Key	first year that the cost is in effect
laborCost		Labor cost ($/hour)
otherVarCost		Other variable costs ($/hour)
fixed Cost		Annual fixed costs

1B.2.9.1.11 FuelCost Table

Fuel costs discussed in section 1B.2.5.3 are loaded into the "*FuelCost*" table as shown in TABLE 1B.2.34. ORNIM allows storage and analysis of different fuel costs by networkID by year. For this validation of the WSDM least-cost shipping plans, the existing ORS network (i.e., networkVersion 1) is utilized along with the average 2004 through 2006 No. 2 low sulfur diesel fuel price. The "*beginYear*" and "*endYear*" fields allow specification of fuel costs to a specific year or years. Year "*9999*" was used to signify the 2004-2006 average.

TABLE 1B.2.34 – FuelCost Table Description

Database Field	DB Key	Description	Value
networkID	DB Key	River system network (1 = existing ORS)	1
beginYear	DB Key	first year that the price is in effect	9999
endYear		last year that the price is in effect	9999
fuelCost		cents per gallon fuel cost (no tax)	171.1639

1B.2.9.1.12 TowSizeLimits Table

A component of the movement shipping plans is the movement tow-size(s). If movement tow-sizes were set based solely on the physical limitations of the river and equipment, WSDM would tend to produce shipping plans with larger tows than historically observed, since WSDM calculates the resources required to satisfy the demand on a least-cost basis. To account for other factors that are considered in determining the shipping plan tow-size, the model contains a barge type tow-size limit calibration parameter that is specified at a river segment level (rather than at the movement level) and stored in the "*TowSizeLimits*" table as shown in TABLE 1B.2.35. When the model develops a shipping plan for a movement, it considers all the river segment restrictions in its route (i.e., the minimum of "*maxTowSize*" along the route), along with the towboat class specific characteristics (e.g., "*maxTowSize*" in TABLE 1B.2.32).

TABLE 1B.2.35 – TowSizeLimits Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
sectorID	DB Key	Sector ID (from Sectors table)
linkIndex	DB Key	Link ID (from Links table, 0 specifies Sector level specification)
bargeTypeID	DB Key	Barge Type ID (from BargeTypes table)
maxTowSize		Calibration maximum tow-size in/out/thru the link (number of barges per tow)
limitTowSize		Maximum tow-size in/out/thru the link (number of barges per tow)

As discussed, river segments in the model network are defined as rivers, sectors, nodes, and links (FIGURE 1B.2.1). The tow-size limits and towboat class efficiency factors are specified at the link level, however, a sector level setting can be specified. The "*linkIndex*" corresponds to the link ID specified in the "*Links*" table (TABLE 1B.2.29). When "*linkIndex*" is set to zero, however, the parameters are used for all links within that sector except for any link specific records which will override any sector level specification.

While the river segment tow-size limits can be manually set and adjusted by the user, an automated calibration programs called the Sector Tow-size Limits Calibrator was developed (see section 1B.5.3). The user, or the Sector Tow-size Limits Calibrator, adjusts the "*maxTowSize*" field in the "*TowSizeLimits*" table. The "*limitTowSize*" parameter provides an upper boundary for the "*maxTowSize*" field. The "*limitTowSize*" field is loaded by the user and is determined by calculating the maximum tow-size for the projects upstream and downstream from the river segment assuming a homogeneous barge type tow. For example, a river segment bounded by 1200' x 110' main chambers would have a "*limitTowSize*" for jumbo barges (195' x 35') of 17 barges per tow; 1,170' long by 105' wide in a knockout configuration with enough room for the towboat in the sixth row of barges.

The "*maxTowSize*" is calibrated by the model to observed data (i.e., 2004-2006 average targets). To develop shipping plans with a system containing larger lock chambers, these "maxTowSize" parameters are adjusted (see section 1B.6.1).

When an investment option increases (or decreases) chamber size, a separate "*networkVersionID*" is set up with the appropriate "*maxTowSize*" adjustments (see section 1B.6.1). To minimize the duplication of data, only the changes need specification under the new "*networkVersionID*", all other limits revert to the base network version (i.e., "*networkVersion*" 1).

1B.2.9.1.13 TowboatUtilization Table

Not only is the tow-size a major component of the movement shipping plans, but so also is the towboat class utilized to move the barges. The towboat cost is the major cost component of the waterway shipment. If movement towboat types were chosen based solely on the physical capability of the equipment, WSDM would tend to produce tows with smallest towboat that could move the barges (i.e., the "*maxTowSize*" in the "*TowboatTypes*" table). This typically produces utilization of smaller towboats than historically observed, since WSDM calculates the resources required to satisfy the demand on a least-cost basis. To account for other factors that play into the shipping plan towboat class selection, the model contains a towboat efficiency calibration parameter that is specified at a river segment level (rather than at the movement level) and stored in the "*TowboatUtilization*" table as shown in TABLE 1B.2.36. When the model develops a shipping plan for a movement, it considers all of the towboat class specific characteristics including the maximum towboat tow-size and the towboat efficiency factor. Specifically the towboat efficiency factors for each river segment are multiplied by the towboat class maximum tow-size (TABLE 1B.2.35) to develop the river segment tow-size limits by towboat class.

TABLE 1B.2.36 – TowboatUtilization Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
sectorID	DB Key	Sector ID (from Sectors table)
linkIndex	DB Key	Link ID (from Links table, 0 specifies Sector level specification)
towboatTypeID	DB Key	Towboat Type ID (from TowboatTypes table)
capUtilFactor		proportion of the towboat's capability that can be utilized on the link

Like the tow-size limits, the towboat class efficiency factors are specified at the link level, however, sector level settings can be specified. The "*linkIndex*" corresponds to the link ID specified in the "*Links*" table

(TABLE 1B.2.29). When "*linkIndex*" is set to zero, however, the parameters are used for all links within that sector except for any link specific records which will override any sector level specification.

While the river segment towboat efficiency limits can be manually set and adjusted by the user, an automated calibration programs called the Sector Towboat Efficiency Factor Calibrator was developed (see section **1B.5.3**). The user, or the Sector Towboat Efficiency Factor Calibrator, adjusts the "*capUtilFactor*" field in the "*TowboatUtilization*" table. The "*capUtilFactor*" parameter specifies the proportion of the towboat class capability that can be utilized on the specified link. For example, say the "*capUtilFactor*" is 0.50 on a given link for "*towboatTypeID*" 5 (3,400 BHP). As shown in TABLE 1B.2.13, the maximum tow-size is 14 barges per tow. As a result, with a "*capUtilFactor*" of 0.50 the towboat would only be allowed to move up to a 7 barge tow through this link.

As with the "*TowSizeLimits*" table, a separate "*networkVersionID*" can be set up with the "*capUtilFactor*" adjustments. Again, to minimize the duplication of data, only the changes need specification under the new "*networkVersionID*"; all other utilization factors revert to the base network version (i.e., "*networkVersion*" 1). Typically, in adjusting the shipping-plans to a different chamber size the towboat utilization factors are not adjusted (only the tow-size limits are adjusted). Discussion of the large lock fleet adjustments can be found in section 1B.6.1.

1B.2.9.2 Movement Characteristics

This category of data includes database tables describing shipment data specifying the origin, destination, commodity group, annual tonnage (historic and forecasted), barge type, barge loading, willingness-to-pay, river closure response, and river closure response externality cost of existing and projected port-to-port commodity movements.

1B.2.9.2.1 CommodityTypes Table

The commodity types and costs discussed in section 1B.2.2 (TABLE 1B.2.11) are loaded into the "*CommodityTypes*" table as shown in TABLE 1B.2.37. The data is stored at a "*networkID*" level.

TABLE 1B.2.37 – CommodityTypes Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
commodityID	DB Key	Unique commodity ID
commodityName		Commodity Name
value		Commodity value in $/ton (for inventory holding cost calculation)
holdingCostFactor		Percent of commodity value to charge as holding cost
density		Commodity density in lbs per cubic foot
displayColor		Color to use for output graphs
comments		Additional description if needed

1B.2.9.2.2 Movement Classification Tables

The movement data discussed in section 1B.2.6 are defined through multiple database tables. Not only does the model's database structure allow for storage and use of various waterway networks and variations of each network, the model also allows for storage and use of multiple forecasted demand scenarios as well as variations of each of these defined forecasted demand scenarios.

1B.2.9.2.2.1 Forecast Table

The forecasted demand scenarios are defined in the "*Forecast*" table shown in TABLE 1B.2.38. As shown in TABLE 1B.2.39, the database contains definitions for eight forecast scenarios: the five older ORMSS-SIP forecast scenarios and the three updated forecast scenarios. The "*forecastID*" of 0 is used to identify historic (observed) data in the database. The annual tonnage is stored by calendar year, but in the case of the historic data a year "*9999*" was generated to store an average of 2004-2006 data.

TABLE 1B.2.38 – Forecast Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
forecastID		Unique forecasted demand ID
forecastName		Forecast name
comments		Additional user description if needed

TABLE 1B.2.39 – Forecast Scenarios (Forecast Table Data)

networkID	forecastID	forecastName	comments
1	0	na (forecastID for historic/actual flows)	year 9999 represents 2004-2006 average
1	1	FY2003 Clear Skies Flat	ORMSS-SIP forecast scenario
1	2	FY2003 Clear Skies no Hg	ORMSS-SIP forecast scenario
1	3	FY2003 NAAQS Growth	ORMSS-SIP forecast scenario
1	4	FY2003 Utility Based (Coal Model)	ORMSS-SIP forecast scenario
1	5	FY2003 Utility Based High (Coal Model High)	ORMSS-SIP forecast scenario
1	6	FY2009 ORS Low (Oct 2009)	UpperOH forecast scenario
1	7	FY2009 ORS Base (Oct 2009)	UpperOH forecast scenario
1	8	FY2009 ORS High (Oct 2009)	UpperOH forecast scenario

1B.2.9.2.2.2 MovementSet Table

To allow for additional delineation of the forecasted demand scenario, it is further defined by a "*movementSetID*" in the "*MovementSet*" table shown in TABLE 1B.2.40. As shown in TABLE 1B.2.41 the database defines four variations of each forecasted demand scenario (again, as in the "*Forecast*" table, "*movementSet*" 0 represents observed historic tonnages). There are two variations expressed: 1) routing through the Kentucky Lock and Barkley Lock routing options; and 2) induced movements. For the Upper Ohio Navigation Study analysis, "*movementSetID*" 0 and 2 are used.

TABLE 1B.2.40 – MovementSet Table Description

Database Field	DB Key	Description
networkID	DB Key	River system network (1 = existing ORS)
movementSetID		Unique movement set ID
movementSetName		Movement set name
comments		Additional user description if needed

TABLE 1B.2.41 – Movement Sets (MovementSet Table Data)

networkID	movementSetID	movementSetName	comments
1	0	Historic/Actual (KyBk routings)	
1	1	Base (KyBk routings)	base forecast with distinction between Ky & Barkley routings
1	2	Base (Ky only routings)	base forecast with Ky & Barkley routing through Ky.
1	3	Base + EDM Induced (KyBk routins)	base + induced with distinction between Ky & Barkley routings
1	4	Base + EDM Induced (Ky only routings)	base + induced with Ky & Barkley routing through Ky.

ORS traffic has a routing option between the use of Kentucky and Barkley Locks. Often, if the primary study area has little traffic commonality with this area of the system (as in the case of the Upper Ohio River primary study area), the modeling is done with all Kentucky and Barkley traffic routed through

Kentucky (with the Kentucky Lock tonnage-transit curve representing the capacity of both Kentucky and Barkley).

As discussed in ATTACHMENT 1 ORNIM (section 1.2.3.5.4, FIGURE 1.2.19), when induced traffic is considered the demand curves shift to the right. Instead of creating a new forecasted demand scenario, a variation of the forecasted demand scenario with the induced demands added is specified through the "*movementSetID*".

1B.2.9.2.3 MovementDetail and MovementBarge Tables

The basic movement data discussed in section 1B.2.6 is loaded into the "*MovementDetail*" table. The barge type and barge loading information is placed in a separate "*MovementBarge*" table. This separation is done to allow changing of the movement barge type and loading assumptions (section 1B.2.7) by "*networkVersion*". As can be noted in TABLE 1B.2.21, the model is set up with network versions that not only allow for adjustment of tow-sizes in the system at user specified locations and under user specified investment options, but the network version also allows a change in barge types. In the Upper Ohio region regular and stumbo barges are being replaced by jumbo barges. The "*MovementDetail*" table is shown in TABLE 1B.2.42 and the "*MovementBarge*" table is shown in TABLE 1B.2.43.

When setting up a network version with barge type changes, currently all movements must be listed in the "MovementBarge" table under the specified network version, regardless of whether the barge type specification varies from the base network version ("*networkVersion*" 1). This duplicates data. In the future the model will be modified to allow only specification of the changes under the new network version (similar to the new network version in the "*TowSizeLimits*" and "*TowboatUtilization*" tables).

TABLE 1B.2.42 – MovementDetail Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
movementID		Unique movement ID
Origin		Movement origin portID (Ports table)
Destination		Movement destination portID (Ports table)
ForcedSec		Movement must be routed through this sectorID (Sectors table)
ForcedLk		Movement must be routed through this lockID (Locks table)
AvoidSec		Movement must not be routed through this sectorID (Sectors table)
Commodity		Movement commodityID group (CommodityTypes table)
WWLineHaul		Base waterway line-haul rate in dollars per ton
WWRate		Total base waterway rate in dollars per ton
AltRate		Base least-cost all-overland alternative rate in dollars per ton
WWExternality		Waterway externality cost in dollars per ton
AltExternality		Alternative routing externality cost in dollars per ton
Comment		Additional description if needed

TABLE 1B.2.43 – MovementBarge Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion		River system network version (1 = existing UpperOH)
movementID		Unique movement ID
bargeTypeID		Movement bargeTypeID class (BargeTypes table)
tonsPerBarge		Movement average barge loading in tons

1B.2.9.2.4 MovementTonnage Table

The yearly tonnage data are stored in the "*MovementTonnage*" table under the "*networkID*", "*forecastID*", "*movementSetID*", "*movementID*" (called in this table just "*ID*"), and year. TABLE 1B.2.44 shows the "*MovementTonnage*" database fields.

TABLE 1B.2.44 – MovementTonnage Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
forecastID	DB Key	Unique movement set ID (defined in table Forecasts)
movementSetID	DB Key	Unique movement set ID (defined in table MovementSets)
ID	DB Key	Unique movement ID
year	DB Key	Year
cargoAmount		Annual tonnage (observed for historic, forecasted for future)

1B.2.9.2.5 Movement Willingness-to-Pay

For movements defined as inelastic, field "*AltRate*" of the "*MovementDetail*" table (TABLE 1B.2.42) defines the movement's willingness-to-pay. For movements defined as elastic, the willingness-to-pay is defined through four database tables which will not be discussed in this ADDENDUM since they do not factor into the specification, verification, and validation of the WSDM least-cost shipping plans or in the adjustment of the calibrated shipping plans for future lock size and barge fleet changes.

1B.2.9.2.6 Movement River Closure Response

The movement river closure response data will not be discussed in this ADDENDUM since it does not factor into the specification, verification, and validation of the WSDM least-cost shipping plans or in the adjustment of the calibrated shipping plans for future lock size and barge fleet changes.

1B.2.9.3 System Tax / Fee Characteristics

Included in this database table category are data specifying government cost recovery levels and cost recovery options such as lockage fees, barge fees, river segment tolls, and fuel taxes. ORNIM allows analysis of these various revenue generating policies, however, for this validation of the WSDM least-cost shipping plans, only fuel taxes are applicable. The following two tables are used in the specification, verification, and validation of the WSDM least-cost shipping plans.

1B.2.9.3.1 FuelTaxPlan and FuelTaxPlanYear Tables

In WRDA 1978 Congress passed the first excise tax on inland waterway users of $0.04 per gallon (taking effect Oct 1980) and rising to $0.10 per gallon in 1986[6]. WRDA 1986 then mandated that the tax increase to $0.20 per gallon by 1995[7]. Fuel taxes actually peaked over 1998 through 2004 at $0.253 per gallon with an additional Deficit Reduction Tax of $0.043 and a Leaking Underground Storage Tank (LUST) tax of $0.01 per gallon. Fuel tax has since dropped to the current $0.20 per gallon after the LUST tax expired 1 January 2005 and the deficit reduction tax expired 1 January 2007. Over the 2004 through 2006 period, the average fuel tax was 24.63 cents per gallon.

ORNIM allows storage and analysis different fuel taxes by year (tax plan) by networkID. In the "*FuelTaxPlan*" table the various tax plans are assigned an ID so that the yearly tax data can be stored in the "*FuelTaxPlanYear*" table. For this validation of the WSDM least-cost shipping plans, the existing ORS

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[6] *Inland Waterways Revenue Act of 1978 (Public Law 95-502, October 21, 1978), Sections 203 and 204. Section 202 specifies the amount of tax and certain exemptions, and Section 206 specifies the waterways where the tax applies.*

[7] *Water Resources Development Act (WRDA) of 1986 (Public Law 99-662, November 17, 1986), Section 1405. Section 1404 amends the two sections in the earlier act to increase the amount of fuel tax and to add the Tennessee-Tombigbee Waterway to the waterways where the tax applies.*

network (i.e., networkVersion 1) is utilized and the existing tax law is defined and stored under fuelTaxPlanD 1. Data loaded into the "*FuelTaxPlanYear*" table are shown in TABLE 1B.2.45.

TABLE 1B.2.45 – FuelTaxPlanYear Table

Database Field	Description	Value
networkID	River system network (1 = existing ORS)	1
fuelTaxPlanID	Tax plan (1 = existing tax law)	1
beginYear	first year that the cost is in effect	9999
endYear	last year that the cost is in effect	9999
fuelTax	cents per gallon fuel tax	24.63333333

1B.2.10 Model Calibration Targets

The calibration targets represent lock performance statistics that the model should replicate in order to be considered verified and validated. The model was calibrated and validated against an average of 2004 through 2006 WCSC and LPMS data. This was done primarily because the rate data was developed using the shipping characteristics for this time period, but this averaging also allows for a smoothing of the data to avoid individual year irregularities. Development of the targets, unfortunately, is not straightforward as discussed in the sections below.

1B.2.10.1 Lock Tonnage Target

As noted, the calibration targets are lock performance statistics. While the movements are loaded as origin to destination traffic, the tonnage past each navigation project is easily tabulated. There are two data sources for target lock tonnage statistics; WCSC and LPMS. Since the model is supplied origin to destination tonnage flows derived from WCSC data, the lock tonnage targets were derived from averaging 2004 through 2006 WCSC origin to destination flows and then tabulating the tonnage past each navigation project. Since the origin to destination traffic data loaded into the model comes from the same data source as the lock tonnage targets, there is no reason that the model will not hit these targets. As a result, this target serves as a verification test (rather than a validation test).

The lock tonnage targets, their comparison to model output, and discussion on how the LPMS lock tonnage statistics are compared against the WCSC data, can be found in section 1B.3.1.

1B.2.10.2 Lock Number of Loaded Barges Target

The origin to destination tonnage flows in the model are converted to loaded barge trips, which can then be used to tabulate the number of loaded barges transiting each navigation project. The model has the capability to calculate barge loadings for each movement based on depth restrictions enroute, the barge type loading capacity, the commodity density, and a barge draft calculation. However, since the data are available, the model is supplied a barge loading for each movement. As a result, the model calculates the required number of barge trips to move the tonnage by dividing the annual tonnage by the average barge loading.

Again there are two data sources for the target number of loaded barges through each navigation project; WCSC and LPMS. Again, since the model is supplied origin to destination tonnage flows derived from WCSC data, and since the WCSC data includes a number of trips field, the movement average barge loading supplied to the model and the target number of loaded barges through each navigation project, were derived from averaging 2004 through 2006 WCSC data. Since the origin to destination tonnage and average barge loading loaded into the database comes from the same data source as the lock number of loaded barge targets, there is no reason that the model will not hit these targets. As a result, this target also serves as a verification test (rather than a validation test). If the barge loading feature is exercised, this comparison test would convert to a validation test.

The loaded barge targets, and its comparison to model output, can be found in TABLE 1B.3.2.

1B.2.10.3 Lock Number of Empty Barges Target

The derivation of the target number of empty barges through each navigation project is not as straightforward as the tonnage and loaded barge targets. As discussed in section 1B.5.2, a movement level barge dedication factor is set (either manually or automatically) specifying how dedicated the loaded barges are to the movement. As a result, comparison of the model empty barge results against the empty barge target is a true validation test.

The lock number of empty barges target was developed by the equation below. By taking the minimum of either 1 or the LPMS empty to loaded barge ratio, the target is capped to no more than 50% empty. While a percent empty greater than 50% would appear unsustainable in the long-run, it could occur, however it is rare. ORNIM, however, is not capable of generating empty barge movements for reasons other than supplying barges for loaded flows.

$$\text{Lock No. of Empty Barges} = \text{MIN}\left(1\ ,\ \frac{\text{LPMS No. of Empty Barges}}{\text{LPMS No. of Loaded Barges}}\right) \times \text{Target No. of Loaded Barges} \qquad (1B.2\text{-}3)$$

1B.2.10.4 Lock Number of Tows Target

The lock number of tows target was developed by the equation below. Since the movement empty back-haul (number of empty barges) and tow-size are estimated by the model, the comparison of the model number of tows results against the tow targets is a validation test.

$$\text{Lock No. of Tows} = \frac{\left(\text{Target No. of Loaded Barges} + \text{LPMS No. of Empty Barges}\right)}{\text{LPMS Av. Barges per Tow}} \qquad (1B.2\text{-}4)$$

1B.2.10.5 Lock Average Tow Processing and Delay Time Targets

Transit times (processing and delay) past locks in the system are represented by tonnage-transit curves relating an average tow transit time to an annual aggregate traffic level at the project. In the verification, calibration, and validation of the model's movement shipping plans, however, these tonnage-transit curves are not used. Instead, the model uses the observed (target) transit time in the "*Targets*" database table (1B.2.10.7.1) as input in its calculations. Validation of the project tonnage-transit curves are done as part of project level capacity analyses and not part of this model verification, calibration, and validation. Storage of the transit times in the "Targets" table is a misnomer. The storage of a delay time separate from the processing time is a remnant of older modeling where the processing time was fixed and a tonnage-delay curve (rather than a tonnage-transit time curve) was used. Fixing the processing time was abandoned since processing time can increase as congestion increases at dual chamber projects as a result of chamber interference and in situations where the auxiliary chamber is smaller than the main (and gets increased usage as traffic levels increase).

1B.2.10.6 Lock Average Towboat Horsepower Target

The lock average horsepower targets were calculated from 2004 through 2006 LPMS data utilizing horsepower data from a 2008 inland vessel directory developed by CEIWR-GW under the NETS program

NaSS project. This IWR vessel directory consolidated LPMS Vessels, WCSC Master Vessel, Coast Guard PSix, and Inland River Record data.

As discussed in section 1B.2.4, the model summarizes and simplifies towboats into eight horsepower classes (TABLE 1B.2.13). As a result, since the model averages the horsepower classes rather than the vessel horsepowers themselves, the targets need to be similarly developed. A comparison of the vessel averages (average of all vessel horsepowers) with the vessel class averages (weighted average of the towboat class frequencies) for the Ohio River and lower four projects on the Monongahela River is shown in TABLE 1B.2.46.

TABLE 1B.2.46 – Average Horsepower versus Towboat Class Average Horsepower

Navigation Lock Project	Average Project Rated Horsepower (LPMS)			
	Actual	Towboat Class Av.	Difference HP	Difference Percentage
OHIO RIVER				
LOCK & DAM 53 (OHIO)	4,204	4,150	54	1.3%
LOCK & DAM 52 (OHIO)	3,728	3,700	28	0.8%
SMITHLAND L/D	4,081	4,028	53	1.3%
MYERS L/D	4,386	4,320	66	1.5%
NEWBURGH L/D	4,144	4,084	60	1.4%
CANNELTON L/D	4,055	3,974	81	2.0%
MCALPINE L/D	3,952	3,885	67	1.7%
MARKLAND L/D	4,064	3,964	100	2.5%
MELDAHL L/D	3,993	3,862	131	3.3%
GREENUP L/D	3,892	3,750	142	3.6%
R.C. BYRD L/D	3,675	3,550	125	3.4%
RACINE L&D	3,654	3,508	146	4.0%
BELLEVILLE L&D	3,694	3,536	158	4.3%
WILLOW ISLAND L&D	3,643	3,479	164	4.5%
HANNIBAL L&D	3,390	3,239	151	4.5%
PIKE ISLAND L&D	3,137	3,037	101	3.2%
NEW CUMBERLAND L&D	3,054	2,972	82	2.7%
MONTGOMERY L&D	1,830	1,995	-165	-9.0%
DASHIELDS L&D	1,803	1,924	-121	-6.7%
EMSWORTH L&D	1,784	1,890	-106	-5.9%
MONONGAHELA RIVER				
MON LOCK & DAM 2 L&D	1,786	1,864	-78	-4.4%
MON LOCK & DAM 3 L&D	1,313	1,389	-76	-5.8%
MON LOCK & DAM 4 L&D	1,244	1,333	-89	-7.1%
MAXWELL L&D	1,224	1,293	-69	-5.6%

SOURCE: 2004-2006 WCSC and LPMS data.

1B.2.10.7 Loading the ORNIM Target Files

ORNIM target data are also stored in Microsoft Sequel Server database tables, as discussed below.

1B.2.10.7.1 Targets Table

The majority of the target data are stored in the "*Targets*" table shown in TABLE 1B.2.47. The "*year*" field allows storage of different years for calibration. In this verification, calibration, and validation a 2004 through 2006 system average was used and stored as year 9999.

TABLE 1B.2.47 – Targets Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
year	DB Key	Applicable year (9999 = 2004 through 2006 average)
lockID	DB Key	Lock ID (from Locks table)
lockName		Text name used for output report labeling
loadedBarges		Target # of loaded barges (WCSC)
emptyBarges		Target # of empty barges (est from WCSC loaded & LPMS % empty)
delayTime		Target av. tow delay time in min (LPMS av 2004-2006)
processingTime		Target av. tow processing time in min (LPMS av 2004-2006)
tonnage		Target tonnage (WCSC)
tows		Target # of tows (est from target loaded & empty barges, & LPMS barges per tow)
horsepower		Target av. Horsepower (LPMS)

1B.2.10.7.2 TargetTowSizeDistribution Table

Additional target data on tow-size distributions are stored in the "*TargetTowSizeDistribution*" table shown in TABLE 1B.2.48. The "*year*" field allows storage of different years for calibration. In this verification, calibration, and validation a 2004 through 2006 system average was used and stored as year 9999.

TABLE 1B.2.48 – TargetTowSizeDistribution Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
lockID	DB Key	Lock ID (from Locks table)
year	DB Key	Applicable year (9999 = 2004 through 2006 average)
towSize	DB Key	Tow size in number of barges per tow (integer)
distribution		Proportion of tows of tow-size towSize (0-1.0)

1B.3 INPUT VERIFICATION

While model verification is the determination that the model's code performs as intended, the focus here is more on input data verification to guard against "*Garbage in, Garbage out*" results.

1B.3.1 Lock Tonnage Verification

Since WCSC data contains waterside origin to destination information, it is used to develop the traffic demand forecasts and is used to develop the ORNIM movements. WCSC data is collected from shippers monthly, and contains specific: waterside origin and destination location; routing (e.g., transit through Kentucky or Barkley Lock); commodity type classification; tonnage; number of trips; and barge dimensions. Determination of which navigation projects transited, and total project tonnages, must be deduced. Statistics on the number of loaded barges between the origin and destination locations, and loaded barge counts at the navigation projects must also be calculated. The WCSC movement number of trips is essentially equivalent to the number of barges. However, partial trips are coded as "*0 trips*" and can distort the estimation of the number of loaded barges moving in the system.

LPMS data are collected at the navigation projects, and contain vessel counts by direction and time. Loaded barge counts are considered quite accurate, however, barge tonnages are often rounded and as a result tonnages transiting the locks are only estimates.

These two data sets rarely match. While LPMS barge loadings are often rounded, the discrepancy occurs primarily because of underreporting in the WCSC data.

1B.3.1.1 Input Tonnage Verification Against LPMS Data

For model calibration and for this verification step, an average of 2004 through 2006 WCSC and LPMS data was used. This was done primarily because the rate data was developed using the shipping characteristics for this time period, but this averaging also allows for a smoothing of the data to avoid individual year irregularities.

As shown in TABLE 1B.3.1, the WCSC data appear quite accurate except for the Lower Monongahela River Locks and Dams 3 and 4 where there appears to be missing data. This discrepancy appears in both the tonnage and loaded barge count comparison. No attempt was made as a part of this study to track down the missing Lower Monongahela River data.

1B.3.1.1.1 Output Tonnage Verification Against Input

The initial verification check is to compare the model output against the WCSC input as shown in TABLE 1B.3.2. This verifies network movement routing, correct traffic accounting at the navigation projects, and correct conversion of annual tonnages into loaded barge counts.

TABLE 1B.3.1 – Comparison of Input Tonnage and Loaded Barges to LPMS Data

Navigation Lock Project	Tonnage				Number of Loaded Barges			
			Difference				Difference	
	WCSC	LPMS	Tonnage	Percentage	WCSC	LPMS	Number	Percentage
OHIO RIVER								
LOCK & DAM 53 (OHIO)	81,613,688	85,454,333	-3,840,645	-4.7%	49,738	53,074	-3,335	-6.7%
LOCK & DAM 52 (OHIO)	95,648,485	96,231,333	-582,848	-0.6%	58,260	60,201	-1,941	-3.3%
SMITHLAND L/D	82,477,322	79,580,667	2,896,655	3.5%	49,815	49,819	-5	0.0%
MYERS L/D	73,348,924	70,650,000	2,698,924	3.7%	44,607	44,433	174	0.4%
NEWBURGH L/D	69,589,809	67,945,667	1,644,142	2.4%	43,052	43,164	-112	-0.3%
CANNELTON L/D	59,143,757	58,036,667	1,107,090	1.9%	36,733	36,799	-66	-0.2%
MCALPINE L/D	56,701,852	54,551,000	2,150,852	3.8%	34,419	33,949	470	1.4%
MARKLAND L/D	54,041,630	52,198,000	1,843,630	3.4%	32,638	32,496	142	0.4%
MELDAHL L/D	59,314,186	59,059,667	254,519	0.4%	34,887	35,806	-919	-2.6%
GREENUP L/D	71,566,262	68,158,667	3,407,595	4.8%	42,377	42,284	94	0.2%
R.C. BYRD L/D	60,811,235	59,275,000	1,536,235	2.5%	37,100	37,006	94	0.3%
RACINE L&D	54,801,938	52,420,667	2,381,271	4.3%	33,621	33,835	-214	-0.6%
BELLEVILLE L&D	54,221,170	51,126,000	3,095,170	5.7%	33,265	33,150	116	0.3%
WILLOW ISLAND L&D	51,011,845	48,272,000	2,739,845	5.4%	31,413	31,426	-13	0.0%
HANNIBAL L&D	53,836,241	51,026,333	2,809,908	5.2%	33,120	33,305	-185	-0.6%
PIKE ISLAND L&D	40,802,415	39,287,333	1,515,082	3.7%	25,773	25,676	96	0.4%
NEW CUMBERLAND L&D	33,296,680	32,482,667	814,013	2.4%	21,334	21,438	-104	-0.5%
MONTGOMERY L&D	21,829,002	21,386,000	443,002	2.0%	15,000	14,942	58	0.4%
DASHIELDS L&D	20,923,289	21,245,000	-321,711	-1.5%	15,387	15,535	-149	-1.0%
EMSWORTH L&D	19,998,867	20,464,667	-465,800	-2.3%	14,260	14,701	-442	-3.1%
MONONGAHELA RIVER								
MON LOCK & DAM 2 L&D	18,826,623	19,082,000	-255,377	-1.4%	13,447	13,715	-267	-2.0%
MON LOCK & DAM 3 L&D	12,614,903	13,898,333	-1,283,430	-10.2%	9,704	10,690	-986	-10.2%
MON LOCK & DAM 4 L&D	10,820,928	11,919,667	-1,098,739	-10.2%	8,455	9,353	-897	-10.6%
MAXWELL L&D	12,646,794	13,714,667	-1,067,873	-8.4%	11,100	11,832	-732	-6.6%

SOURCE: WCSC and LPMS 2004-2006 averages.

TABLE 1B.3.2 – Comparison of Output Tonnage and Loaded Barges to Input Data

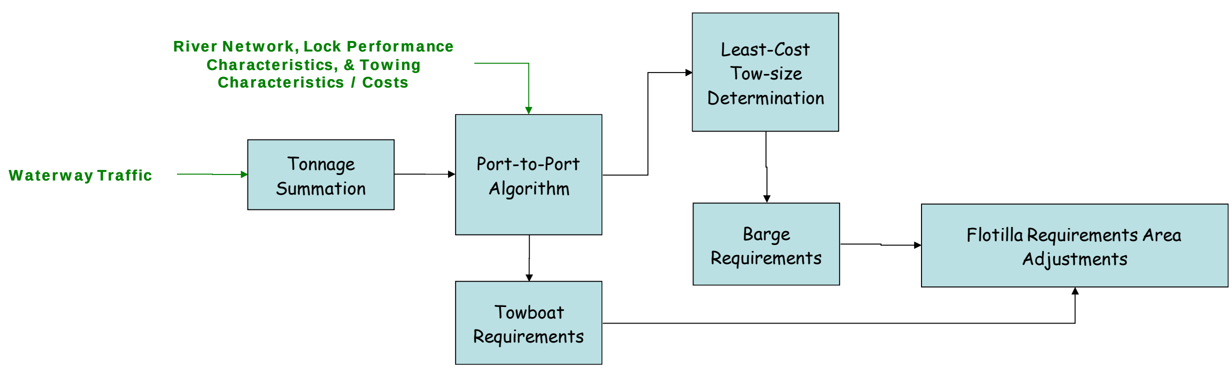
Navigation Lock Project	Tonnage				Number of Loaded Barges			
	WCSC	Model	Difference		WCSC	Model	Difference	
	Input	Output	Absolute	Percentage	Input	Output	Absolute	Percentage
OHIO RIVER								
LOCK & DAM 53 (OHIO)	81,613,688	81,613,688	0	0.0%	49,738	49,738	0	0.0%
LOCK & DAM 52 (OHIO)	95,648,485	95,648,485	0	0.0%	58,260	58,260	0	0.0%
SMITHLAND L/D	82,477,322	82,477,322	0	0.0%	49,815	49,815	0	0.0%
MYERS L/D	73,348,924	73,348,924	0	0.0%	44,607	44,607	0	0.0%
NEWBURGH L/D	69,589,809	69,589,809	0	0.0%	43,052	43,052	0	0.0%
CANNELTON L/D	59,143,757	59,143,757	0	0.0%	36,733	36,733	0	0.0%
MCALPINE L/D	56,701,852	56,701,852	0	0.0%	34,419	34,419	0	0.0%
MARKLAND L/D	54,041,630	54,041,630	0	0.0%	32,638	32,638	0	0.0%
MELDAHL L/D	59,314,186	59,314,186	0	0.0%	34,887	34,887	0	0.0%
GREENUP L/D	71,566,262	71,566,262	0	0.0%	42,377	42,377	0	0.0%
R.C. BYRD L/D	60,811,235	60,811,235	0	0.0%	37,100	37,100	0	0.0%
RACINE L&D	54,801,938	54,801,938	0	0.0%	33,621	33,621	0	0.0%
BELLEVILLE L&D	54,221,170	54,221,170	0	0.0%	33,265	33,265	0	0.0%
WILLOW ISLAND L&D	51,011,845	51,011,845	0	0.0%	31,413	31,413	0	0.0%
HANNIBAL L&D	53,836,241	53,836,241	0	0.0%	33,120	33,120	0	0.0%
PIKE ISLAND L&D	40,802,415	40,802,415	0	0.0%	25,773	25,773	0	0.0%
NEW CUMBERLAND L&D	33,296,680	33,296,680	0	0.0%	21,334	21,334	0	0.0%
MONTGOMERY L&D	21,829,002	21,829,002	0	0.0%	15,000	15,000	0	0.0%
DASHIELDS L&D	20,923,289	20,923,289	0	0.0%	15,387	15,387	0	0.0%
EMSWORTH L&D	19,998,867	19,998,867	0	0.0%	14,260	14,260	0	0.0%
MONONGAHELA RIVER								
MON LOCK & DAM 2 L&D	18,826,623	18,826,623	0	0.0%	13,447	13,447	0	0.0%
MON LOCK & DAM 3 L&D	12,614,903	12,614,903	0	0.0%	9,704	9,704	0	0.0%
MON LOCK & DAM 4 L&D	10,820,928	10,820,928	0	0.0%	8,455	8,455	0	0.0%
MAXWELL L&D	12,646,794	12,646,794	0	0.0%	11,100	11,100	0	0.0%

1B.4 DETERMINATION OF THE LEAST-COST SHIPPING PLANS

The movement shipping-plan is a specification on how barges are loaded, grouped (tow-sizes) and moved (towboat classes) between the origin and destination ports. The shipping-plan, which ultimately dictates the transportation cost for moving tonnage on the waterway, depends on the commodity shipped, the equipment used, the characteristics and limitations of the waterway system, and the total transportation trip time. As previously noted, the focus of this addendum is ultimately on the specification, verification, and validation of the WSDM least-cost cargo shipping-plans. To completely understand the calibration process, the model's process of analyzing shipping-plans, estimating shipping-plan costs and determining the least-cost shipping-plan must be understood. The model's process to calculate shipping-plans is called the Port-to-Port Algorithm.

The process of determining the least-cost shipping-plans can be described as three phases: 1) summarizing system utilization; 2) analyzing the potential shipping-plans; and 3) selection and storage of the least-cost shipping-plan for the equilibrium process. The general structure of this process is shown in FIGURE 1B.4.1.

FIGURE 1B.4.1 – Process to Determine the Least-Cost Shipping-Plan



The first phase is reading, checking, and storage of the input data describing the waterway system. The system is represented as a network with ports, locks, and river junctions as nodes and connecting waterway links between them. For computational purposes the network is partitioned into sectors which are linear, un-branched sets of links and nodes (FIGURE 1B.2.1). In addition to the network data, the system description includes data on the types of towboats and barges available and cargo characteristics.

While the movement least-cost shipping-plan is based primarily on a movement-by-movement basis, collective information about the system as a whole is needed and used to determine shipment times, etc. The model next reads the list of shipments to be processed, which are characterized by the movements' origin and destination ports, type of commodity, tonnage, and if applicable, the portion carried by dedicated equipment. The model then calculates a number of parameters needed for the Port-to-Port Algorithm, including total tonnages through various elements of the network, system transit times, and tow speeds.

The following sections describe the Port-to-Port Shipping-Plan Algorithm and many of the computations made by the model. The Port-to-Port Algorithm is the name applied to the collective procedures by which the model evaluates the time and cost required to transport cargo between a given pair of ports using a given towboat class.

1B.4.1 Analyzing the Least-Cost Shipping-Plans

In this phase the model uses an optimization algorithm to determine the most cost effective way to ship cargo between each pair of ports having traffic between them. The shipping-costs between these port pairs are calculated (the number of towboats and barges required are no longer calculated). Essentially, for each movement, the model tests each possible combination of towboat classes and fleeting between the ports, thereby determining an optimum "*Least-Cost Tow*" routing scenario.

Even though the Port-to-Port Algorithm computes times and costs on a movement-by-movement basis, and most shipping-plan decisions are based on an individual movement basis, there are system-wide interactions to be considered. Most notable of these system-wide interactions are the lock transit times. Higher lock transit times (resulting from higher utilization and increased congestion) encourages larger tow-sizes (with higher HP towboats) as the trip time for each shipment increases. Shippers can lower their total movement transportation costs by minimizing their number of trips through the locks. As a result, the trip time for a movement is dependent upon the shipping-plan decisions of other movements in that movement's path (i.e., the number of lock transits for all movements through the locks in question). This is not an issue in the calibration step because the target lock transit times are known and are used (i.e., the lock transit times are fixed and are not adjusted as movements increase and decrease their number of trips as they decrease and increase their tow-sizes). Transit times are adjusted, however, when the least-cost shipping-plans are re-planned in the middle of an analysis (if the user specifies to do so).

The trip is divided into six activities, or functions, for analysis:

(1) Cargo loading and unloading

(2) Waiting for access to docks (to begin loading or unloading)

(3) Barges waiting for pickup by a towboat

(4) Tow makeup and breakdown

(5) Travel on waterway links

(6) Lockage transit operations (processing and delay)

Shipping costs arise from four sources, or categories, in the model:

(1) Towboat operating costs (including fuel tax and any other towboat level fees)

(2) Barge operating costs (including any other barge level fees)

(3) Cargo inventory costs

(4) Lockage and segment tolls

The results of the Port-to-Port Algorithm can thus be visualized as an array of the time per trip spent in each of the six activities, and a matrix of shipping costs in each of four cost categories arising from each activity (TABLE 1B.4.1). Note that certain functional costs apply only to certain sources. The crossed out cells indicate cost entries which are not used. In agreement with normal operating practice it is assumed that towboats do not wait while barges are loaded and unloaded. Thus the first three activities do not apply to towboats and the average trip time for a towboat is shorter than that for a barge. Physically this occurs because towboats do not simply shuttle the same set of barges back and forth but pick them up and drop them off as available.

Cargo inventory costs are accumulated for the time accounted for by the six listed activities. The time and cost of commodity or towing equipment storage at either end of the trip is not considered (note however, that the cargo is assumed to be waiting during the time that barges are waiting for dock access). The Port-to-Port Algorithm allows for computation of each of the cost elements for each movement by first computing the amount of towing equipment and the times required for each of the itemized waterway activities.

TABLE 1B.4.1 – Cost Accounts Matrix

	Waterway Trip Activity Time (days / round-trip)					
	Load / Unload *(Activity 1)*	Wait Dock *(Activity 2)*	Wait Pick-Up *(Activity 3)*	Tow Make Up *(Activity 4)*	Link Travel *(Activity 5)*	Lockage Transit *(Activity 6)*
Time						

	Waterway Trip Activity Costs (mills / ton-mile)					
Shipping Cost Sources	Load / Unload *(Activity 1)*	Wait Dock *(Activity 2)*	Wait Pick-Up *(Activity 3)*	Tow Make Up *(Activity 4)*	Link Travel *(Activity 5)*	Lockage Transit *(Activity 6)*
Towboat *(Cost 1)*	X	X	X			
Barges *(Cost 2)*						
Cargo *(Cost 3)*						
User Fees *(Cost 4)*	X	X	X	X		

The remainder of this section will first discuss some general computational factors used by the Port-to-Port Algorithm, then treat each of the six waterway trip activities individually, and finally consider the conversion of calculated operating times to a shipping-plan cost.

1B.4.1.1 Shipment Aggregation

As discussed in sections 1B.2.1 through 1B.2.3, individual shipments are aggregated into annual modeling level ports, commodity groups, and barge types; i.e., movements.

The Port-to-Port Algorithm stipulates that for each movement, the most efficient tow-size will be used between each pair of fleeting points along the route (tow-size changes can occur only at specified re-fleeting points). It should be noted that the most efficient tow-size is specified for each trip movement regardless of movement tonnage. For example, if a particular movement consists only of a single barge load per year between ports A and B, a four- or eight-barge tow may still be specified as the optimal and most efficient tow-size. In this case, however, the movement is shown as having a fractional number of trips (employing a fractional towboat). Considering the traffic flow along most portions of the waterway system, such a movement is assumed to be a fractional part of other movements between ports A and B. This assumption is important since the model is not a simulator; it cannot explicitly consider interaction between movements

Of course, by considering movement groupings on a trip basis, in complete isolation of other movements, the model would tend to overestimate equipment and trip requirements since the potential for intermediate backhauls is not considered. For certain ports A and B having freight flows in one direction only, strict adherence to the trip shuttle assumption would ignore potential for backhauls between ports located intermediate to A and B.

In the original Port-to-Port Algorithm (TCM) this is handled by algebraically reducing the number of round trips (and hence reducing the number of barges and towboats) by an additional aggregation to a transportation class (trans-class) and then application of a specific port-to-port-trans-class grouping e_L (percent loaded trips) factor. The model computes a fraction of loaded barge trips (e_L) for each trans-class combination by the model by considering the up-bound and down-bound tonnage and the percentage of dedicated movements for each trans-class within a single link. This then indirectly considers back-haul potential for any particular movement. Additional discussion of e_L can be found in section 1B.4.1.3 and equation (1B.4-5).

The current Port-to-Port Algorithm (ORNIM) is simplified and makes no such adjustment. It is yet to be determined whether this functionality will be re-coded into ORNIM in future versions.

Once the number of trips and barges is computed, the Port-to- Port Algorithm provides the means for computing various lock and port factors, considering aggregate traffic levels using each lock or port. Furthermore, link travel times and speed, fleeting costs, and various cargo handling costs are accounted for. The following section describes how all of the assumptions and procedures are brought together in the actual tow cost calculations.

1B.4.1.2 Barge Loading Capacity

The procedures used by the Port-to-Port Algorithm require a movement level barge loading so that equipment resources can be estimated and cost. While the barge type and barge loading are part of the overall shipping-plan, in the model the movement barge type (see section 1B.2.3) and movement barge loading (see sections 1B.2.7 and 1B.5.1) are specified through input data. As a result, only the various movement tow-size and towboat class combinations are analyzed to determine the movement's least-cost shipping-plan algorithm. The model, however, does have the capability to determine movement barge loadings if not specified through input. These model generated barge loadings are done prior to execution of the Port-to-Port Algorithm as discussed below.

A maximum barge capacity by barge type is given by input data (TABLE 1B.2.17). The actual usable capacity for a movement, however, can be reduced by two factors: limited channel depth along the shipping route can restrict the usable draft of the barge, or low density cargo can fill its available volume before the maximum tonnage is loaded (cubing out). If the barge loading is derived from historic data and specified to the model through direct input, this reduction in barge capacity from draft restrictions and commodity density can be accounted for through a barge loading factor e_d as discussed below.

First the barge usable draft "*d*" (in feet) is computed as:

$$\text{Barge Usable Draft} = d = \text{MIN}\left(\left(\begin{matrix}\text{barge}\\ \text{loaded}\\ \text{draft}\end{matrix} - \begin{matrix}\text{barge}\\ \text{empty}\\ \text{draft}\end{matrix} \right), \left(\begin{matrix}\text{controlling}\\ \text{channel}\\ \text{depth}\end{matrix} - \begin{matrix}\text{Required}\\ \text{Barge}\\ \text{Clearance}\end{matrix} - \begin{matrix}\text{empty}\\ \text{barge}\\ \text{draft}\end{matrix} \right) \right) \quad (1B.4\text{-}1)$$

The controlling channel depth is the minimum channel depth encountered along the shipping route as input on the Sector definition records. The other parameters are derived from barge class input data items (TABLE 1B.2.17).

The maximum barge tonnage which can be carried is equivalent to that obtained by loading the barge to a draft "*d*" with cargo having a density equal to that of water, 62.4 pounds per cubic foot (0.0312 tons per cubic foot). With lower density cargo, fewer tons can be loaded into the barge. The actual tonnage which can be carried is thus:

$$Y_{usable} = \text{MIN}\left(p \,,\; 0.0312 \right) \times L \times W \times d \times s \quad (1B.4\text{-}2)$$

where:

Y_{usable} = *usable barge capacity (in tons)*
L = *barge length (in feet)*
W = *barge width (in feet)*
d = barge usable draft (in feet)
s = barge block coefficient (ratio of actual volume of barge to the product of it's length, width, & draft
p = cargo density factor (tons per cubic foot)

Note that the parameter p above is defined as a "*density factor*" which is not the density of the cargo material itself. Also note that the capacity of the barge is a function of the density of the medium (i.e., water) displaced by the barge. This displacement depends on how high the cargo can be piled on the barge or on how tightly packed it is; it is not directly a function of the textbook density of the commodity itself. Since most barges are designed to carry as much bulk material as the controlling channel depth will allow, a density factor of 62.4 (density of water) should be input for most bulk commodities. A slightly lower p would be specified for commodities which are extremely light or which are subject to inefficient packing, such as manufactured goods and certain steel products (see TABLE 1B.2.11 for the current density settings).

For certain tow-size calculations, the model defines a barge loading factor e_d as Y_{usable} / Y_{max}, where Y_{max} is the specified maximum barge capacity (TABLE 1B.2.12), hence:

$$Y_{usable} = e_d Y_{max} \qquad (1B.4\text{-}3)$$

1B.4.1.3 Tow Capacity

The maximum potential tonnage capacity of a tow would be the product of the maximum number of barges in the tow and the maximum capacity of each barge. However, the actual tow cargo tonnage will be reduced by the presence of empty barges in the tow, by the fact that the average number of barges included will generally be less than the maximum permitted, and by barges not loaded to their maximum capacity. The maximum number of barges which can be moved by a towboat of a given towboat class is the minimum of the towing capacity of the towboat and the smallest tow-size limit along the shipping route. In other words, the maximum towboat barge capacity is reduced according to the tow capacity factors input for each network link along the shipping route. The towboat barge capacity factor e_c used for the round trip between two ports is the minimum e_c encountered over the shipping route. The average number of barges in a tow is thus given by:

$$n_{average} = n_{max} e_c \qquad (1B.4\text{-}4)$$

where:
n_{max} *= the maximum number of barges which can be moved by the towboat class*

Note that the model does not attempt to intentionally reduce the tow-size in order to obtain higher speeds, reduced lockage times, etc.

Despite the Port-to-Port Algorithm's focus on a movement-by-movement basis, the other system-wide interaction (besides lock transit times which are a function of lock utilization and the shipping-plan decisions of all movements transiting the lock) that is considered is the loaded backhaul potential. The movement loaded barge backhaul assumption is key in a round-trip cost calculation. Unless commodity shipments are exactly balanced, it will be necessary to move some empty barges in order to balance the barge flows in the system. Empty barge movements also result from the use of dedicated barges which, by definition, return empty and are not available for backhaul tonnage. The presence of empty barges reduces the effective tonnage capacity of a tow.

In the original Port-to-Port Algorithm (TCM) barge balancing is accomplished through a model calculated empty barge factor e_L, which is used to reflect the presence of empty barges. The e_L factor is defined as the average fraction of barges which are loaded, considering both directions of the round trip. Consider the shipments of non-dedicated cargo of a single transportation class on a single network link. The number of (one-way) trips made by loaded barges on the link will be proportional to $q_{up} + q_{down}$, where q_{up} is the tonnage moving upstream and q_{down} the tonnage moving downstream. The upstream and downstream flows can share the same barges since they belong to the same transportation class. However, since all barges must return, either loaded or empty, the total number of barge trips on the links will be proportional to 2 x MAX (q_{up} , q_{down}). Hence, the fraction of barge trips which are loaded is:

$$e'_L = \frac{q_{up} + q_{down}}{2 \times \text{MAX}\left(q_{up}\ ,\ q_{down}\right)} \qquad (1B.4\text{-}5)$$

Note, for example, that if $q_{up} = q_{down}$ then $e'_L = 1.0$; while if there are flows in one direction only $e'_L = 0.5$.

The preceding factor is calculated for each combination of waterway link, transportation class, and season. For use in the Port-to-Port Algorithm, the factors are averaged over the links along the shipping route under consideration. The final value of e_L is obtained by combining the resulting average value of e'_L, which applies to non-dedicated traffic, with an implied factor of 0.5 which applies to the dedicated movements between the two port pairs in question:

$$e_l = \frac{q_{non} + q_{ded}}{\frac{q_{non}}{e'_L} + \frac{q_{ded}}{0.5}} \qquad (1B.4\text{-}6)$$

Strict adherence to the assumption of tows shuttling between each pair of ports would suggest that the empty barge factors should be calculated on the basis of the shipments between the ports rather than on the total cargo flows on the links making up the route. However, this would introduce the risk of significantly overestimating the number of empty barge movements required. Therefore, the model uses the procedure described which, in effect, indirectly reflects the practice of picking up and dropping off barges en-route.

Combining the above results with those of the preceding section we obtain the formula for the total tons moved by a tow in a single round trip:

$$Y_t = 2ne_ce_Le_dY \qquad (1B.4\text{-}7)$$

The ton-miles produced is thus:

$$M_t = Y_tD = 2ne_ce_Le_dYD \qquad (1B.4\text{-}8)$$

where:
D = *is the distance between ports*

The number of round trips required annually will be:

$$N = \frac{Q}{Y_t} = \frac{Q}{2ne_ce_Le_dY} \qquad (1B.4\text{-}9)$$

where:
Q = *is the total annual tonnage in both directions between the ports*

In terms of actual barge-types, as specified by the transportation class, the average loading per barge for the tow in a round trip can be computed as:

$$Y_b = 2e_ce_Le_dY \qquad (1B.4\text{-}10)$$

where:
Y_b = *is the usable capacity for the barge type used*

Note that this round-trip loading often considers an empty backhaul, depending on the value of e_L, and is therefore often equal to one-half a full tow loading.

The current Port-to-Port Algorithm (ORNIM) is simplified and does not consider barge balancing. As previously noted, it is yet to be determined whether this functionality will be re-coded into ORNIM in future versions. The lack of this barge balancing has not adversely affected ORS calibration, and application of just the barge dedication factors is sufficient. In short, the movement barge dedication (discussed in section 1B.5.2) was a potential empty barge return probability in TCM while it is an absolute empty barge return in ORNIM.

1B.4.1.4 Cargo Loading and Unloading Time

The time required for loading and unloading barges depends on the type of cargo and the port facilities available. In the model, commodities are divided into three handling classes based on their loading and unloading characteristics. Although the definition of these classes is an option of the user, the normal classification will be (1) dry granular cargo, such as coal or grain, (2) dry bulk cargo, such as steel products, and (3) liquid cargo, such as petroleum. Loading and unloading rates for each cargo handling class are specified for each port in the network and are the basis for calculating loading and unloading times (see section 1B.2.1.1).

In the course of a trip between two ports A and B, a barge will, in general, be loaded at port A, and unloaded at B. The total time (Activity 1 of TABLE 1B.4.1) consumed annually in such operations for shipments between A and B will be:

$$T_1 = \Sigma_{i=1}^{3} (q_{iAB} * h_{ilA} + qi_{AB} * h_{iuB}) \qquad (1B.4\text{-}11)$$

where:

q_{iAB} = *annual cargo tonnage of handling class I moving from Port A to Port B*
h_{ilA} = *loading rate for handling class I at Port A (days per ton)*
h_{iuB} = *unloading rate for handling class I at Port B (days per ton)*

The average time spent by a single trip tow in these operations is obtained by dividing by the annual number of round trips from Equation (1B.4-9):

$$\text{Round Trip time for Activity 1} = t_1 = \frac{T_1}{N} = \frac{2T_1 n e_c e_L e_d Y}{Q} \qquad (1B.4\text{-}12)$$

1B.4.1.5 Pickup Waiting Time

After loading and unloading of the barges making up a tow is complete, they will normally have to wait to be picked up by a towboat (see section 1B.2.1.1). The waiting time will depend on the scheduling of tows, which is not treated by the model. The average barge waiting time per round trip is:

$$\text{Round Trip time for Activity 3} = t_3 = u_A + u_B \qquad (1B.4\text{-}13)$$

where:

u_A = *specified waiting time per barge at Port A (days)*
u_B = *specified waiting time per barge at Port B (days)*

1B.4.1.6 Tow Make-up and Break-up Time

When a towboat arrives at a port, time is consumed in dropping off barges which have reached their destination and picking up a new group. The model assumes that all such activity occurs at the endpoints of the trip under consideration. The time required is computed from two parameters specified for each port: a fixed delay which is experienced whenever a towboat stops at a port, regardless of the number of barges handled, and an additional delay incurred for each barge picked up or dropped off (see section 1B.2.1.1). Since the average number of barges in a tow is ne_c and this number of barges is both dropped off and picked up at each port, the average total time spent per round trip in such operations is:

$$\text{Round Trip time for Activity 4} = t_4 = m^A_f + 2ne_c m^A_v + m^B_f + 2ne_c m^B_v \qquad (1B.4\text{-}14)$$

$$= m^A_f + m^B_f + 2ne_c\,(m^A_v + m^B_v)$$

where:
m^A_f = *fixed tow stopping time at Port A*
m^B_f = *fixed tow stopping time at Port B*

1B.4.1.7 Link Travel Time

The activity which generally consumes the majority of the trip time of a tow is travelling the links of the waterway system between ports and locks. The time spent in link travel is calculated from a tow speed function described in section 1B.4.1.11. The speed function is applied at each link. The total link travel time (Time 5 of TABLE 1B.4.1) is the sum of the link travel over all the sectors included in the route:

$$\text{Time 5} = T_5 = \sum_{i=m}^{n} \left(D_i \left(\frac{1}{V_{ui}} + \frac{1}{V_{di}} \right) \right) \qquad (1B.4\text{-}15)$$

where:
D_i = *one way distance travelled on sector i (miles)*
V_{ui} = *average up-stream tow speed on sector i (mph)*
V_{di} = *average down-stream tow speed on sector i (mph)*

1B.4.1.8 Lockage Transit Time

Transit times (processing and delay) past locks in the system are represented by tonnage-transit curves relating an average tow transit time to an annual aggregate traffic level at the project. In the verification, calibration, and validation of the model's movement shipping plans, however, these tonnage-transit curves are not used. Instead, the model uses the target (observed) transit time in the "*Targets*" database table (1B.2.10.7.1) as input in its calculations. The total lockage transit time for a trip is the sum of the individual lockage transit times:

$$\text{Time 6} = T_6 = \sum_{i=m}^{n} \left(\left(1 - P_{oi}\right) L_i + P_{oi} S_i \right) \qquad (1B.4\text{-}16)$$

where:
L_i = *is the average transit time at lock i*
S_i = *is the average seasonal process at lock i*
The sum is over the locks along the tow's route.

1B.4.1.9 Shipment Cost Calculation

After the Port-to-Port Algorithm has determined the round trip times T_1 through T_6, it converts them to cost per ton using the cost factors specified for towboats, barges, and cargo, and the applicable user fees.

For towboats and barges, the input data specifies variable operating costs and also fixed annual ownership costs. In order to allocate the fixed costs, they are converted to equivalent daily costs by dividing by the number of operating days per vessel per year. The number of operating days takes into consideration the specified availability factors for the vessels.

The effective daily operating cost for a towboat is thus:

$$Z_{tv} = gf + L + Z_{tv} + \frac{Z_{tf}}{365a_t} \qquad (1B.4\text{-}17)$$

where:

- Z_t = *total operating cost ($/day)*
- *g = fuel consumption rate (gal/day)*
- *f = price of fuel, including tax ($/day)*
- *L = labor cost ($/day)*
- Z_{tv} =*other variable operating costs ($/day)*
- a_t =*availability factor*
- Z_{tf} =*annual fixed cost, including registration fee if applicable ($/year)*

Note that two fuel consumption rates are specified, one applying to line-haul operations and the other to maneuvering operations. This leads to two corresponding operating rates which will be denoted Z_{to}, for line-haul, and Z_{tm} for maneuvering.

Barge costs are also specified by fixed and variable components. These costs are converted to an effective daily operating cost in a manner similar to that done for towboats:

$$Z_b = Z_{bv} + \frac{Z_{bf}}{365a_b} \qquad (1B.4\text{-}18)$$

An additional source of shipping cost is the inventory cost of the cargo being transported. This cost is specified for each commodity class as the product of the value of the commodity and the inventory cost factor:

$$Z_c = \frac{V_c h_c}{365} \qquad (1B.4\text{-}19)$$

where:

- Z_c = *inventory cost ($ per ton per day)*
- v_c = *commodity value ($ per ton)*
- h_c = *annual holding cost factor*

The inventory cost rates are average during both stages of shipment aggregation to yield the value of Z_c used by the Port-to-Port algorithm.

Combining the operating costs above with the shipping times and tow capacities derived previously produces the shipping costs per ton-mile. The towboat contribution to these costs (i = 1) is:

$$C_{ij} = 0 \qquad j = 1,2,3$$

$$C_{i,5} = \frac{Z_{t0}\, t_5}{2ne_c\, e_L\, e_d\, YD} \qquad (1B.4\text{-}20)$$

$$C_{ij} = \frac{Z_{tm} t_j}{2ne_c\, e_L\, e_d\, YD} \qquad j = 4,6$$

The numerator in these equations is the total towboat cost for a round trip, and the denominator is the number of ton-miles produced from equation (1B.4-8). The fact that towboats do not participate in the first three activities (TABLE 1B.4.1) has already been noted.

Shipping costs due to barges (i = 2) are given by:

$$C_{2j} = \frac{ne_c\, z_b\, t_j}{2ne_c\, e_L\, e_d\, YD} = \frac{z_b\, t_j}{2e_L e_d YD} \qquad j = 1,2,...,6 \qquad (1B.4\text{-}21)$$

Cargo inventory costs for the trip (i = 3) are computed as:

$$C_{3j} = \frac{ne_c\, e_L\, e_d YZ_c\, t_j}{2ne_c\, e_L\, e_d\, YD} = \frac{z_c\, t_j}{2D} \qquad j = 1,2,...,6 \qquad (1B.4\text{-}22)$$

The final source of shipping costs arises from lockage fee and/or segment tolls (other user fees are included in vessel operating costs). These costs do not depend on the trip time. The contribution of loackage fees (summed over the locks transited) to shipping costs will be:

$$C_{4,6} = \frac{2_i\, F_i}{2ne_c\, e_L\, e_d\, YD} \qquad (1B.4\text{-}23)$$

where:
F_i = *is the lockage fee at lock i*

Segment tolls (summed over the segments transited) are specified directly on a mills per ton-mile basis so they contribute directly to shipping costs:

$$C_{4,5} = \frac{\sum_{i=m}^{n} F_i\, D_i}{D} \qquad (1B.4\text{-}24)$$

where:
F_i = *is the toll*
D_i = *is the distance traveled on river segment i*

1B.4.1.10 Fleeting Operations

The previous discussion has assumed that cargo is carried from its origin to its destination using the same towboat and barges which were selected by the Port-to-Port Algorithm. However, this tow configuration, while being optimum for the total route, is likely to be less efficient for some of the sectors through which it must travel. The model provides an opportunity for the tow to change the number of barges and/or the size (horsepower) of the towboat being used. This is allowed only at re-fleeting ports. For a movement which passes through such ports, the Port-to-Port Algorithm is applied to the individual sections of the route, between an origin/destination and an intermediate fleeting point or between two such fleeting points to determine the best trip plan for each section. The algorithm is also applied to the complete route with no re-fleeting allowed.

When a trip endpoint is a fleeting point rather than a final destination, no cargo loading or unloading takes place. Therefore, the times and costs associated with activities 1 (loading and unloading) and 2 (waiting for dock access) at an intermediate port are zero. The time (and thererfore the cost) for waiting for a towboat and tow makeup and breakdown are specified at the port level, and so the intermediate ports are treated in the same manner as the origin port was at the beginning of the trip. Link travel and lock operations are unaffected.

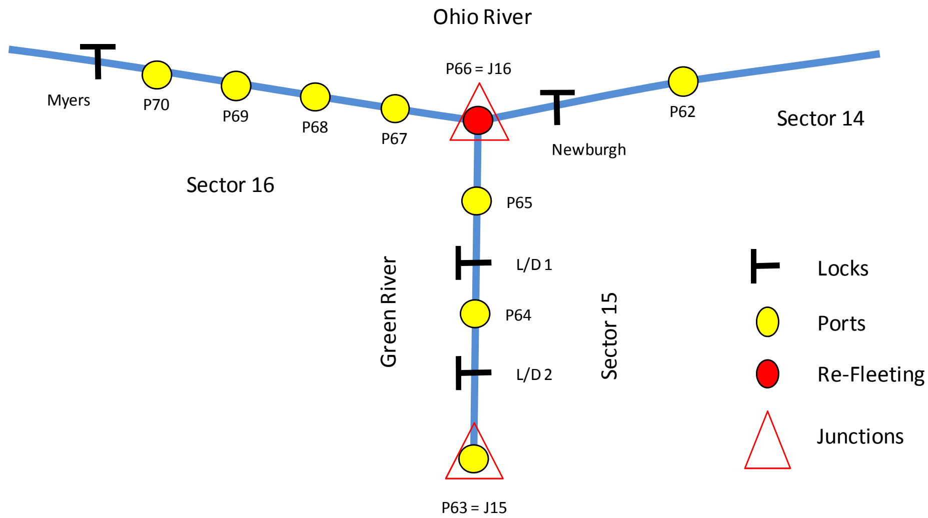
The time and cost of a route involving fleeting is the sum of the times and costs of the individual section trips. Compared to a straight-through route, the fleeting alternative requires extra towboat waiting and tow makeup time at the intermediate ports. However, this may be more than compensated for by the ability to use the most efficient towboat and tow-size on each route selection.

The model does not operate within a time continuum; it is not a dynamic waterway simulator. Instead, the model is a waterway cost accounting tool; it endeavors to account waterway costs primarily by summing the costs of each individual movement, i.e., each origin-destination-commodity combination. Each movememt is considered independently of every other movement, even when fleeting is to take place. The model does not explicitly consider interaction between specific movements. Even extremely small movements, such as one or two barge-loads per year are accounted separately. The model often uses fractional “towboats” and fractional “round trips” to consider these movements as portions of larger movements (tows). The model does, however, consider the aggregate traffic levels of each waterway element, and uses these aggregate levels to determine the transit time at locks (and back-haul potential in the case of the original Port-to-Port Algorithm)

The purpose of fleeting in the model is to allow for major changes in tow-sizes, particularly as certain shipments move between waterways having different channel and lock sizes. Thus, fleeting is best accomplished at waterway junctions, such as at the mouth of the Green River where four-jumbo-barge Green River coal tows are assembled into fifteen-jumbo-barge tows for the Ohio River transit.

The actual placement of the fleeting ports within the network (section 1B.2.9.1.6) is critical. Model ports to be used for fleeting must be located in common with (at a zero distance from) waterway junction ports. However, the choice of the sector in which the fleeting point is located is also important. In fact, in some cases two fleeting points are required at the same junction. As an example, as shown in FIGURE 1B.4.2, the junction point J16 is common to each of Sectors 14, 15, and 16. These is one port shown located at J16; P66. However, in the model each port (including Fleeting Ports) can belong to only one sector. Port P66 is considered a portion only of Sector 15 (Green River). Movements between Sectors 14 and 15, and those between Sectors 15 and 16 move through P66. Conversely, main-stem movements between Sectors 14 and 16 pass through J16 but not through P66. Therefore, in order to consider fleeting between all three possible sector interfaces (between Sectors 14 and 16, Sectors 14 and 15, and Sectors 15 and 16), two fleeting ports would be required at this same junction.

FIGURE 1B.4.2 – Waterway Network Re-Fleeting Ports



As mentioned previously, the number of fleeting points has a direct effect upon model run costs since all shipments passing through a fleeting point are considered for re-fleeting. Typically, most fleeting points are located in the smaller tributary sector (e.g., Sector 15) at zero miles from the junction with the main-stem waterway. This way only movements passing into or out of the tributary stream will be considered for re-fleeting. Occasionally, however, it may be desirable to locate another fleeting point at the junction in one of the main-stem sectors to allow for further re-fleeting of the non-tributary movements.

1B.4.1.11 Tow Speed Calculation

In order to calculate the time required to travel between two points in the network it is necessary to estimate the average speed as a function of tow and waterway characteristics.

1B.4.1.11.1 The Basic Idea

A tow moving through the water at a constant speed is in a state of equilibrium where resistance R of the tow is balanced by an equal and opposite thrust T from the towboat propeller (R = T). The resistance of a vessel tends to increase with the square of the speed so it is useful to define the specific resistance as:

$$r = \frac{R}{v^2} \qquad (1B.4\text{-}25)$$

where:
r = specific resistance
R = tow resistance
v = speed (mph)

In unrestricted water the specific resistance is, to a first approximation, a function only of the vessel size and shape and is independent of speed. Since the range of tow speeds is relatively limited, the thrust is also nearly independent of speed. Combining these results yields the basic formula for tow speed in unrestricted water:

$$v = \sqrt{T/r} \qquad (1B.4\text{-}26)$$

where:
v = speed (mph)
r = specific resistance
T = tow thrust

To estimate the speed of a tow the specific resistance is obtained for each of the component vessels and then combined to produce the resistance of the tow. The thrust is assumed to be proportional to the towboat horsepower. Equation (1B.4-26) is then used to obtain the speed for the influence of shallow water. Adding or subtracting current speed, depending on the direction of travel, completes the calculation.

1B.4.1.11.2 Vessel Resistance

The remaining sections describe the actual formulas and sequence of computation. The specific resistance of each vessel, towboat, or barge making up a tow is computed from the empirical relation[8]:

$$r = 0.0118\, bd^{2/5} \left(L + 70.5 \left(1 - \frac{L}{328} \right) \sqrt{\frac{\delta}{1-\delta}} \right) k_c \qquad (1B.4\text{-}27)$$

where:
- r = *specific resistance*
- b = *beam (width) of vessel (in feet)*
- d = *draft of vessel (in feet)*
- L = *length of vessel (in feet)*
- δ = *block coefficient (ratio of the actual displacement of the vessel to the product of length, width, & draft)*
- k_c = *resistance coefficient (discussed below)*

The resistance coefficient k_c is, in general, a function of the vessel lock coefficient and a quantity known as the Froude Number F_r.

$$F_r = \frac{v}{\sqrt{gL}} \qquad (1B.4\text{-}28)$$

where:
- g = *the gravitational acceleration, 32.2 ft / sec^2*

The dependence of the Froude number on the speed v means that the specific resistance is also a function of the as yet unknown tow speed. Fortunately, the effect is not strong over the narrow range of speeds encountered in practice and k_c may be approximated by a function of δ only. Specifically, the minimum value of k_c for each value of δ was selected from the empirical derived relationship of the Froude number (F_r) and the resistance coefficient (k_c). The resulting function k_c (δ) was then approximated by the quadratic function:

$$k_c(\delta) = 2.42\delta^2 - 3.43\delta + 1.34 \qquad (1B.4\text{-}29)$$

The maximum approximation error is about 3%.

The resistance of each towboat class can be calculated and stored for use by the speed function. The same procedure cannot be used for barges because the draft can vary in the analysis. What is done is to calculate and store the resistance r_{empty} of each barge type when empty. The resistance of a loaded barge is then computed whenever needed as:

[8] *Fomkinsky, L., Method of Drag Calculation for Flotilla Determination, Transport, Moscow, USSR, 1967.*

$$r = r_{empty} \left(d / d_{empty} \right)^{2/5} \qquad (1B.4\text{-}30)$$

where:
d_{empty} = *is the draft when empty*

This follows directly from equation (1B.4-27). In practice the computation of a 2/5 power is replaced by a linear approximation:

$$x^{2/5} \doteq 0.136x + 1.22 \qquad (1B.4\text{-}31)$$

This is a least squares fit over the range 4-8, a typical range of values for the ratio (d/d_{empty}). The maximum error of this approximation on the given interval is about 1%.

1B.4.1.11.3 Tow Resistance

The resistance of a tow is less than the sum of the resistances of its component vessels. A fastening coefficient k_f is defined as the ratio of the actual tow resistance (not including towboat) to the sum of the individual barge resistances. Hence the tow resistance r_f is given by:

$$r_f = K_f \quad r_i \qquad (1B.4\text{-}32)$$

where:
r_i = *the individual barge resistances*

The value of K_f depends on the configuration of barges in the tow and on the individual barge shapes and types of fastenings, none of which are available in the model. However, by assuming typical conditions it is possible to approximate K_f as a function of only the number of barges in the tow and whether they are loaded or empty. In general a tow may include both loaded and empty barges, though WSDM models tows as being composed of only empty barges or only loaded barges. The value of K_f is then interpolated as:

$$K_f = \frac{n_{empty} K_{f\,empty} + n_{loaded} K_{f\,loaded}}{n_{empty} + n_{loaded}} \qquad (1B.4\text{-}33)$$

where:
n_{empty} = *the number of empty barges*
n_{loaded} = *the number of loaded barges*
$K_{f\ empty}$ = *the empty barge resistance*
$K_{f\ loaded}$ = *the loaded barge resistance*

A similar consideration applies to the towboat. A constant coefficient of 0.6 is applies to the towboat resistance before it is added to the tow resistance computed above. In the special case of a light boat the "*tow*" resistance is just that of the towboat, the full value being used in this case.

1B.4.1.11.4 Speed in Still and Unrestricted Water

The remaining quantity necessary to apply equation (1B.4-26) is the thrust force produced by the towboat. This is taken to be proportional to the horsepower, specifically:

$$T = 26.4H \qquad (1B.4\text{-}34)$$

where:
T = *towboat thrust (in pounds)*
H = *horsepower*

Although the assumption of proportionality is not strictly correct it is an adequate approximation in view of the fact that thrust is also influenced by various difficult to quantify aspects of boat design, and also in view of the aggregation of towboats into a relatively small set of classes in the model. It is also true that the effective thrust changes somewhat as the speed changes, but within the range of practical towing speeds this is also a secondary effect and is ignored here. Using equation (1B.4-26) the tow speed v_o in still water of unlimited depth is now computed.

1B.4.1.11.5 Shallow Water Correction

The speed which a tow actually attains is reduced by the influence of restricted waterway conditions. On the inland navigation system the effect of restricted depth is by far the most significant factor and is the only one accounted for in the model.

The shallow water coefficient is determined by an empirical formula:

$$e_h = \left(1 + 2\,\frac{7b}{L}\,\frac{d}{h}\,\frac{V_o^2}{gh}\right)^{-1/2} \qquad (1B.4\text{-}35)$$

where:

h = *is the average depth of the waterway route*
b = *tow width*
L = *tow length*
d = *tow draft*

Since the model does not know the configuration of the barges in the tow a constant ratio of 0.18 is assumed for b/L. b/L is the ratio for a single standard jumbo barge as well as the ratio for a 110' x 600' lock chamber. The draft value used is the average draft of the tow, with the draft of each barge being weighted by its area. When the constant values of b/L and g are inserted, the formula reduces to:

$$e_h = \left(1 + 0.0697\,d\,\frac{V_o^2}{h}\right)^{-1/2} \qquad (1B.4\text{-}36)$$

Multiplying the speed V_o by e_h yields the actual speed of the tow through the water V_w. However, there is an additional physical restriction which must be considered. As the speed of a vessel approaches the speed at which waves travel through the water the resistance increases very sharply. The wave speed in water of depth is SQRT(gh) or 5.67 x SQRT(h) ft/sec. As a practical matter a vessel will not exceed about 70 percent of this critical speed even if it is capable of doing do, because it will be very inefficient. Hence the actual water speed is calculated as:

$$V_w = \text{MIN}\left(e_h V_o\,,\ 3.97\sqrt{h}\right)\ \text{ft}/\text{sec} \qquad (1B.4\text{-}37)$$

Under typical navigation conditions, the ratio $A = A_c/A_t$, where A_c is the channel cross-section area and A_t is the tow middle-section area, exceeds 8.0, the influence of channel width on tow speed can be safely ignored. In the case of canals or other restricted channels, however, A can be less than 8.0, and maximum tow speed is a function of both channel depth and channel width, as follows:

$$V_w = 11.2\sqrt{\cos^3\left(\frac{\pi + \arccos(1 - 1/A)}{3}\right)h} \qquad (1B.4\text{-}38)$$

Tow speeds in canals are nearly always equal to the above limit, and hence equation (1B.4-38) could be used to compute speeds in this situation. Equation (1B.4-38) is not presently used in the model, since the tow middle-section is unknown. However, it could be used as a basis for estimating the factor e_r (discussed below) for channels with restricted dimensions. It would be rather easy to add equation (1B.4-38) to the model later should a need for it become evident.

1B.4.1.11.6 Final Adjustment

At this point the speed is multiplied by the user specified coefficient e_r (section 1B.2.9.1.8) appropriate to the network reach and direction of travel. This coefficient, which should be derived from empirical data, helps account for the many factors not explicitly considered in the speed calculation. Included here, for example, are the presence of sharp bends or obstacles, narrow channels, and the effect of the water level gradient (a tow moving upstream is also moving uphill). The final travel speed is obtained by adding or subtracting the current speed, c.

$$v = e_r v_w \pm c \qquad (1B.4\text{-}39)$$

1B.4.2 Selecting the Least-Cost Shipping-Plan

The shipping plans considered by the model are limited by the characteristics and limitations of the waterway system. The network defined re-fleeting areas (see section 1B.2.9.1.6), river reach tow-size limits (see section 1B.2.9.1.12), and towboat efficiency characteristics (see section 1B.2.9.1.13) reduce the number of shipping plans that must be cost and compared.

In developing the shipping plans, the model's first action is to determine the shipping route of each movement. This step, however, is not needed in the calibration, verification, and validation effort since the historic routings are used to allow comparisons against known targets. Movement routing is controlled through the "*forcedLock*", "*forcedSector*", and "*avoidSector*" fields in the "*MovementDetail*" table (section 1B.2.9.2.3) which are loaded with the historic routing specification. In the calibration model runs, these specification must be adhered to, which reduces the possibilities for shipping routes.

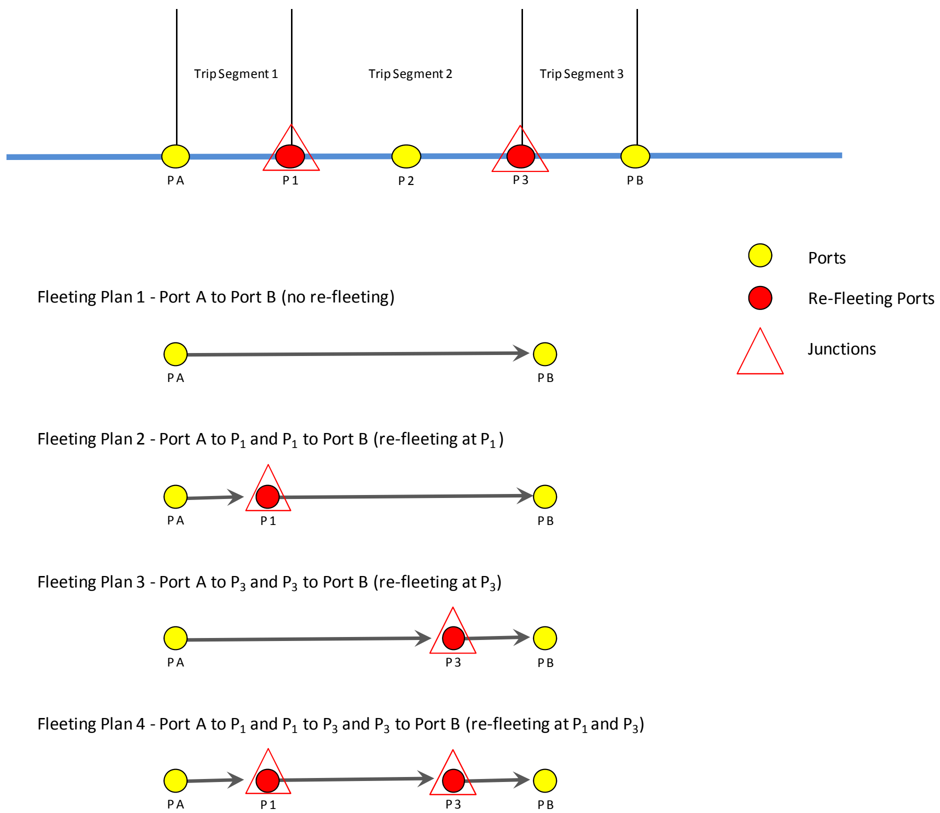
In the second step, the route is then divided into sections called "*trip segments*" defined by the designated re-fleeting points along the route. For example, if the route from Port A to Port B passes through three ports, P_1, P_2, and P_3 of which P_1 and P_3 have been specified as potential re-fleeting points. The movement will be divided into three trip segments: A to P_1, P_1 to P_3, and P_3 to B. If the shipping route under consideration contains more than one trip segment the shipping plan optimization procedure must determine whether or not re-fleeting should actually take place at each fleeting point along the route. A particular choice as to which fleeting points along a route are and are not used is termed a "*fleeting plan*". For the example used previously, there are four possible fleeting plans for traffic between A and B as shown in FIGURE 1B.4.3.

Each component of a shipping-plan is called a "*trip*". Fleeting plan 1 consists of one trip segment, fleeting plans 2 and 3 of two trips, and plan 4 of three trips. Of course, in the case where there are no fleeting points on a route, there will be only one shipping plan with a single trip to consider. The model cycles through all possible shipping-plans for each pair of ports. The towboat optimization procedure described below is applied separately to each trip included in a shipping-plan and the trip costs summed to obtain the total shipping cost for the plan. The plan having the lowest total cost is selected as the one that will be used.

Evaluation of the shipping cost for a trip involves selecting the most efficient towboat and tow-size. This is where the Port-to-Port Algorithm comes directly into use. It is applied to determine the cost of shipping cargo using each towboat class in turn. The class which produces the lowest cost per ton is selected.

For the example route the tow optimization procedure would be called upon to find the optimal tow for different trips: A to B, A to P_1, P_1 to B, A to P_2, P_2 to B, and P_1 to P_2. The optimal trip costs would then be combined according to the four shipping-plans to determine the best overall way of moving cargo from A to B.

FIGURE 1B.4.3 – Example Trip Segments and Fleeting Plans



After the best shipping-plan has been determined, the equipment requirements are computed and recorded along with some other summary statistics. The number of towboats (of the selected class) required to handle the tonnage between two ports is computed as follows. The tonnage moved by a single trip is derived by equation (1B.4-7) in section 1B.4.1.3. The number of trips is then derived by equation (1B.4-9) in section 1B.4.1.3. The time required for a towboat round trip as:

$$\text{Towboat Round-Trip time} = t_t = t_4 + t_5 + t_6 \qquad (1B.4\text{-}40)$$

Since each boat is available for use 365a_t days per year, where a_t is the towboat availability factor, the number of towboat round-trips can be calculated as:

$$\text{Number of Towboat Round-Trips per Year} = N_t = \frac{365a_t}{t_t} \qquad (1B.4\text{-}41)$$

Therefore the number of towboats required is:

$$\text{Number of Towboats Required} = n_t = \frac{N}{N_t} = \frac{Qt_t}{730a_t\, ne_c e_L e_d Y} \qquad (1B.4\text{-}42)$$

From reasoning similar to the above, and remembering that an average of nec barges are required per tow, the total number of barges required is found to be:

$$\text{Number of Barges Required} = n_b = \frac{Qt_b}{730a_t e\ e_d Y} \qquad (1B.4\text{-}43)$$

where:

t_b = *barge round trip time* = $t_1 + t_2 + t_3 + t_4 + t_5 + t_6$

In addition to the towboat and barge requirements the model also records statistics on tow-size distributions, port and lock utilization, and the costs associated with individual ports, locks, and links of the network. If the appropriate run option switches are specified, information about each trip is saved in the "*ShippingPlan*" table (see section 1.4.8.1.1.1 Optional ShippingPlan and ModeSelection Tables of ATTACHMENT 1 Ohio River Navigation Investment Model Version 5.1).

1B.4.3 Storage of the Least-Cost Shipping-Plan

The model developed least-cost shipping plans are stored in the "*LinkShippingPlan*" table as described in TABLE 1B.4.2. As can be seen, the database key is quite large allowing storage of different shipping plans for different system configurations (e.g., without-project versus with project). Additionally, the specification of the shipping plan to a sector-link level allows for specification of shipping plan variation along the waterway route. This allows for re-fleeting specification as tonnage moves from one size waterway segment to another. For example, 60 loaded jumbo barges moving from the upper Kanawha River to the Gulf might take 7 trips with an average 8.57 barges per tow (say, six 9 barge tow trips and one 6 barge tow trip) to the mouth of the Kanawha River where it meets the Ohio River. Then it would have 4 trips of 15 barges per tow to the mouth of the Ohio River where it meets the Mississippi River. Then it may have 3 20 barges per tow to the final waterside destination in the Gulf. Each of these three legs (or tow-sizes) would have its own towboat class specification.

TABLE 1B.4.2 – LinkShippingPlan Table Description

Database Field		Description
networkID	DB Key	River system network (1 = existing ORS)
investmentPlanID	DB Key	Investment plan ID (from InvestmentPlan table)
forecastID	DB Key	Forecasted demand ID (from Forecast table, forecastID = 0 represents historic data).
networkVersion	DB Key	Network version (1 = existing, 2 = 1200' UpperOH main chambers)
movementSetID	DB Key	Movement set ID (from MovementSet table)
movementID	DB Key	Unique movement ID (from MovementDetail table)
sectorID	DB Key	Sector ID (from Sectors table)
linkIndex	DB Key	Link ID (from Links table, 0 specifies Sector level specification)
loadStatus	DB Key	Loading status (F = full or loaded, E = empty).
towboatTypeID		Towboat class ID (from TowboatTypes table).
numberBarges		Number of barges per tow on the leg (tow-size).
speed		Tow speed (mph) for the defined towboat class, tow-size, and link direction.
rpm		Propeller RPM.

The actual descriptors of the shipping plans themselves in the "*LinkShippingPlan*" table are only the towboat class ("*towboatTypeID*"), number of barges in the tow ("*numberBarges*"), speed, and rpm. The "*rpm*" field is inconsequential in this discussion since it has no influence on transportation costs and is only a parameter that is passed through the model to the environmental NAVPAT model.

1B.5 WATERWAY SUPPLY AND DEMAND MODULE CALIBRATION

To validate that the Ohio River Navigation Investment Model (ORNIM) Waterway Supply and Demand Module (WSDM) is developing accurate shipping plans and is capable of replicating observed shipper behavior and system operating characteristics, the model requires calibration. Specifically, the model requires calibration of movement empty barge backhaul flows, movement tow-sizes (including towboat type), and movement re-fleeting (if applicable). During this calibration process, the description of the waterway system being modeled is fine-tuned so the model most accurately replicates observed shipping behavior in the system. Unfortunately, movement level targets are not available and the validation is achieved by comparison of the model results against statistics observed and recorded at the navigation projects in the system.

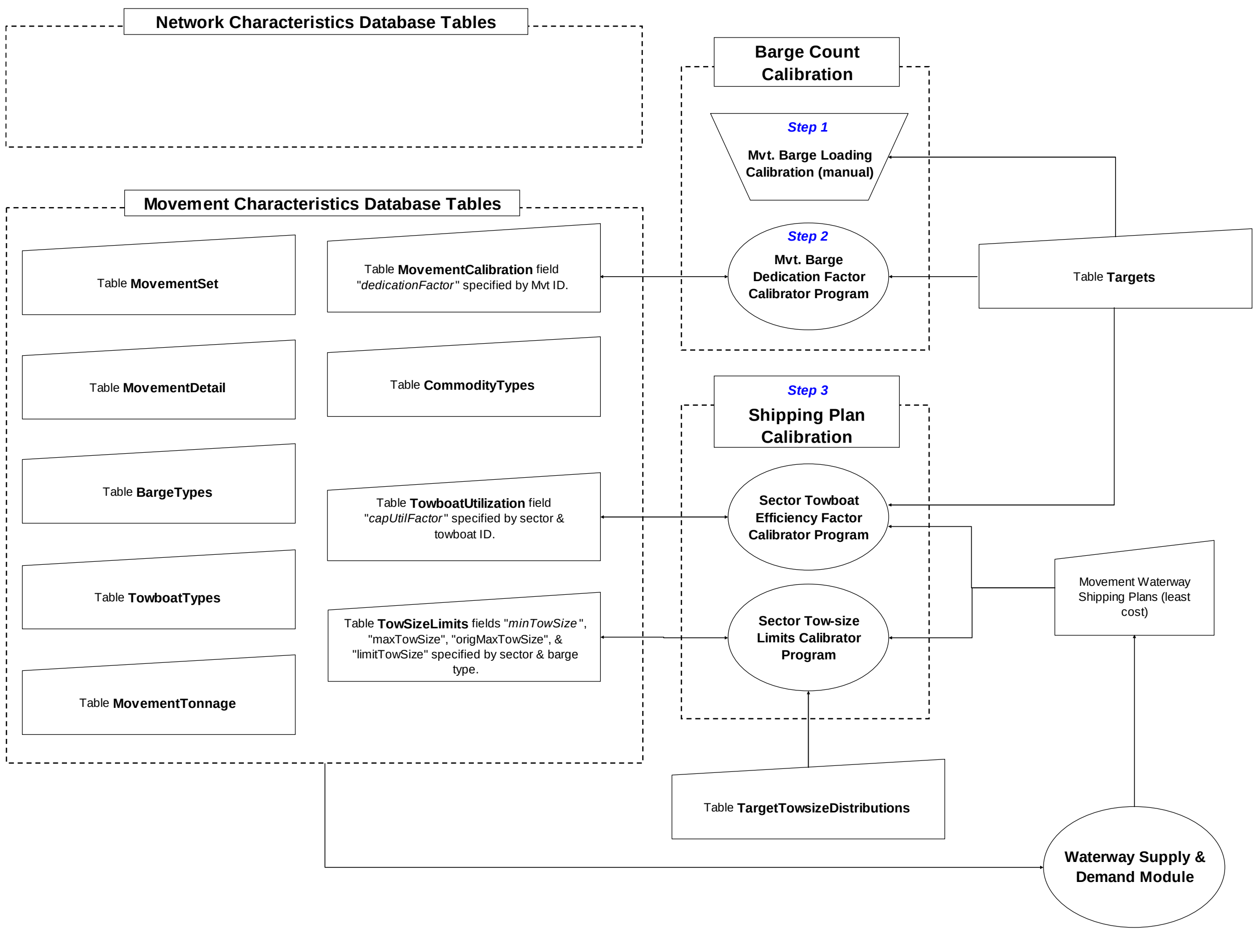
WSDM is a behavioral model and as previously noted WSDM actually serves two tasks: develop least-cost shipping plans and estimate equilibrium system traffic levels from a bottom-up movement level analysis. The focus of calibration is on WSDM movement shipping plan development. By using detailed data describing the waterways network, the equipment used for towing operations, and the commodity flow volume and pattern, WSDM calculates the resources (i.e., number towboats, trip time, and fuel consumption) required to satisfy the demand on a least-cost basis for each movement in the system. These results are then aggregated and summarized at each navigation project in the system and compared with observed behavior.

Calibration is a sequential process involving several iterative steps; at each step, certain static components of the model's waterway system description are adjusted or fine-tuned, the model is exercised, and specific results are compared with corresponding target values. There are three primary calibration steps: calibration of loaded barge flows; calibration of empty barge flows (movement barge dedication); and calibration of the shipping plans. Calibration of the movement shipping plans is further broken into calibration of tow-size and the selection of towboat type (horsepower).

In the past (late 1970's through mid-1990's) these calibrations were completed essentially manually. However, ORNIM now has three automated routines to fine-tune the calibration parameters to the user specified target statistics for the dedication factors and shipping plans. An automated routine to calibrate the loaded barges has not yet been developed since it is currently not needed. As shown in FIGURE 1B.5.1, the three automated calibration routines are known as: 1) the Movement Barge Dedication Factor Calibrator; 2) the Sector Tow-size Limits Calibrator; and 3) the Sector Towboat Efficiency Factor Calibrator. The yet to be developed calibration routine is the Movement Barge Loading Calibrator. The naming and function of these calibration programs are covered in the following sections.

For model calibration, verification and validation for this Upper Ohio analysis, an average of 2004 through 2006 data was used. This was done primarily because the rate data developed for this study assumed the shipping characteristics for this 2004-2006 time period and model costs need to be synchronized with these rates. Additionally, this averaging over several years also allows for a smoothing of the data to avoid individual year irregularities.

FIGURE 1B.5.1 – Calibration Process



1B.5.1 Calibrating the Loaded Barge Flows

The first calibration step is to determine the loaded barge flows in the system. The model determines the number of loaded barges in the system by dividing each movement's annual tonnage by each movement's average barge loading. The average barge loading for each movement can be either calculated internally to the model or it can be calculated externally and specified as an input.

The movement barge loading is stored in the "*TonsPerBarge*" field of the "*MovementDetail*" table (TABLE 1B.2.42). If there is a record for the movement in the MovementCalibration table, then that record overrides the tonsPerBarge value from the MovementDetail table. If, after looking in both of these tables, the value of the "*TonsPerBarge*" field equals zero, the model will automatically calculate a barge loading for the movement using the equation shown below.

$$\text{Mvt. Barge Loading} = \text{MIN}\left(\text{Barge Type Capacity}\;,\;\left(\text{barge Type Length} \times \text{barge Type Beam} \times \text{barge Type Blocking Coefficient}\right) \times \text{MIN}(0.0312, a) \times \text{MIN}(b, c)\right) \quad (1B.5\text{-}1)$$

where:

a = commodity density in tons/cubic foot (field "density" in table "CommodityTypes")
b = barge draft loaded – barge draft empty
c = min depth of link along path – required barge clearance – barge draft empty

For the Upper Ohio analysis the barge loadings were calculated external to the model and supplied as an input directly into the "*MovementDetail*" table. Since channel depths and barge loadings were not expected to change through the analysis period, or between the without and with-project conditions, externally calculating the barge loadings was the most straight forward and accurate method. The external calculation of the movement barge loading is discussed in section 1B.2.7.

Since studies to date have not needed an analysis of barge loading effects, an automated calibration of the barge loadings (to be called the Movement Barge Loading Calibrator) has not been developed.

Since the movement barge loadings are specified as input in this analysis, and as a result the system loaded barge statistics that the model should produce given this input are known, this calibration step converts to a verification test (TABLE 1B.3.2).

1B.5.2 Calibrating the Empty Barge Flows

The second calibration step is to determine the empty barge flows in the system, or more specifically, the empty barge backhaul flows associated with each loaded movement. This is done at the movement level so that the loaded front-haul movement can be cost with applicable charges for empty return trips.

Loaded movement empty barge backhauls are determined from a "*dedication*" factor assigned to each movement listed in the "*MovementDetail*" table, which specifies how dedicated the loaded barges are to the movement. If the dedication factor is 0.0, the barges are totally undedicated, meaning that when they have finished the loaded trip from the movement's waterside origin to its waterside destination, they are free to move to another movement and are no longer part of the movement's cost calculation. If the dedication factor is 1.0, the barges are totally dedicated to the movement, meaning that when they have finished the trip from the movement's origin to its destination, they are required to move empty back to the movement's origin. If the dedication factor is between 0.0 and 1.0, the barges are partially dedicated, and the dedication factor indicates what portion of the set of barges must make the trip back to the movement's origin empty.

1B.5.2.1 Loaded Back-Haul Potential

The original Port-to-Port Algorithm (TCM) defined the barge "*dedication*" factor as the probability that the back-haul of a movement will be empty if a back-haul potential exists. The current Port-to-Port Algorithm, however, defines the barge "*dedication*" factor as a simple proportion of movement empty barge back-hauls.

1B.5.2.1.1 Original Barge Dedication Factor Definition

Defining the barge dedication factor as the probability that the back-haul will be empty requires several additional modeling steps. In short, the dedication factor was used as a means to limit potential backhauls even though bidirectional flows of a particular transportation class may exist. And, if a backhaul movement for a particular movement does not exist, there is no other choice than to return empty.

Loaded backhauls are controlled by three factors: 1) the direction of commodity flows carried by the barge; 2) the adaptability of the barge for backhaul (the dedication factor); and 3) the level of towing company efficiency (as affected by institutional and market arrangements, long-term contractual arrangements, imperfect knowledge of potential shippers and consumers, delivery timing, etc.).

As an extreme example, say there is only one movement in the system generating 100 loaded barges from origin port A downbound to destination port B with a dedication factor of 0.0 transiting one lock project. Simply using the dedication factor in this case would cost the movement for only the loaded shipment(s) and result in 100 loaded barges downbound and zero barges upbound through the lock. With this example there is no conservation of barge equipment (there are no loaded backhauls and no empty barge deliveries to port A) and the system is unsustainable. In this example, despite a dedication factor of 0.0, there is no other choice than to return empty. The movement will have to generate, and be cost for, empty return trips in order to supply its own empty barge needs. In effect, the applied dedication factor is 1.0 resulting in 100 loaded barges downbound and 100 empty barges upbound through the lock.

As an additional example, say there are two movements in the system. MovementID 1 consists of 100 loaded barges from origin port A down-bound to destination port B with a dedication factor of 0.0 transiting one lock project. MovementID 2 consists of 100 loaded barges from origin port B upbound to destination port A with a dedication factor of 0.75 transiting the same lock project. While all 100 loaded barges from movementID 1 are released and available for loaded backhaul, movementID 2 has 75% of its loaded barges dedicated to the movement which means that only 25% (or 25) of its barges are released at port A and available for loading by movementID 1. As a result, despite movementID 1 having a dedication factor of 0.0, it will require 75 of its loaded barges to return empty; an effective dedication factor of 0.75.

1B.5.2.1.2 Current Barge Dedication Factor Definition

The current Port-to-Port Algorithm defines the barge dedication factor as a simple proportion of movement empty barge backhauls (assuming the remaining barges return to the origin as loaded fronthauls of other movements. This simplification avoids specification of transportation classes (section 1B.4.1.1), speeds up the shipping-plan calculations, and simplified the empty barge calibration.

1B.5.2.2 Movement Barge Dedication Factor Calibrator

Empty trips are recorded by WCSC, however, the data files have been found to be incomplete (although improving through time). As a result, backhaul characteristics between specific origin-destinations can only be estimated. While the movement dedication factors can be manually set and adjusted by the user, an automated calibration program called the Movement Barge Dedication Factor Calibrator (FIGURE 1B.5.1) was developed. In this process, the dedication factor is assigned using a set of linear programming problems. In the first linear program the objective is to minimize the deviation from the target number of empty barges at each navigation project, given the path that each of the movements is taking. Solving this, the program determines a total "*best deviation from targets*" value. In general, there may be several assignments of dedication factors to movements that will achieve this best deviation. Tanker barges are more likely to be dedicated than are hopper barges, due to the nature of the cargo that they carry. The second linear program attempts to maximize the dedication factors for the tanker classes of barges, and minimize the dedication factors for the hopper classes of barges. Using this objective and the added constraint that the total deviation is equal to the "*best deviation*" found in the first linear program, the model determines a final setting of the dedication values which are then stored.

The empty barge flows are then aggregated and summarized at each navigation project in the system and compared against observed behavior. As shown in TABLE 1B.5.1, calibration of movement level dedication factors appear to reproduce system empty barge flows quite well. There appear to be slightly more empty barges moving through Monongahela River L/D 2 in the model's estimation.

Since the empty barge flows are generated from loaded movements through the movement's dedication factor, when the model is exercised with a future traffic demand, the empty barge flows automatically adjust as the loaded barge flows adjust to equilibrium. Given that the demand growth and equilibrium mix of movements could, and most likely will be, different than in the calibrated year, the percent empty barges at the projects can, and most likely will, vary from the values shown. For an extreme example, say the demand for movements in the system with 0.0 barge dedication factors decline through time to zero, while demand for movements in the system with 1.0 barge dedication factors increase. Through time the percent empty at all projects will rise to 50% empty as more and more trips in the system require empty barge returns.

If for some reason, a future fleet is needed that assumes different empty barge return characteristics, the dedication factors can be re-calibrated using the anticipated navigation project empty barge count targets. If the empty barge backhaul on individual movements are identified as needing adjustment under a new future fleet, they can be adjusted manually. As shown in FIGURE 1B.5.1, the movement dedication factors are stored in the "*MovementCalibration*" database table summarized in TABLE 1B.5.2. The database contains a "*year*" field in the key allowing for specification of a year specific calibration of the dedication factors, as well as a year specific barge loading. As noted, for model calibration for the Upper

Ohio analysis an average of 2004 through 2006 data was used, and in this case the calibration parameters and target statistics were stored in the database as year "*9999*".

TABLE 1B.5.1 – Empty Barge Calibration

Navigation Lock Project	Number of Empty Barges: Estimated Target *	Number of Empty Barges: Model Output	Number of Empty Barges: Difference Absolute	Number of Empty Barges: Difference Percentage	Percent Empty: Estimated Target *	Percent Empty: Model Output	Percent Empty: Difference Absolute	Percent Empty: Difference Percentage
OHIO RIVER								
LOCK & DAM 53 (OHIO)	21,360	21,363	-3	0.0%	30%	30%	0	0.0%
LOCK & DAM 52 (OHIO)	30,746	30,749	-4	0.0%	35%	35%	0	0.0%
SMITHLAND L/D	25,634	25,636	-3	0.0%	34%	34%	0	0.0%
MYERS L/D	22,015	22,017	-2	0.0%	33%	33%	0	0.0%
NEWBURGH L/D	25,096	25,098	-2	0.0%	37%	37%	0	0.0%
CANNELTON L/D	18,386	18,388	-2	0.0%	33%	33%	0	0.0%
MCALPINE L/D	15,440	15,442	-2	0.0%	31%	31%	0	0.0%
MARKLAND L/D	12,990	12,991	-2	0.0%	28%	28%	0	0.0%
MELDAHL L/D	17,598	17,600	-1	0.0%	34%	34%	0	0.0%
GREENUP L/D	25,063	25,065	-1	0.0%	37%	37%	0	0.0%
R.C. BYRD L/D	17,810	17,812	-2	0.0%	32%	32%	0	0.0%
RACINE L&D	17,175	17,177	-3	0.0%	34%	34%	0	0.0%
BELLEVILLE L&D	17,177	17,179	-3	0.0%	34%	34%	0	0.0%
WILLOW ISLAND L&D	16,450	16,452	-2	0.0%	34%	34%	0	0.0%
HANNIBAL L&D	18,490	18,492	-2	0.0%	36%	36%	0	0.0%
PIKE ISLAND L&D	17,705	17,707	-2	0.0%	41%	41%	0	0.0%
NEW CUMBERLAND L&D	14,793	14,795	-2	0.0%	41%	41%	0	0.0%
MONTGOMERY L&D	8,541	8,542	-1	0.0%	36%	36%	0	0.0%
DASHIELDS L&D	9,051	9,052	-1	0.0%	37%	37%	0	0.0%
EMSWORTH L&D	8,069	8,070	0	0.0%	36%	36%	0	0.0%
MONONGAHELA RIVER								
MON LOCK & DAM 2 L&D	7,091	7,113	-22	-0.3%	35%	35%	0	-0.2%
MON LOCK & DAM 3 L&D	7,400	7,400	0	0.0%	43%	43%	0	0.0%
MON LOCK & DAM 4 L&D	7,693	7,693	0	0.0%	48%	48%	0	0.0%
MAXWELL L&D	9,378	9,378	-1	0.0%	46%	46%	0	0.0%

** Averaged 2004-2006 LPMS data.*

TABLE 1B.5.2 – MovementCalibration Table Description

Field		Field Description
networkID networkVersion movementID year	DB Key	*identifies the waterway network (e.g. ORS)* *network version ID which allows variations in the base network (e.g. 2 for 3 locks)* *identifies the specific origin-destination-commodity-barge annual movement* *calendar year which allows specification of the barge loading & empty return characteristics by year.*
tonsPerBarge		*barge loading (annual tonnage divided by this loading gives the number of loaded barge trips).*
dedicationFactor		*percent of loaded barges requiring empty barge return.*

1B.5.3 Calibrating Tow-sizes, Number of Tows, and Towboat Type

The third component of the calibration process is the calibration of the movement shipping-plans, or specifically movement level tow-sizes and towboat types used between waterside origin to waterside destination. If movement tow-sizes and towboat types were set based solely on the physical limitations of the river and the towing capacity of the equipment, WSDM would tend to produce shipping plans with larger tows and smaller towboats than historically observed. This occurs because WSDM calculates the resources (i.e., number towboats, trip time, and fuel consumption) required to satisfy the demand on a least-cost basis. Because of economies of scale, the smallest towboat to move the largest tow is the least-cost shipping plan, however, the world is not perfect and other factors are considered in the shipping plan determination.

Unlike the calibration of empty barge flows in the system where movement dedication factors are adjusted, calibration of the movement shipping plans involves two sets of calibration parameters specified at the river segment level (rather than at the movement level). When the model develops a shipping plan for a movement, it considers all the river segment restrictions in its route. To account for the factors causing shippers to use smaller tow-sizes than possible, WSDM contains a calibration parameter specifying river segment tow-size limitations. To account for the factors causing shippers to use larger horsepower towboats than possible, WSDM contains a calibration parameter specifying river segment towboat class efficiency limitations. These two calibration parameters are interrelated in their effect on the selection of a movement's least-cost shipping plan and ultimately the fleet distributions observed at each navigation project.

Given the specified river segment tow-size and towboat class efficiency limitations WSDM calculates the least-cost shipping plan for each movement in the system. Note that this shipping plan might involve multiple waterway legs, each having their own tow-size and towboat characteristics. The shipping plans for all the movements can then be aggregated and summarized at each navigation project in the system and compared against observed behavior (e.g., number of tows and average horsepower).

In addition, each towboat type specified in the model has a maximum limit as to the number of barges that it can tow, regardless of where in the river system it is working. These towboat class towing limits are typically fixed and are not adjusted in the calibration process. However, they limit the ability of calibrating to movement tow-sizes larger than these equipment limits. To summarize, the tow-sizes selected by the model are limited by: 1) river segment barge type tow-size limits along the movement's route; 2) river segment towboat class efficiency factors along the movement's route which are used to determine the towboat type; and 3) the towboat class towing capacity (maximum barges per tow).

As discussed, river segments in the model network are defined as rivers, sectors, nodes, and links (FIGURE 1B.2.1). The tow-size limits and towboat class efficiency factors are specified at the link level, however, sector level setting can be specified. The "*linkIndex*" in the "*TowSizeLimits*" table (TABLE 1B.2.35) corresponds to the link ID specified in the "*Links*" table (TABLE 1B.2.29). When "*linkIndex*" is set to zero, however, the parameters are used for all links within that sector except for any link specific records which will override any sector level specification.

1B.5.3.1 Tow-Size Limits and Towboat Efficiency Factor Calibrators

While the river segment tow-size limits and towboat efficiency factors can be manually set and adjusted by the user, two automated calibration programs called the Sector Tow-size Limits Calibrator and the Sector Towboat Efficiency Factor Calibrator (FIGURE 1B.5.1) were developed. Because the determination of the shipping plan is a complex process, an analytic procedure similar to that used to set the dedication factors (empty barge flows) could not be used. Instead, the calibration of movement tow-size and towboat type is done in an iterative process, by making a small change to a sector level tow-size limit or towboat efficiency factor (i.e., "*linkIndex*" = 0), running WSDM with the changed value, and noting whether the result is closer to the targets than before the change. This is done for every barge type and for every towboat type on every specified river segment. Once all of the possible changes have been examined, the calibration program chooses the change that will result in the most improvement, changes that value in the database, and then iterates again. When improvements are negligible (less than a .001 change), or the analyst determines the improvements are negligible, the calibration program is stopped.

The Sector Tow-size Limits Calibrator and the Sector Towboat Efficiency Factor Calibrator can be run separately, but are typically run simultaneously. These automated calibration programs are very CPU intensive, especially when run together. To speed up the calibration process in the study area, ORNIM allows the specification of a sector range (an aggregation of links) to calibrate.

1B.5.3.2 Determination of the Calibration Network Sectors

As noted, the shipping plan calibration programs adjust the various calibration parameters for every barge type and for every towboat type on every specified river segment. These river segments are referred to in the model as sectors (FIGURE 1B.2.1). Iterating through all 200 sectors in the ORS network and adjusting the tow-size limit and towboat efficiency factors can be very CPU intensive. By focusing calibration on the most important sectors, the two automated shipping plan calibration processes can be sped up. To do this ORNIM allows the specification of a sector range on which to iterate these two calibration programs.

As discussed in section 1B.2.8, for model verification, calibration, and validation the focus is on the Ohio River and the lower four projects on the Monongahela River given the commonality of Upper Ohio River flows with these areas of the ORS. As a result, sectors 2 (middle Monongahela River) through 18 (lower Ohio River) were specified as the calibration sector range.

1B.5.3.3 Sector - level Tow-size Limits

The Sector Tow-size Limits Calibrator was run to adjust and calibrate the "*maxTowSize*" field in the "*TowSizeLimits*" table (TABLE 1B.2.35) with "*linkIndex*" set to zero. When "*linkIndex*" is set to zero the parameter is used for all links within that sector unless overridden with a link specific "*maxTowSize*" entry. Once adjustments to the tow-size limits are made, the model re-estimates the least-cost movement shipping plans which are then aggregated and summarized at each navigation project in the system and compared against observed behavior (the targets) as shown in TABLE 1B.5.3.

TABLE 1B.5.3 – Tow and Tow-size Calibration

Navigation Lock Project	Number of Tows				Average Barges Per Tow			
	Estimated Target *	Model Output	Difference Count	Difference Percentage	LPMS Target **	Model Output	Difference BPT	Difference Percentage
OHIO RIVER								
LOCK & DAM 53 (OHIO)	6,574	6,862	-288	-4.4%	10.8	10.4	0.5	4.2%
LOCK & DAM 52 (OHIO)	9,268	8,627	642	6.9%	9.6	10.3	-0.7	-7.4%
SMITHLAND L/D	7,270	7,229	41	0.6%	10.4	10.4	-0.1	-0.6%
MYERS L/D	5,991	5,994	-3	-0.1%	11.1	11.1	0.0	0.0%
NEWBURGH L/D	6,346	6,290	56	0.9%	10.7	10.8	-0.1	-0.9%
CANNELTON L/D	5,162	5,211	-50	-1.0%	10.7	10.6	0.1	0.9%
MCALPINE L/D	5,275	4,932	343	6.5%	9.5	10.1	-0.7	-6.9%
MARKLAND L/D	4,791	4,628	162	3.4%	9.5	9.9	-0.3	-3.5%
MELDAHL L/D	5,030	5,418	-388	-7.7%	10.4	9.7	0.7	7.2%
GREENUP L/D	6,115	6,685	-570	-9.3%	11.0	10.1	0.9	8.5%
R.C. BYRD L/D	5,260	5,380	-121	-2.3%	10.4	10.2	0.2	2.2%
RACINE L&D	4,564	4,628	-64	-1.4%	11.1	11.0	0.2	1.4%
BELLEVILLE L&D	4,412	4,608	-197	-4.5%	11.4	10.9	0.5	4.3%
WILLOW ISLAND L&D	4,345	4,343	2	0.0%	11.0	11.0	0.0	-0.1%
HANNIBAL L&D	4,773	4,981	-208	-4.4%	10.8	10.4	0.5	4.2%
PIKE ISLAND L&D	4,679	4,964	-285	-6.1%	9.3	8.8	0.5	5.7%
NEW CUMBERLAND L&D	4,116	4,120	-5	-0.1%	8.8	8.8	0.0	0.1%
MONTGOMERY L&D	3,953	3,968	-15	-0.4%	6.0	5.9	0.0	0.4%
DASHIELDS L&D	3,802	3,890	-89	-2.3%	6.4	6.3	0.1	2.3%
EMSWORTH L&D	3,919	3,610	308	7.9%	5.7	6.2	-0.5	-8.5%
MONONGAHELA RIVER								
MON LOCK & DAM 2 L&D	3,382	3,408	-26	-0.8%	6.1	6.0	0.0	0.7%
MON LOCK & DAM 3 L&D	5,152	5,184	-32	-0.6%	3.3	3.3	0.0	0.6%
MON LOCK & DAM 4 L&D	4,342	4,642	-301	-6.9%	3.7	3.5	0.2	6.5%
MAXWELL L&D	3,374	4,065	-691	-20.5%	6.1	5.0	1.0	17.0%

** Sum of WCSC loaded barges plus estimated empty barges (using averaged 2004-2006 LPMS percent empty) divided by averaged 2004-2006 LPMS barges per tow.*

*** Averaged 2004-2006 LPMS barges per tow data.*

While not a perfect match, it should be noted that the modeling process simplifies tows to one commodity (or empty) and one barge type, while in the real world tows are often comprised of multiple commodities, including empties, in multiple types of barges. Expectation of a perfect match between the observed target data and the model results would be unrealistic.

While the Sector Tow-size Limits Calibrator can adjust the "*maxTowSize*" field up or down, there is also a "*limitTowSize*" field in the "*TowSizeLimits*" table to cap the upper adjustment. This is to ensure that tow-sizes do not exceed the operating policy of the locks (e.g., main chamber single cut).

1B.5.3.4 Sector - level Towboat Efficiency Factor

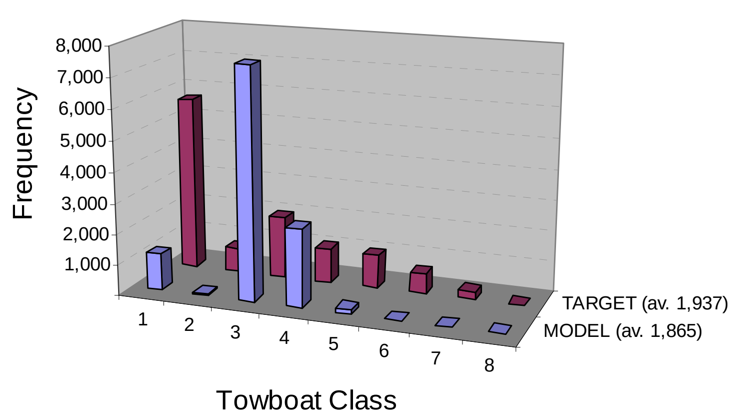
The Sector Towboat Efficiency Factor Calibrator was run to adjust and calibrate the "*capUtilFactor*" field in the "*TowboatUtilization*" table (TABLE 1B.2.35) with "*linkIndex*" set to zero. When "*linkIndex*" is set to zero the parameter is used for all links within that sector unless overridden with a link specific "*capUtilFactor*" entry. Once adjustments to the towboat efficiency factors are made, the model re-estimates the least-cost movement shipping plans which are then aggregated and summarized at each navigation project in the system and compared against observed behavior (the targets) as shown in TABLE 1B.5.4. Additionally, the 2004 through 2006 LPMS towboat class frequencies for Emsworth, Dashields, and Montgomery were summarized and compared against model output as shown in FIGURE 1B.5.2.

TABLE 1B.5.4 – Towboat Type (Average Horsepower) Calibration

Navigation Lock Project	Average Project Rated Horsepower			
	LPMS Class Av. Target	Model	Difference HP	Difference Percentage
OHIO RIVER				
LOCK & DAM 53 (OHIO)	4,150	3,579	570	13.7%
LOCK & DAM 52 (OHIO)	3,700	3,564	136	3.7%
SMITHLAND L/D	4,028	3,912	116	2.9%
MYERS L/D	4,320	4,138	182	4.2%
NEWBURGH L/D	4,084	4,055	29	0.7%
CANNELTON L/D	3,974	4,003	-29	-0.7%
MCALPINE L/D	3,885	3,887	-2	-0.1%
MARKLAND L/D	3,964	3,878	86	2.2%
MELDAHL L/D	3,862	3,823	39	1.0%
GREENUP L/D	3,750	3,920	-170	-4.5%
R.C. BYRD L/D	3,550	4,082	-532	-15.0%
RACINE L&D	3,508	4,190	-683	-19.5%
BELLEVILLE L&D	3,536	4,179	-643	-18.2%
WILLOW ISLAND L&D	3,479	4,199	-720	-20.7%
HANNIBAL L&D	3,239	3,867	-628	-19.4%
PIKE ISLAND L&D	3,037	2,874	162	5.3%
NEW CUMBERLAND L&D	2,972	2,895	78	2.6%
MONTGOMERY L&D	1,995	1,818	177	8.9%
DASHIELDS L&D	1,924	1,896	29	1.5%
EMSWORTH L&D	1,890	1,883	8	0.4%
MONONGAHELA RIVER				
MON LOCK & DAM 2 L&D	1,864	1,860	4	0.2%
MON LOCK & DAM 3 L&D	1,389	1,327	62	4.5%
MON LOCK & DAM 4 L&D	1,333	1,364	-31	-2.3%
MAXWELL L&D	1,293	1,660	-368	-28.5%

SOURCE: 2004-2006 WCSC and LPMS data.

FIGURE 1B.5.2 – Emsworth, Dashields, and Montgomery Towboat Class Distributions



While the average horsepower through the Upper Ohio projects is only 3.7% low, when comparing the horsepower class distributions it becomes obvious that the model is producing too many towboat class 3 tows and too few towboat class 1 tows. A better towboat class distribution match can be achieved through the auto tow-size and towboat type calibration programs discussed below, however, at this time for the draft analysis the horsepower calibration was considered adequate.

The Sector Towboat Efficiency Factor Calibrator adjusts the "*capUtilFactor*" between 0.0 – 1.0 which is then applied to the "*maxTowsize*" field in the "*TowboatType*" table (TABLE 1B.2.32) to determine maximum tow-size allowed for that towboat class on that sector. These towboat class towing limits ("*maxTowsize*" field in the "*TowboatType*" table) are fixed at the system level and are not adjusted in the calibration process. These towboat class towing limits do, however, limit the ability of calibrating to movement tow-sizes larger than these equipment limits.

1B.5.3.5 Auto Shipping Plan Calibration Logic

The auto tow-size and towboat type calibration programs (Sector Tow-size Limits Calibrator and Sector Towboat Efficiency Factor Calibrator) use a heuristic approach to minimize the difference between the model's least-cost shipping plan tow configurations and the target (observed) lock statistics in the system. At a summary level, this heuristic generates a set of potential changes to each sector's tow-size and towboat constraints, regenerates all the movement shipping plans under each changed constraint one at a time, and then chooses the single change that produces the greatest improvement. This process continues until no significant improvement can be made.

1B.5.3.5.1 Incumbent Calibration Fitness

The calibration process begins by determining summary lock statistics and comparing them to the specified targets. It calculates three "offness" measures based on: (1) difference in the number of tows ("*offTows*"), (2) difference in the number of tows of each size ("*offTowSize*"), and (3) difference in average horsepower ("*offHorsepower*"). In each case, the absolute difference between the model results and the target at each lock is weighted by the lock's "*calibration weight*" which reflects the importance of the lock in the overall analysis.

These offness measures are calculated as:

$$\text{offTows} = \sum_{\textit{over all locks}} \text{ABS}\left(\begin{matrix}\text{Target \#}\\ \text{of Tows}\end{matrix} - \begin{matrix}\text{Model \#}\\ \text{of Tows}\end{matrix}\right) \times \begin{matrix}\text{Lock}\\ \text{Calibration}\\ \text{Weight}\end{matrix} \quad \text{(1B.5-2)}$$

$$\text{offHorsePower} \sum_{\textit{over all locks}} \text{ABS}\left(\begin{matrix}\text{Target}\\ \text{Av. HP}\end{matrix} - \begin{matrix}\text{Model}\\ \text{Av. HP}\end{matrix}\right) \times \begin{matrix}\text{Lock}\\ \text{Calibration}\\ \text{Weight}\end{matrix} \quad \text{(1B.5-3)}$$

$$\text{offTowSize} = \sum_{\textit{over all locks}} \left(\sum_{\textit{over all tow-size}} \text{ABS}\left(\begin{matrix}\text{Target}\\ \text{Tow-}\\ \text{Size \%}\end{matrix} - \begin{matrix}\text{Model}\\ \text{Tow-}\\ \text{Size \%}\end{matrix}\right)\right) \times \begin{matrix}\text{Lock}\\ \text{Calibration}\\ \text{Weight}\end{matrix} \quad \text{(1B.5-4)}$$

Where the target number of tows and average horsepower for each navigation project in the system are stored in the "Targets" table discussed in section 1B.2.10.7.1 and the target tow-size distributions for each navigation project in the system are stored in the "TargetTowSizeDistribution" table discussed in section 1B.2.10.7.2

These three offness values are measured independently, but they are related. In general, as the number of tows at a lock decreases, the size of the tows going through the lock and the average horsepower of the towboats will tend to increase.

For an overall measure of how well the model parameters have been calibrated to achieve the target values, a single system-wide "*calibration fitness*" value is calculated. To calculate the calibration fitness value these three offness measures are combined with positive weighting factors:

$$\text{Calibration Fitness } \left(\text{offTow} \times \begin{matrix}\text{offTow}\\ \text{Weighting}\\ \text{Factor}\end{matrix}\right) + \left(\text{offTowSize} \times \begin{matrix}\text{offTowSize}\\ \text{Weighting}\\ \text{Factor}\end{matrix}\right) + \left(\text{offHorsePower} \times \begin{matrix}\text{offHorsePower}\\ \text{Weighting}\\ \text{Factor}\end{matrix}\right) \quad (1B.5\text{-}5)$$

The weighting factors are user specified according to the importance of the individual measure in their analysis. In a perfectly calibrated system, the calibration fitness value (and each offness measure) would be zero.

For this Upper Ohio analysis, the twenty Ohio River and the four lower Monongahela River projects were set with lock calibration weights of 1.0, while the remaining thirty-two projects were set with a 0.1 weight. These settings were selected based on an analysis of Upper Ohio River traffic flow commonality as discussed in section 1B.2.8.

The offness weighting factors are primarily used to keep the absolute differences at the same order of magnitude. The offness weighting factors were set as:

offTows weighting factor = 1

offHorsePower weighting factor = 1

offTowSize weighting factor = 500

Once this "*incumbent*" calibration fitness value is calculated, the calibration program examines the effects of small and large changes to the tow-size limit and towboat utilization factor parameters for each sector specified that are inputs to the WSDM model. Recall that the tow-size limits in barges per tow are specified for each combination of sector and barge type, and that the towboat utilization factors are specified for each combination of sector and towboat type. Recall further that for each sector and barge type, there is a user-specified absolute maximum tow-size limit (and an implicit minimum tow size limit of 0 barges), and that towboat utilization factors range from 0.0 to 1.0 (including 0.0 and 1.0) representing a towing capacity utilization of the absolute maximum towing capacity for that towboat class. The calibration process examines modifications to the tow-size limits and towboat utilization factors while staying within these limits. While the user can specify to run the Sector Tow-size Limits Calibrator and the Sector Towboat Efficiency Factor Calibrator, the discussion following assumes both are being run.

The user first specifies a list of sectors the calibration process can modify (1B.5.3.2) and for each of these sectors, the calibration process first considers modifications to the tow-size limit parameters and then to the towboat utilization factors as discussed below.

1B.5.3.5.2 Tow-size Limit Trails

For each barge type in each sector in the calibration sector range, the Sector Tow-size Limits Calibrator program determines the calibration fitness that would result if it increased or decreased that barge type's tow-size limit by 5 barges, and if it increased or decreased that barge type's tow-size limit by 1 barge. If the tow-size increase exceeds the absolute maximum tow-size limit for that barge type and sector, the trial is skipped. If the tow-size decrease results in a negative tow-size for that barge type and sector, the trial is skipped. Only one parameter is modified from the original in each of these four trials; the other parameters are left as they were when the incumbent value was determined. As an example, say 2 sectors are specified in the calibration range and there are 12 barge types. In this example there will be up to 96 trials, each with a calibration fitness value based on the unique shipping plans developed under each tow-size limit parameter settings.

1B.5.3.5.3 Towboat Utilization Factor Trails

For each towboat type in each sector in the calibration sector range, the Sector Towboat Efficiency Factor Calibrator program determines the calibration fitness that would result if that towboat type's towboat utilization factor were increased or decreased by 0.9. If the increase or decrease lies outside of a [0.0 – 1.0] range, the trial is skipped. Note that smaller adjustments to the towboat utilization factors will be considered in subsequent iterations (discussed further below).

A side note: When changing the towboat utilization factor of a towboat on a sector, there is logic in the code that requires that all sectors downstream of that sector have at least that large of a towboat utilization factor for that towboat and similarly that all towboat utilization factors upstream of that sector cannot exceed that sector's towboat utilization factor. The logic behind this is that a towboat operating on a sector should be at least as capable on downstream sectors. Therefore, a towboat class utilization factor change may ripple up or down the river system when a change is considered. Unlike the tow-size limit trial where only one parameter is changed, in the towboat efficiency trial multiple towboat efficiency factors downstream may be increased and multiple towboat efficiency factors upstream may be decreased to maintain the towboat efficiency monotonicity discussed. After this modification's calibration fitness measure is determined, all towboat utilization factors are reverted to their initial values before the next modification is evaluated.

As an example, say 2 sectors are specified in the calibration range and there are 8 towboat class types. In this example there will be up to 32 trials, each with a calibration fitness value based on the unique shipping plans developed under each tow-size limit parameter settings.

1B.5.3.5.4 Selection of the Best Parameter Adjustment

The calibration process then determines what the best (*i.e.*, lowest) calibration fitness value is among the incumbent calibration fitness value and the (possibly large) set of trials calculated due to parameter modifications. For example, say 2 sectors are specified in the calibration range, with 12 barge types and 8 towboat class types. In this example there are up to 128 trials to compare (assuming no skipped trials from exceeding the adjustment boundaries). If the best fitness value is one of the trials, then that modification is made in the database, and the corresponding fitness value becomes the new incumbent fitness value. If the modification was a towboat utilization factor change, the "*ripple effect*" on towboat utilization factors is imposed upstream and downstream from the sector involved to assure that the towboat utilization factors are non-decreasing as you go from the head of a river to its mouth.

1B.5.3.5.5 Iteration

If the improvement in the calibration fitness value is greater than 20, the program goes through the list of sectors again to determine the effects on the calibration fitness with modifications (+/- 5, +/- 1) to the tow-size limits and (+/- 0.9) to the towboat utilization factors. As long as the improvement to the fitness value is greater than 20, the calibration process will continue looking at all sectors, at all barge types and towboat types, evaluating up to four (+/- 5, +/- 1) changes to each tow-size limit and up to two (+/- 0.9) changes to each towboat utilization factor.

If the incumbent fitness value was determined to be the best fitness value, or the improvement to the fitness value is less than 20, the Sector Towboat Efficiency Factor Calibrator program reduces the change considered in its towboat utilization factor adjustments. Instead of looking at changes of 0.9, it considers increasing or decreasing the towboat utilization factors by 0.8. The rest of the calibration process remains the same, looking at all sectors, at all barge types and towboat types, evaluating up to four (+/- 5, +/- 1) changes to each tow size limit and two (+/- 0.8) changes to each towboat utilization factor.

Each time the improvement drops below 20 for an iteration, the calibration routine will decrease the towboat utilization factor change by 0.1. Regardless of what the magnitude of the towboat utilization factor is, the program will look at all sectors, at all barge types and all towboat types to determine the possible parameter changes that will be beneficial in decreasing the calibration fitness value. The magnitude of the towboat utilization factor change never increases during a calibration run, and once it is set to 0.1, it remains there for the duration of the calibration run. As long as the calibration fitness value decreases at every iteration, the calibration program will continue to run, each time making the change the resulted in the largest decrease. The program terminates with its best estimate of the tow size limits and towboat utilization factors for all sectors when it cannot find an improvement in the fitness value and the towboat utilization factor change equals 0.1.

1B.5.3.5.6 Upper Ohio Calibration

For the Upper Ohio analysis the calibration focus was on the Ohio River and the lower four projects on the Monongahela River (given the commonality of Upper Ohio River flows with these areas of the ORS). As a result, ORNIM sectors 2 (middle Monongahela River) through 18 (lower Ohio River) were specified as the calibration sector range. Calibration to an average 2004 through 2006 system resulted in the following calibration offness and calibration fitness measures:

offTows = 14,222

offHorsePower = 7,697

offTowSize = 44

Calibration Fitness = 43,922

1B.5.4 Movement Cost-to-Rate Delta

The validated calibration process also allows for the movement’s estimated cost to be compared against the movement’s base water routed rate to form a cost-to-rate delta. In the equilibrium process when the model is exercised in a cost-benefit analysis, the movement cost-to-rate delta is used to convert the model’s waterway line-haul cost calculation to a rate (or price) so that it can be used with the movement’s barge transportation willingness-to-pay (which is price-quantity).

These values are not stored in the database, however, but are just regenerated and stored in memory at the beginning of each WSDM (i.e., equilibrium) run.

1B.6 THE FUTURE FLEET

In the preceding sections the model is calibrated to historic data, i.e. the existing condition. The existing condition, however, is not always equivalent to the future condition. In the calibration process the movement barge dedication factors, sector tow-size limits, and sector towboat efficiency factors are set so that the model can predict movement shipping plans that replicate shipping plans observed in the historic data. Once the movement (i.e. movement dedication factor) and system (sector tow-size limits, and sector towboat efficiency factors) parameters are calibrated and set, other shipping characteristics can be changed and the effect on movement shipping plans, shipping costs, and equilibrium traffic levels can be estimated.

Typically, changing the shipping characteristics means adding an investment in the transportation system that lowers vessel transit time through a project. Accessing the impacts of this change in the system is relatively straight forward; movement trip times are adjusted and movement cost is re-calculated.

Under a investment, or "*with-project*" condition where the main lock chamber dimensions are increased, however, movement's transiting the project may not only experience a transit time savings, but they might also experience a shipping cost decrease through a increase in their tow-size allowed by the larger chamber. While more barges increases the tow's cost, and movement of the additional barges may require a larger more costly towboat, overall cost for the movement (not the shipment) may actually decrease through a reduction in the number of trips required to move the annual tonnage volume. By only changing the sector tow-size limits (and no other calibration variables), the model can re-assess the shipping-plan options and re-determine the least-cost waterway shipping-plan (see section 1B.4.2)[9]. It should also be noted, that a change in a lock chamber dimension, may also necessitate a change in the fleeting points in the system (see section 1B.2.9.1.7). This was not the case, however, in the Upper Ohio with-project conditions. Section 1B.6.1 below discusses the increase the sector tow-size limits, and summarizes the shipping-plan impacts, of increasing the tow-size limits for the 800' and 1200' Upper Ohio lock alternatives.

Further complicating the future fleet, the future may also necessitate a change in barge type usage. In the case of the Upper Ohio area, a shifting of regular and stumbo hopper barges to the more typical jumbo hopper barge is expected to continue (see section 1B.6.2 below) regardless of the alternative selected. In this situation, no a "*calibration*" parameters are adjusted. In this case, only the movement's barge type is re-specified. When this is done, the model re-assess the shipping plan options and re-determines the least-cost waterway shipping plan. Section 1B.6.2 below discusses the barge type re-specification, and summarizes the shipping-plan impacts, of changing Upper Ohio regular and stumbo hopper movements to jumbo hopper movements.

A summary of the average tow-sizes at the Upper Ohio River projects is shown in TABLE 1B.6.1. The statistics in the top section of the table do not include the future barge fleet change (Upper Ohio regular and stumbo hopper barges changed to jumbo hopper barges) since that would skew the comparison against the shipping-plan calibration discussions in the earlier sections. The statistics in the bottom section of the table do include the future barge fleet change.

[9] *In the case of a lock chamber decrease, tow-size must be reduced because of the physical limitation and the number of trips through the project must increase to move the annual volume.*

TABLE 1B.6.1 – Average Tow-size by Fleet - Upper Ohio Projects

Existing Upper Ohio Barge Type Fleet Mix						
	Number of Tows			Average Barges Per Tow		
Navigation Lock Project	600' Fleet (existing)	800' Fleet *	1200' Fleet *	600' Fleet (existing)	800' Fleet *	1200' Fleet *
MONTGOMERY L&D	3,968	3,014	2,437	5.9	7.8	9.7
DASHIELDS L&D	3,890	3,044	2,489	6.3	8.0	9.8
EMSWORTH L&D	3,610	2,780	2,275	6.2	8.0	9.8

FUTURE Upper Ohio Barge Type Fleet Mix (regulars & stumbos switched to Jumbos)						
	Number of Tows			Average Barges Per Tow		
Navigation Lock Project	600' Fleet (existing)	800' Fleet *	1200' Fleet *	600' Fleet (existing)	800' Fleet *	1200' Fleet *
MONTGOMERY L&D	3,925	2,828	2,257	5.7	7.9	9.8
DASHIELDS L&D	3,839	2,856	2,314	5.8	7.8	9.6
EMSWORTH L&D	3,573	2,618	2,118	5.7	7.8	9.6

* *Assumes all three Upper Ohio projects have a larger main chamber.*

1B.6.1 The Future Shipping Plans

The with-project conditions considered in the Upper Ohio Navigation Study include alternatives where the main chamber dimensions are increased at each of the three sites. The alternatives include:

- New single 600’x110’ at all three projects.
- New 600’x110’ with original 600’x110’ as an auxiliary at all three projects.
- New twin 600’x110’ at all three projects.
- New single 800’x110’ at all three projects.
- New 800’x110’ with original 600’x110’ as an auxiliary at all three projects.
- New 800’x110’ with new 600’x110’ at all three projects.
- New single 1200’x 110’ at all three projects.
- New 1200’x110’ with original 600’x110’ as an auxiliary at all three projects.
- New 1200’x110’ with new 600’x110’ at all three projects.

With larger main lock chambers, the existing shipping plan calibration (assuming 600’ main chambers) is not valid since in all likelihood tow-sizes will increase with larger main chambers. Additionally, formulation of the NED plan may mix the with-project conditions between each project site, if not in the long-run, certainly in the short-run as each new lock will most-likely be constructed sequentially rather than simultaneously. The increase in Upper Ohio tow-sizes, however, is only assumed to occur once all three projects are up-sized. This assumption is founded on the high commonality of traffic between the projects.

No shipping plan modifications were needed for the new 600’x110’ alternatives since the existing (WOPC) system consists of main 600’x110’ chambers, hence the labeling in TABLE 1B.6.1 as “*600’ Fleet (existing)*”. A summary of the average tow-sizes at the Upper Ohio River projects without the future barge fleet change is shown in TABLE 1B.6.1 above. The process and results of modification of the model’s tow-size limit parameters for the 800’ and 1,200’ Upper Ohio system follows in the sections below.

1B.6.1.1 Upper Ohio 800' Fleet Shipping Plan Adjustments

As discussed in section 1B.5.3.3 tow-size selection in the shipping plan is partially controlled by a sector tow-size limit that constrains tow-size by barge type by waterway sector. When the model develops a shipping plan for a movement, it considers all the river segment restrictions in its route (i.e., the minimum of "*maxTowSize*" along the route), along with the towboat class specific characteristics. Given the existing 600' x 110' main chambers at the Upper Ohio projects these sector tow-size limits have been calibrated and the resulting tow-sizes (shipping plans) validated.

As discussed in section 1B.2.9.1.12, the "*TowSizeLimits*" table (TABLE 1B.2.35) contains a "*maxTowSize*" field which contains the calibrated maximum tow-size through each link in the waterway network. Remember that Links exist in Sectors and that the tow-size limits can be specified at a sector level (which means the specification applies to all links within the sector). The Upper Ohio projects lie within Sectors 6, 7, and 8.

The calibrated tow-size limits were calibrated at the sector level under "*networkVersion*" 1 (the base network version for "*networkID*" 1). For an 800' x 110' Upper Ohio system, the tow-size limits for the Upper Ohio River sectors are increased as discussed in the following section and placed under "*networkVersion*" 5 (TABLE 1B.2.21). Only the tow-size limits changed need stored under this new network version, all other limits revert to the base network version (i.e., "*networkVersion*" 1).

Since these adjustments are stored under a separate "*networkVersion*", "*PortsRefleeting*" data (TABLE 1B.2.28) must be set up for this new network version. For the Upper Ohio analysis there was no need to adjust the re-fleeting points (there were already re-fleeting ports immediately above and below the Upper Ohio projects), however, the "*PortsRefleeting*" data for "*networkVersion*" 1 still needed to be duplicated under "*networkVersion*" 5.

The "*TowboatUtilization*" table (TABLE 1B.2.36) required no adjustment. Like the "*TowSizeLimits*" table, the "*TowboatUtilization*" table only requires specification of changes. With no changes the model reverts to the base network version (i.e., "*networkVersion*" 1).

To assure that the calibrated barge dedication factors are used for this "*networkVersion*" 5, the calibrated movement level dedication factors under "*networkVersion*" 1 need to be copied under "*networkVersion*" 5 in the "*MovementCalibration*" table (TABLE 1B.5.2). To assure that the project transit times are utilized in the shipping plan cost calculations for this "*networkVersion*" 5, the transit times under "*networkVersion*" 1 need to be copied under "*networkVersion*" 5 in the "*Targets*" table (TABLE 1B.2.47).

1B.6.1.1.1 Increasing the Tow-Size Limits

Given the dimensions of the twelve barge types and given the dimensions of the eight towboat classes (and their maximum towing capacity) it is possible to calculate the maximum powered tow-size that can single cut through the 800' x 110' chamber. In the existing calibrated system, however, the calibration process might have adjusted the "*maxTowSize*" below this maximum tow-size (also known as the original maximum tow-size or "*origMaxTowSize*"). As a result the "*maxTowSize*" for the 800' fleet in sectors 6, 7, and 8 were set at the existing "*maxTowSize*" to "*origMaxTowSize*" percent of the 800' "*origMaxTowSize*". The existing "*origMaxTowSize*" and calibrated "*maxTowSize*" tow-sizes are shown with their estimated 800' fleet "*maxTowSize*" for Emsworth, Dashields, and Montgomery in TABLE 1B.6.2, TABLE 1B.6.3, and TABLE 1B.6.4.

TABLE 1B.6.2 – TowSizeLimits 800' Fleet Adjustment - Emsworth

	Emsworth Locks and Dam (sectorID = 6)				
	EXISTING Tow-size (barges per tow)			800' FLEET Tow-size (barges per tow)	
	Minimum	Maximum	Original Max.	Maximum	Original Max.
Barge Type	(minTowSize)	(maxTowSize)	(origMaxTowSize)	(maxTowSize)	(origMaxTowSize)
Irregular Hopper	1	15	15	15	15
Regular Hopper	1	10	11	13	14
Stumbo	1	11	11	14	14
Jumbo Open Hopper	1	8	8	11	11
Jumbo Covered Hopper	1	8	8	11	11
Super Jumbo Hopper	1	6	6	8	8
Giant Hopper	1	3	3	5	5
Jumbo Tanker	1	5	8	7	11
147 ft Tanker	1	2	7	3	9
175 ft Tanker	1	2	2	7	7
264 ft Tanker	1	3	3	5	5
297 ft Tanker	1	1	1	2	2

TABLE 1B.6.3 – TowSizeLimits 800' Fleet Adjustment - Dashields

	Dashields Locks and Dam (sectorID = 7)				
	EXISTING Tow-size (barges per tow)			800' FLEET Tow-size (barges per tow)	
	Minimum	Maximum	Original Max.	Maximum	Original Max.
Barge Type	(minTowSize)	(maxTowSize)	(origMaxTowSize)	(maxTowSize)	(origMaxTowSize)
Irregular Hopper	1	15	15	15	15
Regular Hopper	1	11	11	14	14
Stumbo	1	11	11	14	14
Jumbo Open Hopper	1	8	8	11	11
Jumbo Covered Hopper	1	8	8	11	11
Super Jumbo Hopper	1	6	6	8	8
Giant Hopper	1	3	3	5	5
Jumbo Tanker	1	5	8	7	11
147 ft Tanker	1	7	7	9	9
175 ft Tanker	1	2	2	7	7
264 ft Tanker	1	3	3	5	5
297 ft Tanker	1	1	1	2	2

TABLE 1B.6.4 – TowSizeLimits 800' Fleet Adjustment - Montgomery

	Montgomery Locks and Dam (sectorID = 8)				
	EXISTING Tow-size (barges per tow)			800' FLEET Tow-size (barges per tow)	
	Minimum	Maximum	Original Max.	Maximum	Original Max.
Barge Type	(minTowSize)	(maxTowSize)	(origMaxTowSize)	(maxTowSize)	(origMaxTowSize)
Irregular Hopper	1	15	15	15	15
Regular Hopper	1	11	11	14	14
Stumbo	1	11	11	14	14
Jumbo Open Hopper	1	7	8	10	11
Jumbo Covered Hopper	1	8	8	11	11
Super Jumbo Hopper	1	6	6	8	8
Giant Hopper	1	3	3	5	5
Jumbo Tanker	1	8	8	11	11
147 ft Tanker	1	7	7	9	9
175 ft Tanker	1	2	2	7	7
264 ft Tanker	1	3	3	5	5
297 ft Tanker	1	1	1	2	2

1B.6.1.1.2 System Statistics Under the 800' Fleet

The adjustments described above resulted in the system statistics shown in TABLE 1B.6.5. The Upper Ohio tow-size increased 21.8 to 24.0 percent with the number of tows reducing 27.8 to 31.6%. There were insignificant tow-size and tow count effects elsewhere in the system.

TABLE 1B.6.5 – Tow and Tow-size Comparison – Existing versus 800' Fleet

Navigation	Number of Tows				Average Barges Per Tow			
	Existing	800'	Difference		Existing	800'	Difference	
Lock Project	Fleet	Fleet	Count	Percentage	Fleet	Fleet	BPT	Percentage
OHIO RIVER								
LOCK & DAM 53 (OHIO)	6,862	6,863	2	0.0%	10.4	10.4	0.0	0.0%
LOCK & DAM 52 (OHIO)	8,627	8,628	1	0.0%	10.3	10.3	0.0	0.0%
SMITHLAND L/D	7,229	7,232	3	0.0%	10.4	10.4	0.0	0.0%
MYERS L/D	5,994	5,997	3	0.0%	11.1	11.1	0.0	0.0%
NEWBURGH L/D	6,290	6,293	3	0.0%	10.8	10.8	0.0	0.0%
CANNELTON L/D	5,211	5,214	3	0.1%	10.6	10.6	0.0	-0.1%
MCALPINE L/D	4,932	4,935	3	0.1%	10.1	10.1	0.0	-0.1%
MARKLAND L/D	4,628	4,631	3	0.1%	9.9	9.9	0.0	-0.1%
MELDAHL L/D	5,418	5,421	3	0.0%	9.7	9.7	0.0	0.0%
GREENUP L/D	6,685	6,688	3	0.0%	10.1	10.1	0.0	0.0%
R.C. BYRD L/D	5,380	5,384	4	0.1%	10.2	10.2	0.0	-0.1%
RACINE L&D	4,628	4,630	2	0.0%	11.0	11.0	0.0	0.0%
BELLEVILLE L&D	4,608	4,610	2	0.0%	10.9	10.9	0.0	0.0%
WILLOW ISLAND L&D	4,343	4,343	0	0.0%	11.0	11.0	0.0	0.0%
HANNIBAL L&D	4,981	4,992	11	0.2%	10.4	10.3	0.0	-0.2%
PIKE ISLAND L&D	4,964	5,381	417	7.8%	8.8	8.1	-0.7	-8.4%
NEW CUMBERLAND L&D	4,120	4,525	405	8.9%	8.8	8.0	-0.8	-9.8%
MONTGOMERY L&D	3,968	3,014	-954	-31.6%	5.9	7.8	1.9	24.0%
DASHIELDS L&D	3,890	3,044	-847	-27.8%	6.3	8.0	1.7	21.8%
EMSWORTH L&D	3,610	2,780	-830	-29.8%	6.2	8.0	1.8	23.0%
MONONGAHELA RIVER								
MON LOCK & DAM 2 L&D	3,408	3,388	-21	-0.6%	6.0	6.1	0.0	0.8%
MON LOCK & DAM 3 L&D	5,184	5,184	0	0.0%	3.3	3.3	0.0	0.0%
MON LOCK & DAM 4 L&D	4,642	4,642	0	0.0%	3.5	3.5	0.0	0.0%
MAXWELL L&D	4,065	4,065	0	0.0%	5.0	5.0	0.0	0.0%

1B.6.1.2 Upper Ohio 1200' Fleet Shipping Plan Adjustments

For the 1200' x 110' Upper Ohio system, the tow-size limits for the Upper Ohio River sectors are increased as discussed below. Again:

- the "*PortsRefleeting*" table (TABLE 1B.2.28) settings for the calibrated network version (i.e. "*networkVersion*" 1) must be duplicated for the specified 1200' fleet network version (i.e. "*networkVersion*" 6);
- the "*TowboatUtilization*" table (TABLE 1B.2.36) requires no adjustment;
- the "*MovementCalibration*" table (TABLE 1B.5.2) barge dedication settings for the calibrated network version (i.e. "*networkVersion*" 1) must be duplicated for the specified 1200' fleet network version (i.e. "*networkVersion*" 6); and
- the "*Targets*" table (TABLE 1B.2.47) transit time assumptions used in the calibrated network version (i.e. "*networkVersion*" 1) must be duplicated for the specified 1200' fleet network version (i.e. "*networkVersion*" 6).

1B.6.1.2.1 Increasing the Tow-Size Limits

Given the dimensions of the twelve barge types and given the dimensions of the eight towboat classes (and their maximum towing capacity) it is possible to calculate the maximum powered tow-size that can single cut through the 1200' x 110' chamber. In the existing calibrated system, however, the calibration process might have adjusted the "*maxTowSize*" below this maximum tow-size (also known as the original maximum tow-size or "*origMaxTowSize*"). As a result the "*maxTowSize*" for the 1200' fleet in sectors 6, 7, and 8 were set at the existing "*maxTowSize*" to "*origMaxTowSize*" percent of the 1200' "*origMaxTowSize*". The existing "*origMaxTowSize*" and calibrated "*maxTowSize*" tow-sizes are shown with their estimated 1200' fleet "*maxTowSize*" for Emsworth, Dashields, and Montgomery in TABLE 1B.6.6, TABLE 1B.6.7, and TABLE 1B.6.8.

TABLE 1B.6.6 – TowSizeLimits 1200' Fleet Adjustment - Emsworth

	Emsworth Locks and Dam (sectorID = 6)				
	EXISTING Tow-size (barges per tow)			1200' FLEET Tow-size (barges per tow)	
	Minimum	Maximum	Original Max.	Maximum	Original Max.
Barge Type	(minTowSize)	(maxTowSize)	(origMaxTowSize)	(maxTowSize)	(origMaxTowSize)
Irregular Hopper	1	15	15	23	23
Regular Hopper	1	10	11	20	22
Stumbo	1	11	11	22	22
Jumbo Open Hopper	1	8	8	16	16
Jumbo Covered Hopper	1	8	8	16	16
Super Jumbo Hopper	1	6	6	12	12
Giant Hopper	1	3	3	8	8
Jumbo Tanker	1	5	8	10	16
147 ft Tanker	1	2	7	4	15
175 ft Tanker	1	2	2	12	12
264 ft Tanker	1	3	3	8	8
297 ft Tanker	1	1	1	4	4

TABLE 1B.6.7 – TowSizeLimits 1200' Fleet Adjustment - Dashields

	Dashields Locks and Dam (sectorID = 7)				
	EXISTING Tow-size (barges per tow)			1200' FLEET Tow-size (barges per tow)	
	Minimum	Maximum	Original Max.	Maximum	Original Max.
Barge Type	(minTowSize)	(maxTowSize)	(origMaxTowSize)	(maxTowSize)	(origMaxTowSize)
Irregular Hopper	1	15	15	23	23
Regular Hopper	1	11	11	22	22
Stumbo	1	11	11	22	22
Jumbo Open Hopper	1	8	8	16	16
Jumbo Covered Hopper	1	8	8	16	16
Super Jumbo Hopper	1	6	6	12	12
Giant Hopper	1	3	3	8	8
Jumbo Tanker	1	5	8	10	16
147 ft Tanker	1	7	7	15	15
175 ft Tanker	1	2	2	12	12
264 ft Tanker	1	3	3	8	8
297 ft Tanker	1	1	1	4	4

TABLE 1B.6.8 – TowSizeLimits 1200' Fleet Adjustment - Montgomery

	Montgomery Locks and Dam (sectorID = 8)				
	EXISTING Tow-size (barges per tow)			1200' FLEET Tow-size (barges per tow)	
	Minimum	Maximum	Original Max.	Maximum	Original Max.
Barge Type	(minTowSize)	(maxTowSize)	(origMaxTowSize)	(maxTowSize)	(origMaxTowSize)
Irregular Hopper	1	15	15	23	23
Regular Hopper	1	11	11	22	22
Stumbo	1	11	11	22	22
Jumbo Open Hopper	1	7	8	14	16
Jumbo Covered Hopper	1	8	8	16	16
Super Jumbo Hopper	1	6	6	12	12
Giant Hopper	1	3	3	8	8
Jumbo Tanker	1	8	8	16	16
147 ft Tanker	1	7	7	15	15
175 ft Tanker	1	2	2	12	12
264 ft Tanker	1	3	3	8	8
297 ft Tanker	1	1	1	4	4

1B.6.1.2.2 System Statistics Under the 1200' Fleet

The adjustments described above resulted in the system statistics shown in TABLE 1B.6.9. The Upper Ohio tow-size increased 36.0 to 38.6 percent with the number of tows reducing 56.3 to 62.8%. There were insignificant tow-size and tow count effects elsewhere in the system.

TABLE 1B.6.9 – Tow and Tow-size Comparison – Existing versus 1200' Fleet

Navigation Lock Project	Number of Tows				Average Barges Per Tow			
	Existing Fleet	1200' Fleet	Difference Count	Difference Percentage	Existing Fleet	1200' Fleet	Difference BPT	Difference Percentage
OHIO RIVER								
LOCK & DAM 53 (OHIO)	6,862	6,863	-2	0.0%	10.4	10.4	0.0	0.0%
LOCK & DAM 52 (OHIO)	8,627	8,628	-1	0.0%	10.3	10.3	0.0	0.0%
SMITHLAND L/D	7,229	7,232	-3	0.0%	10.4	10.4	0.0	0.0%
MYERS L/D	5,994	5,997	-3	0.0%	11.1	11.1	0.0	0.0%
NEWBURGH L/D	6,290	6,293	-3	0.0%	10.8	10.8	0.0	0.0%
CANNELTON L/D	5,211	5,214	-3	0.1%	10.6	10.6	0.0	-0.1%
MCALPINE L/D	4,932	4,935	-3	0.1%	10.1	10.1	0.0	-0.1%
MARKLAND L/D	4,628	4,631	-3	0.1%	9.9	9.9	0.0	-0.1%
MELDAHL L/D	5,418	5,421	-3	0.0%	9.7	9.7	0.0	0.0%
GREENUP L/D	6,685	6,688	-3	0.0%	10.1	10.1	0.0	0.0%
R.C. BYRD L/D	5,380	5,385	-5	0.1%	10.2	10.2	0.0	-0.1%
RACINE L&D	4,628	4,630	-3	0.1%	11.0	11.0	0.0	-0.1%
BELLEVILLE L&D	4,608	4,611	-3	0.1%	10.9	10.9	0.0	-0.1%
WILLOW ISLAND L&D	4,343	4,344	-1	0.0%	11.0	11.0	0.0	0.0%
HANNIBAL L&D	4,981	4,988	-7	0.1%	10.4	10.3	0.0	-0.1%
PIKE ISLAND L&D	4,964	5,054	-90	1.8%	8.8	8.6	0.2	-1.8%
NEW CUMBERLAND L&D	4,120	4,192	-72	1.7%	8.8	8.6	0.2	-1.8%
MONTGOMERY L&D	3,968	2,437	1,531	-62.8%	5.9	9.7	-3.7	38.6%
DASHIELDS L&D	3,890	2,489	1,402	-56.3%	6.3	9.8	-3.5	36.0%
EMSWORTH L&D	3,610	2,275	1,335	-58.7%	6.2	9.8	-3.6	37.0%
MONONGAHELA RIVER								
MON LOCK & DAM 2 L&D	3,408	3,336	72	-2.2%	6.0	6.2	-0.1	2.3%
MON LOCK & DAM 3 L&D	5,184	5,184	0	0.0%	3.3	3.3	0.0	0.0%
MON LOCK & DAM 4 L&D	4,642	4,642	0	0.0%	3.5	3.5	0.0	0.0%
MAXWELL L&D	4,065	4,065	0	0.0%	5.0	5.0	0.0	0.0%

1B.6.2 The Future Barge Fleet

Based on the "*Probable Size of Future Barge Fleet at Emsworth, Dashields, and Montgomery Locks*", Linare Consulting dated 20 August 2008, the future barge fleet on the Upper Ohio is expected to continue to shift toward the use of jumbo hopper barges (195' x 35'). Specifically, it is assumed in this analysis that movements historically shipped in regular (175' x 26') and stumbo (195' x 26') hopper barges through one or more of the three Upper Ohio projects, will switch to jumbo hopper barges. This assumption affects the 600' (existing) Upper Ohio system as well as the 800' and 1200' systems. A summary of the average tow-sizes at the Upper Ohio River projects with the future barge fleet change was shown in TABLE 1B.6.1 above. A comparison of the Upper Ohio barge fleet change throughout the system assuming the 600' Upper Ohio system is shown in TABLE 1B.6.10.

At the Upper Ohio projects tons/tow remains relatively constant, barges/tow drops slightly, and the number of tows drops slightly. Immediately downstream, however, tons/tow and barge/tow increase. This results in a significant drop in tow transits immediately downstream. This occurs because of re-fleeting immediately below the Upper Ohio and the fact that the jumbo sized barges are much more compatible with the 1200'x110' chambers downstream. The effect tapers off as the extend of the replaced regular and stumbo barges tapers off.

1B.6.3 Future Fleet Movement Cost-to-Rate Delta

There are no future fleet specific cost-to-rate deltas. In the equilibrium process when the model is exercised in a future fleet cost-benefit analysis (e.g., 1200' mains at the Upper Ohio projects with the existing barge fleet mix), the base (or calibration) movement cost-to-rate delta is used (i.e., existing projects with existing barge fleet mix).

1B.6.4 Conclusions

Larger lock chambers allow larger tows to transit in a single cut, and barring channel or bend constraints, one would expect tow-sizes would increase given the economies of scale of larger tows. The extent of the tow-size increase is not only a function of the chamber dimension, but also a function of the barge type mix. This increasing tow-size response is predicted by the model as demonstrated in the top section of TABLE 1B.6.1. With a tow-size increase the tow cost typically increases, however, fewer round trips are required to move the annual tonnage and as a result the movement transportation cost can decrease (while the individual shipment transportation cost increases). Additionally, fewer transits through the project decreases congestion and tow queuing at the projects which extents to all lock projects the shipments transit.

TABLE 1B.6.10 – Tow and Tow-size Comparison – Existing versus Future Barge Fleet

	Number of Tows (600' System)				Average Barges Per Tow (600' System)			
	Existing	FUTURE			Existing	FUTURE		
Navigation	Barge	Barge	Difference		Barge	Barge	Difference	
Lock Project	Fleet	Fleet	Count	Percentage	Fleet	Fleet	BPT	Percentage
OHIO RIVER								
LOCK & DAM 53 (OHIO)	6,862	6,863	-2	0.0%	10.4	10.3	0.0	-0.3%
LOCK & DAM 52 (OHIO)	8,627	8,628	-1	0.0%	10.3	10.3	0.0	-0.2%
SMITHLAND L/D	7,229	7,232	-3	0.0%	10.4	10.4	0.0	-0.3%
MYERS L/D	5,994	5,997	-3	0.0%	11.1	11.1	0.0	-0.3%
NEWBURGH L/D	6,290	6,293	-3	0.0%	10.8	10.8	0.0	-0.3%
CANNELTON L/D	5,211	5,214	-3	0.1%	10.6	10.5	0.0	-0.4%
MCALPINE L/D	4,932	4,935	-3	0.1%	10.1	10.1	0.0	-0.4%
MARKLAND L/D	4,628	4,631	-3	0.1%	9.9	9.8	0.0	-0.4%
MELDAHL L/D	5,418	5,421	-3	0.0%	9.7	9.6	0.0	-0.4%
GREENUP L/D	6,685	6,688	-3	0.0%	10.1	10.1	0.0	-0.3%
R.C. BYRD L/D	5,380	5,385	-5	0.1%	10.2	10.2	0.1	-0.5%
RACINE L&D	4,628	4,437	190	-4.3%	11.0	11.3	-0.3	2.6%
BELLEVILLE L&D	4,608	4,418	190	-4.3%	10.9	11.2	-0.3	2.6%
WILLOW ISLAND L&D	4,343	4,151	192	-4.6%	11.0	11.3	-0.3	2.8%
HANNIBAL L&D	4,981	4,782	199	-4.2%	10.4	10.6	-0.2	2.2%
PIKE ISLAND L&D	4,964	4,508	456	-10.1%	8.8	9.4	-0.6	6.5%
NEW CUMBERLAND L&D	4,120	3,650	470	-12.9%	8.8	9.6	-0.8	8.2%
MONTGOMERY L&D	3,968	3,925	43	-1.1%	5.9	5.7	0.3	-4.8%
DASHIELDS L&D	3,890	3,839	51	-1.3%	6.3	5.8	0.5	-8.1%
EMSWORTH L&D	3,610	3,573	38	-1.1%	6.2	5.7	0.5	-8.6%
MONONGAHELA RIVER								
MON LOCK & DAM 2 L&D	3,408	4,571	-1,163	25.4%	6.0	3.3	2.7	-83.5%
MON LOCK & DAM 3 L&D	5,184	3,799	1,385	-36.5%	3.3	5.1	-1.8	35.7%
MON LOCK & DAM 4 L&D	4,642	1,048	3,594	-343.0%	3.5	6.4	-2.9	45.3%
MAXWELL L&D	4,065	1,024	3,041	-297.0%	5.0	6.4	-1.4	21.4%

Barge type mix changes could increase or decrease transportation efficiency through a project depending upon the relationship between the barge and chamber dimensions. The phasing out of the regular and stumbo barges, and replacement of the equipment in those movements with jumbo barges is occurring because of the increased compatibility of the jumbo barge dimension with the predominant chamber dimensions in the ORS. The alternative chamber dimensions considered in the Upper Ohio study are jumbo compatible dimensions. As shown in TABLE 1B.6.1 and TABLE 1B.6.10, the barge type mix change has small effect at the three Upper Ohio projects, however, the change results in efficiencies downstream of the Upper Ohio and inefficiencies above.

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 1
Ohio River Navigation Investment Model (ORNIM) Version 5.1

Ohio River System Willingness-to-Pay for Barge Transportation
Addendum C

February 2011

THE DEMAND FOR TRANSPORTATION

IN THE

OHIO RIVER BASIN

by

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August 2008

Report

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EXECUTIVE SUMMARY AND INTRODUCTION

The Army Corps of Engineers (ACE) uses a simulation model to evaluate the benefits of alternative investments in the waterway system. Since the late 1980s, it has been well recognized that the responsiveness of demanders to changes in rates as well as other variables can have sizeable and measurable effects on benefit measurement. In this study, we report the results of a survey and an examination of the demand for transportation of eight different commodity groups in the Ohio River Valley that are pertinent to the Ohio River Navigation system. The results of the analysis can be used to identify key determinants of demand choices and volumes and can be used to empirically identify the level of the responsiveness of shippers to changes in the determinants. Further, as demonstrated in Train and Wilson (2004a; 2007a) and Sweeney (2005), the results can be used to provide market level demand functions used by ACE in their simulation models.

The survey was conducted in the fall of 2007 by the Washington State University Social and Economic Sciences Research Center (SESRC). The survey was conducted with multiple survey methods. Shippers were contacted by a variety of different mechanisms that included mail, telephone, personal visit, and the internet. Responses could come through any of these contacts, but the primary contacts were made by telephone. A list of 3190 possible shipment locations[1] was identified from the Harris Business Directory and other sources.[2] The list contained the location of facilities from or to which shipments could originate or terminate. The bulk of shippers were first contacted by mail and given an internet website address through which they could participate. If they did not fill out the questionnaire, they were then contacted by the telephone. For non-respondents at least six telephone contacts were made, and if they still did not fill out the questionnaire, they were sent a mail version of the questionnaire.[3] From this strategy, a total of 437 different shippers responded to the survey; 22 by mail, 280 by telephone, and 135 by the internet.

The questionnaires solicited a variety of information that enables the estimation of demand models. This information includes shipper characteristics, shipment characteristics, and the responsiveness of shippers to changes in key characteristics. Shipper characteristics include the access shippers have to modes, location, total firm size (measured by volume shipped and capacity), and the length of time in business at that location. Shipment characteristics were collected for a recent shipment as well as for alternative shipments that could have been made. These represent "revealed" data that

[1] The term location is used rather than shipper in that many shippers in the study region had multiple facilities. The sampling strategy was based on locations in the eight state study region from which shipments could originate (in the case of "originators") or terminate (in the case of receivers).

[2] A variety of other sources were used. For grain products these included a list of grain warehouses from the United States Department of Agriculture, various grain directories, and state level public service commission files. For coal products, these included a list of electricity and others taken from Platt's CoalDat and PowerDat databases.

[3] This strategy applied to all but nine large shippers that represented 94 locations, and 14 "self-registered" participants who were initially contacted through trade associations. The nine large shippers were each individually interviewed and solicited to fill out "mail" versions of the mail survey, while the 14 self-registered are shippers that were contacted by their trade associations i.e., they are not on the original contact list, and chose to participate.

are used to estimate the effects both price and non-price attributes that vary across the choices available to the shipper. These attribute data include the price received at alternative destinations or price paid from alternative origins, rate, time in transit, and reliability of different alternatives available to the shipper. Such data reflect the actual discrete decisions made by shippers and, as such, represent "revealed preference" data, which are commonly used to estimate parameters underlying demand decisions. Standard estimation of such data, however, can be complicated by the lack of sufficient variation and multicollinearity, each of which means that the data may not "precisely" identify the parameters of interest.[4] A second form of data collected to ameliorate these issues reflects what shippers state what they would do if confronted with a change in the attributes that underlie their decisions e.g., a change in rates. These data are a specific form of stated preference data and can be used to estimate the parameters underlying the decision process as well. Finally, through NETS, Train and Wilson (2008a), develop a procedure in which this form of stated preference data can supplement the revealed data. Versions of this approach have been used by Train and Wilson (2004b, 2006, 2007b, 2007d, and 2008a) and, generally, the combination of such combined data can and has provided precise estimates of the key parameters of decision-making.

The survey methods and characteristics of the data are presented in section 1. Generally, the population was limited to commodities and locations in the Ohio River Basin wherein shippers could plausibly consider shipment by barge. Such shippers were identified by commodity and by proximity to the waterway. Commodity groups were identified in conjunction with the Army Corps, map directly into their simulation models, and represent (almost) the majority of commodities that travel on the waterway. The commodity groups are aggregates, chemicals, coal, grains, iron & steel, ores and minerals, petroleum, and a set of "other" commodities. In terms of proximity to the waterways, the population was limited to waterside cities, waterside counties, and counties adjacent to waterside counties. Grain and coal were treated differently. In both cases, the commodities often travel further than one adjacent county to the waterways. The number of coal locations is held by relatively few shippers, and all known coal shippers were contacted. Grain locations were held to be the eight state region encompassing the Ohio River Valley (AL, IL, IN, KY, MS, OH, PA, TN, WV).

The overall raw response rate was estimated by SESRC to be about 13.6% (437/3204). However, this response rate was much lower than expected. There are at least two explanations. First, the list of shippers, despite considerable screening, still included a number of locations/commodities that are not part of the population. Second, eligibility and/or response determination was not completed for over ½ of the contacts. In terms of completed contacts, about 57 percent of the sample was not eligible and there was about a 51 percent response rate for those eligible. Of course, a large fraction of the non-completed contacts could be regarded as refusals, in which case, the response rate is

[4] While the model may be correctly specified given the data, the data themselves may not yield sufficient variability to yield statistically important effects and what variability exists may be highly correlated with other variables included. This is a common problem in such studies and substantially impacts the ability to measure responses. The examples are numerous. One such example is rate per unit shipped and transit times, two variables that are likely functions of distance and, as such, are very likely highly corrected.

much lower. While the raw response rate is somewhat low, the sample was randomly drawn using stratification sampling techniques, and, importantly, information is available from shippers representing 437 locations in the study regions and all eight commodity groups.[5]

From these data, there are a number of descriptive statistics of import to understanding demand for the waterway and the entire transportation system. First, shippers have limited access to modal options. Specifically, the majority of shippers (57%) have direct access to only one mode (trucks), while thirty-nine percent of the sample has direct access to rail, and 16% have direct access to barge. Hence, if shippers at truck only location use rail or barge, they must truck it to or from a rail or barge access facility. On average, shippers without direct rail access must travel an average of 26 miles to access rail, while shippers without direct barge access must travel an average of 58 miles. The level of access is, of course, central to decision-making and is discussed in more detail in the ensuing sections.

The sample consists of information from shippers on locations of facilities that receive or ship commodities. The data point to substantial differences in size both in terms of annual shipments as well as on-site storage capacities, longevity (experience), value of the product transported, and the number of similar facilities held by the firm owning the location. On the latter, the majority of the locations are held by firms that own multiple facilities, ranging from 2 to over 100. This suggests that there is not only a wide range of location sizes but also firm sizes. These characteristics point to the extreme heterogeneity of shippers in the transportation markets.

Central to choice modeling are differences in shipment characteristics, and considerable effort was made in the analysis to identify the shipment alternatives of shippers and the characteristics of the alternatives. At the outset, it is noted that most shipments (over 90%) are single mode shipments. There are a total of 29 barge, 35 rail, and 319 truck shipments. While the number of barge and rail shipments is comparatively small relative to truck, it is noted that shippers can and do access rail and barge with truck movements. Indeed, there are a total of 45 shipments that involve barge, 53 that involve rail, and 363 that involve truck. Further, the shipments are self-contained. Specifically, shipments generally originate or terminate from or to a final origin or destination e.g., mines to electricity plant. In total, only about 31 percent of the movements travel from or to a railroad or barge terminal or a distribution center for further transit. From inspection of the data, most of the 31 percent mark single mode movements wherein the respondent's relationship begins or ends with the movement e.g., most do not ship by truck to a barge terminal and then ship by barge to an ultimate destination. Rather, they purchase/sell at the rail/barge/distribution terminals.

As expected and is consistent with previous work, there is a natural ordering to the selection to the attributes of the different modes. Specifically, barge shipments are generally commodities of lower value, longer distances, and travel at lower rates than rail,

[5] It is important to note that the sample was drawn on the basis of locations not shippers. Indeed, in the list of locations, there were substantial numbers of shippers that own multiple locations.

which are generally of commodities of lower value, longer distances and travel at lower rates than truck. In addition, barge travel slower than rail which travels slower than truck. However, rail shipments are less reliable than barge, which are less reliable than trucks. Generally, these statistics are very similar to previous studies that provide such statistics.

The stated preference choice data are based on switching behavior. Essentially, shippers are asked if their choice, consisting of a mode and/or location (where to get the product or where to sell the product), would change with changes in rates, prices, transit times, or reliability. In all cases, switching does occur, as expected, and increases with the level of the change in the attribute. The stated preference volume data is constructed somewhat differently. Essentially, shippers are asked if their volumes would be affected by a change in attributes, and, if so, by how much. As with the choice data, shippers do state that their volumes are affected by each of the attributes considered, and the likelihood of adjustment increases with change in the attribute.

Transportation demand modeling proceeds with two distinct approaches. These are choice modeling and volume modeling. In section 2, we present the results of three approaches. These are logit models based on revealed data, stated preference data, and an approach that combines the revealed and stated preference data. Each of the models can be used to predict the responsiveness of shippers to changes in prices (received or paid) for the product shipped, the rates paid for transportation, the transit times and reliability.

The revealed preference approach yields parameter estimates that are largely not statistically different from zero at conventional levels and no differences were found across commodities. This may be due to insufficient numbers of observations or a myriad of other econometric issues e.g., multicollinearity, measurement error, etc. The stated preference approach yields very strong econometric results. In this case, changes in rates, values, transit times, reliability, and the presence of alternative modes are generally statistically different from zero and have magnitudes that indicate the effects are important from an economic sense. From this model, we calculated elasticities for each attribute and level of change in the attribute (2, 5, 10, 20, 30, 40, 50 and 60 percent). We find a general pattern of elasticities that fall in magnitude at the change in the prompt increases and range from relatively elastic to relatively inelastic responses. Generally, the level of responsiveness to price attributes (rates of the chosen and alternative) are larger than for the non-price attributes (transit times and reliability). We also estimated the model using approach that combines the revealed and stated preference data. Generally, these results are consistent with the other results in that rates have a negative effect on choices, and that rates have larger effects than time or reliability. While the price paid for the product transported (receivers) has the correct sign, the price received for the product transported (originators) has an incorrect sign. Further, both coefficients are relatively small and not statistically significant. More generally, there are only a few coefficients of interest that have statistical significance with this approach. From all three approaches, there is substantial uniformity in the finding that increases in rates have a negative effect on choices that shippers make, and there is also uniformity in the direction of the effects of other variables with the exception the price received for the product transported by originators. The stated preference approach, however, provides the most precise estimates of the parameters of interest, and these parameters provide elasticity estimates that range from relatively elastic to inelastic depending on the level of the change in the attributes (rates, price, transit times, reliability).

In section 3, we present the volume modeling as developed in Sitchinava, Wilson and Burton (2005) and Train and Wilson (2008b). These results are based on the stated responsiveness (by shippers) of their annual volumes to changes in the price received or paid for the product shipped, transportation rates, transit times and reliability. These stated responses are grounded in an optimization model and can be estimated through Heckman (1979) selection and/or tobit models (see Tobin (1958)). In the present case, a tobit model was used. As with the choice models, the results suggest that annual volumes are affected by changes in the attributes, and that prices (rates, product price) generally have larger effects than non-price factors. In all cases, the likelihood of adjusting volumes increases with the level of the percentage change in the attribute. In some attributes, there are modest differences in elasticities across commodities, but most other variables are not affected the results very much. Two different elasticities, unconditional and conditional, are calculated and presented. The unconditional elasticity is the percentage change in volumes from a one percent change in the attribute. This percentage change in volumes can be, and often is, zero. The conditional elasticity is the percentage change in volumes from a one percentage change in the attribute *given that volumes change*. The latter are, by definition, larger in magnitude than the former. The elasticity estimates range from elastic for small changes in the attribute to inelastic for large changes in the attributes. The estimates are largest for grain and smallest for coal shippers.

SECTION 1

SURVEY AND DATA

The data for this study were collected by the Washington State University Social and Economic Sciences Research Center (SESRC) in a survey of shippers located in the Ohio River Valley. The population consists of locations in eight states (Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, and West Virginia) that could plausibly use or consider the Ohio River or one of its tributaries for its transportation needs. Shippers that may have one or more facilities in the study area were contacted using a variety of techniques (a mixed-mode survey design). This means that respondents could have been contacted through telephone, mail, the internet, and/or personal visits and could have responded through a telephone interview, a mail survey form, or a web based survey form. In all, there is information available from shippers representing a total of 437 locations from which shipments could be received or made. This section describes the population, the sampling design and methods, the questionnaire and provides summary statistics on shippers, shipments, and sensitivity of decision-making to changes in key variables. Each is discussed in turn.

1.1 Population and Sample Design

The population consists of shippers that could plausibly use the Ohio River or one of its tributaries. Plausible use was determined on the basis of commodity and proximity to the waterways. Based on conversations with ACE, there are eight primary commodity groups that account for the bulk of traffic that could be affected by waterway investments in the region. These groups are aggregates, iron and steel, ores and minerals, grain, coal, petroleum, chemicals, and a variety of miscellaneous "other" commodities (identified by ACE). Proximity to the waterway was determined by the location of facilities. Shippers were sampled if they had a facility located in a waterside community, a waterside county, or a county adjacent to a waterside county. Such shippers are close enough to the waterway to at least consider the waterway as an alternative. Coal and grain were treated differently. In particular, all known coal shippers were contacted. This was done for a variety of reasons. First, coal accounts for more than 50 percent of the tonnage on the waterway. Second, there are comparatively few coal shippers, and they own a multiplicity of locations from which shipments may originate or terminate. Finally, there are a number of coal movements to the waterway that violate the one county adjacent rule. The population of grain shippers included all known shippers of grain in the eight states under analysis. The broader geographic definition for grain was made because initial samples of grain using the geographic strata from the Harris Selectory source did not contain enough grain shippers to complete the commodity sample. Second, grain shipments often violate the adjacent county rule. That is, grain shippers commonly ship to a river terminal and often ship truck distance greater than that implied by the one county removed designation.

Identification of shippers in the populations involved a variety of information sources. The primary source of shipper contact information was taken from the Harris Business Selectory database (http://www.harrisinfo.com/harrisinfo), which is a Dun and Bradstreet subsidiary. These data provide company names, addresses, telephone, North American

Industry Classification System (NAICS) and Standard Industrial Classification (SIC) codes and descriptions, county, and a variety of other data. The codes and descriptions were used to identify potential target shippers. This list was supplemented by Platt's PowerDat and CoalDat databases and a list of grain shippers, developed in previous surveys (e.g., Train and Wilson, 2004b, 20067b).[6] In addition, SESRC also developed a website with an on-line survey form; trade associations were contacted and asked to send their members an endorsement, a call to participate, and the website address. This approach allowed the survey to reach shippers that were interested in participating, but were not part of the list or not selected in the sample from the list.[7]

As stated above, all coal shippers were contacted. For the other commodities, the initial sample was designed to draw 3000 locations to or from which shipments could terminate or originate. These were drawn with equal sampling probabilities weights across the commodities. Geographically, sampling probabilities of 50, 25 and 25 percent were assigned to locations in waterside communities, waterside counties and counties adjacent to waterside counties.[8] From the list of shipping locations (including all of the grain observations), there were a total of 7777 possible shipment locations. And, from this list, a sample was drawn according to the stratifications. A total of 2851 locations were drawn. Across commodities, there were 428 from each group except iron and steel. In the case of iron and steel, there were only 283 total in the original list and all were included in the initial sample.

The initial sample was combined with coal locations and then carefully inspected by ACE and one of the authors for inclusion in the sample. Each location was screened with information available from the Harris Selectory along with knowledge of the waterway and commodity groups. Shippers that were obviously not part of the population were removed and replaced by an alternate from the non-sample list of locations.[9] The final list of locations, which were targeted to receive the survey from this process, is summarized in table 1.1.

[6] The grain list came from the Harris Selectory, United States Department of Agriculture, State Public Service Commissions, and various state grain association directories.

[7] It is noted that a separate survey protocol was used for such respondents. In principle, this allows survey biases to be identified. In practice, however, the response from this effort was very modest.

[8] The purpose of the stratifications was to obtain adequate representation in the sample of the various commodities as well as the various modes, and, in particular, barge.

[9] In some cases, this was not possible. Specifically, the cell (geographic, commodity) did not have enough in the list to replace. In such cases, an alternate shipper within the same commodity was drawn.

Table 1.1: Commodity Groups in the Population

Commodity	Number	Percent
Aggregates	430	13.45
Chemicals	423	13.23
Coal	351	10.98
Grain	434	13.58
Iron & Steel	273	8.54
Ores & Minerals	427	13.36
Other	428	13.39
Petroleum	431	13.48
Total	**3197**	**100.01**

Notes: The figures include 7 shippers that self-registered but did not identify the commodity. In addition, as noted below, all known coal locations (receiving) locations were sampled and all known iron and steel locations were sampled. The remaining are roughly proportional by design.

Table 1.2 identifies the proportion of the list from which the sample is drawn, by geographic strata. Overall, there is slightly more representation from waterside communities than was intended *a priori*, but not sizably so.

Table 1.2: Geographic Proportions by Commodity

Commodity	Waterside Community	Waterside County	Adjacent County	Total
Aggregates	217	103	110	430
	50%	24%	26%	100%
Chemicals	234	90	97	421
	56%	21%	23%	100%
Iron & Steel	144	44	85	273
	53%	16%	31%	100%
Ores & Minerals	211	84	132	427
	49%	20%	31%	100%
Other	207	91	130	428
	48%	21%	30%	100%
Petroleum	213	112	106	431
	49%	26%	25%	100%
Total	**1,226**	**524**	**660**	**2,410**
	51%	**22%**	**27%**	**100%**

Notes: The percentages may not add due to rounding. Coal and grain were facilities in the Region rather than by geographic strata and are not included in the table. Descriptions of the data received is provided below.

1.2 Questionnaire Design

The survey was conducted with mixed techniques that involved mail, telephone, the internet, and personal visits. Each of these modes had a separate questionnaire design. The questions are based on previous surveys conducted by SESRC and used by the authors in analysis of transportation demands for the Upper Mississippi and Illinois and Columbia-Snake Waterways (Train and Wilson (2004; 2006; 2007a, 2007b)). The questionnaires were pre-loaded with scripts to reflect commodity, location, whether the shipper was a receiver or a shipper, etc. in an effort to personalize the questionnaire as much as possible to each shipper and commodity.[10] The questionnaires were then pre-tested through interviews, telephone, and the internet by shippers as well as ACE and industry analysts. Examples of the various survey instruments are provided in Social & Economic Sciences Research Center (SESRC) and Appendix A along with initial contact letter. The on-site visits involved a solicitation to send in mail versions of the survey form.

There are four categories of questions. These include question to solicit information relating to the access shippers have to modes (Access, Firm Characteristics, Shipment Characteristics, Mode and Volume Sensitivity). These questions are designed to solicit information on primary determinants of transportation decision-making. These include, the access that shippers have to different modes, shipper loading capabilities, the distance to access other modes, the size of the plant and firm (measured by capacity and annual volumes), and the shipment attributes corresponding to different alternatives (prices paid or received for the product transported, rates, transit times, and reliability). In addition, there are also a set of questions related to the sensitivity of the revealed decisions. That is, would the discrete choice made for a shipment i.e., would the mode chosen or the location from which the commodity was received or shipped to change or would annual volumes be affected, and, if so, by how much, if prices, rate, transit time, or reliability change? These are each described later in this section.

1.3 Sampling and Responses

SESRC (2008) conducted the survey in the fall of 2007 and used the list described above to conduct the survey. Most of the contact list was first sent a letter to introduce the survey, provide respondents with an Internet address (and unique access number to access the questionnaire), and provide respondents with a postcard to update their contact information. Two and one-half weeks later, the telephone survey was initiated. All contacts that had not responded to the internet address were contacted with at least 6 phone calls over an 8 week period. At the end of this 8 week period, non-respondents were sent a mail version of the questionnaire. In addition to this strategy, there were two other forms of contact. First, one of the authors of this report and an ACE representative personally interviewed nine large coal shippers, which together account for 97 locations in the study region. Seventy-eight mail versions of the questionnaire were handed out along with a solicitation to participate. Second, a separate survey protocol (i.e., introduction, registration, and address of questionnaire) was established to allow shippers

[10] In addition, in the telephone and web versions, there were follow up questions to reconcile outliers. Specifically, from previous work, expected rate and transit time formulae were used to predict the rate and transit times. If outside bounds, follow up questions were asked to determine if the answers were as intended and/or the reason for the outlier.

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that were not contacted, but interested in participating to do so. The web address was publicized through various shipper associations[11], who, in turn, solicited members to participate.

A major issue in implementation was the determination of whether a location on the contact list was part of the population or not. As discussed earlier, this was resolved with careful screening of the original list. In addition, SESRC established eligibility screens for both the internet and telephone protocols.

From these efforts, there are a total of 437 responses, including 280 from telephone, 135 from web, and 22 from mail. Of these, there were 362 completed contacts and 75 partially complete contacts.[12] The raw response rate is 13.6 percent i.e., of the 3204 attempted contacts, there are responses from 437 that provide some information relevant to the study. In conducting the survey, SESRC keeps track of the treatment and disposition of each attempted contact. Of these, there were: 1) 437 completed or partially completed; 2) 429 refusals; 3) 1687 incomplete contacts wherein eligibility could not be established; and 4) 651 deemed ineligible. From the completed contacts (437+429+651) and for whom eligibility could be established, the eligibility rate is estimated as: (437+429)/(437+429+651)=57%, and the response rate as 437/(437+429)=51%.[13]

The sample has eight different commodity groupings *a priori*. These commodity groupings were used in the interviews, but there was also a question relating to the "specific" commodity shipped. This last was then visually inspected with the original groupings for consistency, and the original grouping was changed if warranted. The frequency of each commodity group in the sample is documented in Table 1.3. Generally, given the number of responses, the frequencies are about as expected. By design, the commodities should be about the same frequency (with the exception of coal), and the percentages should be about 14% (1 in 7). After removal of coal, the percentages, as indicated in Table 1.3 are somewhat lower for aggregates and higher for grain. This may be due to the difficulty in identifying appropriate aggregate shippers and the relative simplicity of identifying grain shippers. The other commodities are quite close in sample proportions.

[11] The industry associations that ACE and we were able to identify are: Edison Electric Institute, National Coal Association, National Stone Association, National Sand and Gravel Association, American Waterway Operators, American Petroleum Institute, American Chemistry Council, The Fertilizer Institute, National Feed and Grain Association, National Corn Growers' Association, National Soybean Growers' Association, American Iron and Steel Institute, American Coal, Coke and Chemical Institute, Association for Iron and Steel Technology, National Association of Manufacturers, National Petrochemical Refiners Association, Metals Service Centers Institute, and North American Steel Alliance.

[12] As might be expected, telephone contacts gave the highest completion rates. There were 257 telephone completes and 23 partial telephone completes; 83 web completes and 52 partial web completes. The 22 mail were all termed "complete" by SESRC.

[13] The eligibility rate and the response rate (given eligible) differ from that of SESRC (2008). In discussions, they note that theirs is conservative. The primary difference is in the treatment of non-completed contacts. SESRC calculates the response rate at 25.4 percent and then adjusts for eligibility, placing the overall response rate at 26 percent.

Table 1.4 and figure 1.1 contain information by the geographic strata. As discussed earlier, the noncoal and nongrain commodity groups were sampled by geographic strata. The responses by geographic strata are provided in table 1.4. As indicated, overall 49% of the respondents came from locations in waterside communities, 18 percent from locations in waterside counties and 32 percent from locations in adjacent counties. While there are some modest differences from the information provided in table 1.2, none of it suggests any major discrepancies.

Table 1.3: Commodity Groups and Frequencies in Sample

Commodity	**N**	**%**	Coal Excluded **%**
Aggregates	31	7	7
Chemicals	69	15	17
Coal	20	5	N.I.
Grain	101	23	24
Iron & Steel	65	15	16
Ores & Minerals	40	9	10
Other	62	14	15
Petroleum	49	11	12
Total	**437**	**100**	**100**

Table 1.4: Commodity Groups, Geography and Frequencies in the Sample

Commodity	Waterside Community	Waterside County	Adjacent County	Total
Aggregates- N	15	5	11	31
	48.39%	16.13%	35.48%	100%
Chemicals	27	12	20	59
	45.76%	20.34%	33.9%	100%
Iron & Steel	30	8	24	62
	48.39%	12.9%	38.71%	100%
Ores & Minerals	20	13	7	40
	50%	32.5%	17.5%	100%
Other	25	9	24	58
	43.1%	15.52%	41.38%	100%
Petroleum	29	9	10	48
	60.42%	18.75%	20.83%	100%
Total	**146**	**56**	**96**	**298**
	48.99%	**18.79%**	**32.21%**	**100%**

Notes: The first row for each commodity contains the frequency, the send row contains the row percentage. Grain and Coal are excluded as they were sampled differently.

Figure 1.1: Sampled Locations in Ohio River Basin.

1.4 Data Attributes

In the raw data, there are a total of 437 responses which include aggregate (31), chemical (69), coal (20), grain (101), iron and steel (65), ores and minerals (40), petroleum (49) and other (62) shippers.[14] In terms of mode use, there are 353, 53 and 45 movements that involve truck, rail, or barge.[15] Of express interest to the Army Corps is the demand responsiveness of shipper decisions to changes in attributes of shipments. To this end, we provide a variety of shipper, shipment and sensitivity to attributes descriptive statistics. Each is discussed in turn.

1.4.1 Shipper Attributes

Of obvious importance to shipper decisions is the access they have to modes. Modal access can be direct or through another mode. In addition, access can be affected by the attributes of the shipper e.g., the number of rail cars they can handle and the ease with which the shipper can use the mode e.g., the time it takes to setup a load. The responses are summarized by table 1.5.

[14] The frequency of responses is in ().
[15] The numbers do not add to 437 due to the presence of multimodal shipments.

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Nearly all respondents reported direct truck access, 168 of 435 (39%) reported direct access to rail, and 70 (16%) reported direct access to barge. For shipment locations without rail access, there were 182 respondents (of 269 possible) that report distance to rail from less than one mile to 400 miles away. Access is good in that over 75 percent have rail access within 30 miles. For shipment locations without direct access to barge, there were 299 respondents that report distance to barge from less than one mile to 450 miles. Again, access is good for a large part of the sample, with over 60 percent having access within 50 miles. In both the case of rail and barge, direct access to rail and barge is limited in the sense that most shippers in the sample have access only to motor carriage. However, indirect access to both rail and barge can occur through motor carriage, and there is a high proportion of shippers that are located relatively close to both.

The costs of using modes can be aided through the ease of loading and setting up loads. Each is considered in table 1.5. Specifically, on average shippers can load/unload between 4 and 5 truck, with a range from 1 to 100. This capacity measure, however, is heavily skewed, with 382 of 406 responses reporting 10 trucks or less (the median value is 2). Rail and barge have similar distributions. On average shippers can load/unload 47 rail cars, ranging from 1 to 400 cars, the latter represents a response from a very large coal receiving location. About 70 percent of the sample can handle up to 50 cars and the median value is 16. On average, shippers can load/unload between 2 and 3 barges (the average value is 2.2), with a range from 1 to 30. Similar to truck, the bulk of shippers are small with capacities of only one barge (43/62=69%) of shippers that report barge capacities).

A final access consideration is the ease of setting up loads. Again, there are differences across modes. This question was phrased to those that have direct and indirect access to modes i.e., all were asked to provide information of how long it takes to set up the transportation and then wait for the equipment to arrive and be usable. Trucks are, on average, available within two days, while barge and rail take about two weeks. However, as with capacity, there are tremendous differences across shippers. For trucks, the range is from 8 hours to 90 days, with a median value of one day; for rail, the range is from an hour to 6 months, with a median value of 5 days; and for barge, the range is from one hour to 72 days, with a median value of 7 days.

Table 1.5: Modal Access

Mode	Truck	Rail	Barge
Number of Respondents	N.A.	435	436
Direct Access	N.A.	168/436=39%	70/436=16%
Distance to Nearest Access (given no direct access)	N.A.	26 miles (N=182)	58 miles (N=299)
Loading capacity (given access)	4.5 Trucks (N=406)	47 Cars (N=138)	2.2 Barges (N=62)
Time to Set Up Load (If one were to use it)	40 hours (N=345)	245 hours (N=220)	238 Hours (N=177)

In addition to the access that shippers have to modes, there are a series of other attributes considered. These are summarized in table 1.6 and include annual volumes shipped to/from the respondent location, storage capacity, number of facilities operated by the firm, whether they have import/export facilities, and the type of organization. As indicated, there is a wide range of shipper sizes. Some of the variables e.g., size, capacity, vary so much across shipper locations that 10, 50 and 90 percentile values are also indicated. Shipper size is indicated by the value of annual shipments and also by the commodity value of storage capacity (the total value that can be stored when the storage facility is at full capacity). Each point to tremendous differences in shipper sizes. In both cases, the difference between the 10 and 90 percentile values is quite large. The average value of the product shipped also varies widely. On average, this is about $2021 per ton. However, once again, the range (measured by the 10 and 90 percent values) is quite large.

On average, the facilities surveyed have been in operation for an average of 39 years, with 10 and 90 percentile values of 7 and 80, respectively. The facilities are most often privately owned by corporations that operate multiple facilities. Specifically, the sample is dominated by locations owned by corporations (249/426) and "private" firms (118/426), although the sample has a number of cooperatives (50/426) and public organizations (9/426) represented. Generally, the firms that own facilities operate a number of others; the average number of similar facilities operated by the owning firm is 41. However, the most common, however, is a single plant firm, which represents 41 percent of the sample (172/423).

Table 1.6: Shipper Characteristics

Variable	N	Average	Std. Dev.	10%	50%	90%
Size ($000k)	305	556,755	4,046,153	23	3,000	100,000
Cap ($000)	276	29,847	307,247	10	1,000	18,600
Value/Ton	289	2,021	6,245	30	300	2,500
Years	426	39	20	7	35	80
Number Facilities	423	41	488	1	3	32

1.4.2 Shipment Characteristics

The survey collected information on the last shipment taken as well as different shipments that could have been made. Together, these form the dependent variable in the revealed choice model reported in the next section. For an originator, the shipment is represented by the destination of the shipment and the mode used, while for a receiver the shipment is represented by the origin of the shipment and the mode used. In the sample, there are single and multi-mode shipments. The frequencies and percentages of each are summarized in Table 1.7. Most of the shipments (384/420=91.4 percent) are single mode shipments, with 29 barge, 35 rail, and 319 truck. However, there were a total of 45 shipments that involved barge, 53 shipments that involved rail, and 363 that involved truck.

Table 1.7 Chosen Modes		
Modes	**Frequency**	**Percentage**
B	29	6.9
B-O	1	0.24
O	1	0.24
R	35	8.33
R-B	1	0.24
T	319	75.95
T-B	11	2.62
T-O	6	1.43
T-R	13	3.1
T-R-B	3	0.71
T-R-O	1	0.24
Total	**420**	**100**
Note: B=Barge, R=Rail, T=Truck, O=Other		

These shipments originate from or terminate to (originate if a receiver, and terminate if an originator) a variety of different locales. These include shipments to/from river terminals (56 of 410), distribution centers (63 of 410), railroad terminals (9 of 410), processing/fabrication plants (155 of 410), mines and quarries (31 of 410). Inspection of these origins/destinations suggests that many movements (314) can be categorized into terminal or transshipment movements (all but the 96 "other"). Many of the movements are direct from or to processing/fabrication plants, mines, or quarries. These represent final origins or destinations and total 186 (59% of categorized) responses, but there are a number others that travel to or from other locations that came from or are intended for further shipment by the same mode or another mode. These transshipment movements total 128 (41% of categorized) observations (river, distribution center, or railroad terminal) that are part of a transshipment wherein apparently ownership of the commodity shipped changed.

Table 1.8: Chosen Origin/Destinations		
Type of Origin/Destination	**Frequency**	**Percentage**
River Terminal	56	13.66
Distribution Center	63	15.37
Railroad Terminal	9	2.2
Processing/Fabrication Plant	155	37.8
Mine	21	5.12
Quarry	10	2.44
Other	96	23.41
Total	**410**	**100**

Shipment attributes are provided in Table 1.9. The shipment attributes include value of commodity shipped, rate, transit times, reliability and distance shipped. To facilitate comparisons across modes, both rates and transit times are captured by rate per ton mile and miles per hour. In some of the attributes (e.g., value) there is substantial variation (this may be unresolved measurement error or alternatively a specialty product). For this reason, we present for each mode, the number of observations, mean, standard deviation, and median value. By and large, each of the descriptive statistics are consist with priors and consistent with the other surveys analyzed by the authors. In short, typically, barge and rail haul lower valued commodities compared with truck; barge and rail shipment sizes are much larger than that of truck; barge rates per tonmile are lower than that of rail, which are to be lower than for truck; barge shipment distances are larger than that of rail, which are larger than for truck; Barge and rail speeds are slow relative to truck, and the median for barge is slower than that of rail; Finally, rail reliability is less than that of barge, which is less than that of truck.

Table 1.9: Shipment Attribute Descriptive Statistics				
Value ($ per ton)	**N**	**Average**	**Standard Deviation**	**Median**
B	15	158	118	143
R	23	210	300	129
T	166	1390	5113	323
Total	**219**	**1180**	**4490**	**300**
Shipment Size (tons)				
B	28	7400	28083	1578
R	33	8040	26146	2500
T	295	1783	23500	22
Total	**390**	**2707**	**23175**	**23**
Rate per ton-mile				
B	15	0.020	0.009	0.019
R	16	0.042	0.026	0.034
T	203	0.395	0.868	0.143
Total	**249**	**0.337**	**0.796**	**0.123**
Distance (miles)				
B	28	734	537	686
R	31	567	439	500
T	297	278	531	100
Total	**382**	**433**	**827**	**163**
Miles per Hour				
B	27	5.56	11.34	2.17
R	31	4.26	3.13	3.03
T	286	21.56	23.69	16.67
Total	368	18.07	22.30	12.50
Reliability (% on-time)				
B	27	73	24	80
R	33	58	34	60
T	299	92	14	95
Total	397	86	21	95

As discussed in the next section, a key to the analysis are the alternatives available to shippers. If a shipper was not able to receive from or ship to another location, then the only alternative is to switch modes. Recall from table 1.5 that access to trucks is nearly uniform, but direct access to rail or barge is limited, extremely so for the latter. In the survey form, shippers are first asked if they could have shipped by an alternative mode to the same origin/destination and whether they could have received or shipped the commodity from or to another location. The first question reinforces the notion that direct modal access is limited in that only 105 of 405 shippers indicate that an alternative mode is an alternative. However, 331 of 405 indicate they could ship from to alternative origins or destinations. Thus, while modal alternatives are somewhat limited in the sense of direct access, shippers do have alternatives in terms alternative origins or destinations. Indeed, by this set of questions, only 58 of 402 of the respondents report having no alternatives.

1.5 Sensitivity of Choices to Changes in Shipment Attributes

All told, the shipper and shipment characteristics are consistent with prior expectations as do the alternatives available to shippers. In this section, we examine the sensitivity of shippers to changes in attributes. We first discuss the effects of changes in attributes with regard to the discrete choices that shippers make and then with regard to annual volumes. In terms of the discrete choice, recall that a choice in our model is a change in mode and/or a change in the destination (if an originator) or a change in the origin (if a receiver). There are five different stated preference questions with regard to the transportation rate of the chosen alternative, the transportation rate of the next best alternative, the value of the product shipped, the transit time of the chosen alternative, and the reliability of the chosen alternative. In each case, the attribute increases or decreases to make the chosen alternative worse relative to the next best alternative.[16] The level of the increase or decrease varies randomly and contains values 2, 5, 10, 20, 30, 40, 50, and 60 percent. Various forms of the exact questions asked are in the survey instruments provided in Appendix A. The question with regard to rates is provided as an example. This question is "For your last shipment of {commodity}, if the TRANSPORTATION RATE increased by {percentage prompt}, would you continue to use the original option or switch to your best alternative choice. All factors remain the same as before?"[17] The respondent could reply with continue to use original choice, switch to best alternative choice, go out-of-business, don't know or refused. Tables 1.10-1.14 provide a summary of the responses.

[16] Hence, increases in the transportation rate, decreases in the transportation rate of the alternative choice, decreases/increases in the value of the product shipped for originators/receivers, increases in transit times for the chosen alternative, and decreases in the reliability of the chosen alternative are the prompts.
[17] The introductory script for all questions made evident that changes should be regarded as permanent changes, that all other factors but the prompt were to be held constant, that "out-of-business" was considered to be an option, and a recall on would the best alternative was (based on responses to earlier questions).

Theoretically, it is expected that as the value of the prompting variable increases, a greater proportion of switches should be observed for variables that negatively affect profits, and a smaller proportion of switches for variables that positively affect profits. In tables 1.10-1.14, this is almost always the case in each of the tables. Table 1.10 has the results for transportation rates, the primary focus in the analysis. From these results, it is noted that small changes in rates do not generally induce switching to different modes and/or origins/destinations. With progressively large changes in rates, switching does occur, but even with dramatic increases in rates (60%), only about 49 percent switch to the next best alternative, and only one shipper would shut down. It is also pointed out that with a 20 percent increase in transportation rates, about 33 percent of shippers would switch to an alternative mode. Hence, there is a high proportion of shippers that cannot adjust to alternatives from changes in transportation rates, there is also a high proportion that can. There is little evidence from these descriptive statistics that shipper livelihood is threatened by changes in transportation rates.

Table 1.10: SP Responses to Increases in Transportation Rates of the Chosen Alternative

Percentage Change in Rates	Continue with Original Choice	Switch to Alternative	Out-of-Business	Total
2	38	1	0	39
	97.44%	2.56%	0%	100%
5	47	12	0	59
	79.66%	20.34%	0%	100%
10	26	15	0	41
	63.41%	36.59%	0%	100%
20	29	14	0	43
	67.44%	32.56%	0%	100%
30	26	10	2	38
	68.42%	26.32%	5.26%	100%
40	24	15	1	40
	60%	37.5%	2.5%	100%
50	22	17	2	41
	53.66%	41.46%	4.88%	100%
60	22	22	1	45
	48.89%	48.89%	2.22%	100%
Total	**234**	**106**	**6**	**346**
	67.63%	**30.64%**	**1.73%**	**100%**

Note: Each prompt has the frequency of responses (the top number) and the row percentage (the bottom number).

Demand decisions can also be affected by the rates of the non-chosen alternative. These results are summarized in table 1.11, and reinforce the results with respect to rates but even more so. In particular, decreases in the rate of the non-chosen alternative should induce switching away from the chosen alternative to the nonchosen alternative. Indeed, as indicated in the table there is switching behavior, and, with some exception, the proportion of switching increases with the magnitude of the level of the price decrease. However, similar to that of the chosen alternative, changes in rates are somewhat small in the sense that for large changes in rates of 60 percent, only 42 percent are induced to switch. Thus, together with the results of table 1.10, these results suggest that while there are large numbers of shippers that do switch with changes in rates, there remain a large number of shippers that do not switch. It is noted, and this is presented below, that while the mode and origin/destination may not be affected, it is possible that even shippers that do not switch respond by shipping a different level of output.

Table 1.11: SP Responses to Decreases in Transportation Rates of the Next Best Aternative.

Percentage Change in Alternative Rate	Continue with Original Choice	Switch to Altnernative	Total
2	42	13	55
	76.36%	23.64%	100%
5	33	10	43
	76.74%	23.26%	100%
10	39	12	51
	76.47%	23.53%	100%
20	28	16	44
	63.64%	36.36%	100%
30	25	15	40
	62.5%	37.5%	100%
40	31	11	42
	73.81%	26.19%	100%
50	26	11	37
	70.27%	29.73%	100%
60	23	16	39
	58.97%	41.03%	100%
Total	**247**	**104**	**351**
	70.37%	**29.63%**	**100%**

Note: Each prompt has the frequency of responses (the top number) and the row percentage (the bottom number).

In addition to rates, there are a variety of other responses summarized. Table 1.12 describes the effects of changes in the price (value) of the commodity shipped. For originators, decreases indicate lower revenues, while, for receivers, increases indicate higher input costs. In each case, higher values of the change (in absolute value) should point to higher switch rates. Indeed, this is the behavior observed, and although the magnitudes of switching are larger than those for rates they continue to suggest that there are large fractions of unresponsive shipping. Table 1.13 describes the effects of transit times. Higher transit times point to increased inventory costs, and increases in transit times should point to increases in switching. The results are almost a mirror image as the previous results. Increases in time do induce switching, and the fraction of shippers that respond to increases with the magnitude of the change. Again, however, there remain a large fraction of shippers that do not switch (52 percent) that do not switch even with a 60 percent increase in transit time. Table 1.14 describes the effects of reductions in reliability. In this case, reliability is measured as the fraction of shipments (like those taken or could have been taken). Since measured as a proportion, the stated preference questions were in terms of percentage point reductions in reliability. And, of course, reductions in reliability should reduce profits of the chosen alternative and, may induce switching. The results, again, mirror the others. Generally, there is some level of switching as reliability deteriorates, and that the level of switching increases with larger reductions in reliability. Yet, as before, even with very large reductions in reliability (60 percentage points), there remain 52 percent that state they would not switch.

Table 1.12: SP Responses to Decreases in the Price of the Product

Percentage Change in Price	Continue with Original Choice	Switch to Alternative	Out-of-Business	Total
2	33	7	0	40
	82.5%	17.5%	0	
5	33	6	0	39
	84.62%	15.38%	0	
10	27	9	0	36
	75%	25%	0	
20	21	18	0	39
	53.85%	46.15%	0	
30	11	21	1	33
	33.33%	63.64%	3.03	
40	19	16	2	37
	51.35%	43.24%	5.41%	
50	19	17	1	37
	51.35%	45.95%	2.7%	
60	12	15	2	29
	41.38%	51.72%	6.9%	
Total	**175**	**109**	**6**	**290**
	60.34%	**37.59%**	**2.07**	**100**

Note: Each prompt has the frequency of responses (the top number) and the row percentage (the bottom number). The change in price is negative for originators and positive for receivers.

Table 1.13: SP Responses to Increases in the Transit Times of the Chosen Alternative

Percentage Change in Time	Continue with Original Choice	Switch to Alternative	Out-of-Business	Total
2	33	7	0	
	82.5%	17.5%	0%	100%
5	42	8	0	50
	84%	16%	0%	100%
10	32	11	0	43
	74.42%	25.58%	0%	100%
20	28	14	1	43
	65.12%	32.56%	2.33%	100%
30	25	12	0	37
	67.57%	32.43%	0%	100%
40	29	20	0	49
	59.18%	40.82%	0%	100%
50	22	23	0	45
	48.89%	51.11%	0%	100%
60	22	19	1	42
	52.38%	45.24%	2.38%	100%
Total	**233**	**114**	**2**	**349**
	66.76	**32.66**	**0.57**	**100**

Note: Each prompt has the frequency of responses (top number) and the row percentage (bottom number).

Table 1.14: SP Responses to Decreases in the Reliability of the Chosen Alternative

Reduction in Reliability	Continue with Original Choice	Switch to Alternative	Out-of-Business	Total
2	42	11	0	53
	79.25%	20.75%	0%	100%
5	28	7	0	35
	80%	20%	0%	100%
10	33	9	0	42
	78.57%	21.43%	0%	100%
20	30	12	0	42
	71.43%	28.57%	0%	100%
30	22	10	0	32
	68.75%	31.25%	0%	100%
40	38	12	2	52
	73.08%	23.08%	3.85%	100%
50	19	25	1	45
	42.22%	55.56%	2.22%	100%
60	23	30	0	53
	43.4%	56.6%	0%	100%
Total	**235**	**116**	**3**	**354**
	66.38%	**32.77%**	**0.85%**	**100%**

Note: Each prompt has the frequency of responses (top number) and the row percentage (bottom number).

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Generally, the results of 1.10 through 1.14 suggest that many shippers respond to changes in rate of the chosen alternative, the alternative mode and/or origin/destination, the value of the product shipped, transit times, and reliability. However, there are also many shippers that do not respond. Another mechanism through which shippers can respond is by adjusting their annual volumes. To address this issue, there are five different questions that relate to the responsiveness of annual volumes in response to changes in the average transportation rate (given that the change applies not only to the shipper but also its competitors), the average transportation rate (given that the change applies only to the shipper but not its competitors), the price (received/paid) for the product transported, transit times, and reliability. In each case, the respondent was asked if its annual volume was affected and, if affected, the percentage change in annual volumes.

The responses are summarized in tables 1.15-1.19. Table 1.15 contains the results with respect to changes in the average transportation rate where the change applies to the respondent *and its competitors*, while table 1.16 contains the result with respect to changes when the change applies to only the respondent shipper and not its competitors. The former applies to the case wherein shippers compete spatially for the procurement or sales of goods in the same traffic corridor, while the latter applies to the case wherein shippers do not share the same traffic corridor affected by transportation investment.

For all percentage changes in rates, shippers typically adjust volumes more with changes that apply to them but not their competitors than when changes apply to both the respondent and its competitors. Further, in both cases, the elasticity (percentage change in quantity/percentage change in rate) given a change falls in the level of the prompt. That is, for small rate prompts, the proportion of shippers that adjust quantity is small, but the effect given an adjustment is large. As the level of the rate prompt increases, the proportion that adjust increase and the adjustment given it occurs falls. Overall, there are 76 of 344 shippers (22%) that state that volumes would be impacted by a rate change if the change applies to the respondent and its competitors, while there are 205 of 343 (60%) when the change applies only to the respondent. Further, the overall implied elasticity is much smaller when the rate change applies to the respondent and it competitor (.89) than when the change applies only to the respondent (2.12). Such results are very much expected and consistent with priors.

Table 1.15: SP Volume Responses to Increases in Average Transportation Rates that Apply to All Shippers.

Percentage Increase in Rate	Change Volumes	No Change in Volumes	Total	Change in Volume given change	Implied Elasticity	N
2	3	41	44	12.5	6.25	2
	6.82%	93.18%	100.00%			
5	2	42	44	5	1	1
	4.55%	95.45%	100.00%			
10	5	43	48	22.5	2.25	4
	10.42%	89.58%	100.00%			
20	12	31	43	11.14	0.56	7
	27.91%	72.09%	100.00%			
30	14	35	49	24.5	0.82	10
	28.57%	71.43%	100.00%			
40	19	27	46	23.57	0.59	14
	41.30%	58.70%	100.00%			
50	6	24	30	25	0.50	4
	20.00%	80.00%	100.00%			
60	15	25	40	18.15	0.30	13
	37.50%	62.50%	100.00%			
Total	**76**	**268**	**344**	**20.16**	**0.89**	**55**
	22.09	**77.91**	**100.00**			

Note: The unweighted average elasticity is 1.53. That in the table is .89 and is a weighted (by frequency of responses) average.

Table 1.16: SP Volume Responses to Increases Transportation Rate that Apply only to Respondent

Percentage Change in Rate	Change Volumes	No Change in Volumes	Total	Change in Volume given change	Implied Elasticity	N
2	14	29	43	14.00	7.00	10
	32.56%	67.44%	100%			
5	19	23	42	23.72	4.74	18
	45.24%	54.76%	100%			
10	23	21	44	33.00	3.30	20
	52.27%	47.73%	100%			
20	25	16	41	27.89	1.39	19
	60.98%	39.02%	100%			
30	32	24	56	43.60	1.45	25
	57.14%	42.86%	100%			
40	27	7	34	36.00	0.90	20
	79.41%	20.59%	100%			
50	34	8	42	43.43	0.87	30
	80.95%	19.05%	100%			
60	31	10	41	52.27	0.87	22
	75.61%	24.39%	100%			
Total	**205**	**138**	**343**	**36.71**	**2.12**	**164**
	59.77%	**40.23%**	**100%**			

Note: The unweighted average elasticity is 2.57. That in the table is 2.12 and is a weighted (by frequency of responses) average.

There are a number of other results with respect to price, transit times and reliability. The effects of changes in the price (value) of the product transported are in Table 1.17. Economic principles suggest that volumes are increasing in price (in the case of an originator) and decreasing in price (in the case of a receiver). The former represents output to the shipper, while the latter represents the cost of an input. The questions were framed around an "increase" in price and an increase (for originators) and a decrease (for receivers). The results should be considered as market effects in that the price increases apply not only to the respondent but also its competitors. As in the other tables, the percentage of shippers that report a response increases in the size of the prompt. In this case, 10 percent of shippers state volumes would change with a 2 percent change in price, and given they would change, the average implied elasticity is 4.33 (a 4.33 percent change in quantity per one percent change in price). For a 60 percent change in price, 47% of the shipper's state volumes would change, with a .39 percent change in quantity. Overall, 89 of 343 shippers report that quantities would be affected by a change in prices, and the average elasticity given a change is .82.

Table 1.17: SP Volume Responses to Increases in Price of the Transported Product (Volume increase in the case of originators, and volume decrease in the case of receiver).

Percentage Change in Price	Change Volumes	No Change in Volumes	Total	Change in Volume given change	Implied Elasticity	N
2	4	36	40	8.67	4.33	3
	10%	90%	100%			
5	5	43	48	12.50	2.50	4
	10.42%	89.58%	100%			
10	7	36	43	7.43	0.74	7
	16.28%	83.72%	100%			
20	15	31	46	13.89	0.69	9
	32.61%	67.39%	100%			
30	14	36	50	15.55	0.52	11
	28%	72%	100%			
40	11	29	40	19.44	0.49	9
	27.5%	72.5%	100%			
50	20	26	46	25.59	0.51	17
	43.48%	56.52%	100%			
60	14	16	30	23.50	0.39	10
	46.67%	53.33%	100%			
Total	**90**	**253**	**343**	**18.13**	**.82**	**70**
	26.24%	**73.76%**	**100%**			

Note: The unweighted average elasticity is 1.27. That in the table is .82 is weighted (by frequency of responses) average.

The effects with respect to non-price attributes are in tables 1.18 and 1.19. Increases in transit times are expected to reduce annual volumes. As with the previous attributes,

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there are only a few shippers that state they would respond to small changes, but the elasticity given a change is quite large (7.5). However, even with very large changes in transit times (60%), only about 44.9% state that volumes would change and the elasticity given a change is only .46. The reliability results are similar in the sense that progressively larger changes imply more that adjust. However, the responsiveness of this proportion is somewhat higher for reliability than for time, while the elasticities given a change are smaller.

Table 1.18: SP Volume Responses to Increases Transit Times

Percentage Change in Time	Change Volumes	No Change in Volumes Frequency (%)	Total	% Change in Volume given change	Implied Elasticity	N
2	5	41	46	15.00	7.5	4
	10.87%	89.13%	100%			
5	4	30	34	10.00	2	1
	11.76%	88.24%	100%			
10	4	31	35	13.33	1.33	3
	11.43%	88.57%	100%			
20	10	39	49	16.33	0.82	9
	20.41%	79.59%	100%			
30	14	40	54	11.50	0.38	10
	25.93%	74.07%	100%			
40	15	18	33	23.64	0.59	11
	45.45%	54.55%	100%			
50	13	23	36	40.00	0.8	11
	36.11%	63.89%	100%			
60	22	27	49	27.63	0.46	19
	44.9%	55.1%	100%			
Total	**87**	**249**	**336**	**20.16**	**1.74**	**55**
	25.89%	**74.11%**	**100%**			

Note: The unweighted average elasticity is 1.74. That in the table is 1.05 and is weighted (by frequency of responses) average.

Table 1.19: SP Volume Responses to Decreases in Reliability

Percentage Point Change	Change Volumes	No Change in Volumes	Total	Change in Volume given change	Implied Elasticity	N
2	5	28	33	7.33	3.67	3
	15.15%	84.85%	100%			
5	6	36	42	17.50	3.5	4
	14.29%	85.71%	100%			
10	11	29	40	17.73	1.77	11
	27.5%	72.5%	100%			
20	16	28	44	16.33	0.82	15
	36.36%	63.64%	100%			
30	16	24	40	24.00	0.8	15
	40%	60%	100%			
40	30	19	49	24.17	0.6	24
	61.22%	38.78%	100%			
50	24	16	40	33.16	0.66	19
	60%	40%	100%			
60	31	18	49	25.36	0.42	25
	63.27%	36.73%	100%			
Total	**139**	**198**	**337**		**.92**	**116**
	41.25%	**58.75%**	**100%**			

Note: The unweighted average elasticity is 1.53 That in the table is .92 reported in the table is weighted (by frequency of responses) average.

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SECTION 2

MODE AND DESTINATION CHOICE

In this section, we examine shippers' choice of mode and destination for their shipments. We first present a model that describes the choice that shippers made for their last shipment, and then present a model that describes whether the respondent will switch from its chosen mode and destination to an alternative under specified changes in rates, times, and so on. The approach allows mode-specific demand elasticities to be calculated, and, as we have demonstrated elsewhere, the results can be aggregated over shippers and space to provide demand models relevant to the Army Corps models (e.g., Train and Wilson, 2004a, 2004b, 2006, 2007a, 2007b 2007c). Specifically, we examine the extent to which shippers would change modes and/or destinations, or even choose to shut down, in response to changes in rates, time, reliability, and the price received/paid for the commodity at the destination/origin. The analysis constitutes one aspect of shippers' overall responses. The other way that shippers can respond is to change their volume of shipping, by, for example, reducing total volume in response to rate increases. This second component of response is examined in section 4.

The data that are used for the analysis of mode and destination choice are described in section 1 above. To summarize: Shippers were asked the mode(s) and destination of their last shipment, as well as alternative mode(s) and destinations, if any, that were available to the shipper for this shipment. For each available alternative, the respondent was asked to provide rates, transit times, reliability measures, and the price received/paid at the destination/origin. Transit times were specified to include the scheduling, waiting time for equipment, and travel time. Reliability was measured by asking the shippers to estimate the percentage of time that shipments like the one chosen or is an option to that chosen arrive "on-time" at the final destination. As discussed in the previous section, some respondents reported no shipping alternatives, such that their only other option was to shut down. Reportedly "captive" shippers (i.e., with no shipping alternatives from their chosen mode and destination) were also found obtained in previous surveys of shippers in the Columbia/Snake area (Train and Wilson, 2005) and the Upper Mississippi region (Train and Wilson, 2004b, 2006, 2007b, 2007c). We explicitly include the "shut down" option in our modeling.

2.1 Revealed Preference Data

As described in section 2, each respondent identified, for their last shipment, the mode and destination of the shipment, as well as up to four alternative modes/destinations that they could have chosen but did not. Data were obtained from the respondent on the transportation rate, transportation time, reliability, and price received at destination (for shippers) or paid at origin (for receivers). These data provide information on the revealed preference (rp) choices of the respondents. Respondents without an alternative mode or destination/origin, and respondents with missing data for the attributes of their last shipment and at least one alternative, were omitted from the estimation.

Table 2.1 gives the estimated parameters of a standard logit model estimated on these rp data. The choice set for each respondent is the set of alternatives that the respondent reported were available, and the dependent variable identifies the alternative that the respondent actually used. The attributes of each alternative enter as explanatory variables, with rates, time, reliability and price received/paid entering in log form, which was found to be fit the data better than entering linearly.

The estimated coefficients of rate, time, reliability, and price received/paid all take the expected signs. The estimated time and rate coefficients imply that a 1 percent increase in transit time is considered equivalent to a (0.166/0.394=) 0.4 percent increase in the transportation rate. Stated in reverse, a percent increase in rates is considered to be more than twice as onerous (0.394/0.166=2.4) than the same percent increase in transportation time. Percent changes in reliability are estimated to be considered as nearly equivalent to the same percent changes in rates. A percent decrease in the price received by shippers and a percent increase in the price paid by receivers are both estimated to be more important than the same percent increase in rates.

Table 2.1: Logit Model on Revealed-Preference Data

Explanatory Variable	Estimated parameter	Standard error	T-statistic
Log of Transportation Rate, in $/ton	-0.394	0.251	1.57
Log of Transportation Time, in hours	-0.166	0.153	1.09
Log of Reliability	0.363	0.546	0.66
Log of Price at destination, in $/ton, for shippers, 0 for receivers	5.939	5.589	1.06
Log of Price at origin, in $/ton, for receivers, 0 for shippers	-0.802	1.250	0.64
Barge constant	0.896	0.548	1.64
Truck constant	-0.229	0.477	0.48
Number of observations	162		
Log-likelihood	-121.390		

The standard errors are large relative to the estimates, with none of the t-statistics exceeding two. Relatively low significance levels are expected on rp data of shippers' choices, which is the reason for our collecting sp data. However, the significance levels in Table 2.1 are lower than were previously obtained for a similar model on rp data for agricultural shipments along the Upper Mississippi (e.g., Train and Wilson, 2007b, Table 17). There are two possible explanations. First, the earlier model contained more usable observations (261 respondents compared to 162 in Table 2.1). Second, agricultural shipments constitute a more similar set of commodities than those used in the present analysis, which can be expected to result in greater uniformity in the underlying parameters over observations. With the current sample, we estimated models with commodity indicators, but the differences over commodity groups were found not to be significant, quite likely because of the small number of observations in each commodity group.

2.2 Stated Preference Data

As described in section 1 above, each respondent was asked whether they would stay with their chosen mode and destination or switch to their best alternative if rates, times or reliability changed by a specified amount. Each respondent was asked a question of the form "For your last shipment, if the transportation rate increased X percent, would you continue with the original option or switch to your next best alternative?" The amount of change X, which is called the "prompt," was randomly chosen from 2, 5, 10, 20, up to 60. The questionnaire asked the respondents whether, under the specified scenario, they would (i) continue to use their original option, (ii) switch to their best alternative mode and destination, or (iii) go out of business. The third possibility, of going out of business, was explicitly incorporated to account for the possibility that the shipper might not be able to make a profit under the specified condition with their original option or with their best alternative mode and destination. Also, shippers who are apparently "captive" in the sense of having no other viable shipping options could nevertheless switch from their previous mode and destination by shutting down.

Questions were asked for the following scenarios:

a) an increase in the transportation rate for the original option (as discussed above)
b) a decrease in the transportation rate for their best alternative mode and destination,
c) a decrease in the price received for the commodity at its original destination (if the shipper was a sender of the commodity), or an increase in the price paid for the commodity at its original origin (if the shipper was a receiver of the commodity)
d) an increase in the transit time, including scheduling and waiting for equipment, for the original option,
e) a decrease in the reliability of their original option.

The responses to these questions were used to estimate a model of shippers' decision of whether or not to switch in response to these changes. For scenarios (a) and (c)-(e), that is, the scenarios that degrade the original option, the model take the form of a trinary logit, where the options are (1) their current option, (2) their best alternative mode and destination, and (3) going out of business. The probability that the shipper will choose option i, i=1,2 or 3, is:

$$P_i = \frac{e^{\beta x_i}}{e^{\beta x_1} + e^{\beta x_2} + e^{\beta x_3}}$$

where x_1 are explanatory variables that relate to their current option, x_2 are explanatory variables that relate to their best alternative mode and destination, and x_3 are variables relating to going out of business.

For scenario (b), which improves the best alternative mode and alternative, the choices available to the shipper are to continue using the original mode and destination, or switch to the best alternative mode and destination. The shipper would not go out of business in response to this change, since the shipper's original option is unchanged. The choice therefore is binary, with probability for option i, i=1 or 2, being:

$$P_i = \frac{e^{\beta x_1}}{e^{\beta x_1} + e^{\beta x_2}}$$

Each of the specified scenarios (a)-(e), and the shipper's response, constitutes an observation in estimating the model. For each scenario, the log of the prompt is entered, e.g., log(10) for a prompt of ten percent. For scenarios (a) and (c)-(e), the log of the prompt enters as an element of x_1, since the scenario involves changes in the attributes of the original mode and destination. For scenario (b), the log of the prompt enters x_2 since it relates to a change in the second alternative.

By entering the prompts in log form, the model assures that a zero change in rates, prices, time or reliability translates into a zero probability of switching. When there is no change, the variable is $\log(0) = -\infty$. For scenarios (a) and (c)-(e), which affect the original option, the probability of continuing with the original option when there is no change is:

$$P_1 = \frac{e^{\beta(-\infty)}}{e^{\beta(-\infty)} + e^{\beta x_2} + e^{\beta x_3}} = \frac{\infty}{\infty + e^{\beta x_2} + e^{\beta x_3}} \to 1$$

where the second equality arises because β is negative (since the scenarios make the original option worse). In this case, the probability of continuing with the original mode and destination is 1, and the probability of switching is 0. Similarly, for scenario (b), which lowers the rate of the best alternative mode and destination, the log of the prompt enters the second alternative with a positive coefficient (since the scenario improves this alternative). When there is no change, the probability of continuing with the original option is:

$$P_1 = \frac{e^{\beta x_1}}{e^{\beta x_1} + e^{\beta(-\infty)}} = \frac{e^{\beta x_1}}{e^{\beta x_1} + 0} \to 1$$

where the second equality arises because β is positive. Again, the probability of continuing with the original mode and destination is 1when there is no change, and the probability of switching is 0.

Table 2.2 gives the estimated parameters of this switching model. All of the variables enter with the expected signs and are highly significant. As with the model on the rp data, a percent change in price received/paid has a larger impact that a percent change in rates, and a percent change is rates has a larger impact than a percent change in time and has slightly larger impact than a percent change in reliability. Also, a percent reduction in the rate for the best alternative mode and destination has less impact than a percent increase in the rate of the original option. The constant for the original option is large and positive, which is consistent with the concept that a threshold must be reached for the shipper to switch away from its original choice. The constant for going out of business is negative and large in magnitude, indicating, as expected, that shippers do not choose to go out of business unless conditions become very onerous.

Table 2.2. Model of whether shippers switch from their current option			
Explanatory variable (alternatives that variable enters given in parentheses; 0 in other alternatives)	**Estimated coefficient**	**Standard Error**	**t-statistic**
Log of percent increase in rate for original option (1)	-0.488	0.082	5.98
Log of percent decrease in rate for best alternative (2)	0.420	0.083	5.03
Log of percent increase in time for original option (1)	-0.459	0.081	5.65
Log of percent decrease in reliability for original option (1)	-0.466	0.080	5.88
Log of percent decrease in price received at destination for original option, for shippers who send commodity (1)	-0.590	0.107	5.53
Log of percent increase in price paid at origin for original option, for shippers who receive commodity (1)	-0.582	0.092	6.33
Rail or rail-truck is alternative mode (2)	0.392	0.170	2.31
Alternative mode is not specified by respondent (2)	-2.820	0.422	6.69
Out-of-business constant (3)	-2.783	0.257	10.84
Current option (1)	2.601	0.228	11.39
LL at convergence	-672.175		
Number of observations	1406		
Number of respondents	351		

A constant is included that indicates whether the alternative mode is rail alone or rail and truck (i.e., rail without barge). The positive coefficient for this constant indicates shippers more readily switch to the rail or truck-rail than to barge or truck alone. Some respondents did not report that the mode for their best alternative, even though they reported that they had an alternative. A constant was included for these respondents. Its negative coefficient indicates that respondents who do not report the mode of their best alternative are less likely to switch to their best alternative, presumably because they are less familiar with the alternative than respondents who reported the alternative mode. Other mode-specific constants, including constants that indicate the original mode, were tried in the model and found to be highly insignificant. The only significant mode effect is that for rail and truck-rail compared to barge and truck only.

The model in Table 2.2 can be used to forecast the share of shippers who would switch from their current mode and destination under various conditions. We present these switch rates in the subsections below.

Switching Induced by Changes in Rates for Original Option

We first consider an increase in the rate for the shipper's chosen mode and destination. Since the model includes a constant for rail being the alternative mode, we present forecasted switch rates for two situations: (A) Shippers whose best alternative mode is rail or truck-rail. (B) Shippers whose best alternative mode is barge or truck alone.

The forecasted switch rates and implied arc elasticities for these two situations are given Tables 2.3 and 2.4, respectively. The percent of shippers who switch rises, of course, with the percent increase in rates; however, the arc elasticities drop, which implies that the switching rate rises less than proportionately with the size of the rate increase. For shippers whose alternative is rail alone or rail-truck, the arc elasticity exceeds 4 for 5% rate increases. This estimate indicates that a sizeable share of these shippers respond to fairly small changes in rates. However, there is also a sizeable share of shippers who continue to use their current mode and destination even in the face of large rate increases. For example, a 50% increase in rates for the original option is forecast to induce only 44% of shippers whose alternative is rail to switch away from their original option, which leaves 56% who would continue to use their current mode and destination.

Shippers whose alternative mode is barge or truck alone have lower switch rates than shippers whose alternative is rail or truck-rail. For a 5% increase in rates for their original mode and destination, the arc elasticity is below 3 for shippers whose alternative is barge or truck alone, compared to over 4 for shippers whose alternative is rail or truck-rail. These results imply that shippers switch more readily from barge to rail than from rail to barge.

Table 2.3. Percent of Shippers forecasted to switch in response to rate increases for their current mode and destination: Best alternative mode is rail or truck-rail.

Percent increase	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	19.25	0.80	20.06	4.01
10	24.99	1.04	26.03	2.60
20	31.72	1.33	33.05	1.65
30	36.05	1.51	37.56	1.25
40	39.26	1.64	40.91	1.02
50	41.81	1.75	43.56	0.87
60	43.92	1.84	45.76	0.76

Table 2.4. Percent of Shippers forecasted to switch in response to rate increases for their current mode and destination: Best alternative mode is barge or truck only.

Percent increase	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	13.88	0.86	14.73	2.95
10	18.37	1.14	19.51	1.95
20	23.89	1.48	25.37	1.27
30	27.59	1.71	29.29	0.98
40	30.40	1.88	32.28	0.81
50	32.69	2.02	34.71	0.69
60	34.61	2.14	36.75	0.61

Switching Induced by Changes in Rates for Best Alternative Mode and Destination

We now consider the impact of reducing the rate for the best alternative mode and destination, rather than increasing the rate for the original option. Tables 2.5 and 2.6 give the estimated switch rates and arc elasticities for this change. The switch rates are lower than those given above, which indicates that shippers are somewhat less responsive to a decrease in the rate of the alternative mode and destination than to an increase in the rate for their original mode and destination.

Table 2.5. Percent of Shippers forecasted to switch in response to rate decreases for their best alternative mode and destination: Best alternative mode is rail or truck-rail.

Percent increase	Percent who switch to best alternative mode and destination	Arc elasticity
5	17.75	3.55
10	22.41	2.24
20	27.87	1.39
30	31.42	1.05
40	34.08	0.85
50	36.22	0.72
60	38.00	0.63

Table 2.6. Percent of Shippers forecasted to switch in response to rate decreases for their best alternative mode and destination: Best alternative mode is barge or truck only.

Percent increase	Percent who switch to best alternative mode and destination	Arc elasticity
5	12.73	2.55
10	16.33	1.63
20	20.71	1.04
30	23.64	0.79
40	25.89	0.65
50	27.73	0.55
60	29.29	0.49

Switching Induced by Changes in Transit Times

Table 2.7 and 2.8 gives switch rates and arc elasticities for a change in the transit time for the shipper's original mode and destination. The switch rates are lower for time increases than for rate increases for the original option. While shippers are less responsive to changes in transit time than in rates, they nevertheless do indeed respond to transit time.

The arc elasticity exceeds 3 for a 5% increase in transit time for shippers whose best alternative mode is rail or rail-truck, and exceeds 2 for shippers whose best alternative is barge or truck-alone. Larger time increases induce more switching, but considerably less than proportionately, such that the arc elasticities are below 1 for increases of 40% or more.

Table 2.7. Percent of Shippers forecasted to switch in response to increases in transit time for their current mode and destination: Best alternative mode is rail or truck-rail.

Percent increase	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	18.55	0.78	19.32	3.86
10	23.77	0.99	24.77	2.48
20	29.90	1.25	31.15	1.56
30	33.86	1.42	35.28	1.18
40	36.81	1.54	38.35	0.96
50	39.16	1.64	40.80	0.82
60	41.11	1.72	42.83	0.71

Table 2.8. Percent of Shippers forecasted to switch in response to increases in transit time for their current mode and destination: Best alternative mode is barge or truck only.

Percent increase	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	13.33	0.82	14.16	2.83
10	17.40	1.08	18.48	1.85
20	22.37	1.38	23.76	1.19
30	25.70	1.59	27.29	0.91
40	28.24	1.75	29.99	0.75
50	30.31	1.87	32.18	0.64
60	32.05	1.98	34.04	0.57

Switching Induced by Changes in Reliability

Tables 2.9 and 2.10 give switch rates and arc elasticities when reliability of the original mode and destination is reduced. Response to reliability is lower than for rate increases for the original option and about the same (only slightly higher) as for time increases. The relevance of reliability in shippers' decisions has been found in the earlier surveys (e.g., Train and Wilson, 2007b) and constitutes an important benefit of waterway improvements that reduce unexpected delays.

Table 2.9. Percent of Shippers forecasted to switch in response to decreases in reliability for their current mode and destination: Best alternative mode is rail or truck-rail.

Percent decrease	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	18.71	0.78	19.50	3.90
10	24.06	1.01	25.07	2.51
20	30.34	1.27	31.60	1.58
30	34.38	1.44	35.82	1.19
40	37.40	1.56	38.96	0.97
50	39.80	1.66	41.46	0.83
60	41.79	1.75	43.53	0.73

Table 2.10. Percent of Shippers forecasted to switch in response to decreases in reliability for their current mode and destination: Best alternative mode is barge or truck only.

Percent decrease	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	13.46	0.83	14.30	2.86
10	17.63	1.09	18.72	1.87
20	22.73	1.41	24.14	1.21
30	26.15	1.62	27.77	0.93
40	28.76	1.78	30.53	0.76
50	30.87	1.91	32.78	0.66
60	32.66	2.02	34.68	0.58

Switching Induced by Changes in Price Received or Paid for Commodity

We now consider changes in the price received for the commodity at its destination for shippers who send commodities, and the price paid for the commodity at its origin for shippers who receive commodities. Tables 2.11 and 2.12 gives the relevant statistics for a decrease in price received for the commodity at it original destination by shippers who send, and Tables 2.13 and 2.14 gives the statistics for an increase in price paid at the original origin by shippers who receive. In both situations, the estimated switch rates are higher than for a change in the transportation rate. This result is an important finding that had not been explored in our previous surveys. Insofar waterway improvements change the geographical distribution of prices, an additional benefit or cost is incurred by shippers.

Table 2.11. Percent of Shippers who send commodity forecasted to switch in response to decreases in price received under their current mode and destination: Best alternative mode is rail or truck-rail.

Percent decrease	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	21.90	0.92	22.82	4.56
10	29.56	1.24	30.80	3.08
20	38.51	1.61	40.12	2.01
30	44.13	1.84	45.97	1.53
40	48.20	2.01	50.21	1.26
50	51.35	2.15	53.50	1.07
60	53.91	2.25	56.16	0.94

Table 2.12. Percent of Shippers who send commodity forecasted to switch in response to decreases in price received under their current mode and destination: Best alternative mode is barge or truck only.

Percent decrease	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	15.93	0.99	16.92	3.38
10	22.09	1.37	23.46	2.35
20	29.73	1.84	31.57	1.58
30	34.80	2.15	36.95	1.23
40	38.60	2.39	40.99	1.02
50	41.63	2.57	44.20	0.88
60	44.14	2.73	46.87	0.78

Table 2.13. Percent of Shippers who receive commodity forecasted to switch in response to increases in price paid under their current mode and origin: Best alternative mode is rail or truck-rail.

Percent increase	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	21.69	0.91	22.59	4.52
10	29.19	1.22	30.41	3.04
20	37.96	1.59	39.54	1.98
30	43.48	1.82	45.30	1.51
40	47.49	1.98	49.47	1.24
50	50.60	2.11	52.72	1.05
60	53.13	2.22	55.35	0.92

Table 2.14. Percent of Shippers who receive commodity forecasted to switch in response to increases in price paid under their current mode and origin: Best alternative mode is barge or truck only.

Percent increase	Percent who switch to best alternative mode and destination	Percent who go out of business	Percent who switch (sum of columns 2 and 3)	Arc elasticity
5	15.76	0.97	16.74	3.35
10	21.78	1.35	23.13	2.31
20	29.25	1.81	31.06	1.55
30	34.20	2.12	36.32	1.21
40	37.93	2.35	40.27	1.01
50	40.90	2.53	43.43	0.87
60	43.37	2.68	46.06	0.77

2.3 Combined stated-preference and revealed-preference data

The sp data are conditioned on the rp choice, in the sense that the respondent was asked about changes in the alternative that they chose in the rp setting. Train and Wilson (2005, 2007) describe a procedure that explicitly accounts for the relation of the sp questions to the rp choice. We applied this method to the Ohio data with results that in some ways confirm the results described above. However, significance levels are low and one of the estimated coefficients (namely, the coefficient for the price received by shippers who send the commodity) takes the wrong sign. We present the estimated model in this section.

The specification of the model is the same as in Train and Wilson (2007b) for the Upper Mississippi agricultural movements. We repeat the explanation of the specification here, so that readers do not need to refer to the previous report. However, readers who remember the specification can skip to the subsection 2.3.2 below to see the estimation results.

2.3.1 Specification

A shipper's choice in the rp setting is a standard logit model. The shipper faces J alternatives for its last shipment, which are the alternatives that the shipper reports are available. The utility of each alternative depends on observed variables, namely, rate, transit time, and reliability, as well as unobserved factors.[18] The observed variables are denoted x_j for alternative j (with the subscript for the shipper omitted for simplicity), and the unobserved random factors are denoted collectively ε_j as for alternative j. Utility of alternative j is denoted $U_j=\beta x_j+\varepsilon_j$. Under the assumption that each ε_j is distributed iid extreme value, the probability that the shipper chooses alternative i is the logit formula:[19]

$$P_i = \frac{e^{\beta x_i}}{\sum_j e^{\beta x_j}}$$

The researcher presents the shipper with a series of sp-off-rp questions that are constructed on the basis of the shipper's rp choice. We provide more general notation than is necessary for our particular sp-off-rp questions, to facilitate the use of the method in other settings that might use different types of sp-off-rp questions. The researcher asks T sp-off-rp questions, with attributes $\tilde{x}_{jt}^{i}$ for alternative j in question t based on alternative i having been chosen in the rp setting. For our questions, $\tilde{x}_{it}^{i} \neq x_i$ for the alternative that was chosen in the rp setting, while $\tilde{x}_{jt}^{i} = x_j \, \forall j \neq i$ for the non-chosen alternatives; however, more general specifications of $\tilde{x}_{jt}^{i}$ are possible. The shipper is asked to choose among the alternatives in response to each sp-off-rp question.

The shipper's choice in the sp-off-rp setting can be affected by factors that did not arise in the rp setting. We allow for both systematic and random effects. First, respondents might have a tendency to stay with, or switch away, from their chosen rp alternative for reasons that are unrelated to the prompt. To account for this possibility, we include a constant for the chosen rp alternative in the sp-off-rp choices. This constant is defined as $c_j^i = 1$ if $j=i$ and 0 otherwise. If respondents tend to say that they will stay with their rp alternative, independent of the prompt and the values of their other alternatives, then the constant will be positive. If, on the other hand, respondents tend to say that they will switch away from their chosen alternative, perhaps as a protest against the implications of the prompt or as a strategic response intended to induce the ACE to invest in infrastructure, then the constant will be negative. The inclusion of the constant prevents the strategic responses

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[18] The model is framed in a utility context although the term profit maximization can be employed so long as there are no agency issues i.e., the shipper makes decisions consistent with the firm's objective of maximizing profit.

[19] This formula can be interpreted as follows as a example. Suppose the shipper faces two alternatives with the observed portion of utility being $\beta x_1=3$ for the first alternative and $\beta x_2=4$ for the second alternative. Even though the observed portion of utility is lower for the first alternative, the shipper might still choose the first alternative because of unobserved factors. The formula states that the probability that the shipper chooses the first alternative is $exp(3)/(exp(3)+exp(4))=0.27$ and the probability that the shipper chooses the second alternative is $exp(4)/(exp(3)+exp(4))=0.83$.

from influencing the estimates of the coefficients of rates, times, and reliability.[20] Second, the responses might be affected by inattention by the agent to the task, pure randomness in the agent's responses, or other quixotic aspects of the sp choices. We consider these effects to be random factors, taking the value of random term η_j for alternative *j*. The relative importance of these factors will be estimated, as described below. The shipper obtains utility $W_{jt} = \beta x'_{jt} + \varepsilon_j + c'_j + \eta_{jt}$ from alternative *j* in sp-off-rp question *t*. That is, the shipper evaluates its original and best alternative using the same utility coefficients and with the same unobserved attributes as in the rp setting, with the addition of new errors that reflect quixotic aspects of the shippers' responses to the sp-off-rp questions.

In the "sp-off-rp" questions, one alternative for the shipper is to shut down. This option has no associated rates, time, and other shipment attributes. The utility, or more precisely, the disutility of shutting down, differs over shippers. The average disutility (relative to shipping alternatives) is denoted λ and the deviation of a given shipper's disutility from this average is denoted $\sigma \cdot \mu_s$, where μ_s is assumed to be distributed extreme value and σ is a parameter to be estimated that is proportional to the standard deviation over shippers of the disutility of shutting down. The shipper's disutility of shutting down is the same in each of the "sp-off-rp" questions. However, a second error component, labeled η_{st}, is also included to capture the quixotic aspects of responses to these question, similar to the η_{jt}'s above. Combining these concepts, the disutility of shutting down is specified as: $W_{st} = \lambda + \sigma \cdot \mu_s + \eta_{st}$ where subscript *s* denotes shutting down. As discussed below in connection to the empirical results, we estimate a different λ for shippers with large storage capacity than others, reflecting the fact that these shippers are less likely to shut down than those with smaller storage capacity.

In response to each sp-off-rp question, the shipper chooses the alternative with the greatest utility. To complete the model, we specify each η_{jt} to be iid extreme value with scale $1/\alpha$, which is proportional to the standard deviation of these errors. A large value of parameter α indicates that there are few purely random aspects to the sp-off-rp responses. The sp-off-rp responses are, under this specification, standard logits with ε_j as an extra explanatory variable. Since the ε_j's are not observed, these logits must be integrated over their conditional distribution, as follows. The chosen alternative in response to question *t* is denoted k_t and vector $k = \langle k_1, \ldots, k_T \rangle$ collects the sequence of responses to the sp-off-rp questions.

For notation convenience, denote $V_{jt} \equiv \beta x'_{jt} + \varepsilon_j$ for each $j \neq s$, that is, for each alternative other than shutting down, and denote $V_{st} = \lambda + \sigma \cdot \mu_s$ for the shut-down option. The probability of choosing alternative k_t in response to sp-off-rp question *t*, conditional on *i* being chosen in the rp choice is:

[20] In models of standard SP and RP data (as opposed to our SP-off-RP data), it is common practice to include separate constants for the SP data, analogous to the constant we add for the Sp-off-RP responses. See Train, 2003, pages 156-60 and its references for a discussion of this practice.

$$P_{k_t|i} = \Pr ob\left[V_{k_t t} + \eta_{k_t t} > V_{jt} + \eta_{jt} \forall j \neq k_t \mid \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j \forall j \neq i, s\right]$$
$$= \int \frac{e^{\alpha V_{k_t t}}}{\sum e^{\alpha V_{jt}}} f(\varepsilon \mid \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j \forall j \neq i, s) d\varepsilon.$$

This probability is a mixed logit (Train, 2003), mixed over the conditional distribution of the ε 's that enter the V's. It can be simulated by taking draws from the distribution of ε, calculating the logit formula for each draw, and averaging the results. The procedure for taking such draws is given in Train and Wilson (2005; 2007a).

Combining these results, and using the independence of η_{jt} over t, the probability of the agent's rp choice and the sequence of responses to the sp-off-rp questions is:

$$P_{ki} = \int \left[L_{1i}(\varepsilon) \ldots L_{Ti}(\varepsilon)\right] f(\varepsilon \mid \beta x_i + \varepsilon_i > \beta x_j + \varepsilon_j \forall j \neq i, s) d\varepsilon \frac{e^{\beta x_i}}{\sum e^{\beta x_j}}$$

where

$$L_{ti}(\varepsilon) = \frac{e^{\alpha V_{k_t t}}}{\sum e^{\alpha V_{jt}}}.$$

This probability is simulated by taking draws of ε from its conditional distribution as described above, calculating the product of logits within brackets for each draw, averaging the results, and then multiplying by the logit probability of the rp choice.

2.3.2 Estimation Results

Table 2.15 gives the estimated parameters of this model. The attributes of the alternatives enter in log form, the same as they did in the model on rp data in section 2.1. A one percent increase in transit time is estimated to be considered to be equivalent to (0.094/0.207=) 0.45 percent in rates, which is similar to the 0.4% obtained on the rp data alone. The model on the sp data also found that changes in time have less impact than rate changes. A percent decrease in reliability is considered slightly less onerous than the same percent increase in rates, which is also consistent with the findings of the models in the previous sections. The estimates regarding price received/paid are not consistent with the results in the previous section. In particular, the price received by shippers who sent the commodity enters with a negative sign, which is opposite of expected, implausibly implying that shippers prefer obtaining lower prices for their goods at the destination. The price paid by shippers who receive the commodity enters with the correct sign but the coefficient is small in magnitude and highly insignificant.

Other aspects of the model are reasonable. The constant for going out of business is negative and large in magnitude, indicating, as we found in section 2.2, that shippers choose to go out of business only under particularly onerous conditions. The constant for the chosen rp alternative in the sp choice enters with a negative sign. Note that this variable has a different meaning than the same variable in the model in section 2.2. In the current model, the conditional errors enter the alternatives, and these errors have a positive mean for the chosen rp alternative in the sp choices. In the model in section 2.2, this mean was absorbed into the constant for the rp alternative, such that the estimated constant is positive. In the current model, the constant for the rp alternative is net of the mean of the conditional error, and its coefficient indicates the extent to which respondents say they will stay with their current alternative more or less than the conditional errors would suggest. The negative sign for the constant indicates that respondents report that they will switch away from their original alternative more readily than would be indicated by the mean of their conditional errors.

The scale is estimated to be about 2. As stated above, this estimate implies that the standard deviation of the errors entering the sp choices is about half as large as the standard deviation of the errors entering the rp choices. Finally, the error associated with the option of shutting down is estimated to have a standard deviation of 1.44, that is, about 44% greater than the error for the other alternatives.

Table 2.15: Model on Revealed-Preference and Stated-Preference Data Using Explicit Conditioning for the Unobserved Factors.

Explanatory Variable	Estimated parameter	Standard error	T-statistic
Log of Transportation Rate, in $/ton	-0.207	0.130	1.60
Log of Transportation Time, in hours	-0.094	0.095	0.99
Log of Reliability	0.200	0.352	0.57
Log of Price at destination, in $/ton, for shippers, 0 for receivers	-0.154	0.126	1.22
Log of Price at origin, in $/ton, for receivers, 0 for shippers	-0.029	0.094	0.31
Barge constant	0.523	0.421	1.24
Truck constant	-0.221	0.361	0.61
Out of business constant	-3.38	1.73	1.96
Constant for rp alt in sp choice	-0.762	0.087	8.73
Scale	2.01	0.273	7.38
Std dev of out-of-business error	1.44	0.840	1.72
Number of observations	242		
Log-likelihood	-559.289		

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SECTION 3
ANALYSIS OF VOLUME ADJUSTMENTS

The previous section develops and presents estimates of the discrete choices that shippers make. In this section, we present an econometric model of adjustments in annual volumes of shippers in response to changes in attributes. The attributes considered are rates, prices, transit times and reliability. As discussed in section 1, these data consistent of responses to questions soliciting first whether annual volumes would change or not, and if they change how much do they change.

In econometric modeling, these data have limited dependent variables. That is, the range of volume changes is limited by zero and 100 percent. If there is no adjustment to a prompt change the stated volume change is by definition equal to zero. On the other side, if firms reduce output by 100 percent, this is akin to a shutdown (they cannot reduce further). Hence, the dependent variable is limited to values between 0 and 100 percent. In analyzing this type of data in previous studies, Train and Wilson (2004b; 2006; 2007b; 2007c; and 2008) and Sitchinava *et al.* (2005) have used both tobit and selection type empirical models.[21]

The model is based theoretically on a function that represents the optimum level of output in terms of exogenous economic variables (rates, transit times, reliability etc.). In theory, there is a continuum of output for each value of these variables, and comparative static results typically have a change in output to be associated with a change in one of these variables. Such changes are almost always present theoretically unless the output also represents a capacity point in which case output changes are zero. Empirically, however, we observe a lot of "zero" changes in output related to changes in the explanatory variables. The observation of a zero may be a response to the prompt and whether its effect on output is sizeable or not. To identify the response at a point, we first estimate the model of changes in terms of attribute changes and control variables for the shipper and commodity.[22] We then calculate two different elasticities – one that is conditioned on observing a non-limit response to the prompt and one that is unconditioned i.e., allows for a zero percentage response of volumes to changes in the attributes. In specifying the model, we report the results from three different models. All models (labeled as model 1, 2, and 3) contain the percentage change in the prompting variable (e.g., the percentage change in rates). Model 1 contains only this variable, model 2 adds an commodity intercept dummies, while model 3 uses interactions of the commodity dummies with the prompting variable. We considered a variety of different control variables. These include the access shippers have to different modes, the years at that location, the number of facilities, the annual volumes shipped, capacity, etc. The parameters presented in the tables are not sizably influenced by the inclusion of these variables, and they often yield non-significant coefficient estimates. Further, the elasticities are very similar numerically.

[21] See Heckman (1978) and Tobin (1958).

[22] We considered a variety of different control variables. These include the access shippers have to different modes, the years at that location, the number of facilities, the annual volumes shipped, capacity, etc. The parameters presented in the tables are not sizably influenced by the inclusion of these variables, and they tend to yield non-significant coefficient estimates. Further, the elasticities are very similar numerically.

Tables 3.1 and 3.2 present the model for shipper responses to changes in rates that apply to the respondent as well as its competitors. In all models, the % change in the rate is statistically important and numerically similar. The commodity dummies add little in terms of statistical importance. In the case of coal, the estimate is quite large in magnitude. This is an artifact of the data, there are 16 coal observations and none of them adjust volumes in response to rate changes that apply to all shippers. So the coefficient estimate is set to a large value to explain non-responsiveness. The interactive model (Model 3) does point to a difference in elasticities for the "other" commodity group.

The probability of adjustment and the associated elasticities for model 2 are presented in table 3.2. As indicated, the probability of adjustment is quite low for small changes in rates, and increases as the level of the prompt increases. This is as expected, however, in no case, does the estimated probability of adjustment exceed 50 percent, *even for a 60 percent increase in rates*. Given these probabilities the associated expected elasticities are small, and in no case, exceed 1. This result points to relatively inelastic demands. However, if shippers are induced to change output and report the change, the elasticities are much larger, and for small rate increases are relatively elastic. With the exception of coal, these elasticities quite large for small changes in rates (7.32 to 8.55) and vary little across commodities. For larger changes, the elasticities dissipate to relatively inelastic levels.

Table 3.1: Tobit Estimates of Volume Responses to Changes in Rates that Apply to the Respondent and its Competitors

Variable	1	2	3
% Change in Rate	0.688	0.669	0.691
	(4.22)***	(4.10)***	(4.26)***
Aggregates		9.398	
		(0.78)	
Chemicals		0.879	
		(0.09)	
Coal		-198	
		N.A.	
Iron and Steel		7.867	
		(0.82)	
Ores and Minerals		-4.200	
		(0.34)	
Other		-0.894	
		(0.09)	
Petroleum		11.535	
		(1.18)	
% Change * Aggregates			0.109
			(0.32)
% Change * Chemicals			0.046
			(0.19)
% Change * Coal			-101.479
			(.)
% Change * Iron & Steel			0.141
			(0.47)
% Change * Ores and Minerals			-0.641
			(1.36)
% Change * Other			-0.683
			(1.78)*
% Change * Petroleum			0.100
			(0.43)
Constant	-54.554	-55.159	-50.464
	(6.24)***	(5.48)***	(5.76)***
Sigma	35.18436	34.14526	34.61678
Observations	326	326	326

Note: The absolute value of t statistics in parentheses, a *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively. The commodity variables are each dummies, there were no coal values with switches and the coefficients were arbitrarily small to predict them as zero chance of change. The % Change indicates, the percentage change in rate.

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Table 3.2: Probabilities of Adjustment and Volume Elasticities for Rate Changes that Apply to the Respondent and its Competitors

% Change	Commodity	Probability of Adjustment	Expected Elasticity	Conditional Elasticity	Estimated Change	Probability of Adjustment	Expected Elasticity	Conditional Elasticity
2	Aggregates	0.10	0.86	8.36	Iron & Steel	0.10	0.79	8.23
5	Aggregates	0.11	0.39	3.41	Iron & Steel	0.11	0.36	3.36
10	Aggregates	0.13	0.24	1.77	Iron & Steel	0.12	0.22	1.74
20	Aggregates	0.18	0.17	0.95	Iron & Steel	0.17	0.16	0.93
30	Aggregates	0.23	0.16	0.68	Iron & Steel	0.22	0.15	0.67
40	Aggregates	0.29	0.16	0.55	Iron & Steel	0.28	0.15	0.54
50	Aggregates	0.36	0.17	0.48	Iron & Steel	0.35	0.16	0.47
60	Aggregates	0.43	0.19	0.43	Iron & Steel	0.42	0.18	0.42
2	Chemicals	0.07	0.51	7.69	Ores & Minerals	0.05	0.36	7.32
5	Chemicals	0.07	0.23	3.14	Ores & Minerals	0.06	0.17	2.99
10	Chemicals	0.09	0.14	1.62	Ores & Minerals	0.07	0.10	1.54
20	Chemicals	0.12	0.11	0.87	Ores & Minerals	0.10	0.08	0.82
30	Chemicals	0.17	0.10	0.62	Ores & Minerals	0.13	0.08	0.59
40	Chemicals	0.22	0.11	0.50	Ores & Minerals	0.18	0.08	0.47
50	Chemicals	0.28	0.12	0.43	Ores & Minerals	0.23	0.09	0.41
60	Chemicals	0.34	0.13	0.39	Ores & Minerals	0.29	0.11	0.37
2	Coal	0.00	0.00	2.38	Other	0.06	0.45	7.56
5	Coal	0.00	0.00	0.95	Other	0.07	0.21	3.08
10	Coal	0.00	0.00	0.48	Other	0.08	0.13	1.59
20	Coal	0.00	0.00	0.25	Other	0.11	0.10	0.85
30	Coal	0.00	0.00	0.17	Other	0.15	0.09	0.61
40	Coal	0.00	0.00	0.13	Other	0.20	0.10	0.49
50	Coal	0.00	0.00	0.11	Other	0.26	0.11	0.42
60	Coal	0.00	0.00	0.09	Other	0.32	0.12	0.38
2	Grain	0.06	0.48	7.62	Petroleum	0.11	0.98	8.55
5	Grain	0.07	0.22	3.11	Petroleum	0.13	0.44	3.49
10	Grain	0.08	0.13	1.61	Petroleum	0.15	0.27	1.81
20	Grain	0.12	0.10	0.86	Petroleum	0.19	0.19	0.97
30	Grain	0.16	0.10	0.61	Petroleum	0.25	0.18	0.70
40	Grain	0.21	0.10	0.50	Petroleum	0.32	0.18	0.56
50	Grain	0.27	0.12	0.43	Petroleum	0.39	0.19	0.49
60	Grain	0.33	0.13	0.38	Petroleum	0.46	0.21	0.44

Tables 3.3 contain the tobit model results and associated elasticities for changes in rates that apply to the respondent, but not its competitors. As before, the attribute variable (rate) is statistically significant in all specifications and is much larger in magnitude. Unlike the earlier results, the results do suggest significant differences in the commodity groups. In particular, in model 2, all of the commodity dummies are statistically different from grain (the base group) with the exception of petroleum which has a large (in magnitude) point estimate. The results in model 3 are similar in that many of the commodity dummy interactions are statistically important. The associated probabilities and elasticities presented in table 3.4 allow for differences in commodities and for differences for each level of the prompting variable (% changes in rates).

The behavior of the probabilities and elasticities are similar to that of the earlier results, but the magnitudes are different. In particular, as before, the probability of adjustment grows with the level of the prompt, but the probability of volume adjustments is larger throughout the range than the earlier results. Further, the elasticities generally dissipate in magnitude with the level of the prompt, as before. However, the magnitudes are much larger, in some cases, with sizeable differences across commodities.

Table 3.3: Tobit Estimates of Volume Responses to Changes in Rates that Apply to the Respondent but not its Competitors

Variable	1	2	3
% Change in Rate	0.903	0.844	1.117
	(6.54)***	(6.27)***	(6.48)***
Aggregates		-32.142	
		(2.63)***	
Chemicals		-16.195	
		(1.97)*	
Coal		-37.664	
		(2.90)***	
Iron and Steel		-28.314	
		(3.20)***	
Ores and Minerals		-26.82	
		(2.75)***	
Other		-22.859	
		(2.64)***	
Petroleum		-10.319	
		(1.13)	
% Change * Aggregates			-0.645
			(1.82)*
% Change * Chemicals			-0.154
			(0.61)
% Change * Coal			-0.554
			(1.55)
% Change * Iron & Steel			-0.523
			(1.72)*
% Change * Ores and Minerals			-0.577
			(2.05)**
% Change * Other			-0.413
			(1.58)
% Change * Petroleum			-0.095
			(0.38)
Constant	-18.947	-0.26	-17.257
	(3.81)***	-0.04	(3.53)***
Sigma	42.22784	40.587	41.37566
Observations	305	305	305

Note: The absolute value of t statistics in parentheses, a *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively. The commodity variables are each dummies. The % change indicates, the percentage change in rate.

Tables 3.5 and 3.6 contain the results with respect to increases in the price of the commodity transported. For originators, the volume adjustment is positive, while for receivers the volume adjustment is negative. The former represents an increase in the price received for the product the shipper sells, while the latter represents the price paid for an input. The tobit model points again to the statistical importance of changes in price. In all three specifications, the magnitudes of the prompting variable are virtually identical. The addition of intercept dummy variables does suggest differences across commodities, with chemicals, ores & mineral, and petroleum effects statistically larger than for grain, while the addition of interactive dummies points to differences only for chemical products.

The probabilities and elasticities follow the same patterns as with the rate change variables i.e., the probability of adjustment is small for small price changes, and increases with progressively larger percentage changes in price, and the elasticities are largest for small percentage price changes and dissipate with progressively larger percentage price changes. The expected elasticities are almost all less than one in magnitude pointing to relatively inelastic responses. The two exceptions are for Ore & Mineral and Petroleum products, but these hold only for small percentage price changes. The conditional elasticities are, again, larger, and point to relatively elastic volume responses to small percentage changes in price and relatively inelastic volume responses for large percentage changes in price. Further, the elasticities are larger for Chemicals and Petroleum but only modestly more than aggregates and grain, with Iron & Steel and Coal products being somewhat smaller.

Table 3.4: Probabilities of Adjustment and Volume Elasticities for Rate Changes that Apply to the Respondent but not its Competitors

% Change	Commodity	Probability of Adjustment	Expected Elasticity	Conditional Elasticity	Commodity	Probability of Adjustment	Expected Elasticity	Conditional Elasticity
2	Aggregates	0.22	2.63	11.59	Iron & Steel	0.25	3.08	12.01
5	Aggregates	0.24	1.17	4.75	Iron & Steel	0.27	1.37	4.92
10	Aggregates	0.28	0.69	2.47	Iron & Steel	0.31	0.81	2.56
20	Aggregates	0.35	0.48	1.34	Iron & Steel	0.38	0.55	1.39
30	Aggregates	0.43	0.43	0.97	Iron & Steel	0.46	0.48	1.01
40	Aggregates	0.51	0.42	0.79	Iron & Steel	0.54	0.47	0.82
50	Aggregates	0.58	0.43	0.69	Iron & Steel	0.61	0.47	0.72
60	Aggregates	0.65	0.44	0.62	Iron & Steel	0.68	0.49	0.65
2	Chemicals	0.36	4.92	13.50	Ores & Minerals	0.26	3.28	12.19
5	Chemicals	0.38	2.15	5.54	Ores & Minerals	0.29	1.45	4.99
10	Chemicals	0.42	1.25	2.89	Ores & Minerals	0.32	0.85	2.60
20	Chemicals	0.50	0.82	1.57	Ores & Minerals	0.40	0.58	1.41
30	Chemicals	0.57	0.69	1.14	Ores & Minerals	0.48	0.51	1.02
40	Chemicals	0.64	0.65	0.93	Ores & Minerals	0.55	0.49	0.84
50	Chemicals	0.70	0.63	0.81	Ores & Minerals	0.63	0.49	0.73
60	Chemicals	0.75	0.63	0.73	Ores & Minerals	0.69	0.50	0.66
2	Coal	0.19	2.06	11.01	Other	0.30	3.83	12.66
5	Coal	0.20	0.92	4.51	Other	0.32	1.69	5.19
10	Coal	0.23	0.55	2.34	Other	0.36	0.99	2.70
20	Coal	0.30	0.39	1.27	Other	0.43	0.66	1.47
30	Coal	0.38	0.35	0.92	Other	0.51	0.57	1.07
40	Coal	0.45	0.35	0.75	Other	0.59	0.55	0.87
50	Coal	0.53	0.37	0.65	Other	0.66	0.54	0.76
60	Coal	0.61	0.39	0.59	Other	0.71	0.55	0.68
2	Grain	0.51	8.41	15.85	Petroleum	0.41	6.04	14.31
5	Grain	0.53	3.63	6.50	Petroleum	0.43	2.63	5.87
10	Grain	0.57	2.04	3.39	Petroleum	0.47	1.51	3.06
20	Grain	0.64	1.28	1.84	Petroleum	0.55	0.97	1.66
30	Grain	0.70	1.04	1.33	Petroleum	0.62	0.81	1.21
40	Grain	0.74	0.93	1.08	Petroleum	0.69	0.75	0.98
50	Grain	0.77	0.87	0.93	Petroleum	0.74	0.72	0.85
60	Grain	0.78	0.84	0.84	Petroleum	0.77	0.70	0.77

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Table 3.5: Tobit Estimates of Volume Responses to Changes in Prices of the Commodity Transported

Variable	1	2	3
% Change in Price	0.641	0.642	0.623
	(4.89)***	(4.96)***	(4.98)***
Aggregates		1.902	
		(0.17)	
Chemicals		15.09	
		(2.12)**	
Coal		-18.578	
		(1.23)	
Iron and Steel		-9.739	
		(1.08)	
Ores and Minerals		14.23	
		(1.71)*	
Other		7.901	
		(1.04)	
Petroleum		13.715	
		(1.77)*	
% Change * Aggregates			-0.069
			(0.2)
% Change * Chemicals			0.547
			(3.04)***
% Change * Coal			-1.241
			(1.28)
% Change * Iron & Steel			-0.524
			(1.34)
% Change * Ores and Minerals			0.31
			(1.45)
% Change * Other			0.012
			(0.06)
% Change * Petroleum			0.148
			(0.83)
Constant	-42.676	-46.838	-42.401
	(6.84)***	(6.27)***	(6.65)***
Sigma	30.90229	29.45629	28.80468
Observations	325	325	325

Note: The absolute value of t statistics in parentheses, a *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively. The commodity variables are each dummies. The % change indicates, the percentage change in the prompt (Price).

Table 3.6: Probabilities of Adjustment and Volume Elasticities for Changes in the Price of the Product Transported

% Change	Commodity	Probability of Adjustment	Expected Elasticity	Conditional Elasticity	Commodity	Probability of Adjustment	Expected Elasticity	Conditional Elasticity
2	Aggregates	0.07	0.45	6.50	Iron & Steel	0.03	0.17	5.71
5	Aggregates	0.08	0.21	2.66	Iron & Steel	0.04	0.08	2.33
10	Aggregates	0.10	0.13	1.38	Iron & Steel	0.04	0.05	1.21
20	Aggregates	0.14	0.10	0.75	Iron & Steel	0.07	0.04	0.65
30	Aggregates	0.19	0.10	0.54	Iron & Steel	0.10	0.05	0.47
40	Aggregates	0.26	0.11	0.44	Iron & Steel	0.15	0.06	0.38
50	Aggregates	0.33	0.13	0.39	Iron & Steel	0.20	0.07	0.33
60	Aggregates	0.41	0.15	0.35	Iron & Steel	0.27	0.08	0.30
2	Chemicals	0.15	1.15	7.63	Ores & Minerals	0.14	1.09	7.55
5	Chemicals	0.17	0.52	3.13	Ores & Minerals	0.16	0.49	3.10
10	Chemicals	0.19	0.32	1.63	Ores & Minerals	0.19	0.30	1.61
20	Chemicals	0.26	0.23	0.89	Ores & Minerals	0.25	0.22	0.88
30	Chemicals	0.34	0.22	0.65	Ores & Minerals	0.33	0.21	0.64
40	Chemicals	0.42	0.22	0.53	Ores & Minerals	0.41	0.22	0.53
50	Chemicals	0.50	0.24	0.47	Ores & Minerals	0.49	0.23	0.47
60	Chemicals	0.59	0.26	0.43	Ores & Minerals	0.58	0.25	0.43
2	Coal	0.01	0.08	5.21	Other	0.10	0.70	6.98
5	Coal	0.02	0.04	2.13	Other	0.11	0.32	2.86
10	Coal	0.02	0.02	1.10	Other	0.13	0.20	1.49
20	Coal	0.04	0.02	0.59	Other	0.19	0.15	0.81
30	Coal	0.06	0.02	0.42	Other	0.25	0.15	0.59
40	Coal	0.09	0.03	0.34	Other	0.33	0.16	0.48
50	Coal	0.13	0.04	0.29	Other	0.41	0.17	0.42
60	Coal	0.18	0.05	0.27	Other	0.49	0.19	0.39
2	Grain	0.06	0.39	6.36	Petroleum	0.14	1.05	7.50
5	Grain	0.07	0.18	2.60	Petroleum	0.15	0.48	3.08
10	Grain	0.09	0.11	1.35	Petroleum	0.18	0.29	1.60
20	Grain	0.12	0.09	0.73	Petroleum	0.25	0.21	0.87
30	Grain	0.17	0.09	0.53	Petroleum	0.32	0.20	0.64
40	Grain	0.24	0.10	0.43	Petroleum	0.40	0.21	0.52
50	Grain	0.31	0.12	0.38	Petroleum	0.49	0.22	0.46
60	Grain	0.39	0.13	0.34	Petroleum	0.57	0.24	0.42

Tables 3.7 and 3.9 contain the tobit results for non-price factors – transit time and reliability. Increases in transit times and decreases in reliability are expected to induce changes in volumes. The results in both 3.7 and 3.9 are consistent with the previous results and follow the same patterns. The prompting variable (transit times and reliability) are statistically important in each case. Model 2 results with intercept dummies for commodities generally suggest that relative to grain, the other commodities are less volume responsive to changes in transit times and reliability. Model 3 results which use interactive effects on the prompting variable do not generally suggest statistical differences across commodities.

As with the other commodities, the probabilities of a volume adjustment generally are lowest for small changes in transit times and reliability and increase with progressively larger increases. For transit time changes, the probability of adjustment exceeds .5 only for grain and "other" products and only then for large percentage changes. For reliability changes, the probabilities are larger, and for grain and ores & minerals, exceed .7 for large percentage changes. In some sense, these results suggest that the effects of reliability outweigh those of time, and for some commodities, the effects are sizable.

In terms of transit time elasticities, the estimates, with the exception of small transit time changes for grain, point to relatively inelastic estimates. The conditional elasticities are substantially larger, which suggest that given a response to transit times, they are large responses. In terms of reliability elasticities, the estimates are somewhat larger. For small changes in reliability, the effects generally are relatively elastic (greater than one), but as the change increases, the effects generally are relatively inelastic. The behavior across commodities is quite similar, for small changes in reliability, the estimates are from 7.08 (Iron & Steel) to 8.62 (Grain). For larger changes, the elasticities range from .42 (Coal) to .57 (Grain).

Table 3.7: Tobit Estimates of Volume Responses to Changes in Transit Times.

Variable	1	2	3
% Change in Transit Times	0.898	0.894	0.914
	(5.51)***	(5.62)***	(5.60)***
Aggregates		-20.140	
		(1.64)	
Chemicals		-20.935	
		(2.21)**	
Coal		-25.690	
		(1.86)*	
Iron and Steel		-26.874	
		(2.55)**	
Ores and Minerals		-18.749	
		(1.61)	
Other		-5.801	
		(0.64)	
Petroleum		-12.833	
		(1.22)	
% Change * Aggregates			-0.757
			(1.65)*
% Change * Chemicals			-0.126
			(0.48)
% Change * Coal			-0.441
			(1.15)
% Change * Iron & Steel			-0.824
			(1.87)*
% Change * Ores and Minerals			-0.215
			(0.59)
% Change * Other			-0.025
			(0.09)
% Change * Petroleum			-0.166
			(0.57)
Constant	-57.527	-43.705	-52.328
	(6.86)***	(5.18)***	(6.30)***
Sigma	37.58525	36.09629	36.81105
Observations	318	318	318

Note: The absolute value of t statistics in parentheses, a *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively. The commodity variables are each dummies. The % change indicates, the percentage change in the prompt (Transit Times).

Table 3.8: Probabilities of Adjustment and Volume Elasticities for Changes in Transit Times

% Change	Commodity	Prb	Expected Elasticity	Conditional Elasticity	Estimated Change	Prb	Expected Elasticity	Conditional Elasticity
2	Aggregates	0.04	0.31	7.36	Iron & Steel	0.03	0.20	6.93
5	Aggregates	0.05	0.15	3.01	Iron & Steel	0.03	0.10	2.84
10	Aggregates	0.06	0.10	1.57	Iron & Steel	0.04	0.06	1.48
20	Aggregates	0.10	0.09	0.86	Iron & Steel	0.07	0.06	0.80
30	Aggregates	0.15	0.10	0.62	Iron & Steel	0.11	0.07	0.58
40	Aggregates	0.22	0.11	0.51	Iron & Steel	0.17	0.08	0.48
50	Aggregates	0.30	0.14	0.45	Iron & Steel	0.24	0.10	0.42
60	Aggregates	0.39	0.16	0.42	Iron & Steel	0.32	0.12	0.39
2	Chemicals	0.04	0.30	7.30	Ores & Minerals	0.05	0.35	7.45
5	Chemicals	0.05	0.14	2.99	Ores & Minerals	0.05	0.17	3.05
10	Chemicals	0.06	0.10	1.56	Ores & Minerals	0.07	0.11	1.59
20	Chemicals	0.10	0.08	0.85	Ores & Minerals	0.11	0.09	0.87
30	Chemicals	0.15	0.09	0.62	Ores & Minerals	0.16	0.10	0.63
40	Chemicals	0.21	0.11	0.51	Ores & Minerals	0.23	0.12	0.52
50	Chemicals	0.29	0.13	0.45	Ores & Minerals	0.31	0.14	0.46
60	Chemicals	0.38	0.16	0.42	Ores & Minerals	0.40	0.17	0.43
2	Coal	0.03	0.21	7.00	Other	0.09	0.78	8.41
5	Coal	0.04	0.10	2.87	Other	0.11	0.37	3.45
10	Coal	0.05	0.07	1.49	Other	0.13	0.24	1.81
20	Coal	0.08	0.06	0.81	Other	0.19	0.19	0.99
30	Coal	0.12	0.07	0.59	Other	0.26	0.19	0.73
40	Coal	0.18	0.09	0.48	Other	0.35	0.21	0.60
50	Coal	0.25	0.11	0.43	Other	0.45	0.24	0.54
60	Coal	0.33	0.13	0.39	Other	0.54	0.28	0.50
2	Grain	0.12	1.10	8.91	Petroleum	0.06	0.51	7.87
5	Grain	0.14	0.51	3.66	Petroleum	0.07	0.24	3.23
10	Grain	0.17	0.32	1.92	Petroleum	0.09	0.16	1.68
20	Grain	0.24	0.25	1.05	Petroleum	0.14	0.13	0.92
30	Grain	0.32	0.25	0.78	Petroleum	0.20	0.14	0.67
40	Grain	0.41	0.27	0.65	Petroleum	0.28	0.16	0.56
50	Grain	0.51	0.30	0.57	Petroleum	0.37	0.18	0.49
60	Grain	0.60	0.33	0.53	Petroleum	0.47	0.22	0.46

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Table 3.9: Tobit Estimates for Volumes with Changes in Reliability

Variable	1	2	3
% Change in Reliability	0.723	0.699	0.706
	(6.61)***	(6.45)***	(6.46)***
Aggregates		-10.459	
		(1.17)	
Chemicals		-10.549	
		(1.69)*	
Coal		-14.937	
		(1.44)	
Iron and Steel		-15.236	
		(2.18)**	
Ores and Minerals		-2.585	
		(0.36)	
Other		-14.195	
		(2.02)**	
Petroleum		-7.158	
		(0.98)	
% Change * Aggregates			-0.285
			(0.99)
% Change * Chemicals			-0.157
			(0.85)
% Change * Coal			-0.074
			(0.28)
% Change * Iron & Steel			-0.252
			(1.05)
% Change * Ores and Minerals			-0.019
			(0.09)
% Change * Other			-0.345
			(1.58)
% Change * Petroleum			-0.115
			(0.61)
Constant	-30.962	-22.404	-27.145
	(6.56)***	(4.09)***	(5.42)***
Sigma	29.92666	29.39169	29.67466
Observations	315	315	315

Note: The absolute value of t statistics in parentheses, a *, ** and *** indicate statistical significance at the 10, 5 and 1% levels, respectively. The commodity variables are each dummies. The % indicates, the percentage change in the prompt (Reliability).

Table 3.10: Probabilities of Adjustment and Volume Elasticities for Changes in Reliability

% Change	Commodity	Prb	Expected Elasticity	Conditional Elasticity	Commodity	Prb	Expected Elasticity	Conditional Elasticity
2	Aggregates	0.14	1.07	7.51	Iron & Steel	0.11	0.77	7.08
5	Aggregates	0.16	0.49	3.09	Iron & Steel	0.12	0.36	2.91
10	Aggregates	0.19	0.31	1.62	Iron & Steel	0.15	0.23	1.52
20	Aggregates	0.26	0.23	0.89	Iron & Steel	0.21	0.18	0.83
30	Aggregates	0.34	0.22	0.65	Iron & Steel	0.29	0.17	0.61
40	Aggregates	0.43	0.24	0.54	Iron & Steel	0.37	0.19	0.51
50	Aggregates	0.53	0.26	0.48	Iron & Steel	0.46	0.21	0.45
60	Aggregates	0.62	0.28	0.45	Iron & Steel	0.56	0.23	0.42
2	Chemicals	0.14	1.06	7.51	Ores & Minerals	0.21	1.76	8.33
5	Chemicals	0.16	0.49	3.08	Ores & Minerals	0.23	0.80	3.43
10	Chemicals	0.19	0.30	1.61	Ores & Minerals	0.27	0.49	1.80
20	Chemicals	0.26	0.23	0.89	Ores & Minerals	0.35	0.35	0.99
30	Chemicals	0.34	0.22	0.65	Ores & Minerals	0.45	0.33	0.73
40	Chemicals	0.43	0.24	0.54	Ores & Minerals	0.54	0.33	0.61
50	Chemicals	0.53	0.26	0.48	Ores & Minerals	0.63	0.35	0.55
60	Chemicals	0.62	0.28	0.45	Ores & Minerals	0.72	0.37	0.51
2	Coal	0.11	0.79	7.10	Other	0.12	0.83	7.17
5	Coal	0.12	0.36	2.92	Other	0.13	0.38	2.94
10	Coal	0.15	0.23	1.52	Other	0.16	0.24	1.54
20	Coal	0.21	0.18	0.84	Other	0.22	0.19	0.84
30	Coal	0.29	0.18	0.61	Other	0.30	0.18	0.62
40	Coal	0.37	0.19	0.51	Other	0.38	0.20	0.51
50	Coal	0.47	0.21	0.45	Other	0.48	0.22	0.46
60	Coal	0.56	0.24	0.42	Other	0.57	0.24	0.42
2	Grain	0.24	2.05	8.62	Petroleum	0.17	1.32	7.84
5	Grain	0.26	0.92	3.55	Petroleum	0.19	0.60	3.22
10	Grain	0.30	0.56	1.86	Petroleum	0.22	0.37	1.69
20	Grain	0.39	0.40	1.03	Petroleum	0.30	0.28	0.93
30	Grain	0.48	0.37	0.76	Petroleum	0.39	0.26	0.69
40	Grain	0.57	0.37	0.64	Petroleum	0.48	0.27	0.57
50	Grain	0.66	0.38	0.57	Petroleum	0.57	0.29	0.51
60	Grain	0.74	0.40	0.53	Petroleum	0.66	0.32	0.47

SYNOPSIS

This report contains an analysis of demand behavior in the Ohio River Basin. The analysis continues a long list of demand studies conducted on other waterways and, generally, has similar conclusions to the previous studies. A total of 437 responses were received from the survey. The survey provided information that allows relatively detailed descriptive statistics that relate to the access shippers have to different modes, the size of operations, longevity of the shipper, value of the product shipped etc. There are two striking facts that arise. First, this study as the others point to the heterogeneity across products and shippers. Second, the access that firms have to different modes is somewhat limited in that most shippers report they have access only to truck. Through, truck, however, the shippers can access different modes i.e., barge and rail. The descriptive statistics also point out that barge shipments are of lower value, travel greater distance, command a lower rate, travel slower, and are more reliability than rail.

The survey also provided information on a recent shipment and solicited information on alternatives that could have been chosen. Evident from the results is that while shippers have alternatives, they are dominated by the option of alternative locations rather than alternative modes. In addition to these "revealed data", the survey also solicited information on the responsiveness of decisions to changes in key variables such as rate, transit times, and reliability. In this, shippers stated whether their choices would be affected by changes in these variables. Overwhelmingly, the results do point to responsiveness. That is, changes in discrete choices (mode/location) and annual volumes would occur, particularly for large changes in the variables.

Econometrically, there were two types of decisions analyzed. First, a choice model of shippers as to the mode they use and the destination from which they receive or ship a product is considered. There are several different techniques that could be used, and these apply to the data analyzed. We proceeded by considering models with the revealed data alone, the stated preference data alone, and with the data combined. Generally, the results, together, provide evidence that shippers are responsive to changes in both price and non-price factors, and, of primary import to the simulation models of the Army Corps, to changes in rates. The stated preference models provided very strong econometric results, and the elasticities generated suggested a range of elasticities that depend on the level of the change in rates. These elasticities range from "elastic" i.e., greater than one in magnitude, to inelastic i.e., less than one in magnitude.

The second decision analyzed is of the responsiveness of annual volumes to changes in the attributes. In principle, these decisions are the result of optimal behavior on the part of the shipper and are stated responses. The estimation proceeded by the use of a two-limit tobit for each variable with the result that annual volumes are responsive to changes and, for some of the variables (and, in particular, for rates), the level of responsiveness varies across commodities.

The two sets of results together are framed in terms of optimizing behavior of shippers. The choice model is very powerful in that it allows for the alternatives that are relevant to the shippers to be analyzed. The volume model is an easily cast question posed of the respondent to which they can readily respond and avoids the difficulties of specifying a complete equilibrium model of volumes that would otherwise be necessary to analyze demands. Together these two sets of results provide information and can be fit directly into the Army Corps simulation models with little difficulty. Finally, theoretically, this approach can be shown to address many of the criticisms of the National Research Council. Nevertheless, this new approach and line of research continues to be refined, and our experience is that the data collection effort is central to this refinement.

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APPENDIX A

Pages 63-101 provide the scripts that underlie the telephone and web surveys. These instruments use considerable skip logic and utilize pre-sample fills to personalize the document according to commodity and whether they are a shipper or receiver. There are also fills for the various stated preference questions. These fills were assigned randomly and take on values of 2, 5, 10, 20, 30, 40, 50, 60 with equal probability.

Pages 102-112 provides a letter for initial contact and an example of the mail version of the questionnaire.

Page 113 provides the pre-contact letter.

A.1 TELEPHONE SURVEY

IDNUM:
SESRC ID NUMBER -- SAMPLE

OH_ID:
OHIO CLIENT ID -- SAMPLE

CMPNY:
COMPANY NAME -- SAMPLE

ADDR1:
ADDRESS LINE 1 -- SAMPLE

CITY:
CITY -- SAMPLE

STATE:
STATE -- SAMPLE

ZIP:
ZIP CODE -- SAMPLE

LOC:
LOCATION -- SAMPLE

PHONE:
TELEPHONE NUMBER -- SAMPLE

AGGRE:

PETRO:

GRAIN:
Different commodity 0
Grain 1

CHEM:

IRON:

ORES:

OTHER:

COMM:
COMMODITY -- SAMPLE

SHPRC:
SHIPPER OR RECEIVER CODE -- SAMPLE 0=SHIPPER 1=RECEIVER
Shipper 0
Receiver 1

PC1:
PERCENT CHANGE 1 -- SAMPLE

PC2:
PERCENT CHANGE 2 -- SAMPLE

PC3:
PERCENT CHANGE 3 -- SAMPLE

PC4:
PERCENT CHANGE 4 -- SAMPLE

PC5:
PERCENT CHANGE 5 -- SAMPLE

PC6:
PERCENT CHANGE 6 -- SAMPLE

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PC7:
PERCENT CHANGE 7 – SAMPLE

PC8:

PC9:

PC10:

REP:
REPLICATE – SAMPLE
Replicate 1 1
Replicate 2 2
Replicate 3 3
Replicate 4 4
Replicate 5 5
Replicate 6 6
Replicate 7 7

STYPE:
Sample Type This variable is for branching for Listed and RDD samples.
Listed...1
RDD 2

TZONE:
Time Zone This is a variable calculated by Voxco based on the area code of the phone number. If in quotas you get numbers with no Time Zone, then that area code is missing from the Zones tab in the Installation module. Also, please let the maintainer of this file know so that changes can be made for future projects.
Newfoundland..1
Atlantic..2
Eastern...3
Central...4
Mountain...5
Pacific 6
Alaskan 7
No Time zone set 0

INTRO:
Place Sample and Callback information here as needed. Company Name: <CMPNY> Address: <ADDR1> City: <CITY> State: <STATE> Phone: <PHONE> Commodity: <COMM> Shipper/Receiver: <SHPRC> Respondent's name for call back: <NAME> F9 Notes: <F9:O>
Press ENTER to continue ....ST

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FIL1:
FILL FOR 0 = TO (SHIPPER) 1 = FROM (RECEIVER)
to 0
from 1

FIL2:
FILL FOR 0 = destination (SHIPPER) 1 = origin (RECEIVER)
destination 0
origin 1

FIL3:
FILL FOR 0 = OUTBOUND (SHIPPER) 1 = INBOUND (RECEIVER)
outbound 0
inbound 1

FIL4:
FILL FOR 0 = load (SHIPPER) 1 = unload (RECEIVER)
load 0
unload 1

FIL5:
FILL FOR 0=outgoing (Shipper) 1=incoming (Receiver)
outgoing 0
incoming 1

FIL6:
FILL FOR 0=made (Shippers) 1=received (Receivers)
made 0
received 1

FIL7:
FILL FOR 0=sold (Shippers) 1=bought (Receivers)
sold 0
bought 1

FIL8:
FILL FOR 0=sent (Shipper) 1=received (Receiver)
sent 0
received 1

FIL9:
FILL FOR 0 = shipped (SHIPPER) 1 = received (RECEIVER)
shipped 0
received 1

FIL10:
FILL FOR 0=sell (Shippers) 1=buy (Receivers)
sell 0
buy 1

FIL11:
FILL FOR 0 = receive (Shippers) 1 = paid (Receivers)
receive 0
paid 1

FIL12:
FILL FOR 0=shipping (Shippers) 1=receiving (Receivers)
shipping 0
receiving 1

FIL13:
FILL FOR 0=ship (Shippers) 1=recieve (Receivers)
ship 0
recieve 1

FIL14:
FILL FOR 0=sending (Shippers) 1=receiving (Receivers)
sending 0
receiving 1

FIL15:
FILL FOR 0=price you receive (Shippers) 1=price you pay (Receivers)
price you receive 0
price you pay 1

FIL16:
FILL FOR 0=decreased (Shippers) 1=increased (Receivers)
decreased 0
increased 1

FIL17:

FILL FOR 0=from (Shippers) 1=to (Receivers)

from.......................................0
to.......................................1

FIL18:

FILL FOR 0=receive (Shippers) 1=pay (Receivers)

receive.......................................0
pay.......................................1

FIL19:

FILL FOR 0 = INCREASE (SHIPPER) 1 = DECREASE (RECEIVER)

increase.......................................0
decrease.......................................1

BEGIN:

Hello, my name is __________ and I am calling from Washington State University The person that I need to speak to is the Logistics or Shipping manager or someone else who is responsible for making shipment decisions at your location. (Hello,) we are conducting a study for the federal government (U.S. Army Corps of Engineers)to gather information on how firms make transportation decisions. The results will be used to help make decisions on transportation investments in your area. The survey will take about 20 minutes to complete and is very important to policy makers. Your participation is critical to the accuracy of the results.

Speaking to R	1	=> /CONFD
Check Respondent Eligibility	2	=> ELIG1
R not available / Set callback (GB, CB, HB)	3	=> /INT01
Non contacts (AM, BC, BZ, ED, NA)	4	=> /INT02
Refusals (R1, R2, R3, RP)	5	=> /F10
Non-working numbers (CC, DS, MP, WN)	6	=> /VERFY
Communication barrier (DF, HC, LG)	7	=> /INT03
Other codes (DD, DP, OT, RN)	8	=> /INT04
Ineligibles (IE)	9	=> /INT05
Special project codes ()	10	=> /INT99
Web/Mail codes	11	=> /INT98

ELIG1:

What type of business is this?

Open Text Box.......................................1
Don't know.......................................D
Refused.......................................R

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ELIG2:

What products do you sell?

Open Text Box	1	
Do NOT sell products	2	=> ELIG4
Don't know	D	
Refused	R	

ELIG3:

How do you deliver the products you sell?

Truck, Rail or Barge	1	=> ELIG6
UPS, FedEx, DHL, Post Office	2	
Customer comes and picks up	3	
Don't know	D	
Refused	R	

ELIG4:

Do you receive any products, supplies, or commodities such as rock, sand, stone, grain, chemical, coal, minerals, or petroleum products (gasoline, diesel fuel)?

Yes	1	
No	2	=> /INT05
Don't know	D	=> /INT05
Refused	R	=> /INT05

ELIG5:

Do you receive anything by Truck, Rail car, or barge or do you receive them in smaller shipments such as UPS or FedEx packages?

Truck, Rail, Barge	1	=> ELIG6
UPS or FedEx	2	=> /INT05
Don't know	D	=> /INT05
Refused	R	=> /INT05

ELIG6:

Based on these answers, your company is the type we would like to interview. Could we start the survey?

Continue with survey	1	=> /CONFD
No - Try refusal prevention	2	=> /F10
Not a good time - Call back later	3	=> /INT01

CONFD:

This study has been reviewed and approved by Washington State University and the Office of Management and Budget. While my supervisor may monitor this call, all your answers are voluntary and will be kept strictly confidential. If I come to any question you would prefer not to answer, just let me know and I will skip over it. Okay?

Continue with survey .... 1 => /Q01
No - Try refusal prevention .... 2 => /F10
Not a good time - Call back later .... 3 => /INT01

Q01:

First, we would like to ask a few short questions about your transportation options. Do you have rail service at your facility located near <CITY>, <STATE>?

Yes 1
No .... 2 => Q01B
Don't know .... D
Refused .... R

Q01A:

What is your rail car siding capacity at that site? (IWR PROMPT: "Please give us your best estimate")

$E 0 9999

Don't know .... D
Refused .... R

Q01B:

How far is it in miles to the nearest rail facility you use or would use? (IWR PROMPT: "Please give us your best estimate") (IWR NOTE: If rail siding is located at that facility, enter 0.)

$E 0 3000

Rail NOT AVAILABLE from this site .... N
Don't know .... D
Refused .... R

FIL20:

If you were to use 0
For 1

Q02D:

écran [modèle 0] -> Q02H

(FIL20) rail, how long would it take you typically to spend setting up the transportation and then waiting for the equipment? That is, the time it takes to locate and order the equipment and have it arrive and available for use? (DAYS) (BLOCK SCREEN) (DAYS) (BLOCK SCREEN)

$E 0 365

Don't know .... D
Refused .... R

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Q02H:

(FIL20) rail, how long would it take you typically to spend setting up the transportation and then waiting for the equipment? That is, the time it takes to locate and order the equipment and have it arrive and available for use? (DAYS) (BLOCK SCREEN) (HOURS) (BLOCK SCREEN)
$E 0 72
Don't know ....D
Refused ....R

Q03:

Do you have barge service at this facility (<CITY>, <STATE>).
Yes 1
No..2 => Q03B
Don't know ....D
Refused ....R

Q03A:

How many barges can you <FIL4> at one time at this site (in <CITY>, <STATE>)? (IWR PROMPT: "Please give us your best estimate")
$E 0 999
Don't know ....D
Refused ....R

Q03B:

How far is it in miles to the nearest barge facility you use or would use? (IWR PROMPT: "Please give us your best estimate") (* * * IWR NOTE: If Barge loading/unloading is located at that facility, enter 0. * * *)
$E 0 3000
Don't know ....D
Refused ....R

FIL21:

If you were to use..0
For 1

Q04D:

écran [modèle 0] -> Q04H
(FIL21) barge, how long would it take you typically to spend setting up the transportation and then waiting for the equipment? That is, the time it takes to locate and order the equipment and have it arrive and available for use? (DAYS) (BLOCK SCREEN)
$E 0 365
Don't know ....D
Refused ....R

Q04H:

(FIL21) barge, how long would it take you typically to spend setting up the transportation and then waiting for the equipment? That is, the time it takes to locate and order the equipment and have it arrive and available for use? (HOURS) (BLOCK SCREEN)
$E 0 72
Don't know ....D
Refused ....R

Q05:

Do you use truck services for transporting your product shipment <FIL1> market?
Yes 1
No ....2 => FIL22
Don't know ....D
Refused ....R

Q05A:

How many trucks can you <FIL4> at one time? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

FIL22:

If you were to use..........0
For 1

Q06D:

écran [modèle 0] -> Q06H
(FIL22) truck, how long would it take you typically to spend setting up the transportation and then waiting for the equipment? That is, the time it takes to locate and order the equipment and have it arrive and available for use? (DAYS) (BLOCK SCREEN)
$E 0 365
Don't know ....D
Refused ....R

Q06H:

(FIL22) truck, how long would it take you typically to spend setting up the transportation and then waiting for the equipment? That is, the time it takes to locate and order the equipment and have it arrive and available for use? (HOURS) (BLOCK SCREEN)
$E 0 72
Don't know ....D
Refused ....R

Q07:

Shippers of different sizes often face different transportation rates and have decidedly different transportation problems and needs. Next, I'll ask questions that will be used to understand the characteristics of firms of various sizes. Please refer to your current facility

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location at <CITY>, <STATE >. What is the estimated total dollar value of annual shipments (of <COMM>) <FIL9> at this facility's location? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999999999
Don't know ....D
Refused ....R

Q07A:
Can you give us the total tonnage of your ANNUAL SHIPMENTS (of <COMM>)? (IWR PROMPT: Please give us your best estimate")
$E 0 9999999999
Don't know ....D
Refused ....R

Q08:
Storage capacity has been shown to be a key component to transportation decisions. What is the total dollar value of all (<COMM>) products stored when storage is at full capacity? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999999999
Don't know ....D
Refused ....R

Q08A:
Can you give us the total tonnage of (<COMM>) products stored when your facility is at full capacity? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999999999
Don't know ....D
Refused ....R

Q09:
What is the average value per unit (of the <COMM>) that you <FIL13> on a per unit basis.? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99
Don't know ....D
Refused ....R

Q09A:

(IWR ASK IF NECESSARY: "Is that per. . .")

TONS 1
POUNDS..2
HUNDRED WEIGHT (cwt.)..3
GALLONS..4
BUSHELS..5
SHIPMENT..6
OR SOME OTHER UNIT OF MEASURE - (Please Specify) 7
Don't know..D
Refused ....R

Q10:

How many years has this facility been at its current location? (IWR PROMPT: "That is your facility near <CITY>, <STATE>?")

$E 0 999

Don't know..D
Refused ....R

Q11:

How many facilities such as this one does your firm own OR operate? (IWR PROMPT: "Such as your facility near <CITY>, <STATE>?") (ADDITIONAL PROMPT: "Please give us your best estimate.")

$E 0 999

Don't know..D
Refused ....R

Q12:

Does your firm (or parent company) own facilities used to import or export (<COMM>) to and from the United States?

Yes 1
No..2
Don't know..D
Refused ....R

Q13:

Is your company a . . .

COOPERATIVE..1
CORPORATION..2
PRIVATELY OWNED PROPRIETORSHIP 3
OR SOMETHING ELSE - (Please Specify) 4
Don't know..D
Refused ....R

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QR1:

What product do you typically sell?

Open Text Box..1
No products given...2
Don't know..D
Refused...R

QR2:

What do you receive for the product you sell per unit? (IWR PROMPT: "Please give us your best estimate")

$R.2 0.00 99999.99

Don't know..D
Refused...R

QR3:

(IWR Ask if necessary: "What is the unit of weight or volume for that price? Is it. ...")

Tons..1
Pounds...2
Hundred weight (cwt.)...3
Gallon..4
Bushel..5
Shipment..6
Some other unit of measure - (please specify).........................7
Don't know..D
Refused...R

QS1:

What do you pay for, or what does it cost, to produce per unit, the product you typically ship?

$R.2 0.00 99999.99

Don't know..D
Refused...R

QS2:

(IWR Ask if necessary: "What is the unit of weight or volume for that price? Is it. ...")

Tons..1
Pounds...2
Hundred weight (cwt.)...3
Gallon..4
Bushel..5
Shipment..6
Some other unit of measure - (please specify).........................7
Don't know..D
Refused...R

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Q14:

The options that you have in shipping are central to the evaluation of transportation needs. Next, I'll ask about a shipment you just <FIL6> and then I'll ask some parallel questions on any options you have. For the following questions, please consider your last typical <FIL5> shipment <FIL17> this facility. What specific commodity (of <COMM>) was shipped? (IWR: THIS ANSWER WILL BE USED IN UPCOMMING QUESTIONS - PLEASE ENTER A SPECIFIC COMMODITY NAME OR NAMES THAT CAN BE REFERENCED IN UPCOMMING QUESTION FILLS)

Q14A:

What city and state was <Q14> <FIL9> <FIL1>? (IWR ENTER CITY HERE AND STATE IN NEXT QUESTION)

Q14B:

(What city and state was <Q14> <FIL9> <FIL1>?) (IWR ENTER STATE ABBREVIATION HERE)

Q15:

What type of <FIL2> is this? Is it a . . .

RIVER TERMINAL....1
DISTRIBUTION CENTER....2
RAILROAD TERMINAL....3
PROCESSING OR FABRICATION PLANT....4
MINE....5
QUARRY....6
SOME OTHER TYPE - (Please Specify)....7
Don't know....D
Refused....R

Q16:

Do you have an estimate of how much your last single <FIL3> shipment of <Q14> weighed in tons? (IWR PROMPT: "Please give us your best estimate")

$R.2 0.00 999999.99

Depends on Commodity....N
Don't know....D
Refused....R

Q16A:

What was the payload weight or volume of your last single <FIL3> shipment? (IWR PROMPT: "Please give us your best estimate")

$E 0 999999999

Don't know....D
Refused....R

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Q16B:

(IWR: ASK IF NECESSARY: "What is the unit of weight or volume for that shipment? Is it . . .")

Tons..1 => Q17A
Pounds..2 => Q17A
Hundred weight (cwt.)....................................3 => Q17A
Gallon..4
Bushel..5
Shipment..6
Some other unit of measure - (please specify)............7
Don't know..D
Refused...R

Q16C:

How much does a <Q16B> weigh in pounds?
$E 0 9999
Don't know..D
Refused...R

Q17A:

Did you use TRUCK transportation in this last <FIL3> shipment?
Yes...1
No..2
Don't know..D
Refused...R

Q17B:

Did you use RAIL transportation (in this last <FIL3> shipment)?
Yes...1
No..2
Don't know..D
Refused...R

Q17C:

(Did you use) BARGE (transportation in this last <FIL3> shipment)?
Yes...1
No..2
Don't know..D
Refused...R

Q17D:
Did you use any other mode of transportation in this last <FIL3> shipment?
Yes 1
No...2
Don't know ....D
Refused ....R

MODE1:
TRUCK
....0
Truck 1

MODE2:
RAIL
....0
(and) Rail 1

MODE3:
BARGE
....0
(and) Barge..1

MODE4:
OTHER
....0
(and) <Q17D:O>..1

Q18A:
What was the distance traveled in miles by TRUCK for this last shipment ? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

Q18B:
What was the distance traveled in miles by RAIL (for this last shipment)? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

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Q18C:

What was the distance traveled in miles by BARGE (for this last shipment)? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

Q18D:

What was the distance traveled in miles by <Q17D:O> for this last shipment? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

SK1:

MUST SKIP Q19 VALIDATION IF ANY OF Q18A-D ARE D OR R RESPONSES.

E_D0:

CALCULATION VARIABLE SUM OF Q18A-D
$E 0 99999

Q20A:

What was the TRUCK rate per unit? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99
Don't know ....D
Refused ....R

Q20A1:

(IWR: Ask if necessary. "What was the unit of weight or volume for that shipment? Was it . . .")
Tons..1
Pounds..2
Hundred weight (cwt.) 3
Gallon...4
Bushel 5
Shipment 6
Some other unit of measure - (please specify) 7
Don't know ....D
Refused ....R

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Q20B:

What was the RAIL rate per unit? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99

Don't know ....D
Refused ....R

Q20B1:

(IWR: Ask if necessary. "What was the unit of weight or volume for that shipment? Was it . . .")

Tons....1
Pounds....2
Hundred weight (cwt.) 3
Gallon....4
Bushel 5
Shipment 6
Some other unit of measure - (please specify)....7
Don't know....D
Refused ....R

Q20C:

What was the BARGE rate per unit? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99

Don't know....D
Refused ....R

Q20C1:

(IWR: Ask if necessary. "What was the unit of weight or volume for that shipment? Was it . . .")

Tons....1
Pounds....2
Hundred weight (cwt.) 3
Gallon....4
Bushel 5
Shipment 6
Some other unit of measure - (please specify)....7
Don't know....D
Refused ....R

Q20D:

What was the <Q17D:O> rate per unit? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99

Don't know....D
Refused ....R

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Q20D1:

(IWR: Ask if necessary. "What was the unit of weight or volume for that shipment? Was it . . .")

Tons..1
Pounds..2
Hundred weight (cwt.)..3
Gallon..4
Bushel..5
Shipment..6
Some other unit of measure - (please specify)..7
Don't know..D
Refused..R

Q21:

From your answers, the total transport cost for this shipment is about (ETOT0) dollars. Is this correct? (IWR: FIGURE CHECK:

Yes - Continue..1 => Q24D
Return to Q20A and make corrections..2 => /Q20A
No, continue without corrections..3 => Q22
Don't know..D => Q22
Refused..R => Q22

Q22:

What was the total transport cost? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999999.99
Don't know..D => Q24D
Refused..R => Q24D

SK2:

SKIP VERIFICATION IF ANY OF Q18A-D IS D OR R

TR1:

R.5 0.00000 99.99999

TR2:

R.5 0.00000 99.99999

RRW:

....0
....1

RR0:

R.5 0.00000 99.99999

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RR1:
R.5 0.00000 99.99999

RR2:
R.5 0.00000 99.99999

BR1:
R.5 0.00000 99.99999

BR2:
R.5 0.00000 99.99999

COST1:
COST FOR TRUCK
$R.2 0.00 99999999.99

COST2:
PREDICTED COST FOR RAIL
$R.2 0.00 99999999.99

COST3:
PREDICTED COST FOR BARGE
$R.2 0.00 99999999.99

PRATE:
PREDICTED RATE
$R.0 0.00 99999999.99

CHECK:
WEIGHT: <Q16> DISTANCE: TRUCK <Q18A> RAIL <Q18B> BARGE <Q18C> OTHER <Q18D> br1 <BR1> BR2 <BR2> TRUCK COST <COST1> RAIL COST <COST2> BARGE COST <COST3> PREDICTED RATE <PRATE>
Continue...1

E_CU0:
If total cost answer is greater than 200% or less than 20% of predicted cost, go to Q23, else skip to Q24

Q23:

We expected your transport cost to be about <PRATE> dollars. Can you tell us if there was anything unusual about this shipment? (IWR Note: Q22 answer: <Q22> Predicted answer (PRATE): <PRATE>)

Open Text Box..1
No - Continue Without Corrections..............................2
Return and Change Answers.......................................3 => /Q22
Don't know...D
Refused...R

Q24D:

écran [modèle 0] -> Q24H

Shipment time is sometimes a problem for shippers. From the time the equipment becomes available to how long it takes to transport the commodity to the final destination, what do you estimate was the shipment time (in days and hours)? (DAYS) (BLOCK SCREEN)

$E 0 365

Don't know...D
Refused...R

Q24H:

Shipment time is sometimes a problem for shippers. From the time the equipment becomes available to how long it takes to transport the commodity to the final destination, what do you estimate was the shipment time (in days and hours)? (HOURS) (BLOCK SCREEN)

$E 0 72

Don't know...D
Refused...R

SK3:

E_SH0:

CALCULATE SHIPMENT HOURS

$E 0 99999

PTRK:

MODE FOR TRUCK

$R.2 0 999.99

0..0
1..1

PRAIL:

MODE RAIL

$R.2 0 999.99

0..0
1..1

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PBRG:
BARGE COST
$R.2 0 999.99

PTIME:
PREDICTED TIME
$R.2 0 999.99

SK4:
If total shipping time is greater than 200% or less than 20% of predicted time, go to Q25, else skip to Q26

Q25:
We estimated the shipment time to be <PTIME> hours. Can you tell us if there was anything unusual about this shipment? (IWR Respondent answers: Days: <Q24D> Hours: <Q24H>) Q18A <Q18A> Q18B <Q18B> E_D0 <E_D0>

Open Text Box 1
Estimate is reasonable 2
Return to Q24D and correct answers .... 3 => /Q24D
Don't know .... D
Refused .... R

Q26:
Reliability of on-time arrivals can be another concern. For shipments like this one, what percent of the time do you expect them to arrive on time? (IWR PROMPT: "Please give us your best estimate")
$E 0 100
Don't know .... D
Refused .... R

Q28:
How much did you <FIL18> for the <Q14> per unit <FIL1> this <FIL2>? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99
Don't know .... D
Refused .... R

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Q28A:

(IWR Ask if necessary: "What is the unit of weight or volume for that price? Is it. . .")

Tons....1
Pounds....2
Hundred weight (cwt.)....3
Gallon....4
Bushel....5
Shipment....6
Some other unit of measure - (please specify)....7
Don't know....D
Refused....R

Q30B:

Is this a transaction that is internal to your company or is it external?

Internal (within your company)....1
external (involving another company)....2
Don't know....D
Refused....R

ALTIN:

Please consider all alternative ways of handling your last shipment, either by <FIL14> it by a different transportation mode, or transporting it <FIL1> a different <FIL2> or both.

Press ENTER to Continue....1

Q31:

As a reminder, you have told us specifically in this last shipment you <FIL8> <Q14> <FIL1> <Q14A>, <Q14B> by <MODE1> <MODE2> <MODE3> <MODE4>. Could this commodity have been <FIL9> by an alternative mode or set of modes <FIL1> the <FIL2>?

Yes....1
No....2
Don't know....D
Refused....R

Q32:

Could you have <FIL8> <Q14> <FIL1> some other location?

Yes....1
No....2
Don't know....D
Refused....R

SK5:

Q34:
Does this mean you could not <FIL13> <FIL1> any other locations or that you have no other transportation mode options or both?
Could not <FIL13> <FIL1> other locations 1
Do not have other transportation modes 2
Both..3
Don't know ....D
Refused ....R

Q35:
Please explain.
Open Text Box..1
Don't know ....D
Refused ....R

Q36:
If rates are increased to where your firm would choose to not make that shipment, would your establishment go out of business or cease operations at this location?
Yes 1
No...2
Don't know ....D
Refused ....R

SK6:
SKIP FOR R'S WITH NO SHIPPING ALTERNATIVES

Q37I:
BEGIN ALTERNATIVE CONTACT ROSTER FILL FOR "BEST" OR "NEXT BEST" ALTERNATIVE
next best 0
BEST...1

Q37A:
Please tell me your <Q37I> alternative for <FIL12> this commodity. First, what transportation mode would you use? Would you say you use Truck, Rail, Barge or some combination of those?

Truck only 1
Rail only 2
Barge only 3
Truck and rail 4
Truck and barge 5
Rail and barge 6
Truck, rail, and barge 7
Or some other mode - (Please Specify) 8
No other profitable options .... N => QDEC
Don't know .... D
Refused .... R

MOD1R:
TRUCK
.... 0
Truck 1

MOD2R:
RAIL
.... 0
(and) Rail 1

MOD3R:
BARGE
.... 0
(and) Barge 1

MOD4R:
OTHER
.... 0
(and) <Q17D:O> 1

Q37B:
What <FIL2> would you use?
Same <FIL2> 1
Different <FIL2> - Please Specify 2
Don't know .... D
Refused .... R

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Q38:

What type of <FIL2> is this? It is a. . .

RIVER TERMINAL 1
DISTRIBUTION CENTER 2
RAILROAD TERMINAL 3
PROCESSING OR FABRICATION PLANT 4
MINE 5
QUARRY 6
OR SOME OTHER TYPE - (Please Specify) 7
Don't know .... D
Refused .... R

Q39:

Do you have an estimate of how much this <FIL3> shipment of <Q14> would weigh in tons? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 999999.99

Depends on Commodity .... N
Don't know .... D
Refused .... R

Q39A:

How large in weight or volume would this <FIL3> shipment be? (IWR PROMPT: "Please give us your best estimate") (IWR: IF THE RESPONDENT TELLS YOU IT IS THE SAME WEIGHT AND UNIT AS ALREADY ANSWERED PLEASE ENTER: WEIGHT: <Q16> UNIT: <Q16A>)
$R.2 0.00 999999.99

Don't know .... D
Refused .... R

Q39B:

(IWR ASK IF NECESSARY: "What would be the unit of weight or volume for that shipment? Is it . . .") (IWR: IF THE RESPONDENT TELLS YOU IT IS THE SAME WEIGHT AND UNIT AS ALREADY ANSWERED PLEASE ENTER: WEIGHT: <Q16> UNIT: <Q16A>; <Q16A:O>)

Tons 1
Pounds 2
Hundred weight (cwt.) 3
Gallon 4
Bushel 5
Shipment 6
Some other unit of measure - (please specify) 7
Don't know .... D
Refused .... R

Q40A:
What would be the distance traveled by TRUCK? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

Q40B:
What would be the distance traveled by RAIL? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

Q40C:
What would be the distance traveled by BARGE? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

Q40D:
What would be the distance traveled by <Q37A:O>, (the other transportation mode)? (IWR PROMPT: "Please give us your best estimate")
$E 0 9999
Don't know ....D
Refused ....R

SK7:
SKIP IF ANY OF Q40A-D IS D OR R

E_D1:
CALCULATE TOTAL MILES SHIPPED
$E 0 99999

Q41A:
What would be the TRUCK rate per unit of WEIGHT or VOLUME? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99
Don't know ....D
Refused ....R

Q41A1:
(IWR: Ask if necessary. "What would be the unit of weight or volume for that shipment? Would it be . . .")
Tons..1
Pounds..2
Hundred weight (cwt.) 3
Gallon..4
Bushel 5
Shipment 6
Some other unit of measure - (please specify)..........................7
Don't know ....D
Refused ....R

Q41B:
What would be the RAIL rate per unit of WEIGHT or VOLUME? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99
Don't know ....D
Refused ....R

Q41B1:
(IWR: Ask if necessary. "What would be the unit of weight or volume for that shipment? Would it be . . .")
Tons..1
Pounds..2
Hundred weight (cwt.) 3
Gallon..4
Bushel 5
Shipment 6
Some other unit of measure - (please specify)..........................7
Don't know ....D
Refused ....R

Q41C:
What would be the BARGE rate per unit of WEIGHT or VOLUME? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99
Don't know ....D
Refused ....R

Q41C1:

(IWR: Ask if necessary. "What would be the unit of weight or volume for that shipment? Would it be . . .")

Tons..1
Pounds..2
Hundred weight (cwt.)...3
Gallon...4
Bushel...5
Shipment..6
Some other unit of measure - (please specify)..................................7
Don't know...D
Refused..R

Q41D:

What would be the <Q37A:O>rate per unit of WEIGHT or VOLUME? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999.99

Don't know...D
Refused..R

Q41D1:

(IWR: Ask if necessary. "What would be the unit of weight or volume for that shipment? Would it be . . .")

Tons..1
Pounds..2
Hundred weight (cwt.)...3
Gallon...4
Bushel...5
Shipment..6
Some other unit of measure - (please specify)..................................7
Don't know...D
Refused..R

Q42:

From your answers, the total transport cost for this shipment is about (ETOT1) dollars. Is this correct? (IWR: FIGURE CHECK:

Yes - Continue...1 => Q45D
Return to Q40A and make corrections..2 => Q40A
No, continue without corrections...3 => Q43
Don't know...D => Q43
Refused..R => Q43

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Q43:
What would be the total transport cost? (IWR PROMPT: "Please give us your best estimate")
$R.2 0.00 99999999.99
Don't know .... D
Refused .... R

SK8:
SKIP VERIFICATION IF ANY OF Q40A-D IS D OR R

TR1_R:
R.5 0.00000 99.99999

TR2_R:
R.5 0.00000 99.99999

RRW_R:
.... 0
.... 1

RR0_R:
R.5 0.00000 99.99999

RR1_R:
R.5 0.00000 99.99999

RR2_R:
R.5 0.00000 99.99999

BR1_R:
R.5 0.00000 99.99999

BR2_R:
R.5 0.00000 99.99999

CST1R:
COST FOR TRUCK
$R.2 0.00 99999999.99

CST2R:
PREDICTED COST FOR RAIL
$R.2 0.00 99999999.99

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CST3R:

PREDICTED COST FOR BARGE
$R.2 0.00 99999999.99

PRATR:

PREDICTED RATE
$R.0 0.00 99999999.99

CHK_R:

WEIGHT: <Q39> DISTANCE: TRUCK <Q40A> RAIL <Q40B> BARGE <Q40C> <Q37A:O> <Q40D> TRUCK COST <CST1R> RAIL COST <CST2R> BARGE COST <CST3R> PREDICTED RATE <PRATR>

Continue....................1

E_CU1:

If total cost answer is greater than 200% or less than 20% of estimate, go to Q44, else skip to Q45D

Q44:

We would expect your transport cost would be about <PRATR> dollars. Can you tell me if there would be anything unusual about this shipment? (IWR Note: Q43 answer: <Q43> Predicted answer (PRATR): <PRATR>)

Open Text Box....................1
No - Continue Without Corrections....................2
Return and Change Answers....................3 => /Q41A
Don't know....................D
Refused....................R

Q45D:

écran [modèle 0] -> Q45H

Shipment time is sometimes a problem for shippers. From the time the equipment becomes available to how long would it take to transport the commodity to the final destination, what do you estimate the shipment time would be (in days and hours)? (DAYS) (BLOCK SCREEN)
$E 0 365

Don't know....................D
Refused....................R

Q45H:

Shipment time is sometimes a problem for shippers. From the time the equipment becomes available to how long would it take to transport the commodity to the final destination, what do you estimate the shipment time would be (in days and hours)? (HOURS) (BLOCK SCREEN)
$E 0 72

Don't know....................D
Refused....................R

SK9:

E_SH1:
CALCULATE SHIPMENT HOURS
$E 0 99999

PTR_R:
TIME FOR TRUCK
$R.2 0 999.99
0..0
1..1

PRR_R:
TIME FOR RAIL
$R.2 0 999.99
0..0
1..1

PBR_R:
TIME FOR BARGE
$R.2 0 999.99

PTM_R:
PREDICTED TIME
$R.2 0 999.99

SK10:

Q46:
We estimate the shipment time would be <PTM_R> hours. Can you tell me if there would be anything unusual about this shipment? (IWR Respondent answers: Days: <Q45D> Hours: <Q45H>) Q18A <Q40A> Q18B <Q40B> E_D1 <E_D1>
Open Text Box..1
Estimate is reasonable..2
Return and Change Answers...3 => /Q45D
Don't know..D
Refused...R

Q47:

Reliability of on-time arrivals can be another concern. For shipments like this one, what percent of the time would you expect them to arrive on time? (IWR PROMPT: "Please give us your best estimate")

$E 0 100

Don't know ....D
Refused ....R

Q49:

How much would you <FIL18> for the <Q14> per unit <FIL1> this <FIL2>? (IWR PROMPT: "Please give us your best estimate")

$R.2 0.00 99999.99

Don't know ....D
Refused ....R

Q49A:

(IWR Ask if necessary: "What would be the unit of weight or volume for that price? Is it. . .")

Tons..1
Pounds..2
Hundred weight (cwt.) 3
Gallon..4
Bushel 5
Shipment 6
Some other unit of measure - (please specify)..7
Don't know ....D
Refused ....R

Q52:

Would this be a transaction that is internal to your company or would it be external?

Internal (within your company) 1
external (involving another company) 2
Don't know ....D
Refused ....R

Q53:

Could you still make a profit with this transportation alternative?

Yes 1
No..2 => QDEC
Don't know ....D => QDEC
Refused ....R => QDEC

QDEC:

SET ROSTER POSITION TO 1 IN ORDER TO PULL BEST ALTERNATIVE.

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Q107I:

Next, we want to know how you might react to rate and service changes. In the following questions relating to prices, rates and service changes, please regard the changes as permanent changes and also that all other factors (prices of products, mode, etc.) are the same as before the change. Also, if you indicated that you had no options, please consider "out-of-business" as an alternative. From earlier answers, you stated that your best alternative was: Mode: <Q37A> (or <Q37A:O>) <FIL1> <FIL2> of <Q37B> (or <Q37B:O>)

Press ENTER to Continue 1

Q107:

For your last shipment of <Q14>, if the TRANSPORTATION RATE INCREASED <PC1>%, would you continue with the original option or switch to your best alternative choice. All other factors remain the same as before. (IWR: BEST ALTERNATIVE CHOICE IS: Mode: <Q37A> (or <Q37A:O>) <FIL1> <FIL2> of <Q37B> (or <Q37B:O>)

Continue to use Original mode 1
Switch to Best Alternative Choice 2
Go out-of-business 3
Don't know ....D
Refused ....R

Q108:

For your last shipment, if the TRANSPORTATION RATE associated with your best ALTERNATIVE were to DECREASE <PC2>%, would you continue with the original option or switch to your best alternative choice? (IWR: BEST ALTERNATIVE CHOICE IS: Mode: <Q37A> (or <Q37A:O>) <FIL2> of <Q37B> (or <Q37B:O>)

Continue to use Original mode 1
Switch to Best Alternative Choice 2
Go out-of-business 3
Don't know ....D
Refused ....R

Q109:

For your last shipment, if the <FIL15> for the product <FIL16> by <PC3>%, would you continue with the original mode and <FIL2> or switch to an alternative <FIL2>, perhaps, by an alternative mode?

Continue to use Original mode 1
Switch to Best Alternative Choice 2
Go out-of-business 3
Don't know ....D
Refused ....R

Q110:

For your last shipment, if the TRANSIT TIME, including scheduling and wait for equipment, for the original option INCREASED <PC4>%, would you continue with the original mode and destination or switch to your best alternative? (IWR: BEST

ALTERNATIVE CHOICE IS: Mode: <Q37A> (or <Q37A:O>) <FIL2> of <Q37B> (or <Q37B:O>)

Continue to use Original mode 1
Switch to Best Alternative Choice 2
Go out-of-business 3
Don't know ....D
Refused ....R

Q111:

For your last shipment, if the reliability, (percentage of time shipments arrived on-time), of the original option decreased <PC5> percentage points, would you continue with the original mode and destination or switch to your best alternative? (IWR: BEST ALTERNATIVE CHOICE IS: Mode: <Q37A> (or <Q37A:O>) <FIL2> of <Q37B> (or <Q37B:O>)

Continue to use Original mode 1
Switch to Best Alternative Choice 2
Go out-of-business 3
Don't know ....D
Refused ....R

Q112:

Now we need similar information on your ANNUAL volumes shipped. Based on your experience, we will ask for the change in volumes in response to changes in price, rate, time, and reliability given all other variables are held constant at the values you reported earlier. If the average TRANSPORTATION RATES INCREASED by <PC6> percent, and the change applied to BOTH you and your competitors, would your ANNUAL shipping volumes decrease?

Yes 1
No ....2 => Q113
Don't know ....D => Q113
Refused ....R => Q113

Q112A:

By how much would the ANNUAL volume DECREASE (assuming the rate increase applies to BOTH YOU AND YOUR COMPETITORS)? (IWR NOTE: Answer should be a percentage.)

$E 0 100

Don't know ....D
Refused ....R

Q113:

If TRANSPORTATION RATES INCREASED by <PC7> percent, and the change applied to you BUT NOT to your competitors, would your ANNUAL shipping volumes decrease?

Yes 1
No ....2 => Q114
Don't know ....D => Q114
Refused ....R => Q114

Q113A:

By how much would the ANNUAL volume DECREASE, assuming the rate increase applies ONLY TO YOU and NOT to your competitors?

$E 0 99999

Don't know .... D

Refused .... R

Q114:

If the average price you <FIL11> for the product you <FIL10> INCREASED by <PC8> percent, and the change applied to BOTH you and your competitors, would your ANNUAL volume shipped <FIL19>?

Yes 1

No........ 2 => Q115

Don't know .... D => Q115

Refused .... R => Q115

Q114A:

By how much would the ANNUAL volume <FIL19>, assuming the rate increase applies to BOTH YOU AND TO YOUR COMPETITORS?

$E 0 99999

Don't know .... D

Refused .... R

Q115:

If the average time in transit INCREASED by <PC9>% would your ANNUAL volume decrease?

Yes 1

No........ 2 => Q116

Don't know .... D => Q116

Refused .... R => Q116

Q115A:

By how much would the ANNUAL volume DECREASE?

$E 0 99999

Don't know .... D

Refused .... R

Q116:

If the average reliability of shipments DECREASED by <PC10> percentage points, would your ANNUAL volume decrease?

Yes 1

No........ 2 => Q117

Don't know .... D => Q117

Refused .... R => Q117

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Q116A:

By how much would the ANNUAL volume DECREASE?
$E 0 99999
Don't know ....D
Refused ....R

Q117:

That's my last question. I really want to thank you for the time you have spent with me today. If you have any additional comments about transportation needs, I can note them now.
Comments 1
No Comments 2

NOTES:

procédure 8 -> NOTES
*** F5 Notes ***
Press "ENTER" to continue 1

F6:

procédure 1 -> F6
*** Data Corrections *** Interviewer: To note a data correction please type in the variable name (Example: Q##) then the wrong answer, then the correct answer. Example: If you want the data manager to change Q22 from the D currently there to 4000.00, then you would put the following: Q22, D, 4000.00 If any of these pieces of information are missing, the data correction may not be able to be completed. <F6:O>
Enter Data Correction 1

F9:

procédure 4 -> F9
*** Sample Information *** Company Name: <CMPNY> Address: <ADDR1> City: <CITY> State: <STATE> Phone: <PHONE> Commodity: <COMM> Shipper/Receiver: <SHPRC> F9 Notes: <F9:O>
Continue without making changes..1
Edit/enter call back notes..2

F7:

procédure 2 -> F7
*** Definitions *** Aggregates: Sand, gravel, crushed rock and other bulk materials used by the construction industry. Sometimes large stones are classified in this group.
Continue...1

F8:

procédure 3 -> F8
*** Frequently Asked Questions (FAQ) *** —How did you get my name? Your name and address was selected from businesses with certain NAICS codes who are located on or near the Ohio River or in the Ohio River Basin. The Dun and Bradstreet listing of businesses was the primary source for the sample. —What is the purpose of this study? The purpose of the survey is to evaluate the transportation modes and freight costs

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associated with shipping commodities and to determine the investment costs needed to maintain and/or improve these transportation routes. —Who is sponsoring this study? The study is funded by the Washington State University School of Economic Sciences and the US Army Corps of Engineers. —Who are you? Who is conducting this interview? I am a (student/resident of Pullman, Washington) working part-time for the Social and Economic Sciences Research Center (SESRC) at Washington State University. —How will my answers be used and will they be kept confidential? The information you provide will give planners the necessary information to make critical decisions on investments for providing safe and productive transportation routes. —Who can I contact with questions or to verify the legitimacy of this study? I would be glad to give you the telephone number for someone whom you can tell you more about the study. Kent Miller at the Social & Economic Sciences Research Center can be reached at 800-833-0867 or kjmiller@wsu.edu Wes Wilson at the University of Oregon, the lead researcher for the US Army Corps of Engineers, can be reached at 541-346-4690 or wwilson@uoregon.edu Can I complete the survey online or by mail? Yes, you can log on to http://opinion.wsu.edu/OhioRiver (give respondent his/her access code) to complete the survey. —Who can I contact about my rights? If you have any questions concerning your rights about participating in this project, please contact 509-335-3668 and ask for the IRB Coordinator or email irb@wsu.edu —Is this confidential? Yes. Your name and telephone number will be removed from the data base after the survey is completed. Also, because we conduct many surveys maintaining confidentiality is extremely important to the success of our research center. Therefore, we are very careful to protect your privacy. —R is registered on the do not call list The Do Not Call list applies to sales or telemarketing calls only. We are not selling anything and our sole purpose for calling is to conduct a survey to gather information and opinions for decision makers. Your opinions are extremely valuable and we would really appreciate your help with this project. (If R has additional question about the FCC regulations have them contact the Study Director at 800-833-0867)

Continue..1

F10:

procédure 5 -> F10

*** Refusal Prevention screen *** The results will be used to provide a better understanding of transportation investments by the federal government so any information you can share with us is very helpful to the study. If it is more convenient, you can complete the survey online at www.opinion.wsu.edu/ohioriver and your access code is <idnum>

Yes, will continue survey...1
Will do later -- Set Call-Back ....2 => /INT01
Still refuses (set skip to refusal int screen) ....3 => /REFUS

ALTR:

procédure 7 -> RQE

Request for results. Name

RQA:

Request for results Street Address

RQC:

Request for results City

100

RQS:
Request for results State

RQZ:
Request for results Zip

RQE:
Request for results E-mail

F11:
procedure 6 -> F11

NAME:
May I please confirm your / his / her first name so that I will know who to ask for when I call back? (Sample name is: insert fill here)

CB:
When will be a convenient time to call-back?
$CHS

A2. CONTACT LETTER AND MAIL QUESTIONAIRE

2007 Transportation Needs Survey

«CMPNY»
Attention: Logistics/Shipping Manager
«ADDR1»
«city» «state» «zip»

Transportation rates and service are central to the competitiveness of businesses. Transportation is becoming expensive and delayed at times, and there is significant need for investment in highways, railroads, and waterways. Federal and state agencies are typically mandated to assess the costs and benefits of investments. These assessments require information on the ways you send or receive commodities and the options that you have.

The study is being conducted by the Social and Economic Sciences Research Center at Washington State University with support from the federal government. This survey is also being implemented with the knowledge and endorsement of Waterways Council, Inc. All information will be held in the strictest confidence. The results will be used to provide a better understanding of transportation investments by the federal government.

We are centrally interested in transportation movements that could involve or are affected by the waterways and railways. Our assessment of your company suggests that the type of traffic you move and your location may involve these modes or could involve these modes, perhaps through a truck or rail connection. If you have any questions regarding this study, please call 1-800-833-0867 or email SESRCweb3@wsu.edu and mention the "Transportation Demand Study". If you prefer, this survey can also be completed online at **www.opinion.wsu.edu/OhioRiver**. Your access code is **«IDNUM»**

Thank you very much for helping with this study. Your input to this survey is essential!

Sincerely,

Kent Miller
Study Director

PS: The survey has been reviewed and approved by the Washington State University Institutional Review Board (IRB) for the protection of human subjects and the Office of Management and Budget (OMB control number 0710-0001). If you have any questions about your rights as a survey participant, please contact the IRB office at 509-335-3668 or irb@wsu.edu. (IRB# 9362)

What is your job title? ______________________

What is your facility location? ______________ city ____ state

Transportation Options

Q1. Do you have rail service at this facility at «CITY», «STATE»?

1 Yes → **What is your rail car siding capacity?** ______ # of cars
2 No ↓

Q2. How far is it in miles to the nearest rail facility you use or would use?

______ miles

Q3. Do you have barge service at this facility?

1 Yes → **How many barges can you unload at one time at this site?** ______ # of barges
2 No ↓

Q4. How far is it in miles to the nearest barge facility you use or would use?

______ miles

Q5. Do you use truck services for transporting your product shipment from market?

1 Yes → **How many trucks can you unload at one time?** ______ # of trucks
2 No

Your Last Shipment

Q6. The options that you have in shipping are central in the evaluation of transportation needs. The first questions ask about a shipment you just received and the next questions ask some parallel questions on your next best option. For the following questions, please consider your last "typical" incoming shipment to this facility. What specific commodity was shipped?

____________ Commodity

Q7. What city and state was this commodity received from?

______________________ City _______________ State

Q8. What type of origin is this?

1 River terminal
2 Distribution center
3 Railroad terminal
4 Processing or fabrication plant
5 Mine
6. Quarry
7 Some other type - (please specify): _______________

-3-

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Q9. Do you have an estimate of how much your last single inbound shipment of this commodity weighed in tons?

__________ weight in tons
☐ Don't Know

Q10. If tons is not available, what was the payload weight or volume of your last single inbound shipment and please specify the unit?

______ weight or volume

Please specify unit

1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 some other unit (specify): ____________

Q11. Did you use any of the following transportation modes in this last inbound shipment? *(If this shipment is internal to your firm, please indicate the rate you would expect to pay if you used an external company.)*

Mode	Check if used	*If checked* Distance	*If checked* Rate per Unit	*Specify* Unit
Truck	☐	_____ miles	_____ $ per unit	_____
Rail	☐	_____ miles	_____ $ per unit	_____
Barge	☐	_____ miles	_____ $ per unit	_____
Other _____ specify	☐	_____ miles	_____ $ per unit	_____

1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 other unit (specify): ______

Q12. What was the total transport cost?

__________ $ total transport cost

Q13. Shipment time is sometimes a problem for shippers. From the time the equipment becomes available to how long it takes to transport the commodity to the final destination, what do you estimate was the shipment time (in days and hours)?

______ days ______ hours

Q14. How long does it typically take you to set up the transportation for a shipment like this (include the time it takes to locate and order the equipment and have it arrive and available for use)?

______ days ______ hours

Q15. Reliability of on-time arrivals can be another concern. For shipments like this one, what percent of the time do you expect them to arrive on time?

______ percent

4

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Q16. How much did you pay for this commodity per unit from this origin?

_______ $ per unit
Read/specify unit

1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 some other unit (specify): _______________

Q17. Is this a transaction that is internal to your company or is it external?

1 Internal (within your company)
2 External (involving another company)

Shipping Options

Please consider all alternative ways of handling your last shipment, either by receiving it by a different transportation mode, or transporting it from a different origin or both.

Q18. Could this commodity have been received by an alternative mode or set of modes from the origin?

1 Yes
2 No

Q19. Could you have received this commodity from some other location?

1 Yes
2 No

If yes to <u>either</u> Q18 or Q19, skip to Q23, otherwise continue with Q20.

Q20. If you answered no to both Q18 and Q19, does this mean you could not receive from any other locations or that you have no other transportation mode options or both?

1 Could not receive from other locations
2 Do not have other transportation modes
3 Both

Q21. What are the reasons that you have no other options?

____

Q22. If you report that you have no options (no to both Q18 and Q19), and if rates are increased to where your firm would choose to not make that shipment, would your establishment go out of business or cease operations at this location?

1 Yes → **Skip to Q35, page 7**
2 No → **Continue to Q23, page 6**

5

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First Shipping Alternative

Q23. Please tell me your best alternative for receiving this commodity. First, what origin would you use?

1 Same origin
2 Different origin – Please Specify: ___________ city _____ state

Q24. What type of origin is this?

1 River terminal
2 Distribution center
3 Railroad terminal
4 Processing or fabrication plant
5 Mine
6 Quarry
7 Some other type - (please specify): ____________

Q25. Do you have an estimate of how much your last single inbound shipment of this commodity weighed in tons?

___________ weight in tons
☐ Don't Know

Q26. If tons is not available, what was the payload weight or volume of your last single inbound shipment and please specify the unit?

______ weight or volume

Please specify unit
1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 some other unit (specify): ____________

Q27. Did you use any of the following transportation modes in this last inbound shipment? *(If this shipment is internal to your firm, please indicate the rate you would expect to pay if you used an external company.)*

Mode	Check if used	*If checked* Distance	*If checked* Rate per Unit	*Specify* Unit
Truck	☐	______ miles	______ $ per unit	______
Rail	☐	______ miles	______ $ per unit	______
Barge	☐	______ miles	______ $ per unit	______
Other ______ (specify)	☐	______ miles	______ $ per unit	______

1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 other unit (specify): ________

Q28. What was the total transport cost?
___________ $ total transport cost

Q29. Shipment time is sometimes a problem for shippers. From the time the equipment becomes available to how long it would take to transport the commodity to the final destination, what do you estimate the shipment time would be (in days and hours)?

______ days ______ hours

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Q30. How long would it typically take you to set up the transportation for a shipment like this (include the time it takes to locate and order the equipment and have it arrive and available for use)?

_______ days _______ hours

Q31. Reliability of on-time arrivals can be another concern. For shipments like this one, what percent of the time would you expect them to arrive on time?

_______ percent

Q32. How much would you pay for this commodity per unit from this origin? *(If this shipment is internal to your firm, please indicate the rate you would expect to pay if you used an external company.)*

_______ $ per unit

Please specify unit

1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 some other unit (specify) _________________

Q33. Would this be a transaction that is internal to your company or would it be external?

1 Internal (within your company)
2 External (involving another company)

Q34. Could you still make a profit with this transportation alternative?

1 Yes → **Please complete the alternatives table on page 11 and then continue with Q35 on this page**
2 No

Rate and Service Changes

Next, we want to know how you might react to rate and service changes. In the following questions relating to prices, rates and service changes, please regard the changes as permanent changes and also that all other factors (prices of products, mode, etc.) are the same as before the change. Also, if you indicated that you had no options, please consider "out-of-business" as an alternative

Q35. For your last shipment of this commodity, if the TRANSPORTATION RATE INCREASED «pc1»%, would you continue with the original option or switch to your best alternative choice. *All other factors remain the same as before*

1 Continue to use Original mode
2 Switch to Best Alternative Choice
3 Go out-of-business

Q36. For your last shipment, if the TRANSPORTATION RATE associated with your best ALTERNATIVE were to DECREASE «pc2»%, would you continue with the original option or switch to your best alternative choice?

1 Continue to use Original mode
2 Switch to Best Alternative Choice
3 Go out-of-business

Q37. For your last shipment, if the price you pay for the product increased by «pc3»%, would you continue with the original mode and origin or switch to an alternative origin, perhaps, by an alternative mode?

1 Continue to use Original mode
2 Switch to Best Alternative Choice
3 Go out-of-business

Q38. For your last shipment, if the TRANSIT TIME, including scheduling and wait for equipment, for the original option INCREASED «pc4»%, would you continue with the original mode and destination or switch to your best alternative?

1 Continue to use Original mode
2 Switch to Best Alternative Choice
3 Go out-of-business

Q39. For your last shipment, if the reliability, (percentage of time shipments arrived on-time), of the original option decreased «pc5» percentage points, would you continue with the original mode and destination or switch to your best alternative?

1 Continue to use Original mode
2 Switch to Best Alternative Choice
3 Go out-of-business

Q40. Now we need similar information on your ANNUAL volumes shipped. Based on your experience, we will ask for the change in volumes in response to changes in price, rate, time, and reliability given all other variables are held constant at the values you reported earlier. If the average TRANSPORTATION RATES INCREASED by «pc6»%, and the change applied to BOTH you and your competitors, would your ANNUAL shipping volumes decrease?

1 Yes
2 No → **Skip to 42**

→ **Q41. By how much would the ANNUAL volume DECREASE** *(assuming the rate increase applies to BOTH YOU AND YOUR COMPETITORS)?*

_______ % annual volume decrease

Q42. If TRANSPORTATION RATES INCREASED by «pc7»%, and the change applied to you BUT NOT to your competitors, would your ANNUAL shipping volumes decrease?

1 Yes
2 No → **Skip to 44**

→ **Q43. By how much would the ANNUAL volume DECREASE, assuming the rate increase applies ONLY TO YOU and NOT to your competitors?**

_______ % annual volume decrease

Q44. If the average price you paid for the product you buy INCREASED by «pc8»%, and the change applied to BOTH you and your competitors, would your ANNUAL volume shipped decrease?

1 Yes
2 No → **Skip to 46**

→ **Q45. By how much would the ANNUAL volume decrease, assuming the rate increase applies to BOTH YOU AND TO YOUR COMPETITORS?**

_______ % annual volume decrease

Q46. If the average time in transit INCREASED by «pc9»% would your ANNUAL volume decrease?

1 Yes
2 No → **Skip to 47**

→ **Q47. By how much would the ANNUAL volume DECREASE?**

_______ % annual volume decrease

Q48. If the average reliability of shipments DECREASED by «pc10» percentage points, would your ANNUAL volume decrease?

1 Yes
2 No → **Skip to 50**

Q49. By how much would the ANNUAL volume DECREASE?

______ % annual volume decrease

Firm Characteristics

Shippers of different sizes often face different transportation rates and have decidedly different transportation problems and needs. The next questions will be used to understand the characteristics of firms of various sizes.

Q50. What is the estimated total dollar value of annual shipments of «COMM» received at this facility's location?

____________ total dollar value of annual shipments
☐ Don't Know

Q51. Can you give us the total tonnage of your ANNUAL SHIPMENTS of «COMM»? *(Your best estimate is fine.)*

____________ total tonnage of annual shipments

Q52. Storage capacity has been shown to be a key component to transportation decisions. What is the total dollar value of all «COMM» products stored when storage is at full capacity?

____________ total dollar value at full capacity
☐ Don't Know

Q53. Can you give us the total tonnage or alternative unit of «COMM» products stored when your facility is at full capacity? *(Your best estimate is fine.)*

____________ total tonnage at full capacity or total other unit. Specify other unit
____

Q54. What is the average dollar value you pay for «COMM» on a per unit basis?

______ $ per unit

Please specify unit
1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 some other unit (specify): ______________

Q55. How many years has this facility been at its current location?

______ years

Q56. How many facilities such as this one does your firm own OR operate?

______ facilities

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«cnum»

Q57. Does your firm (or parent company) own facilities used to import or export «COMM» to and from the United States?

1 Yes
2 No

Q58. Is your company a . . .

1 Cooperative
2 Corporation
3 Privately owned proprietorship
4 Something else - (please specify)

Q59. What product do you typically sell?

____

Q60. What do you receive for the product you sell per unit?

______ $ per unit

Please specify unit

1 tons
2 pounds
3 hundred weight (cwt)
4 gallons
5 bushels
6 shipment
7 some other unit (specify): ______________

If you have any comments about transportation needs, please write them in the box below.

Please return your completed questionnaire to

Social & Economic Sciences Research Center
PO Box 641801
Pullman, WA 99164-1801

Fax: 509-335-4688

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Please complete the questions in this table if you have more than one shipping alternative.

Additional Shipping Alternatives	Second Alternative	Third Alternative	Fourth Alternative
Q23A. Please tell me your next alternative for receiving this commodity. First, what origin would you use?	1 Same origin 2 Different origin Please Specify: _______ city _______ state	1 Same origin 2 Different origin Please Specify: _______ city _______ state	1 Same origin 2 Different origin Please Specify: _______ city _______ state
Q24A. What type of origin is this?	1 River terminal 2 Distribution center 3 Railroad terminal 4 Procession/fabrication plant 5 Mine 6 Quarry 7 Other (specify) _______	1 River terminal 2 Distribution center 3 Railroad terminal 4 Procession/fabrication plant 5 Mine 6 Quarry 7 Other (specify) _______	1 River terminal 2 Distribution center 3 Railroad terminal 4 Procession/fabrication plant 5 Mine 6 Quarry 7 Other (specify) _______
Q25A. How large in weight or volume would this inbound shipment be?	_______ weight or volume Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify) _______	_______ weight or volume Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify) _______	_______ weight or volume Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify) _______
Q26A. Do you have an estimate of how much this inbound shipment of this commodity would weigh in tons?	_______ weight in tons	_______ weight in tons	_______ weight in tons
Q27A1. Which transportation modes would you use in this inbound shipment? *Circle all that apply.*	1 Truck 2 Rail 3 Barge 4 Other (specify) _______	1 Truck 2 Rail 3 Barge 4 Other (specify) _______	1 Truck 2 Rail 3 Barge 4 Other (specify) _______
Q27A2. What would be the distance traveled for each mode you would use?	_______ Truck miles _______ Rail miles _______ Barge miles _______ Other miles	_______ Truck miles _______ Rail miles _______ Barge miles _______ Other miles	_______ Truck miles _______ Rail miles _______ Barge miles _______ Other miles
Q27A3. What would be the transportation rate for each mode you would use?	_______ $ per unit Truck _______ $ per unit Rail _______ $ per unit Barge _______ $ per unit Other Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify) _______	_______ $ per unit Truck _______ $ per unit Rail _______ $ per unit Barge _______ $ per unit Other Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify) _______	_______ $ per unit Truck _______ $ per unit Rail _______ $ per unit Barge _______ $ per unit Other Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify) _______

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Access Code: _«IDNUM»_

Additional Shipping Alternatives continued

	Second Alternative	Third Alternative	Fourth Alternative
Q28A. What would be the total transport cost?	transport cost	transport cost	transport cost
Q29A. Shipment time is sometimes a problem for shippers. From the time the equipment becomes available to how long it would take to transport the commodity to the final destination, what do you estimate the shipment time would be (in days and hours)?	____ days ____ hours	____ days ____ hours	____ days ____ hours
Q30A. How long would it typically take you to set up the transportation for a shipment like this?	____ days ____ hours	____ days ____ hours	____ days ____ hours
Q31A. Reliability of on-time arrivals can be another concern. For shipments like this one, what percent of the time would you expect them to arrive on time?	____ percent	____ percent	____ percent
Q32A. How much would you pay for this commodity per unit from this origin?	weight or volume Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify)	weight or volume Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify)	weight or volume Specify unit 1 tons 2 pounds 3 hundred weight 4 gallons 5 bushels 6 shipment 7 Other (specify)
Q33A. Would this be a transaction that is internal to your company or would it be external?	1 Internal 2 External	1 Internal 2 External	1 Internal 2 External
Q34A. Could you still make a profit with this transportation alternative?	1 Yes → **Go to third alternative** 2 No → **Go to Q35, page 7**	1 Yes → **Go to fourth alternative** 2 No → **Go to Q35, page 7**	1 Yes → **Go to Q35, page 7** 2 No → **Go to Q35, page 7**

Please return your completed questionnaire to

Social & Economic Sciences Research Center
PO Box 641801
Pullman, WA 99164-1801

Fax: 509-335-4688

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Prior Notification Letter

September 10, 2007

«company»
Attention: Logistics/Shipping Manager
«address»
«city»«state»«zip»

Transportation rates and service are central to the competitiveness of businesses. Transportation is becoming expensive and delayed at times, and there is significant need for investment in highways, railroads, and waterways. Federal and state agencies are typically mandated to assess the costs and benefits of investments. These assessments require information on the ways you send or receive commodities and the options that you have.

The study is being conducted by the Social and Economic Sciences Research Center at Washington State University with support from the federal government. This survey is also being implemented with the knowledge and endorsement of Waterways Council, Inc.

Within the next few weeks, you may receive a telephone call from the Center. During this telephone call you will be asked to provide information on the transportation facilities in your firm, information about shipments that have been made or could have been made and information on shipping decisions and alternatives. If you prefer, you may complete the survey online at **www.opinion.wsu.edu/OhioRiver**. Your access code is: «RespID»

The telephone call should last no longer than about 20 minutes. Of course, all information will be held in the strictest confidence. The results will be used to provide a better understanding of transportation investments by the federal government.

We are centrally interested in transportation movements that could involve or are affected by the waterways and railways. Our assessment of your company suggests that the type of traffic you move and your location may involve these modes or could involve these modes, perhaps through a truck or rail connection. If you have any questions regarding this study, please call 1-800-833-0867 or email SESRCweb3@wsu.edu and mention the "Transportation Demand Study". Additionally, please use the enclosed postcard to update your contact information.

Thank you very much for helping with this study. Your input to this survey is essential!

Sincerely,

Kent Miller
Study Director

PS. This survey has been reviewed and approved by the Washington State University Institutional Review Board (IRB) for the protection of human subjects and the Office of Management and Budget (OMB control number 0710-0001). If you have any questions about your rights as a survey participant, please contact the IRB office at 509-335-3668 or irb@wsu.edu. (IRB# 9892)

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 1
Ohio River Navigation Investment Model (ORNIM) Version 5.1

Demand Curve Inputs
Addendum D

February 2011

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1B.1 INTRODUCTION

The market level demand functions discussed in ADDENDUM 1C (Ohio River System Willingness-to-Pay for Barge Transportation) cannot be directly input into ORNIM. ORNIM is hardwired with a constant elasticity function; however, to allow flexibility and the input of any functional form, the model also allows the input of the demand curve as piecewise-linear approximation. Since the Train-Wilson curves did not fit a constant elasticity form, the piecewise-linear input option was utilized.

Given that the Train-Wilson analysis only displayed results for a limited number of rate increases, to achieve an adequate level of granularity of the price-responsive demand curve, the Train-Wilson functions were executed in 0.5% rate increments resulting in 200 XY coordinates defining each price-responsive demand curve. The sections below describe the application of the Train-Wilson models to generate ORNIM price-responsive demand curve inputs.

The Train-Wilson analysis also produced a multitude of models (discussed in the next section), however, for input into the ORNIM used the stated preference mode choice model (with best alternative is rail or truck-rail) in combination with unconditional (expected) volume model.

1B.2 THE TRAIN-WILSON RESPONSE MODELS

The Train-Wilson response modeling included two distinct approaches: 1) choice modeling; and 2) volume modeling. For the choice model, three multinomial logit models were developed using: 1) revealed preference data; 2) stated preference data; and 3) an approach that combines the revealed and stated preference data. For the volume model, three stated preference two-limit tobit models (models 1, 2, and 3) were developed containing: 1) only the percentage change in the prompting variable (e.g., percentage change in rates); 2) the percentage change in the prompting variable and a commodity intercept dummy; and 3) the percentage change in the prompting variable using interactions of the commodity dummies. These three volume models were then further delineated by a model: 1) conditioned on observing a non-limit response to the prompt; and 2) unconditioned (i.e., allowing for a zero percentage response of volumes to changes in the attributes). As a result the Train-Wilson work resulted in nine response models, not counting the combination choice-volume models.

The parameters for the volume models were not only estimated for rate change, but also commodity price, transit time, and reliability change. The volume Model #2 (containing the percentage change in the prompting variable and a commodity intercept dummy) parameters were also estimated by commodity group. The volume Model #2 for rate change was further delineated by whether or not the rate change was also experienced by competitors. As a result the three volume models were used to produce thirty-two sets of model parameter estimates.

For the choice model the stated preference model resulted in "*… very strong econometric results, and the elasticities generated suggested a range of elasticities that depend on the level of the change in rates.*" [1] For the volume model, Model #2 (containing the percentage change in the prompting variable and a commodity intercept dummy) unconditioned estimated for rate change assuming the rate change was not experienced by the competitor was determined most appropriate for ORNIM input.

The choice and volume models were then combined to generate the price-responsive demand curves for each commodity group. As stated by Train-Wilson:

> *The two sets of results together are framed in terms of optimizing behavior of shippers. The choice model is very powerful in that it allows for the alternatives that are relevant to the shippers to be analyzed. The volume model is an easily cast question posed of the respondent to which they can readily respond and avoids the difficulties of specifying a complete equilibrium model of volumes that would otherwise be necessary to analyze demands. Together these two sets of*

[1] *Train, Kenneth, and Wilson, Wesley (2008). "The Demand for Transportation in the Ohio River Basin". Page 59. Re-printed in ADDENDUM 1C (Ohio River System Willingness-to-Pay for Barge Transportation)*

results provide information and can be fit directly into the Army Corps simulation models with little difficulty. Finally, theoretically, this approach can be shown to address many of the criticisms of the National Research Council. Nevertheless, this new approach and line of research continues to be refined, and our experience is that the data collection effort is central to this refinement.

The following sections document the execution of the Train-Wilson models to develop the ORNIM piecewise-linear price-responsive demand curves.

1B.2.1 The Train-Wilson Stated Preference Choice Model

As documented in ADDENDUM 1C (Ohio River System Willingness-to-Pay for Barge Transportation) the stated preference choice model takes the form of a trinary logit where the options are 1) their current option, 2) their best alternative mode, and 3) going out of business. The probability that the shipper will choose option *i*, *I* = 1, 2, or 3 is:

$$P_i = \frac{e^{\beta x_i}}{e^{\beta x_1} + e^{\beta x_2} + e^{\beta x_3}} \qquad (1B.2\text{-}1)$$

The coefficients used to run this model are shown in TABLE 1B.2.1 and were developed off the survey data. This model with the given coefficients result in percentages in TABLE 1B.2.2 and graphed in FIGURE 1B.2.1. These results are identical to the results show in Table 2.3 of Train and Wilson (2008). These calculations were then exercised in 0.5% rate increments (-----------------------).

TABLE 1B.2.1 – Stated Preference Choice Model Estimated Coefficients

Explanatory Variable (alt that variable enters given in ( ); 0 in other alternatives)	**Estimated Coefficient**	**Standard Error**	**t-Statistic**
Log of % increase in rate for original option (1)	**-0.488**	0.082	5.98
Log of % decrease in rate for best alternative (2)	0.420	0.083	5.03
Log of % increase in time for original option (1)	-0.459	0.081	5.65
Log of % decrease in reliability for original option (1)	-0.466	0.080	5.88
Log of % decrease in dest price for original routing for shippers sending the commodity	-0.590	0.107	5.53
Log of % increase in dest price for original routing for shippers receiving the commodity	-0.582	0.092	6.33
Rail or rail-truck is alternative mode (2)	**0.392**	0.170	2.31
Alternative mode is not specified by respondent (2)	**-2.820**	0.422	6.69
Out-of-business constant (3)	**-2.783**	0.257	10.84
Current Option (1)	**2.601**	0.228	11.39
LL at convergence	-672.175		
Number of observations	1406		
Number of Respondents	351		

SOURCE: The Demand for Transportation in the Ohio River Basin, Train and Wilson (August 2008),Table 2.2

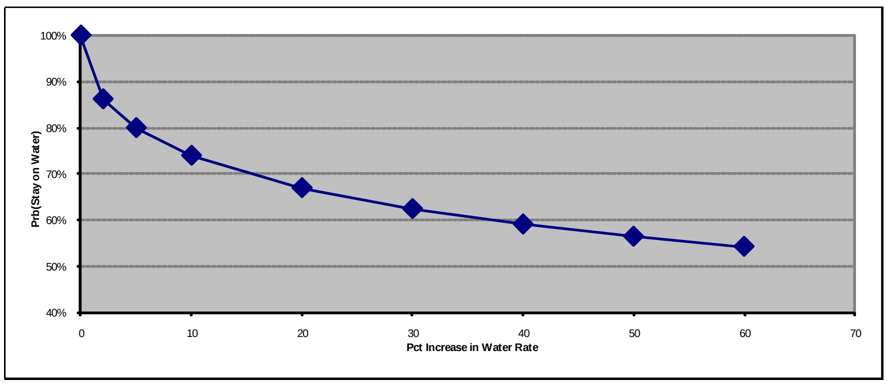
TABLE 1B.2.2 – Stated Preference Choice Model Results

Percent of Shippers Forecasted to Switch in Response to Rate Increases for their Current Mode and Destination: Best Alternative mode is rail or truck-rail

Percent Rate Increase Current Mode	Percent who Switch to best Alternative routing mode & destination	Percent who go out of Business	TOTAL Percent who Switch (sum)	Arc Elasticity
0.000001	0.01%	0.00%	0.01%	135.01
2	13.27%	0.55%	13.83%	0.07
5	19.25%	0.80%	20.06%	4.01
10	24.99%	1.04%	26.03%	2.60
20	31.72%	1.33%	33.05%	1.65
30	36.05%	1.51%	37.56%	1.25
40	39.26%	1.64%	40.91%	1.02
50	41.81%	1.75%	43.56%	0.87
60	43.92%	1.84%	45.76%	0.76

FIGURE 1B.2.1 – Stated Preference Choice Model Results, Total Percent Switch

RESULTING PERCENT OF TONNAGE THAT STAYS ON WATER
99.99%
86.17%
79.94%
73.97%
66.95%
62.44%
59.09%
56.44%
54.24%



1B.2.2 The Train-Wilson Stated Preference Volume Model

As previously noted, the rate change volume Model #2 (containing the percentage change in the prompting variable and a commodity intercept dummy) unconditioned (i.e., allowing for a zero percentage response of volumes to changes in the attributes) assuming the rate change was not experienced by the competitor was utilized. The stated preference EXPECTED volume model is:

$$E(y_i)=0*\Phi_{1i}+\beta^T x_i(\Phi_{2i}-\Phi_{1i})+\sigma(\phi_{1i}-\phi_{2i})+(1-\Phi_{2i})*100 \qquad \text{(1B.2-2)}$$

where:

Φ_{1i} and Φ_{2i} represent the cummulative distribution functions evaluated at the lower and upper limits;

σ is the standard deviation of ε

ϕ_{1i} and ϕ_{2i} represent the standard normal density evaluated at the lower and upper limits.

The cumulative distribution and the density functions are defined in terms of a standard normal. The specifics are:

$$\Phi_{1i} = \Phi_{1i}(z_{1i}) = \Phi_{1i}((0 - b^T x_i)/s)$$
$$\Phi_{2i} = \Phi_{2i}(z_{2i}) = \Phi_{2i}((100 - b^T x_i)/s)$$
$$\phi_{1i} = \phi_{1i}(z_{1i}) = \phi_{1i}((0 - b^T x_i)/s)$$
$$\phi_{2i} = \phi_{2i}(z_{2i}) = \phi_{2i}((100 - b^T x_i)/s)$$

where b is an estimate of β and s is an estimate of σ.

The coefficients used to run this model are shown in TABLE 1B.2.3. Intermediate calculations were made as shown in TABLE 1B.2.4 through TABLE 1B.2.13. This model with the given coefficients result in percentages in TABLE 1B.2.14 which match the results shown in Table 3.4 of Train and Wilson (2008). These elasticities are converted to percent volume (TABLE 1B.2.15) and graphed in FIGURE 1B.2.2. Given this verification of the equation results, these calculations were then exercised in 0.5% rate increments (-----------------------).

TABLE 1B.2.3 – Stated Preference Expected Volume Model Estimated Coefficients

Tobit Estimates of Volume Responses to Changes in Rates that Apply to the Respondent but not its Competitors

Variable	Stated Preference Model
Percent Change in Rate	0.844
Standard Error of the Estimate *	40.587
Aggregates	-32.142
Chemicals	-16.195
Coal	-37.664
Iron & Steel	-28.314
Ores & Minerals	-26.82
Other	-22.859
Petroleum	-10.319
% Change x Aggregates	na
% Change x Chemicals	na
% Change x Coal	na
% Change x Iron & Steel	na
% Change x Ores & Minerals	na
% Change x Other	na
% Change x Petroleum	na
Constant	-0.26

\

SOURCE: The Demand for Transportation in the Ohio River Basin, Train and Wilson (August 2008),Table 3.3
** Provided 6 Oct. 2008 by Wilson.*

TABLE 1B.2.4 – Commodity Specific TOBIT Model Estimates

TOBIT Estimate	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
Percent Change in Rate	0.844	0.844	0.844	0.844	0.844	0.844	0.844	0.844
Commodit Intercept	-0.26	-32.402	-16.455	-37.924	-28.574	-27.08	-23.119	-10.579
Standard Error of the Est. (se)	40.587	40.587	40.587	40.587	40.587	40.587	40.587	40.587

TABLE 1B.2.5 – Calculation of x beta hats

Percent Change in Rate	x beta hats *the interrcept + (% change in rate model estimate x % change in rate)*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	1.42800	-30.71400	-14.76700	-36.23600	-26.88600	-25.39200	-21.43100	-8.89100
5	3.96000	-28.18200	-12.23500	-33.70400	-24.35400	-22.86000	-18.89900	-6.35900
10	8.18000	-23.96200	-8.01500	-29.48400	-20.13400	-18.64000	-14.67900	-2.13900
20	16.62000	-15.52200	0.42500	-21.04400	-11.69400	-10.20000	-6.23900	6.30100
30	25.06000	-7.08200	8.86500	-12.60400	-3.25400	-1.76000	2.20100	14.74100
40	33.50000	1.35800	17.30500	-4.16400	5.18600	6.68000	10.64100	23.18100
50	41.94000	9.79800	25.74500	4.27600	13.62600	15.12000	19.08100	31.62100
60	50.38000	18.23800	34.18500	12.71600	22.06600	23.56000	27.52100	40.06100

TABLE 1B.2.6 – Calculation of the Standard Normal of the Upper Limit (ZU)

Percent Change in Rate	ZU = standard normal of the Upper Limit (i.e 100%, you can only ...) *(100 - x beta hat) / se*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	2.42866	3.22059	2.82768	3.35664	3.12627	3.08946	2.99187	2.68290
5	2.36627	3.15820	2.76529	3.29426	3.06389	3.02708	2.92948	2.62052
10	2.26230	3.05423	2.66132	3.19028	2.95991	2.92310	2.82551	2.51654
20	2.05435	2.84628	2.45337	2.98233	2.75196	2.71516	2.61756	2.30860
30	1.84640	2.63833	2.24542	2.77439	2.54402	2.50721	2.40961	2.10065
40	1.63846	2.43038	2.03748	2.56644	2.33607	2.29926	2.20167	1.89270
50	1.43051	2.22244	1.82953	2.35849	2.12812	2.09131	1.99372	1.68475
60	1.22256	2.01449	1.62158	2.15054	1.92017	1.88336	1.78577	1.47680

TABLE 1B.2.7 – Calculation of Upper Limit Probability - Prob(ZU)

Percent Change in Rate	Prob(ZU) *NORMSDIST(ZU)*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	0.99242	0.99936	0.99766	0.99961	0.99911	0.99900	0.99861	0.99635
5	0.99102	0.99921	0.99716	0.99951	0.99891	0.99877	0.99830	0.99561
10	0.98816	0.99887	0.99611	0.99929	0.99846	0.99827	0.99764	0.99407
20	0.98003	0.99779	0.99292	0.99857	0.99704	0.99669	0.99557	0.98952
30	0.96758	0.99583	0.98763	0.99723	0.99452	0.99392	0.99202	0.98216
40	0.94934	0.99246	0.97920	0.99486	0.99026	0.98925	0.98616	0.97080
50	0.92371	0.98687	0.96634	0.99083	0.98334	0.98175	0.97691	0.95398
60	0.88925	0.97802	0.94755	0.98424	0.97258	0.97017	0.96293	0.93014

TABLE 1B.2.8 – Calculation of Upper Limit Density - Density(ZU)

Percent Change in Rate	Density (ZU) *NORMDIST(ZU,0,1,FALSE)*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	0.02090	0.00223	0.00732	0.00143	0.00301	0.00338	0.00454	0.01091
5	0.02427	0.00272	0.00872	0.00176	0.00365	0.00408	0.00546	0.01287
10	0.03087	0.00376	0.01156	0.00246	0.00499	0.00557	0.00737	0.01682
20	0.04836	0.00695	0.01967	0.00467	0.00904	0.01000	0.01297	0.02777
30	0.07255	0.01229	0.03207	0.00850	0.01569	0.01721	0.02188	0.04392
40	0.10422	0.02081	0.05006	0.01481	0.02605	0.02838	0.03534	0.06653
50	0.14340	0.03376	0.07483	0.02472	0.04145	0.04479	0.05467	0.09651
60	0.18895	0.05244	0.10713	0.03950	0.06314	0.06771	0.08099	0.13407

TABLE 1B.2.9 – Calculation of Lower Limit (ZL)

Percent Change in Rate	ZL = Lower Limit *- x beta hat / se*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	-0.03518	0.75674	0.36384	0.89280	0.66243	0.62562	0.52803	0.21906
5	-0.09757	0.69436	0.30145	0.83041	0.60004	0.56323	0.46564	0.15668
10	-0.20154	0.59039	0.19748	0.72644	0.49607	0.45926	0.36167	0.05270
20	-0.40949	0.38244	-0.01047	0.51849	0.28812	0.25131	0.15372	-0.15525
30	-0.61744	0.17449	-0.21842	0.31054	0.08017	0.04336	-0.05423	-0.36320
40	-0.82539	-0.03346	-0.42637	0.10259	-0.12777	-0.16458	-0.26218	-0.57114
50	-1.03334	-0.24141	-0.63432	-0.10535	-0.33572	-0.37253	-0.47013	-0.77909
60	-1.24128	-0.44936	-0.84226	-0.31330	-0.54367	-0.58048	-0.67807	-0.98704

TABLE 1B.2.10 – Calculation of Lower Limit Probability - Prob(ZL)

Percent Change in Rate	Prob(ZL) *NORMSDIST(ZL)*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	0.48597	0.77540	0.64201	0.81402	0.74615	0.73422	0.70126	0.58670
5	0.46114	0.75627	0.61846	0.79685	0.72576	0.71336	0.67926	0.56225
10	0.42014	0.72253	0.57827	0.76622	0.69008	0.67698	0.64120	0.52102
20	0.34109	0.64893	0.49582	0.69794	0.61337	0.59921	0.56108	0.43831
30	0.26847	0.56926	0.41355	0.62193	0.53195	0.51729	0.47838	0.35823
40	0.20458	0.48665	0.33492	0.54086	0.44916	0.43464	0.39659	0.28395
50	0.15072	0.40462	0.26294	0.45805	0.36854	0.35475	0.31913	0.21796
60	0.10725	0.32659	0.19982	0.37703	0.29333	0.28080	0.24886	0.16181

TABLE 1B.2.11 – Calculation of Lower Limit Density - Density(ZL)

Percent Change in Rate	Density (ZL) *NORMDIST(ZL,0,1,FALSE)*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	0.39870	0.29961	0.37339	0.26781	0.32035	0.32803	0.34703	0.38948
5	0.39705	0.31348	0.38122	0.28260	0.33322	0.34043	0.35795	0.39408
10	0.39092	0.33514	0.39124	0.30642	0.35276	0.35901	0.37369	0.39839
20	0.36686	0.37081	0.39892	0.34877	0.38272	0.38654	0.39426	0.39416
30	0.32971	0.39292	0.38954	0.38016	0.39766	0.39857	0.39836	0.37348
40	0.28378	0.39872	0.36428	0.39685	0.39570	0.39358	0.38546	0.33890
50	0.23391	0.38749	0.32624	0.39673	0.37708	0.37220	0.35720	0.29451
60	0.18464	0.36063	0.27981	0.37984	0.34413	0.33709	0.31701	0.24511

TABLE 1B.2.12 – Percent Change in Volume

Percent Change in Rate	Percent Change in Volume - EXPECTED *[x beta hat x (Prob(ZU)-Prob(ZL))] + [se x (Density (ZL) - Density (ZU))] + [100 x (1-Prob(ZU))]*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	16.81465	5.25495	9.84027	4.12612	6.16718	6.55390	7.66663	12.08783
5	18.12671	5.84586	10.76986	4.61745	6.83307	7.25028	8.44685	13.15505
10	20.44375	6.94077	12.45027	5.53600	8.05943	8.52977	9.87161	15.06758
20	25.54321	9.57433	16.31136	7.78234	10.97608	11.55958	13.20712	19.39219
30	31.19877	12.84419	20.83492	10.63075	14.54597	15.24755	17.20892	24.35666
40	37.30327	16.77922	25.98272	14.12893	18.78323	19.60174	21.86828	29.89655
50	43.72122	21.37436	31.67913	18.29461	23.66606	24.59372	27.13902	35.91194
60	50.29717	26.58718	37.81445	23.11003	29.13492	30.15734	32.93795	42.27300

TABLE 1B.2.13 – Volume Change Arc Elasticity
Percent Change in Volume / Percent Change in Rate

Percent Change in Rate	Volume Change Arc Elasticity - EXPECTED *(these go into TABLE 3.4 of the report)* *Percent Change in Volume / Percent Change in Rate*							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	8.4073	2.6275	4.9201	2.0631	3.0836	3.2769	3.8333	6.0439
5	3.6253	1.1692	2.1540	0.9235	1.3666	1.4501	1.6894	2.6310
10	2.0444	0.6941	1.2450	0.5536	0.8059	0.8530	0.9872	1.5068
20	1.2772	0.4787	0.8156	0.3891	0.5488	0.5780	0.6604	0.9696
30	1.0400	0.4281	0.6945	0.3544	0.4849	0.5083	0.5736	0.8119
40	0.9326	0.4195	0.6496	0.3532	0.4696	0.4900	0.5467	0.7474
50	0.8744	0.4275	0.6336	0.3659	0.4733	0.4919	0.5428	0.7182
60	0.8383	0.4431	0.6302	0.3852	0.4856	0.5026	0.5490	0.7046

TABLE 1B.2.14 – Stated Preference Volume Model Results - Elasticities
Probabilities of Adjustment and Volume Elasticities for Rate Changes that Apply to the Respondent but not its Competitors

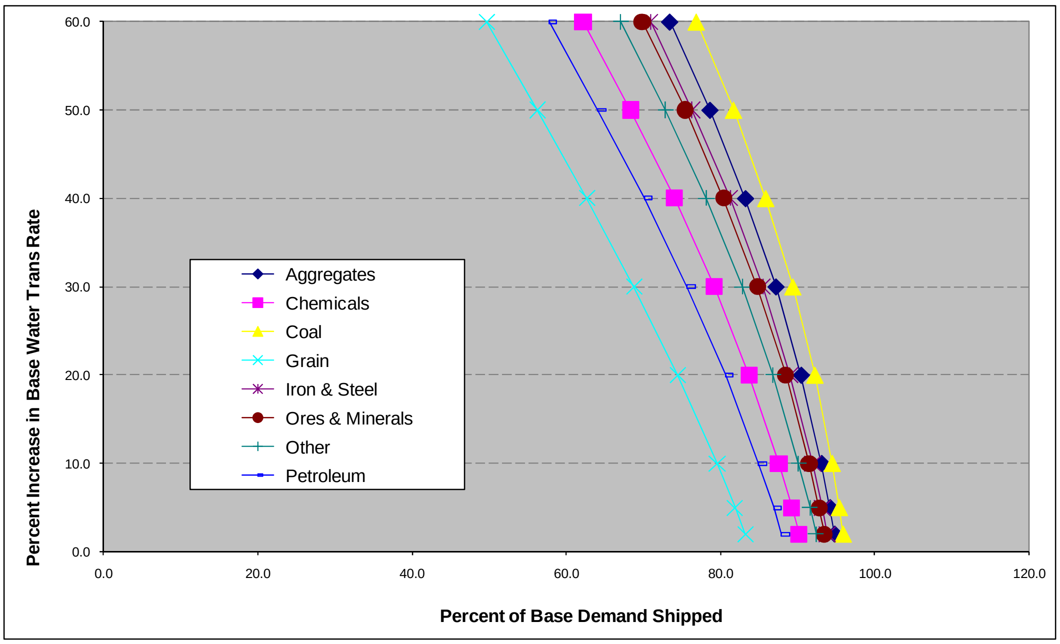
% Change	Commodity	Prob of Adjustment	Expected Elasticity
2	Aggregates	0.22	2.63
5	Aggregates	0.24	1.17
10	Aggregates	0.28	0.69
20	Aggregates	0.35	0.48
30	Aggregates	0.43	0.43
40	Aggregates	0.51	0.42
50	Aggregates	0.58	0.43
60	Aggregates	0.65	0.44
2	Chemicals	0.36	4.92
5	Chemicals	0.38	2.15
10	Chemicals	0.42	1.25
20	Chemicals	0.50	0.82
30	Chemicals	0.57	0.69
40	Chemicals	0.64	0.65
50	Chemicals	0.70	0.63
60	Chemicals	0.75	0.63
2	Coal	0.19	2.06
5	Coal	0.20	0.92
10	Coal	0.23	0.55
20	Coal	0.30	0.39
30	Coal	0.38	0.35
40	Coal	0.45	0.35
50	Coal	0.53	0.37
60	Coal	0.61	0.39
2	Grain	0.51	8.41
5	Grain	0.53	3.63
10	Grain	0.57	2.04
20	Grain	0.64	1.28
30	Grain	0.70	1.04
40	Grain	0.74	0.93
50	Grain	0.77	0.87
60	Grain	0.78	0.84

% Change	Commodity	Prob of Adjustment	Expected Elasticity
2	Iron & Steel	0.25	3.08
5	Iron & Steel	0.27	1.37
10	Iron & Steel	0.31	0.81
20	Iron & Steel	0.38	0.55
30	Iron & Steel	0.46	0.48
40	Iron & Steel	0.54	0.47
50	Iron & Steel	0.61	0.47
60	Iron & Steel	0.68	0.49
2	Ores & Minerals	0.26	3.28
5	Ores & Minerals	0.29	1.45
10	Ores & Minerals	0.32	0.85
20	Ores & Minerals	0.40	0.58
30	Ores & Minerals	0.48	0.51
40	Ores & Minerals	0.55	0.49
50	Ores & Minerals	0.63	0.49
60	Ores & Minerals	0.69	0.50
2	Other	0.30	3.83
5	Other	0.32	1.69
10	Other	0.36	0.99
20	Other	0.43	0.66
30	Other	0.51	0.57
40	Other	0.59	0.55
50	Other	0.66	0.54
60	Other	0.71	0.55
2	Petroleum	0.41	6.04
5	Petroleum	0.43	2.63
10	Petroleum	0.47	1.51
20	Petroleum	0.55	0.97
30	Petroleum	0.62	0.81
40	Petroleum	0.69	0.75
50	Petroleum	0.74	0.72
60	Petroleum	0.77	0.70

TABLE 1B.2.15 – Stated Preference Volume Model Results – Percent Volume Probabilities of Adjustment and Volume Elasticities for Rate Changes that Apply to the Respondent but not its Competitors

% Change	Commodity	Volume Percent	% Change	Commodity	Volume Percent	% Change	Commodity	Volume Percent	% Change	Commodity	Volume Percent
2	Aggregates	94.75	2	Iron & Steel	93.83	2	Chemicals	90.16	2	Ores & Minerals	93.45
5	Aggregates	94.15	5	Iron & Steel	93.17	5	Chemicals	89.23	5	Ores & Minerals	92.75
10	Aggregates	93.06	10	Iron & Steel	91.94	10	Chemicals	87.55	10	Ores & Minerals	91.47
20	Aggregates	90.43	20	Iron & Steel	89.02	20	Chemicals	83.69	20	Ores & Minerals	88.44
30	Aggregates	87.16	30	Iron & Steel	85.45	30	Chemicals	79.17	30	Ores & Minerals	84.75
40	Aggregates	83.22	40	Iron & Steel	81.22	40	Chemicals	74.02	40	Ores & Minerals	80.40
50	Aggregates	78.63	50	Iron & Steel	76.33	50	Chemicals	68.32	50	Ores & Minerals	75.41
60	Aggregates	73.41	60	Iron & Steel	70.87	60	Chemicals	62.19	60	Ores & Minerals	69.84
2	Coal	95.87	2	Other	92.33	2	Grain	83.19	2	Petroleum	87.91
5	Coal	95.38	5	Other	91.55	5	Grain	81.87	5	Petroleum	86.84
10	Coal	94.46	10	Other	90.13	10	Grain	79.56	10	Petroleum	84.93
20	Coal	92.22	20	Other	86.79	20	Grain	74.46	20	Petroleum	80.61
30	Coal	89.37	30	Other	82.79	30	Grain	68.80	30	Petroleum	75.64
40	Coal	85.87	40	Other	78.13	40	Grain	62.70	40	Petroleum	70.10
50	Coal	81.71	50	Other	72.86	50	Grain	56.28	50	Petroleum	64.09
60	Coal	76.89	60	Other	67.06	60	Grain	49.70	60	Petroleum	57.73

FIGURE 1B.2.2 – Volume Demand Curve



1B.2.3 Choice and EXPECTED Volume Response

The choice and volume models discussed above were then combined to generate the price-responsive demand curves for each commodity group. The choice model percentages and each commodity volume percentage () were multiplied to obtain the .

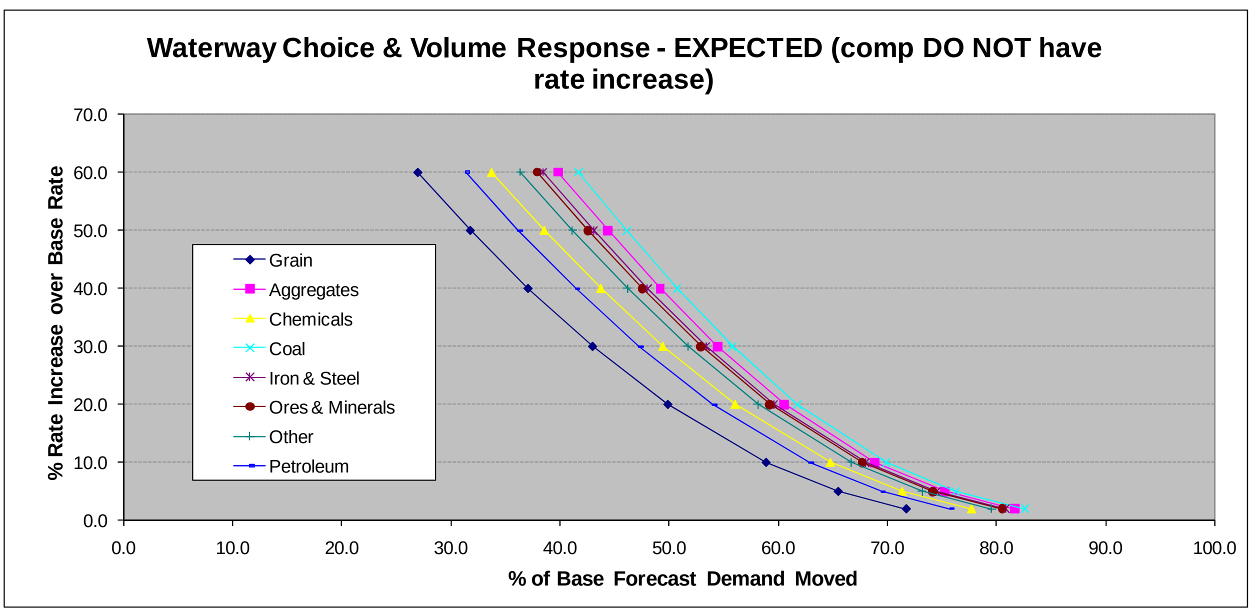
TABLE 1B.2.16 – Choice and Volume Response Percentages

Percent Increase in Water Rate	Choice Response / Probability Keep Mode Route (Stay)	Volume Response / Probability Keep Volume							
		Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	0.86174	83.18535	94.74505	90.15973	95.87388	93.83282	93.44610	92.33337	87.91217
5	0.79942	81.87329	94.15414	89.23014	95.38255	93.16693	92.74972	91.55315	86.84495
10	0.73970	79.55625	93.05923	87.54973	94.46400	91.94057	91.47023	90.12839	84.93242
20	0.66955	74.45679	90.42567	83.68864	92.21766	89.02392	88.44042	86.79288	80.60781
30	0.62440	68.80123	87.15581	79.16508	89.36925	85.45403	84.75245	82.79108	75.64334
40	0.59095	62.69673	83.22078	74.01728	85.87107	81.21677	80.39826	78.13172	70.10345
50	0.56439	56.27878	78.62564	68.32087	81.70539	76.33394	75.40628	72.86098	64.08806
60	0.54240	49.70283	73.41282	62.18555	76.88997	70.86508	69.84266	67.06205	57.72700

TABLE 1B.2.17 – Choice and Volume Response by Commodity Group

Percent Increase in Water Rate	Weight Together Choice & volume Responses							
	Grain	Agg-regates	Chem-icals	Coal	Iron & Steel	Ores & Minerals	Other	Petrol-eum
2	71.68397	81.64540	77.69405	82.61815	80.85930	80.52605	79.56716	75.75725
5	65.45084	75.26835	71.33202	76.25036	74.47916	74.14564	73.18908	69.42526
10	58.84752	68.83563	64.76027	69.87473	68.00816	67.66025	66.66770	62.82425
20	49.85234	60.54427	56.03350	61.74409	59.60573	59.21505	58.11194	53.97074
30	42.95957	54.42019	49.43077	55.80226	53.35760	52.91953	51.69485	47.23179
40	37.05046	49.17909	43.74031	50.74527	47.99483	47.51113	46.17172	41.42744
50	31.76305	44.37534	38.55945	46.11351	43.08193	42.55837	41.12183	36.17051
60	26.95891	39.81924	33.72955	41.70526	38.43734	37.88278	36.37458	31.31123

FIGURE 1B.2.3 – Choice and Volume Response by Commodity Group



1B.3 DEVELOPMENT OF THE COMMODITY DEMAND CURVES

ORNIM's piecewise-linear approximation functional form allows a user to estimate any reasonable demand curve to whatever accuracy is appropriate by specifying a series of points defining the form of the curve. The points represent percentages of the forecast demand and the base price. This format allows the user to be in complete control of the demand function, however, it is incumbent upon the user to specify a curve that has a reasonable shape to allow the system to come to equilibrium. At a minimum, the curve should be decreasing in price as the quantity increases.

If the points input into ORNIM only define the demand function for part of the necessary range, the function is extended to intersect the vertical axis using the slope of the first segment. The function can also be extended toward the right using the slope of the last segment. The percentage form of the demand function is instantiated each year to form the annual demand function by specifying the forecast and base cost as the (100%, 100%) point. The rest of the curve is then defined relative to the forecast

Given the Train and Wilson (2008) calculations discussed in the sections above, the equations were executed in 0.5% rate increments resulting in 200 XY coordinates defining each price-responsive demand curve for each commodity.

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 1 Addendum E
Ohio River Navigation Investment Model

CALCULATION OF TRANSPORTATION SURPLUS

February 2011

Table of Contents

List of Attachment 1 Addendums

1E.1 INTRODUCTION

The initial implementation of elasticity in ORNIM assumes that movements are of two types—fixed demand (totally inelastic for rates less than an alternative rate) or elastic with a fixed elasticity for all rates. This note provides a summary of the mathematical calculations for calculating the transportation surplus (aka consumer surplus) under the elastic assumption and provides an initial discussion of a method to estimate an elasticity which makes the transportation surplus calculation for the elastic and inelastic versions of a movement equivalent in the base year.

Under the constant elasticity assumption, a movement's demand function is of the form:

$$Q = \alpha P^{\varepsilon} \tag{1E.1}$$

where Q is the quantity moved on the waterway (Tons) , P is the waterway rate ($/Ton) ε is the elasticity (assumed to be negative with absolute value greater than 1), and α is a scalar determined by the forecast and base water rate for the movement. If Q* is the forecast tonnage in the base year and P* is the base water rate (also assumed to be in the base year), then:

$$\alpha = \frac{Q^*}{P^*} \tag{1E.2}$$

It is often useful to write the demand function in terms of price for a given quantity:

$$P = \left(\frac{Q}{\alpha}\right)^{\frac{1}{\varepsilon}} \tag{1E.3}$$

1E.2 CALCULATING TRANSPORTATION SURPLUS

In the case of a movement with elastic demand, the transportation surplus is calculated by the difference between the demand curve price and the final price, P*, integrated from 0 to the final quantity, Q*.

$$CS_{Q^*} = \int_0^{Q^*} \left[P - P^*\right] dQ = \int_0^{Q^*} \left[\left(\frac{Q}{\alpha}\right)^{\frac{1}{\varepsilon}} - \left(P^*\right)\right] dQ \tag{2E.1}$$

If $\varepsilon \neq -1$ this integral can be solved[1] as:

$$CS_{(P^*,Q^*)} = \left[\tfrac{\varepsilon}{\varepsilon+1}\left(\tfrac{1}{\alpha}\right)^{\frac{1}{\varepsilon}} Q^{\frac{1}{\varepsilon}+1} - \left(P^*\right) Q\right]_0^{Q^*} \tag{2E.2}$$

Evaluating at the upper and lower limits gives us

$$CS_{(P^*,Q^*)} = \left[\tfrac{\varepsilon}{\varepsilon+1}\left(\tfrac{1}{\alpha}\right)^{\frac{1}{\varepsilon}} \left(Q^*\right)^{\frac{1}{\varepsilon}+1} - \left(P^*\right) Q^*\right] - \lim_{Q \to 0}\left[\tfrac{\varepsilon}{\varepsilon+1}\left(\tfrac{1}{\alpha}\right)^{\frac{1}{\varepsilon}} \left(Q\right)^{\frac{1}{\varepsilon}+1} - \left(P^*\right) Q\right] \tag{2E.3}$$

[1] The integration uses the standard power rule $\int x^n dx = \frac{1}{n+1} x^{n+1}$ which is valid if n is not -1.

If ε < -1 then the exponent $\frac{1}{\varepsilon}+1$ in the limit term is positive and the limit is zero. If $-1<\varepsilon<0$ then the exponent is negative and the limit is infinite (the CS is unbounded). If $\varepsilon=-1$ the integral becomes:

$$\left(\tfrac{1}{\alpha}\right)^{\frac{1}{\varepsilon}}\left[\ln Q-\left(Q^*\right)^{\frac{1}{\varepsilon}}Q\right]_0^{Q^*} \tag{2E.4}$$

And the integral is unbounded because $\lim_{Q\to 0}\left(\ln Q\right)=-\infty$

Thus, if we assume ε < -1,

$$CS_{(P^*,Q^*)}=\left[\tfrac{\varepsilon}{\varepsilon+1}\left(\tfrac{1}{\alpha}\right)^{\frac{1}{\varepsilon}}\left(Q^*\right)^{\frac{1}{\varepsilon}+1}-P^*Q^*\right] \tag{2E.5}$$

This formula allows us to calculate the transportation surplus even if we are not at equilibrium as long as all of the movement is moving at the same rate, P*.

If we are at an equilibrium point on the demand curve, we can substitute $Q^*=\alpha\left(P^*\right)^{\varepsilon}$ to get:

$$\mathrm{CS}_{(P^*,Q^*)}=\tfrac{-\alpha}{\varepsilon+1}\left(P^*\right)^{\varepsilon+1} \tag{2E.6}$$

1E.3 SURPLUS, TOTAL COST, AND ALTERNATIVE RATE

The total cost of the movement is P^*Q^*. Assuming the solution is at a point on the demand curve, we can substitute for Q^* to get :

$$\text{TotalCost}=P^*Q^*=\alpha\left(P^*\right)^{\varepsilon+1} \tag{3E.1}$$

Thus,

$$\mathrm{CS}_{\text{elastic}}=\left(\tfrac{-1}{\varepsilon+1}\right)P^*Q^*=\left(\tfrac{-1}{\varepsilon+1}\right)\text{TotalCost} \tag{3E.2}$$

In the case of fixed demand (inelastic) movements, the transportation surplus is calculated as the difference between the alternative rate and the equilibrium price times the quantity.

$$\mathrm{CS}_{\text{fixed}}=\left(\text{Alt-P}^*\right)Q^* \tag{3E.3}$$

It is interesting to ask, "Given an alternative rate and an equilibrium point, what elasticity value would give the same transportation surplus under the elastic calculation as the transportation surplus under the fixed calculation?" By setting equation (3D.2) equal to equation (3D.3), we get

$$\left(\tfrac{-1}{\varepsilon+1}\right)P^{*}Q^{*}=\left(\text{Alt-P}^{*}\right)Q^{*} \quad \textit{which is equivalent to} \quad \frac{-1}{\varepsilon}=\frac{\left(\text{Alt-P}^{*}\right)}{\text{Alt}} \qquad (3E.4)$$

The right hand side of this equation can be seen as the waterway savings as a proportion of the alternative rate—in a sense, the markup for the alternative.

This relationship provides a means to set the elasticity of a movement based on the alternative rate and the base rate if we are seeking to equate the two ways of calculating transportation surplus in the base year.

For instance, if P* and Q* represent the base year rate and quantity, then given this value for elasticity (assuming the alternative rate is greater than the base rate) the transportation surplus will be the same in the base year whether the movement is treated as elastic or inelastic. This provides a potential starting point for testing and analysis. Note that if the base rate and the alternative rate are close in value, then the elasticity could be extremely large in absolute value; if there is a large difference then the elasticity value would be closer to (but never reaching) -1. If the alternative rate is less than the base rate the calculation is not valid.

This value, the negative reciprocal of the elasticity, is also known as the Lerner Index, a measure of power in a monopolistic market. If the market is assumed to be a monopolistic market with the derived elasticity, and the base price is assumed to be the marginal cost, then the alternative price is the profit-maximizing price for a monopoly. Thus, it seems that this might be interpreted as an assumption that the alternative is acting as a monopoly setting an optimal price, and then we are deriving the elasticity to match that price-setting behavior. (*While Lerner Index is standard in many economic texts and online resources [see http://faculty.insead.edu/vanzandt/teaching/FPM-Aug2006.pdf for instance] I have yet to find the interpretation of the equivalence of these two consumer surplus areas related to the Lerner Index in the literature.--Hilliard*)

Upper Ohio Navigation Study Pennsylvania
Draft Feasibility Report

Appendix B - Project Economics

Attachment 2

LOCK CAPACITY ANALYSIS

Upper Ohio Feasibility Study
Capacity Attachment

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EXECUTIVE SUMMARY

The Lock Capacity Curves presented herein represent a comprehensive update from the Ohio River Main Stem System Study (ORMSS) System Investment Plan (SIP) completed in 2003 of the three Upper Ohio River locks at Emsworth, Dashields, and Montgomery. New capacity curves were prepared for these three locks for the future fleet scenarios. Tonnage-Transit Time (Lock Capacity) curves were developed using the Waterway Analysis Model, a discrete event computer simulation model that determines the impact of tow movements on the inland waterway system. The model defines and represents the waterway network, the vessels that move on it and the cargo that is carried. WAM was developed as part of the U. S. Army Corps of Engineers Inland Navigation Systems Analysis Program (INSA) for the Office of the Chief of Engineers by CACI, Inc. WAM was written in the mid 1970’s and has been continually modified and improved since the early 1980’s. WAM has been used in navigation studies on the Ohio River and its tributaries for the last 20 years. Although WAM was developed with the ability to model a system of locks, it was used as a single lock simulator for this study.

A capacity curve defines the relationship between project throughput and transit time. Throughput is measured as annual tons served, and transit time includes the time the vessel is “delayed” and the time needed to “process” the vessel through the lock. Tow arrives at a lock & either “waits” (facility is busy) or is “processed” (moves tonnage) through a lock chamber. Delay occurs when a vessel arrives at a lock and cannot be served immediately. During chamber downtimes, vessels must either use another chamber or wait until the downtime ends - causing increased processing times and high delays at the lock projects.

In 2005, more than 4,000 tows, 25,000 barges, and 20Mtons transited each of these projects. Tows consisting of towboats, pushing barges of various types and sizes with an average tow size of 6.0 barges per tow. All three projects, Emsworth, Dashields, and Montgomery, are dual chamber projects, consisting of one 600’ main landward chamber and one 360’ auxiliary riverward chamber. During lock chamber shutdowns, usually due to scheduled maintenance and repairs, tows must utilize the smaller auxiliary chamber to lock commercial traffic, resulting in multi-cut lockages, with increased processing and delay times. Lock capacity curves are used to estimate these increase in transit times, processing and delay times, due to long closure events at various traffic levels.

Lock Capacity curves were determined for both the Existing Condition and the With Project Condition for the future fleet scenario only. The future fleet was developed based on the “*Probable Size Of Future Barge Fleet At Emsworth, Dashields And Montgomery Locks*”, Linare Consulting, dated 20 August 2008. The future fleet represents the changes in barge types and sizes that are expected to occur in the year 2028 due to the replacement of the regular, shorter (175’ x 26’) barges, and narrower, stumbos (195’ x 26’) with the longer and wider ,jumbo (195’ x 35’) barges. **Table A2-1** displays the capacity for the Existing Condition at EDM using the future fleet for the full operation, main chamber, and auxiliary chambers. The full operation refers to both the main and auxiliary chambers operating together at full capacity with only random minor downtime events occurring. It should be noted that the full operation capacity is not equal to, but rather slightly lower than, the sum of the main and auxiliary chamber capacities because at dual chamber projects there is interference. Also, the auxiliary chamber does not have sufficient capacity to serve current traffic demands at any of the three projects.

TABLE A2- 1
EDM Without Project Capacities
(Mtons)

Lock	Full Operation	Main Chamber	Auxiliary Chamber
Emsworth	48.7	42.9	11.1
Dashields	51.5	48.1	14.3
Montgomery	50.3	43.2	11.5

In addition to the Existing Condition, nine With Project Condition alternatives were analyzed for each of the three lock projects, using the larger “future” fleet. 1) A new 600’main chamber and the existing 600’ chamber as the auxiliary 2) A new 800’ main chamber and the existing 600’ chamber as the auxiliary 3) A new 1200’ main chamber and the existing 600’ chamber as the auxiliary 4) Twin new 600’ chambers to replace the existing 600’ and 360’ chambers 5) A new 800’ chamber and a new 600’ chamber to replace the existing 600’ and 360’ chambers. 6) A new 1200’ chamber and a new 600’ chamber to replace the existing 600’ and 360’ chambers. 7) A new 600’ single chamber 8) A new 800’ single chamber and 9) A new 1200’ single chamber. **Tables A2-2** through **A2-4** displays the capacities for the nine With Project Condition alternatives at EDM for the full operation, main chamber, and auxiliary chambers. For all the Upper Ohio locks, the With Project capacities are the lowest for the smallest single chamber lock option, or the 600’, and are the highest for the dual chamber alternative with the newer and larger lock sizes, or the new 1200’ main with the new 600’ auxiliary. That is, for all projects, the lock’s capacity will tend to increase with larger lock sizes, improved lock operating conditions, and multi-chamber projects, resulting from reduced processing and delay times.

TABLE A2- 2
Emsworth With-Project Capacities (Mtons)

Lock	Full Operation	Main Chamber	Auxiliary Chamber
Emsworth New 600' Single Project	47.9	47.9	0.0
Emsworth New 800' Single Project	57.2	57.2	0.0
Emsworth New 1200' Single Project	77.3	77.3	0.0
Emsworth New 600' New 600'	91.5	47.9	47.9
Emsworth New 800' New 600'	100.8	57.2	47.9
Emsworth New 1200' New 600'	122.9	77.3	47.9
Emsworth New 600' Old 600'	77.8	43.1	42.9
Emsworth New 800' Old 600'	100.0	59.4	42.9
Emsworth New 1200' Old 600'	121.0	77.5	42.9

TABLE A2- 3
Dashields With-Project Capacities (Mtons)

Lock	Full Operation	Main Chamber	Auxiliary Chamber
Dashields New 600' Single Project	49.6	49.6	0.0
Dashields New 800' Single Project	59.3	59.3	0.0
Dashields New 1200' Single Project	79.6	79.6	0.0
Dashields New 600' New 600'	91.6	49.6	49.6
Dashields New 800' New 600'	103.4	59.3	49.6
Dashields New 1200' New 600'	132.0	79.6	49.6
Dashields New 600' Old 600'	90.7	49.6	48.1
Dashields New 800' Old 600'	102.2	59.3	48.1
Dashields New 1200' Old 600'	130.7	79.6	48.1

TABLE A2- 4
Montgomery With-Project Capacities (Mtons)

Lock	Full Operation	Main Chamber	Auxiliary Chamber
Montgomery New 600' Single Project	43.6	43.6	0.0
Montgomery New 800' Single Project	55.8	55.8	0.0
Montgomery New 1200' Single Project	70.9	70.9	0.0
Montgomery New 600' New 600'	80.8	43.6	43.6
Montgomery New 800' New 600'	99.1	55.8	43.6
Montgomery New 1200' New 600'	117.4	70.9	43.6
Montgomery New 600' Old 600'	79.8	43.7	43.2
Montgomery New 800' Old 600'	97.9	55.8	43.2
Montgomery New 1200' Old 600'	116	70.9	43.2

ATTACHMENT 2. LOCK CAPACITY ANALYSIS

2.1 INTRODUCTION

This attachment describes the methodologies, assumptions, data sources, and the results attained in developing the Tonnage-Transit time (Lock Capacity) curves used for this Upper Ohio Feasibility Study. The analysis was performed between November 2007 and March 2010. The lock capacity curves were developed from two main sources of lock data, Lock Performance Monitoring System (LPMS)[1], standardized lockage and vessel timing data, and Waterborne Commerce Statistics Center (WCSC), origin to destination commodity flow data. Many types of input data are needed to develop capacity curves, fleet size and loadings, chamber processing times, random minor downtimes, etc. all have an effect on the shape of the curve, and the ultimate capacity. Although the target base year was 2005, twelve years of data (1985-2006) were made available for the purpose of this capacity analysis effort.

The Lock capacity curves were developed from a detailed statistical analysis based on the output of the Waterway Analysis Model (WAM), a discrete simulation model that determines, in essence, tow congestion due to various closure events at different traffic levels. A capacity curve consists of many WAM runs at several different traffic levels. For single and multi-chamber projects, the model determines tow transit times at a range of tonnage levels for both full operation and long closure events at the projects. Lock capacity curves were determined for these two types of closure events. The full operation curve represents both the main and auxiliary chambers operating together with only random minor downtime events, unscheduled closures less than one day in duration, while the long closure events involves closures greater than one day in duration, mainly due to maintenance and rehabilitation, either scheduled or unscheduled. History has shown that these main chamber closures have the potential to cause very high transit times. The full operation and long closure events capacity curves, are referred to as the Family of Curves.

Each capacity curve modeled by WAM represents unique main chamber downtime closure duration. Main chamber downtimes can significantly impair the ability of a lock to serve traffic, and has the potential to cause very high transit times. Lock Capacity curves are necessary inputs to the Ohio River Navigation Investment Model (ORNIM), the economic model used in this study to justify the recommended project plan. ORNIM includes engineering reliability which requires a multitude of capacity curves for each lock, or collection of lock closure capacity curves, known as the Family of Curves.

The Lock Capacity curves presented here represent changes in barge sizes, acknowledged by shipping industry experts to be the dominant issue expected to affect future inland barge transportation. The larger future fleet scenario which phases out regular and stumbos with jumbo barges was analyzed for both the existing and With Project Condition alternatives.

[1] https://lpms.usace.army.mil/doc/lpmsframes3.htm

2.2 METHODOLOGY

2.2.1 WAM Model

Tonnage-transit time (capacity) curves were developed using the Waterway Analysis Model (WAM). The WAM is a discrete event computer simulation model developed by the Corps of Engineers for use in simulating tow movements on the inland waterways system. It was developed as part of the U. S. Army Corps of Engineers Inland Navigation Systems Analysis Program (INSA) for the Office of the Chief of Engineers by CACI, Inc. WAM was written in the mid 1970's and has been continually modified and improved since the early 1980's. WAM has been used in navigation studies on the Ohio River and its tributaries for the last 20 years. Although WAM was developed with the ability to model a system of locks, it was used as a single lock simulator for this study.

WAM is a simulation model. That means it incorporates the concept of variability into the modeling process. Instead of an action taking a fixed amount of time to accomplish, say 15 minutes every time, it may take any value between 5 and 30 minutes. Instead of every vessel arriving 60 minutes after the previous vessel, a vessel may arrive anywhere between a couple minutes and several hours after the previous vessel. This type of modeling is well suited for real world events, since real world events seldom take exactly the same amount of time every time they occur.

The interactions between the variability of the arrivals and the variability of the processing times causes times when the lock is idle and times when the lock is busy, with vessels waiting to process. The model monitors and accumulates many statistics as it executes. These statistics are written to files so the results of the model run can be reviewed and analyzed at will.

WAM is a highly detailed lock simulation model. A detailed model explanation is beyond the scope of this Attachment. Fundamentally however, the model is easy to describe. Vessels arrive at the lock where they either begin processing, or are made to wait because the facility is busy. When the lock is ready to process the vessel, the vessel goes through 4 distinct processes, each of which are represented in the model by a period of time. WAM uses these times to define the tow transit times which consists of the time the vessel is delayed plus the time it take to process the vessel through the lock.

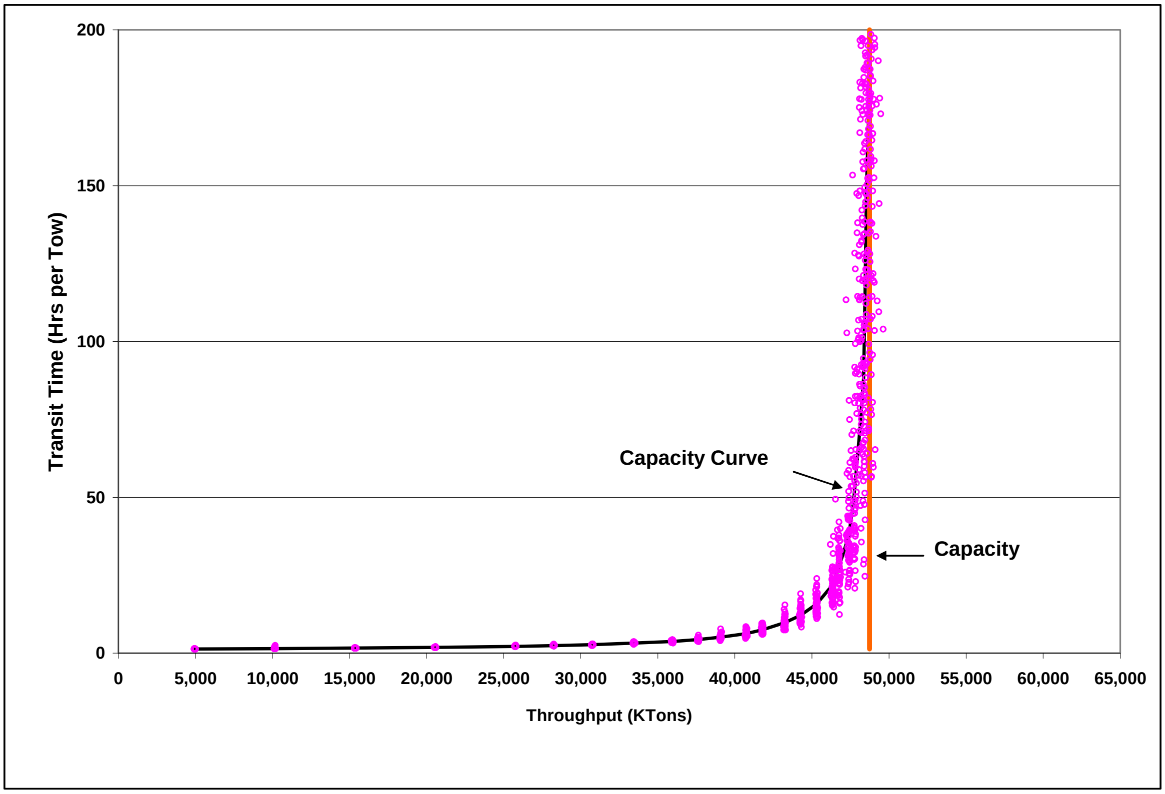
As stated earlier, vessel processing is simulated in the WAM by four sequential periods of time. They are in order of occurrence, the approach, entry, chambering and exit. A vessels total processing time equals the sum of the approach, entry, chambering and exit times. Processing time is added to the delay time, if any, to get total transit time for the vessel. Transit time is shown as the ordinate on capacity curve charts. The Corps Lock Performance Monitoring System serves as the data source for processing times used by WAM. Processing time data is retrieved from the LPMS system

2.2.2 Capacity Curves

The Waterways Analysis Model (WAM) was used to make traffic-transit time estimates in this study. WAM is a discrete event computer simulation model. Being a simulation model, every time WAM is run, it produces an estimate of how the modeled system performs. Many runs are made at several different traffic levels so the performance of a system over its full range of capabilities can be presumed. Many output statistics are generated during each run. The most important of these are the total amount of traffic served and the time needed to serve it. Only these two WAM output data statistics, the tonnage processed and the tow transit (processing & delay) time are used when creating capacity curves. A capacity curve defines the relationship between project throughput and transit time.

Figure A2-1 shows the results of a complete set of runs for one condition and its associated capacity curve. Each point on the figure represent one WAM run and each point on the capacity curve represents the average of these 50 WAM runs at each of the 27 different traffic levels. A capacity curve is created by connecting the average of the tonnage-transit time points over the range of traffic levels.

FIGURE A2- 1
One Set Of WAM Runs



2.2.3 Capacity –Vertical Asymptote

As in **Figure A2-1**, transit times remain very low until demand reaches about 80% of capacity. As traffic levels increase from that level, transit times increase rapidly. Throughput is measured as annual tons served, and transit time includes both the time needed to "process" the vessel and the time the vessel is "delayed". A vessel's process time begins when either the lock operator signals a waiting tow that the lock is ready for processing, or the tow is at the arrival point and the lock is idle. Process time ends when the lock is free to serve another vessel. Delay occurs when a vessel arrives at a lock and cannot be served immediately. "Capacity" is defined as the level of tonnage where the capacity curve reaches its vertical asymptote. At this point, additional demand results in increased delay but no increase in throughput.

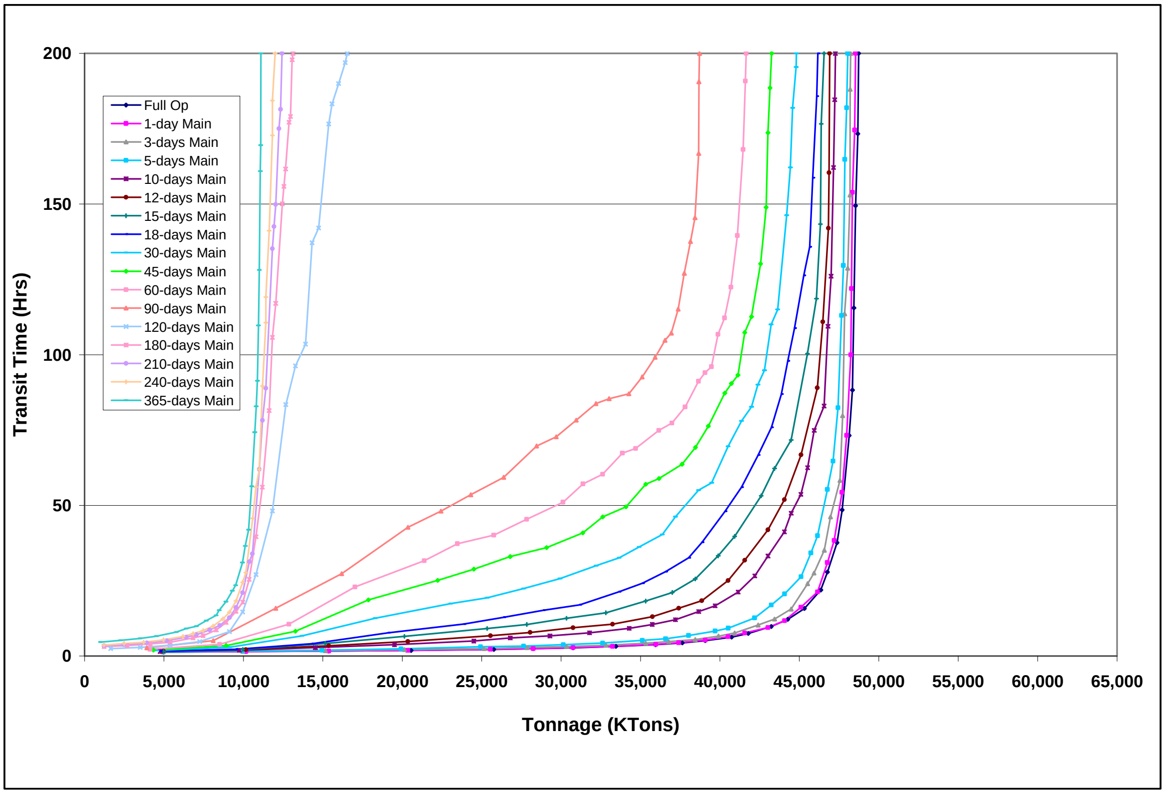
2.2.4 Family of Curves

Every capacity curve represents the relationship between tonnage and transit time for a given, very specific, set of circumstances. Many factors are considered when developing capacity curves. Fleet size and loadings, processing times, physical interference between tows using multi-chambers locks, arrival and inter-arrival patterns, service policies, downtimes, etc., all have an effect on the shape of the curve, and the ultimate capacity. Downtime is defined as time when traffic is unable to use a lock chamber. Downtime can occur because the chamber itself is unavailable, or for reasons that are beyond the control of the lock operator, like weather. When a chamber is "down", processing stops and vessels must either use another chamber or wait until the downtime ends.

Downtime is singled out for attention for two reasons. First, main chamber downtime can significantly impair the ability of a lock to serve traffic. History has shown that main chamber closures have the potential to cause very high transit times. Second, ORNIM, the economic model used in this study, includes engineering reliability. In order to fully consider the effects of reliability related failures, ORNIM needs a multitude of capacity curves for each lock. Hence, a collection of capacity curves are created for each lock, referred to as a Family of Curves. Each capacity curve represents a unique, long duration chamber closure event embedded within the random minor closures. See Section 2.4.5 for a description of random minor downtimes.

Figure A2-2 shows a portion of the family of curves for Emsworth L&D. An entire family consists of one curve that represents a condition where the entire facility is fully operational with only random minor downtimes along with many various longer main chamber closures durations. The 365 day closure curve represents the capacity curve for the auxiliary chamber.

FIGURE A2- 2
Typical Family of Curves



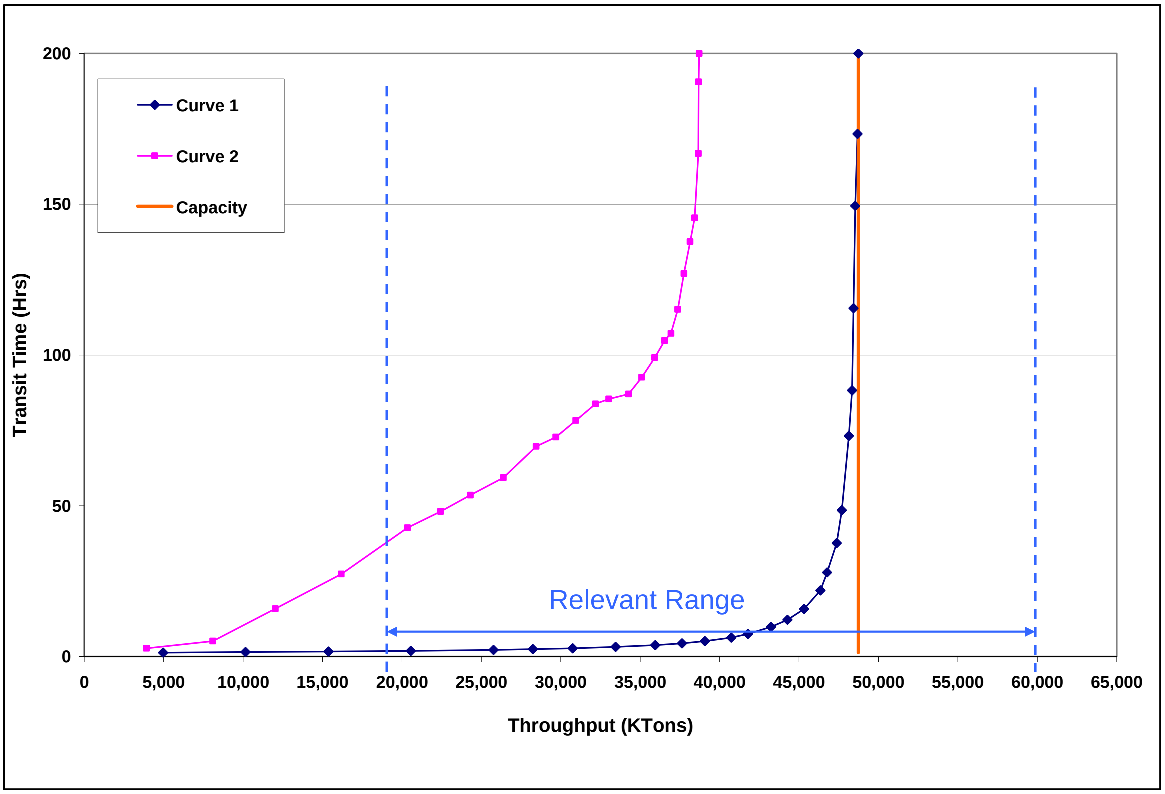
2.2.5 Relevant Range

While capacity is useful to demonstrate relative differences between alternatives, only the relevant range of the curve is used during an economic analysis. Relevant range is lock specific and depends on current and projected future traffic levels. The lower bound of a range is defined as the minimum expected demand, measured in tons, throughout the period of analysis. Conversely, the upper bound is set at the maximum expected tonnage. The capacity of a curve may lie above the relevant range, below the relevant range, or within the relevant range.

As in most Upper Ohio River locks, capacity falls within the relevant range, similar to Curve 1, **Figure A2-3.** If the facility is fully operational, most Upper Ohio River locks have plenty capacity to serve minimum expected demand, but as traffic levels start to reach a lock's capacity, delays significantly increase, Even at full operation, capacity falls well below the upper bound of the relevant range, thus, there is insufficient capacity to serve maximum expected demand.

Curve 2 is representative of many long "main chamber closure" curves on the Upper Ohio. The term "main chamber closure" will be explained later in Section 2.6.1. Even at low traffic demands, delays are extremely high. The important point here is that conditions may exist where delays are expected to even be significant at the low end of the relevant range, or minimum expected traffic demand.

FIGURE A2- 3
Capacity Curves with Relevant Range



2.3 Historic Delays

Table A2-5 shows the historical average delays at Emsworth, Dashields, and Montgomery for both nonclosure and closure years from 2000 to 2008. During closure years, average tow delays during the closure event will be significantly higher than the period outside the closure event. For example, at Emsworth in 2007, during normal lock operating conditions, average delay is 44.2 minutes; the 4.3 day closure resulted in an increase of average delay to 732 minutes during the closure event. Therefore, on average, each tow experienced 688 minutes more delay during the closure than normal. During long main chamber closure events, tows must transit the smaller auxiliary chamber, requiring tows to multi-cut, resulting in higher processing and delay times at the projects.

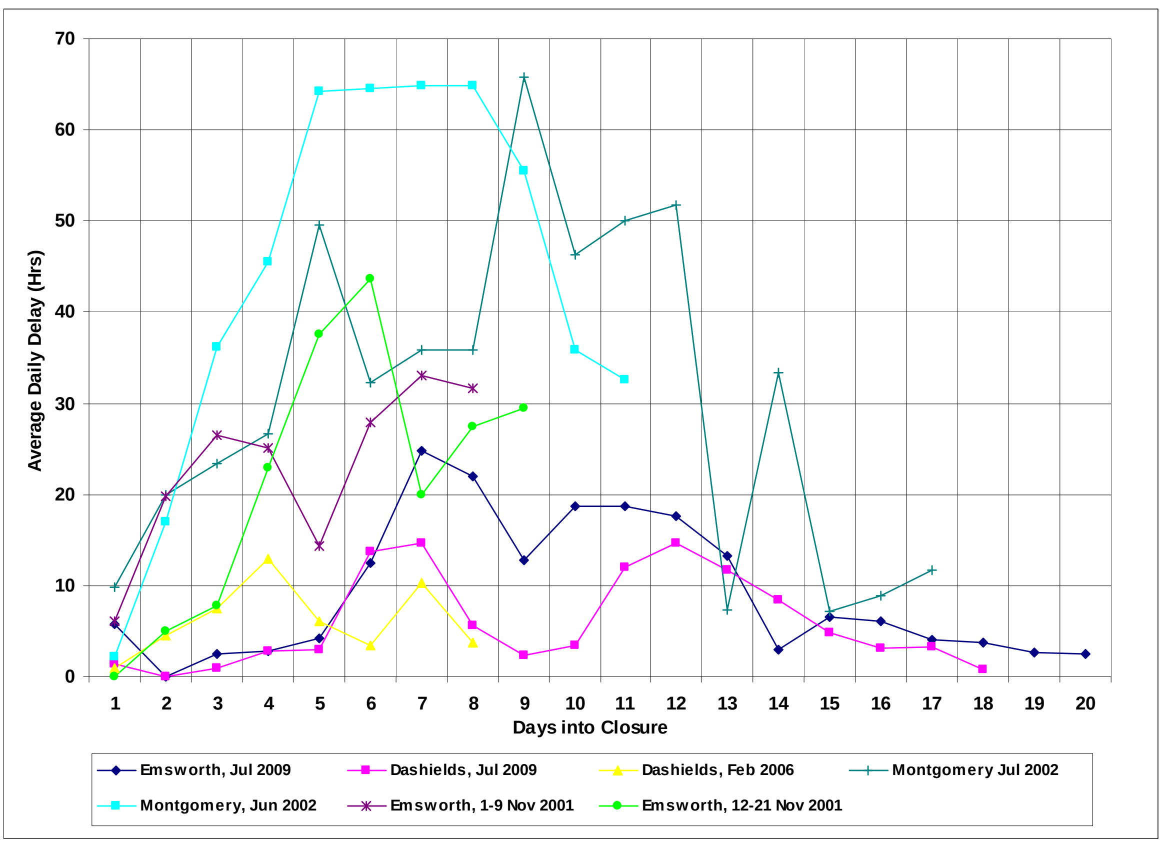
TABLE A2- 5
Historical Average Delays (Minutes)

	Emsworth			Dashields			Montgomery		
	During Normal Operation	Closure Duration (Days)	Avg Delay (Min) During Closure Event	During Normal Operation	Closure Duration (Days)	Avg Delay (Min) During Closure Event	During Normal Operation	Closure Duration (Days)	Avg Delay (Min) During Closure Event
Year	Main & Aux		Aux Only	Main & Aux		Auxiliary	Main & Aux		Auxiliary
2008	36.4		*na*	28.1	4.4	370.2	46.5		*na*
2007	44.2	4.3	732.0	24.9		*na*	53.2		*na*
2006	43.0		*na*	28.0	7.5	431.9	41.9		*na*
2005	34.7		*na*	28.1		*na*	40.2		*na*
2004	34.9		*na*	28.0	3.2	206.2	34.3		*na*
2003	52.2		*na*	32.7	3.7	396.3	32.5		*na*
2002	38.6		*na*	37.6		*na*	43.1	*27.3	*1999
2001	43.6	*17.3	*1044	29.4		*na*	45.4		*na*
2000	39.9		*na*	31.8		*na*	56.6		*na*

**total duration & average delay of two concurrent closure events*

Figure A2-4 shows average daily tow delay during historical closure events at Emsworth, Dashields, and Montgomery.

FIGURE A2- 4
Delays During Long Disruptive Closures



2.4 Assumptions

2.4.1 Random Arrivals

2.4.2 Vessel Types

The fleet is the sum total of all vessels that use the lock. This includes commercial tows, lightboats, and recreation craft. The fleet is fed to WAM as an external event file known as the shipment list. The shipment list is generated based on historic LPMS and WCSC data, and may contain several thousand records. Each record, which represents a shipment, has a unique arrival time and vessel description. When taken in total, a shipment list closely matches the overall characteristics of the actual fleet. A typical shipment can be characterized three ways; by type of vessel, by size of vessel, and by time of arrival. WAM simulates three types of vessels, tows, recreation craft, and lightboats/other vessels. The size of the vessel is dependent on vessel type, and for tows, the number and type of barges. Arrival times are based on historic arrival patterns, with each vessel type having its own arrival pattern.

2.4.3 Vessel Types - # Arrivals

Vessels are grouped into one three types in this study. Tows are commercial towboats pushing one or more barges. Lightboats are commercial towboats without barges. Recreation craft are non-commercial, usually small, vessels. Commercial-passenger vessels, government vessels, and other vessel types are counted and included in the lightboats group. **Table A2-6 – A2-8** shows the number of vessels, by vessel type, for the 2005 EDM fleet.

2.4.3.1 Emsworth Vessels

TABLE A2- 6
Emsworth Number of Vessels by Type

Tows	3,865
Lightboats/Other	1,007
RecreationCraft	2,945

2.4.3.2 Dashields Vessels

TABLE A2- 7
Dashields Number of Vessels by Type

Tows	3,750
Lightboats/Other	563
RecreationCraft	1,610

2.4.3.3 Montgomery Vessels

TABLE A2- 8
Montgomery Number of Vessels by Type

Tows	4,047
Lightboats/Other	739
RecreationCraft	969

2.4.4 Towboat Types - # Arrivals

Towboats were categorized into 9 groups based on horsepower. **Table A2-26** lists the towboat types, horsepowers and dimensions used in this study, and the 2005 arrival rates.

2.4.4.1 Emsworth Towboats

TABLE A2- 9
Emsworth Towboat Types, Horsepowers, & Dimensions

Towboat ID	Horsepower Range	Dimensions	Number of Arrivals
1	0-999	82 x 24	2,066
2	1000-1499	98 x 29	441
3	1500-1899	115 x 30	662
4	1900-2299	131 x 31	257
5	2300-3099	141 x 35	411
6	3100-4199	146 x 38	557
7	4200-5499	162 x 42	49
8	>5499	170 x 45	17

2.4.4.2 Dashields Towboats

TABLE A2- 10
Dashields Towboat Types, Horsepowers, & Dimensions

Towboat ID	Horsepower Range	Dimensions	Number of Arrivals
1	0-999	82 x 24	1,949
2	1000-1499	98 x 29	507
3	1500-1899	115 x 30	692
4	1900-2299	131 x 31	281
5	2300-3099	141 x 35	455
6	3100-4199	146 x 38	519
7	4200-5499	162 x 42	60
8	>5499	170 x 45	8

+qq

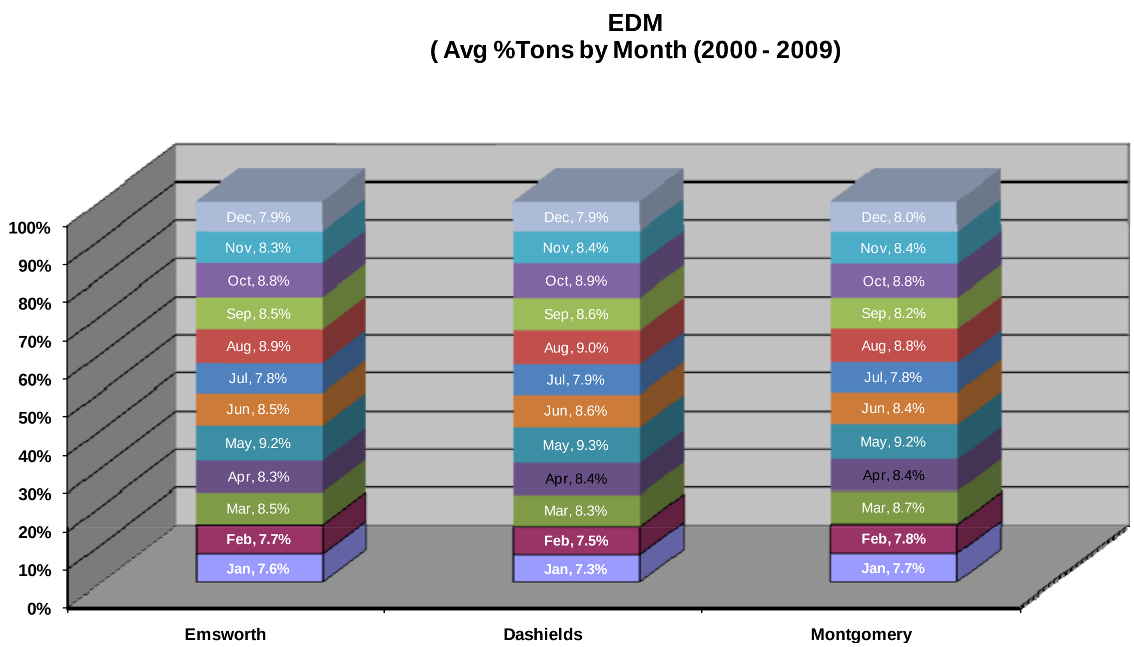
2.4.4.3 Montgomery Towboats

TABLE A2- 11
Montgomery Towboat Types, Horsepowers, & Dimensions

Towboat ID	Horsepower Range	Dimensions	Number of Arrivals
1	0-999	82 x 24	2,186
2	1000-1499	98 x 29	423
3	1500-1899	115 x 30	674
4	1900-2299	131 x 31	509
5	2300-3099	141 x 35	443
6	3100-4199	146 x 38	540
7	4200-5499	162 x 42	89
8	>5499	170 x 45	5

2.4.5 Vessel Arrivals - % Arrivals by Month, Day, & Hour

Traffic demand is evenly distributed throughout the year at each of the three projects. The **Figure** below shows the LPMS average percent of tonnage shipped by month from 2000 through 2009 ranges from 7.3% to 9.3% from January through December over the 10 year period.



Tow arrivals vary by month, day of week, and hour of day in accordance with the arrival tables shown in **Tables A2-12** through **Tables A2-20**. Recreation arrivals however, are highly dependent on the month of the year, day of the week and hour of the day. The shipment lists that drive WAM reflect these variations.

2.4.5.1 Emsworth Arrivals

Tables A2-12 through **A2-14** show the monthly, daily and hourly arrival patterns for tows, lightboats, recreation craft, and other vessels at Emsworth in 2005. **Figures A2-5** through **A2-7** shows the monthly, daily and hourly variation of tow arrivals in graphical form. **Figures A2-8** through **A2-10** show the monthly, daily and hourly variation of recreation craft arrivals in graphical form.

TABLE A2- 12
Emsworth Percent of Arrivals by Month of Year

Month	Tows	Light Boats	Recreation	Others
Jan	5.48	7.03	0.07	0.38
Feb	7.83	6.49	0.14	0.75
Mar	7.73	5.81	0.10	3.75
Apr	9.23	8.78	0.51	4.49
May	9.23	8.92	3.32	18.35
Jun	9.13	7.30	20.05	15.73
Jul	8.69	9.05	38.26	19.48
Aug	8.69	7.57	18.73	16.11
Sep	8.20	7.97	14.42	10.11
Oct	9.10	11.35	3.66	5.99
Nov	8.07	8.38	0.51	2.62
Dec	8.64	11.35	0.24	2.25

SOURCE: 2005 Emsworth LPMS Data.

TABLE A2- 13
Emsworth Percent of Arrivals by Day of Week

Day of Week	Tows	Light Boats	Recreation	Others
Mon	14.58	11.22	31.82	7.12
Tue	12.90	16.76	12.14	8.61
Wed	14.63	18.65	5.16	8.24
Thu	13.96	16.35	6.31	9.36
Fri	13.73	12.43	4.44	20.97
Sat	14.81	15.27	10.99	27.34
Sun	15.38	9.32	29.14	18.35

SOURCE: 2005 Emsworth LPMS Data.

TABLE A2- 14

Emsworth Percent of Arrivals by Hour of Day

Hour Interval	Tows	Light Boats	Recreation	Others
0:00-1:00	5.07	2.57	1.76	1.12
1:00-2:00	3.80	2.84	0.71	2.25
2:00-3:00	3.85	1.89	0.51	0.38
3:00-4:00	4.16	2.97	0.17	0.38
4:00-5:00	3.88	3.24	0.00	0.38
5:00-6:00	3.46	10.14	0.24	0.00
6:00-7:00	3.62	3.51	1.49	0.38
7:00-8:00	3.88	3.78	2.24	1.50
8:00-9:00	4.27	3.11	1.59	4.87
9:00-10:00	4.24	3.92	2.65	4.12
10:00-11:00	3.28	3.65	4.00	9.36
11:00-12:00	3.75	3.65	5.87	7.87
12:00-13:00	3.98	3.78	8.18	7.87
13:00-14:00	4.21	5.54	6.85	17.98
14:00-15:00	4.63	5.81	9.23	14.23
15:00-16:00	4.37	4.60	7.06	4.49
16:00-17:00	4.63	9.60	8.35	5.99
17:00-18:00	4.65	3.78	7.29	3.75
18:00-19:00	4.21	4.32	8.58	1.50
19:00-20:00	5.38	4.60	6.38	2.62
20:00-21:00	4.21	2.70	5.53	4.12
21:00-22:00	3.85	3.65	3.49	1.50
22:00-23:00	4.71	2.57	3.87	1.87
23:00-0:00	3.90	3.78	3.97	1.50

SOURCE: 2005 Emsworth LPMS Data.

FIGURE A2- 5

Emsworth Tow Arrivals by Month of Year

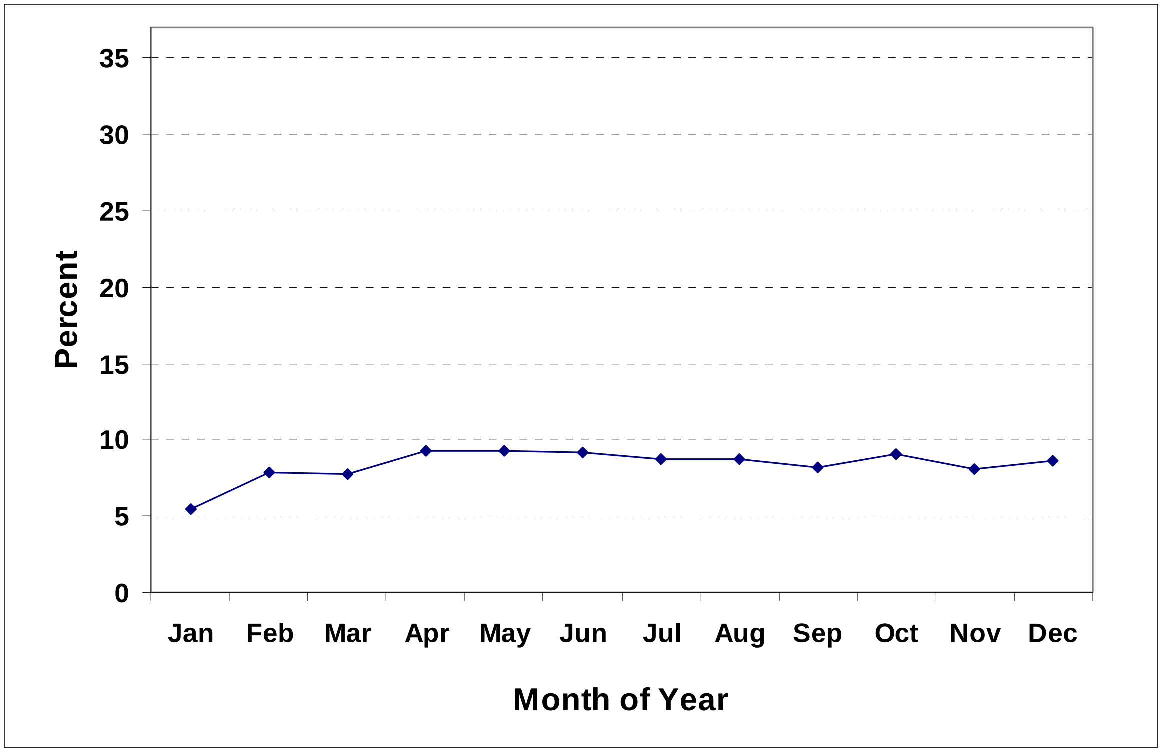


FIGURE A2- 6

Emsworth Tow Arrivals by Day of Week

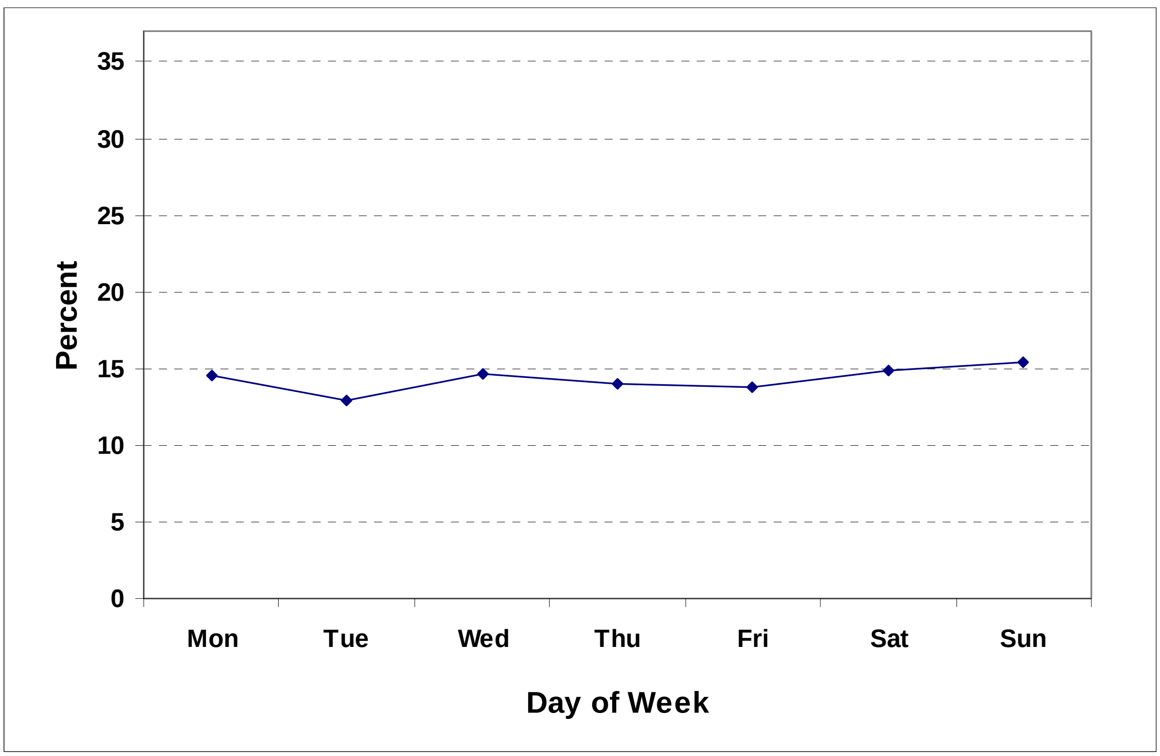


FIGURE A2- 7
Emsworth Tow Arrivals by Hour of Day

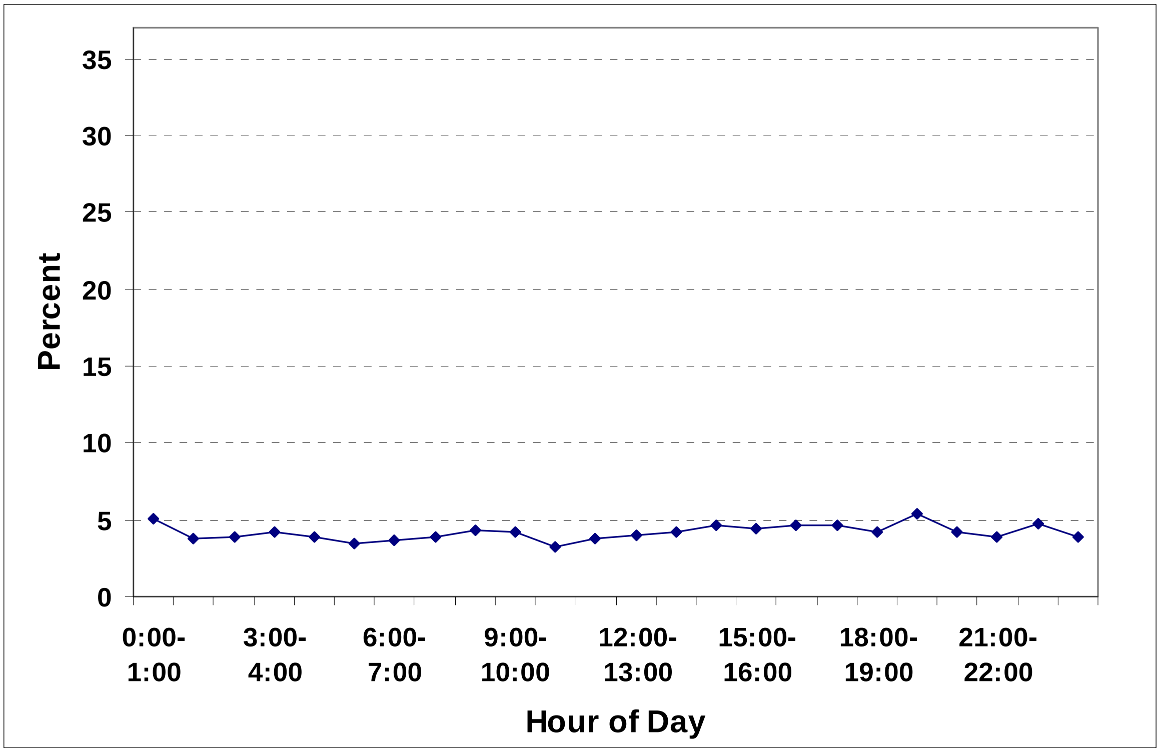


FIGURE A2- 8
Emsworth Recreation Craft Arrivals by Month of Year

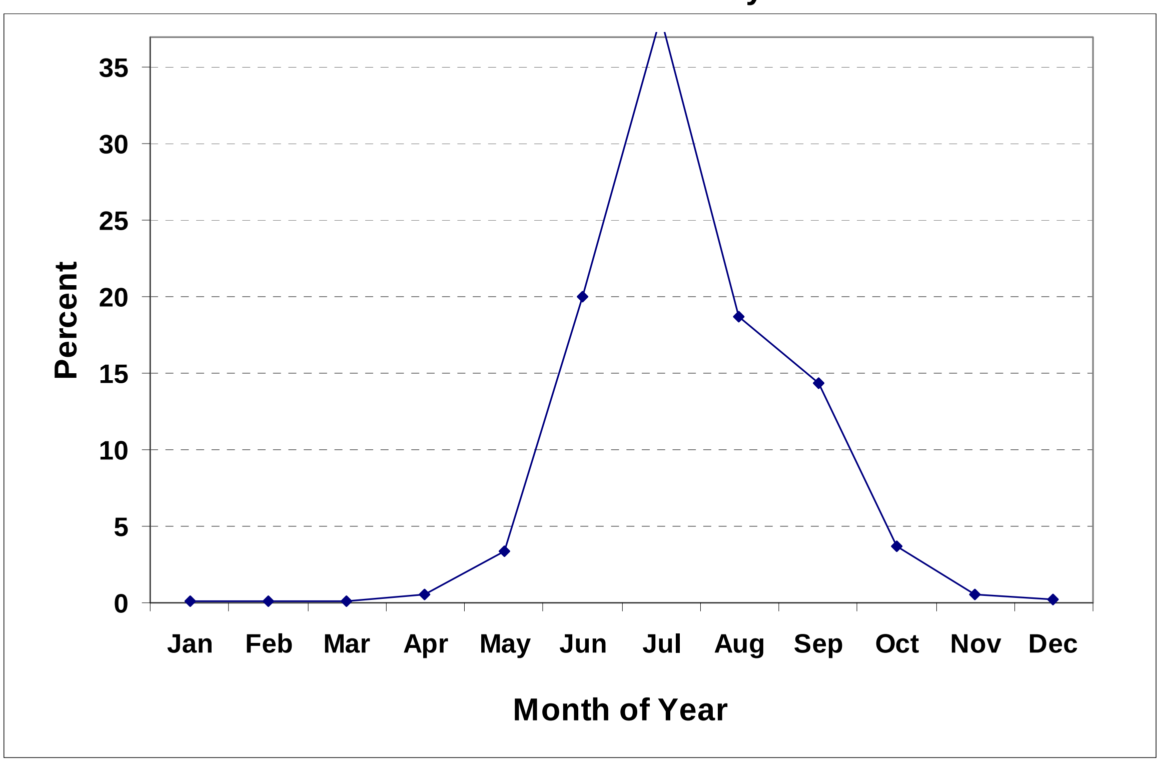


FIGURE A2- 9
Emsworth Recreation Craft Arrivals by Day of Week

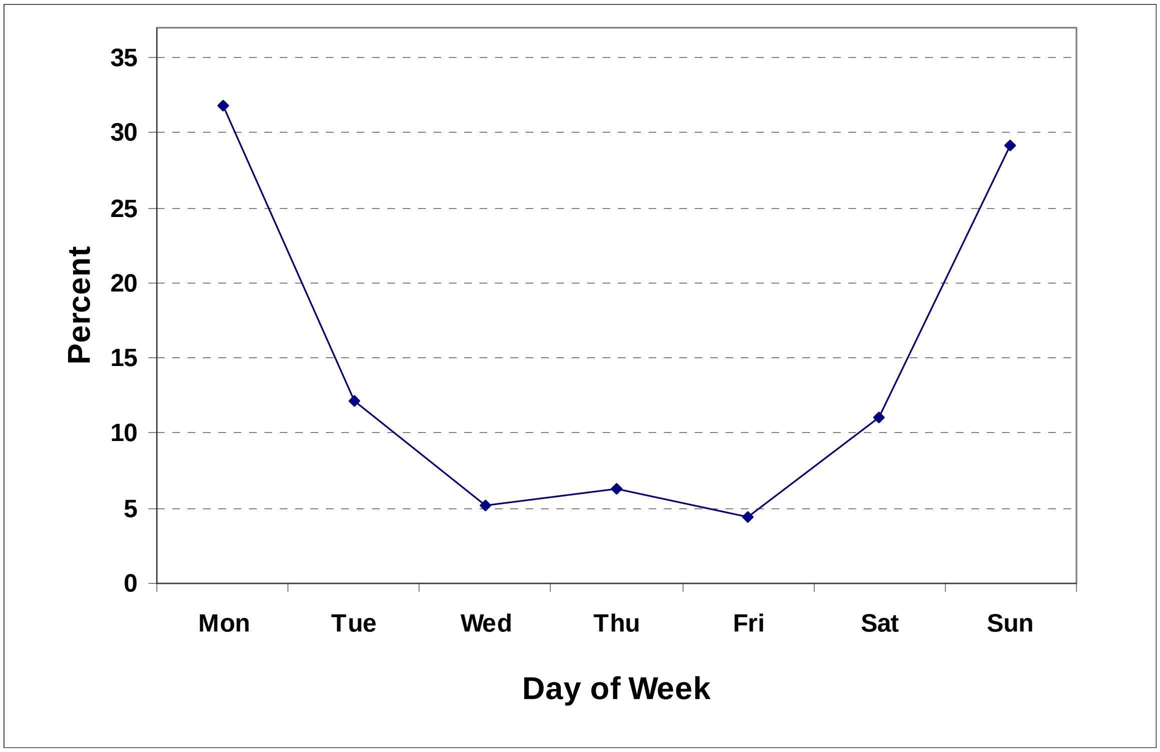
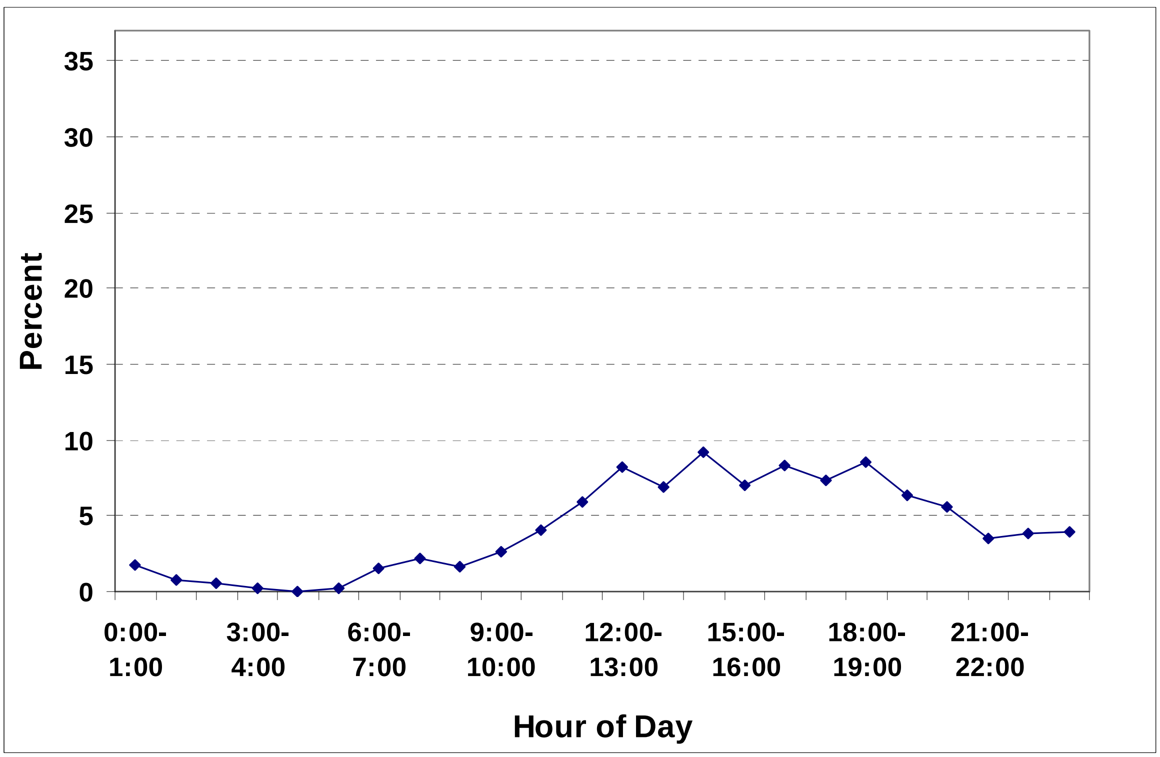


FIGURE A2- 10
Emsworth Recreation Craft Arrivals by Hour of Day



2.4.5.2 Dashields Arrivals

Tables A2-15 through **A2-17** show the monthly, daily and hourly arrival patterns for tows, lightboats, recreation craft, and other vessels at Dashields in 2005. **Figures A2-11** through **A2-13** shows the monthly, daily and hourly variation of tow arrivals in graphical form. **Figures A2-14** through **A2-16** show the monthly, daily and hourly variation of recreation craft arrivals in graphical form.

TABLE A2- 15
Dashields Percent of Arrivals by Month of Year

Month	Tows	Light Boats	Recreation	Others
Jan	5.41	7.06	0.19	3.45
Feb	7.76	8.27	0.12	1.72
Mar	7.97	9.27	0.31	1.72
Apr	9.57	9.27	0.50	3.45
May	9.49	8.67	1.99	3.45
Jun	8.90	7.06	17.80	10.35
Jul	8.56	9.68	35.55	22.41
Aug	8.72	8.67	24.57	6.90
Sep	8.24	4.44	13.03	12.07
Oct	8.69	10.48	4.09	18.97
Nov	8.08	9.48	1.12	8.62
Dec	8.61	7.66	0.74	6.90

SOURCE: 2005 Emsworth LPMS Data.

TABLE A2- 16
Dashields Percent of Arrivals by Day of Week

Day of Week	Tows	Light Boats	Recreation	Others
Mon	14.85	14.32	30.71	5.17
Tue	13.33	15.93	9.74	27.59
Wed	14.56	14.92	4.40	13.79
Thu	13.68	15.32	7.20	3.45
Fri	14.37	12.70	3.97	12.07
Sat	14.48	14.32	9.68	25.86
Sun	14.74	12.50	34.31	12.07

SOURCE: 2005 Emsworth LPMS Data.

TABLE A2- 17

Dashields Percent of Arrivals by Hour of Day

Hour Interval	Tows	Light Boats	Recreation	Others
0:00-1:00	4.67	4.64	1.06	8.62
1:00-2:00	4.08	2.42	0.37	0.00
2:00-3:00	4.13	3.02	0.62	1.72
3:00-4:00	4.16	2.82	0.06	0.00
4:00-5:00	4.35	3.63	0.25	0.00
5:00-6:00	3.97	2.22	0.00	1.72
6:00-7:00	4.03	2.82	0.31	1.72
7:00-8:00	4.56	4.03	2.11	5.17
8:00-9:00	3.63	3.43	3.91	12.07
9:00-10:00	3.95	4.64	3.10	8.62
10:00-11:00	4.00	5.85	7.20	3.45
11:00-12:00	3.71	4.44	8.75	6.90
12:00-13:00	3.84	5.65	11.23	8.62
13:00-14:00	4.24	3.43	10.24	12.07
14:00-15:00	4.24	7.06	10.67	3.45
15:00-16:00	4.00	6.45	7.88	3.45
16:00-17:00	4.11	3.83	7.57	5.17
17:00-18:00	4.16	3.83	5.21	1.72
18:00-19:00	4.21	3.43	6.51	0.00
19:00-20:00	4.51	4.64	5.21	1.72
20:00-21:00	5.25	5.24	3.10	5.17
21:00-22:00	4.43	4.84	1.92	5.17
22:00-23:00	4.08	3.63	0.93	0.00
23:00-0:00	3.73	4.03	1.80	3.45

SOURCE: 2005 Emsworth LPMS Data.

FIGURE A2- 11
Dashields Tow Arrivals by Month of Year

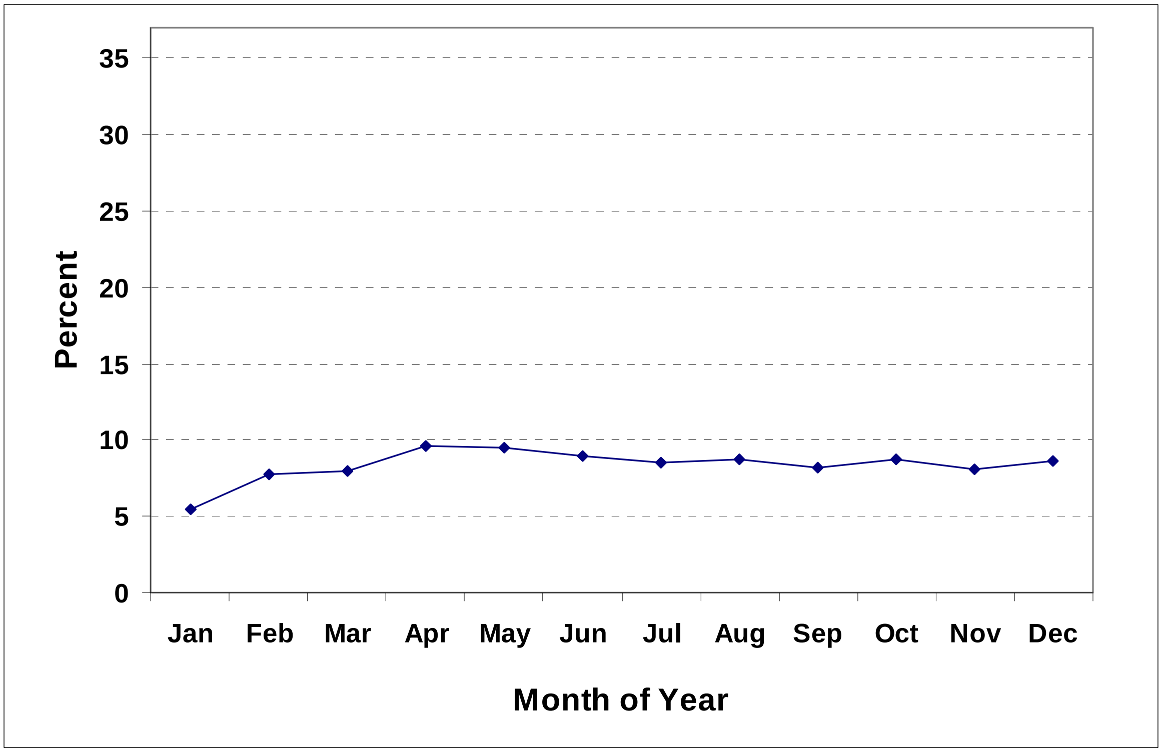


FIGURE A2- 12
Dashields Tow Arrivals by Day of Week

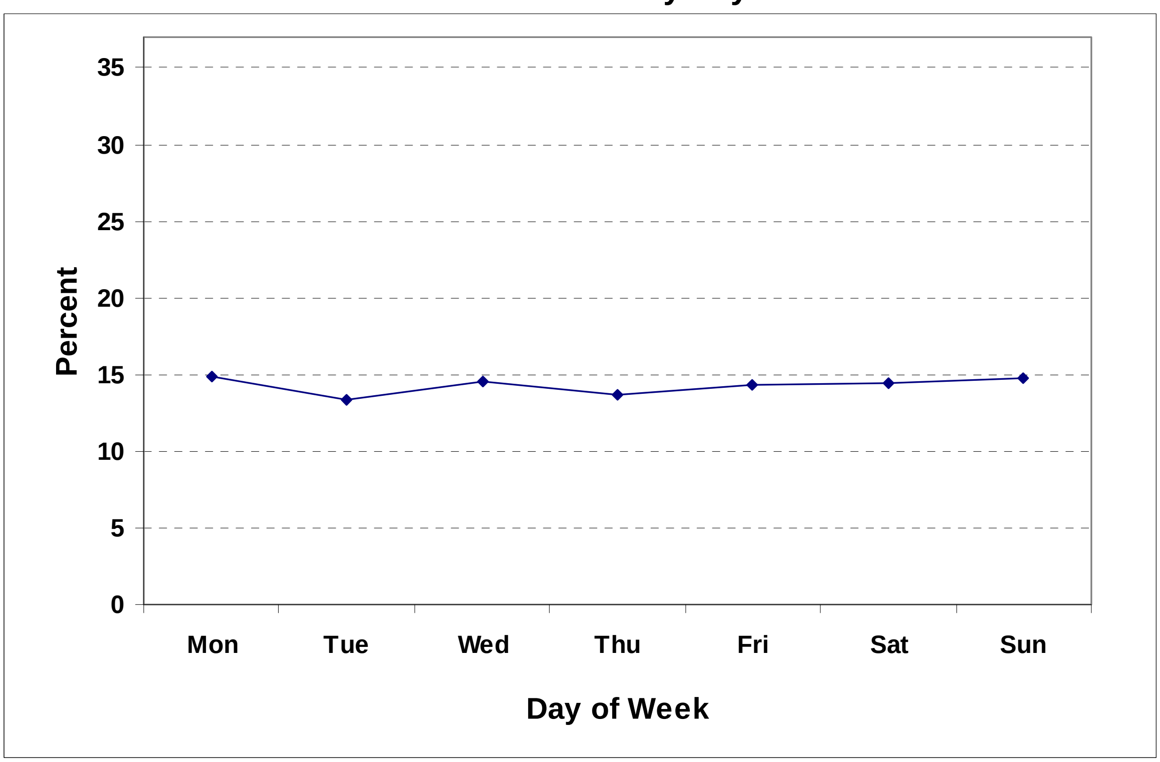


FIGURE A2- 13
Dashields Tow Arrivals by Hour of Day

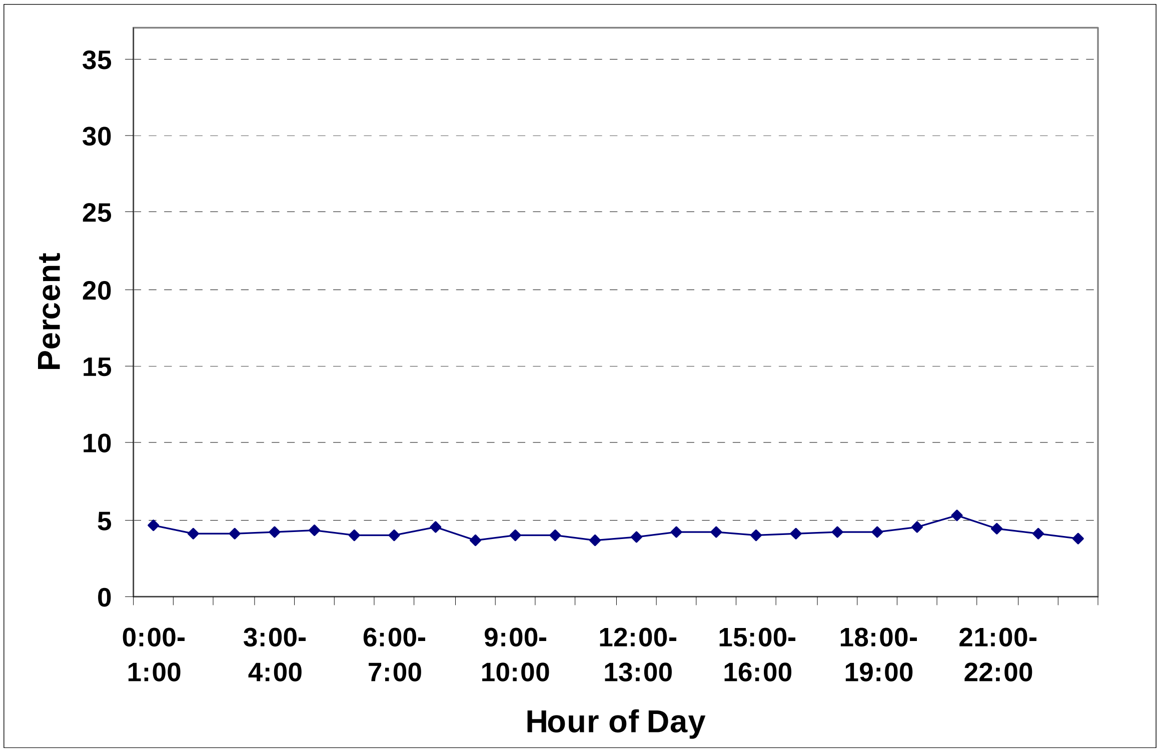


FIGURE A2- 14
Dashields Recreation Craft Arrivals by Month of Year

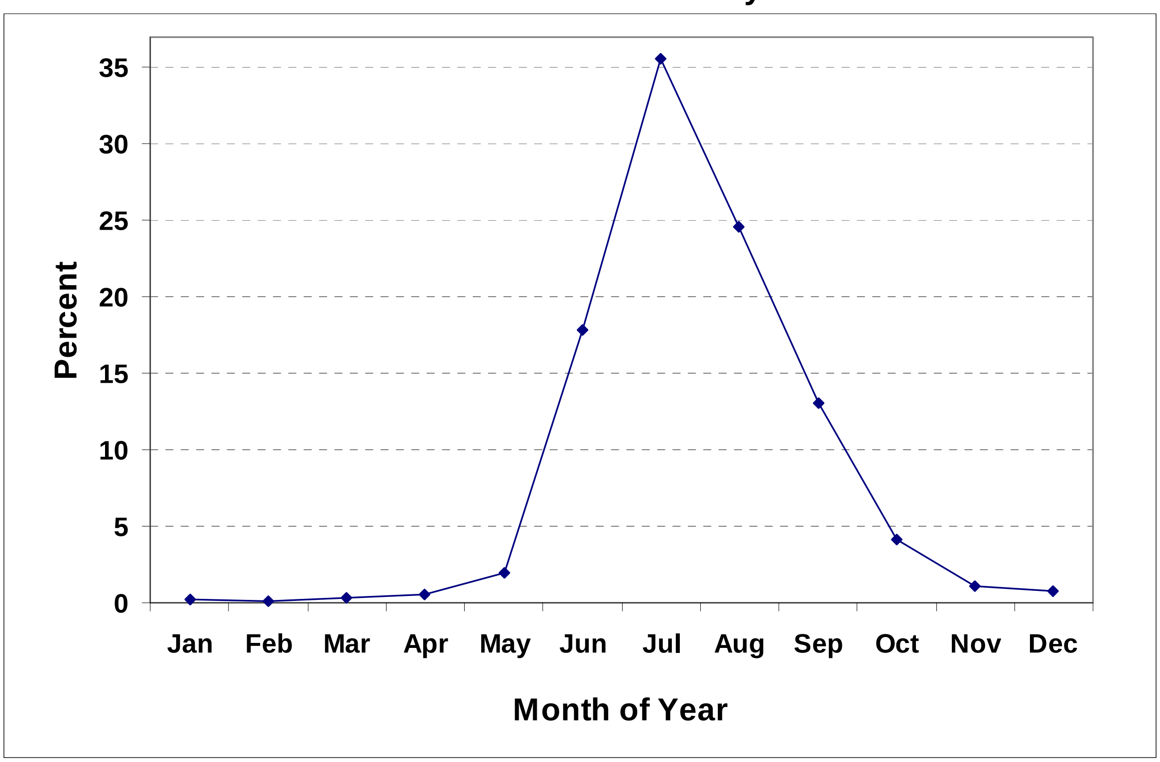


FIGURE A2- 15
Dashields Recreation Craft Arrivals by Day of Week

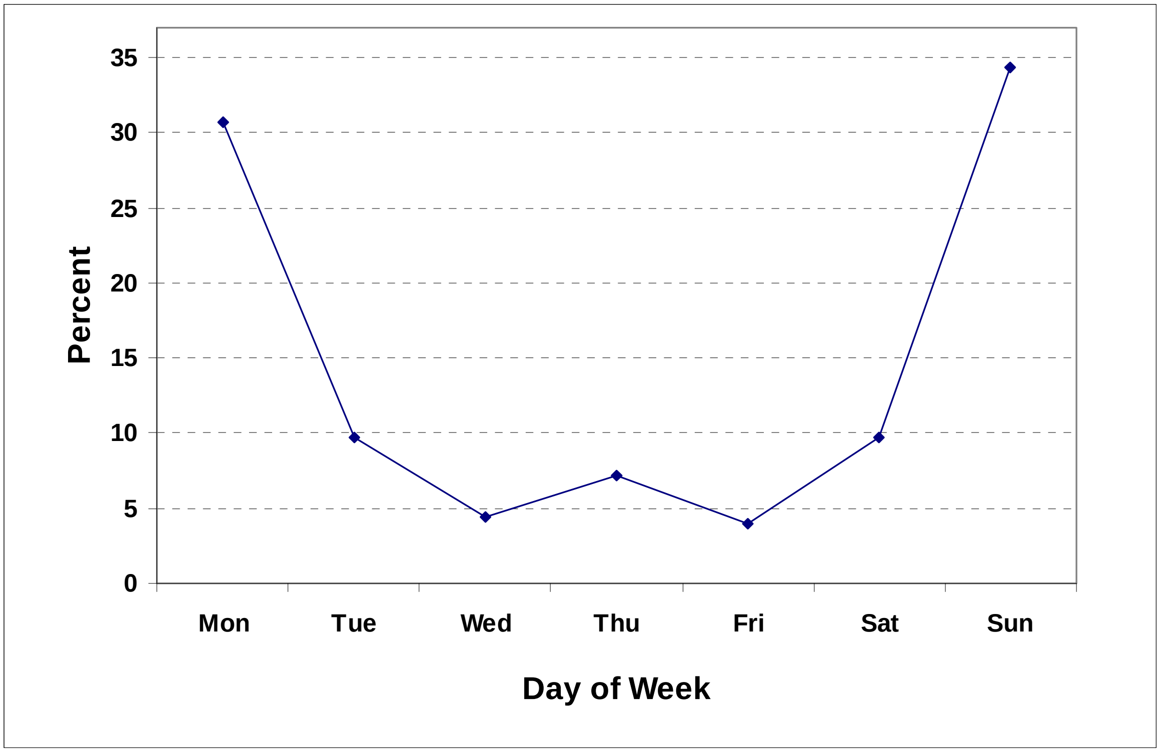
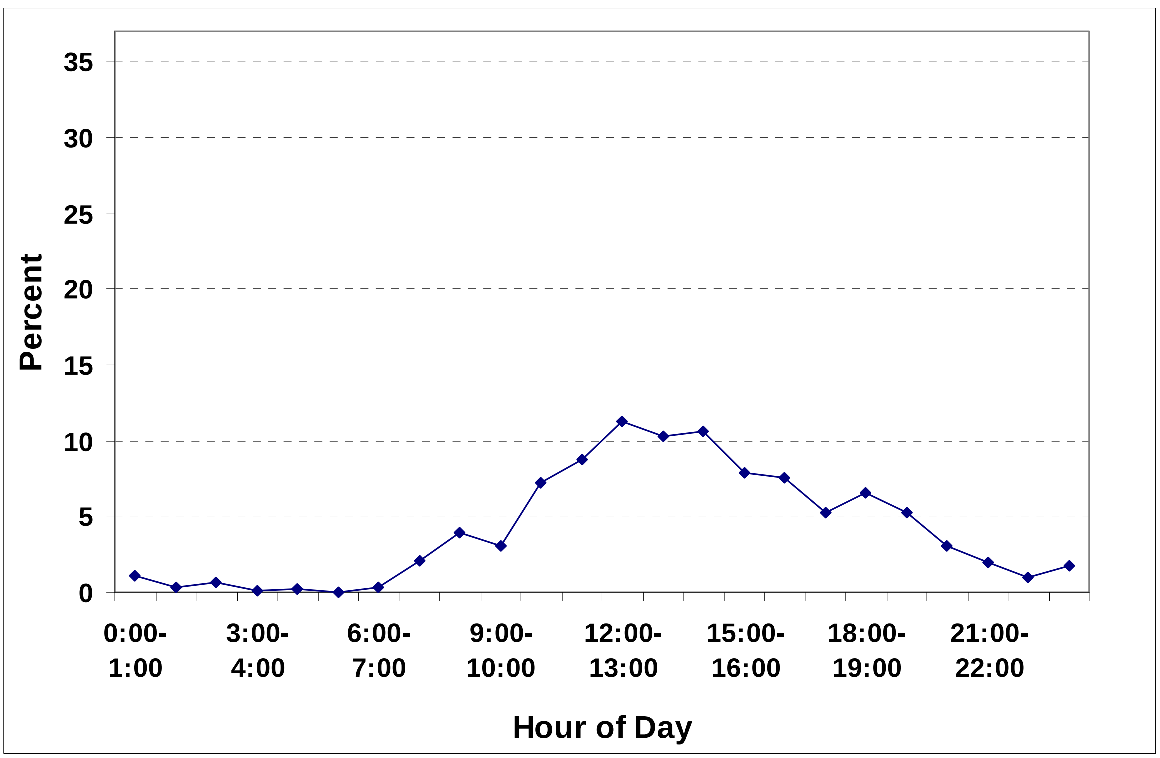


FIGURE A2- 16
Dashields Recreation Craft Arrivals by Hour of Day



2.4.5.3 Montgomery Arrivals

Tables A2-18 through **A2-20** show the monthly, daily and hourly arrival patterns for tows, lightboats, recreation craft, and other vessels at Montgomery in 2005. **Figures A2-17** through **A2-19** shows the monthly, daily and hourly variation of tow arrivals in graphical form. **Figures A2-20** through **A2-22** show the monthly, daily and hourly variation of recreation craft arrivals in graphical form.

TABLE A2- 18
Montgomery Percent of Arrivals by Month of Year

Month	Tows	Light Boats	Recreation	Others
Jan	5.34	6.73	0.21	5.66
Feb	8.03	6.14	1.13	1.89
Mar	8.84	8.33	0.10	1.89
Apr	9.78	8.33	0.72	5.66
May	9.31	9.80	3.30	11.32
Jun	8.65	11.11	13.08	7.55
Jul	8.70	7.90	29.76	16.98
Aug	8.52	8.77	24.31	7.55
Sep	7.81	5.12	18.02	9.43
Oct	8.75	8.77	7.21	18.87
Nov	7.81	8.92	2.16	9.43
Dec	8.47	10.09	0.00	3.77

SOURCE: 2005 Emsworth LPMS Data.

TABLE A2- 19
Montgomery Percent of Arrivals by Day of Week

Day of Week	Tows	Light Boats	Recreation	Others
Mon	13.39	11.84	35.22	7.55
Tue	13.56	14.18	8.14	28.30
Wed	14.45	14.04	4.43	13.21
Thu	15.07	18.13	5.66	3.77
Fri	14.72	16.81	4.02	16.98
Sat	13.79	13.89	9.58	18.87
Sun	15.02	11.11	32.96	11.32

SOURCE: 2005 Emsworth LPMS Data.

TABLE A2- 20

Montgomery Percent of Arrivals by Hour of Day

Hour Interval	Tows	Light Boats	Recreation	Others
0:00-1:00	4.45	3.07	0.31	7.55
1:00-2:00	4.00	4.39	0.93	0.00
2:00-3:00	3.38	2.78	0.10	3.77
3:00-4:00	3.98	3.66	0.00	0.00
4:00-5:00	4.05	3.07	0.93	1.89
5:00-6:00	3.71	2.63	0.10	3.77
6:00-7:00	3.41	1.46	1.44	1.89
7:00-8:00	4.50	6.29	1.13	1.89
8:00-9:00	4.69	6.14	1.55	3.77
9:00-10:00	4.15	4.83	3.09	7.55
10:00-11:00	4.08	3.66	4.43	16.98
11:00-12:00	4.30	4.83	8.75	7.55
12:00-13:00	4.32	5.70	9.06	3.77
13:00-14:00	4.35	4.68	13.49	5.66
14:00-15:00	4.45	4.68	9.58	15.09
15:00-16:00	4.32	5.56	7.11	3.77
16:00-17:00	4.15	4.68	9.78	0.00
17:00-18:00	4.22	3.80	11.74	0.00
18:00-19:00	3.73	4.83	5.15	3.77
19:00-20:00	4.77	4.09	4.74	0.00
20:00-21:00	4.64	2.92	2.68	1.89
21:00-22:00	4.27	3.80	1.75	3.77
22:00-23:00	4.22	3.66	1.44	3.77
23:00-0:00	3.85	4.83	0.72	1.89

SOURCE: 2005 Emsworth LPMS Data.

FIGURE A2- 17

Montgomery Tow Arrivals by Month of Year

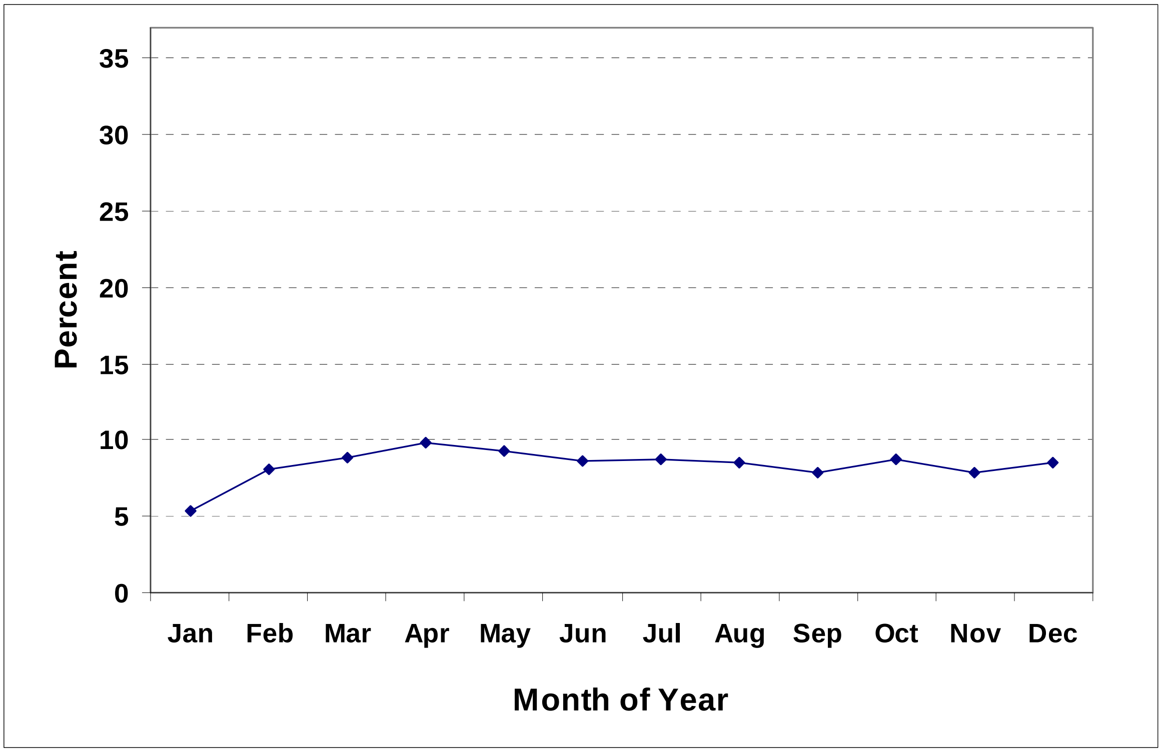


FIGURE A2- 18

Montgomery Tow Arrivals by Day of Week

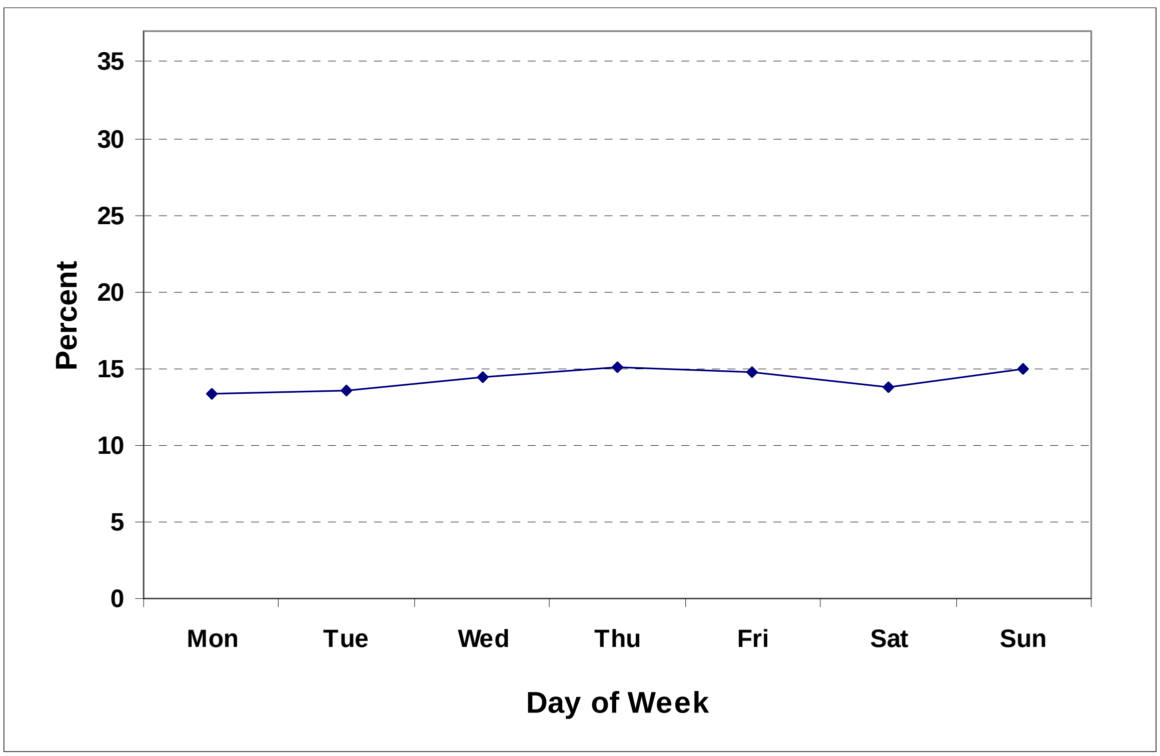


FIGURE A2- 19
Montgomery Tow Arrivals by Hour of Day

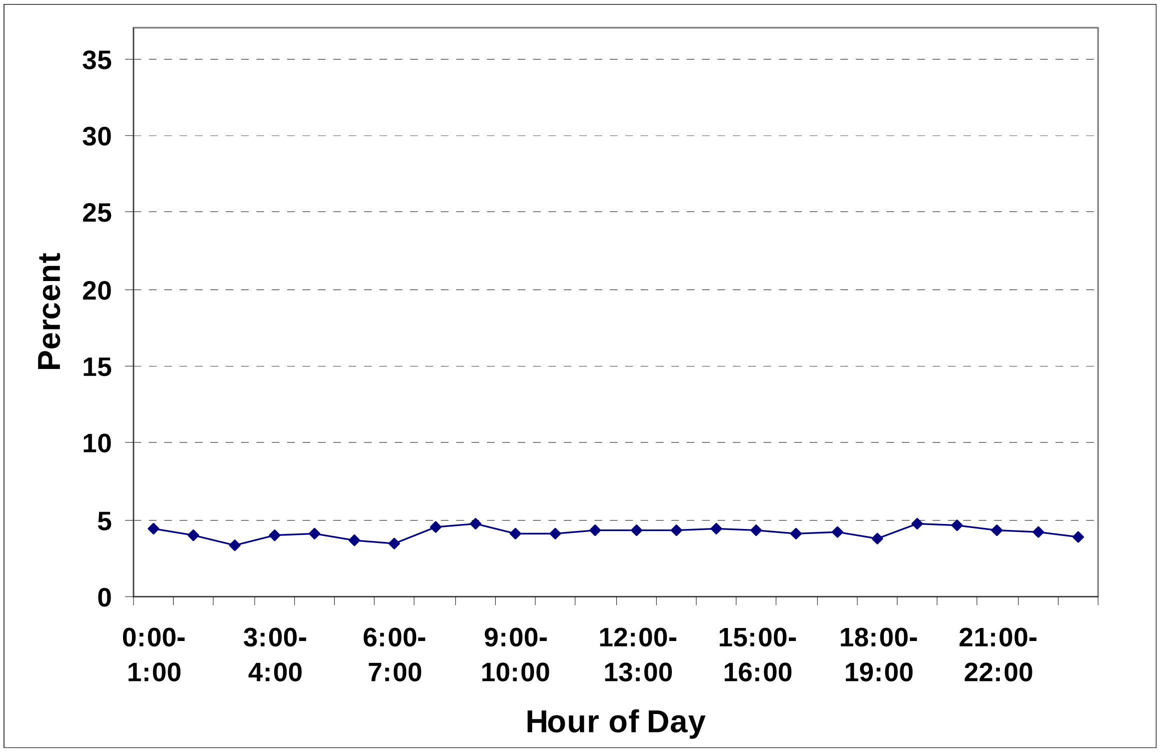


FIGURE A2- 20
Montgomery Recreation Craft Arrivals by Month of Year

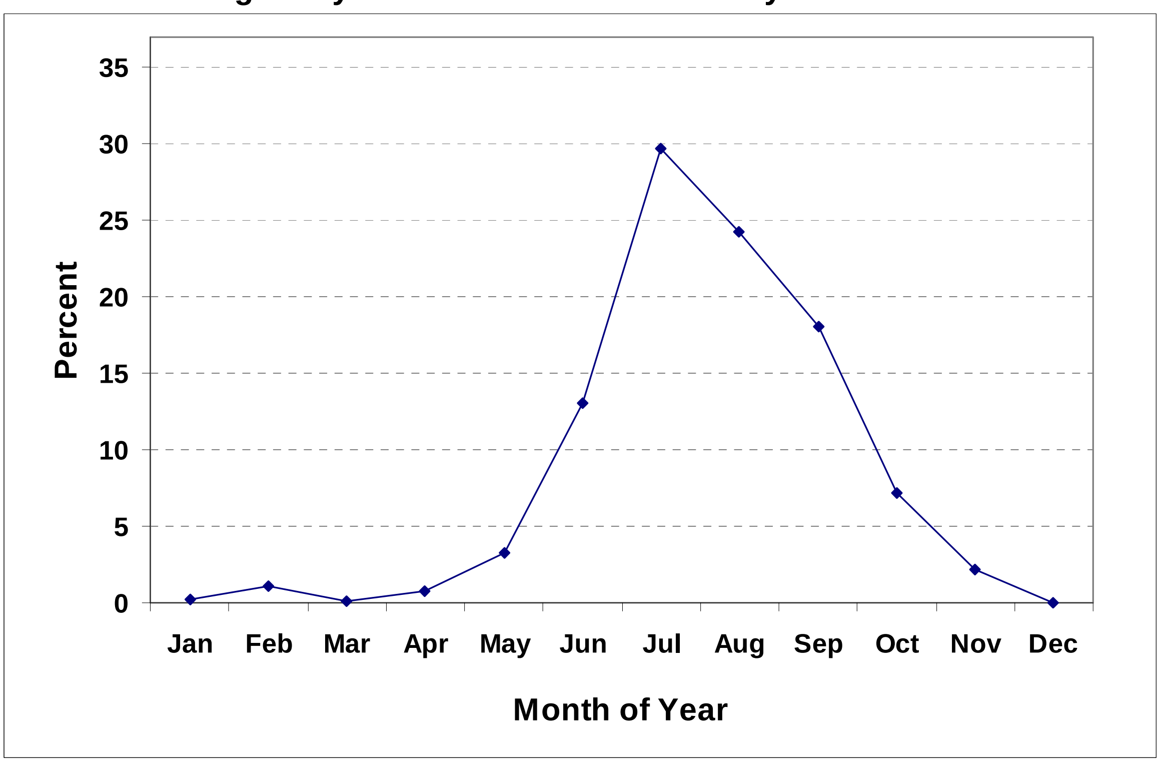


FIGURE A2- 21
Montgomery Recreation Craft Arrivals by Day of Week

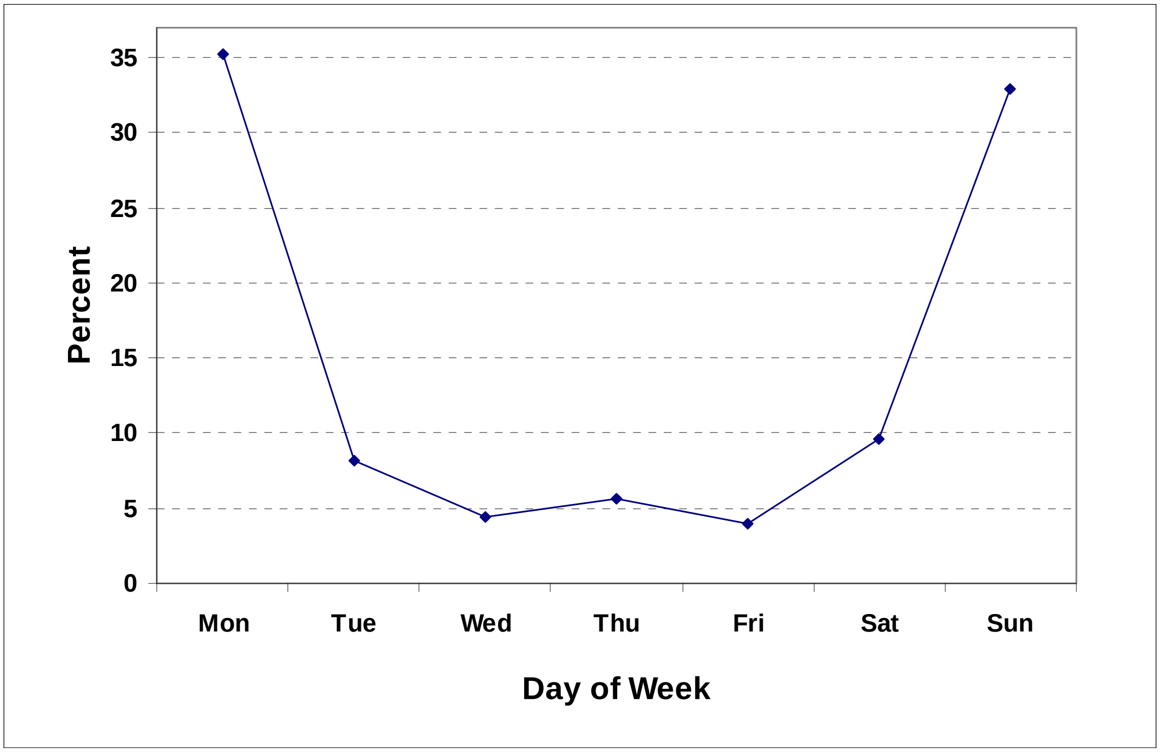
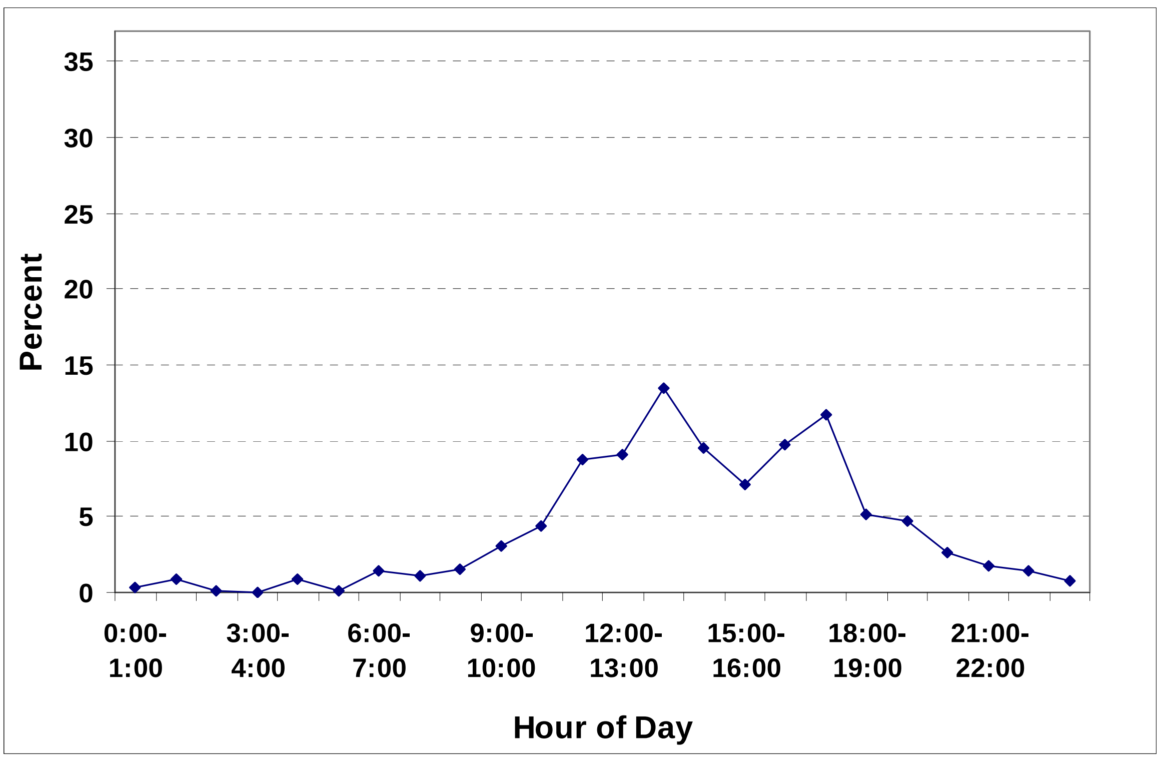


FIGURE A2- 22
Montgomery Recreation Craft Arrivals by Hour of Day



2.4.6 Random Minor Downtimes

Locks experience periods of time when traffic is unable to transit through the facility. These periods are referred to as downtime events. Downtimes happen for a variety of reasons and can last from a few minutes to over a month. Some downtimes are scheduled ahead of time while others occur without warning. This study addresses downtime by segregating these events into two groups, random minor downtimes and major maintenance downtimes. Random minor downtimes are short duration, less than 1 day, unscheduled chamber closures. They are caused by various things such as the weather, mechanical breakdowns, river conditions, lock conditions, and other circumstances.

The Corps LPMS data is the main data source for downtimes. LPMS data includes fields for vessel stalls. These stall events are used to determine how often and for what duration lock chambers are unable to serve traffic. LPMS data from the years 1995 through 2006 were used to develop an estimate of how often and for how long, each lock chamber is “stalled’ or unable to serve traffic. LPMS categorizes the causes of downtime into 5 major groups, and then further subdivides each major group into subgroups, for a total of 19 different causes of downtime. Data was developed for each downtime subgroup by determining the number of events expected each year, and the total annual amount of downtime. **Table A2-21** through **A2-23** shows a summary of the historical LPMS downtime data collected at the EDM locks and the downtimes used as inputs into WAM.

2.4.6.1 Emsworth Downtimes

TABLE A2- 21
Emsworth Historical LPMS Stalls & WAM Downtimes

	Main Chamber				Auxiliary Chamber			
Closure Category (LPMS Code)	1995-2006 LPMS Average		1995-2006 WAM Average		1995-2006 LPMS Average		1995-2006 WAM Average	
	Freq/Yr	Dur(min)	Freq/Yr	Dur(min)	Freq/Yr	Dur(min)	Freq/Yr	Dur(min)
Weather								
Forg (A)	1.3	237	1.0	309.0	1.3	237	1.0	272.0
Rain (B)	0.8	34	1.0	13.0	0.8	36	1.0	14.0
Sleet or Hail(C)	0.6	102	1.0	52.0	0.6	102	1.0	168.0
Snow (D)	0.1	13	0.0	0.0	0.1	13	0.0	0.0
Wind (E)	8.5	106	9.0	112.0	0.4	293	0.0	0.0
Surface Conditions								
Ice (H)	8.3	70	8.0	61.0	1.2	95	1.0	33.0
River current/outdraft (I)	0.5	226	1.0	16.0	0.8	840	1.0	1104.0
Flood (J)	0.2	948	0.0	0.0	0.2	948	0.0	0.0
Tow Conditions								
Interference by other vessels (K)	0.9	36	1.0	26.0	0.2	28	0.0	0.0
Tow Malfunction (L)	0.8	92	1.0	28.0	0.1	110	0.0	0.0
Towstaff elsewhere occupied (M)	0.1	19	0.0	0.0	0	0	0.0	0.0
Lock Condition								
Debris in Chamber (Q)	0.6	114	1.0	30.0	0.2	554	0.0	0.0
Hardware Malfunction ®	1.4	92	1.0	224.0	1.0	336	1.0	90.0
Staff elsewhere occupied (S)	0.3	34	0.0	0.0	0.5	55	1.0	64.0
Testing/maintenance (T)	5.8	135	6.0	158.0	1.7	226	2.0	426.0
Others								
Tow detained (V)	1.2	76	1.0	30.0	0.4	45	0.0	0.0
Collision/accident (W)	0.8	101	1.0	73.0	0.1	130	0.0	0.0
Vehicular/RR bridge (X)	0.0	0	0.0	0.0	0	0	0.0	0.0
Other (Z)	4.8	111	5.0	74.0	1.8	152	2.0	88.0
Average	na	107.7	na	95.1	na	234.4	na	252.1
Totals	37.0	3,986	38	3615	11.4	2671.9	11	2773

2.4.6.2 Dashields Downtimes

TABLE A2- 22
Dashields Historical LPMS Stalls, Responses, & WAM Downtimes

	Main Chamber				Auxiliary Chamber			
Closure Category - LPMS Code	**1995-2006 LPMS Average**		**WAM Downtime**		**1995-2006 LPMS Average**		**WAM Downtime**	
	Freq./Yr	**Dur (min)**	**Freq./Yr**	**Dur (min)**	**Freq./Yr**	**Dur (min)**	**Freq./Yr**	**Dur (min)**
Weather								
Fog - A	2.8	205	3.0	129	2.8	205	3.0	322
Rain - B	0.9	29	1.0	19	0.9	29	1.0	49
Sleet or Hail - C	0.2	258	0.0	0	0.2	258	0.0	0
Snow - D	0	0	0.0	0	0	0	0.0	0
Wind - E	7.7	117	8.0	122	0.6	274	1.0	19
Surface Conditions								
Ice - H	4.8	66	5.0	77	0.6	73	1.0	73
River current/outdraft - I	0.8	45	1.0	31	0	0	0.0	0
Flood - J	0.3	856	0.0	0	0.3	856	0.0	0
Tow Conditions								
Interference by other vessels - K	1.4	100	1.0	30	0.3	30	0.0	0
Tow malfunction - L	1	62	1.0	32	0.7	63	1.0	60
Tow staff elsewhere occupied - M	0.9	24	1.0	25	0	0	0.0	0
Lock Condition								
Debris in Chamber - Q	0.2	281	0.0	0	0.7	77	1.0	54
Hardware malfunction - R	1.2	70	1.0	78	0.3	96	0.0	0
Staff elsewhere occupied - S	0.2	53	0.0	0	0.8	31	1.0	0
Testing/maintenance -T	7.4	81	7.0	72	3.8	106	4.0	77
Others								
Tow detained - V	0.9	73	1.0	50	0.4	42	0.0	0
Collision/accident - W	1.4	94	1.0	71	0.1	25	0.0	0
Vehicular/RR bridge - X	0.1	130	0.0	0	0	0	0.0	0
Other - Z	1.8	55	2.0	50	0.5	22	1.0	37
Average	na	101	na	81	na	132	na	112
Totals	34.0	3,445	33.0	2,688	13.0	1,710	14.0	1,566

2.4.6.3 Montgomery Downtimes

TABLE A2- 23
Montgomery Historical LPMS Stalls & WAM Downtimes

	Main Chamber				Auxiliary Chamber			
Closure Category - LPMS Code	**1995-2006 LPMS Average**		**WAM Downtime**		**1995-2006 LPMS Average**		**WAM Downtime**	
	Freq./Yr	**Dur (min)**	**Freq./Yr**	**Dur (min)**	**Freq./Yr**	**Dur (min)**	**Freq./Yr**	**Dur (min)**
Weather								
Fog - A	3.8	187	4.0	215	3.8	187	4.0	150
Rain - B	0.2	27	0.0	0	0.2	27	0.0	0
Sleet or Hail - C	0	0	0.0	0	0	0	0.0	0
Snow - D	0.2	414	0.0	0	0.2	414	0.0	0
Wind - E	2.6	72	3.0	81	0.1	274	0.0	0
Surface Conditions								
Ice - H	16.2	84	16.0	80	0.5	48	1.0	24
River current/outdraft - I	0.8	55	1.0	50	0.2	1011	0.0	0
Flood - J	0.5	677	1.0	451	0.5	677	1.0	965
Tow Conditions								
Interference by other vessels - K	0.5	52	1.0	62	0.3	20	0.0	0
Tow malfunction - L	2.2	55	2.0	29	0.2	54	0.0	0
Tow staff elsewhere occupied - M	0.8	26	1.0	20	0.1	7	0.0	0
Lock Condition								
Debris in Chamber - Q	0.8	150	1.0	79	0.7	238	1.0	64
Hardware malfunction - R	1.6	69	2.0	78	0.5	125	1.0	149
Staff elsewhere occupied - S	0.1	207	0.0	0	0	0	0.0	0
Testing/maintenance -T	6.1	62	6.0	57	0.6	128	1.0	138
Others								
Tow detained - V	3.4	75	3.0	63	0.2	234	0.0	0
Collision/accident - W	1	99	1.0	0	0.1	260	0.0	0
Vehicular/RR bridge - X	0	0	0.0	0	0	0	0.0	0
Other - Z	1.7	71	2.0	102	0.4	395	0.0	0
Average	na	94	na	91	na	226	na	216
Totals	42.5	4,001	44.0	3,994	8.6	1,945	9.0	1,940

2.5 Existing Condition Project Analysis

2.5.1 Interference

Physical interference may occur between tows at multi-chamber locks. Due to the close proximity of the chambers, a tow using one chamber may interfere with the operation of a tow using the other chamber. WAM simulates two types of interference, approach area and gate area. The approach areas at lock projects are treated as "one-tow-at-a-time" areas. This means if a tow is using an approach area, other tows will not enter the approach area until the first tow has cleared. **Table A2-24** shows the gate area interference parameters used at EDM dual chambers projects. The length shown in the table should be interpreted as the determinant length between tows that cause interference and tows that do not. If interference occurs, the tow that is being interfered with must wait until the tow causing the interference moves out of the way

TABLE A2- 24
EDM Gate Area Interference Parameters - Existing Condition

#	Gate Interference Statement	Answer
1	If a tow is waiting at the upper gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with an upbound tow exit from the Main chamber	360
2	If a tow is waiting at the lower gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with a downbound tow exit from the Main chamber	360
3	If a tow is waiting at the upper gates of the Main chamber, and it is ______ feet long or longer, it interferes with an upbound tow exit from the Auxiliary chamber	1200
4	If a tow is waiting at the lower gates of the Main chamber, and it is ______ feet long or longer, it interferes with a downbound tow exit from the Auxiliary chamber	1200
5	If a tow is waiting at the lower gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with an upbound tow approach to the Main chamber	360
6	If a tow is waiting at the upper gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with a downbound tow approach to the Main chamber	360
7	If a tow is waiting at the lower gates of the Main chamber, and it is ______ feet long or longer, it interferes with an upbound tow approach to the Auxiliary chamber	1200
8	If a tow is waiting at the upper gates of the Main chamber, and it is ______ feet long or longer, it interferes with a downbound tow approach to the Auxiliary chamber	1200

Note that interference can only occur between two tows.
Recreational tows and light boats cannot cause, and are not affected by, interference.
Also note that these answers should reflect what a prudent navigator would usually do.

2.5.2 Processing Times

The Corps of Engineers LPMS served as the data source for defining detailed processing time distributions. Although 2005 was chosen as the base year, data from 1997 through 2007 were reviewed. Seven component processing time sample sets (long approach, short approach, entry, chambering, long exit, short exit, and chamber turn backs) were developed for each chamber, direction, and lockage type. These sample sets were then analyzed with a proprietary software package called Expert Fit®. Expert Fit analyzes each sample set, fits many different probability distributions to the set, determines which distribution fits the best, and displays the parameters needed to define the distribution in WAM. **Tables A2-25** through **A2-45** show sample set sizes, data years, and mean times for each component used for the Existing Condition alternatives at EDM. It should be noted that the sample sizes were extremely small for auxiliary chamber multi-cut (2-5) approach, entry, and exit times. Review of the data indicated that these times are approximately the same. Therefore, all multi-cut approach, entry, and exit times were combined to achieve sufficient sample sizes. These combined sample sets were then used for all three projects.

2.5.2.1 Emsworth Processing Times

TABLE A2- 25
Emsworth Processing Time Information
Main Chamber Single Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	1,045	05	24.1	0	1,009	05	19.8	3
Short Approach	224	05	12.5	0	243	05	13.1	0
Entry	1,265	05	10.0	4	1,250	05	9.0	5
Chambering	1,269	05	19.1	0	1,254	05	16.8	1
Long Exit	1,068	05	9.3	4	1,018	05	10.2	6
Short Exit	387	04, 05	8.5	0	231	05	10.9	0
*Turn back	367	99	11.7	0	268	99	11.7	0

**No single cut turnback obs time from yrs 00-05*

TABLE A2- 26
Emsworth Processing Time Information
Main Chamber Double Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	283	05	31.3	0	280	05	24.9	0
Short Approach	209	02-05	18.3	0	239	02-05	15.0	0
Entry	321	05	17.3	0	324	05	15.3	0
Chambering	305	05	80.2	0	313	05	73.7	0
Long Exit	260	05	23.7	0	264	05	28.8	1
Short Exit	313	02-05	23.4	0	330	02-05	26.1	0
Turn back	321	05	14.1	0	323	05	13.5	1

TABLE A2- 27
Emsworth Processing Time Information
Aux Chamber One Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	330	05	15.7	5	319	05	12.5	1
Short Approach	206	99-05	7.4	0	209	97-05	5.5	0
Entry	360	05	4.3	0	339	05	3.4	0
Chambering	360	05	12.7	0	339	05	9.4	0
Long Exit	338	05	4.1	0	324	05	3.8	0
Short Exit	215	98-05	4.1	0	201	98-05	3.2	0
Turn back	213	97-05	8.6	2	171	97-05	9.0	3

TABLE A2- 28
Emsworth Processing Time Information
Aux Chamber Two Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
***Long Approach**	49	03,04	23.0	0	41	03,04	19.5	0
***Short Approach**	73	03,04	7.9	0	75	03,04	10.5	0
***Entry**	122	03,04	11.7	0	117	03,04	10.8	0
****Chambering**	27	97-01,06	77	0	31	97-01	55.4	0
***Long Exit**	41	03,04	17.1	0	44	03,04	16.9	0
***Short Exit**	81	03,04	11.4	0	73	03,04	12.4	0

No Emsworth Aux 2-5 cut data for yrs 02-05

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*

***Emsworth's Chambering Aux 2-Cut Times*

TABLE A2- 29
Emsworth Processing Time Information
Aux Chamber Three Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
***Long Approach**	49	03,04	23.0	0	41	03,04	19.5	0
***Short Approach**	73	03,04	7.9	0	75	03,04	10.5	0
***Entry**	122	03,04	11.7	0	117	03,04	10.8	0
****Chambering**	49	97-01,06	95.5	0	40	97-01,06	85.9	0
***Long Exit**	41	03,04	17.1	0	44	03,04	16.9	0
***Short Exit**	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*

***Emsworth's Chambering Aux 3-Cut Times*

TABLE A2- 30
Emsworth Processing Time Information
Aux Chamber Four Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	35	97-01,06	148.5	0	27	97-01,06	126.4	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*
***Emsworth's Chambering Aux 4-Cut Times*

TABLE A2- 31
Emsworth Processing Time Information
Aux Chamber Five Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	65	97-01,06	186.4	0	57	97-01,06	174.0	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*
**Emsworth's Chambering Aux 5-Cut Times*

2.5.2.2 Dashields Processing Times

TABLE A2- 32
Dashields Processing Time Information
Main Chamber Single Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	1,072	05	23.8	5	1,081	05	20.5	2
*Short Approach	224	05	10.0	0	235	05	8.6	0
Entry	1,299	05	13.3	2	1,318	05	11.9	0
*Chambering	1,301	05	10.4	0	1,314	05	10.0	4
Long Exit	1,091	05	13.4	6	1,118	05	12.9	2
Short Exit	204	05	13.5	0	370	05,06	11.9	0
*Turn back	223	05	9.9	1	234	05	10.4	1

**Rounding to 10 min (SA, CH, TB)*

TABLE A2- 33
Dashields Processing Time Information
Main Chamber Double Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	285	05	29.6	0	294	05	27.4	0
Short Approach	331	02-06	14.9	0	292	00-06	13.2	0
Entry	327	05	18.5	0	321	05	18.0	0
Chambering	316	05	60.4	0	313	05	55.8	0
Long Exit	267	05	26.6	0	257	05	28.7	1
Short Exit	317	03-06	26.2	0	294	03-06	24.6	0
Turn back	327	05	11.3	0	321	05	10.7	0

TABLE A2- 34
Dashields Processing Time Information
Aux Chamber One Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	236	05	17.7	1	228	05	14.6	2
Short Approach	230	97-06	5.3	0	225	97-06	4.3	0
Entry	247	05	5.5	2	235	05	4.8	0
Chambering	249	05	6.9	0	234	05	6.9	1
Long Exit	233	05	5.9	5	229	05	5.7	3
Short Exit	249	97-06	5.1	0	247	97-06	4.9	0
Turn back	194	97-06	6.8	1	190	97-06	6.8	1

TABLE A2- 35
Dashields Processing Time Information
Aux Chamber Two Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	14	9,00,02,06	47.3	0	11	9,02,05,06	52.2	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*

***Montgomery's Chambering Aux 2-Cut Times*

TABLE A2- 36
Dashields Processing Time Information
Aux Chamber Three Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	10	03,04,06	94.5	0	17	99,02,05	98.2	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*

***Dashields Upstream and Montgomery's Downstream Chambering Aux 3-Cut Times*

TABLE A2- 37
Dashields Processing Time Information
Aux Chamber Four Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	18	99,06	132.7	0	17	02,06	131.0	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*

***Montgomery Aux 4-cut chambering times*

TABLE A2- 38
Dashields Processing Time Information
Aux Chamber Five Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	21	03,04,06	165.0	0	23	03,04,06	148.7	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*

***Dashields Chambering Aux 5-Cut Times*

2.5.2.3 Montgomery Processing Times

TABLE A2- 39
Montgomery Processing Time Information
Main Chamber Single Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	1,101	05	21.4	0	1,042	05	21.4	0
Short Approach	242	05	13.0	0	263	05	10.9	0
Entry	1,342	05	14.0	1	1,303	05	11.9	2
Chambering	1,336	05	13.2	7	1,303	05	11.7	2
Long Exit	1,099	05	13.0	6	1,066	05	11.7	0
Short Exit	238	05	12.7	0	239	05	12.4	0
*Turn back	241	05	11.8	0	263	05	11.1	0

TABLE A2- 40
Montgomery Processing Time Information
Main Chamber Double Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	306	05	28.9	0	327	05	25.9	2
Short Approach	329	03-06	16.7	0	334	02-06	14.9	0
Entry	388	05	20.2	0	402	05	17.6	0
Chambering	378	05	69.5	0	391	05	64.2	0
Long Exit	304	05	29.1	1	309	05	28.3	1
Short Exit	377	03-06	25.3	0	364	03-06	26.6	0
Turn back	388	05	15.7	0	402	05	13.6	0

TABLE A2- 41
Montgomery Processing Time Information
Aux Chamber One Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	286	05	13.5	0	292	05	13.6	1
Short Approach	181	97-06	4.9	0	189	97-06	4.8	0
Entry	296	05	5.4	2	301	05	5.1	4
Chambering	298	05	9.6	0	305	05	9.6	0
Long Exit	287	05	5.1	0	288	05	4.6	3
Short Exit	179	97-06	4.9	0	178	97-06	4.7	0
Turn back	153	97-06	10.4	0	155	97-06	9.3	0

TABLE A2- 42
Montgomery Processing Time Information
Aux Chamber Two Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	14	99,00,02,06	47.3	0	11	99,02,05,06	52.2	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*
No Emsworth Aux 2-5 cut data for yrs 02-05
***Montgomery's Chambering Aux 2-Cut Times*

TABLE A2- 43
Montgomery Processing Time Information
Aux Chamber Three Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	21	99,00,02,05,06	92.7	0	17	99,02,05	98.2	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*
***Montgomery's Chambering Aux 3-Cut Times*

TABLE A2- 44
Montgomery Processing Time Information
Aux Chamber Four Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	18	99,06	132.7	0	17	02,06	131.0	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*
***Montgomery's Chambering Aux 4-Cut Times*

TABLE A2- 45
Montgomery Processing Time Information
Aux Chamber Five Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	49	03,04	23.0	0	41	03,04	19.5	0
*Short Approach	73	03,04	7.9	0	75	03,04	10.5	0
*Entry	122	03,04	11.7	0	117	03,04	10.8	0
**Chambering	80	99,00,02,06	169.2	0	88	,00,02,05,06	168.1	0
*Long Exit	41	03,04	17.1	0	44	03,04	16.9	0
*Short Exit	81	03,04	11.4	0	73	03,04	12.4	0

**Approaches, entry, and exit times are the average of Montgomery & Dashields Aux (2-5) cuts*
***Montgomery's Chambering Aux 5-Cut Times*

2.5 3 Shipment List Calibration, Future Fleet

After the input data is prepared, the next step in running WAM is shipment list calibration. Calibration is a process that fine tunes the input files so that generated shipment lists closely match the real world fleet. Calibration is necessary for two reasons. First, WAM uses two data sources, the LPMS data and the WCSC data, to create the shipment lists, and the data sources are not perfectly compatible. These two data sources are used together to create shipment lists that reflect the actual fleet at a lock. Second, the shipment list generator generates tows that have only one barge type instead of two or more barge types in a single tow. It should be noted that every shipment list contains the same number of recreational craft and lightboats as measured by LPMS

Before shipment lists can be used for WAM production runs, they must first be calibrated to insure that they truly reflect the fleet observed at the lock of interest. Shipment lists are calibrated by manually adjusting the LPMS summary data file until the generated fleet matches the observed fleet. The statistics most often adjusted are the number of empty barges, by barge type, and barges per tow percentages for each barge type. The target values for tons/loaded barge were taken directly from WCSC data. The target values for number of tows, number of loaded barges, and number of empty barges were taken directly from LPMS data. The other remaining values were calculated based on the values taken directly from WCSC and LPMS.

Table A2-46 – A2-48 shows the statistics used when calibrating the shipment lists for EDM existing fleet. The values shown in the WAM Runs column are the averages of ten different WAM shipment lists. Calibration is considered complete when the WAM Runs are within 3% of the Target values for all statistics, regardless of direction.

2.5 3.1 Emsworth Calibration

TABLE A2- 46
Emsworth Shipment List Calibration

	Target 2005	10 WAM Runs	% Difference
Tons (calc)	21,390	21,375	***-0.1%***
Up	11,397	11,116	***-2.5%***
Down	9,992	10,259	***2.7%***
		-	
Tows (LPMS)	3,865	3,969	***2.7%***
Up	1,949	2,064	***5.9%***
Down	1,916	1,905	***-0.6%***
		-	
Tons/Tow (calc)	5,534	5,386	***-2.7%***
Up	5,848	5,386	***-7.9%***
Down	5,215	5,386	***3.3%***
		-	
Barges (calc)	23,107	23,118	***0.0%***
Up	11,591	11,400	***-1.7%***
Down	11,516	11,719	***1.8%***
		-	
Loaded Barges (LPMS)	15,020	15,022	***0.0%***
Up	7,893	7,704	***-2.4%***
Down	7,127	7,318	***2.7%***
		-	
Empty Barges (LPMS)	8,087	8,097	***0.1%***
Up	3,698	3,696	***-0.1%***
Down	4,389	4,401	***0.3%***
		-	
Percent Empty (calc)	35.0%	35.0%	***0.0%***
Up	31.9%	32.4%	***0.5%***
Down	38.1%	37.6%	***-0.6%***
		-	
Tons/Loaded Barge (WC)	1,424	1,423	***-0.1%***
Up	1444	1,443	***-0.1%***
Down	1402	1,402	***0.0%***
		-	
Barges/Tow	5.98	5.83	***-2.6%***
Up	5.95	5.52	***-7.1%***
Down	6.01	6.15	***2.4%***

2.5 3.2 Dashields Calibration

TABLE A2- 47
Dashields Shipment List Calibration

	Target	10 WAM Runs	% Difference
Tons (calc)	22,227	22,192	-0.16%
Up	12,232	12,204	-0.23%
Down	9,995	9,988	-0.07%
		-	
Tows (LPMS)	3,750	3,830	2.13%
Up	1,876	1,912	1.89%
Down	1,874	1,919	2.37%
		-	
Tons/Tow (calc)	5,927	5,794	-2.24%
Up	6,521	6,385	-2.08%
Down	5,333	5,206	-2.38%
		-	
Barges (calc)	24,949	24,900	-0.20%
Up	12,419	12,368	-0.41%
Down	12,530	12,532	0.01%
		-	
Loaded Barges (LPMS)	15,933	15,915	-0.11%
Up	9,021	9,004	-0.19%
Down	6,912	6,911	-0.01%
		-	
Empty Barges (LPMS)	9,016	8,985	-0.35%
Up	3,398	3,365	-0.98%
Down	5,618	5,620	0.04%
		-	
Percent Empty (calc)	36.1%	36.1%	-0.05%
Up	27.4%	27.2%	-0.16%
Down	44.8%	44.8%	0.01%
		-	
Tons/Loaded Barge (WC)	1,395	1,394	-0.05%
Up	1,356	1,355	-0.04%
Down	1,446	1,445	-0.06%
		-	
Barges/Tow	6.65	6.50	-2.28%
Up	6.62	6.47	-2.25%
Down	6.69	6.53	-2.30%

2.5 3.1 Montgomery Calibration

TABLE A2- 48
Montgomery Shipment List Calibration

	Target 2005	WAM Runs	% Difference
Tons (calc)	23,953	23,890	-0.26%
Up	13,548	13,447	-0.75%
Down	10,405	10,443	0.36%
Tows (LPMS)	4,047	3,976	-1.75%
Up	2,030	2,028	-0.09%
Down	2,017	1,948	-3.43%
		-	
Tons/Tow (calc)	5,919	6,009	1.52%
Up	6,674	6,630	-0.65%
Down	5,159	5,362	3.94%
Barges (calc)	25,492	25,456	-0.14%
Up	12,707	12,633	-0.58%
Down	12,785	12,823	0.30%
Loaded Barges (LPMS)	16,114	16,072	-0.26%
Up	9,273	9,205	-0.73%
Down	6,841	6,867	0.38%
Empty Barges (LPMS)	9,378	9,384	0.07%
Up	3,434	3,428	-0.17%
Down	5,944	5,956	0.20%
Percent Empty (calc)	36.8%	36.9%	0.2%
Up	27.0%	27.1%	0.4%
Down	46.5%	46.4%	-0.1%
Tons/Loaded Barge (WC)	1,486	1,486	0.00%
Up	1,461	1,461	-0.01%
Down	1,521	1,521	-0.02%
Barges/Tow	6.30	6.40	1.65%
Up	6.26	6.23	-0.49%
Down	6.34	6.58	3.87%

2.5.4 Processing Time & Delay Validation. Future Fleet

After the shipment list is calibrated, the next step is to validate WAM. Validation ensures that WAM results reasonably reproduce actual base year processing and delay times. Fifty WAM runs were made at base year traffic levels, and the average processing and delay times for those runs was then compared to actual target processing and delay times taken directly from LPMS data. **Table A2-49- A2-51** shows how well WAM reproduces these times.

2.5.4.1 Emsworth Validation

TABLE A2- 49
Emsworth Processing Time Validation

Statistic	Target	Wam Simulations Mean Value	Std Dev.	Pct Diff.
Commercial Transit Performance (min)				
Tow Average Processing	67.7	67.7	0.6	0.0%
Tow Average Delay	34.7	43.2	2.5	24.5%
Tow Average Transit Time	102.4	110.9	2.4	8.3%
Validation Down Time				
Number of Events, Main	42	42	-	0.0%
Number of Events, Aux	18	18	-	0.0%
Total Minutes, Main	4,318	4,318	-	0.0%
Total Minutes, Aux	29,534	29,533	-	0.0%
Percent of Year Closed, Main	0.82%	0.82%	-	0.0%
Percent of Year Closed, Aux	5.62%	5.62%	-	0.0%

2.5.4.2 Dashields Validation

TABLE A2- 50
Dashields Processing Time Validation

Statistic	Target	Wam Simulations Mean Value	Std Dev.	Pct Diff.
Commercial Transit Performance (min)				
Tow Average Processing	65.8	64.8	0.4	-1.5%
Tow Average Delay	28.1	43.2	2.5	53.7%
Tow Average Transit Time	93.9	108.0	2.8	15.0%
Validation Down Time				
Number of Events, Main	32	32		0.0%
Number of Events, Aux	31	31		-0.3%
Total Minutes, Main	6,011	6,009		0.0%
Total Minutes, Aux	17,010	16,999		-0.1%
Percent of Year Closed, Main	1.14%	1.14%		0.0%
Percent of Year Closed, Aux	3.24%	3.23%		-0.1%

2.5.4.3 Montgomery Validation

TABLE A2- 51
Montgomery Processing Time Validation

Statistic	Target	Wam Simulations Mean Value	Std Dev.	Pct Diff.
Commercial Transit Performance (min)				
Tow Average Processing	69.7	69.8	0.6	0.1%
Tow Average Delay	40.2	63.2	13.9	57.3%
Tow Average Transit Time	109.9	133.0	14.2	21.0%
Validation Down Time				
Number of Events, Main	40	40	-	0.0%
Number of Events, Aux	13	13	-	0.0%
Total Minutes, Main	9,270	9,265	-	-0.1%
Total Minutes, Aux	16,658	16,659	-	0.0%
Percent of Year Closed, Main	1.76%	1.76%	-	-0.1%
Percent of Year Closed, Aux	3.17%	3.17%	-	0.0%

2.5.5 Barge Types, Future Fleet

Tow size is a key input determinant when estimating lock capacity. Tow size is determined by the number and type of barges being pushed. This study models the future fleet scenario, based on the "*Probable Size Of Future Barge Fleet At Emsworth, Dashields And Montgomery Locks*", Linare Consulting, dated 20 August 2008. The future fleet represents the changes in barge types and sizes that are expected to occur in the year 2028 due to the replacement of the regular, shorter (175' x 26') barges, and narrower, stumbos (195' x 26') with the longer and wider ,jumbo (195' x 35') barges. Barge loadings were adjusted in the Waterborne Commerce Statistic Center (WCSC) shipment list input file to reflect these changes in barge types. Capacity curves were developed for the Existing Condition and the With Project Condition alternatives using this future fleet. **Table A2-52** through **A2-54** shows the seven barge types, barge dimensions, number of barges, percent loaded, and barges per tow that represent EDM's future fleet.

2.5.5.1 Emsworth Barges

TABLE A2- 52
Emsworth Barge Data 2005 with Future Fleet

Type	Dimensions	Number of Barges	Percent Loaded	Barges per Tow
Sand Flat	135 x 27	1,347	48.6%	4.9
Jumbo	195 x 35	18,528	68.6%	7.4
Jumbo Tanker	195 x 35	1,051	50.1%	1.7
147' Tanker	147 x 52	261	50.2%	1.5
264' Tanker	264 x 50	20	90.0%	2.0
290' Tanker	290 x 54	157	52.2%	2.1

2.5.5.2 Dashields Barges

TABLE A2- 53
Dashields Barge Data 2005 with Future Fleet

Type	Dimensions	Number of Barges	Percent Loaded	Barges per Tow
Sand Flat	135 x 27	3070	53.0%	8.1
Jumbo	195 x 35	19980	68.3%	7.4
Jumbo Tanker	195 x 35	1237	50.2%	2.2
147' Tanker	147 x 52	158	54.4%	1.5
175' Tanker	175 x 54	13	46.2%	1.9
264' Tanker	264 x 50	31	64.5%	1.7
290' Tanker	297 x 54	302	54.6%	1.9

2.5.5.3 Montgomery Barges

TABLE A2- 54
Montgomery Barge Data 2005 with Future Fleet

Type	Dimensions	Number of Barges	Percent Loaded	Barges per Tow
Sand Flat	135 x 27	1,755	50.1%	5.4
Jumbo	195 x 35	21,601	67.2%	8.4
Jumbo Tanker	195 x 35	1,341	51.0%	1.6
147' Tanker	147 x 52	164	53.0%	1.5
175' Tanker	175 x 54	4	0.0%	1.3
264' Tanker	264 x 50	36	69.4%	1.9
290' Tanker	297 x 54	389	53.2%	1.7

2.5.6 Identification of Optimal Lockage Policy

After input preparation, shipment list calibration, and processing and delay time validation, the next step is to determine the most efficient lockage policy. This is done to satisfy Corps regulation ER-1105-2-100 section II, E-9.c.a which states in part "Assume that all reasonably expected non-structural practices …. including … lockage policies are implemented at the appropriate time." Two lockage policies were evaluated at EDM locks, FIFO (First-In, First-Out) and 6-up/6-down lockage policy. Lock personnel indicate that only single cut tows are allowed in the auxiliary chamber when the main chamber is operational. Therefore, multi-cut auxiliary chamber policies were not considered as part of the optimal lockage policy identification process. Refer to the *Ohio River Main Stem System Study System Investment Plan Capacity Attachment*, dated October 2003.

To determine the best or "optimal" lockage policy, 10 WAM runs were made at very high traffic levels for each lockage policy. The 'optimal' lockage policy is the policy that results in the highest tonnage level with the lowest processing time at maximum lock utilization. **Table A2-55** through **A2-57** shows the lockage policy with the highest tonnage level and lowest transit time for the Existing Condition alternatives at EDM.

2.5.6.1 Emsworth Lockage Policy

TABLE A2- 55
Emsworth Existing Condition Optimal Lockage Policy

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth Allow 1 Cut in Aux FIFO	48,369	1.1	259	260
Emsworth Allow 1 Cut in Aux 6U-6D	48,139	1.1	270	271

**Optimal Lockage Policy: 1 Cut FIFO*

2.5.6.2 Dashields Lockage Policy

TABLE A2- 56
Dashields Existing Condition Optimal Lockage Policy

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields Allow 1 Cut in Aux 6U-6D	51,276	0.8	180	181
Dahields Allow 1 Cut in Aux FIFO	50,161	0.9	237	238

**Optimal Lockage Policy: 1 Cut 6U-6D*

2.5.6.3 Montgomery Lockage Policy

TABLE A2- 57
Montgomery Existing Condition Optimal Lockage Policy

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery Allow 1 Cut in Aux FIFO	50,487	1.1	469	470
Montgomery Allow 1 Cut in Aux 6U-6D	50,380	1.0	471	472

**Optimal Lockage Policy: 1Cut FIFO*

2.5.7 Chamber Service Rates & Tow Arrival Rescheduling

After the shipment list calibration, processing time validation and verification, and optimal policy selection, the service rates in tows per day or queue limits are determined for both the main and auxiliary chambers. To determine queue limits for each chamber, one of the locks is completely shut down for the entire year (365 days) while the other lock remains in full operation. The main chamber queue limit (tows per day) is determined by shutting down the auxiliary chamber for an entire year while the auxiliary chamber queue limit is determined b shutting down the main chamber for an entire year. Using a high traffic escalator to build up the queue, 10 WAM runs are made for each chamber, and the number of tows statistic are averaged to determine the lock's service policy by chamber. **Tables A2-58** through **A2-60** shows the results of these WAM runs.

Tow arrival rescheduling is used in order to limit the number of tows that are allowed to arrive at the lock project during main chamber closure events. During long closure events, some traffic reschedules so that it ships before the closure, some reschedules after the closure, and some cannot be rescheduled so it suffers the high delays. Queue limits and chamber service rates are used to determine the maximum number of tow arrivals per day during chamber downtimes. Tow arrival rescheduling will decrease tow arrivals by rescheduling tow arrivals around (either before or after) long disruptive closures, and, thus, will help to reduce delays. For example, the use of the queue limit during a closure will shift the capacity curve to the right, or increase the capacity. This is due to tow arrival rescheduling at the projects which results in lower tow delays when queue limits are enforced. If queue limits are not used, the delays will continue to build until the closure event ends. This continued simulated buildup would result in simulations that overestimate the delay caused by long disruptive closures.

Arrival rescheduling is used only for the durations 18, 30, 45, 60, & 90 days because the queue limit settings has a trigger time of 16 days. This means that the 15-day closure will not cause rescheduling, but the 18, 30, 45, 60, 90 day closures will if the arrival rate exceeds the service rate.

The trigger time is associated with the duration of closure that MAY cause a shipper/carrier to reschedule. Short duration closures are essentially ignored by shippers/carriers. Longer duration closures MAY cause a rescheduling. For example, if the trigger time is 16 days, qlimit will not run for closure durations of 16 days or less. It will run for durations of 17 days or more.

2.5.7.1 Emsworth Tows/Day

TABLE A2- 58
Emsworth Existing Condition Service Rates

RunID	Tows/Day
Emsworth Existing Auxiliary Chamber	5.31
Emsworth Existing Main Chamber	19.7

2.5.7.2 Dashields Tows/Day

TABLE A2- 59
Dashields Existing Condition Service Rates

RunID	Tows/Day
Dashields Existing Auxiliary Chamber	7.94
Dashields Existing Main Chamber	28.7

2.5.7.3 Montgomery Tows/Day

TABLE A2- 60
Montgomery Existing Condition Service Rates

RunID	Tows/Day
Montgomery Existing Condition Aux Chamber	5.45
Montgomery Existing Condition Main Chamber	19.7

2.5.8 Major Maintenance Downtimes

Major maintenance events are long duration, greater than a day, and usually scheduled, chamber closures. These events were modeled in WAM to facilitate the analysis of various maintenance or major rehabilitation strategies. **Table A2-61** shows the major maintenance closure durations modeled foe the three locks in this study. These durations were selected to coincide with the consequences of reliability related failures, projected future major maintenance policies, or to compute individual chamber capacities.

Closure durations of 12, 15, 18, 30, 45, 60 and 90 days, were modeled using arrival rescheduling. Historic LPMS data show that some tows reschedule their arrivals around long disruptive closures. If circumstances permit, the shippers and carriers work together to avoid using a facility by scheduling shipments either before or after the closure. Major lock maintenance activities are announced by the Corps two years before the closure in order to enable maximum possible rescheduling.

TABLE A2- 61
EDM Closure Scenarios Analyzed
Existing Condition

Closure Duration (days)/Chamber
None
1-day Main
3-days Main
5-days Main
10-days Main
12-days Main*
15-days Main*
18-days Main*
30-days Main*
45-days Main*
60-days Main*
90-days Main*
120-days Main
180-days Main
210-days Main
240-days Main
365-days Main
1-day Auxiliary
3-days Auxiliary
5-days Auxiliary
10-days Auxiliary
15-days Auxiliary*
30-days Auxiliary*
45-days Auxiliary*
60-days Auxiliary*
90-days Auxiliary*
180-days Auxiliary
210-days Auxiliary
365-days Auxiliary
19-days Main ½ speed
30-days Main ½ speed
45-days Main ½ speed
60-days Main ½ speed
90-days Main ½ speed
150-days River
240-days River
365-days River

*Arrival Rescheduling used

2.6 Existing Condition Project Results

Full capacity curves were developed .at Emsworth, Dashields, and Montgomery for the Existing Condition for the closure scenarios listed in **Tables A2-61.** The processing time and capacities for each of the scenarios are shown in **Tables A2-64, A2-65,** and **A2-66** for EDM, respectively.

At Emsworth, the processing times for the 360' auxiliary chamber, 259.47 minutes, is 3.5 times as much as the 600' main chamber processing time, 74.37 minutes, **Table A2-62**. The 600' main chamber capacity operating by itself has a much larger capacity, or 42.9 Mtons, almost four times as much capacity, as the smaller 360' auxiliary chamber, which is only 11.1 Mtons, see **Table A2-63**. This is because the vast majority of the tows that transit the smaller auxiliary when the main chamber is inoperable, require multi-cut lockages (2-5 cuts lockages), resulting in higher processing and delay times. At Full operation (both the 600' main and 360' auxiliary existing chambers operating together), Emsworth's capacity is 48.7 Mtons.

At Dashields, the processing times for the 360' auxiliary chamber, 162.23 minutes, is 3.0 times as much as the 600' main chamber processing time, 55.22 minutes, **Tables A2-62**. The 600' main chamber capacity operating by itself is 48.1 Mtons, or about 3.5 times as much capacity as the smaller 360' auxiliary chamber which is only 14.3 Mtons. The two chambers operating together have a capacity of 51.5 Mtons, **Table A2-63**. Again, the main and auxiliary chamber capacities largely differ because of the increase in transit (processing and delay) times due to multi-cut lockages through the auxiliary chamber.

Montgomery's capacity is 50.3 Mtons at full operation, while the 600' main chamber capacity operating by itself is 43.2 Mtons, and the 360' auxiliary chamber is only 11.5 Mtons, **Table A2-63**. The processing times for the 360' auxiliary chamber, 254.3 minutes, is 3.6 times as much as the 600' main chamber processing time, or 71.1 minutes, **Table A2-62**.

2.6.1 EDM Project Processing Times

Processing times are another major determinant of project capacity. **Table A2-63** below shows the processing times for each lock studied.

TABLE A2- 62
Modeled Processing Times at Capacity
(minutes/tow)

Lock	Full Operation	Main Chamber	Auxiliary Chamber
Emsworth	69.1	74.4	259.5
Dashields	58.8	61.5	181.9
Montgomery	66.1	71.1	254.3

2.6.2 EDM Project Capacities

Table A2-64 shows the Existing Condition project capacities determined during this study.

TABLE A2- 63
EDM Existing Condition Project Capacities
(Mtons)

Lock	Full Operation	Main Chamber	Auxiliary Chamber
Emsworth	48.7	42.9	11.1
Dashields	51.5	48.1	14.3
Montgomery	50.3	43.2	11.5

2.6.2.1 Emsworth WOPC Capacities & Transit Times

TABLE A2- 64
Emsworth WOPC Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	48.7	69.08
1-day Main Chamber Closed	48.5	69.22
3-days Main Chamber Closed	48.2	69.66
5-days Main Chamber Closed	48.0	69.88
10-days Main Chamber Closed	47.3	70.63
12-days Main Chamber Closed	46.9	70.59
15-days Main Chamber Closed	46.6	71.03
18-days Main Chamber Closed	46.2	71.76
30-days Main Chamber Closed	44.8	73.55
45-days Main Chamber Closed	43.3	75.81
60-days Main Chamber Closed	41.7	78.20
90-days Main Chamber Closed	38.7	83.43
120-days Main Chamber Closed	16.5	110.20
180-days Main Chamber Closed	13.1	149.23
210-days Main Chamber Closed	12.4	166.95
240-days Main Chamber Closed	12.0	185.79
365-days Main Chamber Closed	11.1	259.47
1-day Auxiliary Chamber Closed	48.7	68.92
3-days Auxiliary Chamber Closed	48.7	69.00
5-days Auxiliary Chamber Closed	48.6	69.00
10-days Auxiliary Chamber Closed	48.5	69.41
15-days Auxiliary Chamber Closed	48.4	69.31
30-days Auxiliary Chamber Closed	48.2	69.48
45-days Auxiliary Chamber Closed	48.1	69.55
60-days Auxiliary Chamber Closed	47.9	69.94
90-days Auxiliary Chamber Closed	47.7	69.92
180-days Auxiliary Chamber Closed	45.5	71.59
210-days Auxiliary Chamber Closed	44.9	72.04
365-days Auxiliary Chamber Closed	42.9	74.37
19-days Main Chamber ½ speed	46.0	71.89
30-days Main Chamber ½ speed	43.9	73.23
45-days Main Chamber ½ speed	39.4	76.50
60-days Main Chamber ½ speed	33.0	80.07
90-days Main Chamber ½ speed	22.0	92.40
150-days River Closure	28.4	69.12
240-days River Closure	16.9	69.01
365-days River Closure	0.0	0.00

2.6.2.2 Dashields WOPC Capacities & Transit Times

TABLE A2- 65
Dashields WOPC Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	51.5	50.11
1-day Main Chamber Closed	51.3	50.27
3-days Main Chamber Closed	51.1	50.49
5-days Main Chamber Closed	50.8	50.60
10-days Main Chamber Closed	50.1	51.20
12-days Main Chamber Closed	49.8	51.26
15-days Main Chamber Closed	49.4	51.62
18-days Main Chamber Closed	48.8	51.94
30-days Main Chamber Closed	47.6	53.15
45-days Main Chamber Closed	46.1	55.32
60-days Main Chamber Closed	44.6	58.40
90-days Main Chamber Closed	41.7	67.15
120-days Main Chamber Closed	20.0	78.22
180-days Main Chamber Closed	16.5	100.47
210-days Main Chamber Closed	15.9	110.93
240-days Main Chamber Closed	15.4	122.47
330-days Main Chamber Closed	15.1	144.84
365-days Main Chamber Closed	14.3	162.23
1-day Auxiliary Chamber Closed	51.5	50.16
3-days Auxiliary Chamber Closed	51.5	50.20
5-days Auxiliary Chamber Closed	51.4	50.22
10-days Auxiliary Chamber Closed	51.4	50.21
15-days Auxiliary Chamber Closed	51.3	50.19
30-days Auxiliary Chamber Closed	51.3	50.41
45-days Auxiliary Chamber Closed	51.3	50.73
60-days Auxiliary Chamber Closed	51.2	50.80
90-days Auxiliary Chamber Closed	51.1	51.14
180-days Auxiliary Chamber Closed	49.5	52.94
210-days Auxiliary Chamber Closed	49.2	53.33
365-days Auxiliary Chamber Closed	48.1	55.22
15-days Main Chamber ½ speed	49.5	51.62
19-days Main Chamber ½ speed	48.7	52.03
30-days Main Chamber ½ speed	46.7	53.15
45-days Main Chamber ½ speed	42.1	55.32
60-days Main Chamber ½ speed	36.6	58.40
90-days Main Chamber ½ speed	25.8	67.15
150-days River Closure	31.2	58.7
240-days River Closure	18.9	58.3
365-days River Closure	0.0	0.00

2.6.2.3 Montgomery WOPC Capacities & Transit Times

TABLE A2- 66
Montgomery WOPC Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing time (min/tow)
No closures (normal operation)	50.3	66.1
1-day Main Chamber Closed	50.2	66.2
3-days Main Chamber Closed	49.9	66.5
5-days Main Chamber Closed	49.7	66.8
10-days Main Chamber Closed	48.9	67.5
12-days Main Chamber Closed	48.7	67.9
15-days Main Chamber Closed	48.3	68.1
18-days Main Chamber Closed	47.9	68.6
30-days Main Chamber Closed	46.6	70.5
45-days Main Chamber Closed	44.8	73.0
60-days Main Chamber Closed	43.2	75.4
90-days Main Chamber Closed	40.0	81.1
120-days Main Chamber Closed	16.8	107.2
180-days Main Chamber Closed	13.5	148.4
210-days Main Chamber Closed	13.1	164.8
240-days Main Chamber Closed	12.6	182.9
330-days Main Chamber Closed	11.5	244.2
365-days Main Chamber Closed	11.5	254.3
1-day Auxiliary Chamber Closed	50.3	66.1
3-days Auxiliary Chamber Closed	50.3	66.1
5-days Auxiliary Chamber Closed	50.3	66.0
10-days Auxiliary Chamber Closed	50.2	65.9
15-days Auxiliary Chamber Closed	50.1	66.1
30-days Auxiliary Chamber Closed	49.9	66.1
45-days Auxiliary Chamber Closed	49.7	66.6
60-days Auxiliary Chamber Closed	49.5	66.8
90-days Auxiliary Chamber Closed	49.0	67.1
180-days Auxiliary Chamber Closed	46.6	68.5
210-days Auxiliary Chamber Closed	46.1	68.9
365-days Auxiliary Chamber Closed	43.2	71.1
15-days Main Chamber ½ speed	48.2	68.3
19-days Main Chamber ½ speed	47.5	68.6
30-days Main Chamber ½ speed	45.2	70.7
45-days Main Chamber ½ speed	40.0	73.5
60-days Main Chamber ½ speed	33.8	77.5
90-days Main Chamber ½ speed	22.4	89.9
150-days River Closure	28.9	65.9
240-days River Closure	17.2	65.7
365-days River Closure	0.0	0.0

2.6.3 Capacity Curves

Capacity is a useful number when making simple comparisons between locks. However, the navigation economic studies do not use the capacity number. Instead, the economic analysis uses capacity curves. Capacity curves are used because they define the relationship between tonnage processed and expected transit time over a range of tonnage levels. This way, the economic model can determine expected transit time for any given tonnage between zero and capacity.

Figures A2-23, A2-24, and **A2-25** shows the capacity curve and other information for EDM L&D, Existing Condition, Full Operation scenario. This capacity curve is used to represent a year where only random downtime occurs. The curve is developed by running WAM at 27 different traffic levels, 50 different runs per level. Therefore, 1350 WAM runs were made to create one curve. The curve connects the averages at tonnage level.

Figures A2-23, A2-24, and **A2-25** also shows a vertical line where the curve goes asymptotic. This value is the capacity for the full operation (no closure scenario) shown in **Table A2-64 through A2-66** at EDM. The capacity is the tonnage that corresponds with a transit time of 200 hours. The 200 hour transit time is an arbitrary value. In this reach of the curve, the different in tonnage between say, 100 hours and 300 hours is very small. At Emsworth, Dashields, and Montgomery, the WOPC capacity was 48.7MTons, 51.5MTons, and 50.3MTons, respectively.

Figures A2-23, A2-24, and **A2-25** also shows the relevant range of traffic demand for each of the three projects. This is the range of tonnage projected to use EDM locks over the study period. The economic model uses this range of the curve when processing traffic at EDM. The relevant range of traffic at Emsworth locks is 17.3 Mtons (lowest expected demand), through 60.7 Mtons (highest expected demand), during the period of analysis (2018 to 2068). The relevant range of traffic at Dashields locks is 17.9 Mtons through 61.8 Mtons. The relevant range of traffic at Montgomery locks is 19.5 Mtons through 66.6 Mtons. Refer to the *Economics Appendix Attachment 3 Traffic Demand Forecasts* for a detailed discussion.

FIGURE A2- 23
Emsworth WOPC Capacity Curve

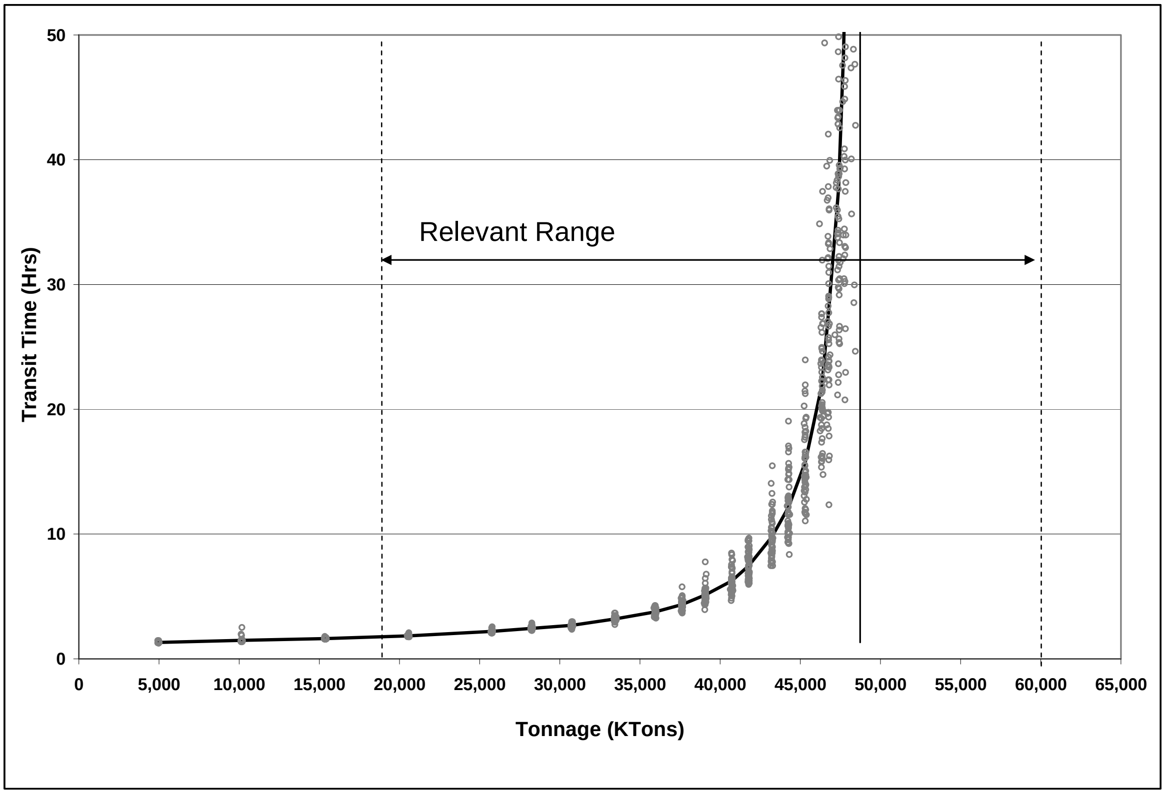


FIGURE A2- 24
Dashields WOPC Capacity Curve

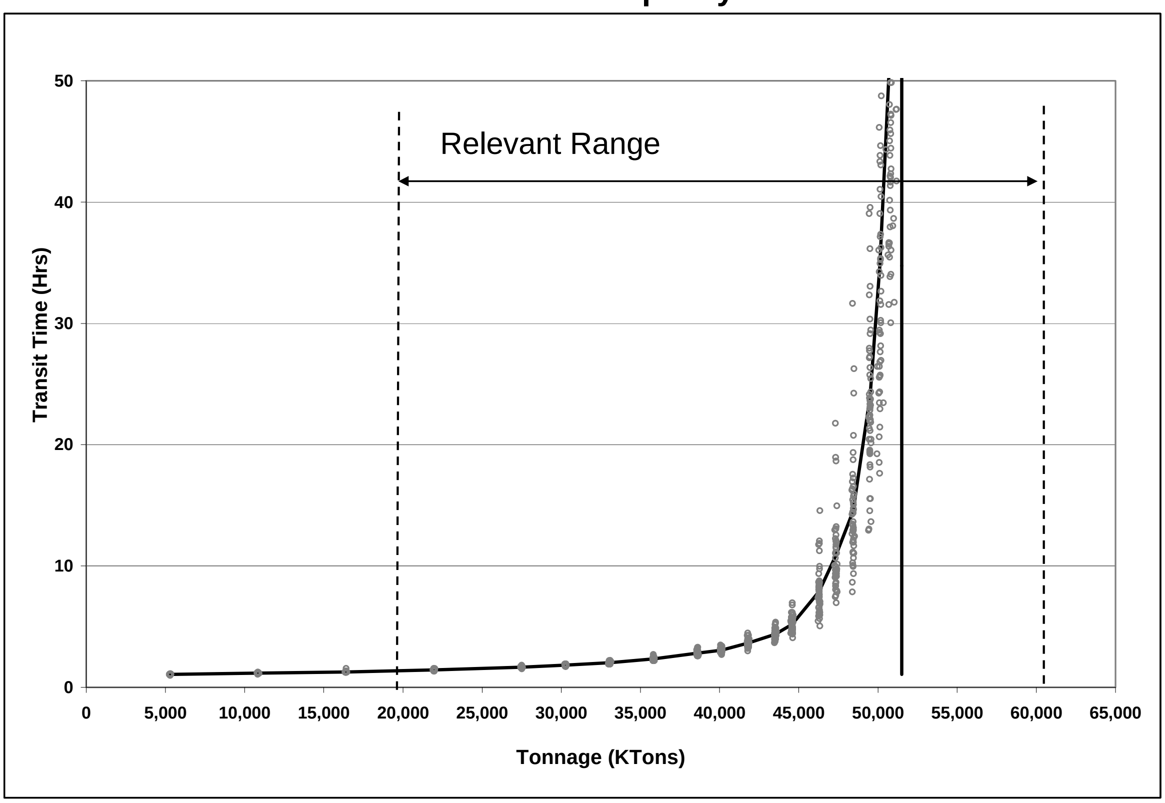
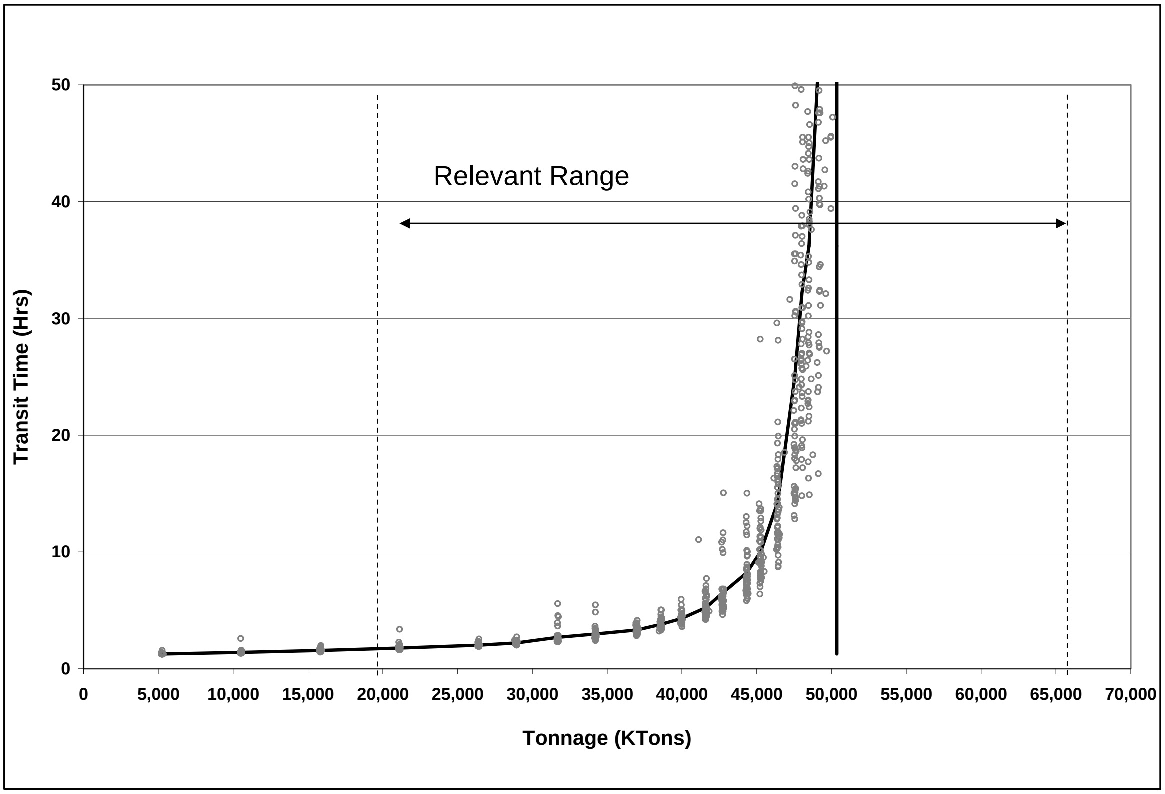


FIGURE A2- 25
Montgomery WOPC Capacity Curve



Figures A2-26, A2-30, and **A2-34** show EDM's Existing Condition main chamber capacity curves. These Figures show a very large difference in the capacity and shapes of the curves between the 90 and 120 closures. The 90 day closure is a scheduled event using a queue limit while the 120 day closure is an unscheduled event without a queue limit. The scheduled event means the shipper is notified in advance. The unmodified downtime file is automatically adjusted at the beginning of the WAM simulation (and after the 30 day warm-up period) with a record (row) on day 1 that there will be a closure 90 days from now, as in the real world, shippers are notified through navigation notices of scheduled chamber closures due to maintenance and repairs. For an unscheduled event there is no advance notice. The queue limit limits the number of tows that arrives at the project during chamber closures. Shippers reschedule their shipments around these long closure events. For example, a 90 day scheduled closure event using a queue limit versus the same 90 day unscheduled closure event without using a queue limit, will result in a higher capacity (e.g., the capacity curve will shift to the right). This is due to lower tow delays at the project using a queue limit. That is the tow arrivals are limited based on the chamber service policy (number of tows the chamber can service per day).If the closure duration is increased by 30 days (90 to 120 days). A 120 day unscheduled closure event versus a 90 day scheduled closure event using a queue limit will shift the capacity curve significantly to the left due to 3 factors, the increase in the closure duration (30 day increase), the removal of the queue limit, and the removal of the shipper's advance notice of the closure event from the downtime file. Thus, the removal of the queue limit and the advance notice for the 120 day closure are the reason for the large difference in the shape of the capacity curve. The delays are significantly higher for the 120 day closure because the tows are allowed to build up at the project (e.g., no queue limit), thus, the capacity is much lower for the 120 day closure.

FIGURE A2- 26
Emsworth Existing Condition Main Chamber Curve Family

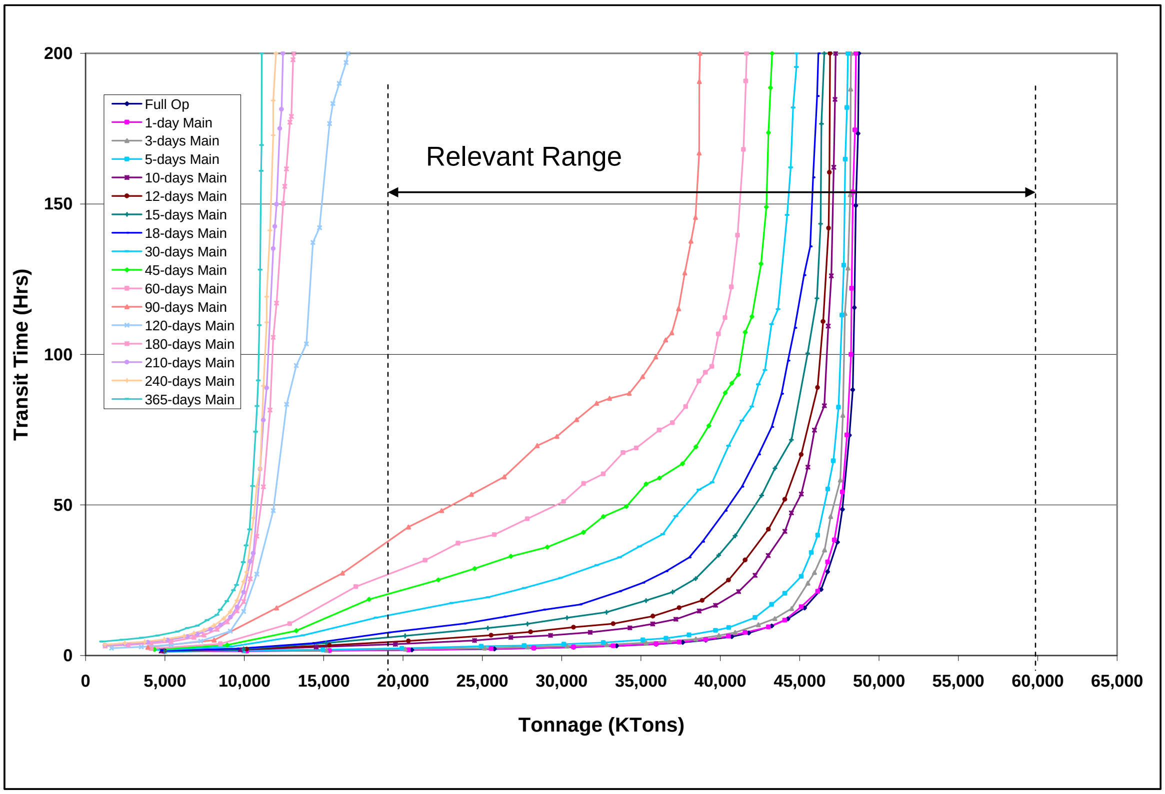


FIGURE A2- 27
Emsworth Existing Condition Auxiliary Chamber Curve Family

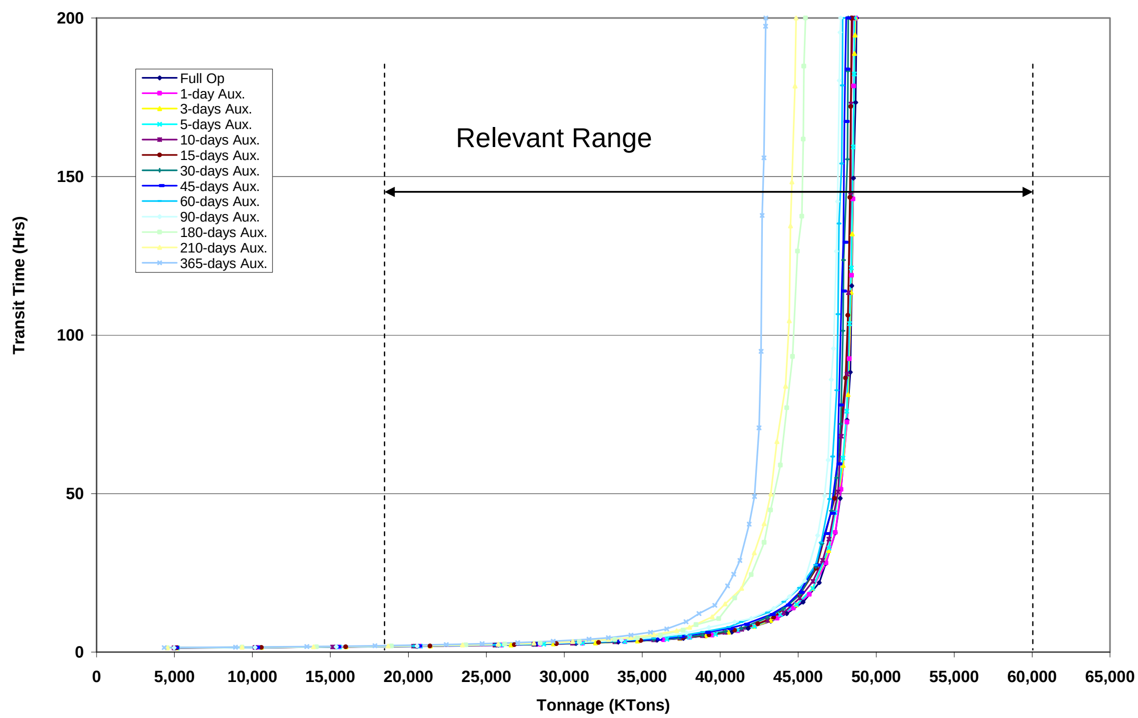


FIGURE A2- 28
Emsworth Existing Main Chamber Half-Speed Curve Family

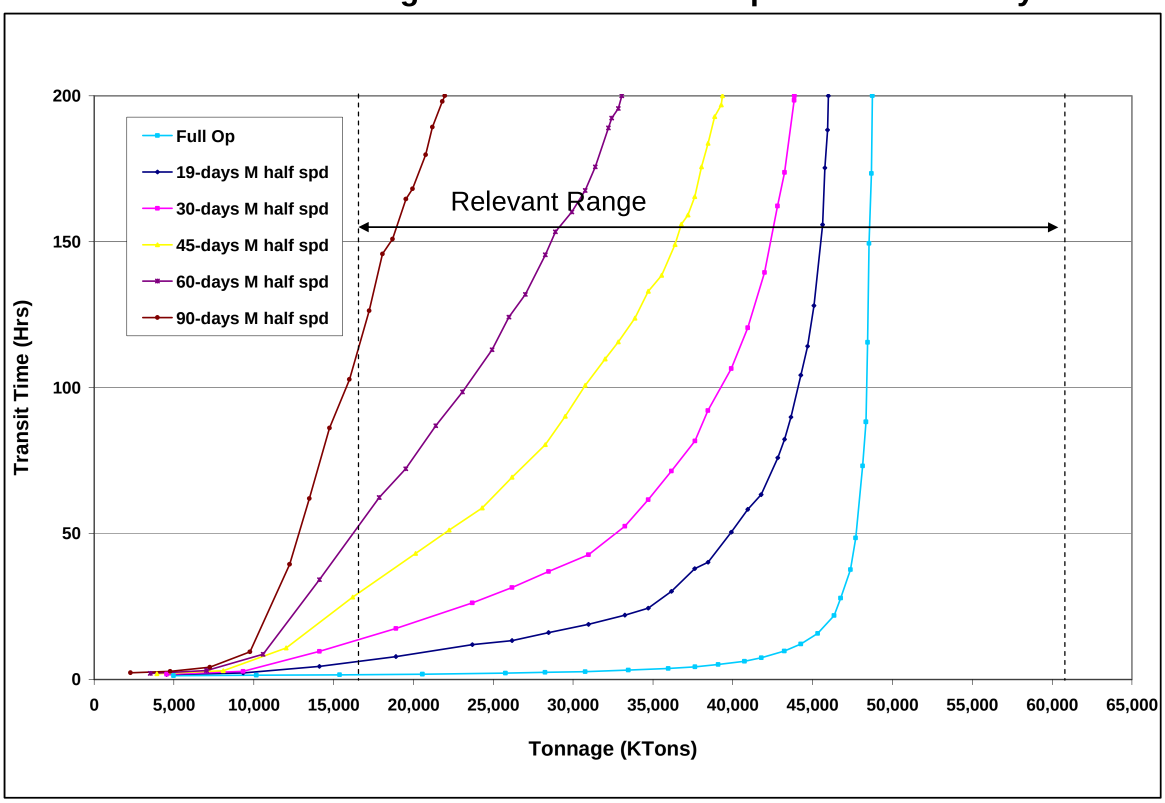


FIGURE A2- 29
Emsworth River Closure Existing Condition

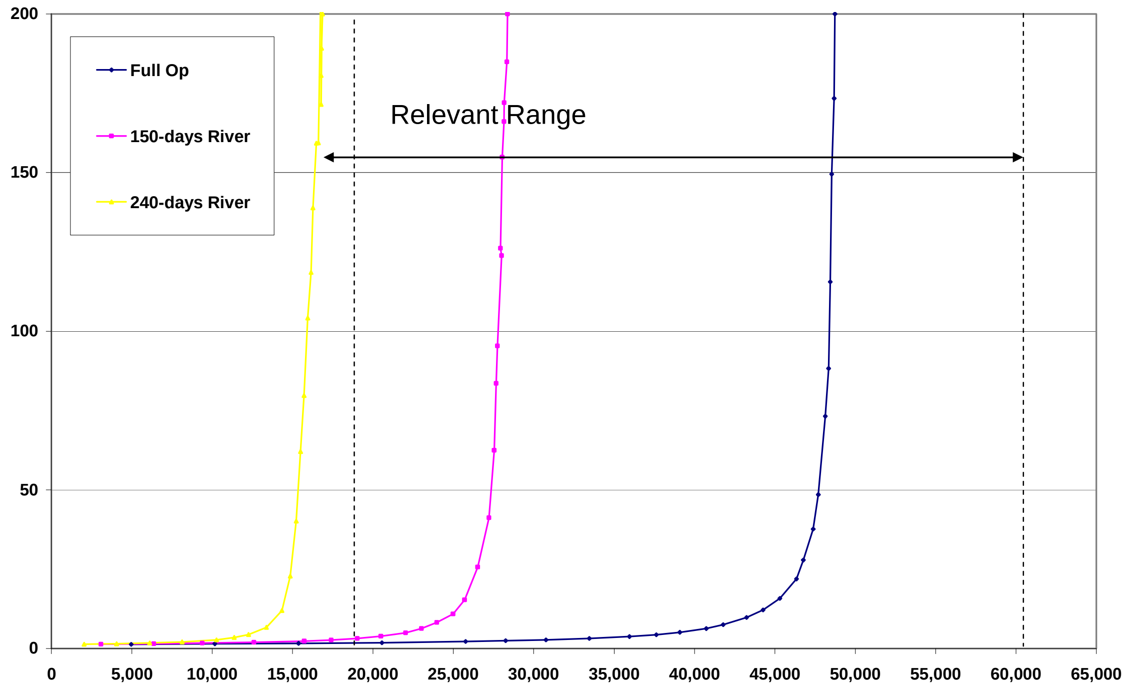


FIGURE A2- 30
Dashields WOPC Main Chamber Curve Family

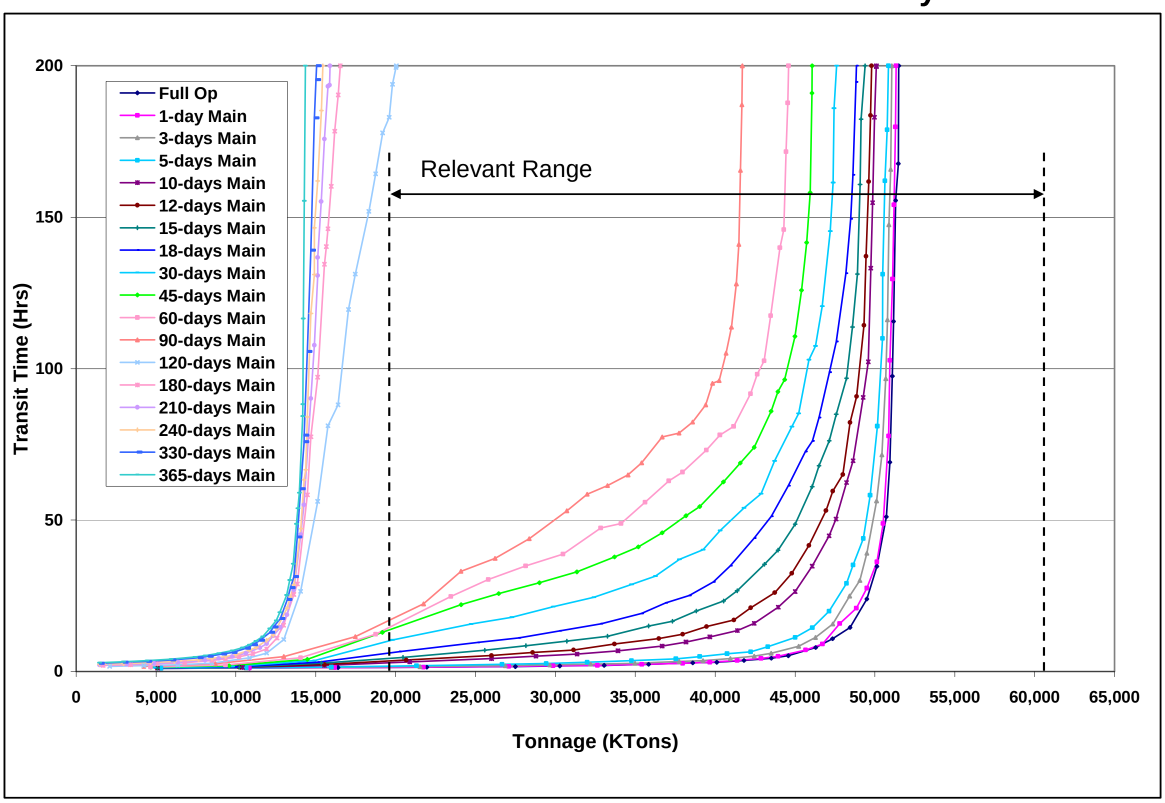


FIGURE A2- 31
Dashields WOPC Auxiliary Chamber Curve Family

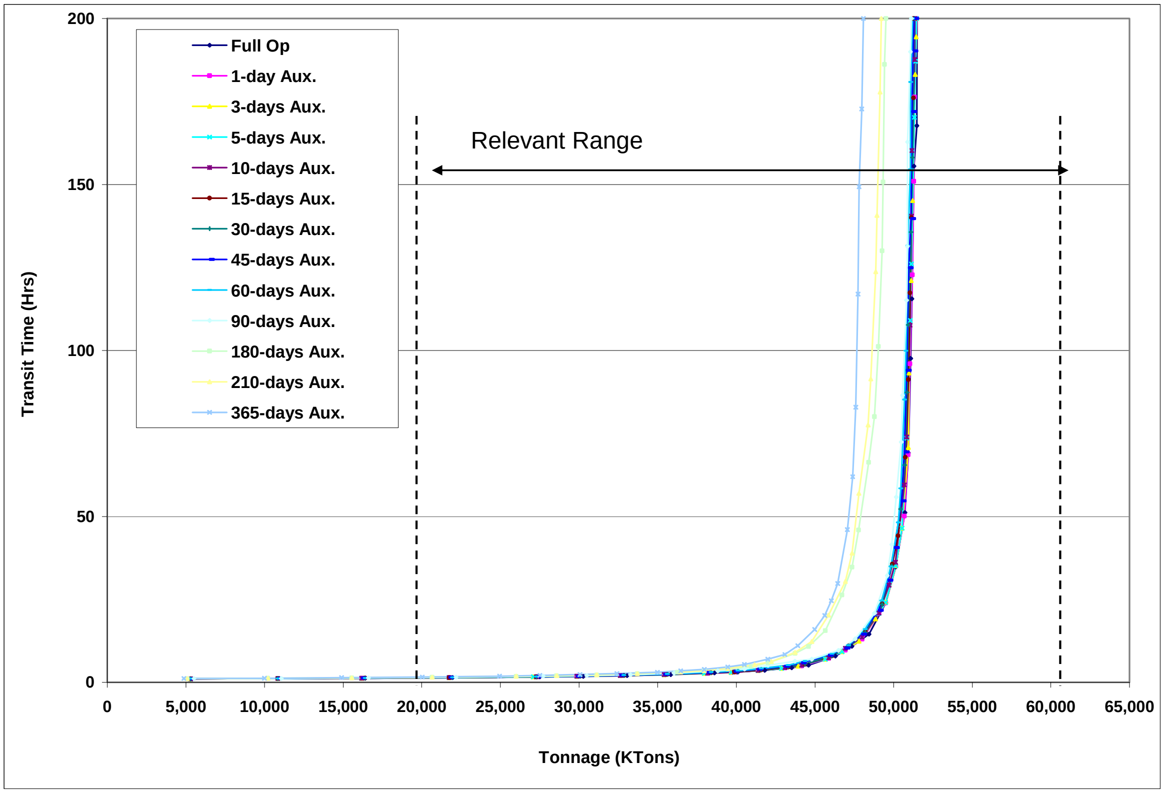


FIGURE A2- 32
Dashields WOPC Main Chamber Half-Speed Curve Family

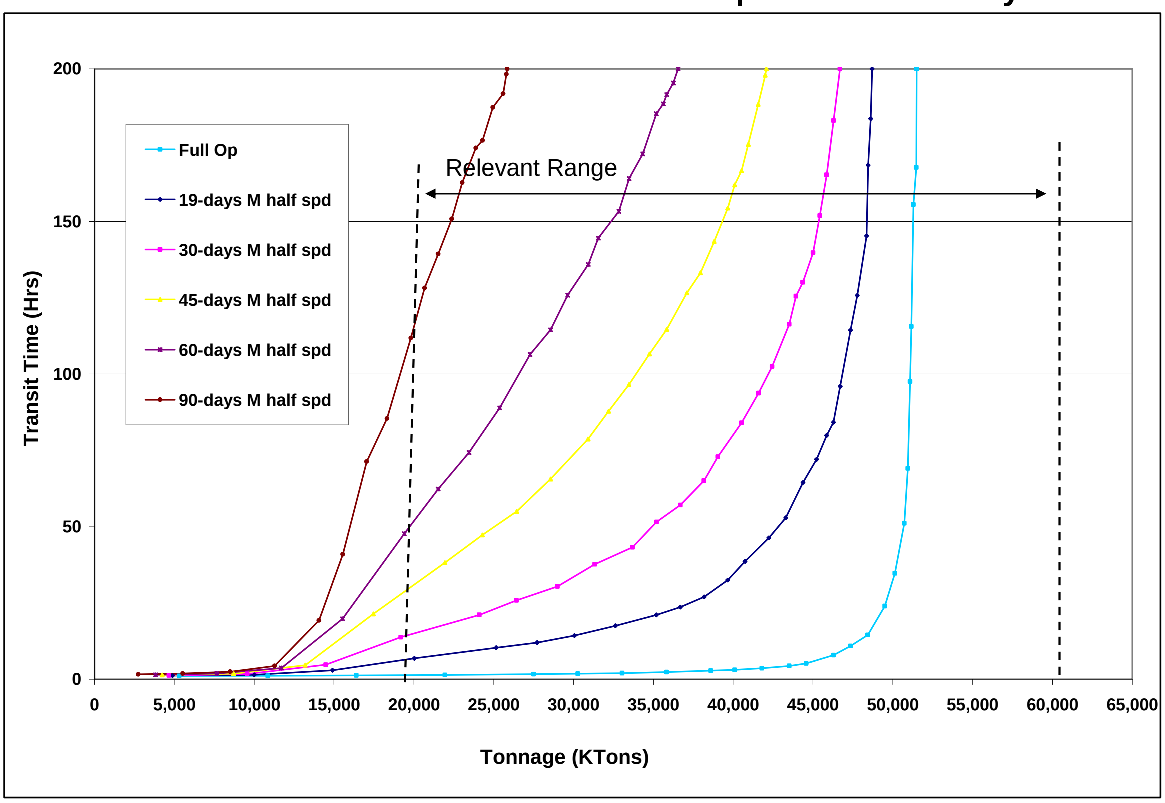


FIGURE A2- 33
Dashields WOPC River Closures

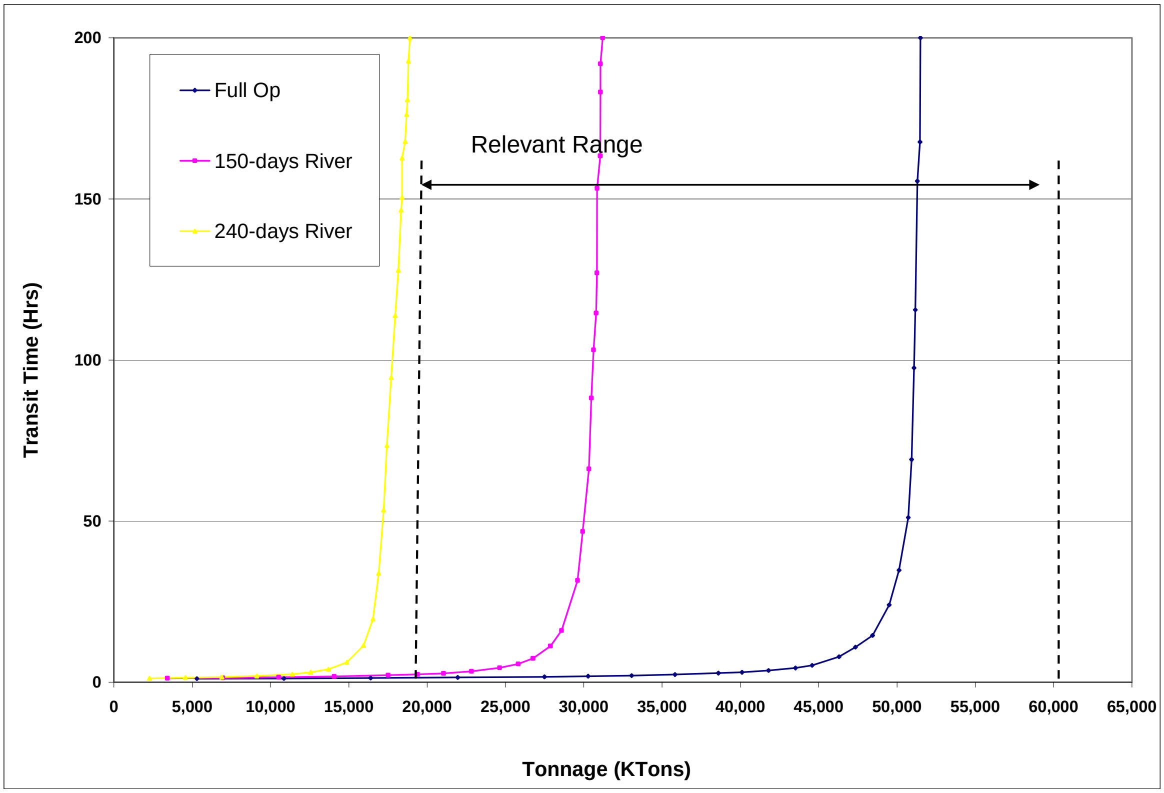


FIGURE A2- 34
Montgomery WOPC Main Chamber Curve Family

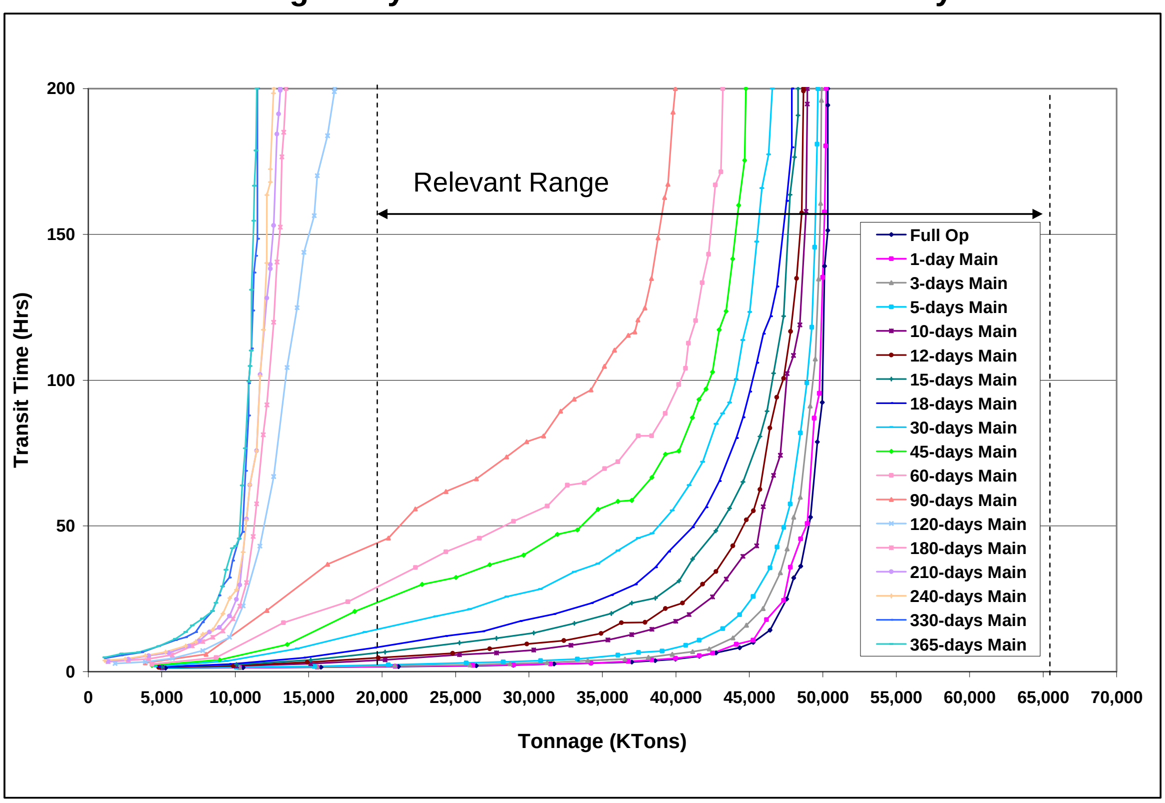


FIGURE A2- 35

Montgomery WOPC Auxiliary Chamber Curve Family

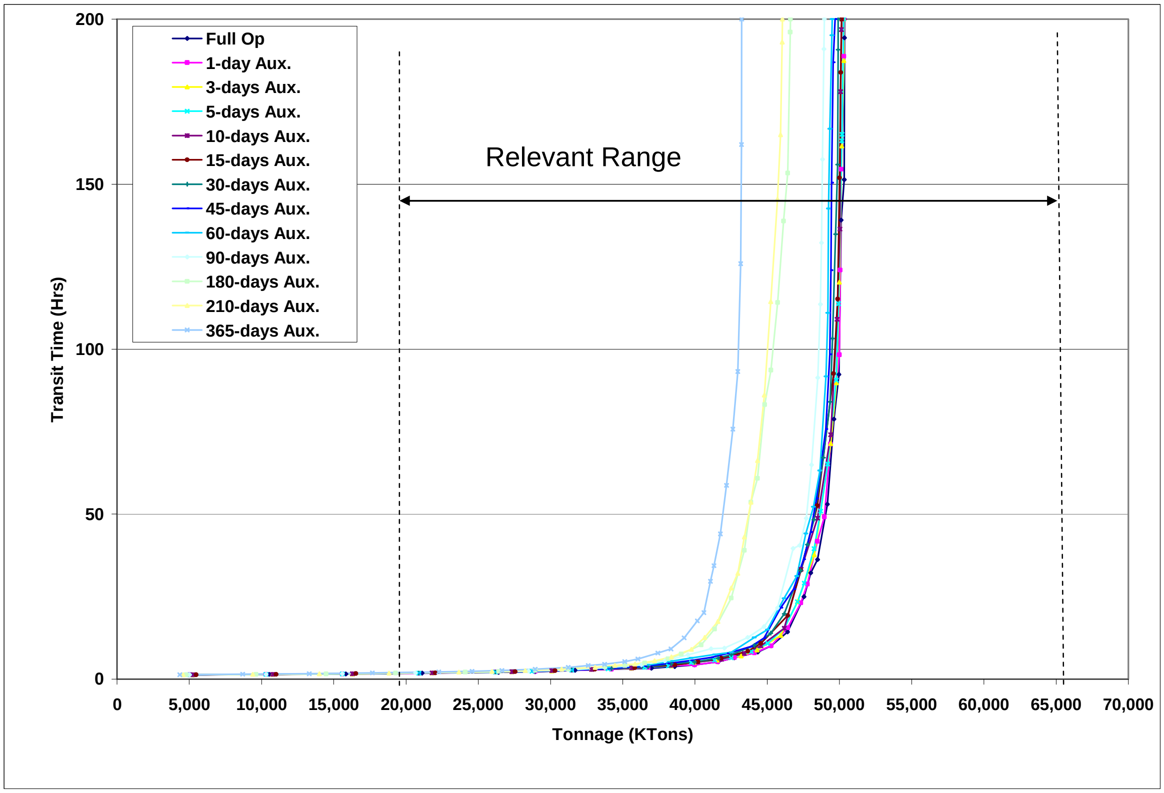


FIGURE A2- 36
Montgomery WOPC Main Chamber Half-Speed Curve Family

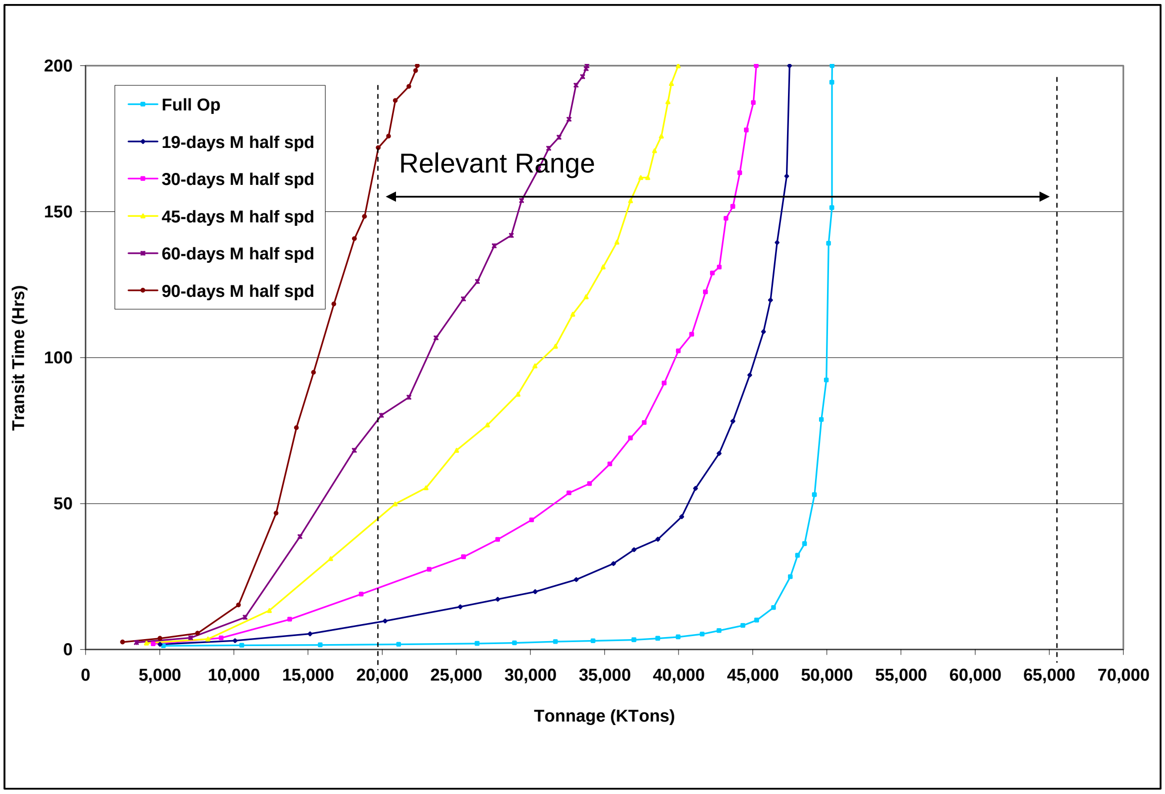
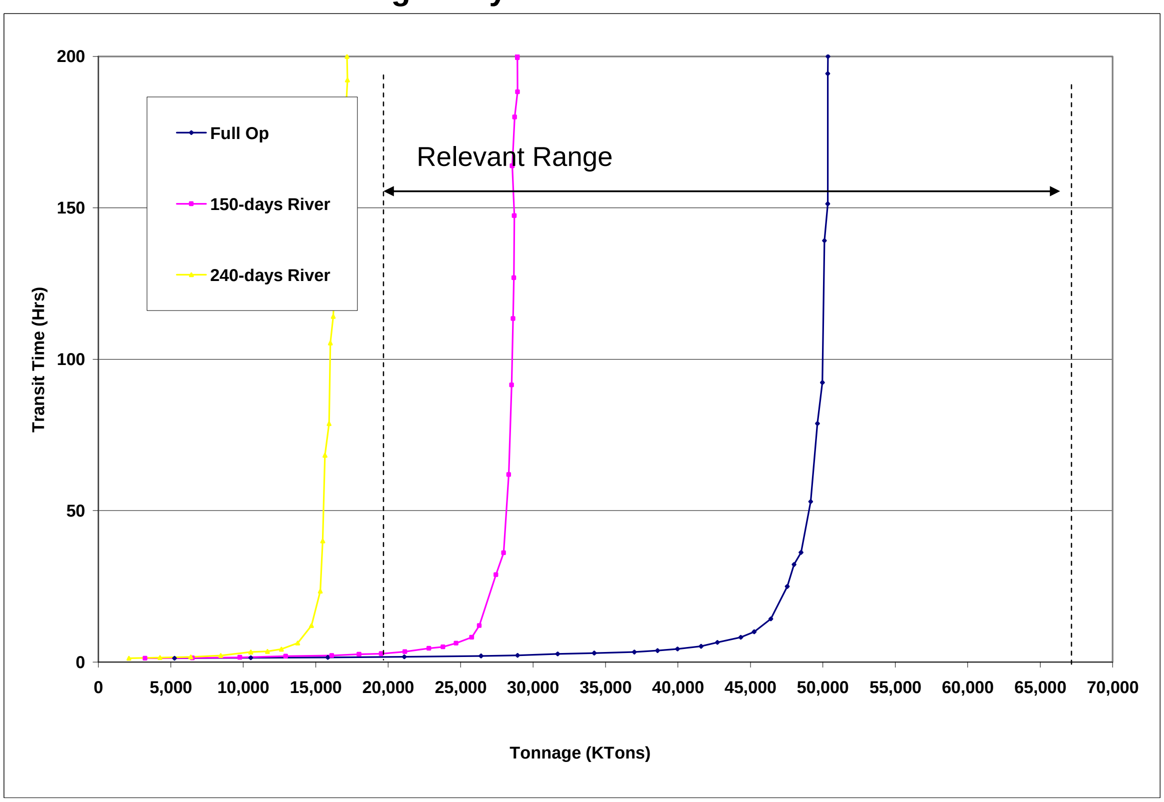


FIGURE A2- 37
Montgomery WOPC River Closures



2.6.4 WOPC Interpretations, Observations, Insights

EDM L&D does not have sufficient capacity to serve navigation demand throughout the period of analysis. At projected demands, routine main chamber maintenance events cause significant transit times, and therefore, significant costs.

2.7 With Project Analysis

Since all three Upper Ohio River locks has insufficient capacity to serve expected future traffic demands, improvements were considered at all three projects. Nine different With Project alternatives were analyzed and capacity curves were created for EDM locks using a larger “future” fleet.

1. Building a new 600’ chamber to replace the existing 360’ chamber, and using the existing 600’ chamber as the auxiliary.
2. Building a new 800’ chamber to replace the existing 360’ chamber, and using the existing 600’ chamber as the auxiliary.
3. Building a new 1200’ chamber to replace the existing 360’ chamber, and using the existing 600’ chamber as the auxiliary.
4. Building twin new 600’ chambers to replace the existing 600’ and 360’ chambers.
5. Building new 800’ chamber and a new 600’ chamber to replace the existing 600’ and 360’ chambers.
6. Building new 1200’ chamber and a new 600’ chamber to replace the existing 600’ and 360’ chambers.
7. Building a new 600’ single riverward chamber, and close off the land chamber.
8. Building a new 800’ single riverward chamber, and close off the land chamber
9. Building a new 1200’ single riverward chamber, and close off the land chamber.

2.7.1 Interference

Table A2-67 shows the interference parameters used for the New WPC 600’, 800’, and 1200’plans.

TABLE A2- 67
EDM Gate Area Interference Parameters

#	Gate Interference Statement	Answer
1	If a tow is waiting at the upper gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with an upbound tow exit from the Main chamber	1200
2	If a tow is waiting at the lower gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with a downbound tow exit from the Main chamber	1200
3	If a tow is waiting at the upper gates of the Main chamber, and it is ______ feet long or longer, it interferes with an upbound tow exit from the Auxiliary chamber	1200
4	If a tow is waiting at the lower gates of the Main chamber, and it is ______ feet long or longer, it interferes with a downbound tow exit from the Auxiliary chamber	1200
5	If a tow is waiting at the lower gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with an upbound tow approach to the Main chamber	1200
6	If a tow is waiting at the upper gates of the Auxiliary chamber, and it is ______ feet long or longer, it interferes with a downbound tow approach to the Main chamber	1200
7	If a tow is waiting at the lower gates of the Main chamber, and it is ______ feet long or longer, it interferes with an upbound tow approach to the Auxiliary chamber	1200
8	If a tow is waiting at the upper gates of the Main chamber, and it is ______ feet long or longer, it interferes with a downbound tow approach to the Auxiliary chamber	1200

Note that interference can only occur between two tows.
Recreational tows and light boats cannot cause, and are not affected by, interference.
Also note that these answers should reflect what a prudent navigator would usually do.

2.7.2 Processing Times

Processing times for a new 600’ chamber were developed from EDM’s exiting 600’ main chamber times except for the long approach and long exit times, these times were reduced by about 10% because the new chamber would be easier to approach and exit. Processing times for a new 800’ chambers were derived from Winfield’s main chamber and processing times for a new 1200’ chamber were derived from New Cumberland’s 1200’ main chamber.

2.7.2.1 Emsworth Processing Times

TABLE A2- 68
Emsworth Processing Times
New 600' Chamber 1 Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	1,045	05	22.1	0	1,009	05	17.8	3
Short Approach	224	05	12.5	0	243	05	13.1	0
Entry	1,265	05	10.0	4	1,250	05	9.0	5
**Chambering	1,301	05	10.4	0	1,314	05	10.0	4
*Long Exit	1,068	05	8.4	4	1,018	05	9.2	6
Short Exit	387	04, 05	8.5	0	231	05	10.9	0
Turn back	367	99	11.7	0	268	99	11.7	0

**Long Approaches and Exits Reduced by 10%*
***Dashields Chambering Times*

TABLE A2- 69
Emsworth Processing Times
New 600’ Chamber 2 Cuts

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	283	05	28.1	0	280	05	22.4	0
Short Approach	209	02-05	18.3	0	239	02-05	15.0	0
Entry	321	05	17.3	0	324	05	15.3	0
**Chambering	316	05	60.4	0	313	05	55.8	0
*Long Exit	260	05	21.3	0	264	05	25.9	1
Short Exit	313	02-05	23.4	0	330	02-05	26.1	0
Turn back	321	05	14.1	0	323	05	13.5	1

**Long Approaches and Exits Reduced by 10%*
***Dashields Chambering Times*

TABLE A2- 70
Emsworth Processing Times
New 800' Chamber

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	1,068	06	26.1	1	1,088	06	25.4	2
Short Approach	421	06-07	4.5	0	387	06-07	5.1	0
Entry	1,262	06	15.5	0	1,263	06	17.4	0
*Chambering	1,262	06	13.4	0	1,262	06	13.3	1
Long Exit	1,058	06	15.2	3	1,081	06	21.0	0
Short Exit	201	06	12.5	0	410	06-07	15.9	0
**Turn back	419	06-07	12.3	2	387	06-07	12.5	0

**Winfield on Kanawha River*

TABLE A2- 71
Emsworth Processing Times
New 1200' Chamber

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	1,045	05	24.1	0	1,009	05	19.8	3
**Short Approach	307	05	14.7	0	232	05	11.4	0
**Entry	1,698	05	11.1	0	1,614	05	9.7	2
**Chambering	1,697	05	14.5	1	1,614	05	14.9	1
*Long Exit	1,068	05	9.3	4	1,018	05	10.2	6
**Short Exit	316	05	9.7	0	239	05	8.7	0
**Turn back	307	05	15.0	0	231	05	13.4	0

**Used Emsworth 600' Long Exit and Long Approach times.*

***Used New Cumberland's 1200' Main Chamber Short Approaches,Entry, Chambering, Short Exit & Turnback times*

2.7.2.2 Dashields Processing Times

TABLE A2- 72
Dashields Processing Times
New 600' Chamber 1 Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	1,072	05	21.4	5	1,081	05	18.4	2
Short Approach	224	05	10.0	0	235	05	8.6	0
Entry	1,299	05	13.3	2	1,318	05	11.9	0
Chambering	1,301	05	10.4	0	1,314	05	10.0	4
*Long Exit	1,091	05	12.1	6	1,118	05	11.6	2
Short Exit	204	05	13.5	0	370	05,06	11.9	0
Turn back	223	05	9.9	1	234	05	10.4	1

**Long Approaches and Exits Reduced by 10%*

TABLE A2- 73
Dashields Processing Times
New 600' Chamber 2 Cuts

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	285	05	26.6	0	294	05	24.7	0
Short Approach	331	02-06	14.9	0	292	00-06	13.2	0
Entry	327	05	18.5	0	321	05	18.0	0
Chambering	316	05	60.4	0	313	05	55.8	0
*Long Exit	267	05	23.9	0	257	05	25.8	1
Short Exit	317	03-06	26.2	0	294	03-06	24.6	0
Turn back	327	05	11.3	0	321	05	10.7	0

**Long Approaches and Exits Reduced by 10%*

TABLE A2- 74
Dashields Processing Times
New 800' Chamber

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	1,068	06	26.1	1	1,088	06	25.4	2
Short Approach	421	06-07	4.5	0	387	06-07	5.1	0
Entry	1,262	06	15.5	0	1,263	06	17.4	0
*Chambering	1,262	06	13.4	0	1,262	06	13.3	1
Long Exit	1,058	06	15.2	3	1,081	06	21.0	0
Short Exit	201	06	12.5	0	410	06-07	15.9	0
Turn back	419	06-07	12.3	2	387	06-07	12.5	0

**Winfield on Kanawha River*

TABLE A2- 75
Dashields Processing Times
New 1200' Chamber

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	1,072	05	23.8	5	1,081	05	20.5	2
**Short Approach	307	05	14.7	0	232	05	11.4	0
**Entry	1,698	05	11.1	0	1,614	05	9.7	2
**Chambering	1,697	05	14.5	1	1,614	05	14.9	1
*Long Exit	1,091	05	13.4	6	1,118	05	12.9	2
**Short Exit	316	05	9.7	0	239	05	8.7	0
**Turn back	307	05	15.0	0	231	05	13.4	0

**Used Dashields 600' Long Exit and Long Approach times.*

2.7.2.3 Montgomery Processing Times

TABLE A2- 76
Montgomery Processing Times
New 600' Chamber 1 Cut

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	1,101	05	19.3	0	1,042	05	19.3	0
Short Approach	242	05	13.0	0	263	05	10.9	0
Entry	1,342	05	14.0	1	1,303	05	11.9	2
Chambering	1,336	05	13.2	7	1,303	05	11.7	2
*Long Exit	1,099	05	11.7	6	1,066	05	10.5	0
Short Exit	238	05	12.7	0	239	05	12.4	0
Turn back	241	05	11.8	0	263	05	11.1	0

**Long Approaches and Exits Reduced by 10%*

TABLE A2- 77
Montgomery Processing Times
New 600’ Chamber 2 Cuts

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	306	05	26.0	0	327	05	23.3	2
Short Approach	329	03-06	16.7	0	334	02-06	14.9	0
Entry	388	05	20.2	0	402	05	17.6	0
Chambering	378	05	69.5	0	391	05	64.2	0
*Long Exit	304	05	26.2	1	309	05	25.4	1
Short Exit	377	03-06	25.3	0	364	03-06	26.6	0
Turn back	388	05	15.7	0	402	05	13.6	0

**Long Approaches and Exits Reduced by 10%*

TABLE A2- 78
Montgomery Processing Times
New 800' Chamber

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
Long Approach	1,068	06	26.1	1	1,088	06	25.4	2
Short Approach	421	06-07	4.5	0	387	06-07	5.1	0
Entry	1,262	06	15.5	0	1,263	06	17.4	0
*Chambering	1,262	06	13.4	0	1,262	06	13.3	1
Long Exit	1,058	06	15.2	3	1,081	06	21.0	0
Short Exit	201	06	12.5	0	410	06-07	15.9	0
Turn back	419	06-07	12.3	2	387	06-07	12.5	0

**Winfield on Kanawha River*

TABLE A2- 79
Montgomery Processing Times
New 1200' Chamber

Lock Component	Up bound				Down bound			
	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed	Number Of Samples	Years Selected	Mean LPMS time (min)	Number of Outliers Removed
*Long Approach	1,101	05	21.4	0	1,042	05	21.4	0
**Short Approach	307	05	14.7	0	232	05	11.4	0
**Entry	1,698	05	11.1	0	1,614	05	9.7	2
**Chambering	1,697	05	14.5	1	1,614	05	14.9	1
*Long Exit	1,099	05	13.0	6	1,066	05	11.7	0
**Short Exit	316	05	9.7	0	239	05	8.7	0
**Turn back	307	05	15.0	0	231	05	13.4	0

**Used Montgomery's 600' Long Exit and Long Approach times.*
***Used New Cumberland's 1200' Main Chamber Short Approaches, Entry, Chambering, Short Exit & Turnback times*

2.7.3 Identification of Optimal Lockage Policy

The optimal lockage policies for each of the nine With Project conditions were determined by making WAM runs at very high traffic levels, and selecting the policy that processes the highest tonnage with the minimum delay.

2.7.3.1 Emsworth Lockage Policy

Tables A2-80 through **A2-88** shows the optimal lockage policy at Emsworth for each of the nine WPC alternatives.

TABLE A2- 80
Emsworth New 600’ & Old 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New 600' & Old 600' FIFO	80,230	1.2	1,457	1,458
Emsworth New 600' & Old 600' 6U-6D	79,313	1.2	1,464	1,465

**Optimal Lockage Policy:FIFO*

TABLE A2- 81
Emsworth New 800’ & Old 600

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New 800' & Old 600' 6U-6D	99,575	0.9	196	197
Emsworth New 800' & Old 600' FIFO	95,254	1.0	385	386

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 82
Emsworth New 1200’ & Old 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New 1200' & Old 600' FIFO	103,891	0.9	3.7	4.7
Emsworth New 1200' & Old 600' 6U-6D	103,883	0.9	4.4	5.3

**Optimal Lockage Policy: FIFO*

TABLE A2- 83
Emsworth New 600’ & New 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New 600' & New 600' FIFO	83,183	1.0	9.4	10.3
Emsworth New 600' & New 600' 6U-6D	83,181	1.0	12.1	13.1

**Optimal Lockage Policy: FIFO*

TABLE A2- 84
Emsworth New 800’ & New 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New 800' & New 600' 6U-6D	100,691	0.9	162	163
Emsworth New 800' & New 600' FIFO	97,152	1.0	321	322

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 85
Emsworth New 1200’ & New 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New 1200' & New 600' 6U-6D	125,416	0.8	488	489
Emsworth New 1200' & New 600' FIFO	124,534	0.9	529	530

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 86
Emsworth New Single 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New Single 600' FIFO	50,318	1.0	815	816
Emsworth New Single 600' 6U-6D	48,884	1.0	913	914

**Optimal Lockage Policy: FIFO*

TABLE A2- 87
Emsworth New Single 800’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New Single 800' 6U-6D	59,296	0.9	1,226	1,227
Emsworth New Single 800' FIFO	56,267	1.0	1,409	1,410

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 88
Emsworth New Single 1200’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Emsworth New Single 1200' FIFO	77,590	0.9	336	337
*Emsworth New Single 1200' 6U-6D	75,782	0.9	396	397

**Optimal Lockage Policy: FIFO*

2.7.3.2 Dashields Lockage Policy

Tables A2-89 through **A2-97** shows the optimal lockage policy at Dashields for each of the nine WPC alternatives.

TABLE A2- 89
Dashields New 600’ & Old 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New 600' & Old 600' 6U-6D	91,620	1.0	611	612
Dashields New 600' & Old 600' FIFO	88,793	1.1	709	710

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 90
Dashields New 800’ & Old 600’

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New 800' & Old 600' 6U-6D	101,647	0.9	226	227
Dashields New 800' & Old 600' FIFO	95,627	1.0	461	462

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 91
Dashields New 1200' & Old 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New 1200' & Old 600' 6U-6D	127,857	0.9	51	51
Dashields New 1200' & Old 600' FIFO	126,443	0.9	99	100

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 92
Dashields New 600' & New 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New 600' & New 600' 6U-6D	95,093	1.0	519	520
Dashields New 600' & New 600' FIFO	92,473	1.0	627	628

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 93
Dashields New 800' & New 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New 800' & New 600' 6U-6D	104,182	0.9	783	784
Dashields New 800' & New 600' FIFO	98,789	1.0	985	986

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 94
Dashields New 1200' & New 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New 1200' & New 600' 6U-6D	128,038	0.9	33	34
Dashields New 1200' & New 600' FIFO	128,038	0.9	42	43

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 95
Dashields New Single 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New Single 600' 6U-6D	51,422	1.0	1,615	1,616
Dashields New Single 600' FIFO	51,067	1.1	1,623	1,624

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 96
Dashields New Single 800'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Dashields New Single 800' 6U-6D	59,196	0.9	2,140	2,141
Dashields New Single 800' FIFO	55,624	1.0	2,279	2,280

**Optimal Lockage Policy: 6U-6D*

TABLE A2- 97
Dashields New Single 1200'

2.7.3.3 Montgomery Lockage Policy

Tables A2-98 through **A2-106** shows the optimal lockage policy at Montgomery for each of the nine WPC alternatives.

TABLE A2- 98
Montgomery New 600' & Old 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New 600' & Old 600' 6U-6D	81,743	1.1	1,249	1,250
Montgomery New 600' & Old 600' FIFO	81,335	1.2	1,276	1,277

*Optimal Lockage Policy: 6U-6D

TABLE A2- 99
Montgomery New 800' & Old 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New 800' & Old 600' 6U-6D	99,152	0.9	660	660
Montgomery New 800' & Old 600' FIFO	95,231	1.0	832	833

*Optimal Lockage Policy: 6U-6D

TABLE A2- 100
Montgomery New 1200' & Old 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New 1200' & Old 600' 6U-6D	117,809	0.9	694	695
Montgomery New 1200' & Old 600' FIFO	117,564	0.9	733	734

*Optimal Lockage Policy: 6U-6D

TABLE A2- 101
Montgomery New 600' & New 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New 600' & New 600' 6U-6D	83,387	1.1	227	228
Montgomery New 600' & New 600' FIFO	82,923	1.2	246	247

*Optimal Lockage Policy: 6U-6D

TABLE A2- 102
Montgomery New 800' & New 600'

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New 800' & New 600' 6U-6D	101,267	0.9	1,178	1,179
Montgomery New 800' & New 600' FIFO	97,238	1.0	1,298	1,299

*Optimal Lockage Policy: 6U-6D

TABLE A2- 103
Montgomery New 1200' & New 600' Project

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New 1200' & New 600' 6U-6D	121,739	0.9	775	776
Montgomery New 1200' & New 600' FIFO	122,396	0.9	790	791

Optimal Lockage Policy: 6U-6D

TABLE A2- 104
Montgomery New 600' Single Project

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New Single 600' FIFO	44,916	1.1	2,749	2,750
Montgomery New Single 600' 6U-6D	43,573	1.1	2,790	2,791

Optimal Lockage Policy: FIFO

TABLE A2- 105
Montgomery New 800' Single Project

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New Single 800' 6U-6D	54,587	0.9	2,489	2,490
Montgomery New Single 800' FIFO	52,008	1.0	2,588	2,589

Optimal Lockage Policy: 6U-6D

TABLE A2- 106
Montgomery New 1200' Single Project

RunID	Tonnage	ProcTime (Hr)	Delay (Hr)	Transit Time (Hr)
*Montgomery New Single 1200' 6U-6D	73,539	0.9	502.0	502.9

Optimal Lockage Policy: 6U-6D

2.7.4 Chamber Service Rates

After the optimal lockage policy was determined for each WPC alternatives, 10 WAM runs were made for each lock chamber within an alternative to determine the chamber service rates. The service rate was determined by shutting down each chamber for 365 days and making 10 WAM runs using the optimal lockage policy previously determined and a high escalation factor to ensure 100% lock utilization of the open chamber. This procedure was done for each of the alternative plans. It was not assumed that the chamber service rates would be the same for similar locks, sizes, and operating conditions (e.g., new versus old). There was a slight variation in the chamber service rates due to one of these data inputs; traffic escalation factor (e.g., this determines the chamber lock utilization – may not be exactly 100%), optimal lockage policy (which may be different for the similar lock options), maximum tow delay, or the simulation output (e.g., only 10 WAM runs were made to estimate the average service rate). The chamber service rate is the average of the number of tows processed for each chamber divided by 365 days, given the other chamber remained idle. The number of tows is simulated, and thus, these 10 numbers will not be exactly the same for each analysis.

2.7.4.1 Emsworth Tows per Day

Tables A2-107 through **A2-115** below show the number of tows that can be served by each chamber at Emsworth for each of the nine With Project conditions.

TABLE A2- 107
Emsworth New 600'& Old 600' Service Rates

RunID	Tows/Day
Emsworth New 600'	20.25
Emsworth Old 600'	18.97

TABLE A2- 108
Emsworth New 800' & Old 600' Service Rates

RunID	Tows/Day
Emsworth New 800'	27.35
Emsworth Old 600'	18.71

TABLE A2- 109
Emsworth New 1200' & Old 600' Service Rates

RunID	Tows/Day
Emsworth New 1200'	36.29
Emsworth Old 600'	19.01

TABLE A2- 110
Emsworth New 600' & New 600' Service Rates

RunID	Tows/Day
Emsworth New 600' Main	23.50
Emsworth New 600' Aux	22.50

TABLE A2- 111
Emsworth New 800' & New 600' Service Rates

RunID	Tows/Day
Emsworth New 800'	27.43
Emsworth New 600'	18.98

TABLE A2- 112
Emsworth New 1200' & New 600' Service Rates

RunID	Tows/Day
Emsworth New 1200'	36.37
Emsworth New 600'	19.51

TABLE A2- 113
Emsworth New Single 600' Service Rates

RunID	Tows/Day
Emsworth Single 600'	22.89

TABLE A2- 114
Emsworth New Single 800' Service Rates

RunID	Tows/Day
Emsworth Single 800'	26.84

TABLE A2- 115
Emsworth New Single 1200' Service Rates

RunID	Tows/Day
Emsworth Single 1200'	35.52

2.7.4.2 Dashields Tows per Day

Tables A2-116 through **A2-124** below show the number of tows that can be served by each chamber at Dashields for each of the nine With Project conditions.

TABLE A2- 116
Dashields New 600' & Old 600' Service Rates

RunID	Tows/Day
Dashields New 600'	22.90
Dashields Old 600'	22.03

TABLE A2- 117
Dashields New 800'& Old 600' Service Rates

RunID	Tows/Day
Dashields New 800'	26.88
Dashields Old 600'	22.04

TABLE A2- 118
Dashields New 1200' & Old 600' Service Rates

RunID	Tows/Day
Dashields New 1200'	36.77
Dashields Old 600'	21.94

TABLE A2- 119
Dashields New 600' & New 600' Service Rates

RunID	Tows/Day
Dashields New 600'	22.88
Dashields Old 600'	22.22

TABLE A2- 120
Dashields New 800' & New 600' Service Rates

RunID	Tows/Day
Dashields New 800'	26.84
Dashields New 600'	22.19

TABLE A2- 121
Dashields New 1200' & New 600' Service Rates

RunID	Tows/Day
Dashields New 1200'	36.90
Dashields New 600'	22.23

TABLE A2- 122
Dashields New Single 600' Service Rates

RunID	Tows/Day
Dashields Single 600'	22.8

TABLE A2- 123
Dashields New Single 800' Service Rates

RunID	Tows/Day
Dashields Single 800'	26.75

TABLE A2- 124
Dashields New Single 1200' Service Rates

RunID	Tows/Day
Dashields Single 1200'	36.77

2.7.4.3 Montgomery Tows per Day

Tables A2-125 through **A2-133** below show the number of tows that can be served by each chamber at Montgomery for each of the nine With Project conditions.

TABLE A2- 125
Montgomery New 600' & Old 600' Service Rates

RunID	Tows/Day
Montgomery New 600'	20.32
Montgomery Old 600'	19.65

TABLE A2- 126
Montgomery New 800' & Old 600' Service Rates

RunID	Tows/Day
Montgomery New 800'	25.56
Montgomery Old 600'	19.48

TABLE A2- 127
Montgomery New 1200' & Old 600' Service Rates

RunID	Tows/Day
Montgomery New 1200'	33.76
Montgomery Old 600'	19.46

TABLE A2- 128
Montgomery New 600' & New 600' Service Rates

RunID	Tows/Day
Montgomery New 600'	20.54
Montgomery New 600'	20.12

TABLE A2- 129
Montgomery New 800' & New 600' Service Rates

RunID	Tows/Day
Montgomery New 800'	25.54
Montgomery New 600'	19.74

TABLE A2- 130
Montgomery New 1200' & New 600' Service Rates

RunID	Tows/Day
Montgomery New 1200'	33.53
Montgomery Old 600'	19.55

TABLE A2- 131
Montgomery New Single 600' Service Rates

RunID	Tows/Day
Montgomery Single 600'	20.38

TABLE A2- 132
Montgomery New Single 800' Service Rates

RunID	Tows/Day
Montgomery Single 800'	25.3

TABLE A2- 133
Montgomery New Single 1200' Service Rates

RunID	Tows/Day
Montgomery Single 1200'	33.76

2.8 With Project Results

2.8.1 Project Capacities and Processing Times

Table A2-134 shows the nine With Project Condition capacities for EDM locks for the full operation, main and auxiliary chambers determined during this study. Refer to Section 2.7 for a description of the With Project Condition alternatives.

TABLE A2- 134
EDM With Project Capacities
Future Fleet

Lock	Full Operation	Main Chamber	Auxiliary Chamber
Emsworth New 600' Single Project	47.9	47.9	0.0
Emsworth New 800' Single Project	57.2	57.2	0.0
Emsworth New 1200' Single Project	77.3	77.3	0.0
Emsworth New 600' New 600'	91.5	47.9	47.9
Emsworth New 800' New 600'	100.8	57.2	47.9
Emsworth New 1200' New 600'	122.9	77.3	47.9
Emsworth New 600' Old 600'	77.8	43.1	42.9
Emsworth New 800' Old 600'	100.0	59.4	42.9
Emsworth New 1200' Old 600'	121.0	77.5	42.9
Dashields New 600' Single Project	49.6	49.6	0.0
Dashields New 800' Single Project	59.3	59.3	0.0
Dashields New 1200' Single Project	79.6	79.6	0.0
Dashields New 600' New 600'	91.6	49.6	49.6
Dashields New 800' New 600'	103.4	59.3	49.6
Dashields New 1200' New 600'	132.0	79.6	49.6
Dashields New 600' Old 600'	90.7	49.6	48.1
Dashields New 800' Old 600'	102.2	59.3	48.1
Dashields New 1200' Old 600'	130.7	79.6	48.1
Montgomery New 600' Single Project	43.6	43.6	0.0
Montgomery New 800' Single Project	55.8	55.8	0.0
Montgomery New 1200' Single Project	70.9	70.9	0.0
Montgomery New 600' New 600'	80.8	43.6	43.6
Montgomery New 800' New 600'	99.1	55.8	43.6
Montgomery New 1200' New 600'	117.4	70.9	43.6
Montgomery New 600' Old 600'	79.8	43.7	43.2
Montgomery New 800' Old 600'	97.9	55.8	43.2
Montgomery New 1200' Old 600'	116	70.9	43.2

2.8.1.1 Emsworth Capacities and Processing Times

Tables A2-135 through **A2-143**- shows the Emsworth capacities and processing times for all the nine With Project Condition alternative.

TABLE A2- 135
Emsworth New 600' & Old 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	77.8	72.2
12-days Main Chamber Closed	76.0	72.3
15-days Main Chamber Closed	75.6	72.3
19-days Main Chamber ½ speed	74.9	72.3
1-day Auxiliary Chamber Closed	77.6	72.2
3-days Auxiliary Chamber Closed	77.3	72.2
5-days Auxiliary Chamber Closed	77.1	72.3
10-days Auxiliary Chamber Closed	76.4	72.2
12-days Auxiliary Chamber Closed	76.1	72.2
15-days Auxiliary Chamber Closed	75.6	72.2
18-days Auxiliary Chamber Closed	75.2	72.3
30-days Auxiliary Chamber Closed	73.9	72.4
45-days Auxiliary Chamber Closed	72.6	72.4
60-days Auxiliary Chamber Closed	71.0	72.3
90-days Auxiliary Chamber Closed	68.6	72.4
120-days Auxiliary Chamber Closed	55.2	72.3
150-days Auxiliary Chamber Closed	52.0	72.3
180-days Auxiliary Chamber Closed	49.7	72.4
210-days Auxiliary Chamber Closed	48.2	72.5
240-days Auxiliary Chamber Closed	46.9	72.6
365-days Auxiliary Chamber Closed	43.1	72.5
30-days Auxiliary Chamber ½ speed	73.2	72.3

TABLE A2- 136
Emsworth New 800' & Old 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	100.0	54.4
12-days Main Chamber Closed	97.3	54.7
15-days Main Chamber Closed	96.6	54.8
19-days Main Chamber ½ speed	95.6	54.9
1-day Auxiliary Chamber Closed	99.9	54.4
3-days Auxiliary Chamber Closed	99.5	54.4
5-days Auxiliary Chamber Closed	99.3	54.4
10-days Auxiliary Chamber Closed	98.3	54.4
12-days Auxiliary Chamber Closed	98.2	54.4
15-days Auxiliary Chamber Closed	97.7	54.4
18-days Auxiliary Chamber Closed	97.1	54.5
30-days Auxiliary Chamber Closed	95.5	54.5
45-days Auxiliary Chamber Closed	93.8	54.5
60-days Auxiliary Chamber Closed	92.0	54.6
90-days Auxiliary Chamber Closed	89.1	54.5
120-days Auxiliary Chamber Closed	74.2	56.3
150-days Auxiliary Chamber Closed	69.8	56.4
180-days Auxiliary Chamber Closed	67.2	56.4
210-days Auxiliary Chamber Closed	65.1	56.3
240-days Auxiliary Chamber Closed	63.4	56.3
365-days Auxiliary Chamber Closed	59.4	56.4
30-days Auxiliary Chamber ½ speed	94.9	54.5

TABLE A2- 137
Emsworth New 1200' & Old 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	121.0	56.0
12-days Main Chamber Closed	117.7	56.4
15-days Main Chamber Closed	116.9	56.6
19-days Main Chamber ½ speed	115.5	56.7
1-day Auxiliary Chamber Closed	121.0	56.0
3-days Auxiliary Chamber Closed	120.6	56.0
5-days Auxiliary Chamber Closed	120.3	56.0
10-days Auxiliary Chamber Closed	119.5	56.0
12-days Auxiliary Chamber Closed	119.2	56.0
15-days Auxiliary Chamber Closed	118.7	56.0
18-days Auxiliary Chamber Closed	118.2	56.0
30-days Auxiliary Chamber Closed	116.8	56.0
45-days Auxiliary Chamber Closed	114.9	56.1
60-days Auxiliary Chamber Closed	113.1	56.1
90-days Auxiliary Chamber Closed	110.0	56.1
120-days Auxiliary Chamber Closed	98.1	56.2
150-days Auxiliary Chamber Closed	93.6	56.3
180-days Auxiliary Chamber Closed	90.4	56.4
210-days Auxiliary Chamber Closed	88.0	56.5
240-days Auxiliary Chamber Closed	84.6	56.6
365-days Auxiliary Chamber Closed	77.5	56.3
30-days Auxiliary Chamber ½ speed	116.4	56.0

TABLE A2- 138
Emsworth New 600' & New 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	91.5	60.9
12-days Main Chamber Closed	89.8	61.0
15-days Main Chamber Closed	89.2	60.9
12-days Auxiliary Chamber Closed	89.8	61.0
15-days Auxiliary Chamber Closed	89.2	60.9
19-days Main Chamber ½ speed	88.5	61.0
19-days Auxiliary Chamber ½ speed	88.5	61.0

TABLE A2- 139
Emsworth New 800’ & New 600’
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	100.8	54.1
12-days Main Chamber Closed	98.2	54.3
15-days Main Chamber Closed	97.4	54.4
12-days Auxiliary Chamber Closed	98.9	54.1
15-days Auxiliary Chamber Closed	98.4	54.1
19-days Main Chamber ½ speed	96.4	54.5
19-days Auxiliary Chamber ½ speed	97.9	54.1

TABLE A2- 140
Emsworth New 1200’ & New 600’
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	122.9	54.8
12-days Main Chamber Closed	119.4	55.2
15-days Main Chamber Closed	118.5	55.3
12-days Auxiliary Chamber Closed	120.9	54.8
15-days Auxiliary Chamber Closed	120.4	54.9
19-days Main Chamber ½ speed	117.3	55.4
19-days Auxiliary Chamber ½ speed	119.8	54.8

TABLE A2- 141
Emsworth New Single 600’
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	47.9	60.2
12-days Main Chamber Closed	45.9	60.3
15-days Main Chamber Closed	45.4	60.2
19-days Main Chamber ½ speed	45.8	62.3

TABLE A2- 142
Emsworth New Single 800'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	57.2	55.5
12-days Main Chamber Closed	54.9	55.4
15-days Main Chamber Closed	54.2	55.5
19-days Main Chamber ½ speed	53.3	55.5

TABLE A2- 143
Emsworth New Single 1200'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	77.5	56.3
12-days Main Chamber Closed	74.4	56.4
15-days Main Chamber Closed	73.6	56.3
19-days Main Chamber ½ speed	72.4	56.4

2.8.1.2 Dashields Capacities and Processing Times

Tables A2-144 through **A2-152**- shows the Dashields capacities and processing times for all the nine With Project Condition alternatives.

TABLE A2- 144
Dashields New 600’ & Old 600’
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	90.7	60.6
12-days Main Chamber Closed	88.6	60.7
15-days Main Chamber Closed	88.0	60.7
19-days Main Chamber ½ speed	87.1	60.8
1-day Auxiliary Chamber Closed	90.4	60.6
3-days Auxiliary Chamber Closed	90.2	60.6
5-days Auxiliary Chamber Closed	89.8	60.6
10-days Auxiliary Chamber Closed	88.9	60.7
12-days Auxiliary Chamber Closed	88.6	60.7
15-days Auxiliary Chamber Closed	88.1	60.7
30-days Auxiliary Chamber Closed	86.1	60.7
45-days Auxiliary Chamber Closed	84.4	60.8
60-days Auxiliary Chamber Closed	82.7	60.9
90-days Auxiliary Chamber Closed	79.8	60.8
120-days Auxiliary Chamber Closed	62.7	61.8
150-days Auxiliary Chamber Closed	58.4	61.9
180-days Auxiliary Chamber Closed	55.8	61.9
210-days Auxiliary Chamber Closed	53.9	61.8
240-days Auxiliary Chamber Closed	52.8	61.5
365-days Auxiliary Chamber Closed	49.6	61.5
19-days Auxiliary Chamber ½ speed	87.3	60.7

TABLE A2- 145
Dashields New 800' & Old 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	102.2	55.6
12-days Main Chamber Closed	99.7	55.6
15-days Main Chamber Closed	99.2	55.8
19-days Main Chamber ½ speed	98.2	55.9
1-day Auxiliary Chamber Closed	102.0	55.6
3-days Auxiliary Chamber Closed	101.7	55.6
5-days Auxiliary Chamber Closed	101.4	55.6
10-days Auxiliary Chamber Closed	100.5	55.6
12-days Auxiliary Chamber Closed	100.3	55.6
15-days Auxiliary Chamber Closed	99.7	55.6
30-days Auxiliary Chamber Closed	97.9	55.6
45-days Auxiliary Chamber Closed	96.0	55.6
60-days Auxiliary Chamber Closed	94.2	55.6
90-days Auxiliary Chamber Closed	90.8	55.6
120-days Auxiliary Chamber Closed	73.8	57.3
150-days Auxiliary Chamber Closed	69.3	57.7
180-days Auxiliary Chamber Closed	66.4	57.5
210-days Auxiliary Chamber Closed	64.4	57.1
240-days Auxiliary Chamber Closed	63.0	56.6
365-days Auxiliary Chamber Closed	59.3	56.6
19-days Auxiliary Chamber ½ speed	99.0	55.7

TABLE A2- 146
Dashields New 1200' & Old 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	130.7	49.3
12-days Main Chamber Closed	127.3	49.5
15-days Main Chamber Closed	126.2	49.6
19-days Main Chamber ½ speed	124.8	49.7
1-day Auxiliary Chamber Closed	130.5	49.3
3-days Auxiliary Chamber Closed	130.2	49.3
5-days Auxiliary Chamber Closed	129.7	49.3
10-days Auxiliary Chamber Closed	128.8	49.4
12-days Auxiliary Chamber Closed	128.6	49.3
15-days Auxiliary Chamber Closed	127.8	49.4
30-days Auxiliary Chamber Closed	125.8	49.4
45-days Auxiliary Chamber Closed	123.7	49.5
60-days Auxiliary Chamber Closed	121.4	49.6
90-days Auxiliary Chamber Closed	117.7	49.7
120-days Auxiliary Chamber Closed	100.4	50.7
150-days Auxiliary Chamber Closed	95.0	51.1
180-days Auxiliary Chamber Closed	91.6	51.5
210-days Auxiliary Chamber Closed	88.9	51.9
240-days Auxiliary Chamber Closed	86.9	52.2
365-days Auxiliary Chamber Closed	79.6	52.7
19-days Auxiliary Chamber ½ speed	127.2	49.4

TABLE A2- 147
Dashields New 600' & New 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	91.6	60.2
12-days Main Chamber Closed	89.6	60.3
15-days Main Chamber Closed	88.8	60.3
12-days Auxiliary Chamber Closed	89.6	60.3
15-days Auxiliary Chamber Closed	88.8	60.3
19-days Main Chamber ½ speed	88.1	60.4
19-days Auxiliary Chamber ½ speed	88.1	60.4

TABLE A2- 148
Dashields New 800' & New 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	103.4	55.2
12-days Main Chamber Closed	100.9	55.3
15-days Main Chamber Closed	100.3	55.4
12-days Auxiliary Chamber Closed	101.4	55.2
15-days Auxiliary Chamber Closed	100.8	55.3
19-days Main Chamber ½ speed	99.3	55.5
19-days Auxiliary Chamber ½ speed	100.1	55.2

TABLE A2- 149
Dashields New 1200' & New 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	132.0	48.7
12-days Main Chamber Closed	128.4	48.9
15-days Main Chamber Closed	127.4	48.9
12-days Auxiliary Chamber Closed	129.8	48.7
15-days Auxiliary Chamber Closed	129.2	48.8
19-days Main Chamber ½ speed	125.9	49.0
19-days Auxiliary Chamber ½ speed	128.4	48.8

TABLE A2- 150
Dashields Single 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	49.6	60.7
12-days Main Chamber Closed	46.7	60.8
15-days Main Chamber Closed	46.0	61.0
19-days Main Chamber ½ speed	44.6	61.0

TABLE A2- 151
Dashields Single 800'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	59.3	56.6
12-days Main Chamber Closed	55.4	55.2
15-days Main Chamber Closed	54.7	55.2
19-days Main Chamber ½ speed	53.2	55.3

TABLE A2- 152
Dashields Single 1200'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	79.6	52.7
12-days Main Chamber Closed	76.1	52.8
15-days Main Chamber Closed	75.2	52.9
19-days Main Chamber ½ speed	73.6	52.8

2.8.1.3 Montgomery Capacities and Processing Times

Tables A2-153 through **A2-161**- shows the Montgomery capacities and processing times for all the nine With Project Condition alternatives.

TABLE A2- 153
Montgomery New 600' & Old 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	79.8	66.9
12-days Main Chamber Closed	78.2	67.0
15-days Main Chamber Closed	77.9	67.0
19-days Main Chamber ½ speed	77.2	67.0
1-day Auxiliary Chamber Closed	79.7	66.9
3-days Auxiliary Chamber Closed	79.3	67.0
5-days Auxiliary Chamber Closed	79.1	67.0
10-days Auxiliary Chamber Closed	78.5	66.9
12-days Auxiliary Chamber Closed	78.2	67.0
15-days Auxiliary Chamber Closed	77.9	67.0
30-days Auxiliary Chamber Closed	76.2	67.0
45-days Auxiliary Chamber Closed	74.6	67.0
60-days Auxiliary Chamber Closed	73.0	67.1
90-days Auxiliary Chamber Closed	70.4	67.1
120-days Auxiliary Chamber Closed	55.0	67.7
150-days Auxiliary Chamber Closed	51.4	67.8
180-days Auxiliary Chamber Closed	49.1	67.8
210-days Auxiliary Chamber Closed	47.7	67.8
240-days Auxiliary Chamber Closed	46.6	67.7
365-days Auxiliary Chamber Closed	43.7	67.6
19-days Auxiliary Chamber ½ speed	77.3	66.9

TABLE A2- 154
Montgomery New 800' & Old 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	97.9	53.7
12-days Main Chamber Closed	95.5	54.0
15-days Main Chamber Closed	95.1	54.1
19-days Main Chamber ½ speed	94.3	54.1
1-day Auxiliary Chamber Closed	97.7	53.7
3-days Auxiliary Chamber Closed	97.3	53.7
5-days Auxiliary Chamber Closed	97.1	53.7
10-days Auxiliary Chamber Closed	96.3	53.7
12-days Auxiliary Chamber Closed	96.1	53.7
15-days Auxiliary Chamber Closed	95.7	53.8
30-days Auxiliary Chamber Closed	94.0	53.7
45-days Auxiliary Chamber Closed	92.0	53.9
60-days Auxiliary Chamber Closed	90.1	53.9
90-days Auxiliary Chamber Closed	86.5	53.9
120-days Auxiliary Chamber Closed	70.2	55.7
150-days Auxiliary Chamber Closed	66.0	56.1
180-days Auxiliary Chamber Closed	62.9	56.1
210-days Auxiliary Chamber Closed	61.1	56.0
240-days Auxiliary Chamber Closed	59.9	55.7
365-days Auxiliary Chamber Closed	55.8	56.0
19-days Auxiliary Chamber ½ speed	95.1	53.8

TABLE A2- 155
Montgomery New 1200’ & Old 600’
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	116.0	52.5
12-days Main Chamber Closed	112.9	53.0
15-days Main Chamber Closed	112.2	53.1
19-days Main Chamber ½ speed	111.2	53.3
1-day Auxiliary Chamber Closed	116.0	52.5
3-days Auxiliary Chamber Closed	115.5	52.5
5-days Auxiliary Chamber Closed	115.2	52.5
10-days Auxiliary Chamber Closed	114.5	52.5
12-days Auxiliary Chamber Closed	114.1	52.5
15-days Auxiliary Chamber Closed	113.7	52.5
30-days Auxiliary Chamber Closed	112.1	52.6
45-days Auxiliary Chamber Closed	110.0	52.6
60-days Auxiliary Chamber Closed	108.2	52.6
90-days Auxiliary Chamber Closed	104.5	52.6
120-days Auxiliary Chamber Closed	91.2	53.4
150-days Auxiliary Chamber Closed	86.2	53.9
180-days Auxiliary Chamber Closed	83.3	54.0
210-days Auxiliary Chamber Closed	81.0	53.9
240-days Auxiliary Chamber Closed	78.6	54.0
365-days Auxiliary Chamber Closed	70.9	52.6
19-days Auxiliary Chamber ½ speed	113.1	52.5

TABLE A2- 156
Montgomery New 600’ & New 600’
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	80.8	68.6
12-days Main Chamber Closed	79.3	68.6
15-days Main Chamber Closed	78.9	68.6
12-days Auxiliary Chamber Closed	79.3	68.6
15-days Auxiliary Chamber Closed	78.9	68.6
19-days Main Chamber ½ speed	78.3	68.6
19-days Auxiliary Chamber ½ speed	78.3	68.6

TABLE A2- 157
Montgomery New 800' & New 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	99.1	53.3
12-days Main Chamber Closed	96.6	53.6
15-days Main Chamber Closed	96.1	53.6
12-days Auxiliary Chamber Closed	97.2	53.4
15-days Auxiliary Chamber Closed	96.8	53.4
19-days Main Chamber ½ speed	95.4	53.7
19-days Auxiliary Chamber ½ speed	96.1	53.4

TABLE A2- 158
Montgomery New 1200' & New 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	117.4	52.1
12-days Main Chamber Closed	114.1	52.4
15-days Main Chamber Closed	113.3	52.5
12-days Auxiliary Chamber Closed	115.3	51.9
15-days Auxiliary Chamber Closed	114.9	52.0
19-days Main Chamber ½ speed	112.2	52.6
19-days Auxiliary Chamber ½ speed	114.2	52.0

TABLE A2- 159
Montgomery New Single 600'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	43.7	67.6
12-days Main Chamber Closed	41.4	69.3
15-days Main Chamber Closed	40.8	69.5
19-days Main Chamber ½ speed	39.9	69.4

TABLE A2- 160
Montgomery New Single 800'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	55.8	56.0
12-days Main Chamber Closed	51.3	54.9
15-days Main Chamber Closed	50.8	54.9
19-days Main Chamber ½ speed	49.7	54.9

TABLE A2- 161
Montgomery New Single 1200'
Capacities and Transit Times

Project/Scenario	Capacity (Millions of Tons)	Avg. Processing Time (min/tow)
No closures (normal operation)	70.9	52.6
12-days Main Chamber Closed	67.6	52.8
15-days Main Chamber Closed	66.8	52.8
19-days Main Chamber ½ speed	65.7	52.8

2.8.2 EDM Capacity Curves

Figures A2-38 through **A2-66** shows Emsworth WPC capacity curves. **Figures A2-67** through **A2-96** shows Dashields WPC capacity curves. **Figures A2-97** through **A2-126** shows Montgomery WPC capacity curves.

FIGURE A2- 38
Emsworth New 600’ & Old 600’ Main Chamber Curves

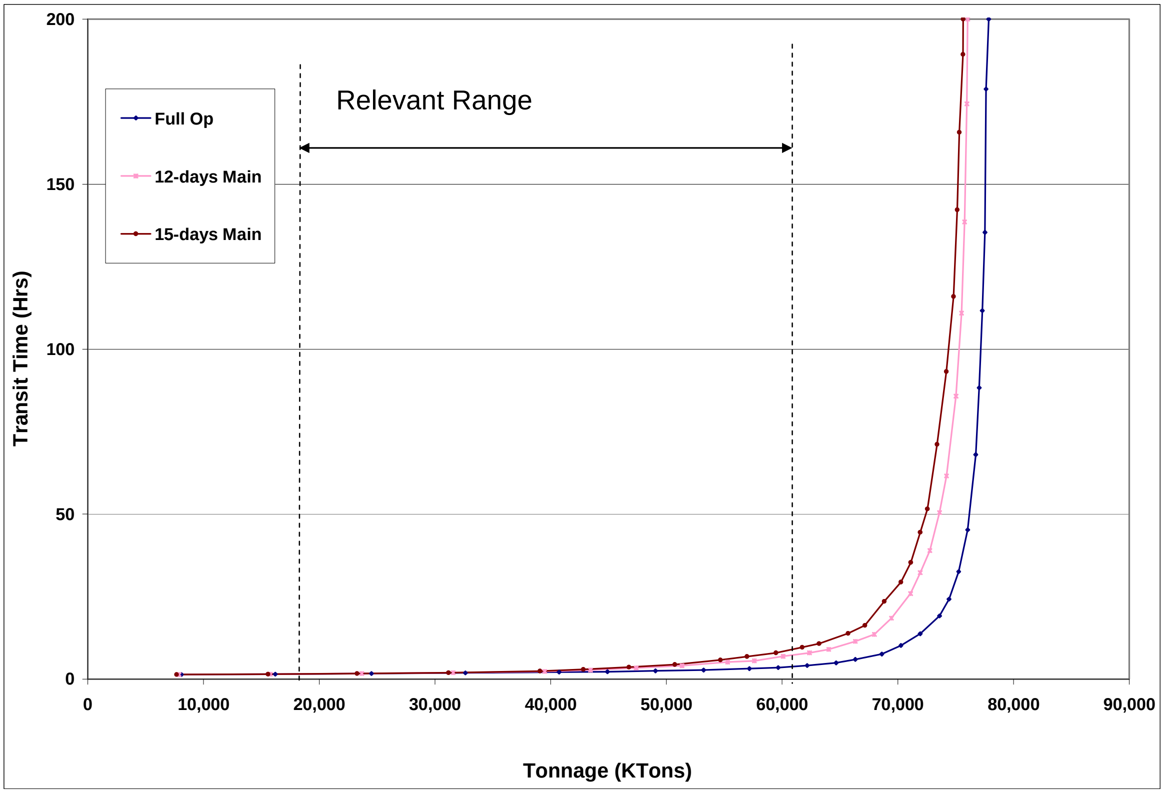


FIGURE A2- 39
Emsworth New 600’ & Old 600’ Main Chamber Half Speed Curves

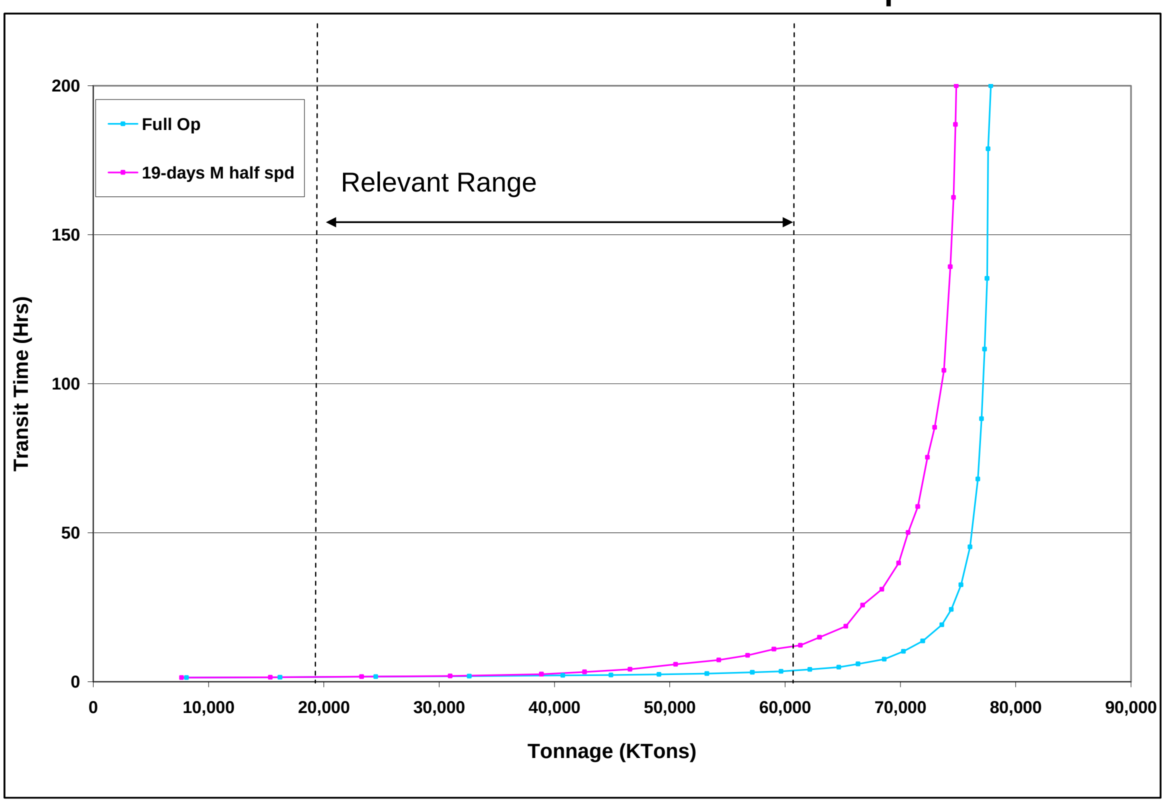


FIGURE A2- 40
Emsworth New 600' & Old 600' Auxiliary Chamber Curves

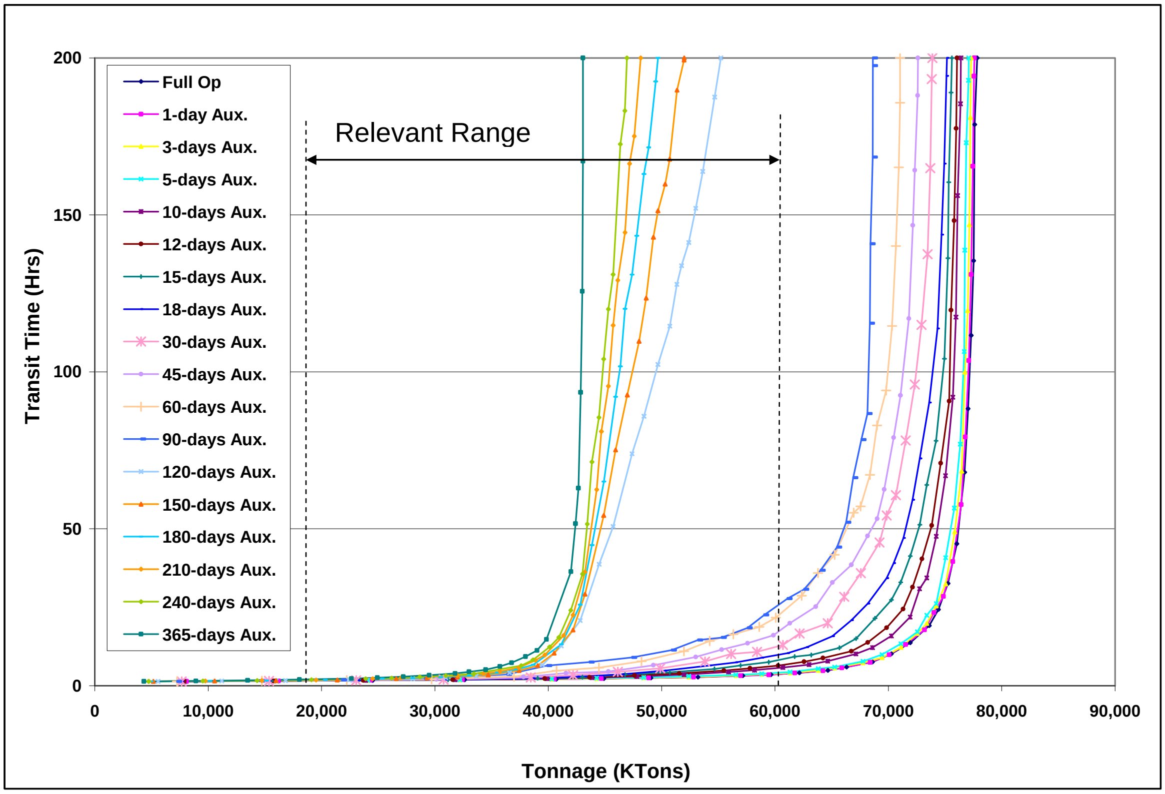


FIGURE A2- 41
Emsworth New 600' & Old 600' Auxiliary Chamber Half Speed Curves

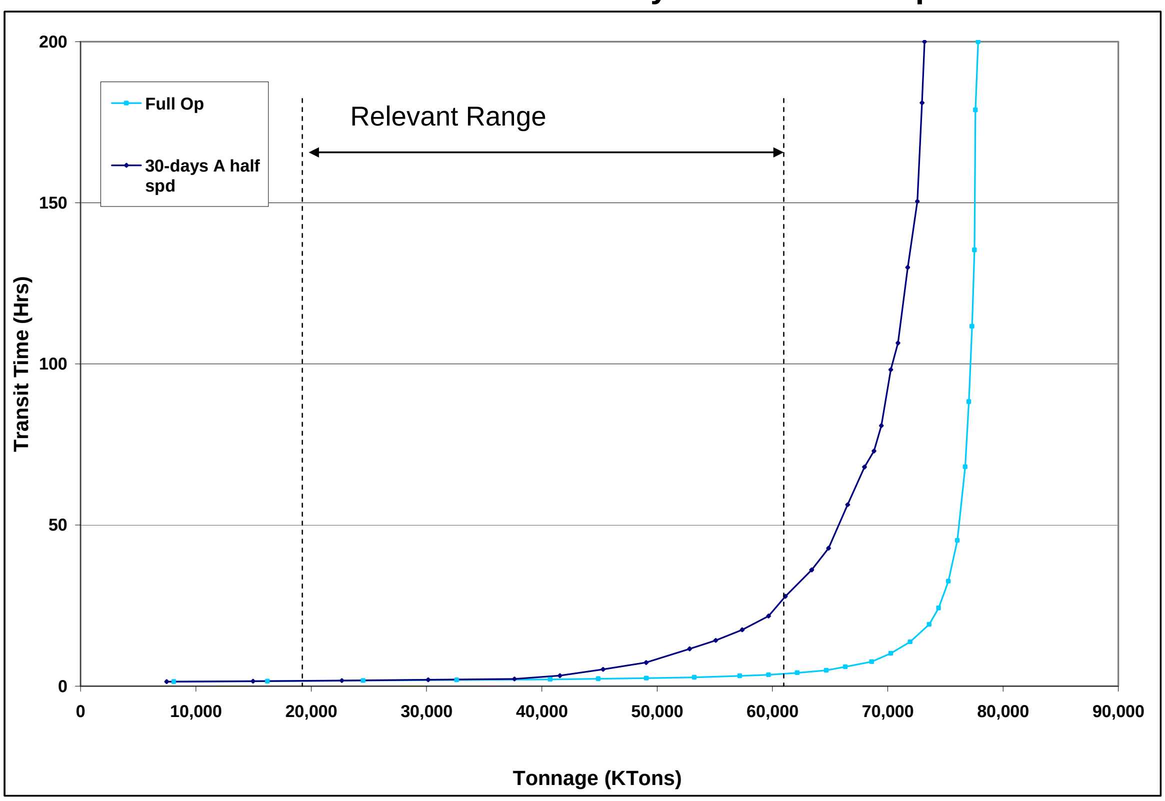


FIGURE A2- 42
Emsworth 42 day River Closure for Construction

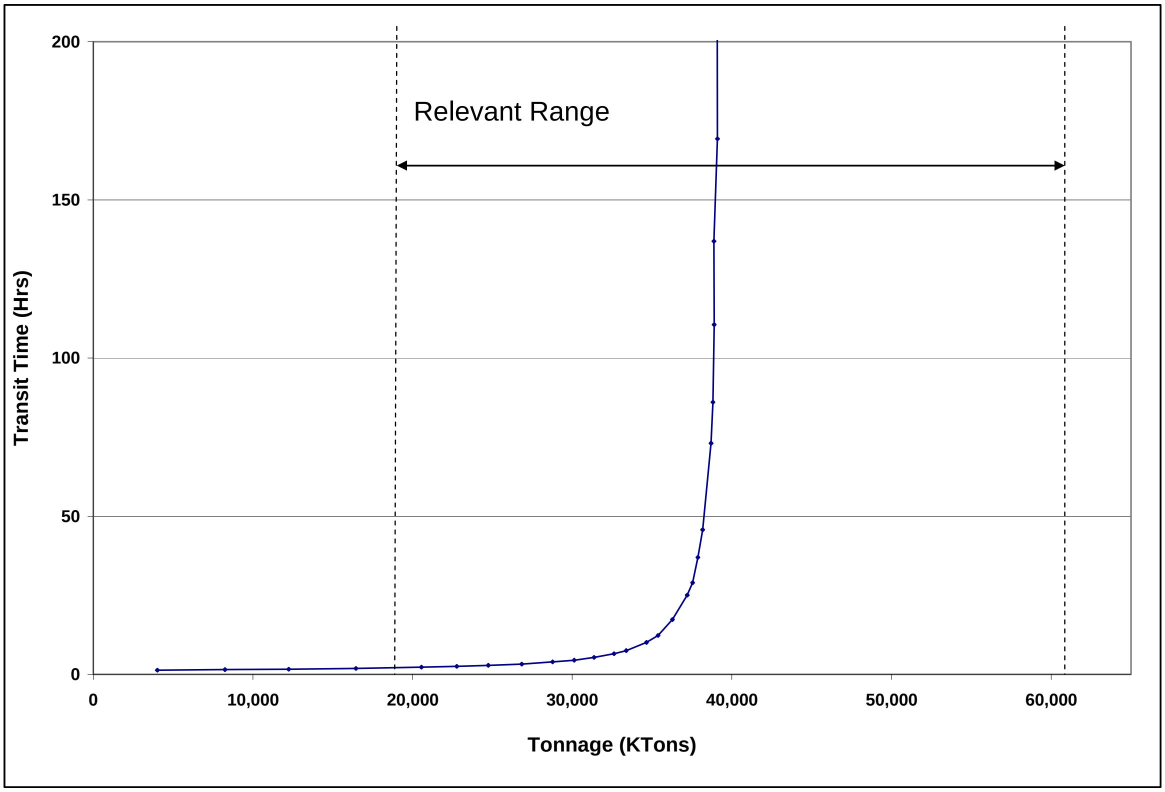


FIGURE A2- 43
Emsworth New 800' & Old 600' Main Chamber Curves

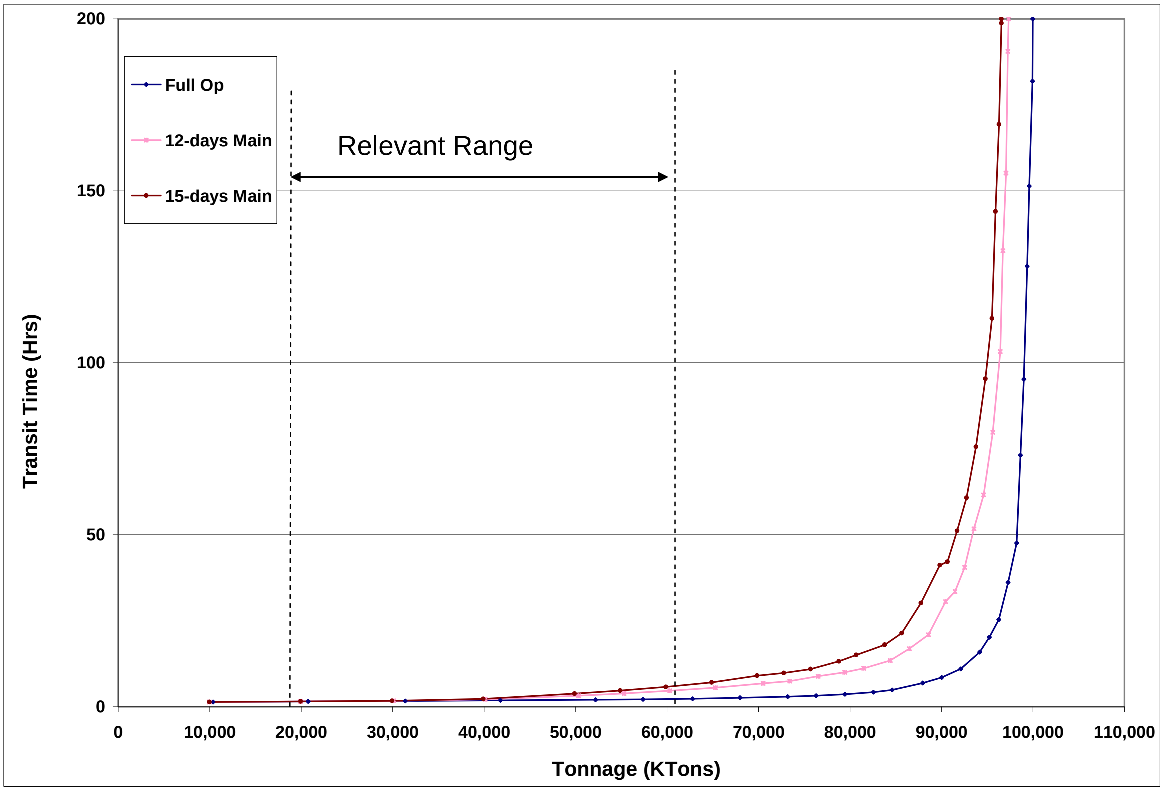


FIGURE A2- 44
Emsworth New 800' & Old 600' Main Chamber Half Speed Curves

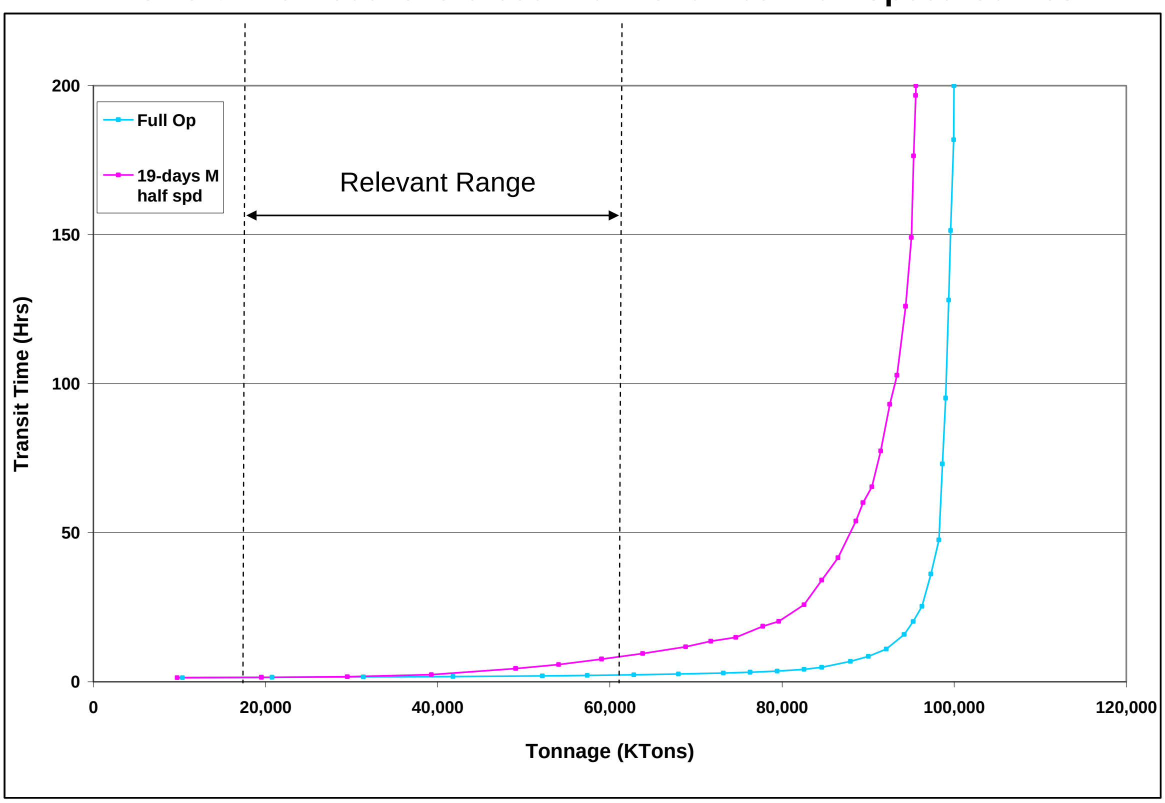


FIGURE A2- 45
Emsworth New 800' & Old 600' Auxiliary Chamber Curves

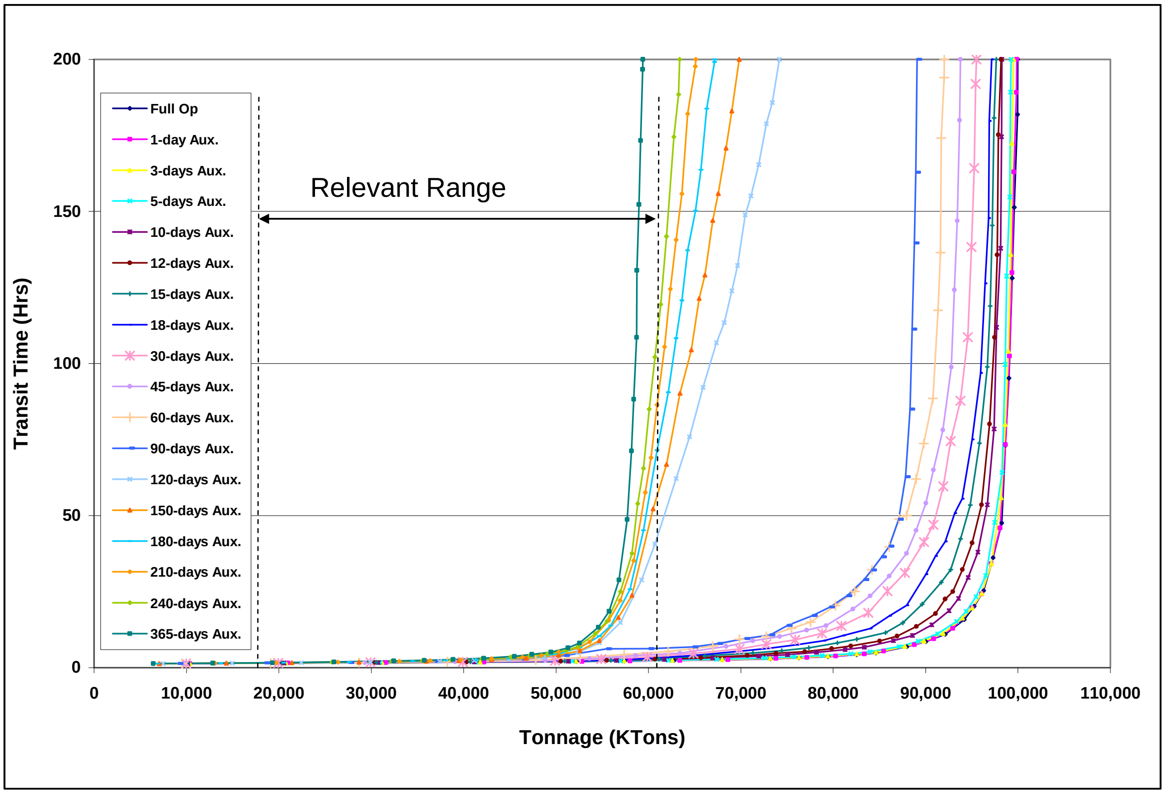


FIGURE A2- 46
Emsworth New 800' & Old 600' Auxiliary Chamber Half Speed Curves

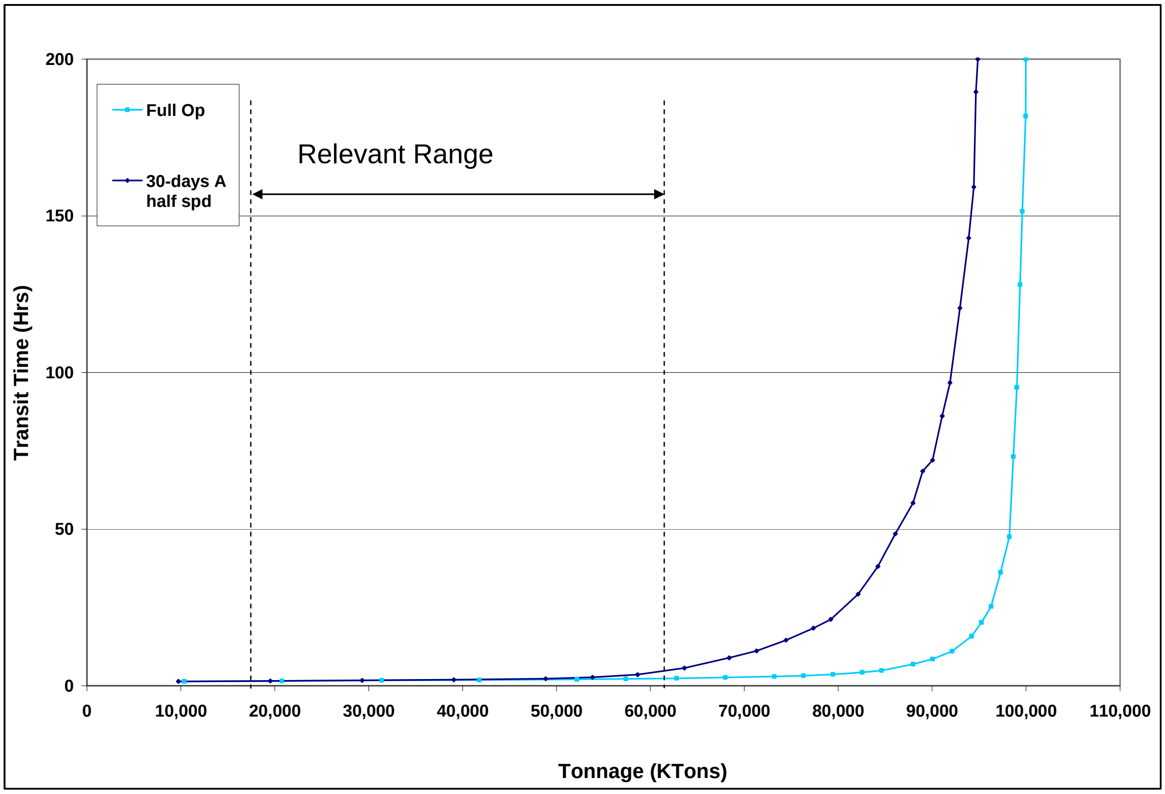


FIGURE A2- 47
Emsworth New 1200' & Old 600' Main Chamber Curves

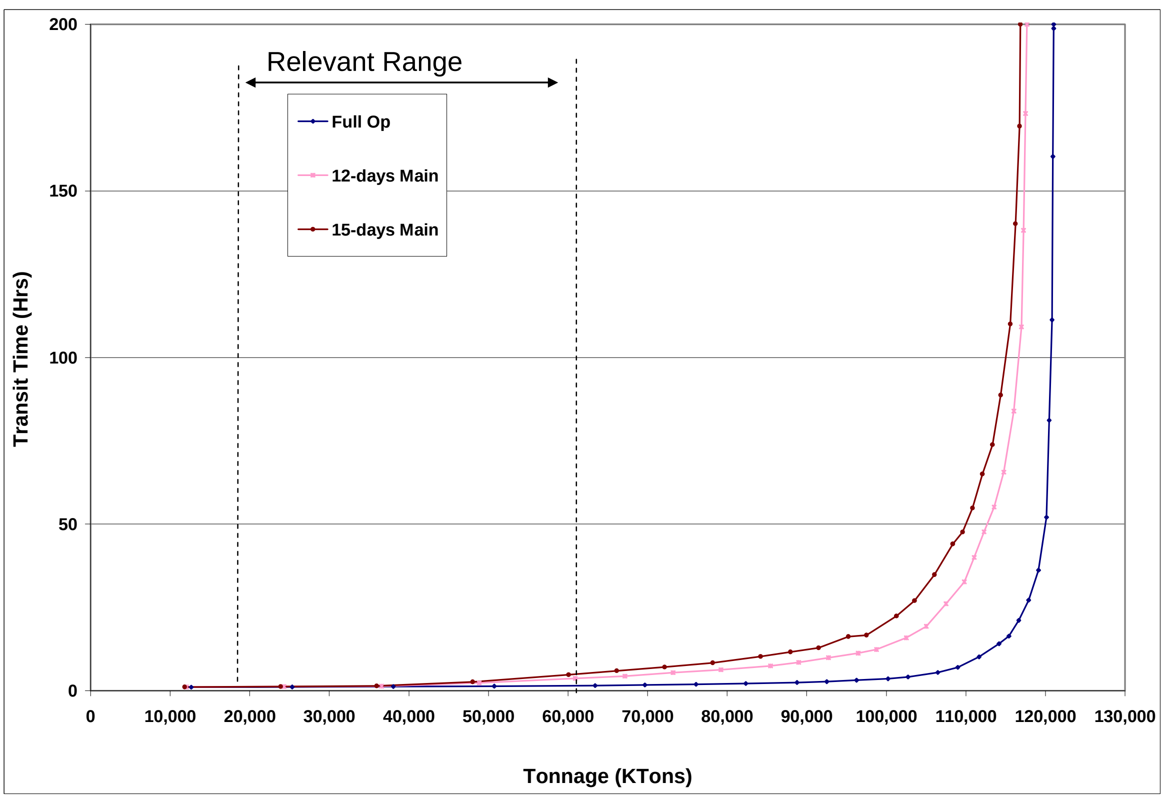


FIGURE A2- 48
Emsworth New 1200' & Old 600' Main Chamber Half Speed Curves

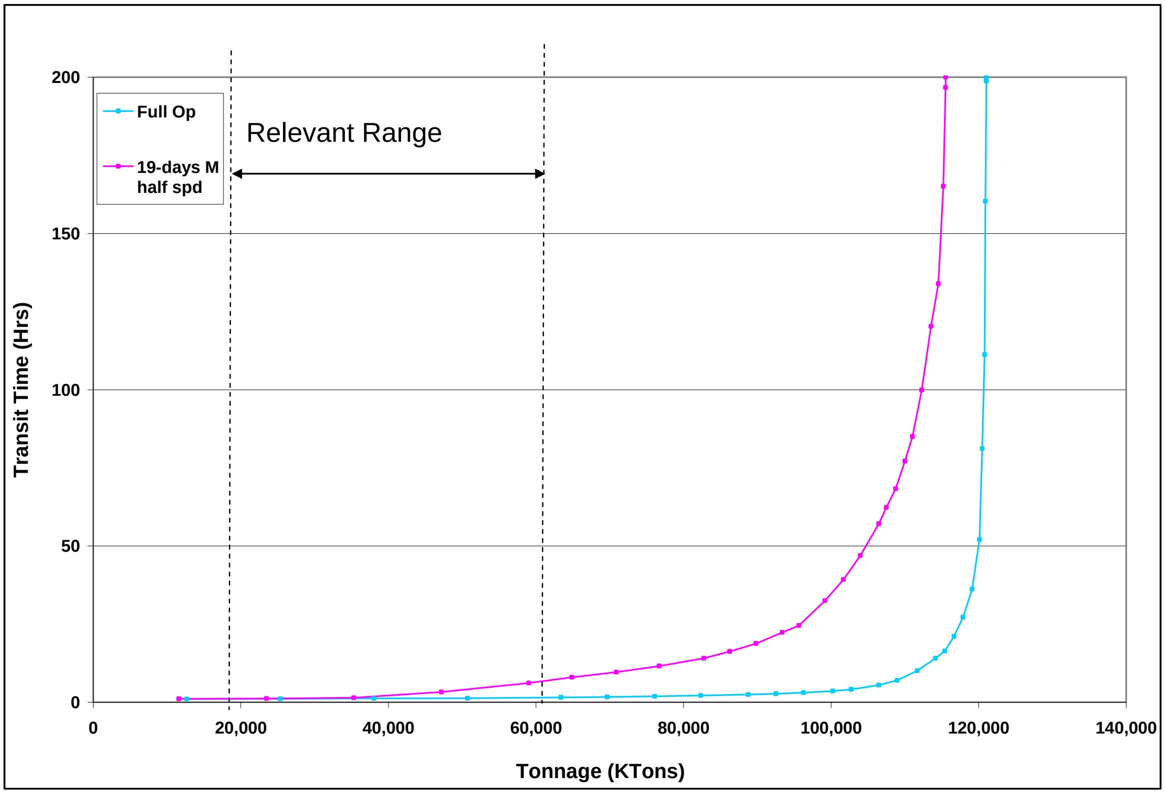


FIGURE A2- 49
Emsworth New 1200' & Old 600' Auxiliary Chamber Curves

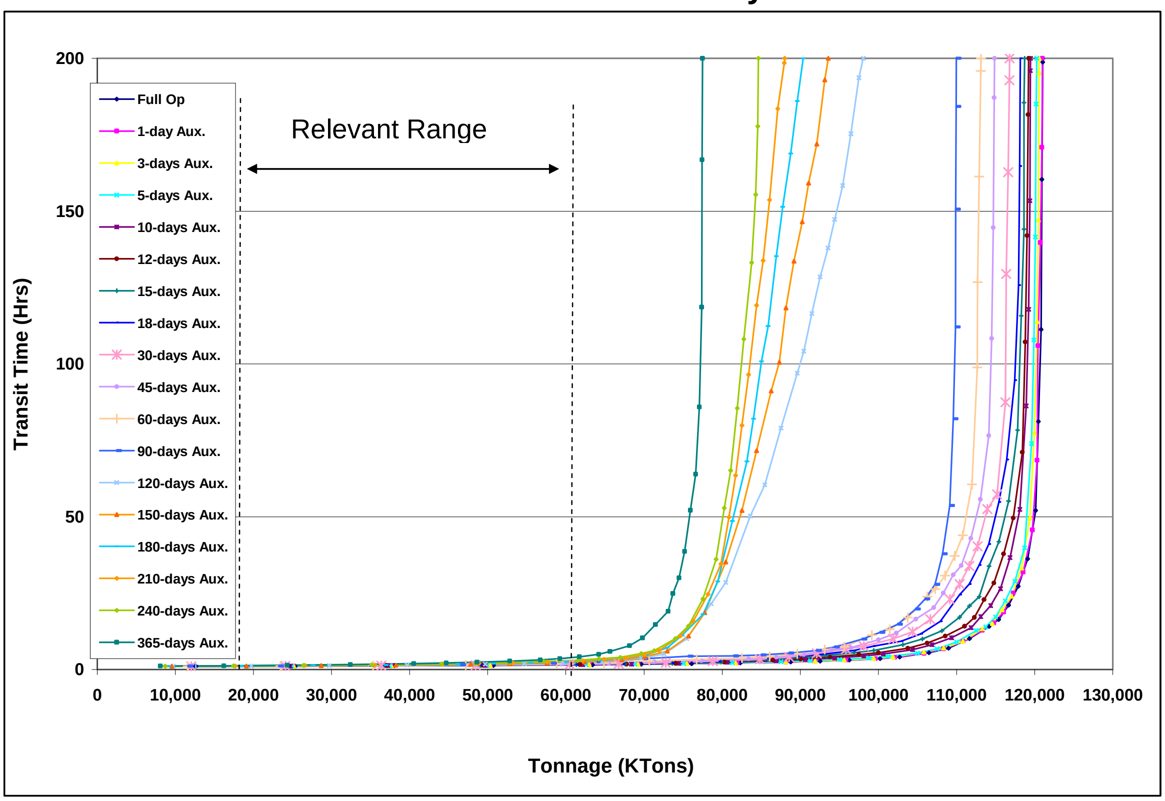


FIGURE A2- 50
Emsworth New 1200’ & Old 600’ Auxiliary Chamber Half Speed Curves

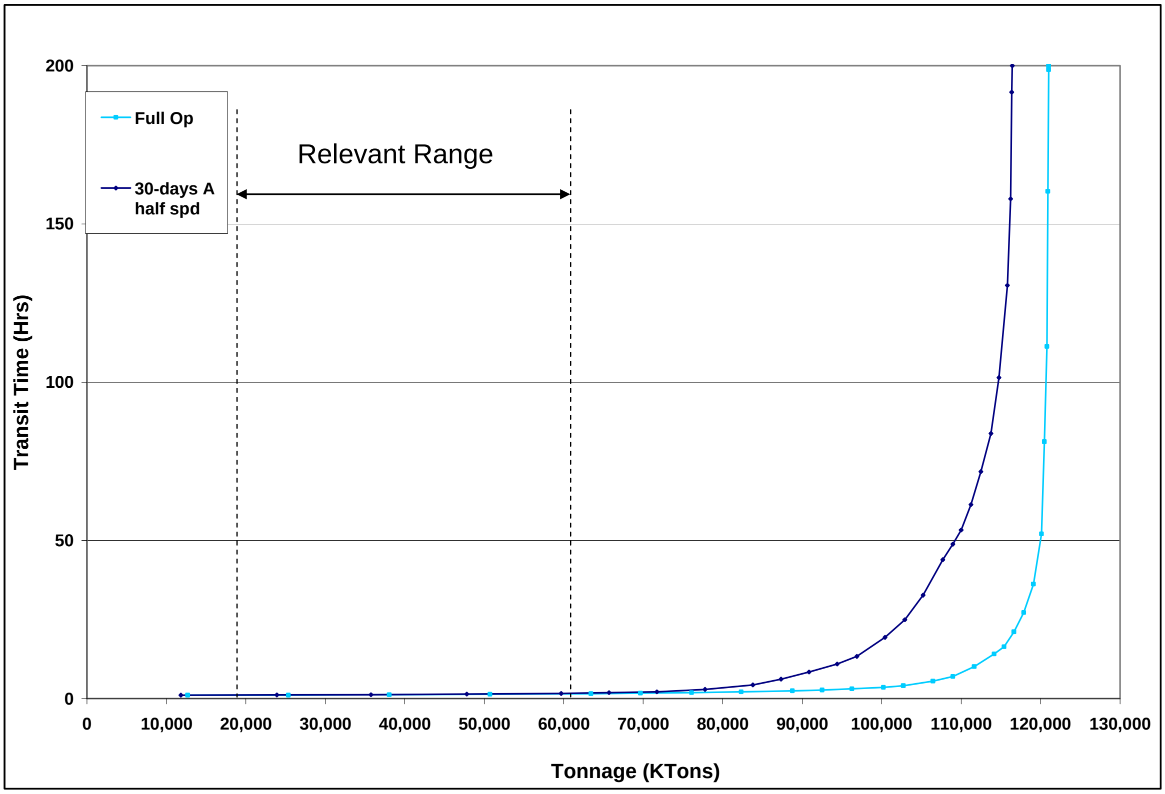


FIGURE A2- 51
Emsworth New 600’ Main & New 600’ Auxiliary Chamber Curves

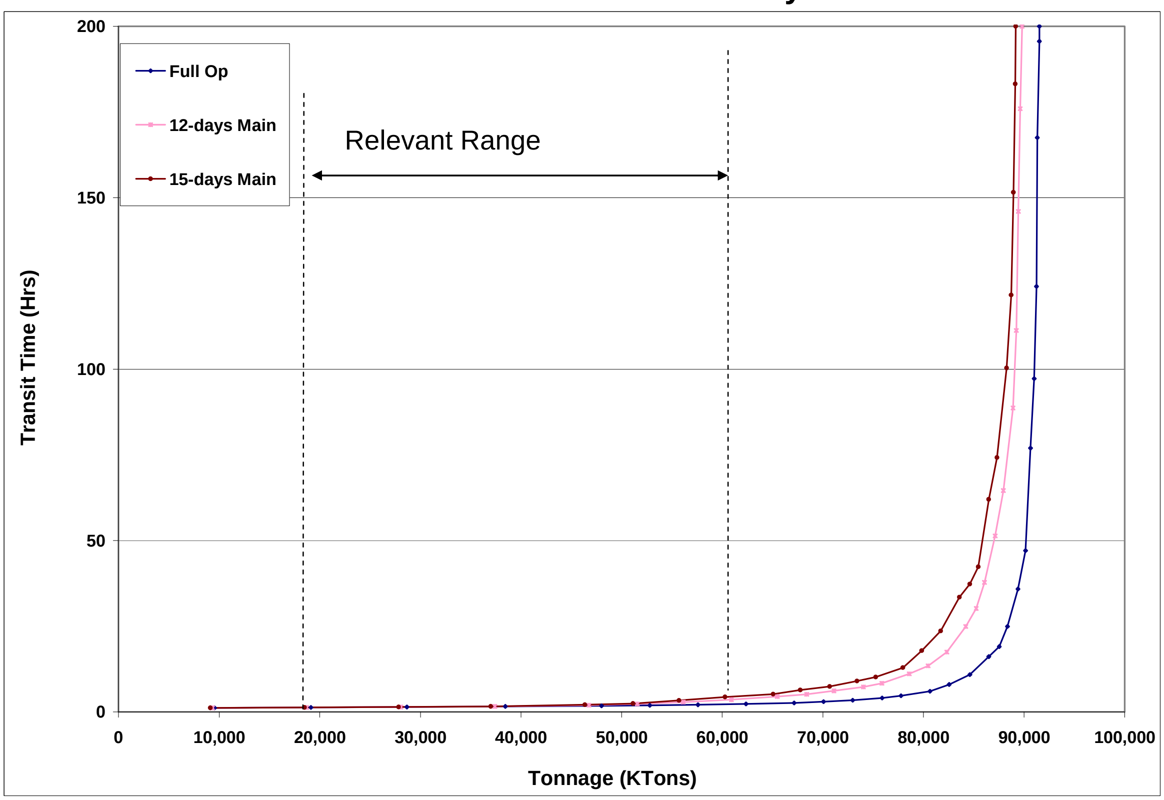


FIGURE A2- 52
Emsworth New 600' Main & New 600' Auxiliary Chamber Half Speed Curves

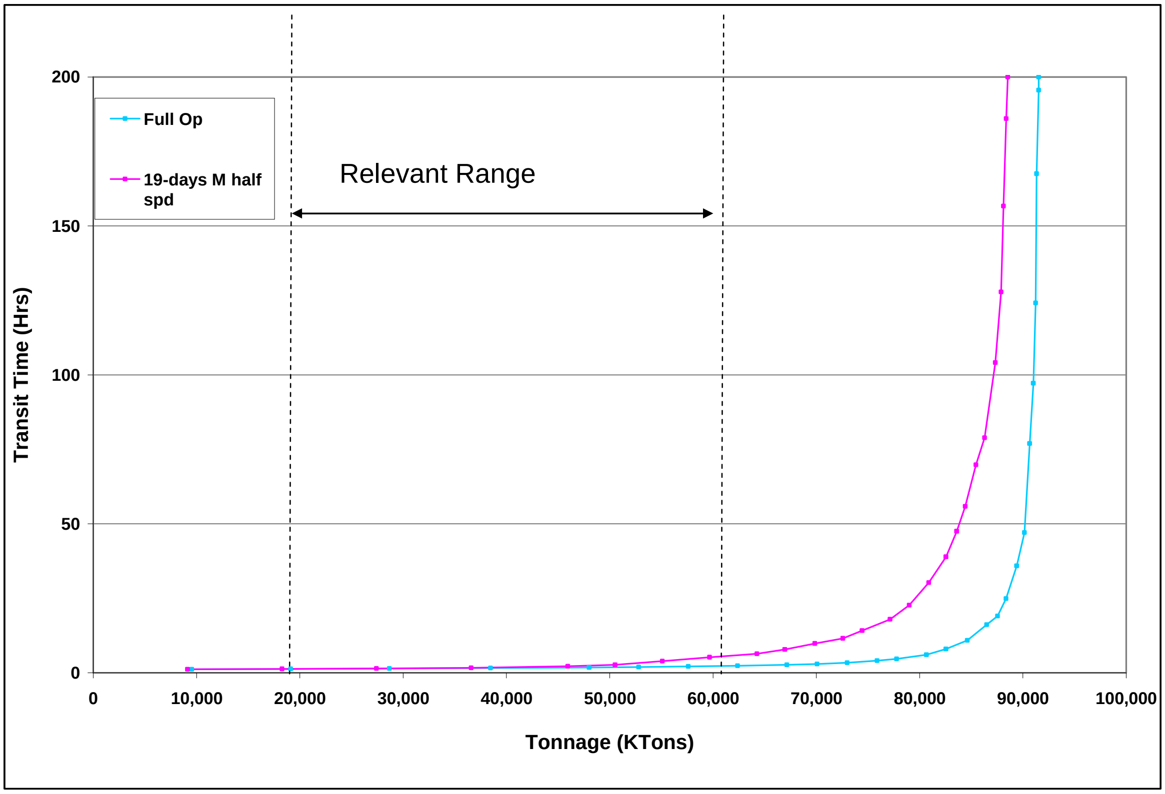


FIGURE A2- 53
Emsworth New 800' & New 600' Main Chamber Curves

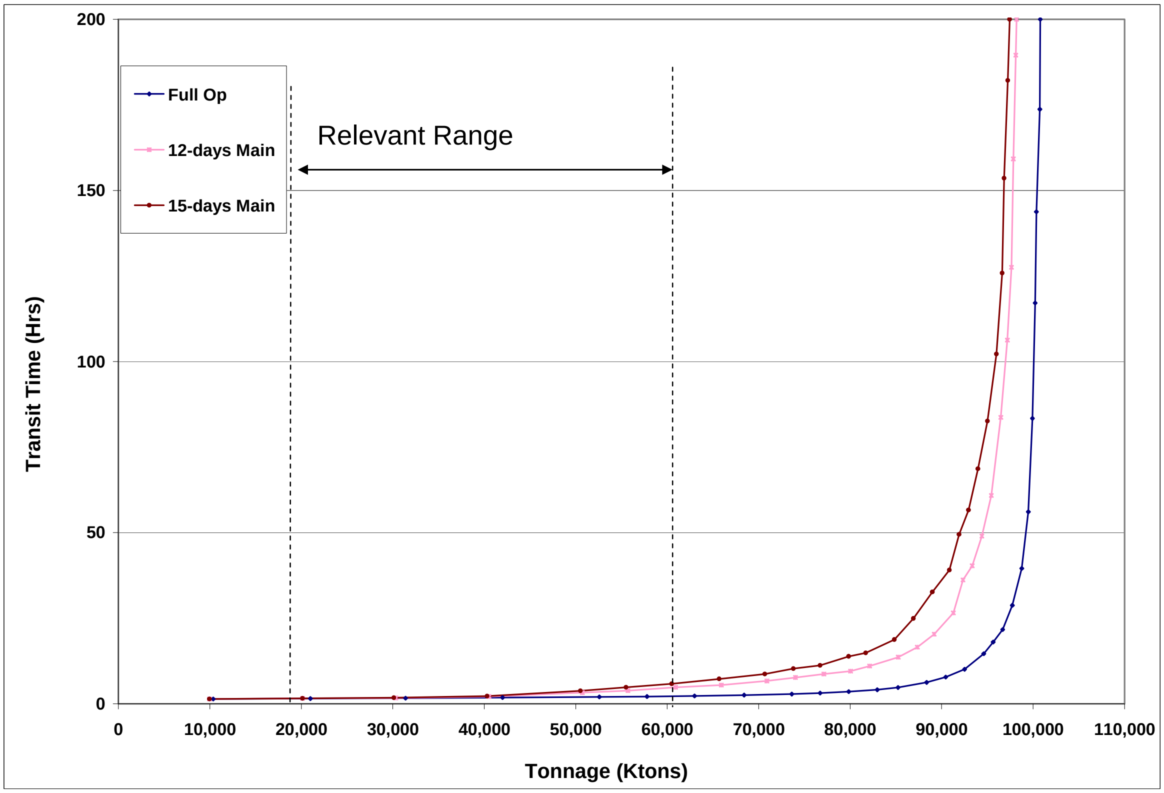


FIGURE A2- 54
Emsworth New 800' & New 600' Main Chamber Half Speed Curves

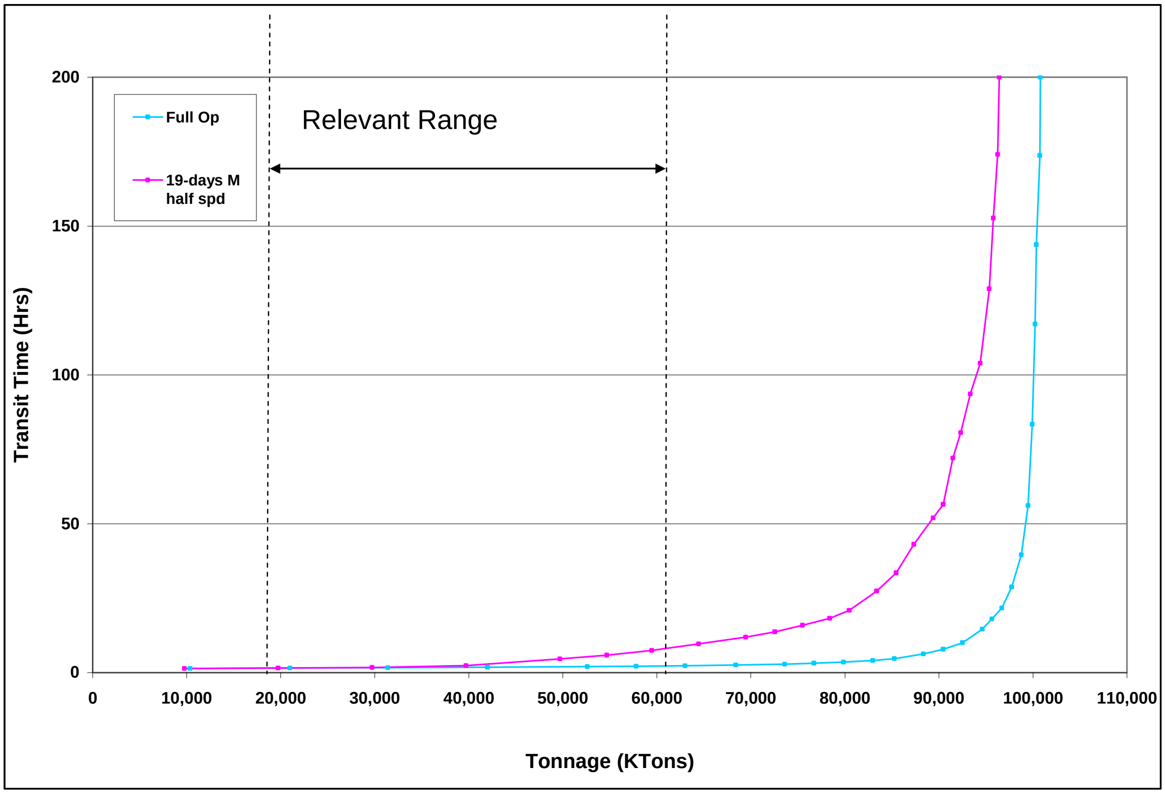


FIGURE A2- 55
Emsworth New 800' & New 600'Auxiliary Chamber Curves

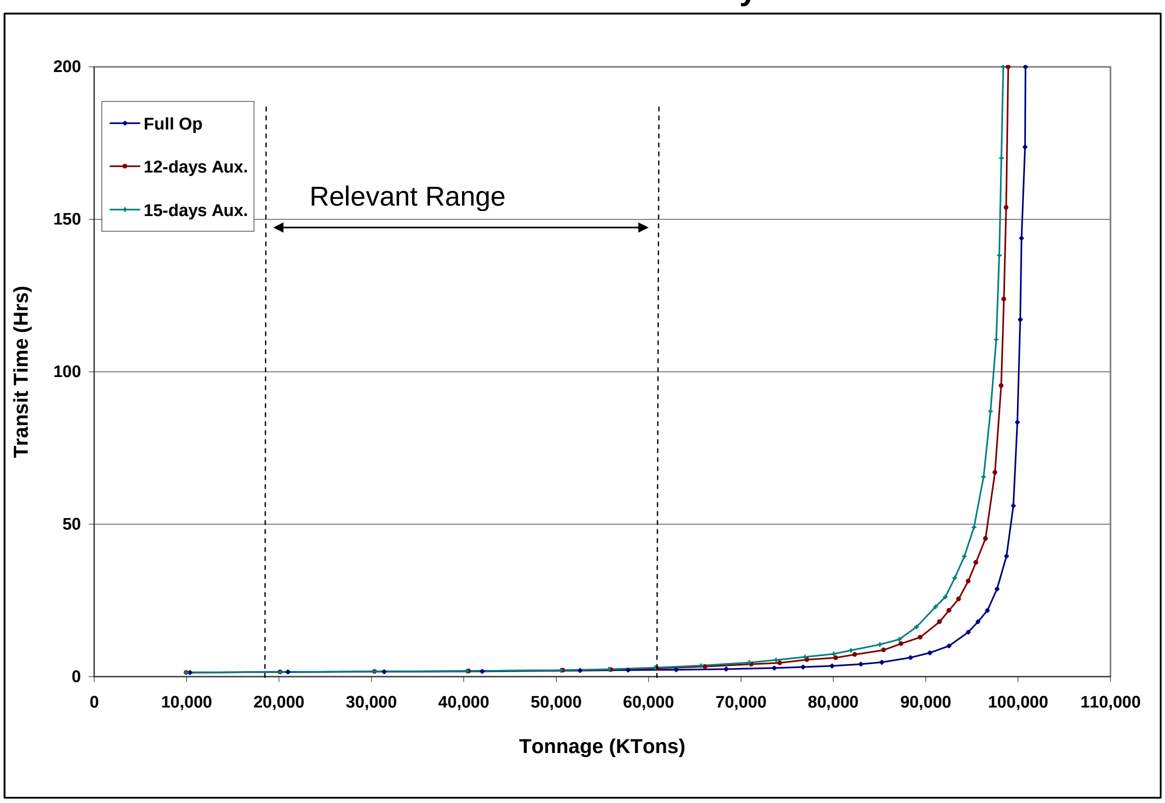


FIGURE A2- 56
Emsworth New 800' & New 600'Auxiliary Chamber Half Speed Curves

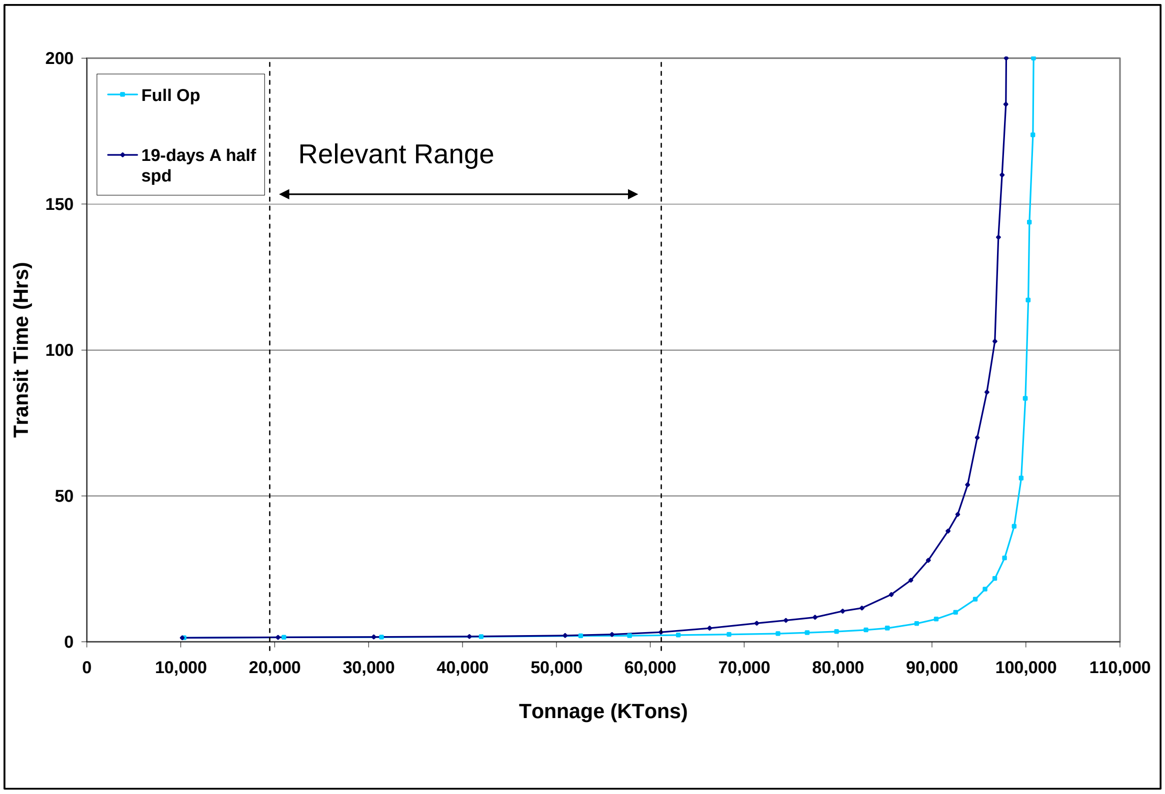


FIGURE A2- 57
Emsworth New 1200' & New 600'Main Chamber Curves

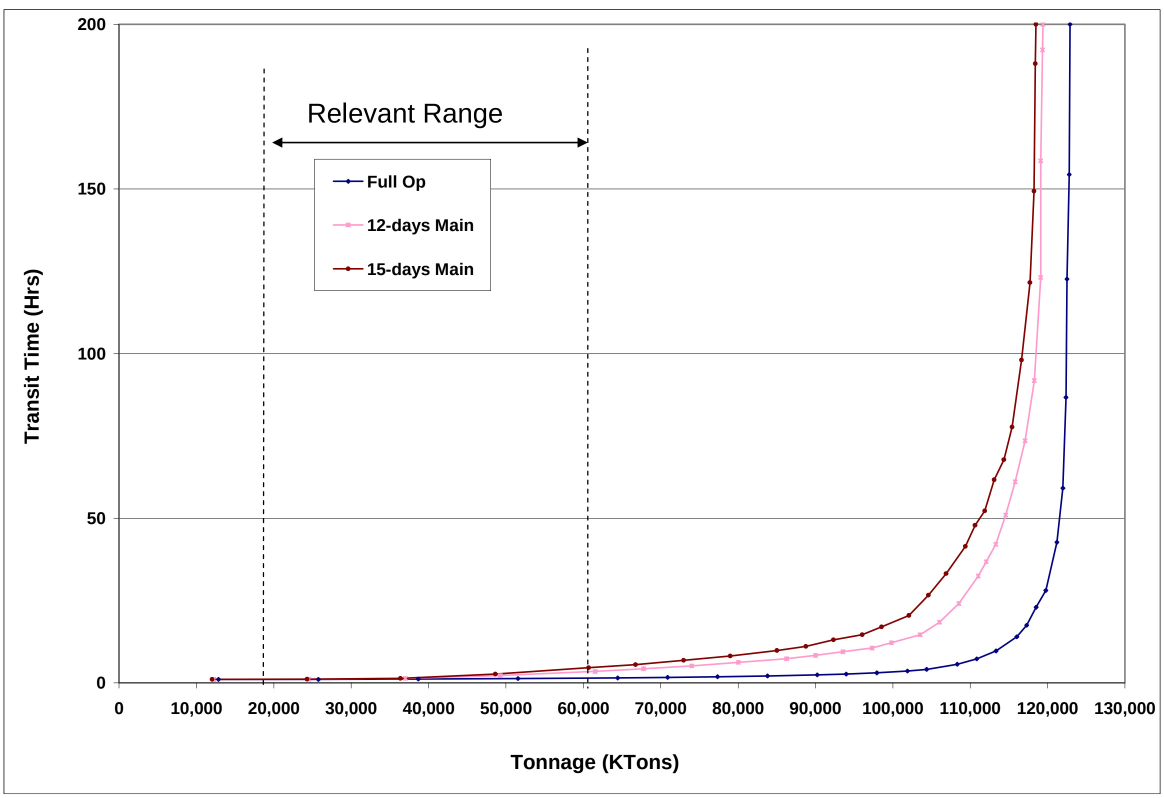


FIGURE A2- 58
Emsworth New 1200' & New 600'Main Chamber Half Speed Curves

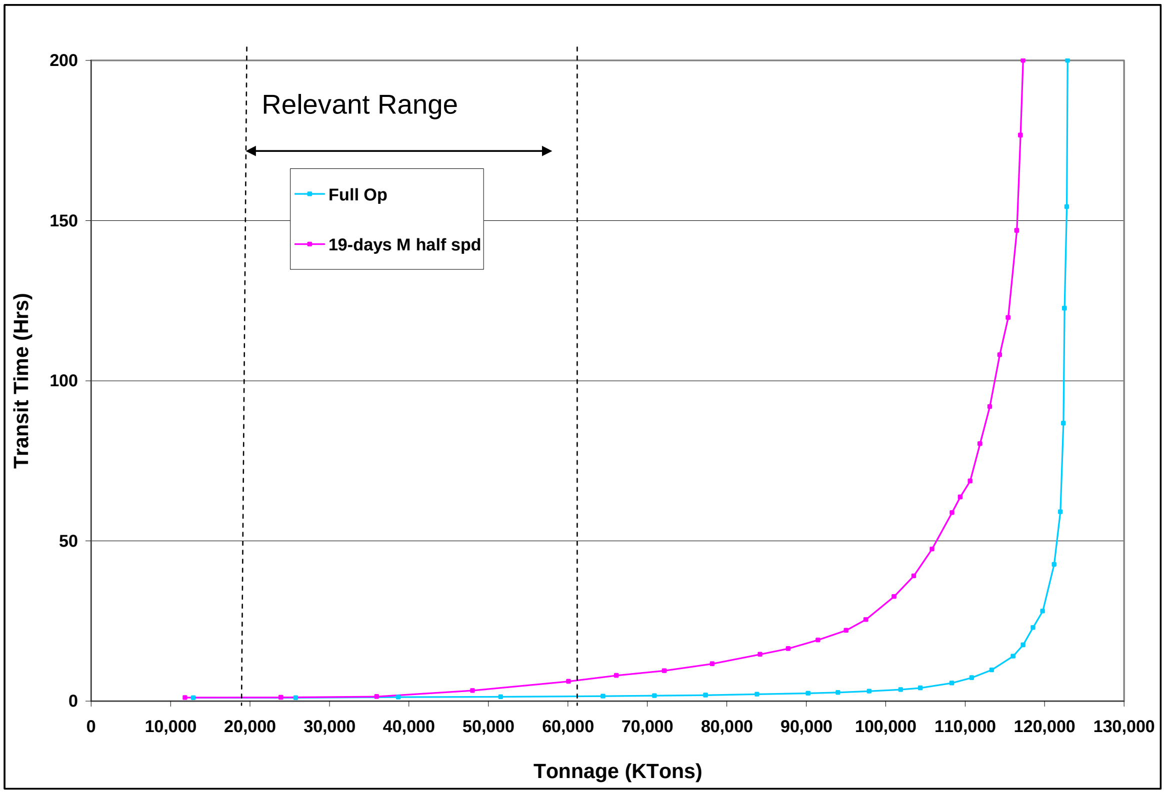


FIGURE A2- 59
Emsworth New 1200' & New 600'Auxiliary Chamber Curves

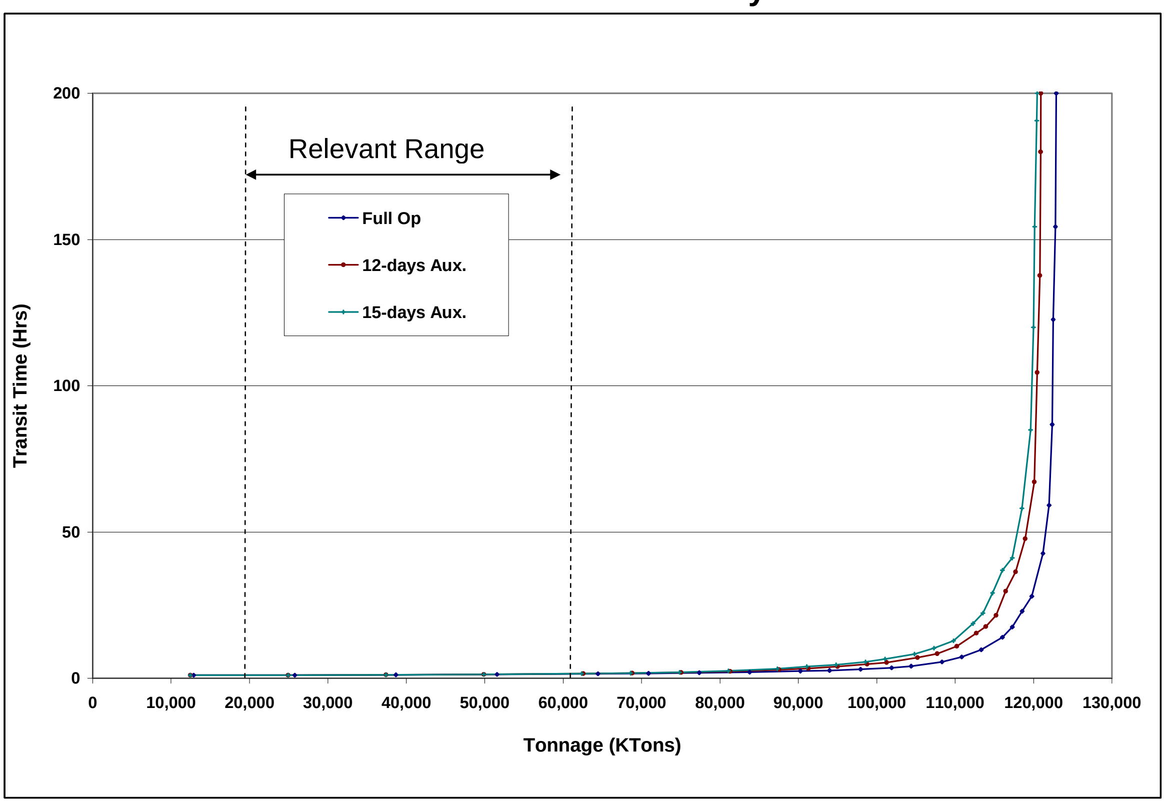


FIGURE A2- 60
Emsworth New 1200' & New 600'Auxiliary Chamber Half Speed Curves

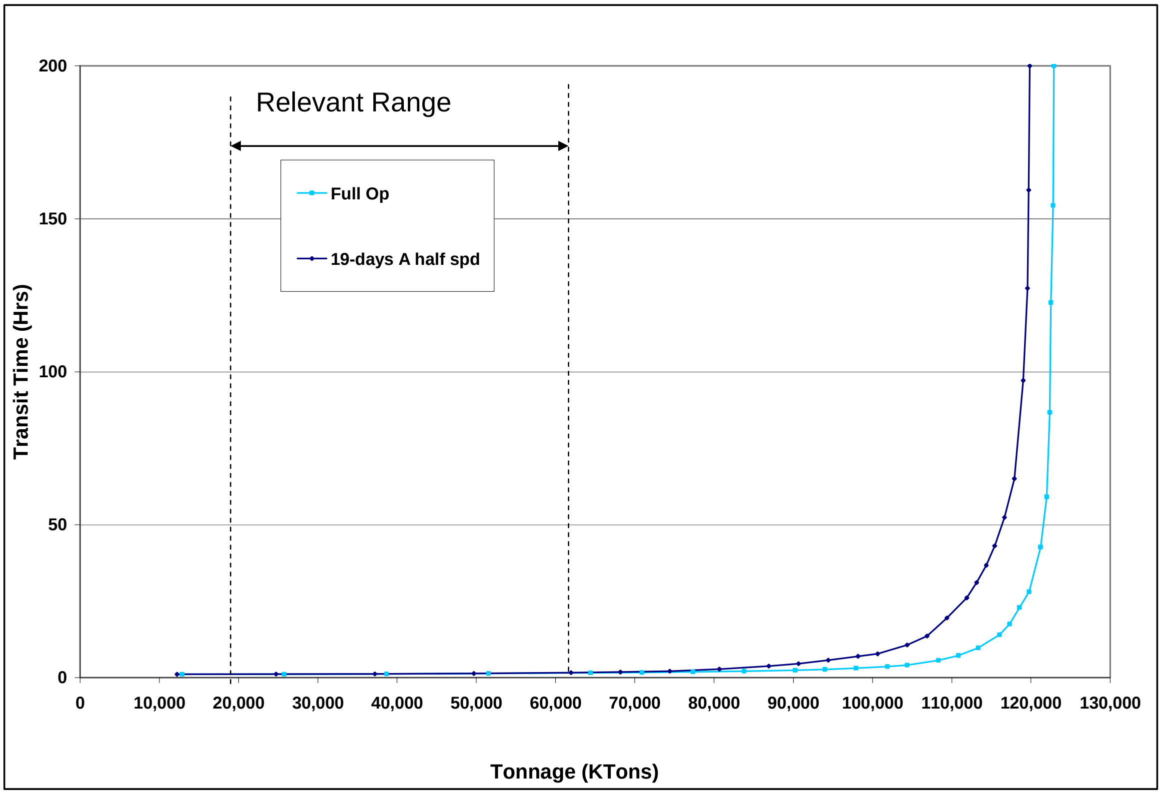


FIGURE A2- 61
Emsworth New Single 600' Main Chamber Curves

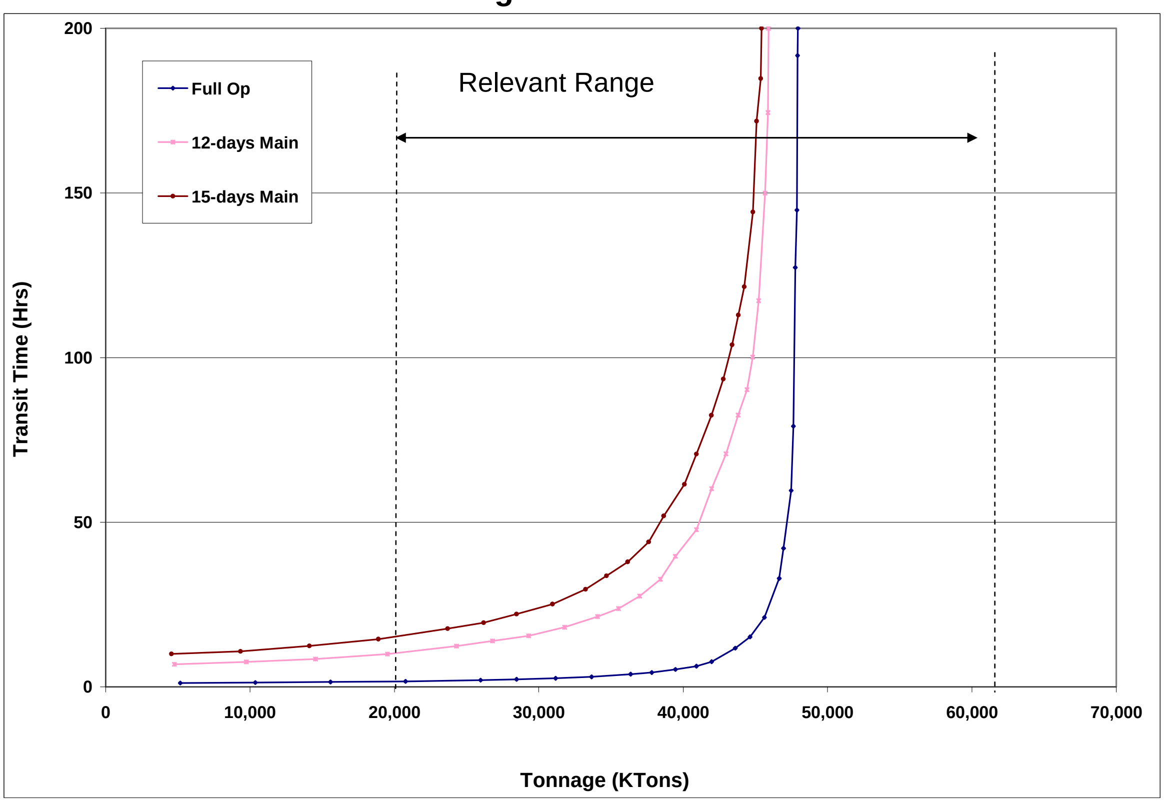


FIGURE A2- 62
Emsworth New Single 600' Main Chamber Half Speed Curves

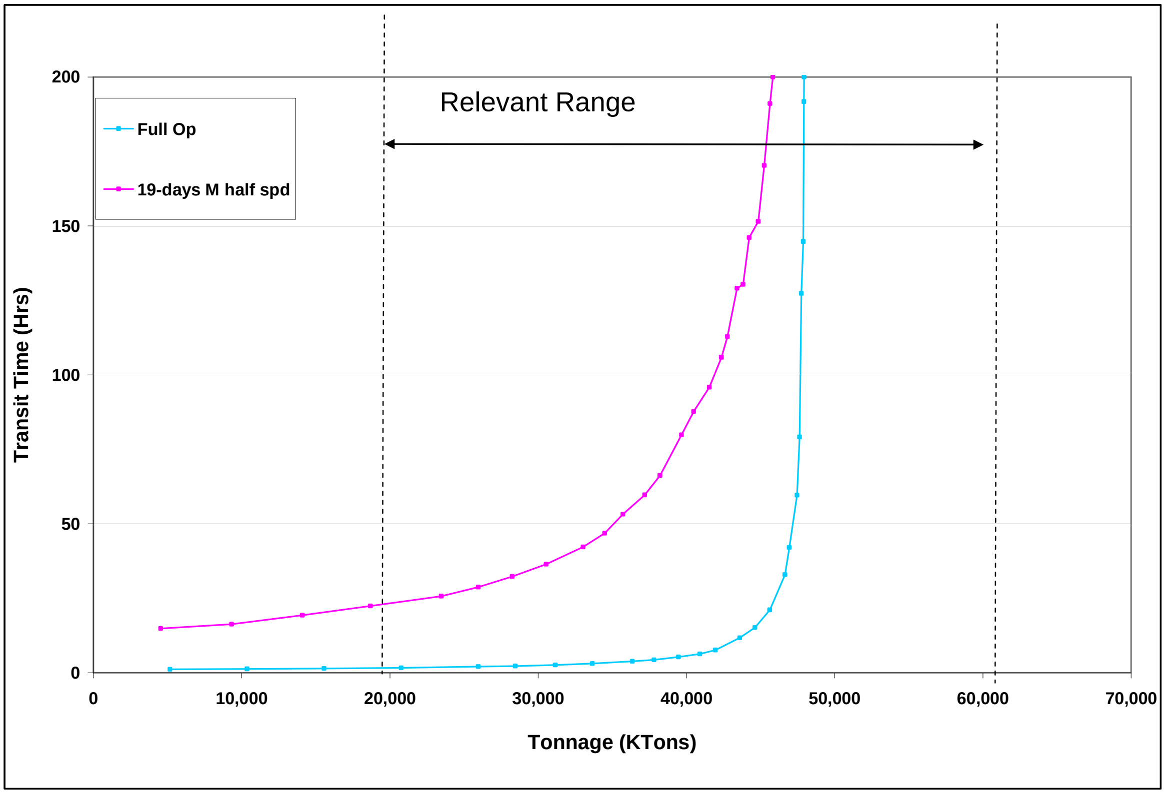


FIGURE A2- 63
Emsworth New Single 800' Main Chamber Curves

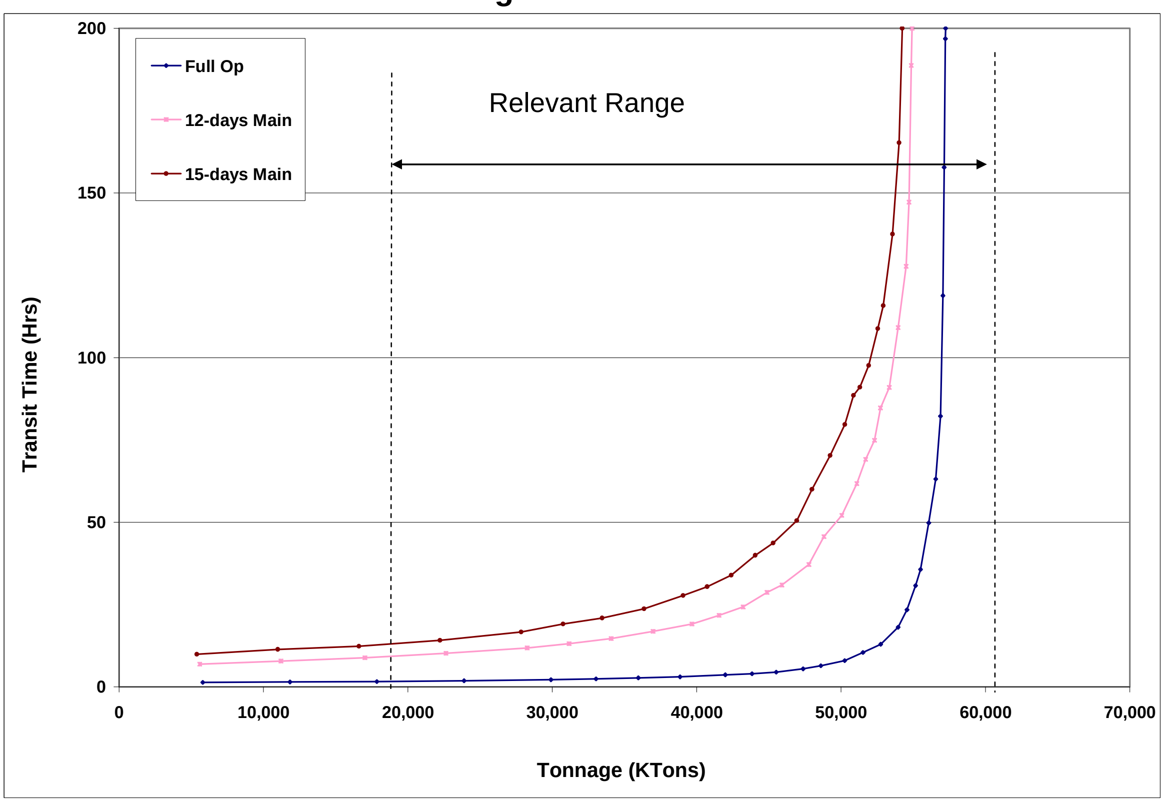


FIGURE A2- 64
Emsworth New Single 800’ Main Chamber Half Speed Curves

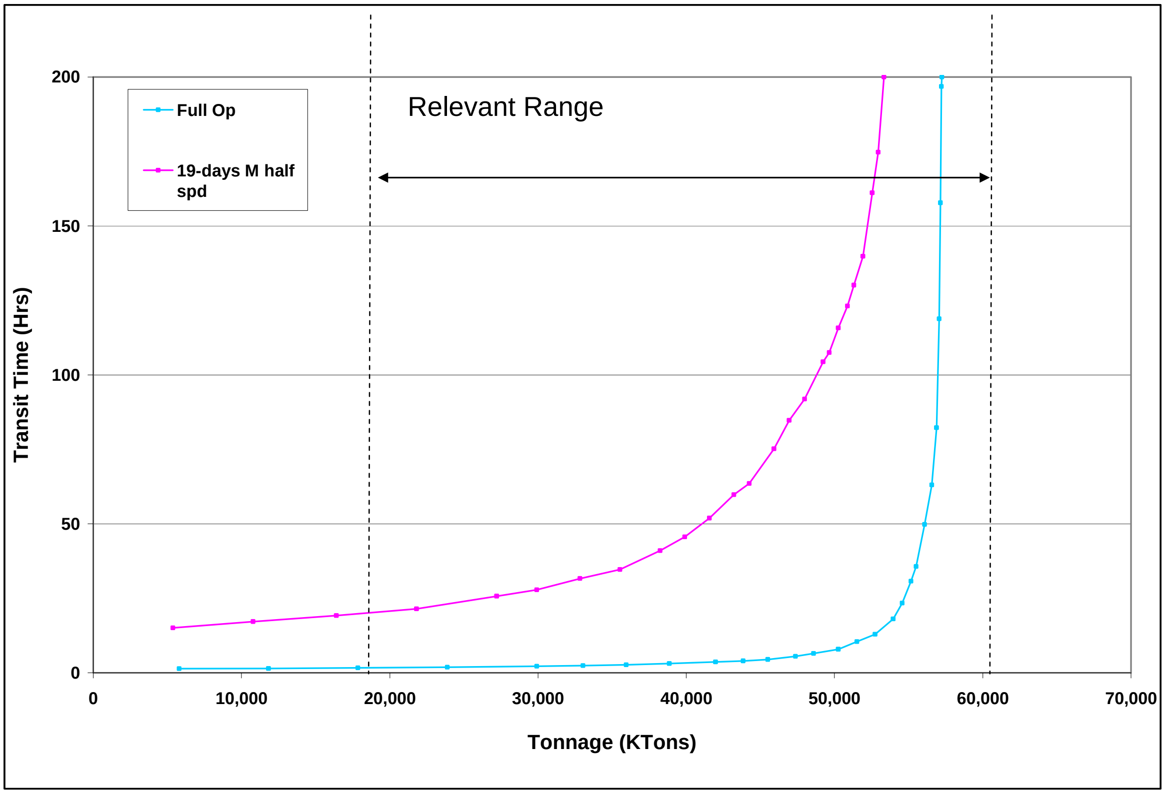


FIGURE A2- 65
Emsworth New Single 1200’ Main Chamber Curves

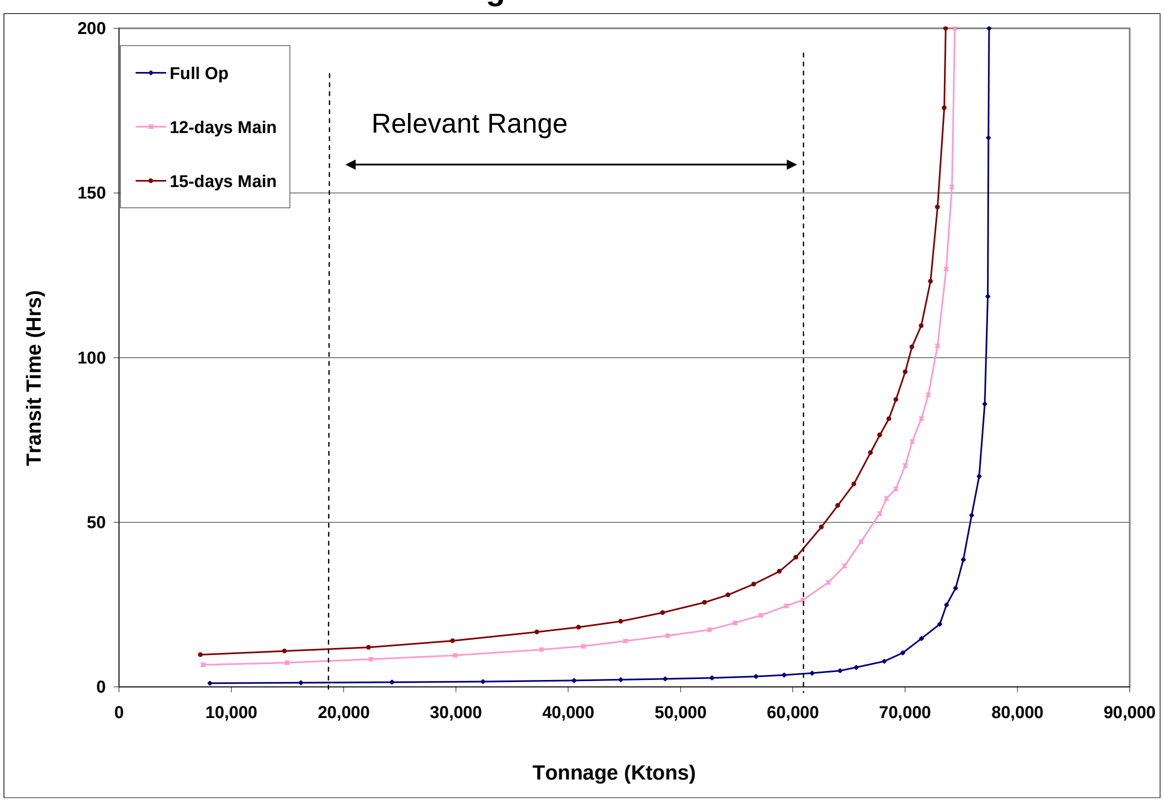


FIGURE A2- 66
Emsworth New Single 1200' Main Chamber Half Speed Curves

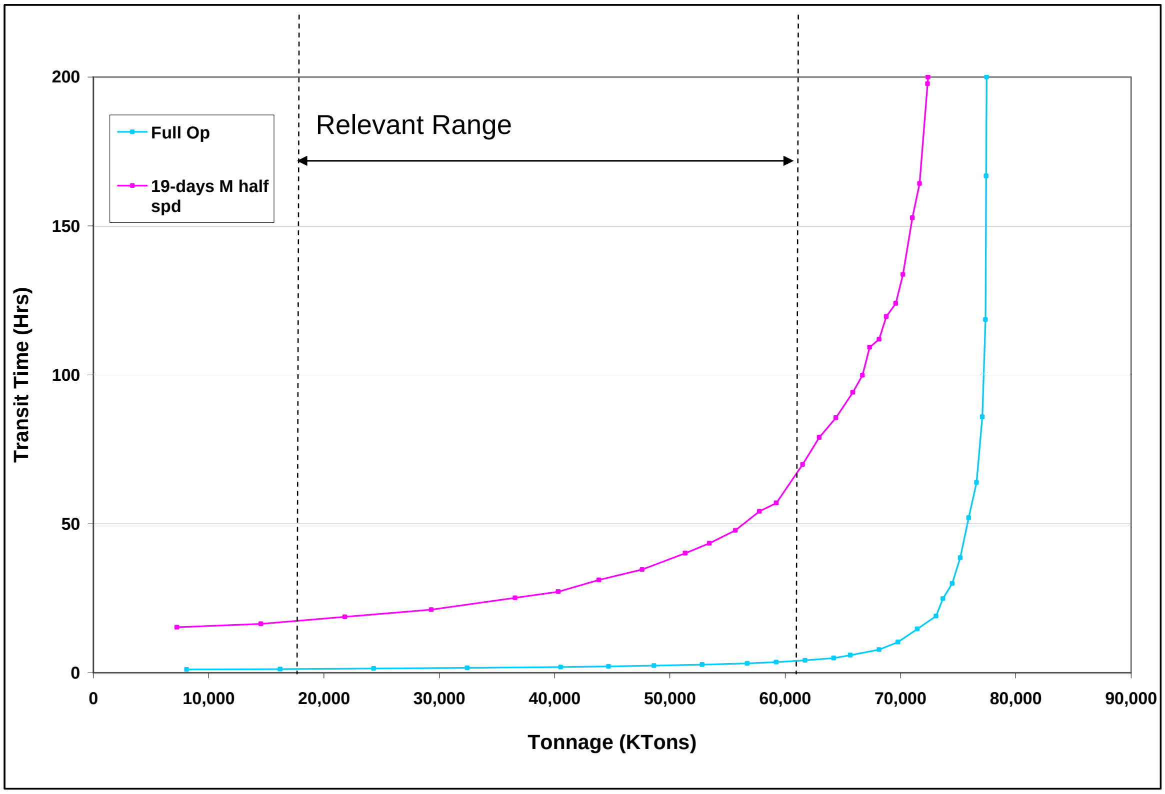


FIGURE A2- 67
Dashields New 600' & Old 600' Main Chamber Curves

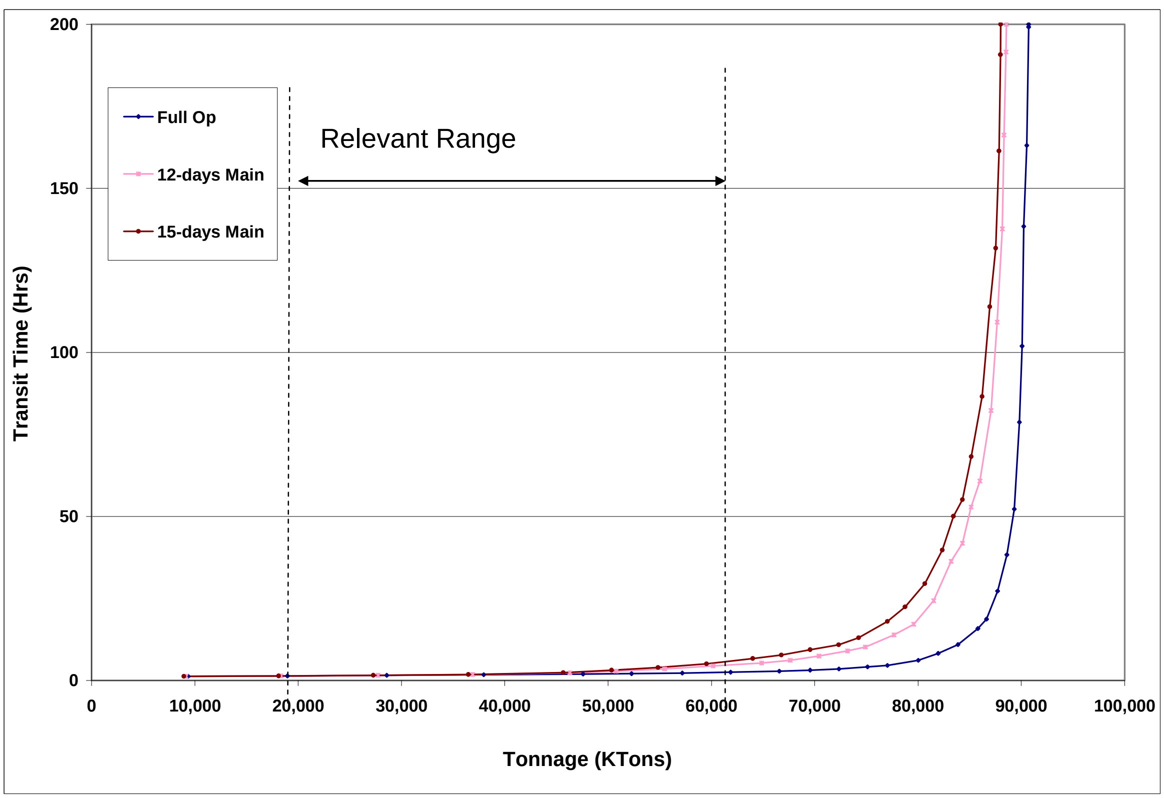


FIGURE A2- 68
Dashields New 600' & Old 600' Main Chamber Half Speeds

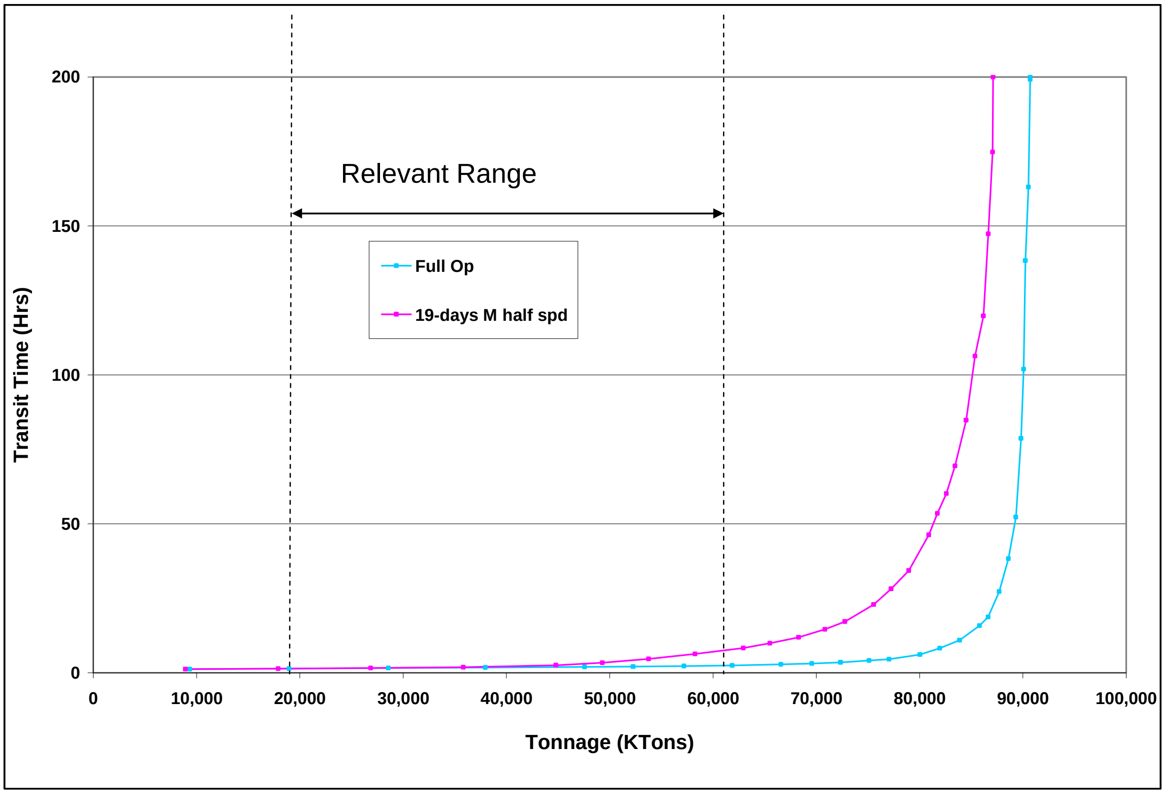


FIGURE A2- 69
Dashields New 600' & Old 600' Auxiliary Chamber Curves

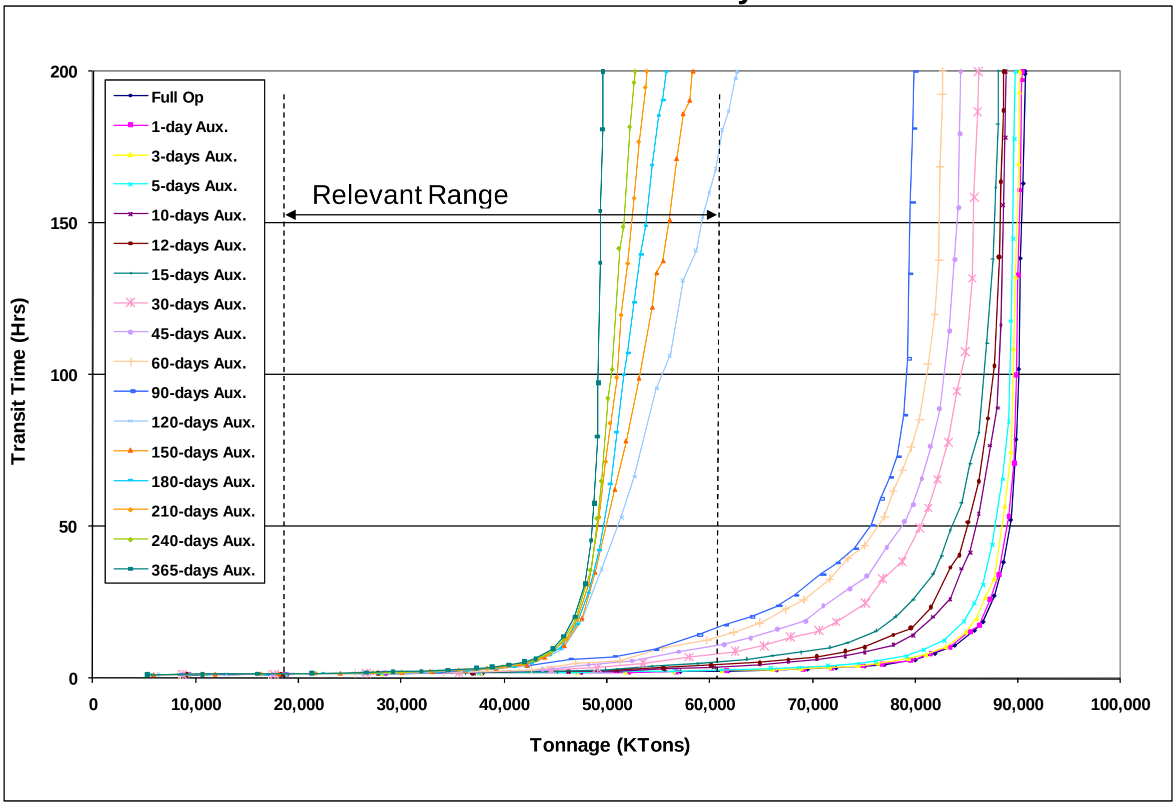


FIGURE A2- 70
Dashields New 600' & Old 600' Auxiliary Half Speeds

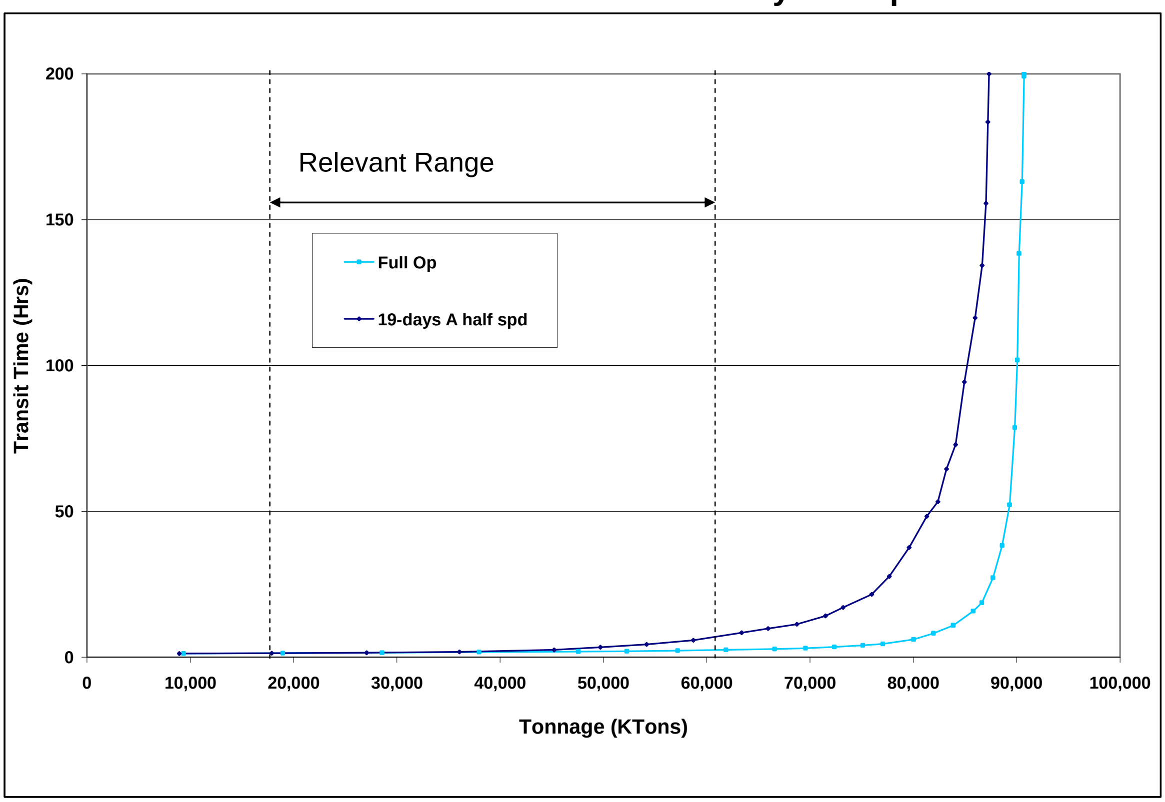


FIGURE A2- 71
Dashields New 800’ & Old 600’ Main Chamber Curves

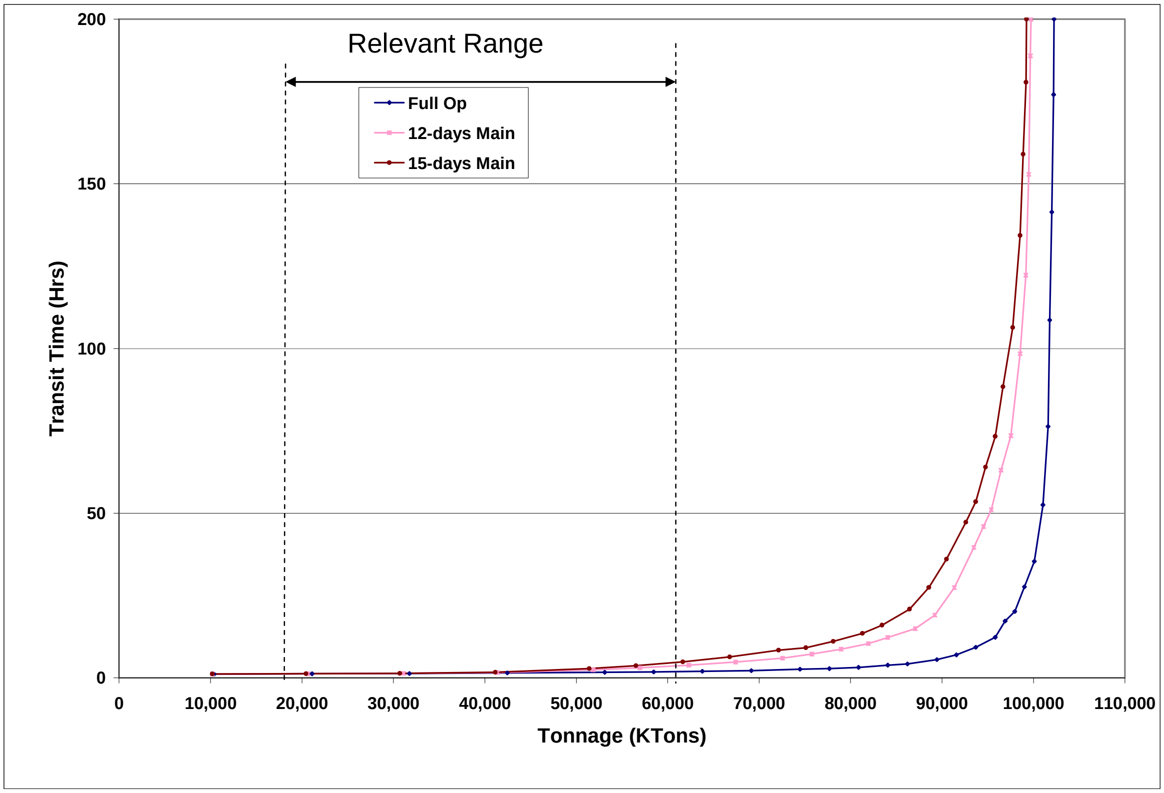


FIGURE A2- 72
Dashields New 800’ & Old 600’ Main Half Speeds

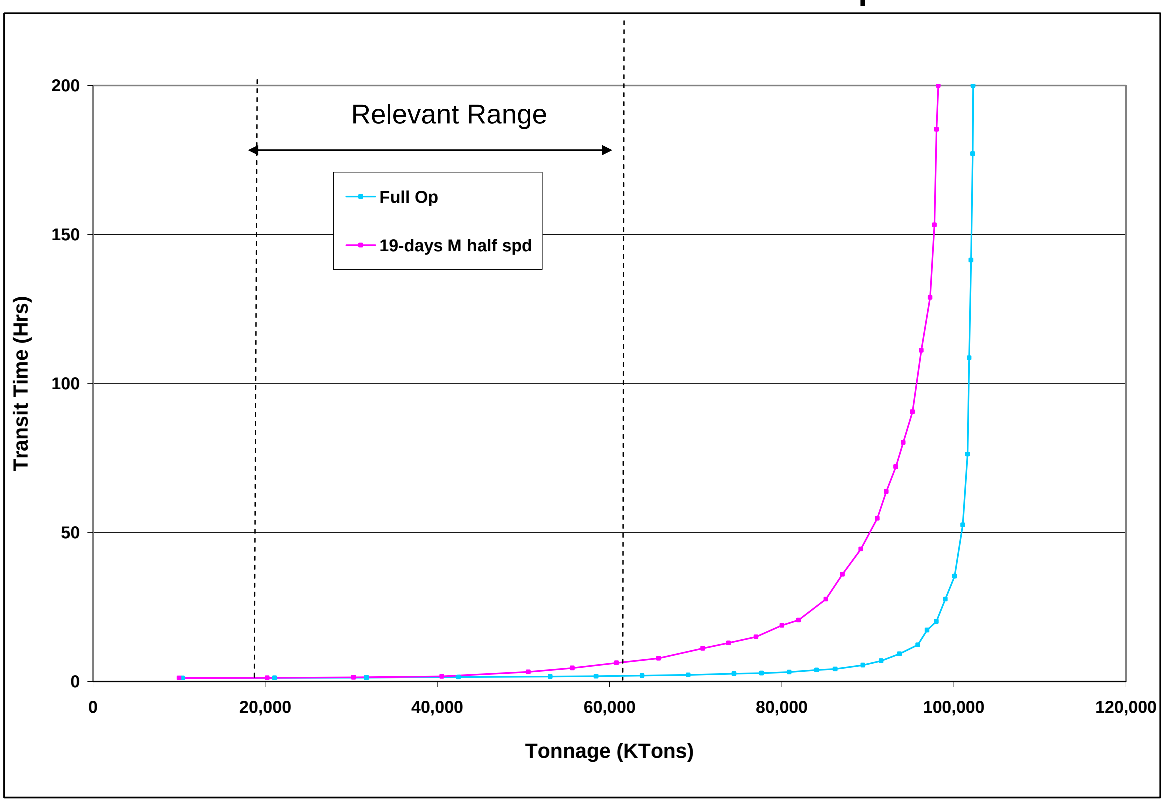


FIGURE A2- 73
Dashields New 800' & Old 600' Auxiliary Chamber Curves

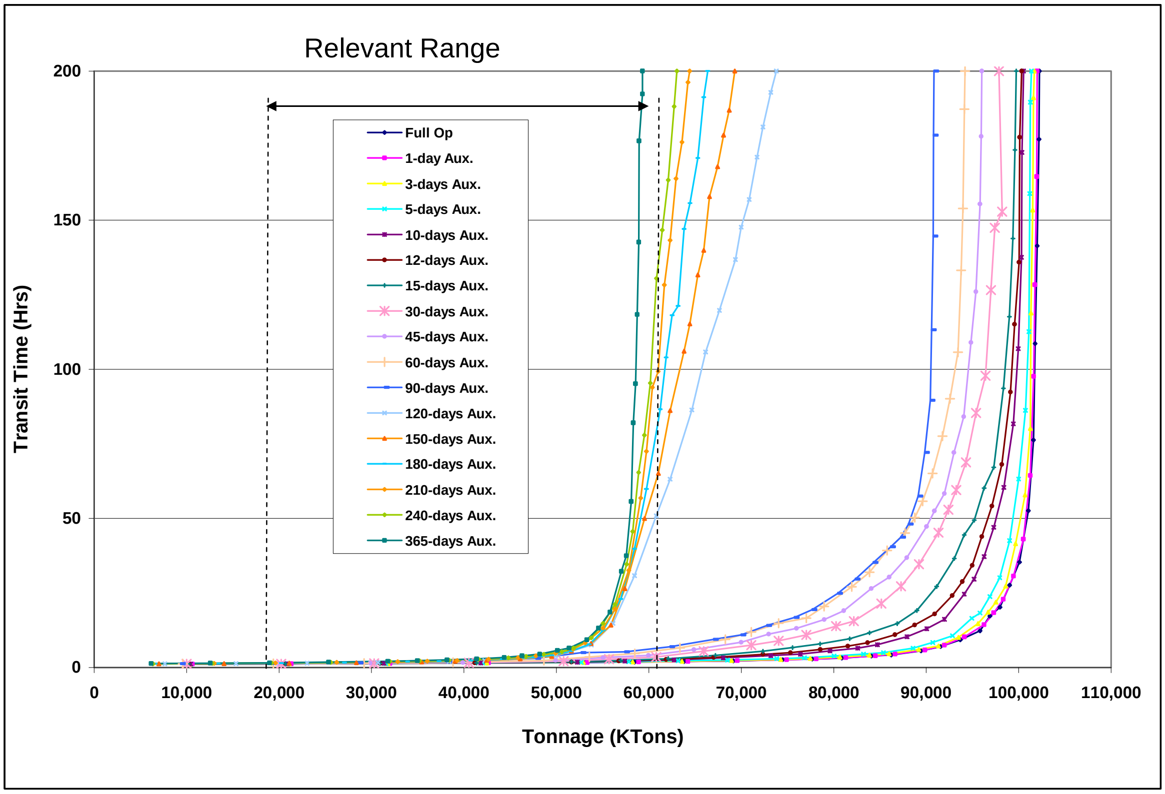


FIGURE A2- 74
Dashields New 800' & Old 600' Auxiliary Half Speeds

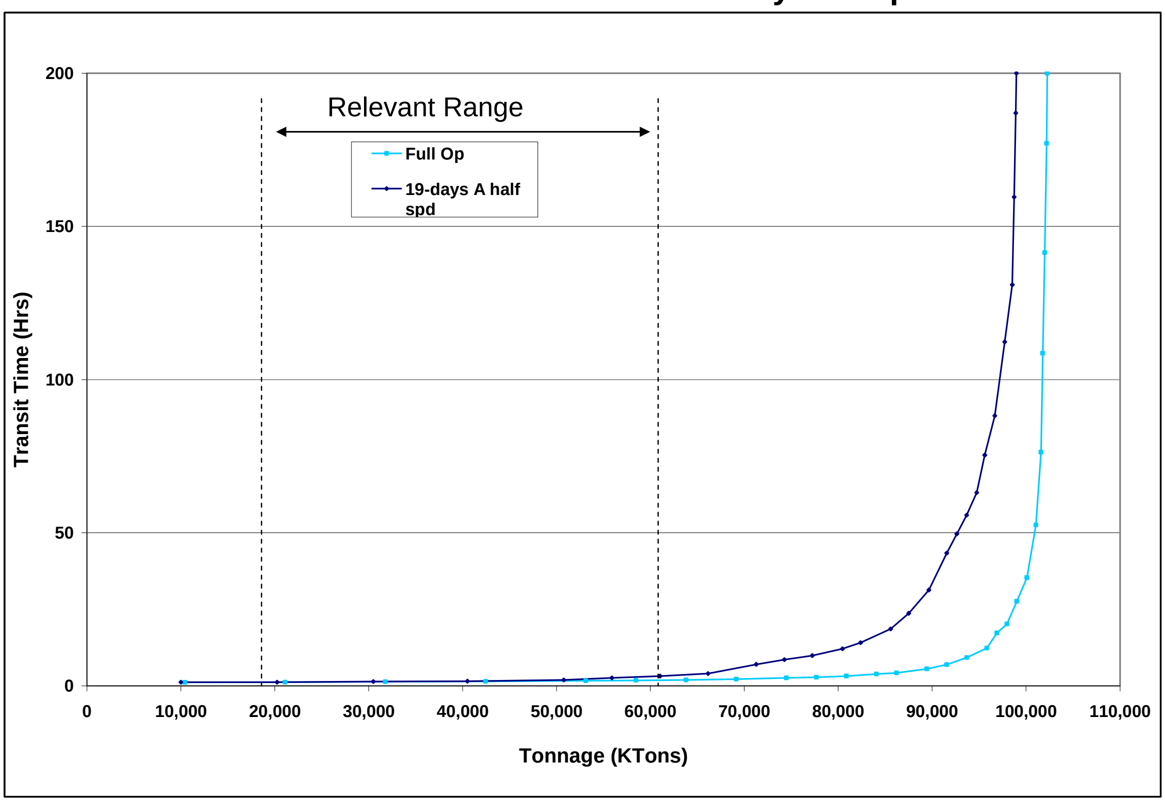


FIGURE A2- 75
Dashields New 1200’ & Old 600’ Main Chamber Curves

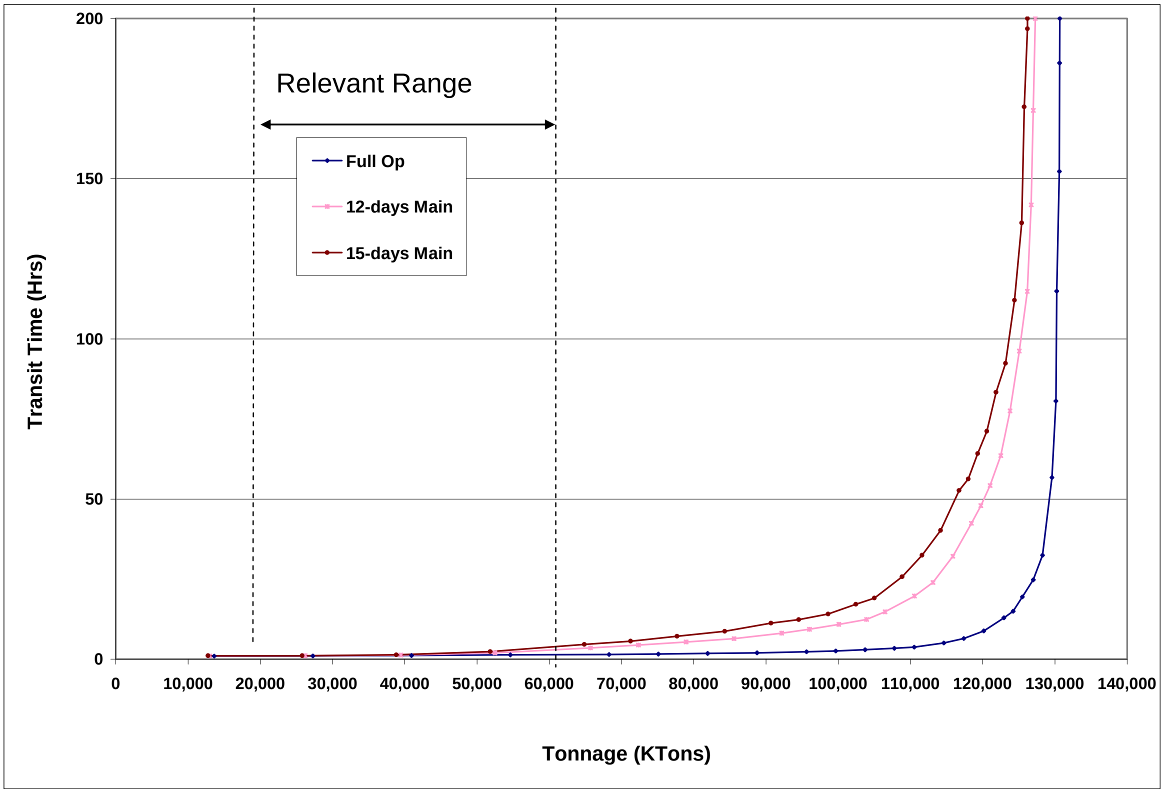


FIGURE A2- 76
Dashields New 1200’ & Old 600’ Main Half Speeds

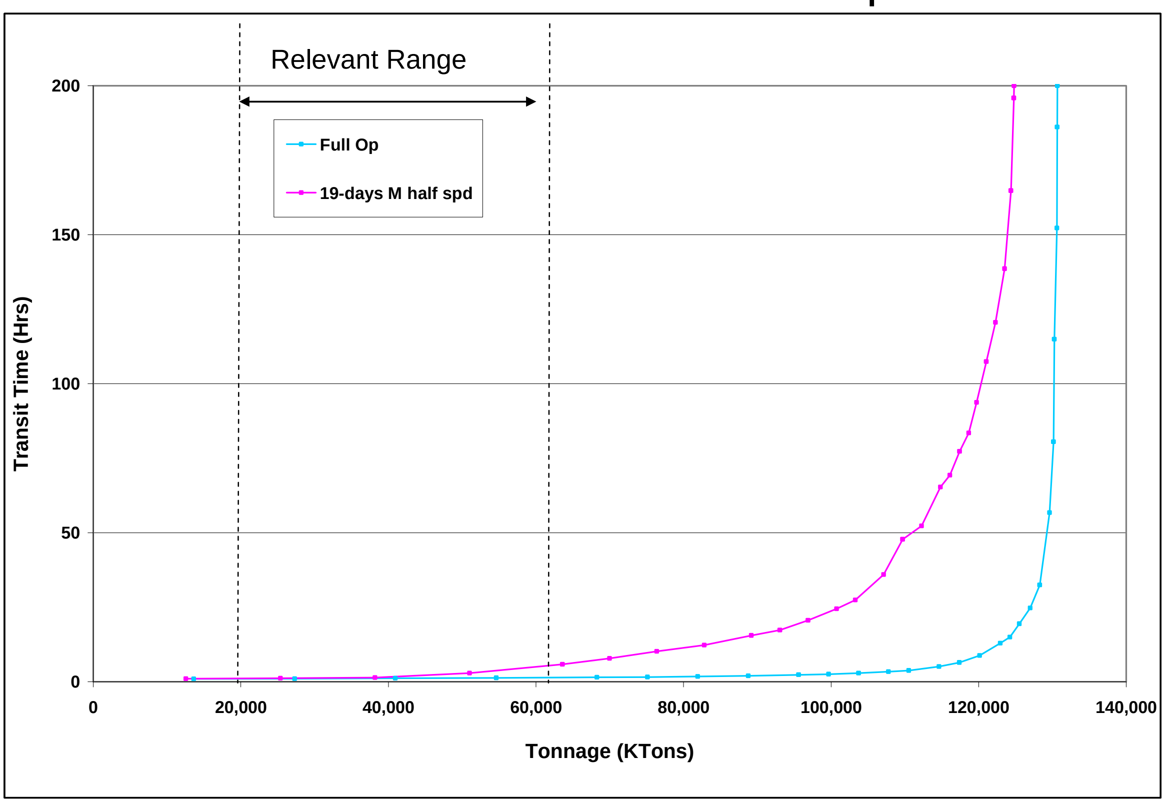


FIGURE A2- 77
Dashields New 1200’ & Old 600’ Auxiliary Chamber Curves

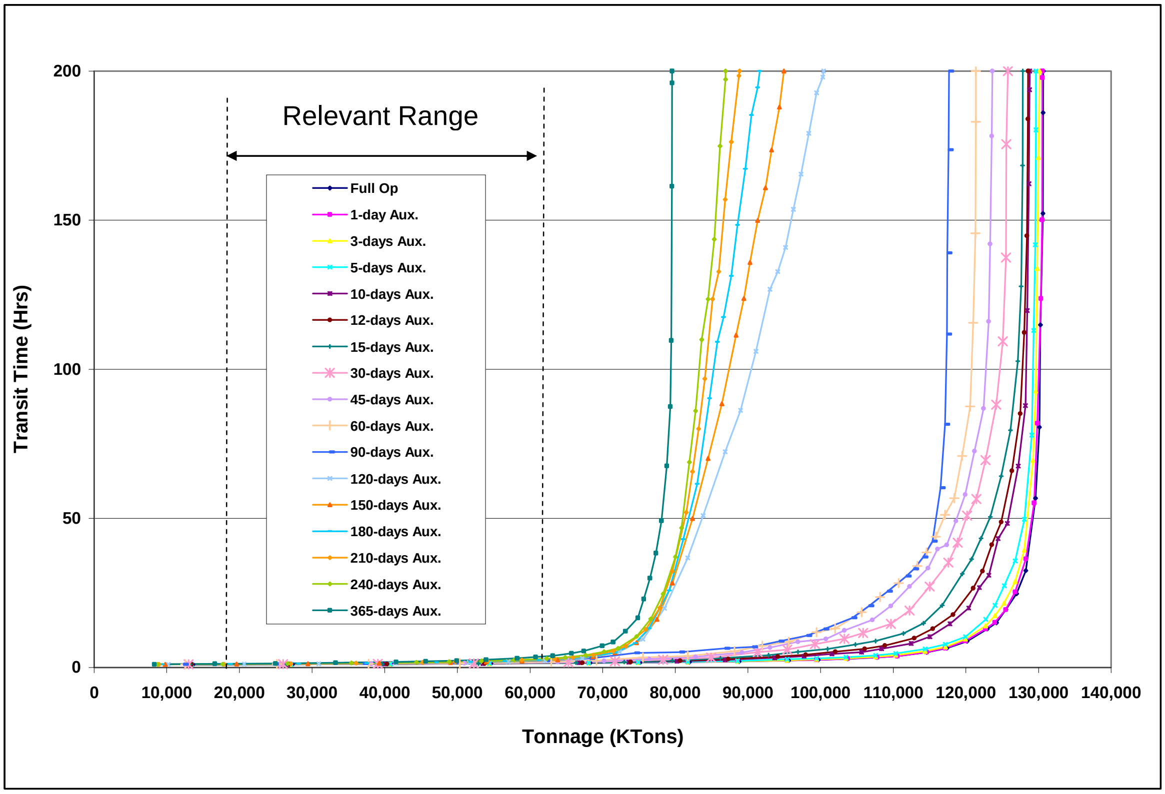


FIGURE A2- 78
Dashields New 1200’ & Old 600’ Auxiliary Half Speeds

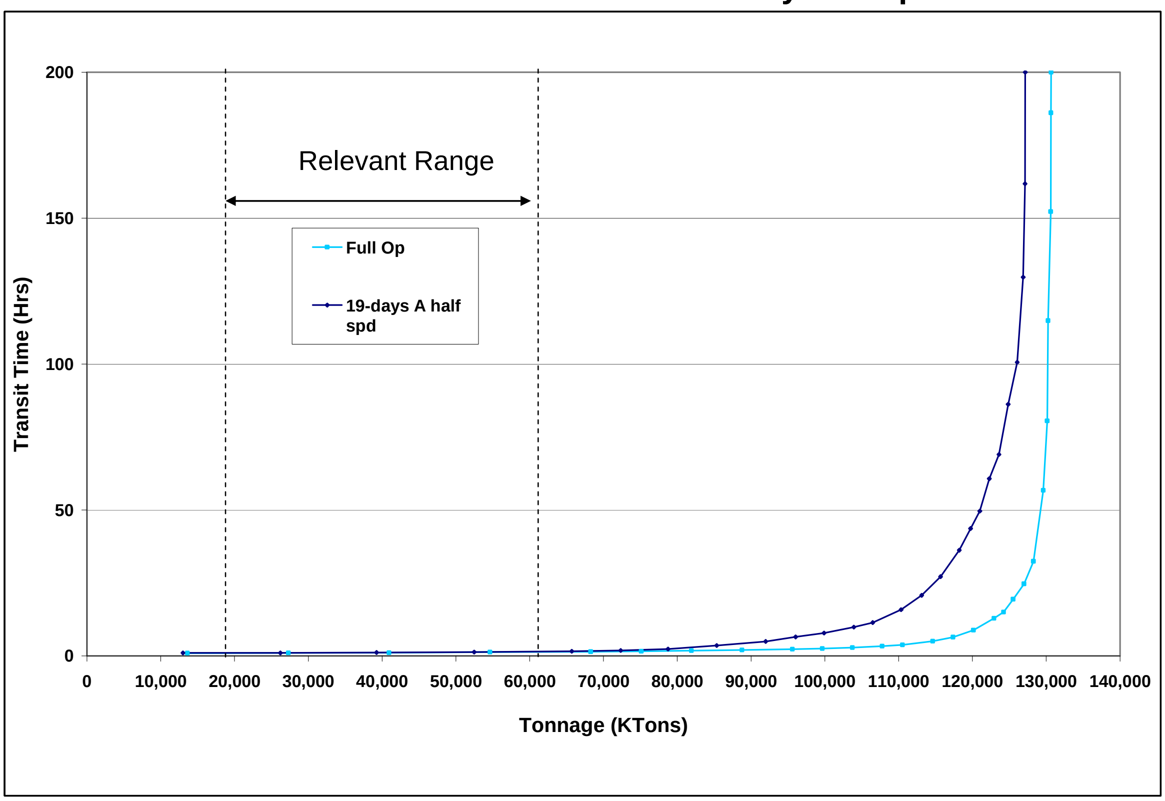


FIGURE A2- 79
Dashields New 600' & New 600' Main Chamber Curves

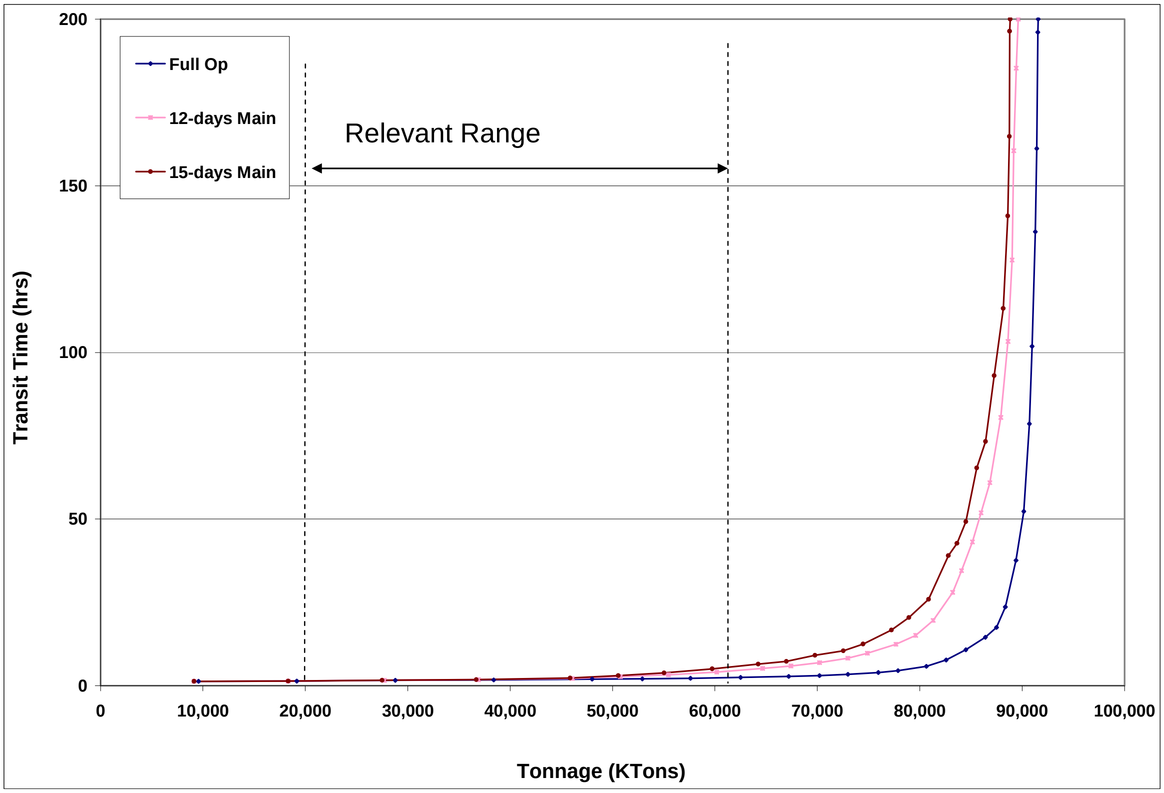


FIGURE A2- 80
Dashields New 600' & New 600' Main Chamber Half Speed Curves

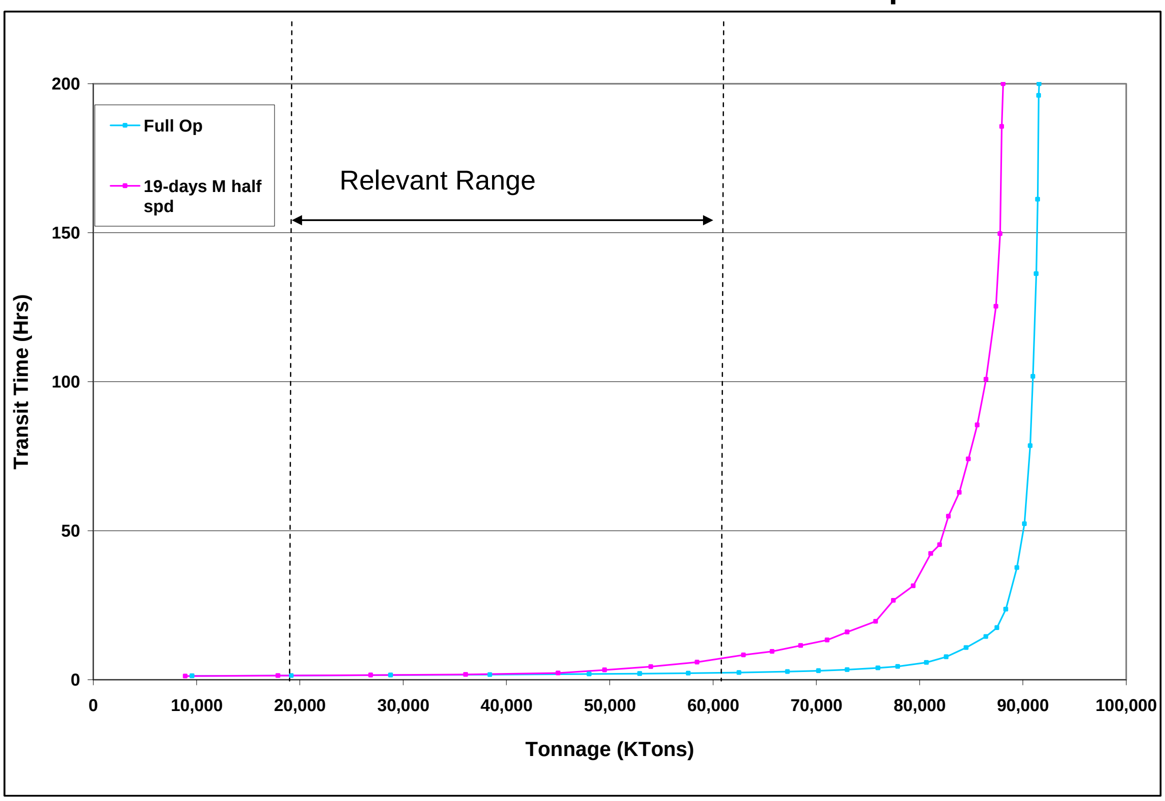


FIGURE A2- 81
Dashields New 600' & New 600' Auxiliary Chamber Curves

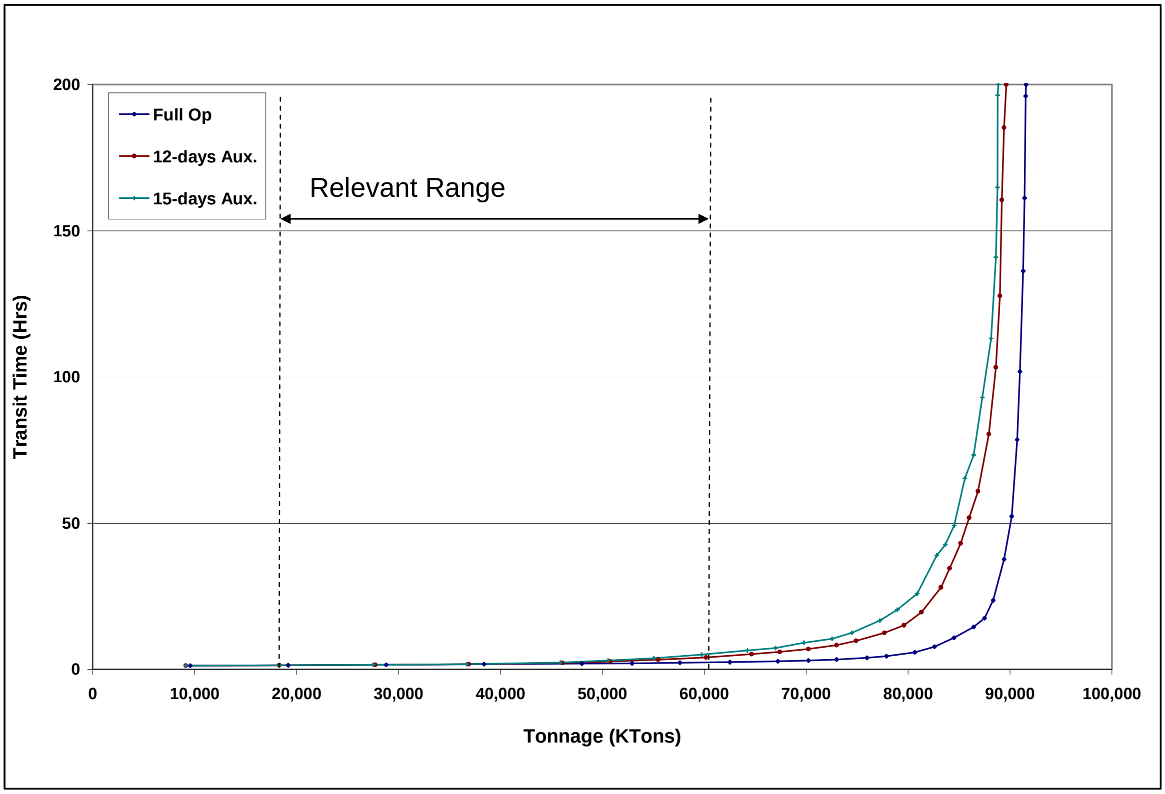


FIGURE A2- 82
Dashields New 600' & New 600' Auxiliary Chamber Half Speed Curves

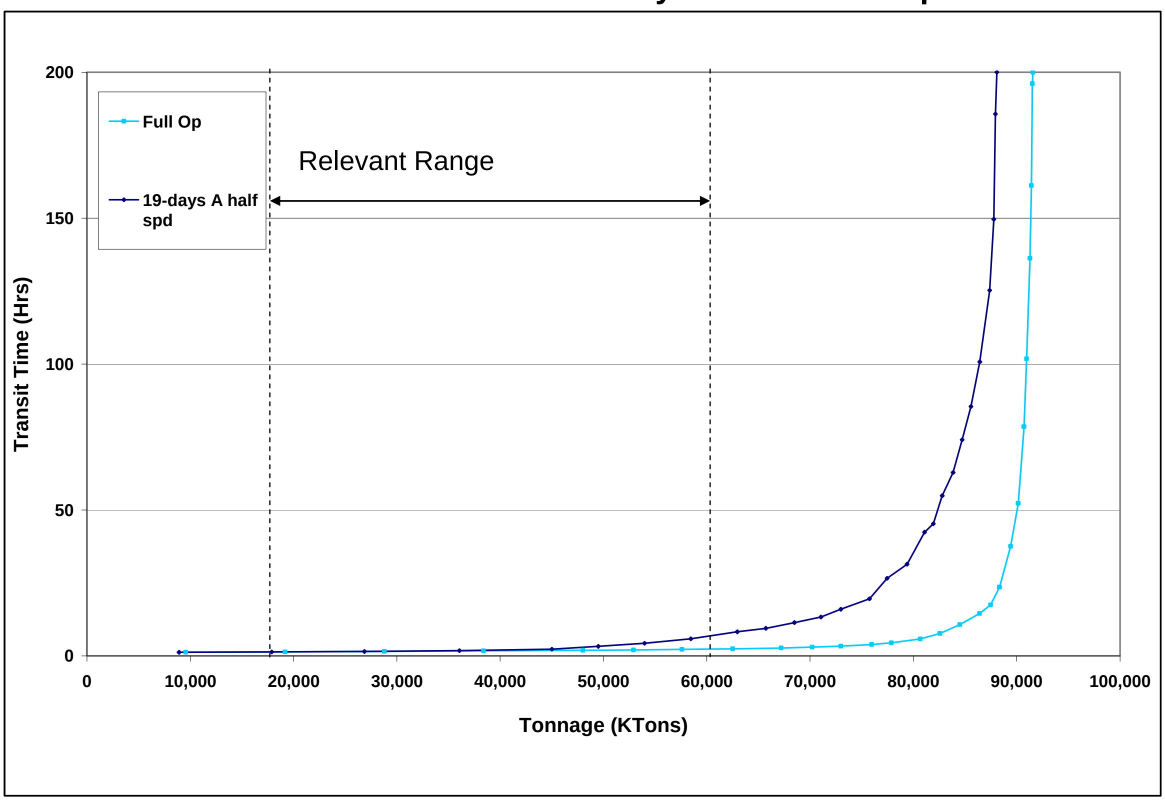


FIGURE A2- 83
Dashields New 800' & New 600' Main Chamber Curves

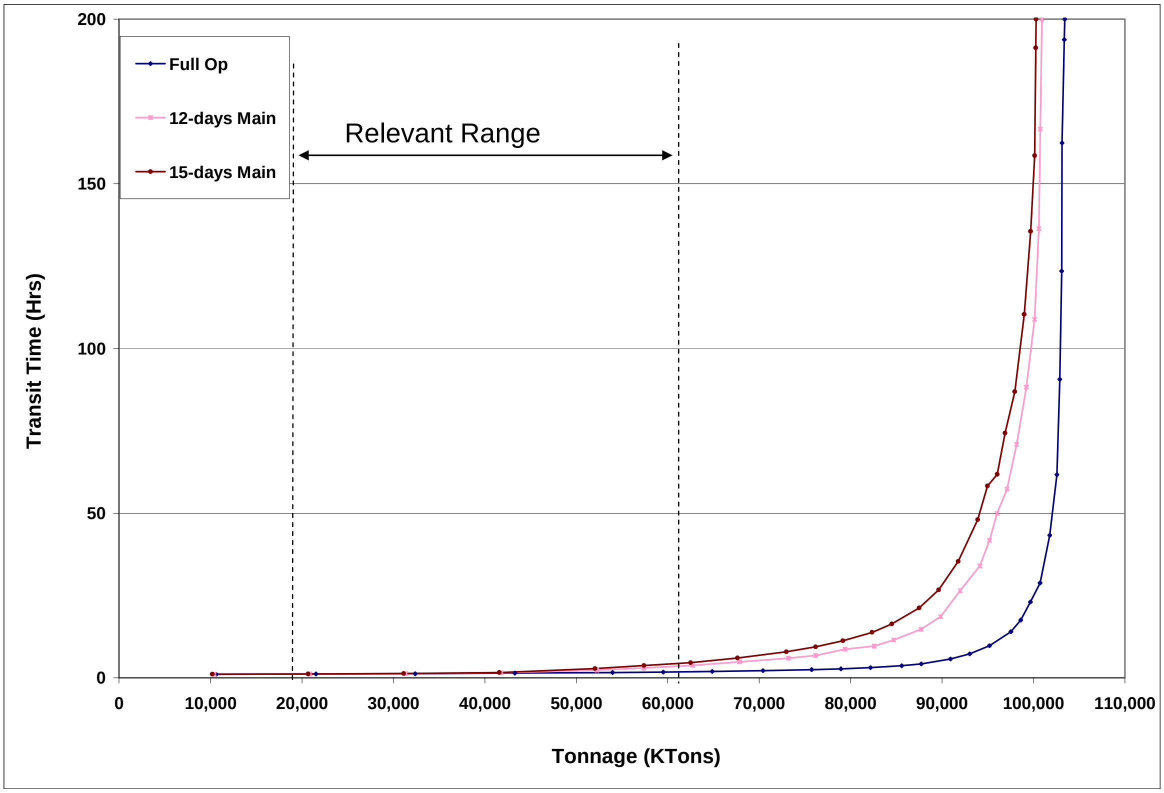


FIGURE A2- 84
Dashields New 800' & New 600' Main Chamber Half Speed Curves

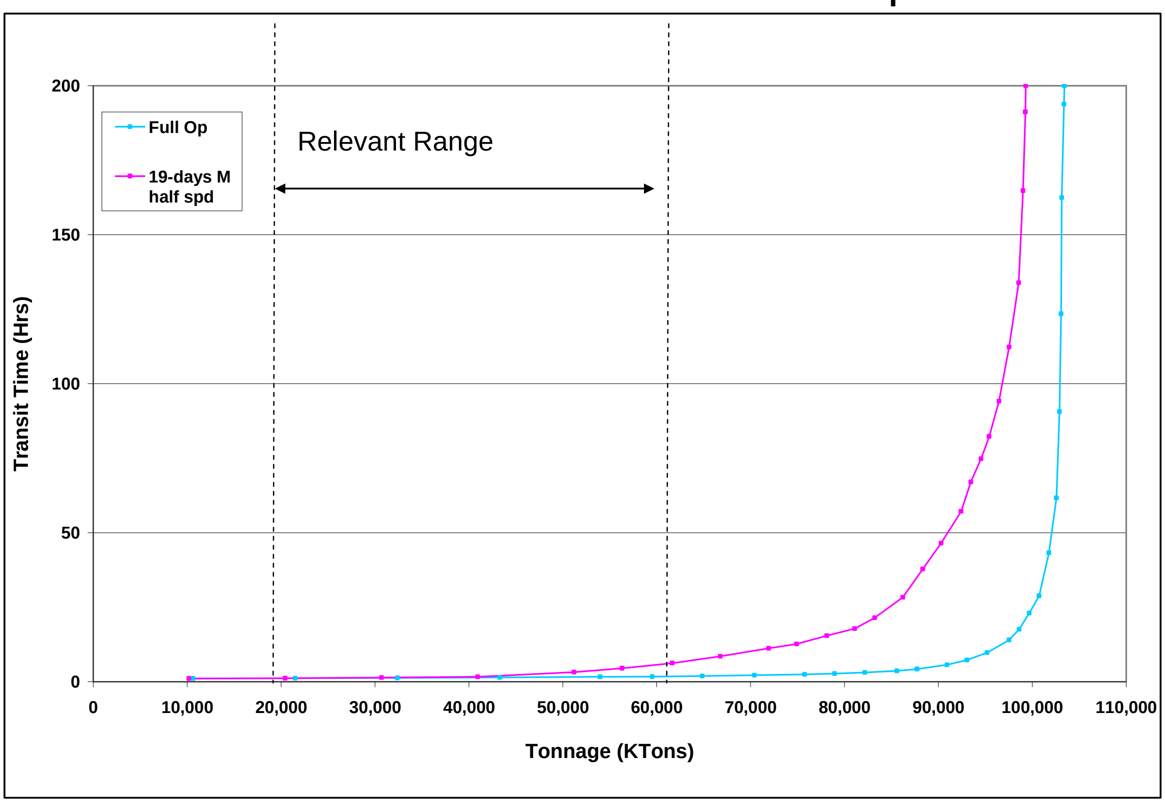


FIGURE A2- 85
Dashields New 800' & New 600' Auxiliary Chamber Curves

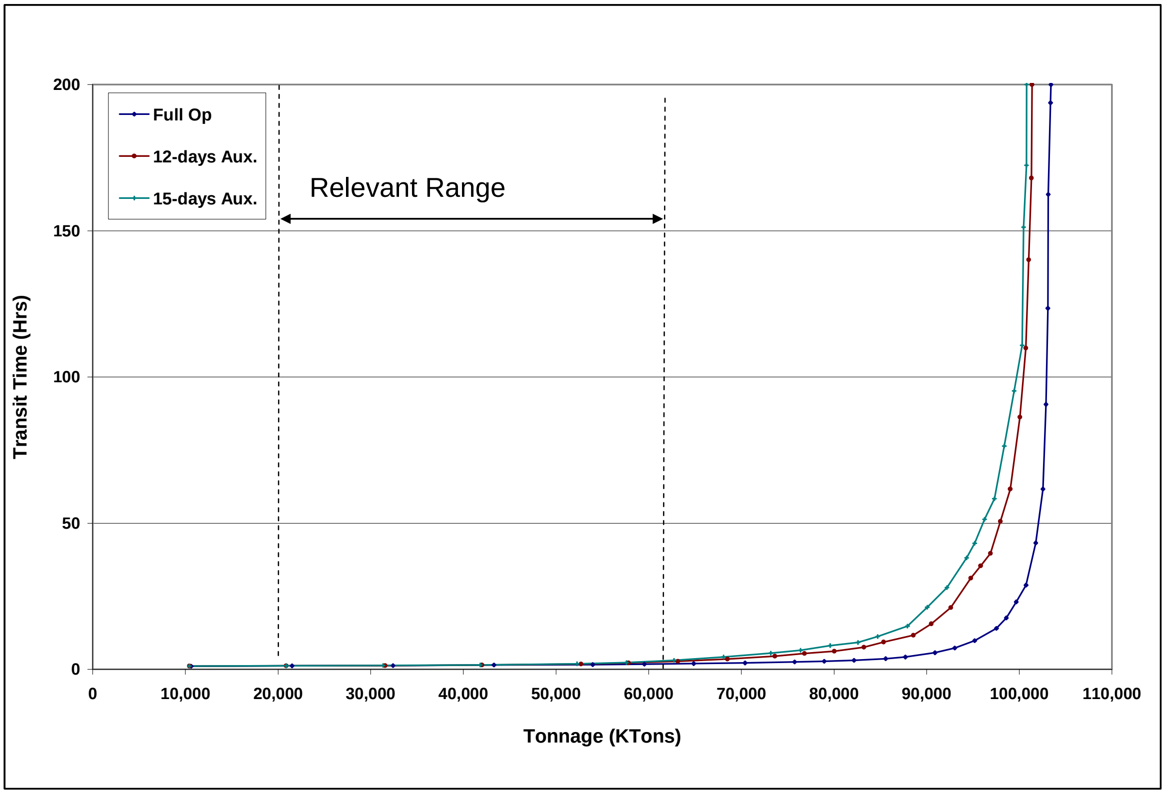


FIGURE A2- 86
Dashields New 800' & New 600' Auxiliary Chamber Half Speed Curves

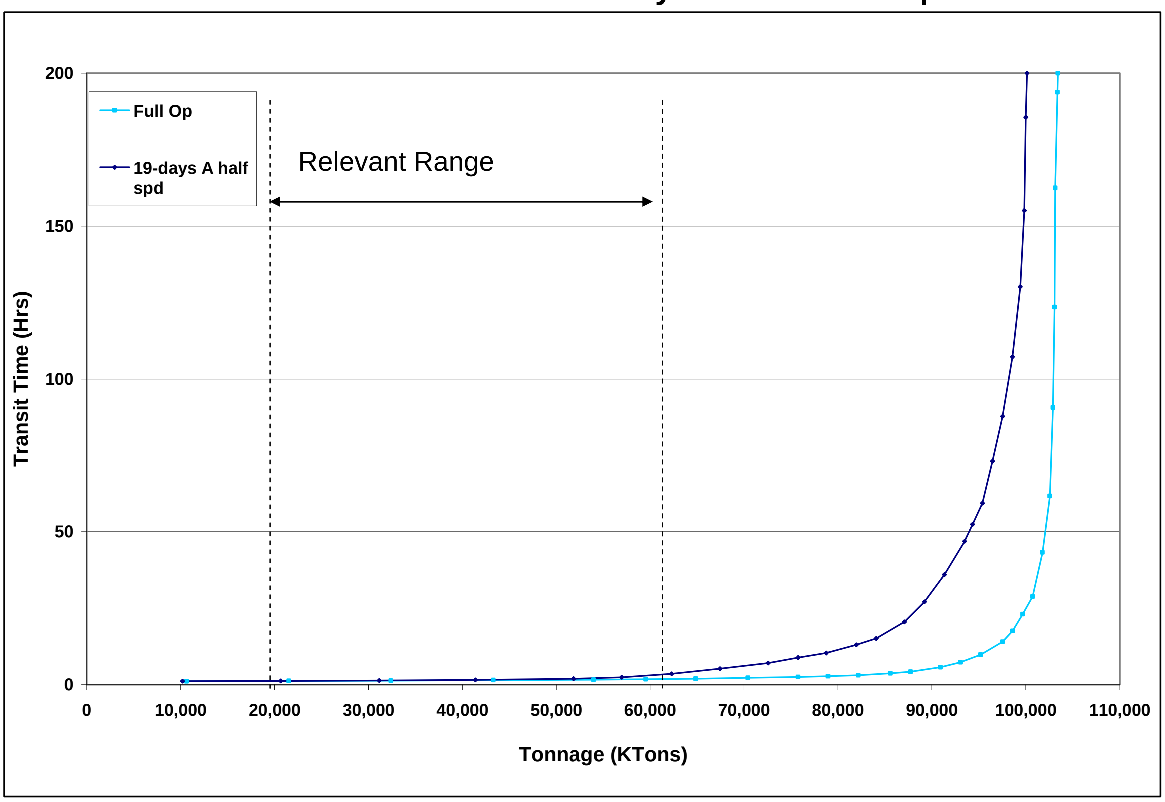


FIGURE A2- 87
Dashields New 1200' & New 600' Main Chamber Curves

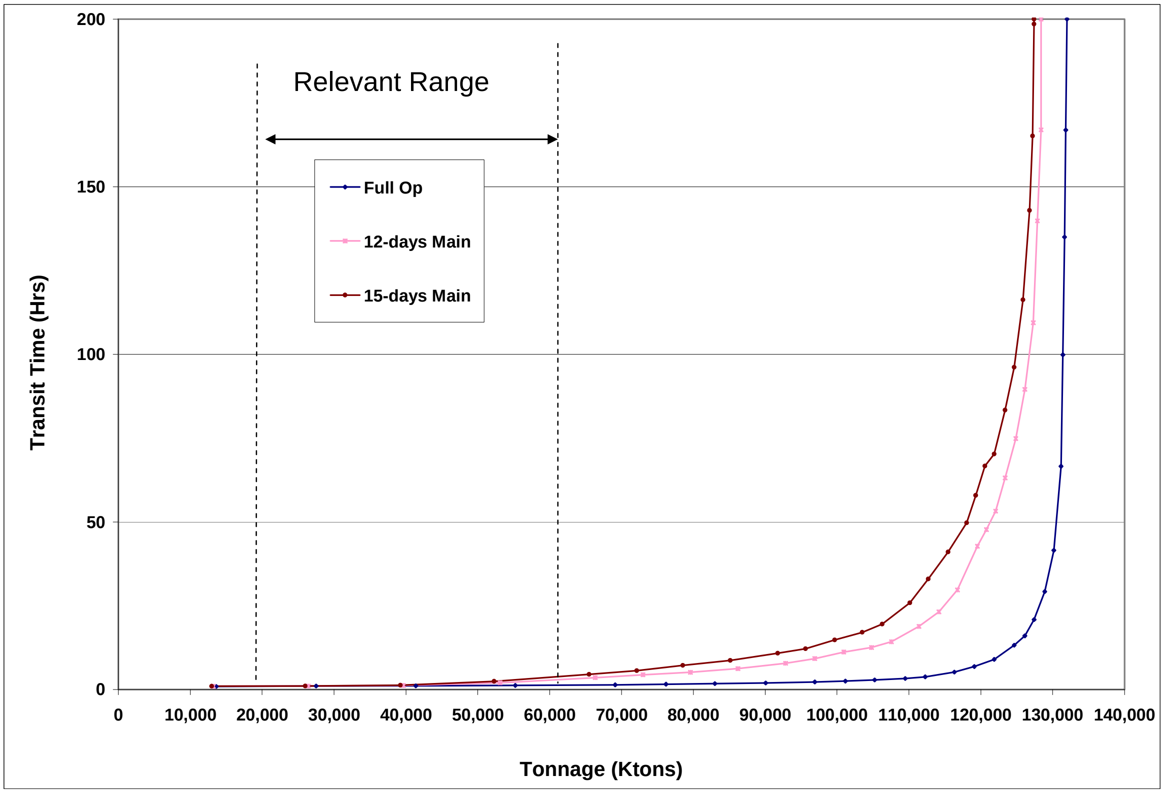


FIGURE A2- 88
Dashields New 1200' & New 600' Main Chamber half Speed Curves

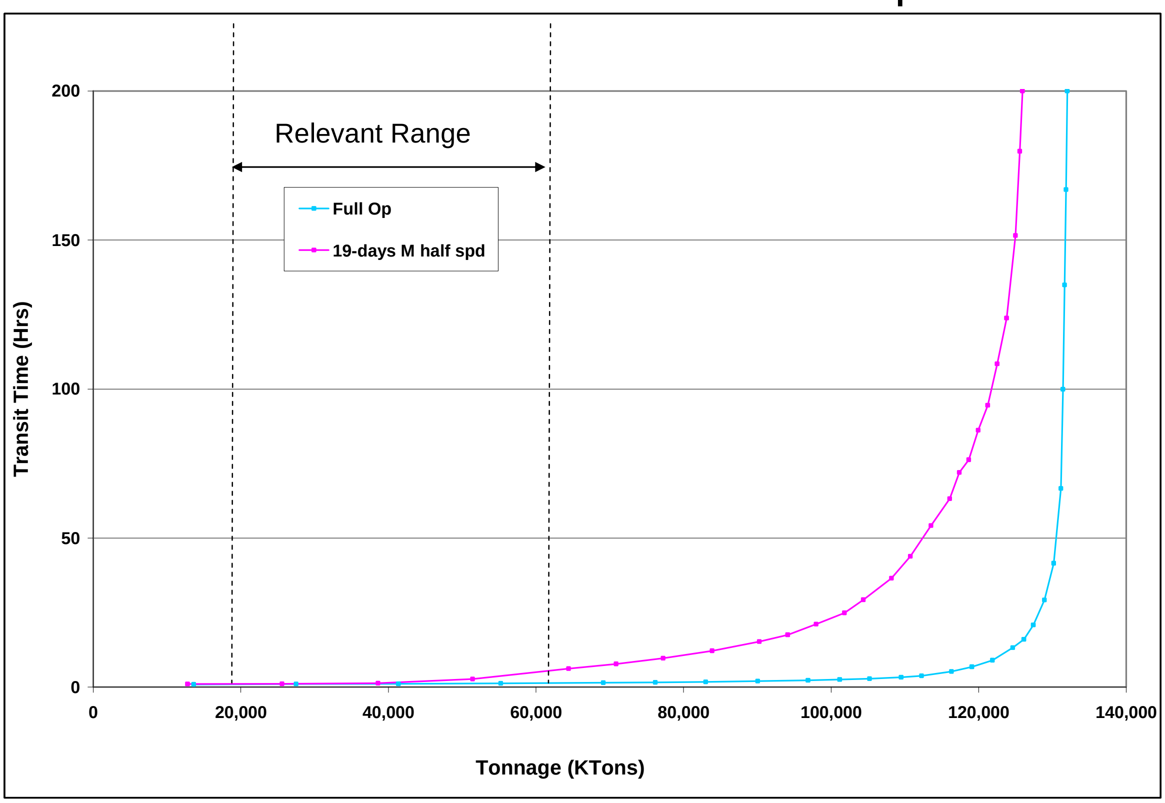


FIGURE A2- 89
Dashields New 1200’ & New 600’ Auxiliary Chamber Curves

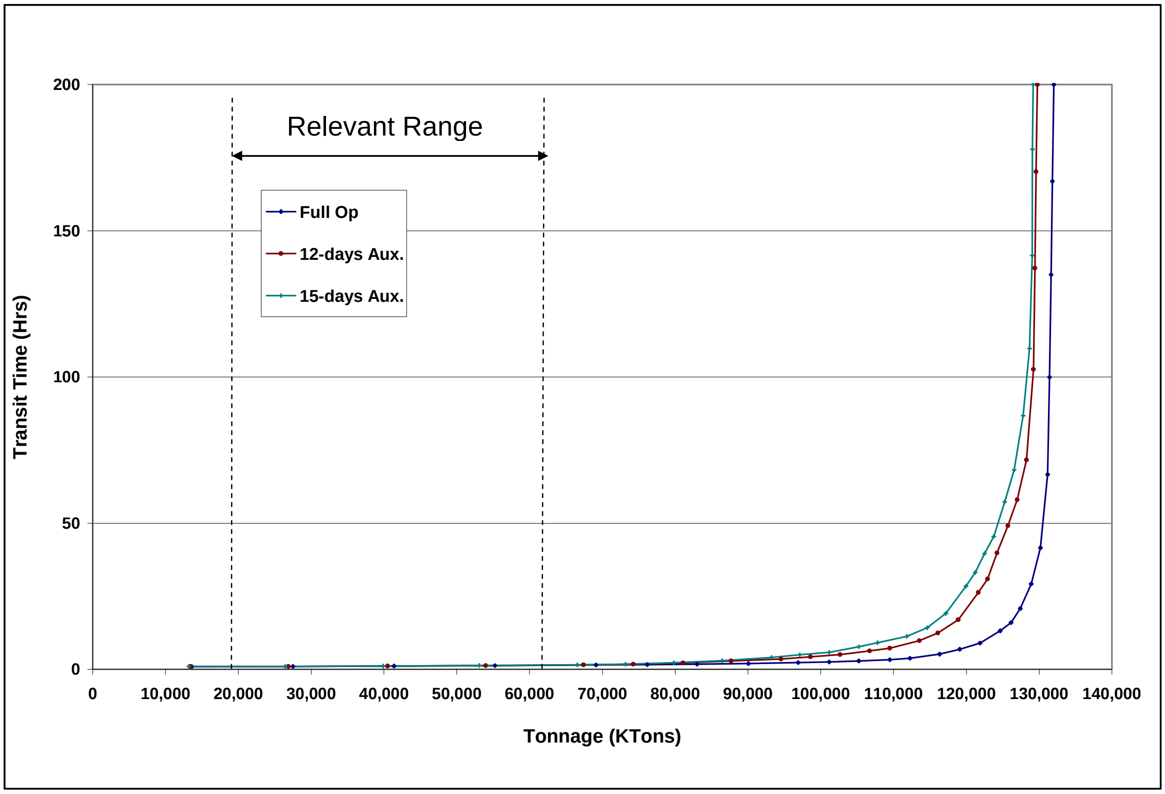


FIGURE A2- 90
Dashields New 1200’ & New 600’ Auxiliary Chamber Half Speed Curves

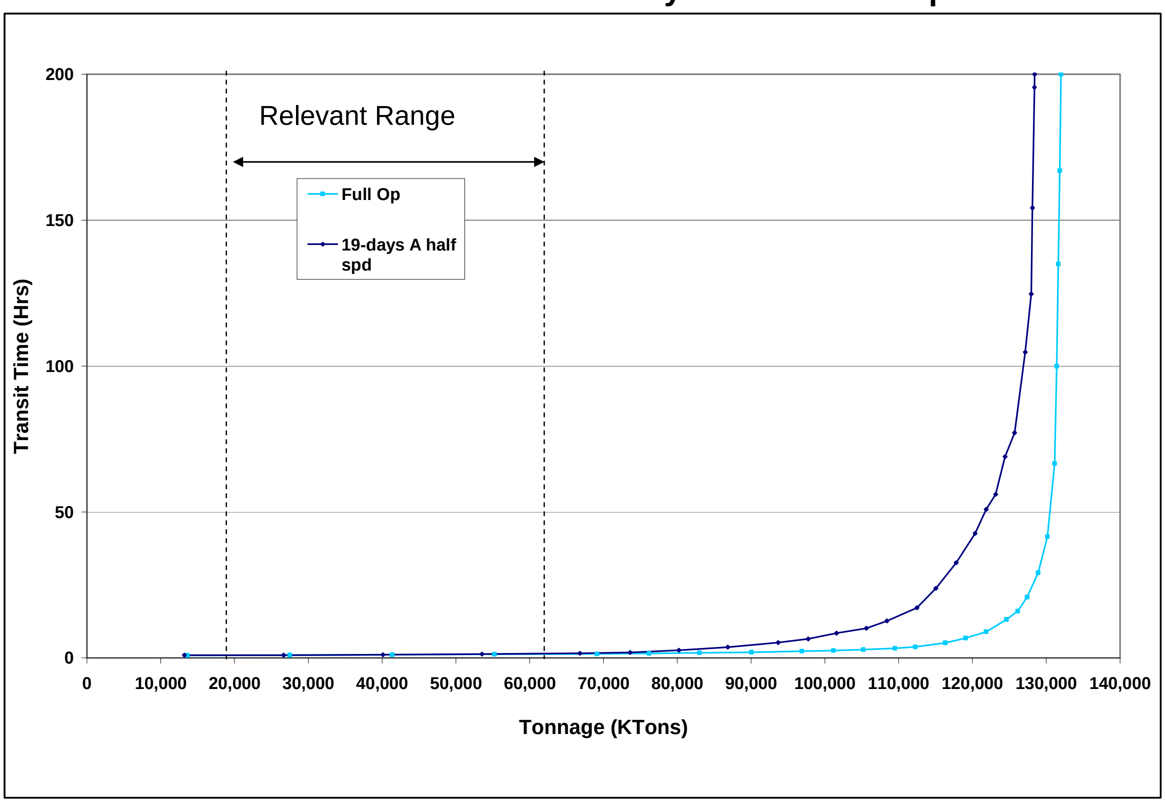


FIGURE A2- 91
Dashields New Single 600' Main Chamber Curves

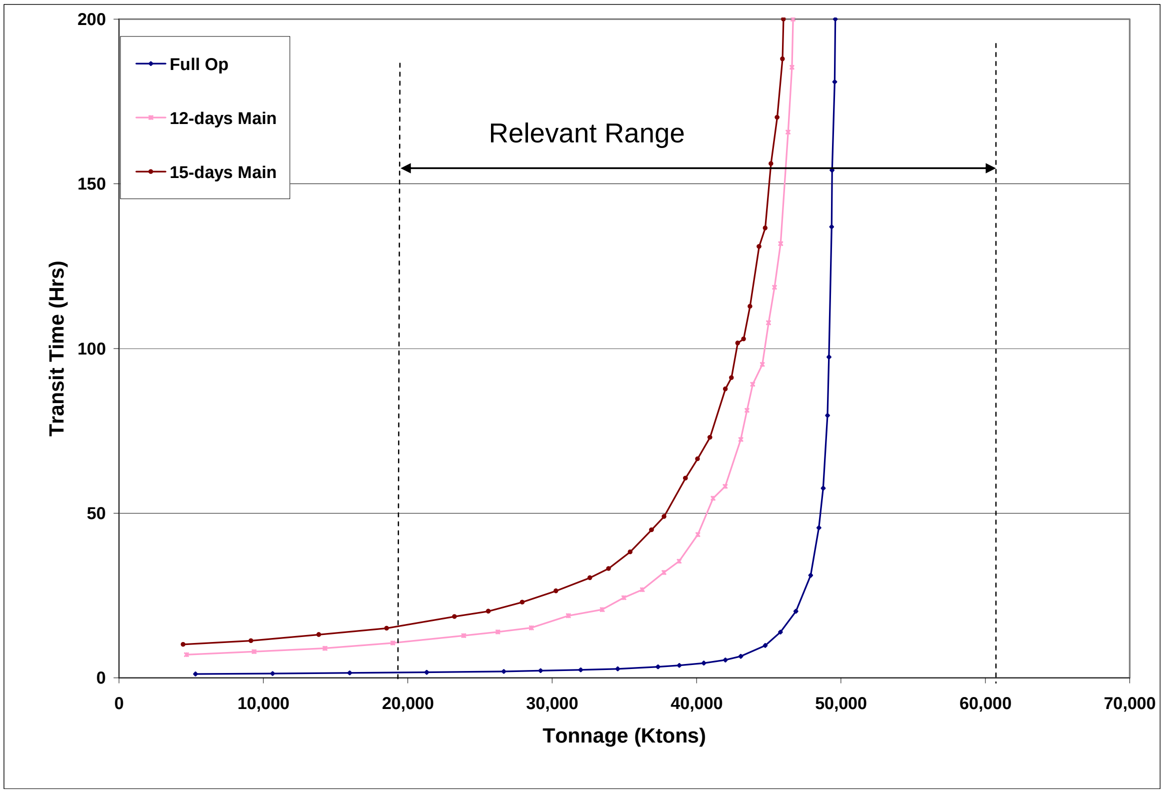


FIGURE A2- 92
Dashields New Single 600' Main Chamber Half Speed Curves

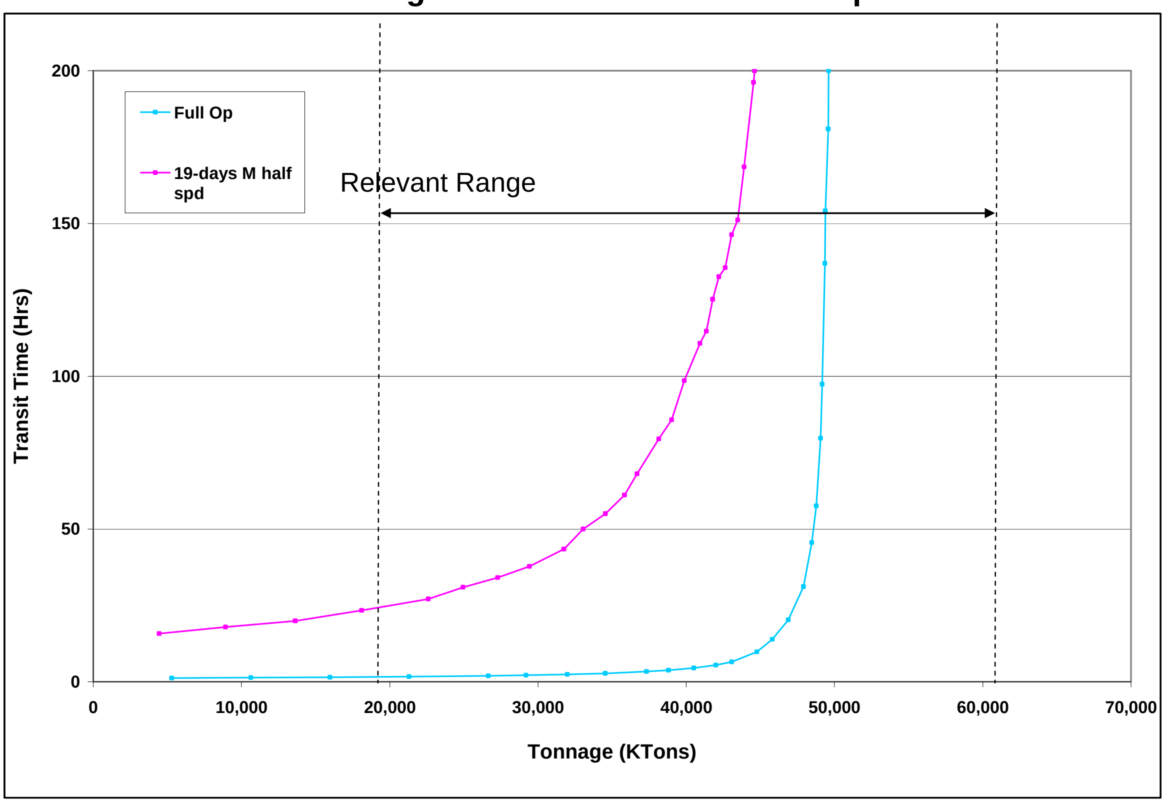


FIGURE A2- 93
Dashields New Single 800' Main Chamber Curves

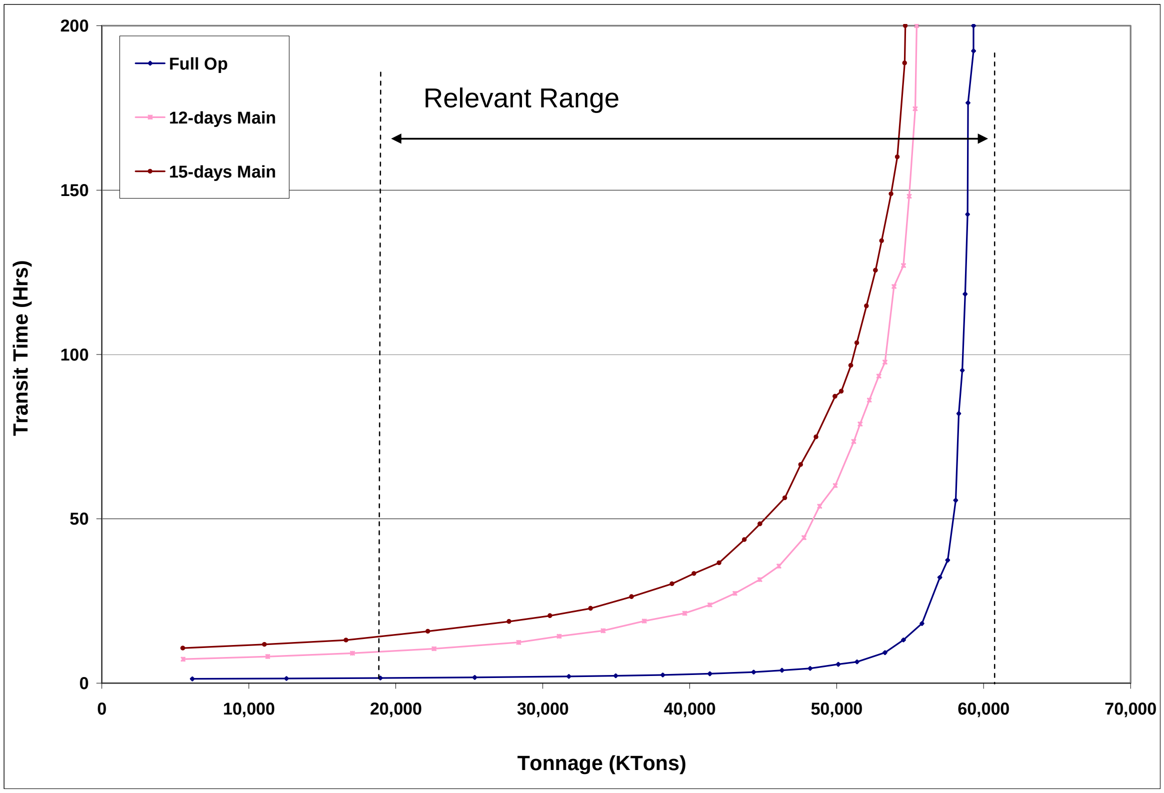


FIGURE A2- 94
Dashields New Single 800' Main Chamber Half Speed Curves

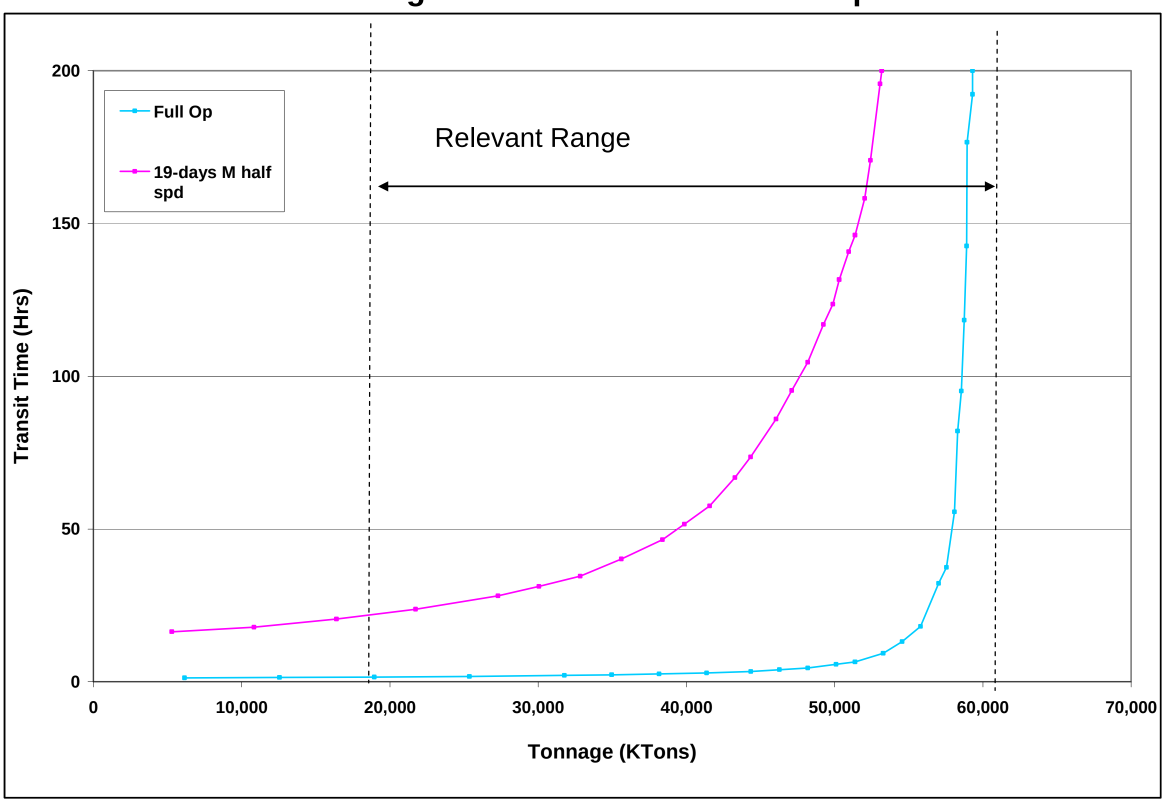


FIGURE A2- 95
Dashields New Single 1200' Main Chamber Curves

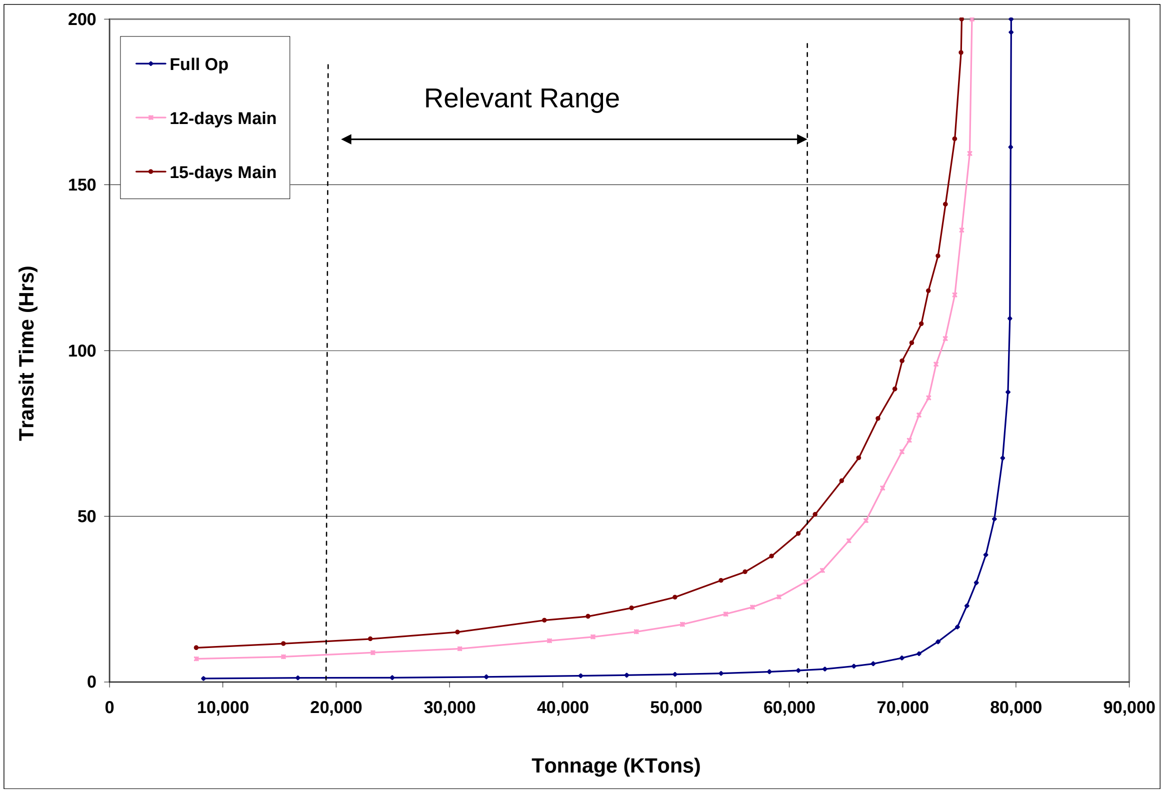


FIGURE A2- 96
Dashields New Single 1200' Main Chamber Half Speed Curves

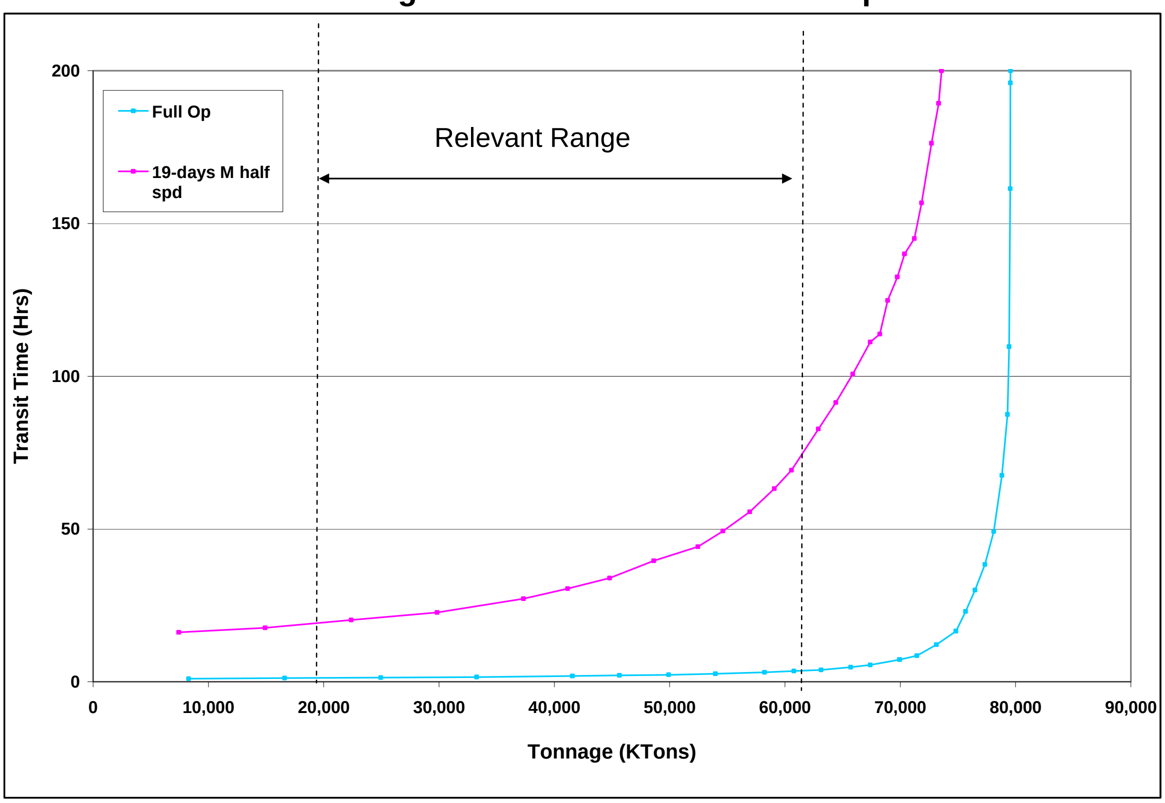


FIGURE A2- 97
Montgomery New 600' & Old 600' Main Chamber Curves

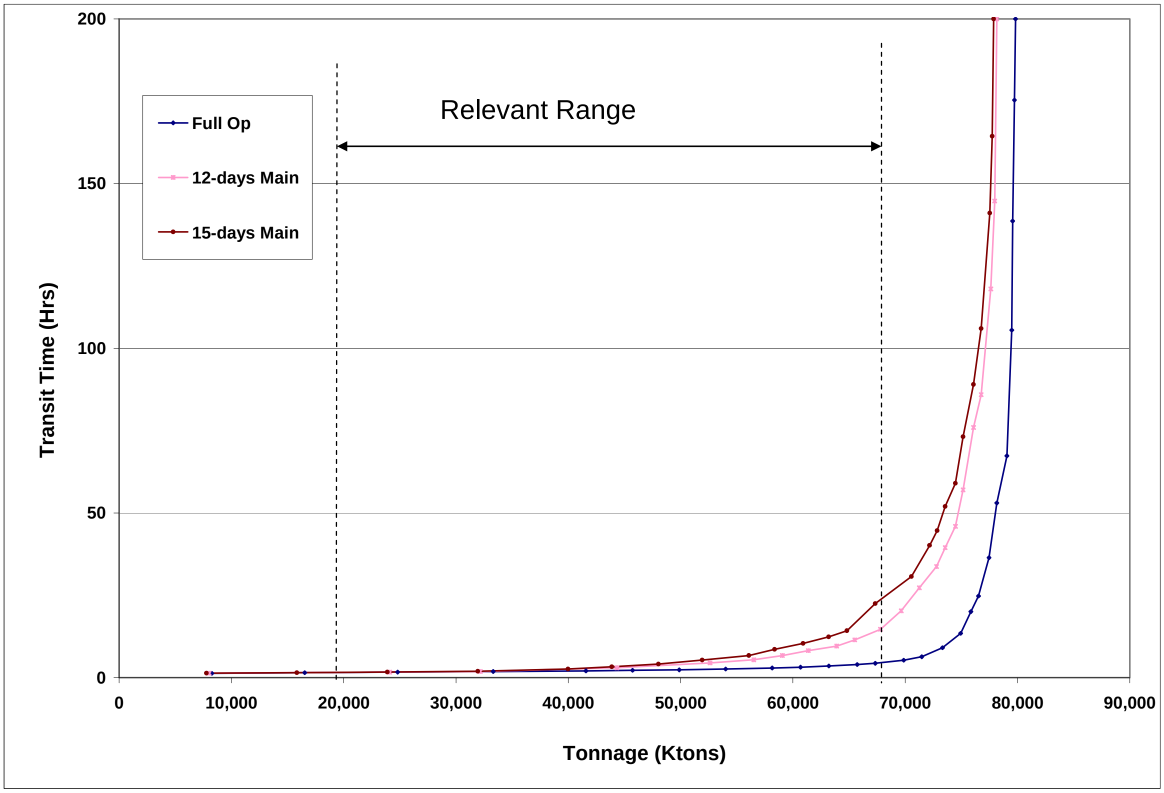


FIGURE A2- 98
Montgomery New 600' & Old 600' Main Chamber Half Speeds

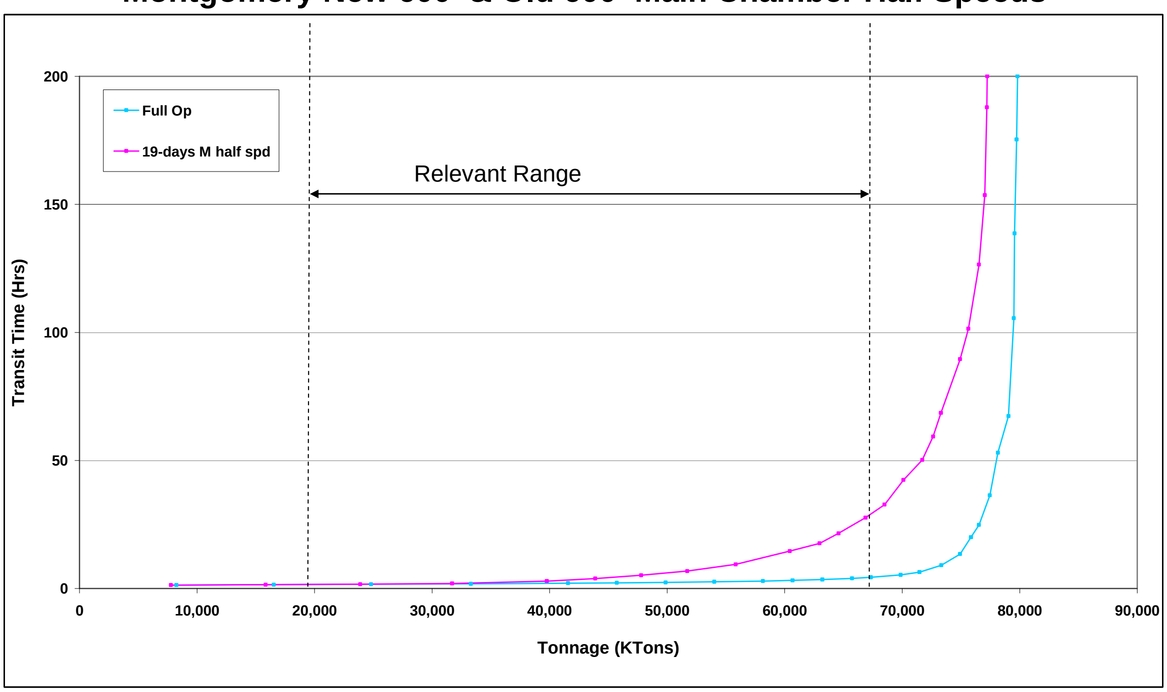


FIGURE A2- 99
Montgomery New 600' & Old 600' Auxiliary Chamber Curves

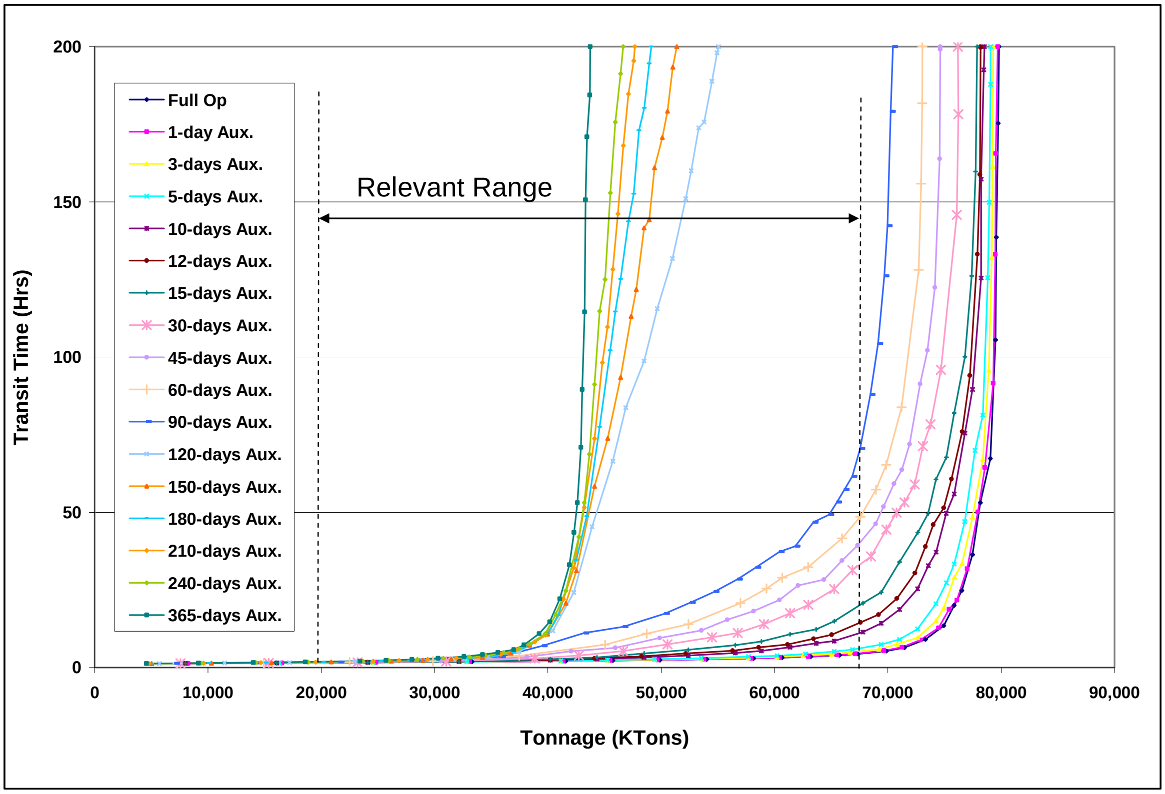


FIGURE A2- 100
Montgomery New 600' & Old 600' Auxiliary Chamber Half Speeds

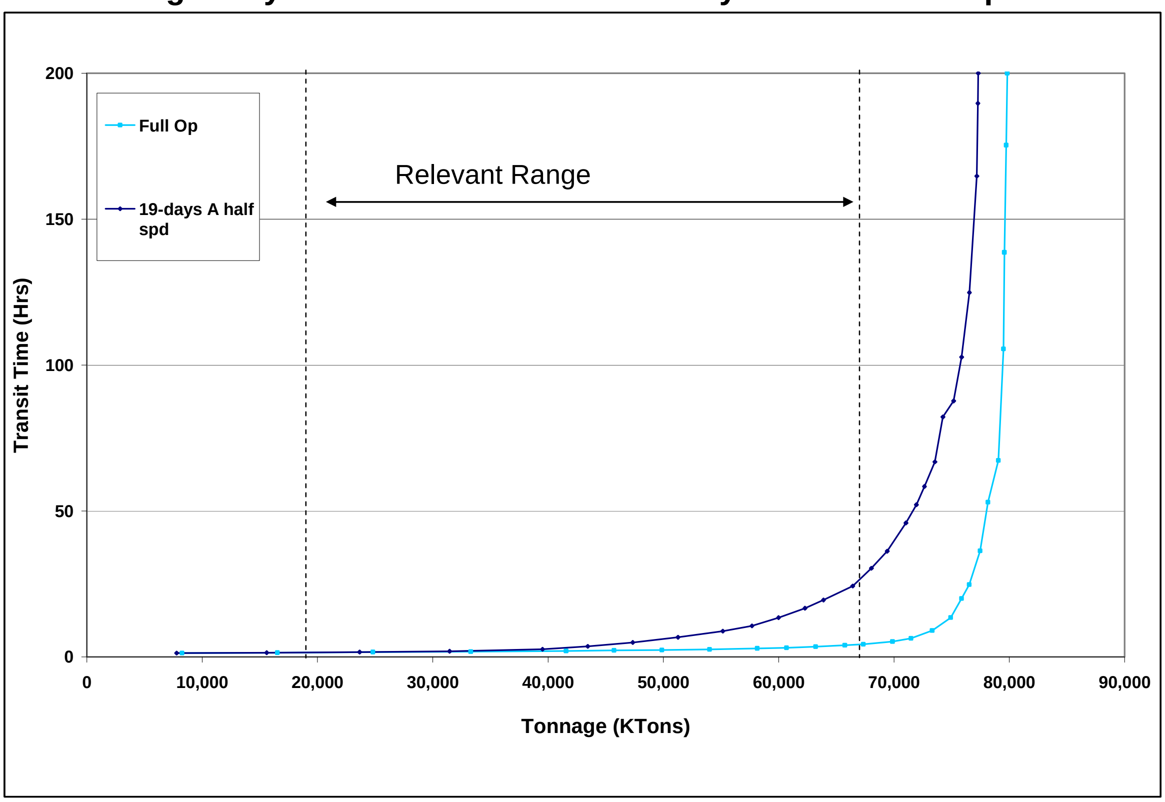


FIGURE A2- 101
Montgomery New 800' & Old 600' Main Chamber Curves

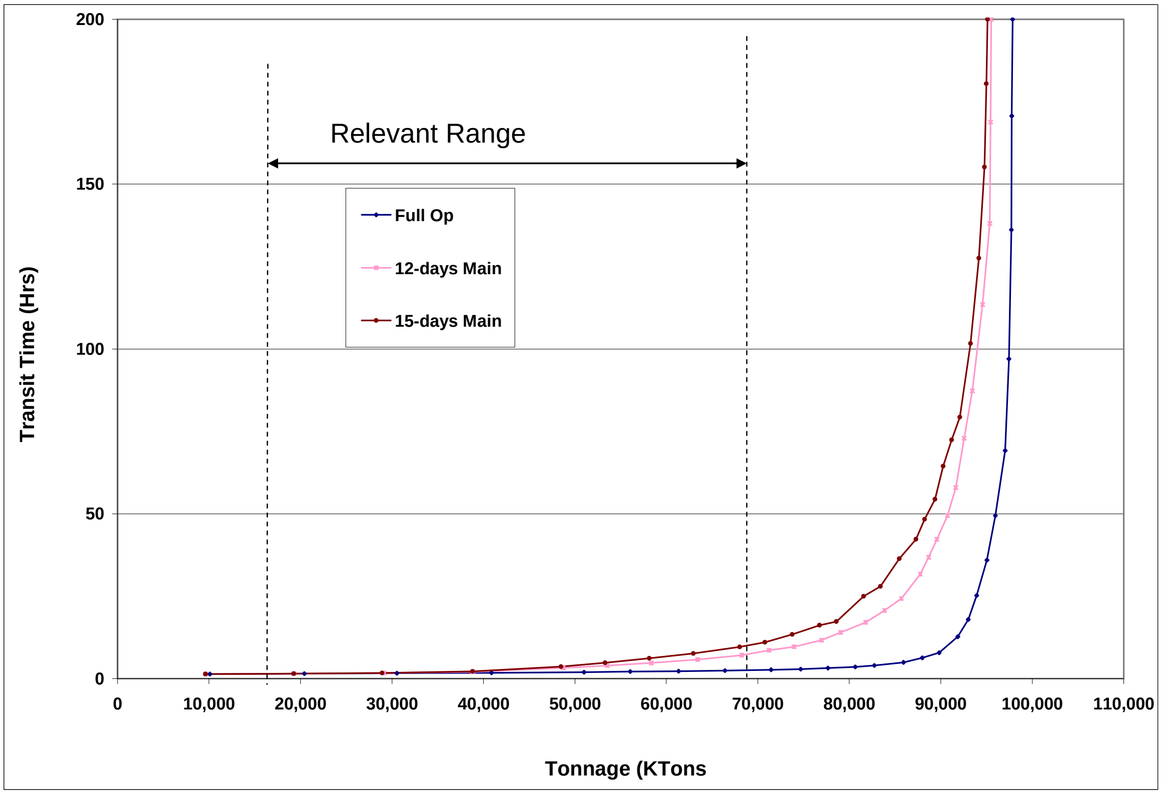


FIGURE A2- 102
Montgomery New 800 & Old 600' Main Chamber Half Speeds

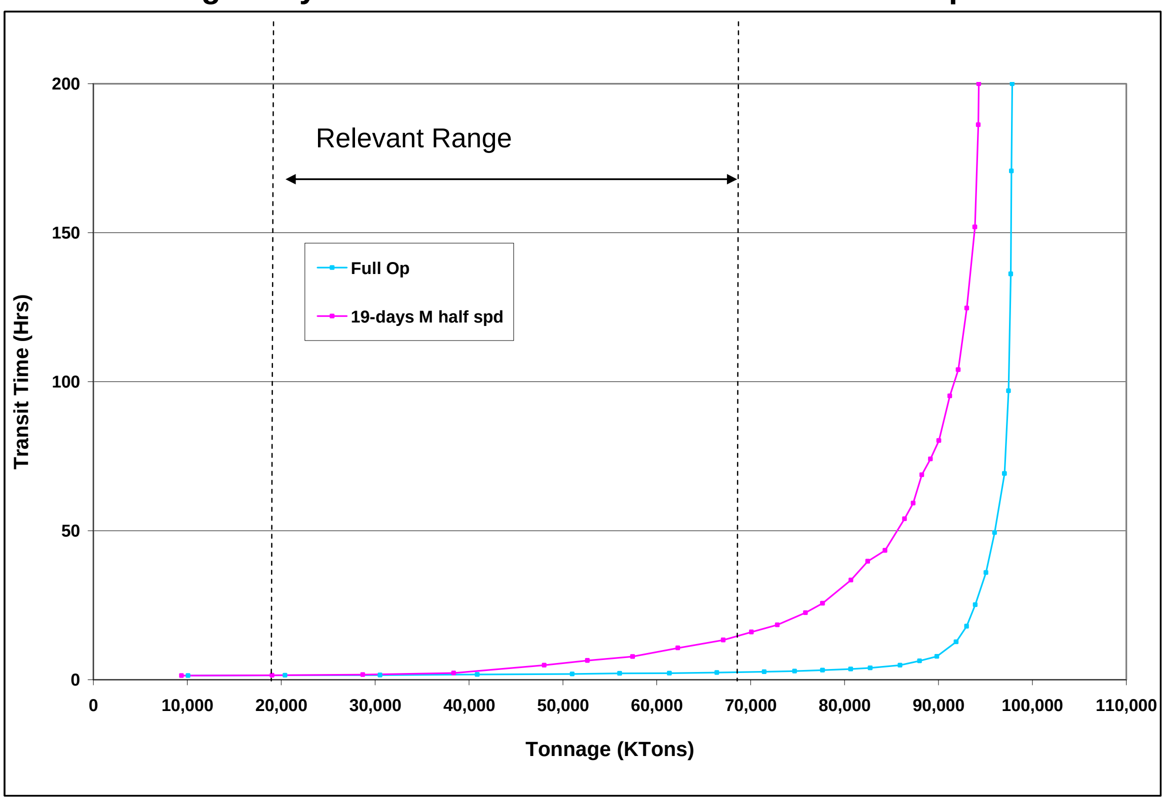


FIGURE A2- 103
Montgomery New 800' & Old 600' Auxiliary Chamber Curves

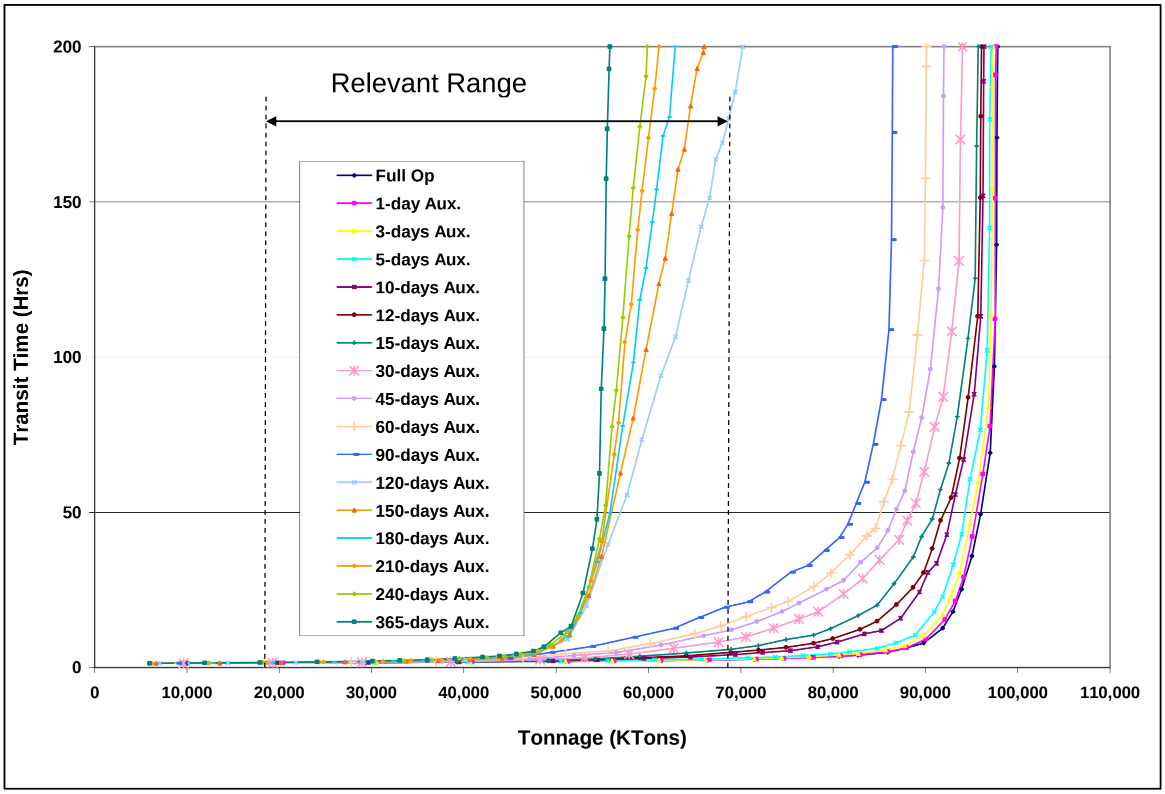


FIGURE A2- 104
Montgomery New 800' & Old 600' Auxiliary Chamber Half Speeds

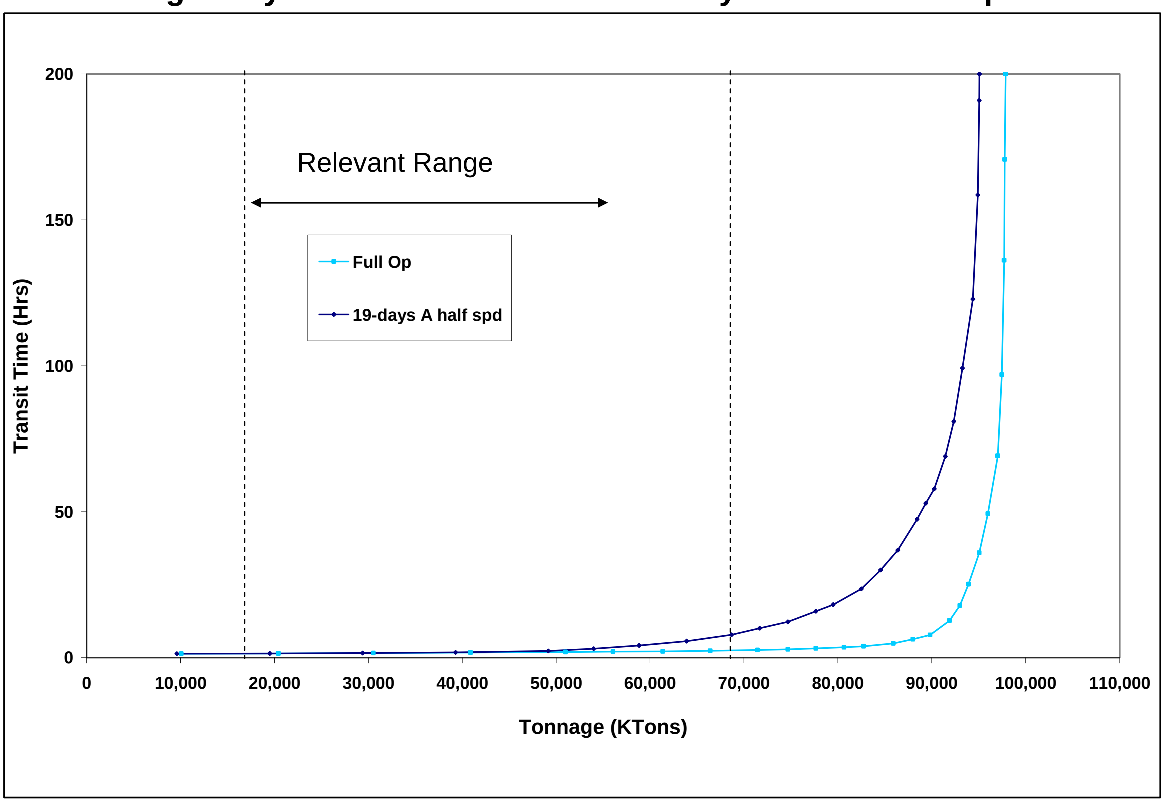


FIGURE A2- 105
Montgomery New 1200 & Old 600' Main Chamber Curves

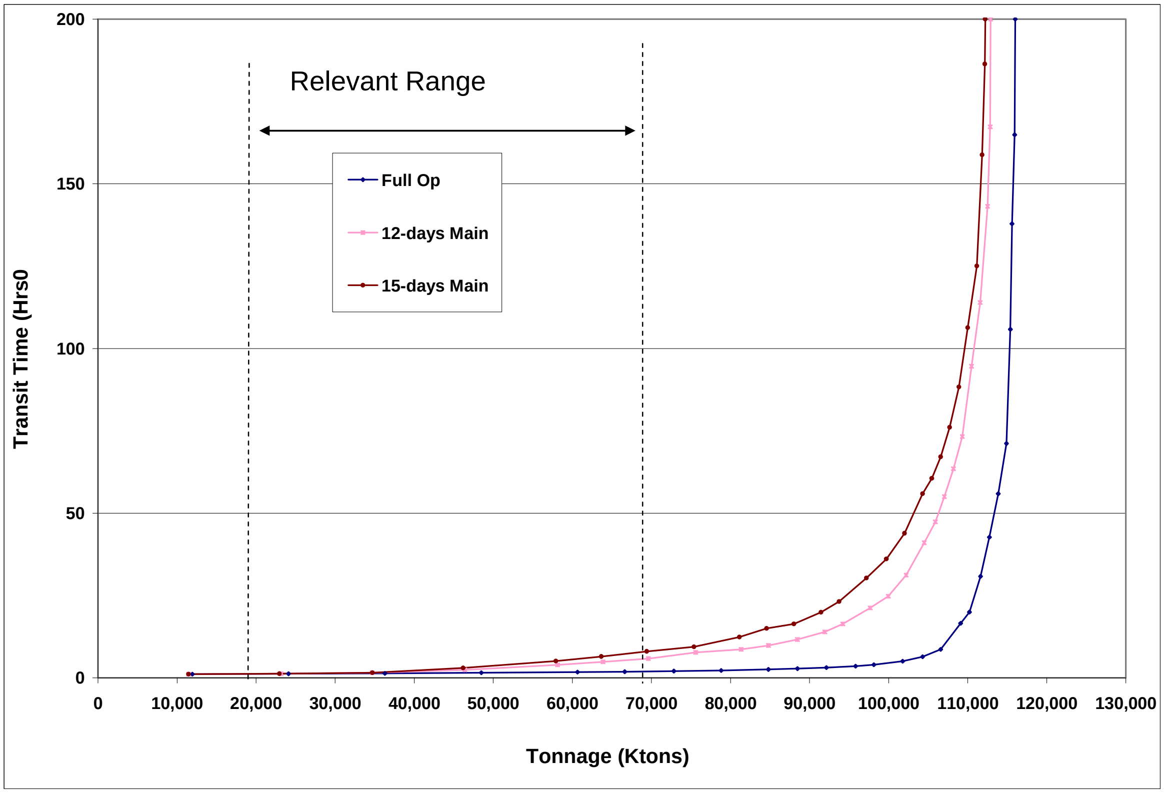


FIGURE A2- 106
Montgomery New 1200' & Old 600' Main Chamber Half Speed Family

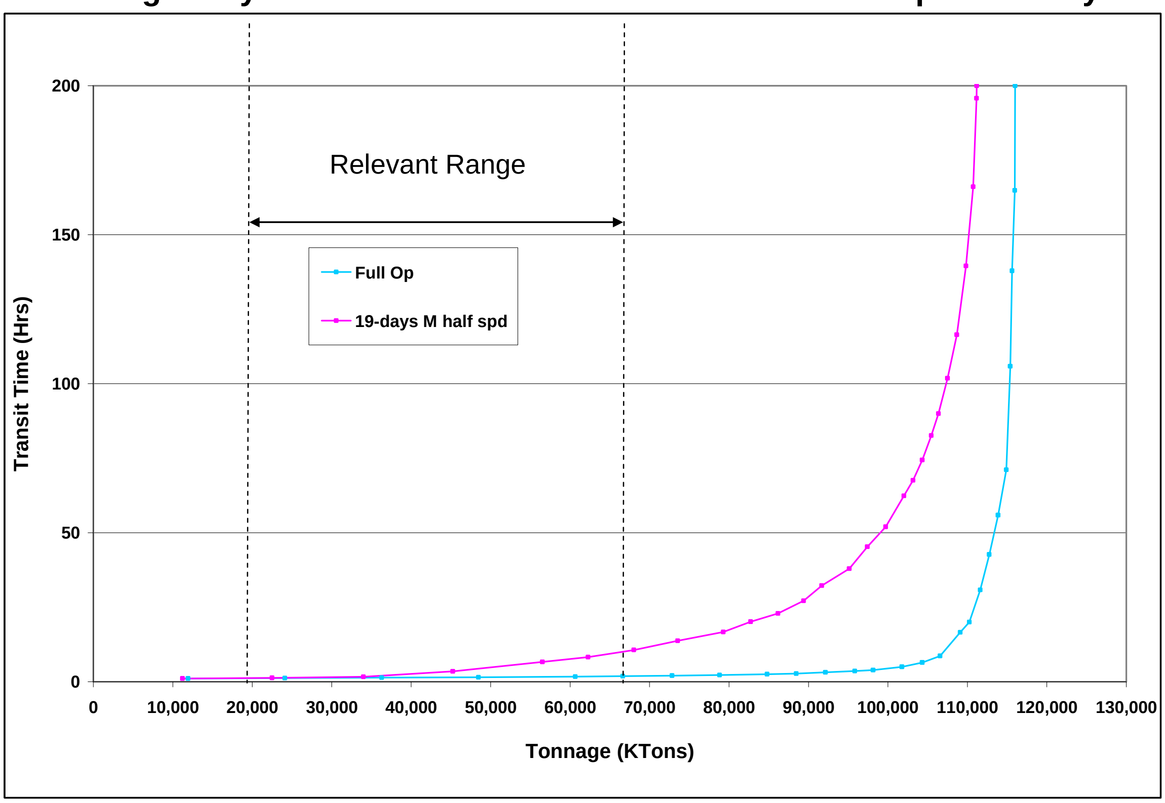


FIGURE A2- 107
Montgomery New 1200' & Old 600' Auxiliary Chamber Curves

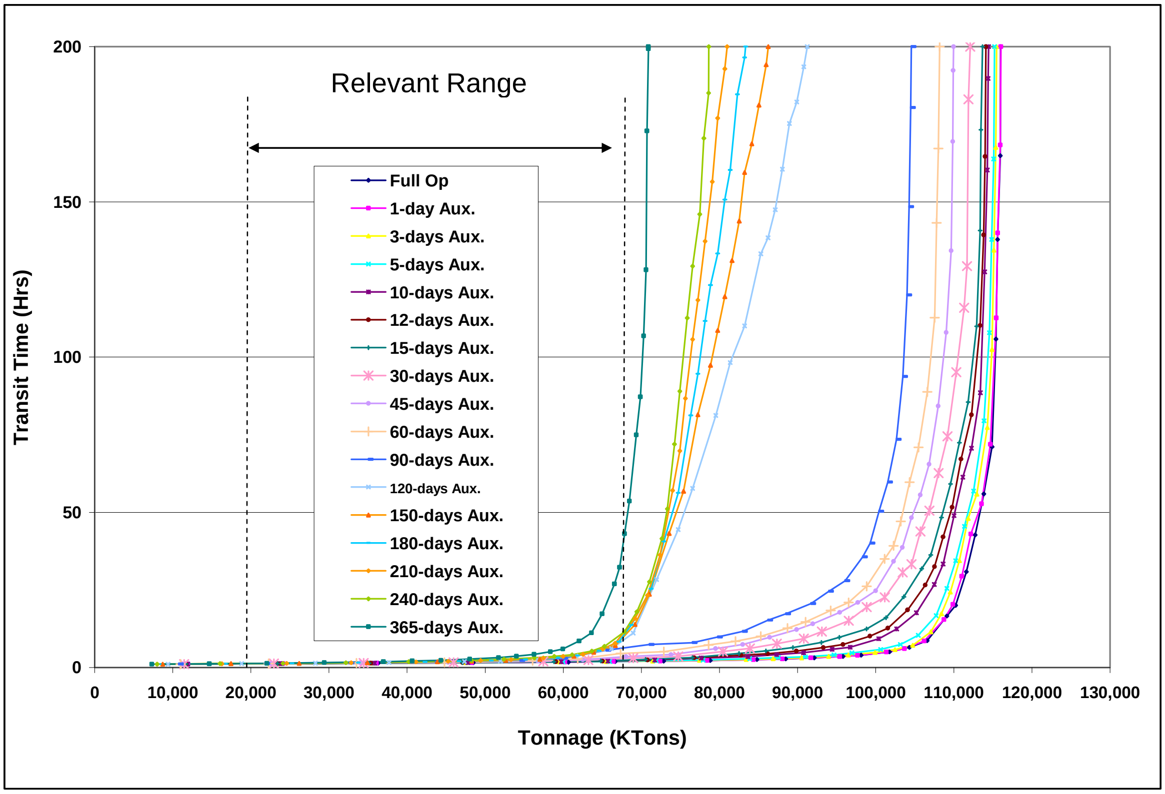


FIGURE A2- 108
Montgomery New 1200' & Old 600' Auxiliary Chamber Half Speeds

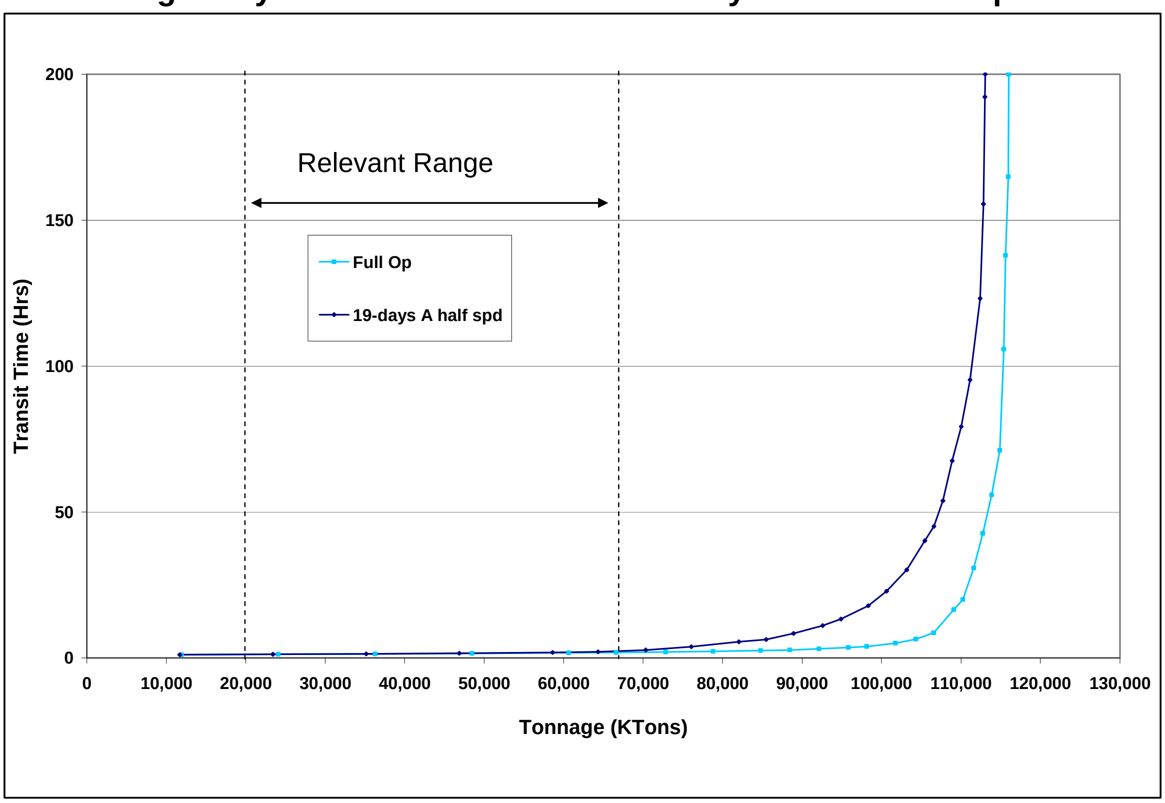


FIGURE A2- 109
Montgomery New 600' & New 600' Main Chamber Curves

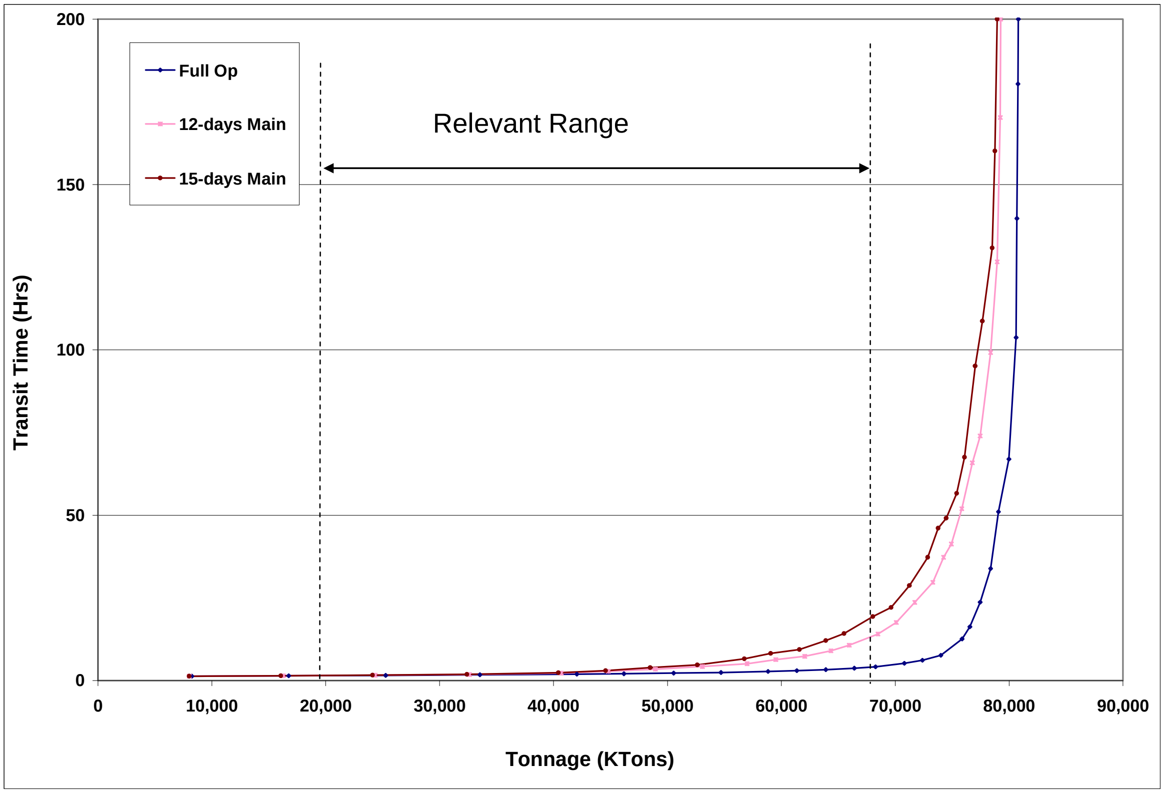


FIGURE A2- 110
Montgomery New 600' & New 600' Main Chamber Half Speeds

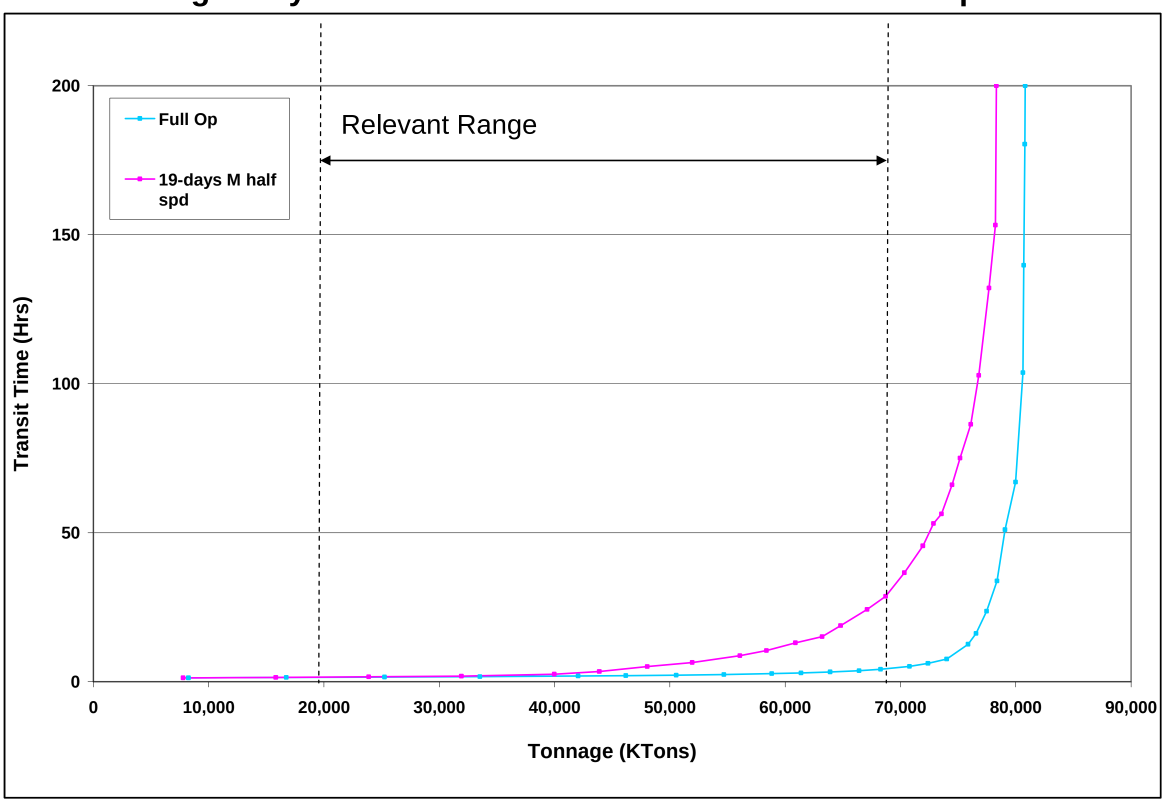


FIGURE A2- 111
Montgomery New 600' & New 600' Auxiliary Chamber Curves

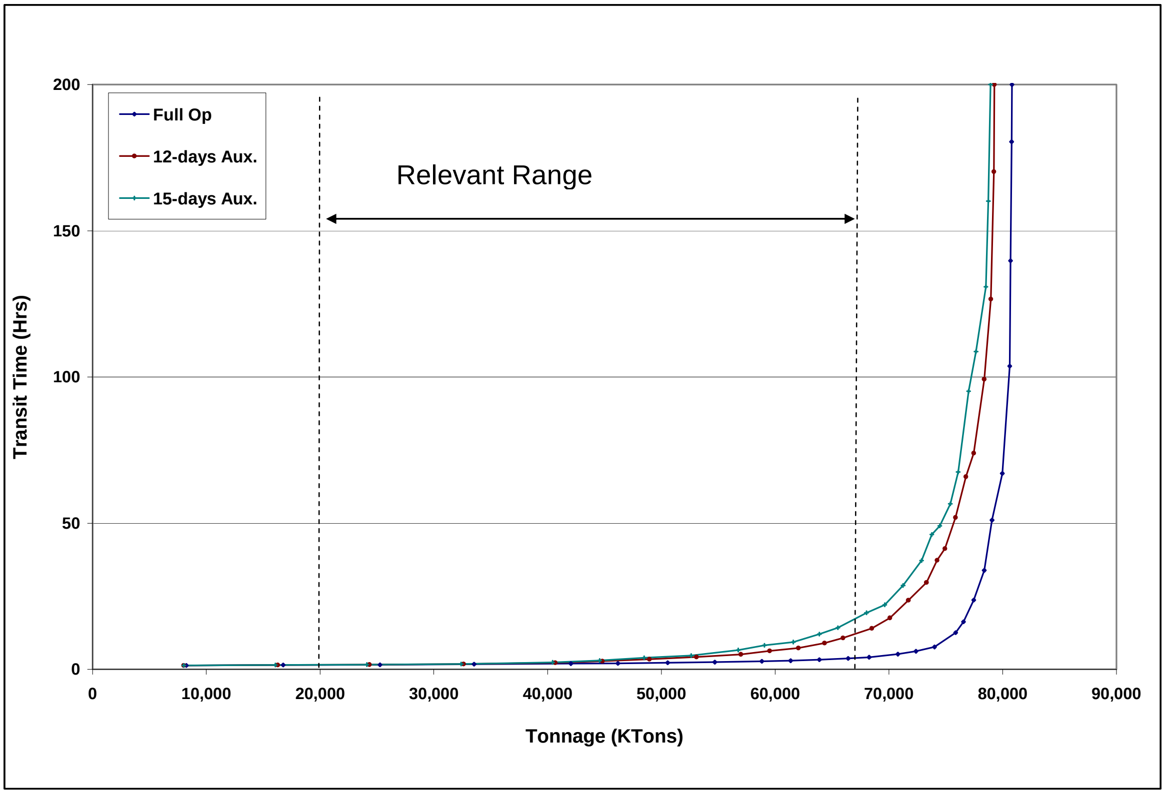


FIGURE A2- 112
Montgomery New 600' & New 600' Auxiliary Chamber Half Speeds

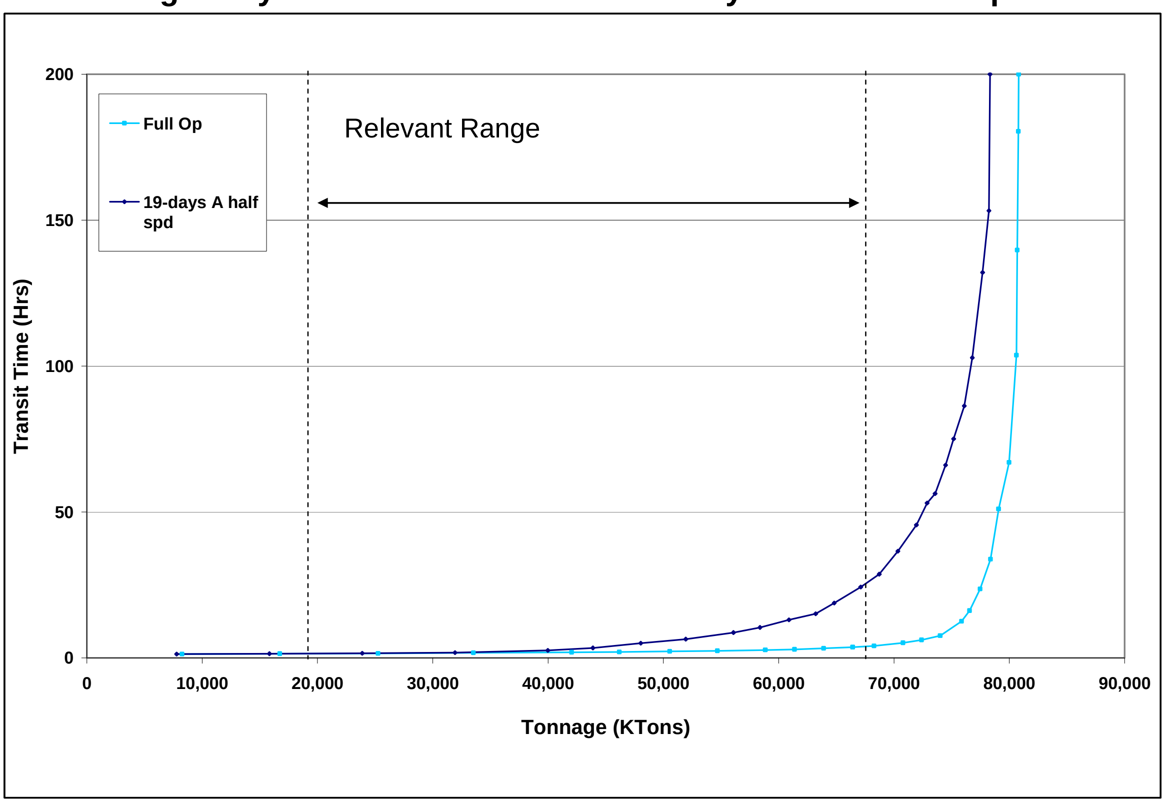


FIGURE A2- 113
Montgomery New 800' & New 600' Main Chamber Curves

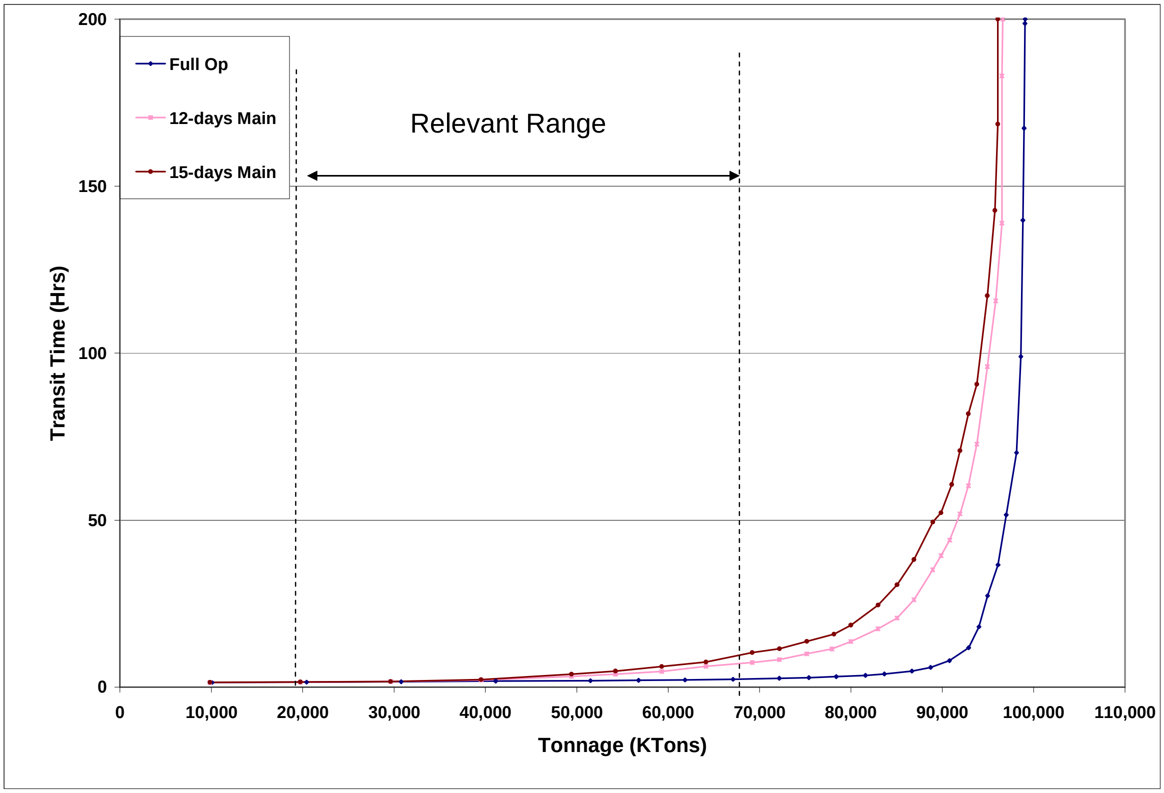


FIGURE A2- 114
Montgomery New 800' & New 600' Main Chamber Half Speeds

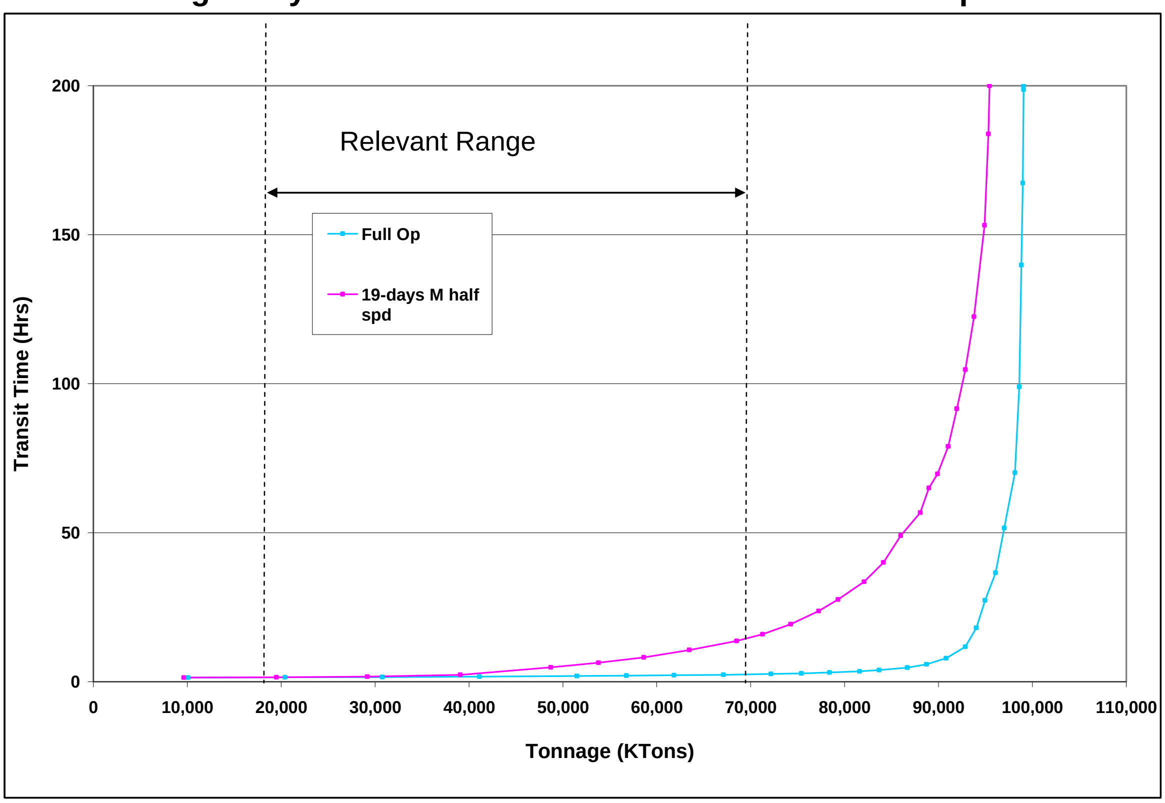


FIGURE A2- 115
Montgomery New 800’ & New 600’ Auxiliary Chamber Curves

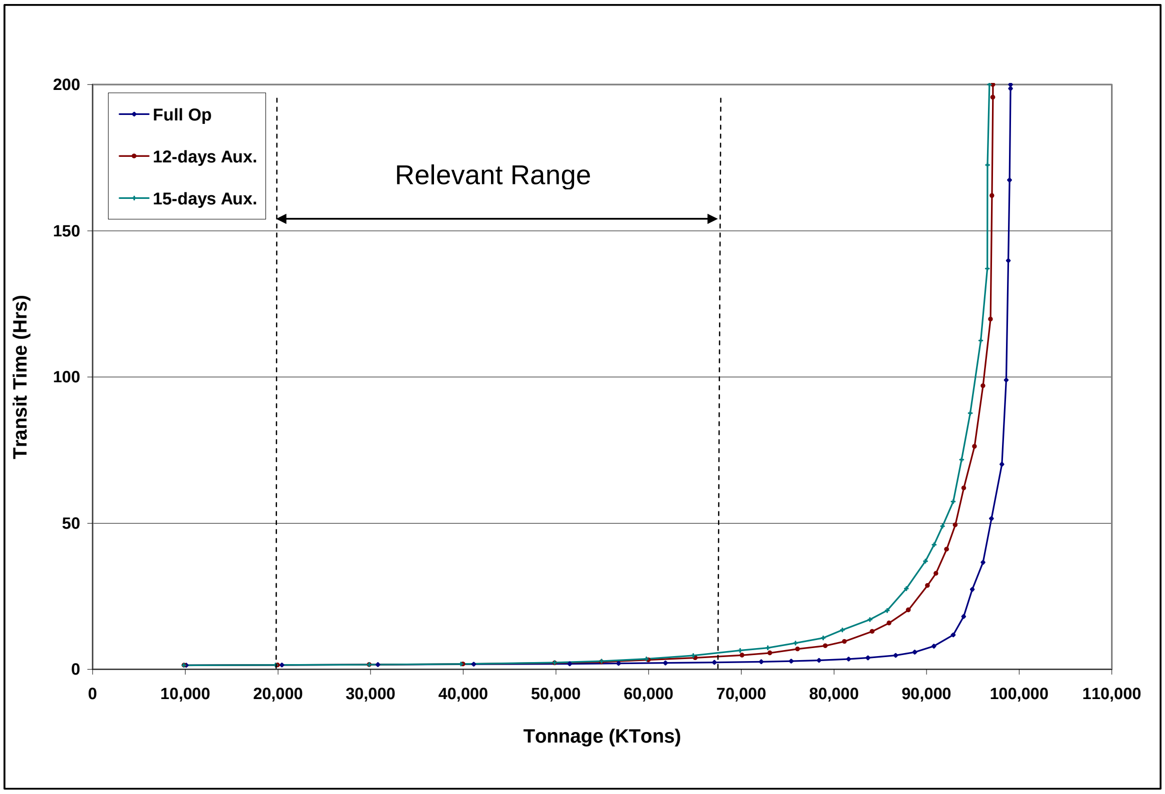


FIGURE A2- 116
Montgomery New 800’ & New 600’ Auxiliary Chamber Half Speeds

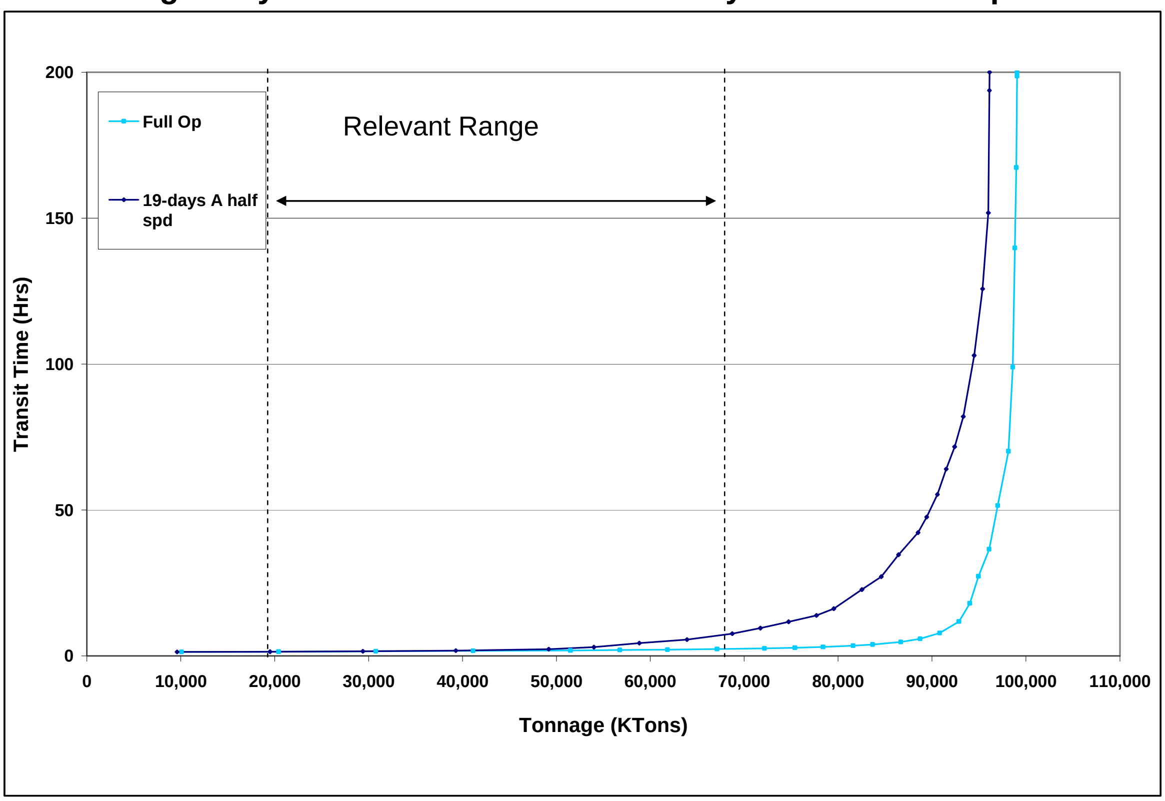


FIGURE A2- 117
Montgomery New 1200' & New 600' Main Chamber Curves

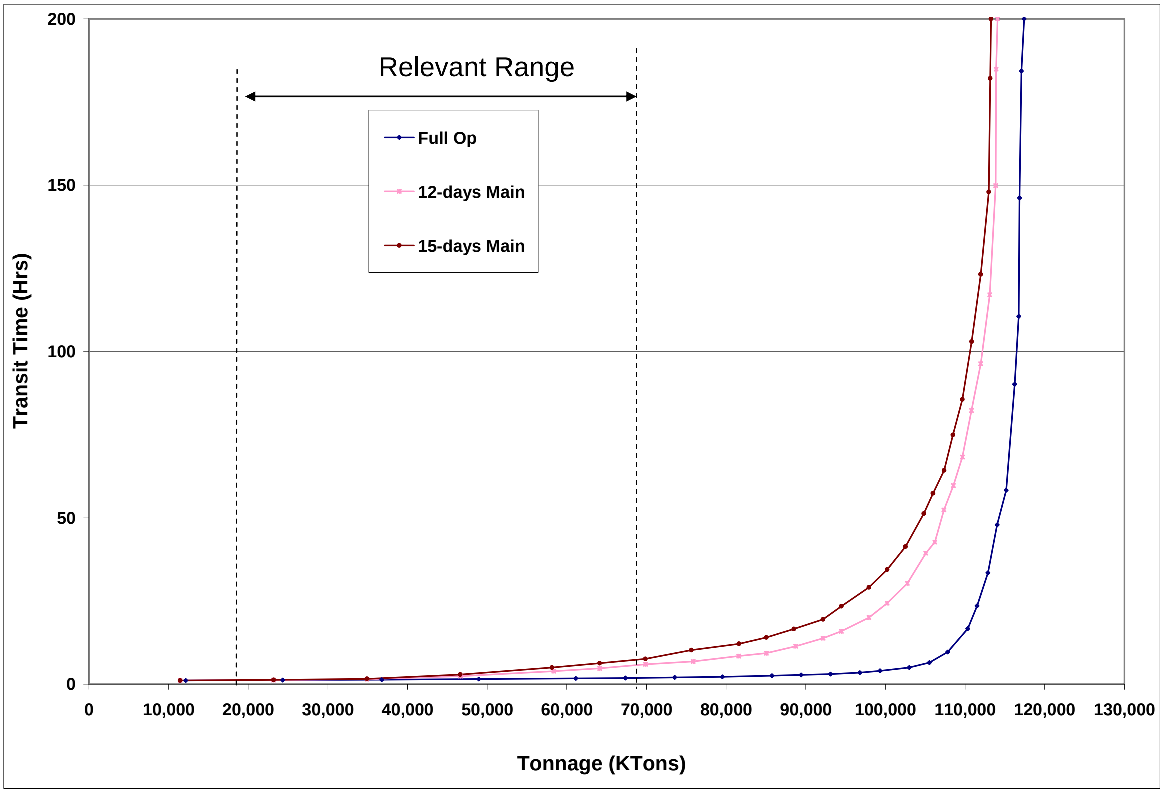


FIGURE A2- 118
Montgomery New 1200' & New 600' Main Chamber Half Speeds

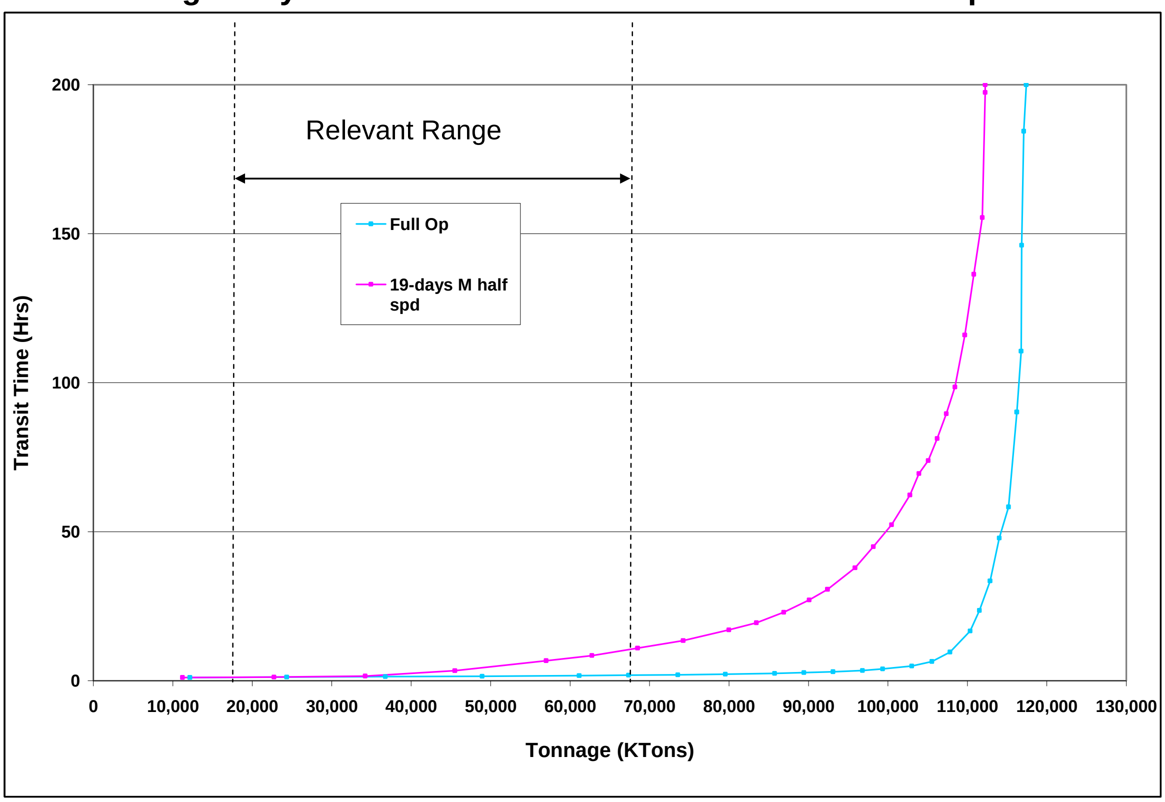


FIGURE A2- 119
Montgomery New 1200’ & New 600’ Auxiliary Chamber Curves

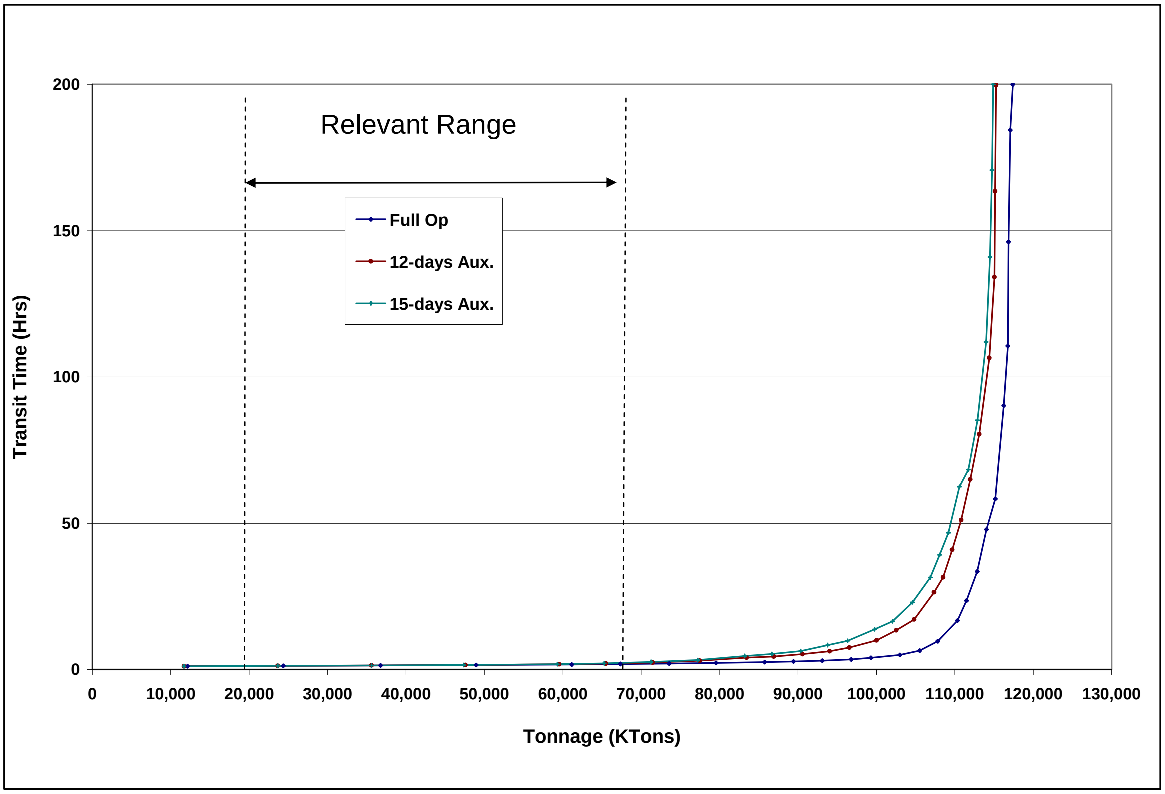


FIGURE A2- 120
Montgomery New 800’ & New 600’ Auxiliary Chamber Half Speeds

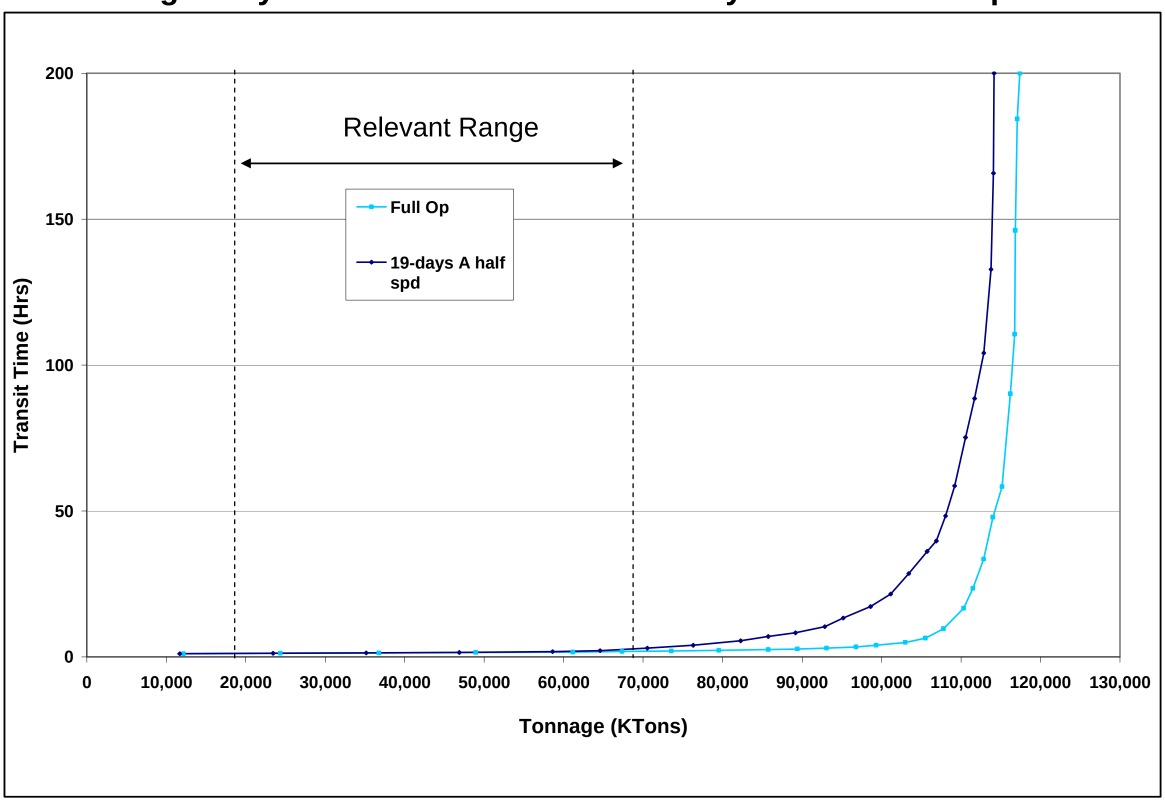


FIGURE A2- 121
Montgomery New Single 600’ Main Chamber Curves

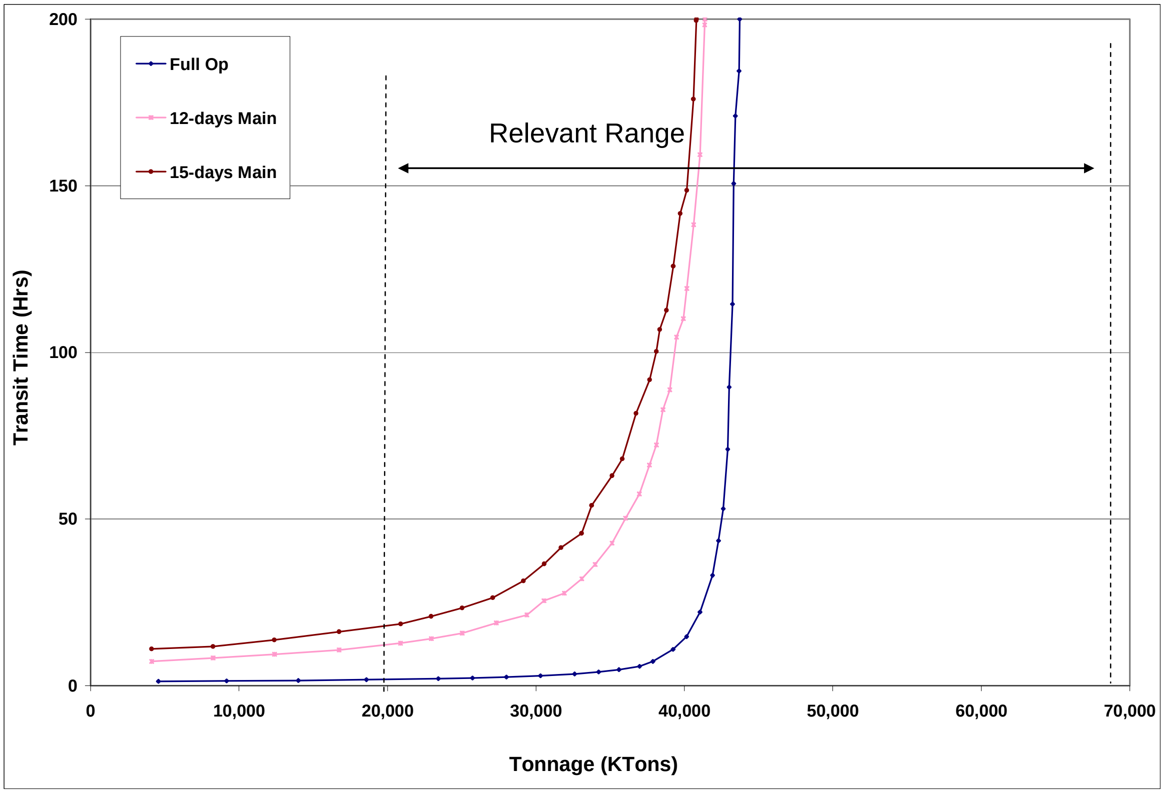


FIGURE A2- 122
Montgomery New Single 600’ Main Chamber Half Speed Curves

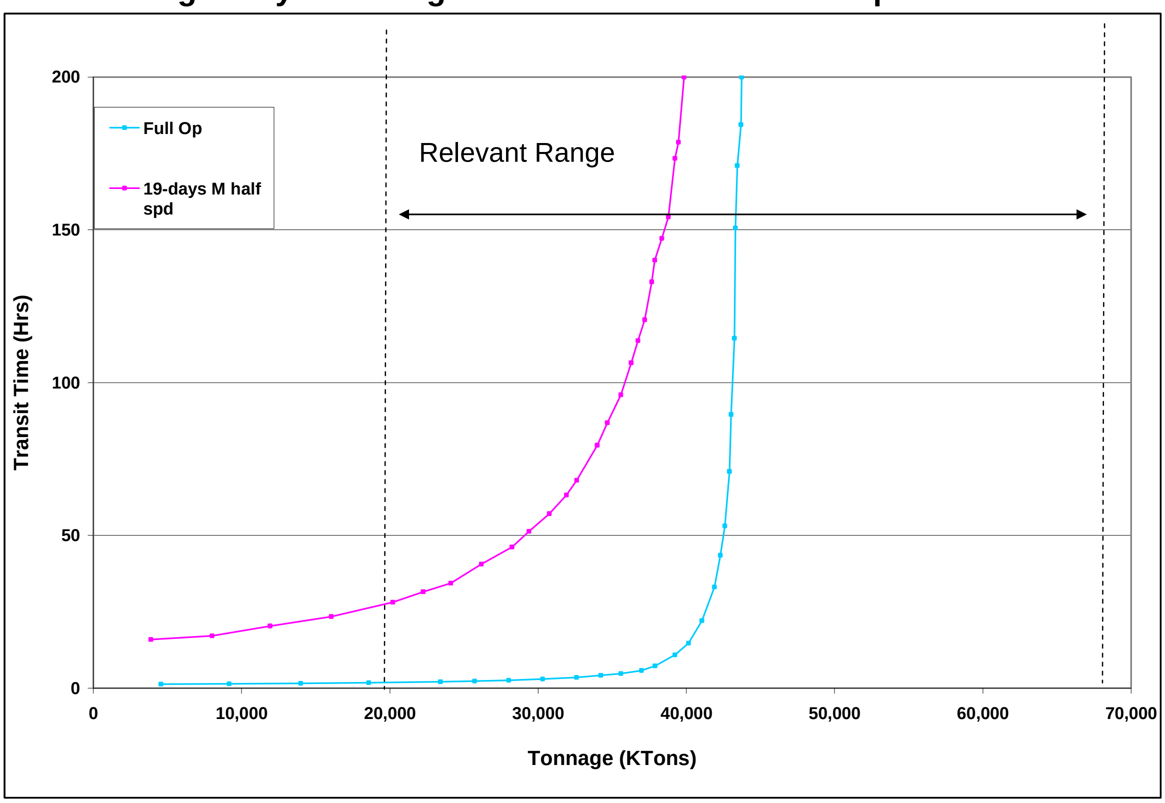


FIGURE A2- 123
Montgomery New Single 800’ Main Chamber Curves

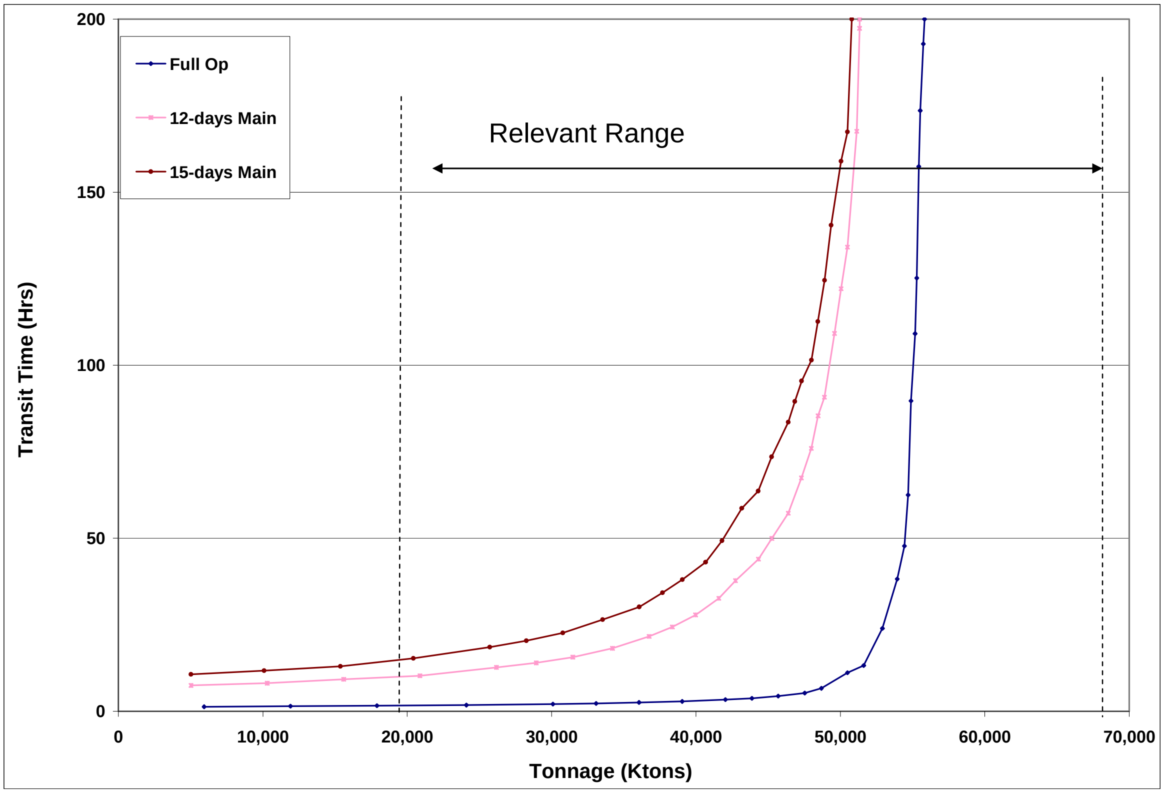


FIGURE A2- 124
Montgomery New Single 800’ Main Chamber half Speed Curves

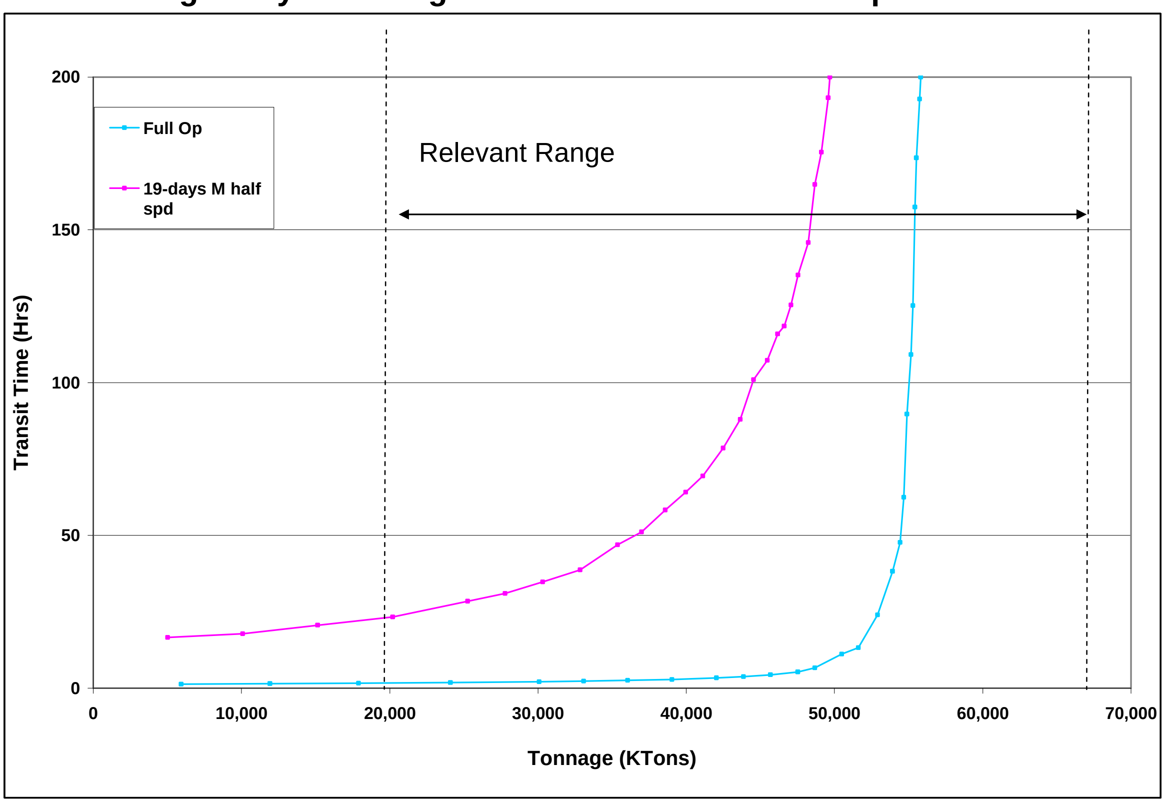


FIGURE A2- 125
Montgomery New Single 1200' Main Chamber Curves

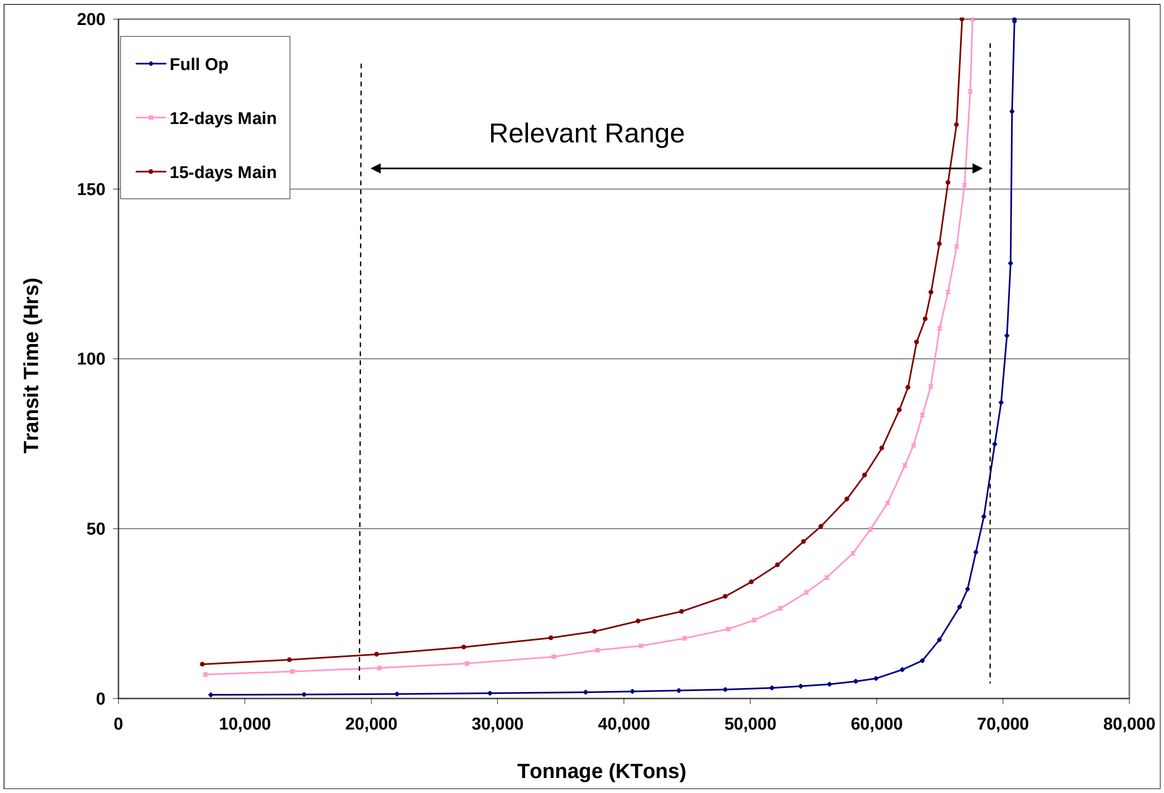
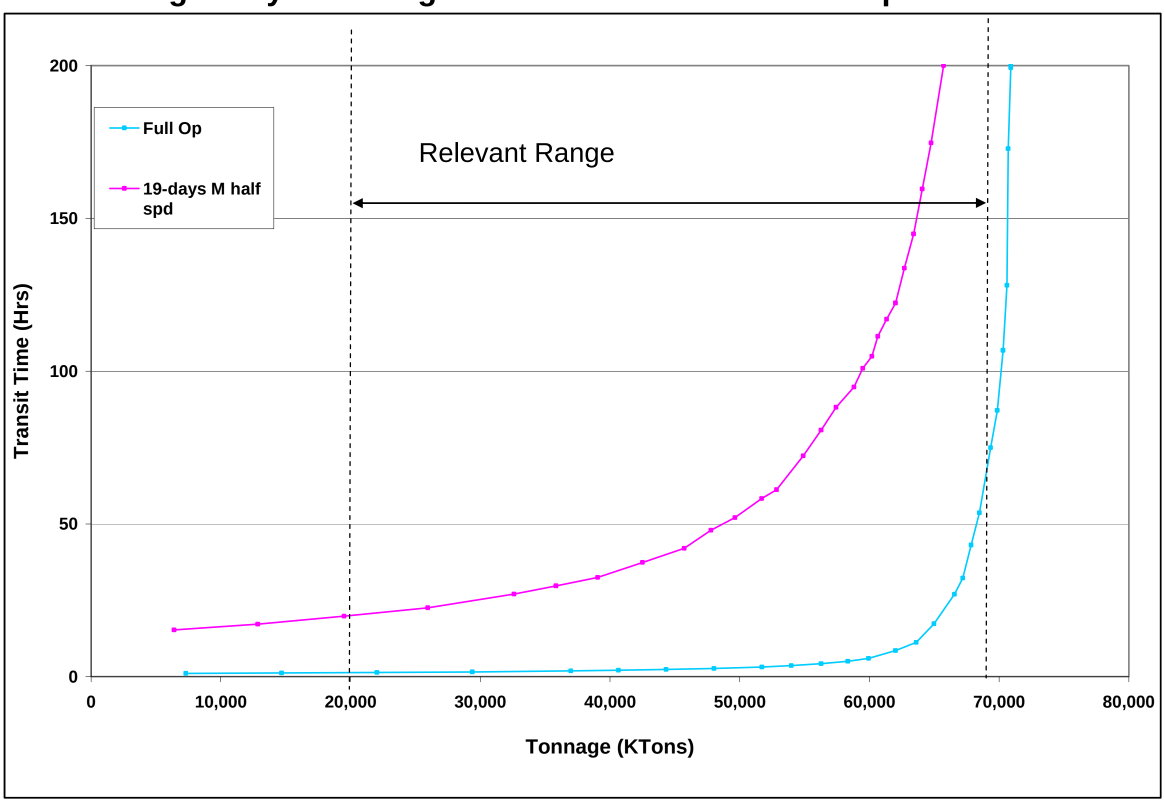


FIGURE A2- 126
Montgomery New Single 1200' Main Chamber Half Speed Curves



2.8.3 WPC Interpretations, Observations, Insights

All nine With Project conditions have sufficient capacity to serve projected future demand during the period of analysis, especially at low traffic levels. At low to moderate traffic levels, the With Project Condition capacities are able to serve traffic with minimal delays, even during chamber closure events.

2.9 Existing Fleet vs Future Fleet Sensitivity Analysis

2.9.1 Existing Condition

2.9.1.1 Emsworth Project Capacities and Processing Times

Table A2-162 shows the Emsworth's With Out Project Condition capacities for the full operation, main and auxiliary chambers, and river closures for the existing versus the future fleet determined during this study. **Table A2-163** shows Emsworth's capacity for the full op, and main chamber closure durations less than 90 days are approximately 3-3.5% higher for the future fleet while the main chamber with closure durations greater than 120 days are about 4-5% lower for the future fleet. The auxiliary chambers closures are 3-5% higher for the future fleet. The future fleet half speed capacity is less than 0.1% higher for the main chamber 19 day closure while the 30 day main chamber closure half speed capacity is 3% lower for the future fleet.

The processing times for the main chamber closures less than 90 days are 4-6% higher for the future fleet. The longer main chamber closure greater than 90 days have much higher processing times (10-19% higher) for the future fleet.

Figure A2-127 through **A2-133** shows the With Out Project Condition capacity curves for the existing versus the future fleet for the main, auxiliary, and total river closures.

TABLE A2- 162
Emsworth WOPC Existing Fleet vs Future Fleet

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	Existing Fleet	Future Fleet	Existing Fleet	Future Fleet
No closures (normal operation)	46.9	48.7	66.3	69.1
5-days Main Chamber Closed	46.3	48.0	66.8	69.9
10-days Main Chamber Closed	45.6	47.3	67.4	70.6
12-days Main Chamber Closed	45.4	46.9	67.7	70.6
15-days Main Chamber Closed	45.0	46.6	68.1	71.0
18-days Main Chamber Closed	44.6	46.2	68.5	71.8
30-days Main Chamber Closed	43.3	44.8	70.1	73.6
45-days Main Chamber Closed	41.9	43.3	72.0	75.8
60-days Main Chamber Closed	40.4	41.7	74.0	78.2
90-days Main Chamber Closed	37.7	38.7	78.5	83.4
120-days Main Chamber Closed	17.2	16.5	100.1	110.2
180-days Main Chamber Closed	13.8	13.1	130.1	149.2
210-days Main Chamber Closed	13.0	12.4	145.0	167.0
240-days Main Chamber Closed	12.7	12.0	160.3	185.8
365-days Main Chamber Closed	11.7	11.1	218.3	259.5
3-days Auxiliary Chamber Closed	46.9	48.7	66.1	69.0
5-days Auxiliary Chamber Closed	46.9	48.6	66.2	69.0
10-days Auxiliary Chamber Closed	46.8	48.5	66.3	69.4
15-days Auxiliary Chamber Closed	46.7	48.4	66.3	69.3
30-days Auxiliary Chamber Closed	46.5	48.2	66.7	69.5
45-days Auxiliary Chamber Closed	46.5	48.1	66.9	69.6
60-days Auxiliary Chamber Closed	46.3	47.9	66.9	69.9
90-days Auxiliary Chamber Closed	46.1	47.7	67.6	69.9
180-days Auxiliary Chamber Closed	43.5	45.5	70.0	71.6
210-days Auxiliary Chamber Closed	42.9	44.9	70.8	72.0
365-days Auxiliary Chamber Closed	40.9	42.9	74.1	74.4
19-days Main Chamber ½ speed	45.9	46.0	67.2	71.9
30-days Main Chamber ½ speed	45.4	43.9	67.7	73.2
5-days River Closure	46.0	*48.1	66.1	*
10-days River Closure	45.2	*47.4	66.0	*
15-days River Closure	44.6	*46.7	66.1	*
18-days River Closure	44.3	*46.3	66.1	*
30-days River Closure	42.7	*44.7	66.0	*
42-days River Closure	41.5	*43.1	66.3	*
45-days River Closure	41.1	*42.7	66.1	*
60-days River Closure	39.2	*40.7	66.1	*
90-days River Closure	35.1	*36.7	66.2	*
180-days River Closure	23.7	*24.7	65.6	*
210-days River Closure	20.2	*20.7	65.5	*
240-days River Closure	16.5	16.9	66.0	69.0
365-days River Closure	0.0	0.0	0.0	0.0

** Calculated Capacities*

TABLE A2- 163
Emsworth WOPC Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
No closures (normal operation)	3.8%	4.2%
5-days Main Chamber Closed	3.7%	4.7%
10-days Main Chamber Closed	3.7%	4.8%
12-days Main Chamber Closed	3.3%	4.3%
15-days Main Chamber Closed	3.5%	4.2%
18-days Main Chamber Closed	3.6%	4.8%
30-days Main Chamber Closed	3.6%	4.9%
45-days Main Chamber Closed	3.2%	5.2%
60-days Main Chamber Closed	3.0%	5.6%
90-days Main Chamber Closed	2.8%	6.3%
120-days Main Chamber Closed	-3.7%	10.1%
180-days Main Chamber Closed	-4.8%	14.7%
210-days Main Chamber Closed	-4.4%	15.2%
240-days Main Chamber Closed	-5.1%	15.9%
365-days Main Chamber Closed	-4.9%	18.8%
3-days Auxiliary Chamber Closed	3.8%	4.3%
5-days Auxiliary Chamber Closed	3.7%	4.2%
10-days Auxiliary Chamber Closed	3.7%	4.7%
15-days Auxiliary Chamber Closed	3.7%	4.5%
30-days Auxiliary Chamber Closed	3.7%	4.2%
45-days Auxiliary Chamber Closed	3.4%	4.0%
60-days Auxiliary Chamber Closed	3.3%	4.5%
90-days Auxiliary Chamber Closed	3.6%	3.5%
180-days Auxiliary Chamber Closed	4.5%	2.2%
210-days Auxiliary Chamber Closed	4.7%	1.8%
365-days Auxiliary Chamber Closed	5.0%	0.4%
19-days Main Chamber ½ speed	0.1%	7.0%
30-days Main Chamber ½ speed	-3.4%	8.2%

TABLE A2- 164
Emsworth WOPC Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
5-days River Closure	4.6%	*
10-days River Closure	4.8%	*
15-days River Closure	4.6%	*
18-days River Closure	4.6%	*
30-days River Closure	4.6%	*
42-days River Closure	3.9%	*
45-days River Closure	4.0%	*
60-days River Closure	3.9%	*
90-days River Closure	4.6%	*
180-days River Closure	4.2%	*
210-days River Closure	2.7%	*
240-days River Closure	2.2%	4.6%
365-days River Closure	0.0%	0.0%
** Calculated Capacities*		

FIGURE A2- 127
Emsworth WOPC Main Chamber Closures – Existing Fleet

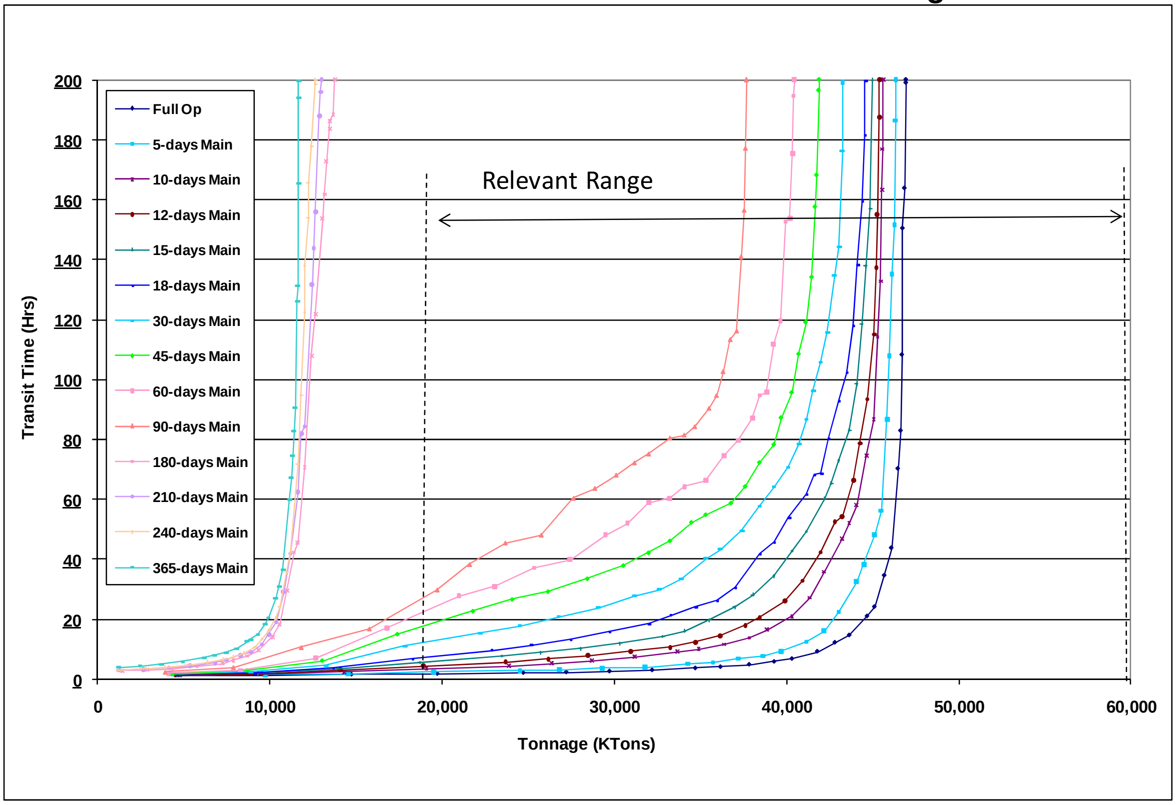
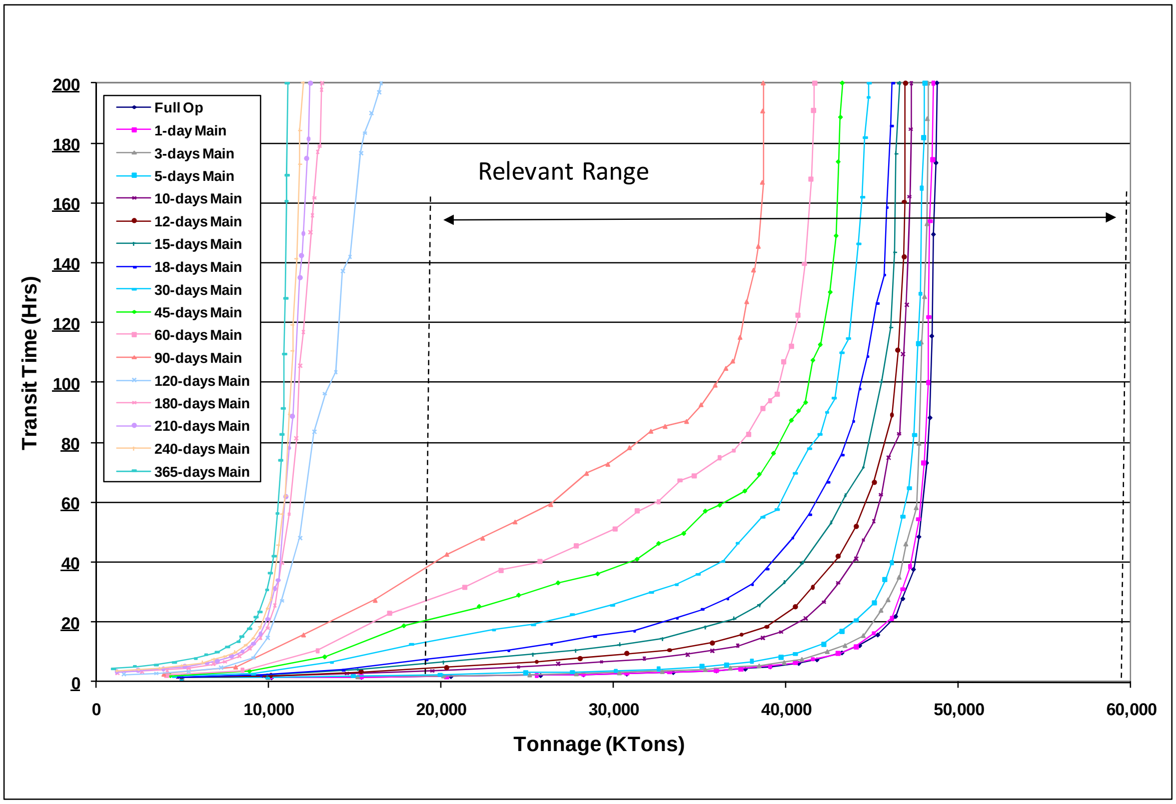


FIGURE A2- 128
Emsworth WOPC Main Chamber Closures – Future Fleet



IGURE A2- 129
Emsworth WOPC Auxiliary Chamber Closures – Existing Fleet

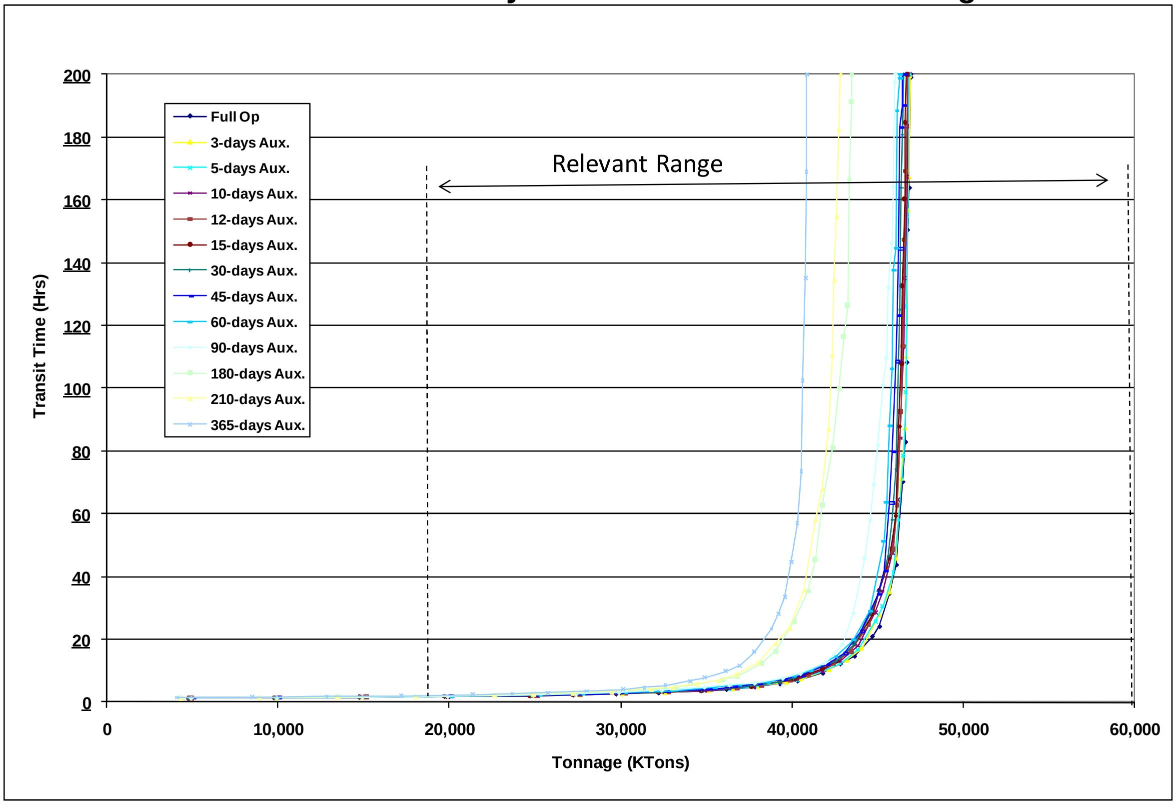


FIGURE A2- 130
Emsworth WOPC Auxiliary Chamber Closures – Future Fleet

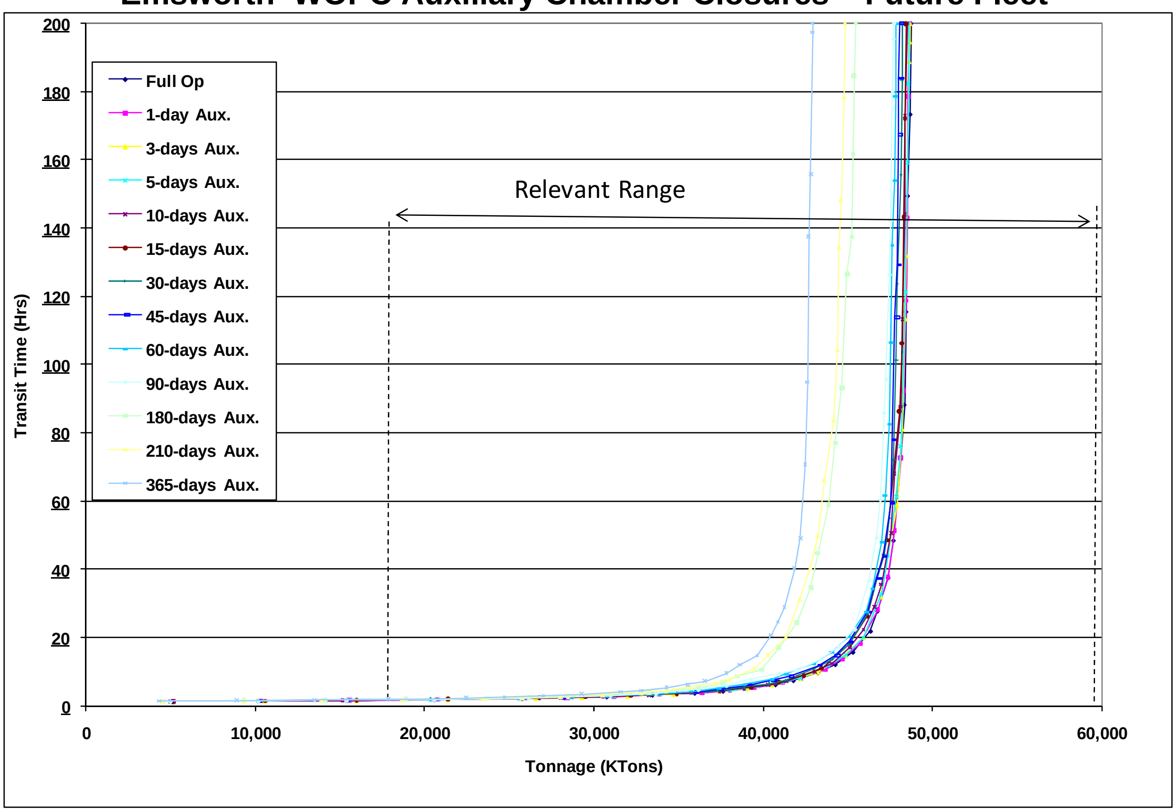


FIGURE A2- 131
Emsworth WOPC Main Chamber Half Speed Closures – Existing Fleet

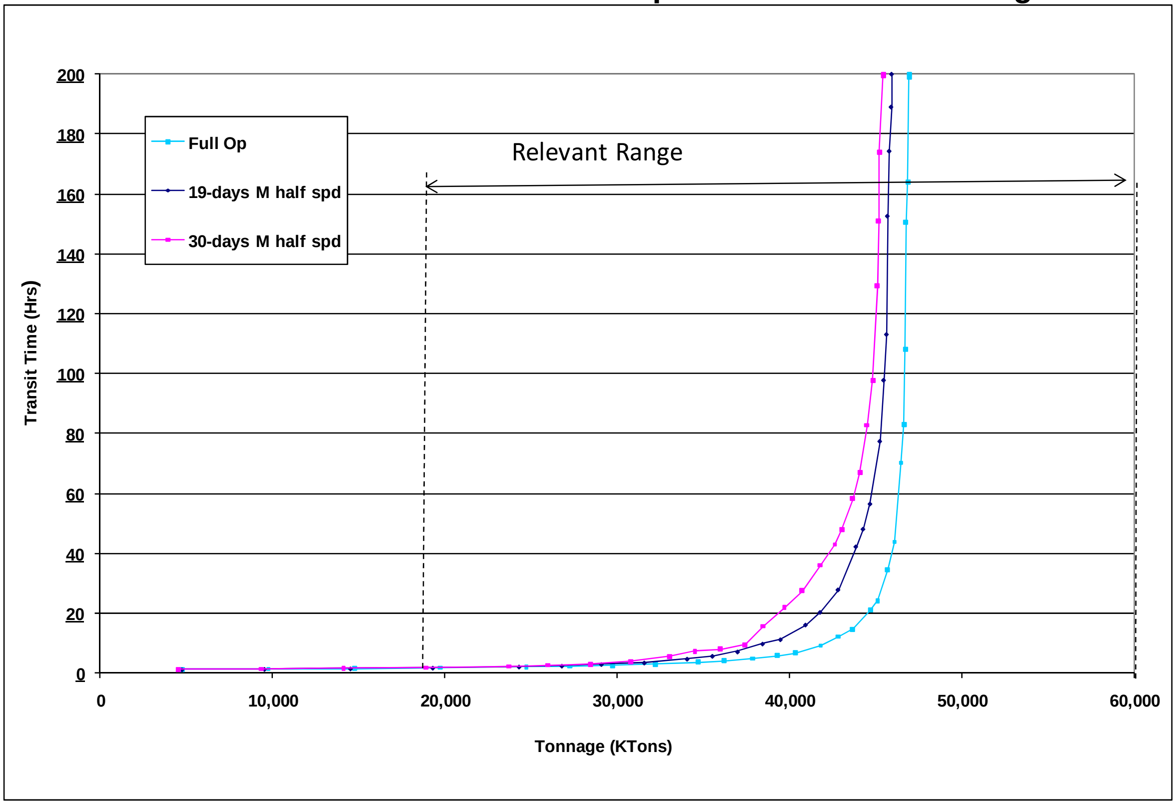


FIGURE A2- 132
Emsworth WOPC Main Chamber Half Speed Closures – Future Fleet

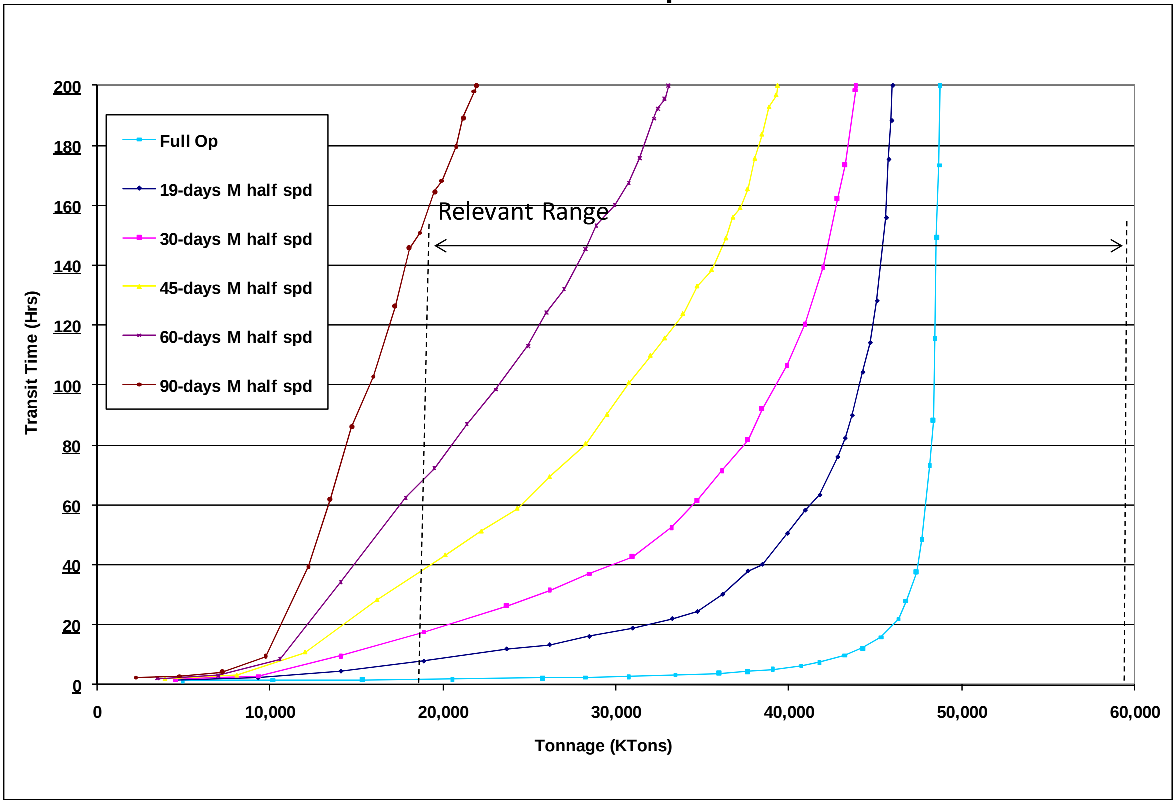


FIGURE A2- 133
Emsworth WOPC River Chamber Closures – Existing Fleet

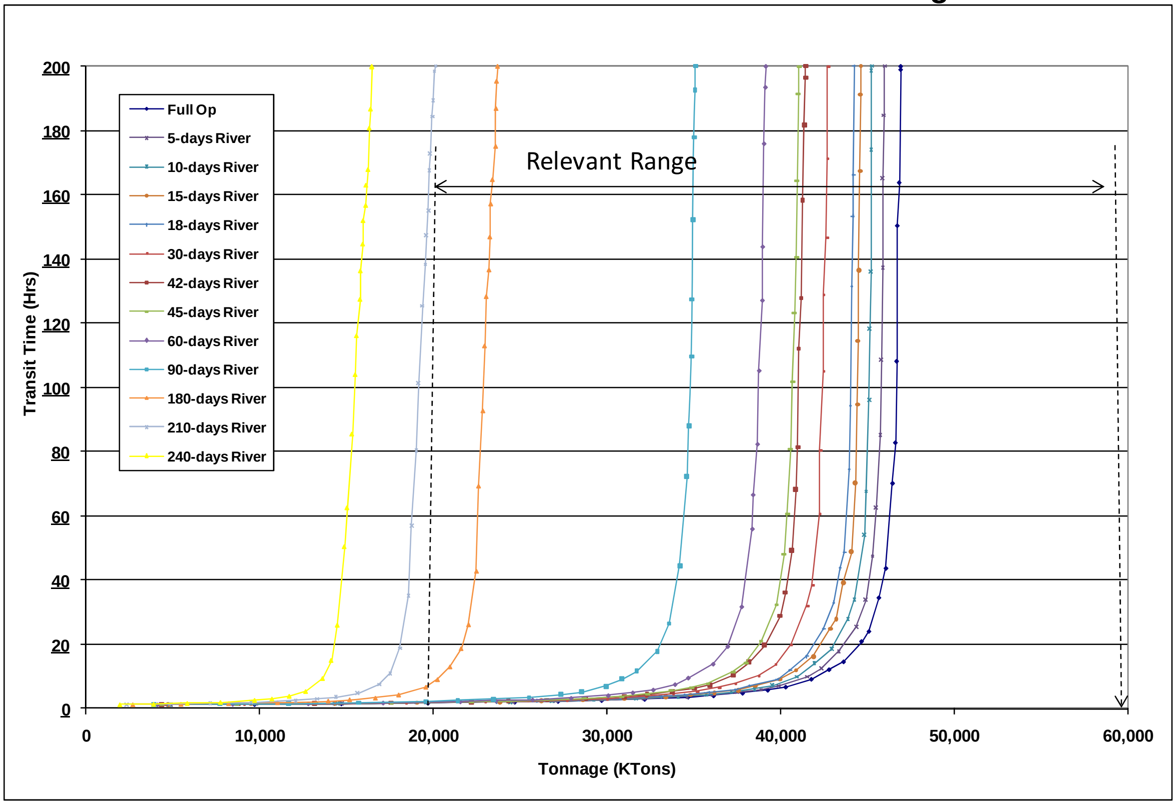
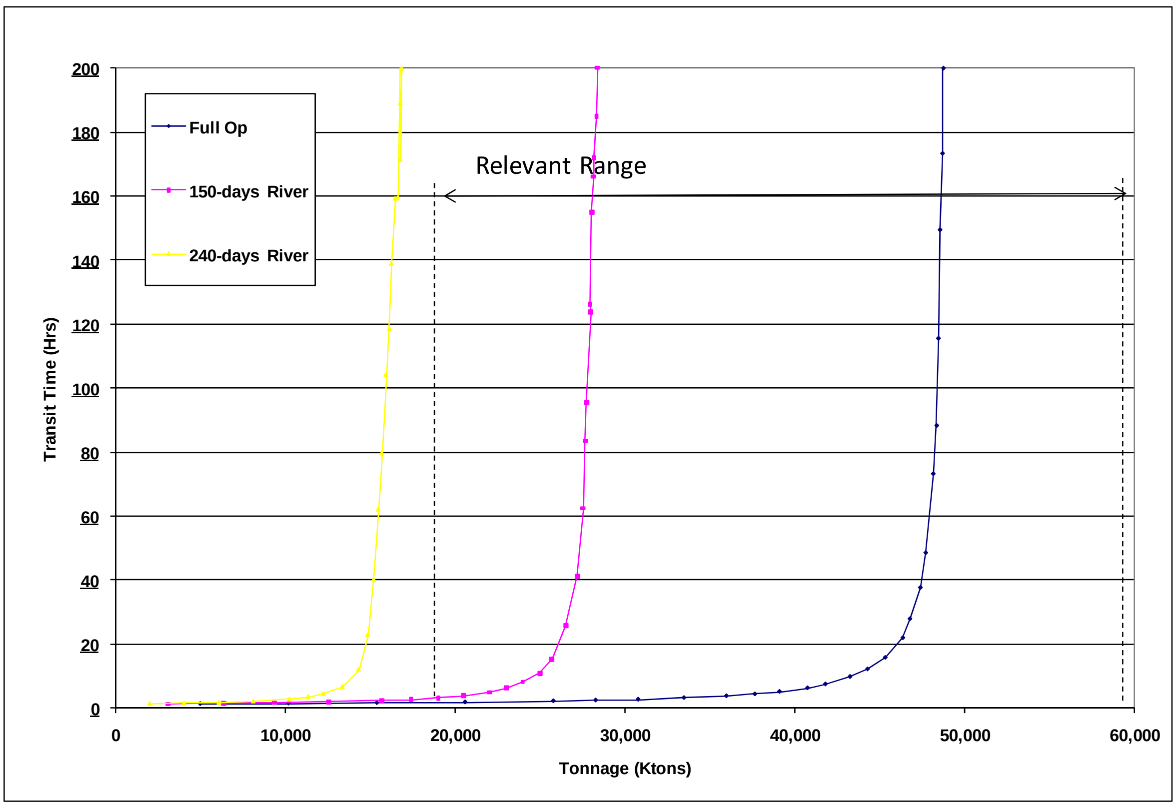


FIGURE A2- 134
Emsworth WOPC River Chamber Closures – Future Fleet



2.9.1.2 Dashields Project Capacities and Processing Times

Table A2-165 shows the Dashields's With Out Project Condition capacities for the full operation, main and auxiliary chambers, and river closures for the existing versus the future fleet determined during this study. **Table A2-166** shows the capacity for the full op, and main chamber closure durations less than 90 days are less than 1% differencer for the existing versus future fleet. The capacity for the main chamber closure durations greater than 120 days are about 12.5% lower for the future fleet. The capacity for the auxiliary chambers closures are 1% higher for the future fleet. The 365 day auxiliary closure is 2% higher using the future fleet. The half speed capacity is 2% lower for the main chamber 19 day closure using the future fleet.

The processing times for the main chamber closures less than 45 days are 14% lower for the future fleet. The processing times for the auxiliary chamber closure less than 30 days are 14% lower using the future fleet while the processing times for the closure durations between 45 – 90 days are 14% lower using the future fleet, and those closure durations greater than 90 days are 10% lower using the future fleet.

Figure A2-135 through **A2-142** shows the With Out Project Condition capacity curves for the existing versus the future fleet for the main, auxiliary, and total river closures.

TABLE A2- 165
Dashields WOPC Existing Fleet vs Future Fleet

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	Existing Fleet	Future Fleet	Existing Fleet	Future Fleet
No closures (normal operation)	50.9	51.5	58.6	50.1
5-days Main Chamber Closed	50.4	50.8	59.1	50.6
10-days Main Chamber Closed	49.6	50.1	59.6	51.2
12-days Main Chamber Closed	49.4	49.8	59.9	51.3
15-days Main Chamber Closed	48.9	49.4	60.2	51.6
18-days Main Chamber Closed	48.4	48.8	60.6	51.9
30-days Main Chamber Closed	47.2	47.6	61.9	53.2
45-days Main Chamber Closed	45.8	46.1	63.7	55.3
60-days Main Chamber Closed	44.5	44.6	65.5	58.4
90-days Main Chamber Closed	42.0	41.7	69.3	67.2
120-days Main Chamber Closed	22.9	20.0	85.7	78.2
180-days Main Chamber Closed	18.9	16.5	107.8	100.5
210-days Main Chamber Closed	18.1	15.9	118.0	110.9
240-days Main Chamber Closed	17.5	15.4	126.5	122.5
365-days Main Chamber Closed	16.4	14.3	166.5	162.2
3-days Auxiliary Chamber Closed	51.0	51.5	58.4	50.2
5-days Auxiliary Chamber Closed	50.9	51.4	58.5	50.2
10-days Auxiliary Chamber Closed	50.8	51.4	58.5	50.2
15-days Auxiliary Chamber Closed	50.8	51.3	58.6	50.2
30-days Auxiliary Chamber Closed	50.8	51.3	58.7	50.4
45-days Auxiliary Chamber Closed	50.7	51.3	58.8	50.7
60-days Auxiliary Chamber Closed	50.6	51.2	58.7	50.8
90-days Auxiliary Chamber Closed	50.6	51.1	58.9	51.1
180-days Auxiliary Chamber Closed	48.8	49.5	60.1	52.9
210-days Auxiliary Chamber Closed	48.4	49.2	60.3	53.3
365-days Auxiliary Chamber Closed	47.0	48.1	61.7	55.2
19-days Main Chamber ½ speed	49.9	48.7	59.3	52.0
5-days River Closure	50.0	*50.8	58.5	*
10-days River Closure	49.3	*50.1	58.5	*
15-days River Closure	48.6	*49.4	58.5	*
18-days River Closure	48.2	*49.0	58.6	*
30-days River Closure	46.4	*47.3	58.6	*
45-days River Closure	44.7	*45.1	58.6	*
60-days River Closure	42.5	*43.0	58.6	*
90-days River Closure	38.2	*38.8	58.5	*
180-days River Closure	25.7	*26.1	57.9	*
210-days River Closure	21.9	*21.9	57.9	*
240-days River Closure	18.1	18.9	57.9	58.3
365-days River Closure	0.0	0.0	0.0	0.0
** Calculated Capacities*				

TABLE A2- 166
Dashields WOPC Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
No closures (normal operation)	1.1%	-14.4%
5-days Main Chamber Closed	0.9%	-14.4%
10-days Main Chamber Closed	0.9%	-14.1%
12-days Main Chamber Closed	0.9%	-14.4%
15-days Main Chamber Closed	1.1%	-14.2%
18-days Main Chamber Closed	0.9%	-14.2%
30-days Main Chamber Closed	0.8%	-14.1%
45-days Main Chamber Closed	0.6%	-13.2%
60-days Main Chamber Closed	0.2%	-10.9%
90-days Main Chamber Closed	-0.7%	-3.0%
120-days Main Chamber Closed	-12.4%	-8.8%
180-days Main Chamber Closed	-12.5%	-6.8%
210-days Main Chamber Closed	-12.3%	-6.0%
240-days Main Chamber Closed	-11.5%	-3.2%
365-days Main Chamber Closed	-12.3%	-2.6%
3-days Auxiliary Chamber Closed	1.0%	-14.1%
5-days Auxiliary Chamber Closed	1.2%	-14.2%
10-days Auxiliary Chamber Closed	1.2%	-14.2%
15-days Auxiliary Chamber Closed	1.0%	-14.4%
30-days Auxiliary Chamber Closed	1.0%	-14.1%
45-days Auxiliary Chamber Closed	1.2%	-13.8%
60-days Auxiliary Chamber Closed	1.1%	-13.5%
90-days Auxiliary Chamber Closed	1.1%	-13.2%
180-days Auxiliary Chamber Closed	1.5%	-11.9%
210-days Auxiliary Chamber Closed	1.7%	-11.6%
365-days Auxiliary Chamber Closed	2.3%	-10.5%
19-days Main Chamber ½ speed	-2.5%	-12.2%

TABLE A2- 167
Dashields WOPC Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
5-days River Closure	1.5%	*
10-days River Closure	1.7%	*
15-days River Closure	1.7%	*
18-days River Closure	1.7%	*
30-days River Closure	1.9%	*
45-days River Closure	0.8%	*
60-days River Closure	1.2%	*
90-days River Closure	1.7%	*
180-days River Closure	1.7%	*
210-days River Closure	-0.1%	*
240-days River Closure	4.2%	0.7%
365-days River Closure	0.0%	0.0%
** Calculated Capacities*		

FIGURE A2- 135
Dashields WOPC Main Chamber Closures – Existing Fleet

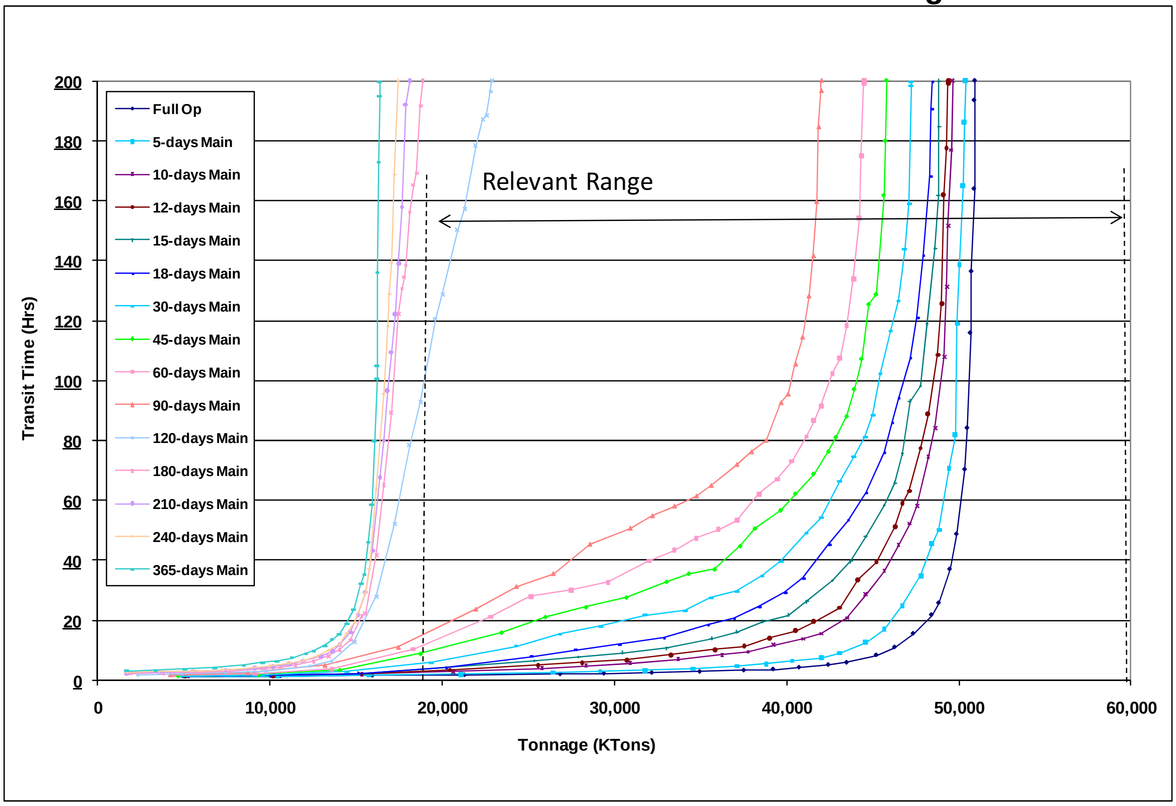


FIGURE A2- 136
Dashields WOPC Main Chamber Closures – Future Fleet

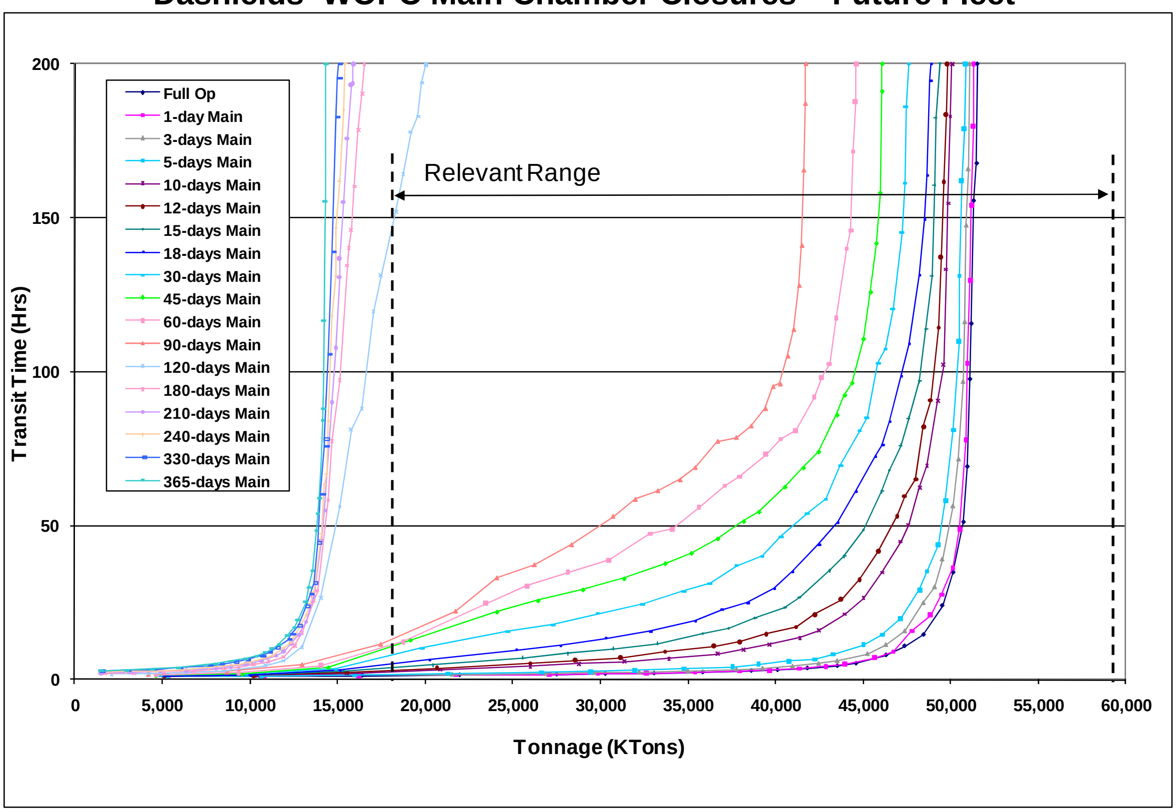


FIGURE A2- 137
Dashields WOPC Auxiliary Chamber Closures – Existing Fleet

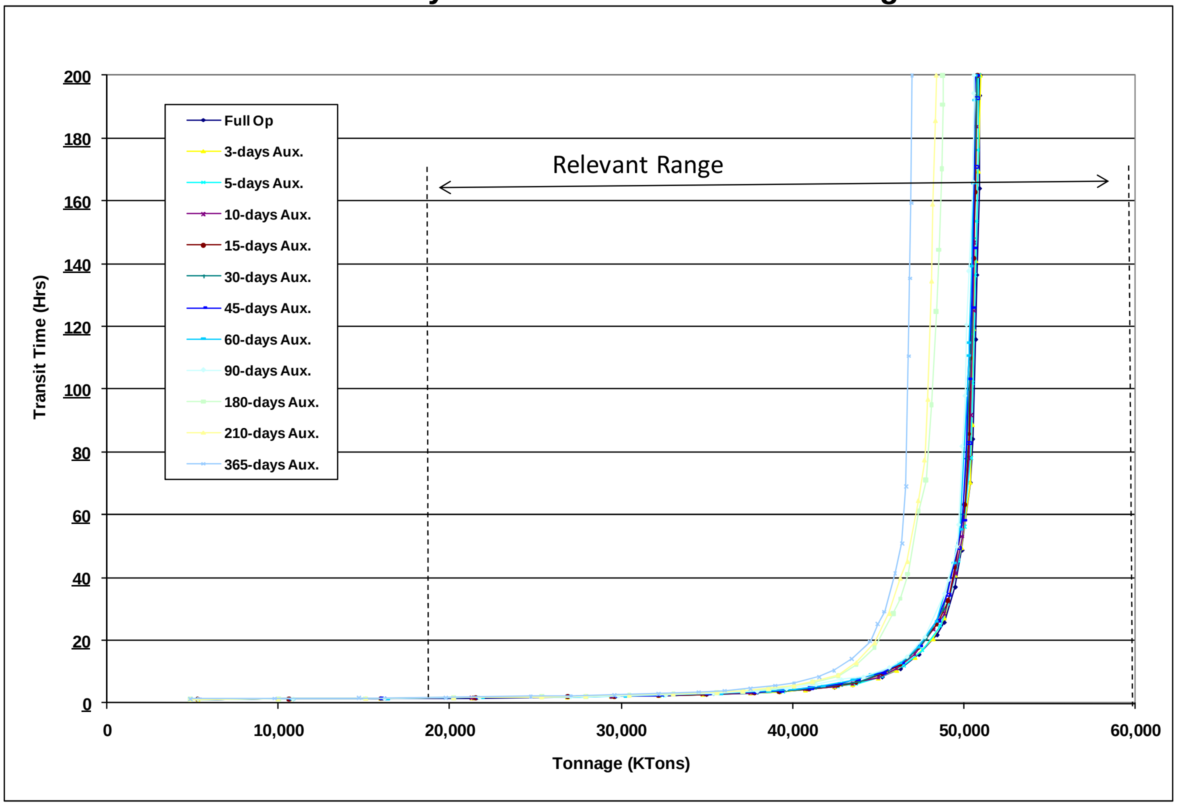


FIGURE A2- 138
Dashields WOPC Auxiliary Chamber Closures – Future Fleet

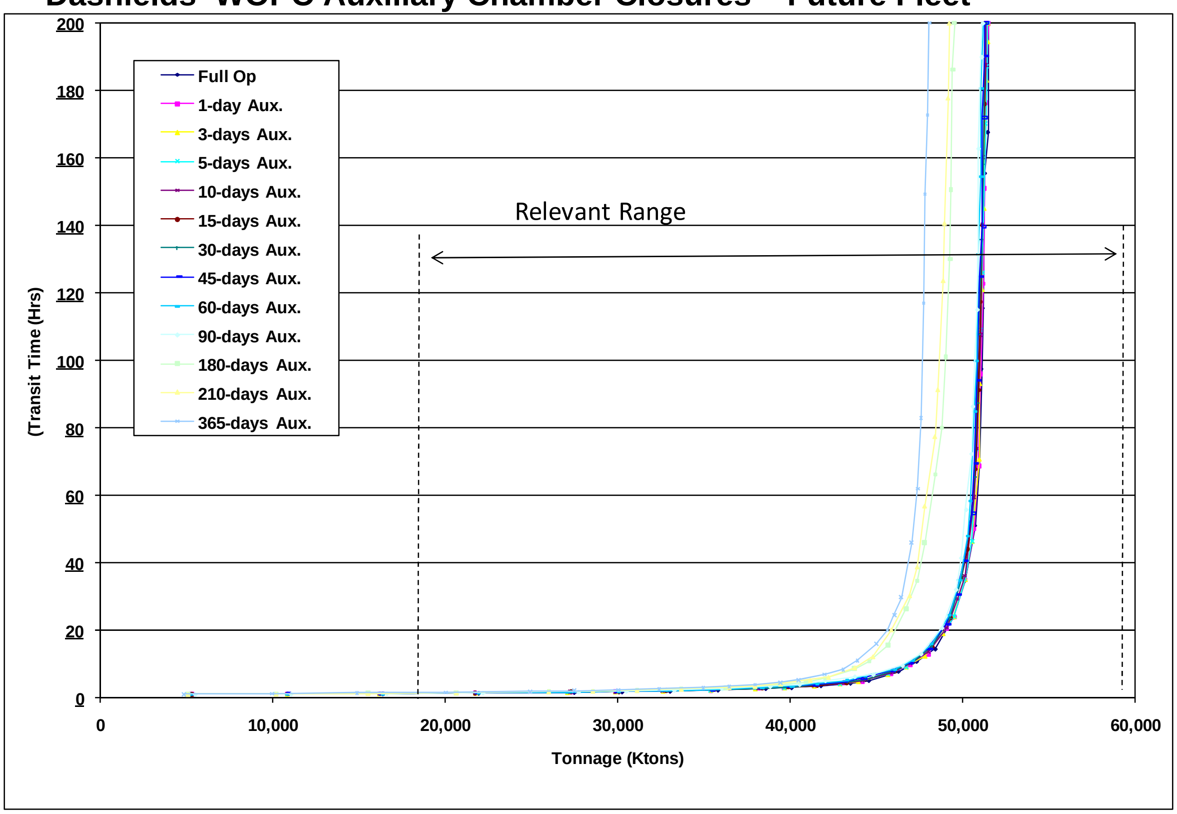


FIGURE A2- 139
Dashields WOPC Main Chamber Half Speed Closures – Existing Fleet

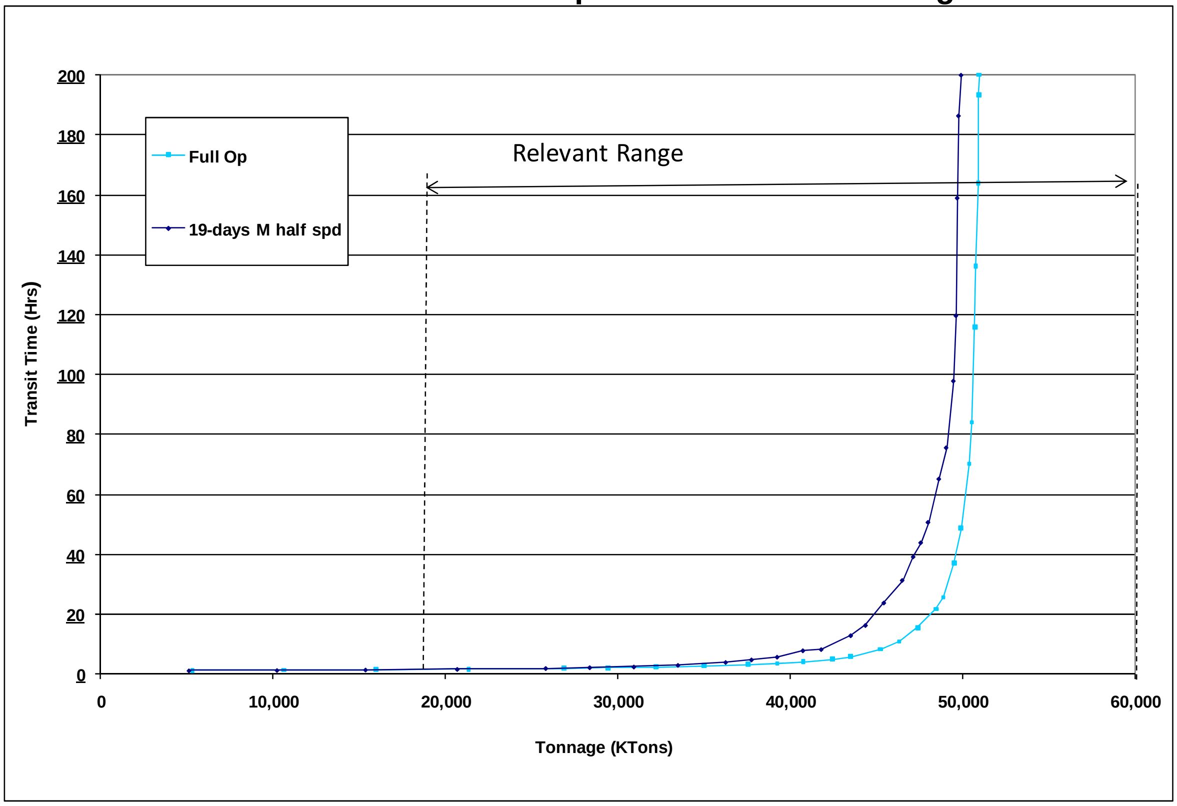


FIGURE A2- 140
Dashields WOPC Main Chamber Half Speed Closures – Future Fleet

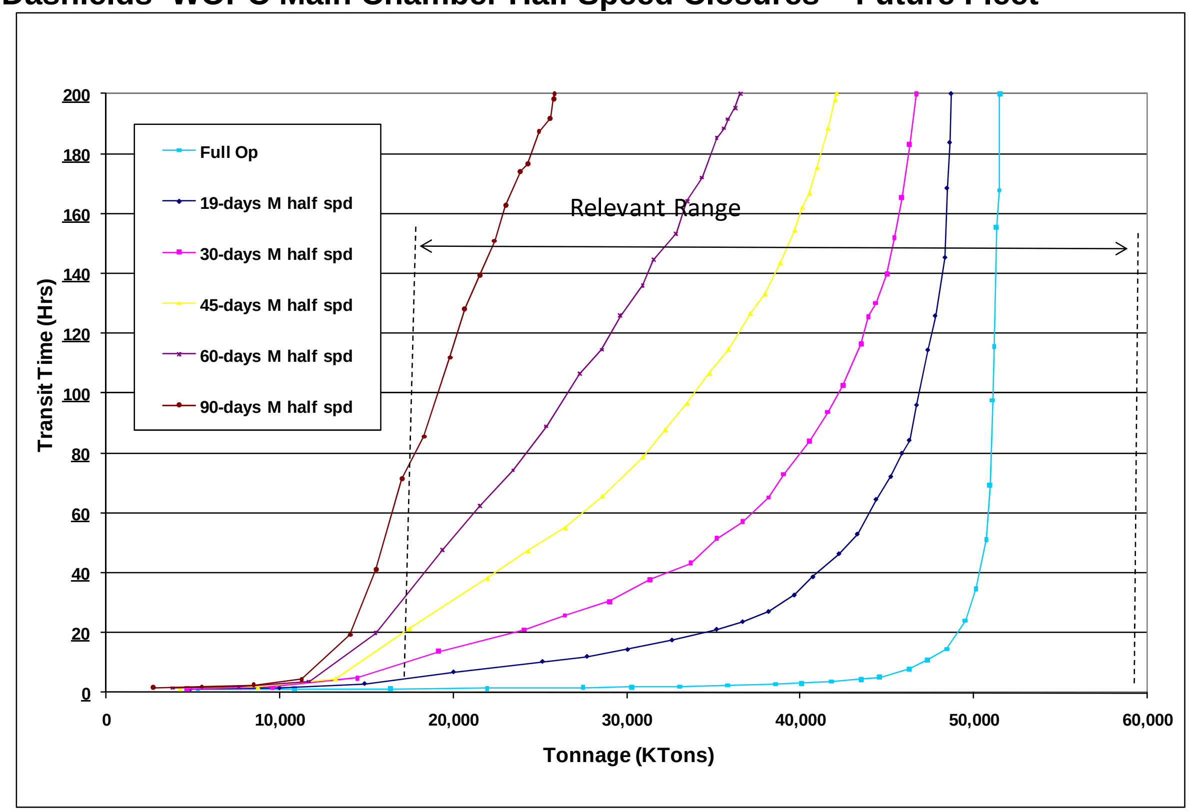


FIGURE A2- 141

Dashields WOPC River Chamber Closures – Existing Fleet

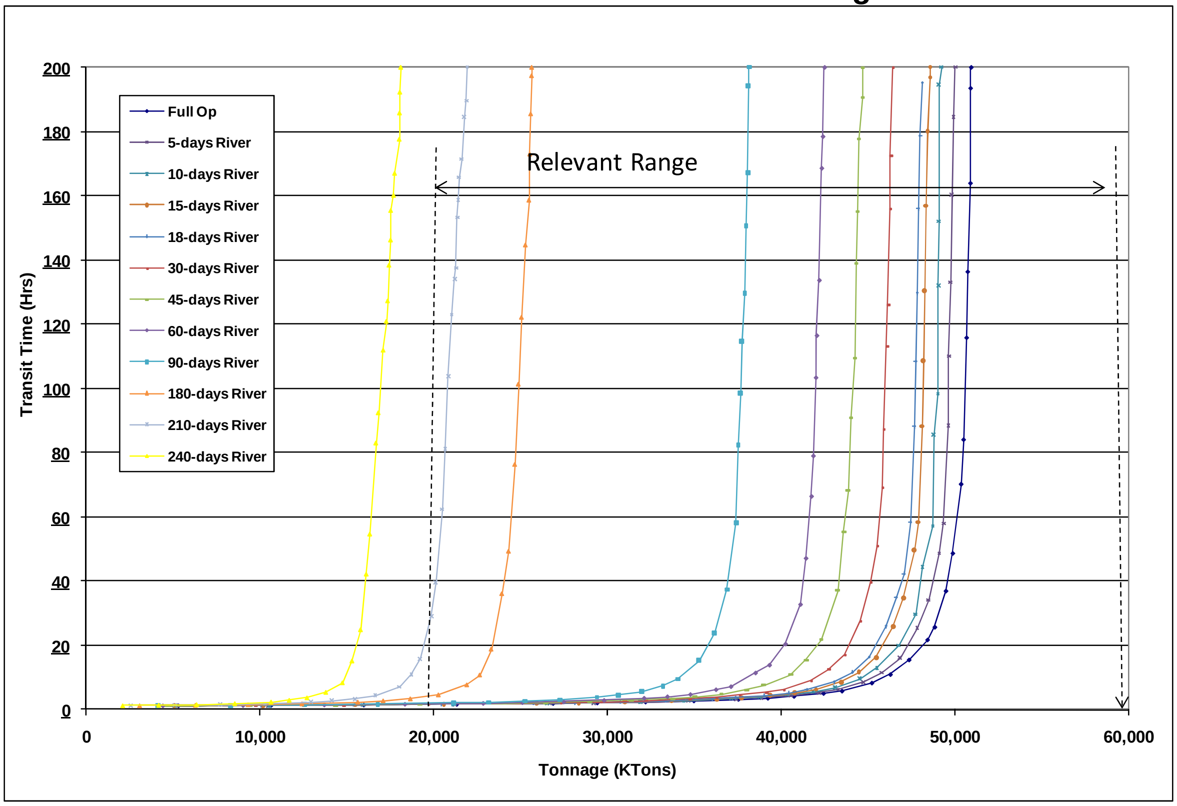
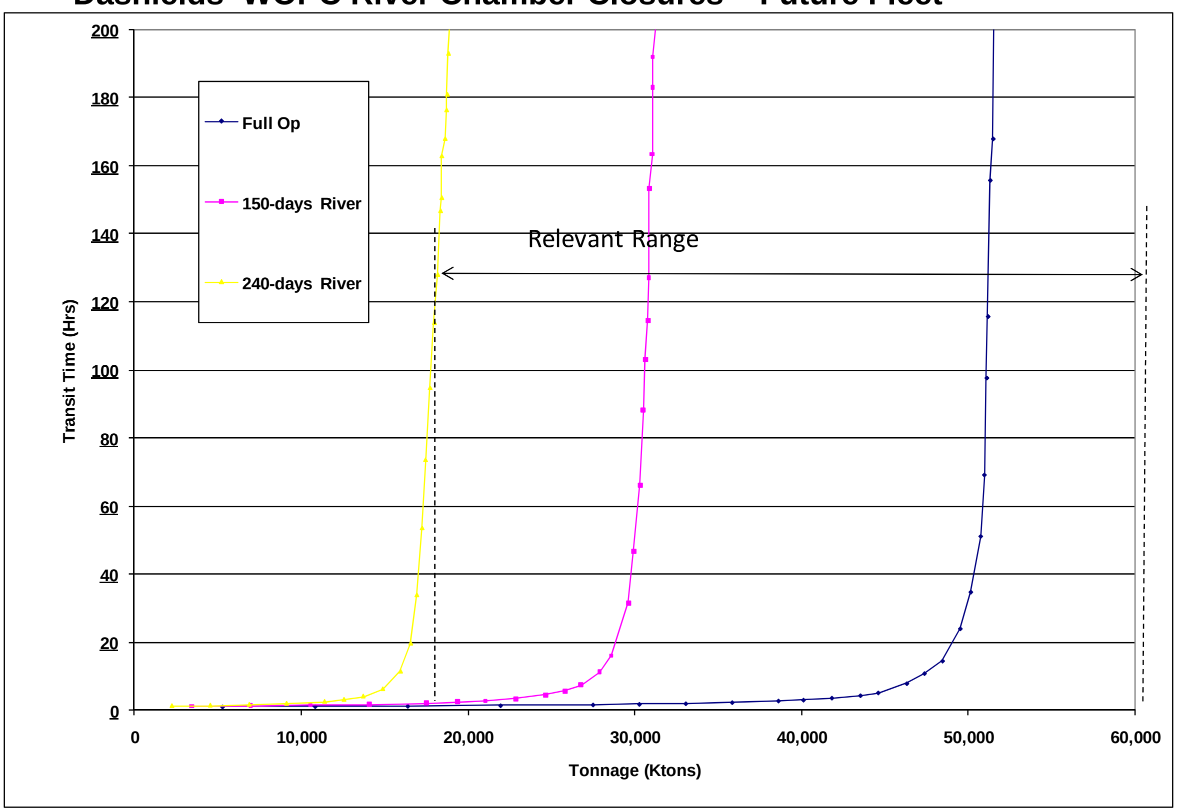


FIGURE A2- 142

Dashields WOPC River Chamber Closures – Future Fleet



2.9.1.3 Montgomery Project Capacities and Processing Times

Table A2-168 shows the Montgomery's With Out Project Condition capacities for the full operation, main and auxiliary chambers, and river closures for the existing versus the future fleet determined during this study. **Table A2-169** shows the capacity for the full op, and main chamber closure durations less than 90 days are approximately 5-6% higher for the future fleet while the capacity for the main chamber closure durations greater than 180 days are only 1% difference for the future fleet. The capacity for the auxiliary chambers closures are 5-6% higher for the future fleet. The half speed capacity is 1-3% higher for the main chamber closures using the future fleet.

The processing times for the main chamber closures less than 90 days are 2-3% lower for the future fleet. The capacity for the longer main chamber closure durations greater than 180 days are 2-4% higher for the future fleet. The capacity for the auxiliary chamber closures are all less than 3% lower using the future fleet.

Figure A2-143 through **A2-150** shows the With Out Project Condition capacity curves for the existing versus the future fleet for the main, auxiliary, and total river closures.

TABLE A2- 168
Montgomery WOPC Existing Fleet vs Future Fleet

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	**Existing Fleet**	**Future Fleet**	**Existing Fleet**	**Future Fleet**
No closures (normal operation)	47.6	50.3	67.7	66.1
5-days Main Chamber Closed	47.0	49.7	68.5	66.8
10-days Main Chamber Closed	46.4	48.9	69.4	67.5
12-days Main Chamber Closed	46.1	48.7	69.5	67.9
15-days Main Chamber Closed	45.8	48.3	69.9	68.1
18-days Main Chamber Closed	45.3	47.9	70.5	68.6
30-days Main Chamber Closed	44.0	46.6	72.3	70.5
45-days Main Chamber Closed	42.6	44.8	74.6	73.0
60-days Main Chamber Closed	41.1	43.2	76.8	75.4
90-days Main Chamber Closed	38.0	40.0	82.5	81.1
180-days Main Chamber Closed	13.7	13.5	143.1	148.4
210-days Main Chamber Closed	13.1	13.1	158.7	164.8
240-days Main Chamber Closed	12.7	12.6	178.7	182.9
365-days Main Chamber Closed	11.7	11.5	243.8	254.3
3-days Auxiliary Chamber Closed	47.6	50.3	67.7	66.1
5-days Auxiliary Chamber Closed	47.6	50.3	67.7	66.0
10-days Auxiliary Chamber Closed	47.5	50.2	67.8	65.9
15-days Auxiliary Chamber Closed	47.5	50.1	67.8	65.8
30-days Auxiliary Chamber Closed	47.4	49.9	67.9	66.1
45-days Auxiliary Chamber Closed	47.1	49.7	68.2	66.6
60-days Auxiliary Chamber Closed	46.9	49.5	68.3	66.8
90-days Auxiliary Chamber Closed	46.4	49.0	68.8	67.1
180-days Auxiliary Chamber Closed	44.3	46.6	70.3	68.5
210-days Auxiliary Chamber Closed	43.7	46.1	70.6	68.9
365-days Auxiliary Chamber Closed	41.2	43.2	72.8	71.1
15-days Main Chamber ½ speed	46.8	48.2	68.5	68.3
19-days Main Chamber ½ speed	46.8	47.5	68.6	68.6
5-days River Closure	46.7	*49.7	67.7	*
10-days River Closure	46.1	*49.0	67.7	*
15-days River Closure	45.3	*48.3	67.7	*
18-days River Closure	45.0	*47.9	67.7	*
30-days River Closure	43.4	*46.2	67.6	*
45-days River Closure	41.6	*44.1	67.9	*
60-days River Closure	39.6	*42.1	67.9	*
90-days River Closure	35.6	*37.9	67.8	*
180-days River Closure	23.5	*25.5	67.2	*
210-days River Closure	20.0	*21.4	67.0	*
240-days River Closure	16.3	*17.2	67.3	*
365-days River Closure	0.0	0.0	0.0	*
** Calculated Capacities*				

TABLE A2- 169
Montgomery WOPC Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
No closures (normal operation)	5.8%	-2.4%
5-days Main Chamber Closed	5.7%	-2.5%
10-days Main Chamber Closed	5.5%	-2.7%
12-days Main Chamber Closed	5.6%	-2.3%
15-days Main Chamber Closed	5.6%	-2.6%
18-days Main Chamber Closed	5.6%	-2.7%
30-days Main Chamber Closed	5.8%	-2.5%
45-days Main Chamber Closed	5.2%	-2.1%
60-days Main Chamber Closed	5.1%	-1.9%
90-days Main Chamber Closed	5.2%	-1.7%
180-days Main Chamber Closed	-1.4%	3.7%
210-days Main Chamber Closed	0.2%	3.8%
240-days Main Chamber Closed	-0.6%	2.3%
365-days Main Chamber Closed	-1.9%	4.3%
3-days Auxiliary Chamber Closed	5.7%	-2.4%
5-days Auxiliary Chamber Closed	5.7%	-2.5%
10-days Auxiliary Chamber Closed	5.6%	-2.7%
15-days Auxiliary Chamber Closed	5.6%	-2.9%
30-days Auxiliary Chamber Closed	5.4%	-2.7%
45-days Auxiliary Chamber Closed	5.6%	-2.4%
60-days Auxiliary Chamber Closed	5.6%	-2.2%
90-days Auxiliary Chamber Closed	5.6%	-2.5%
180-days Auxiliary Chamber Closed	5.2%	-2.6%
210-days Auxiliary Chamber Closed	5.5%	-2.4%
365-days Auxiliary Chamber Closed	4.9%	-2.3%
15-days Main Chamber ½ speed	2.9%	-0.3%
19-days Main Chamber ½ speed	1.4%	0.0%

TABLE A2- 170
Montgomery WOPC Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
5-days River Closure	6.3%	*
10-days River Closure	6.3%	*
15-days River Closure	6.5%	*
18-days River Closure	6.4%	*
30-days River Closure	6.4%	*
45-days River Closure	5.9%	*
60-days River Closure	6.4%	*
90-days River Closure	6.3%	*
180-days River Closure	8.3%	*
210-days River Closure	7.3%	*
240-days River Closure	5.5%	*
365-days River Closure	0.0%	0.0%
** Calculated Capacities*		

FIGURE A2- 143
Montgomery WOPC Main Chamber Closures – Existing Fleet

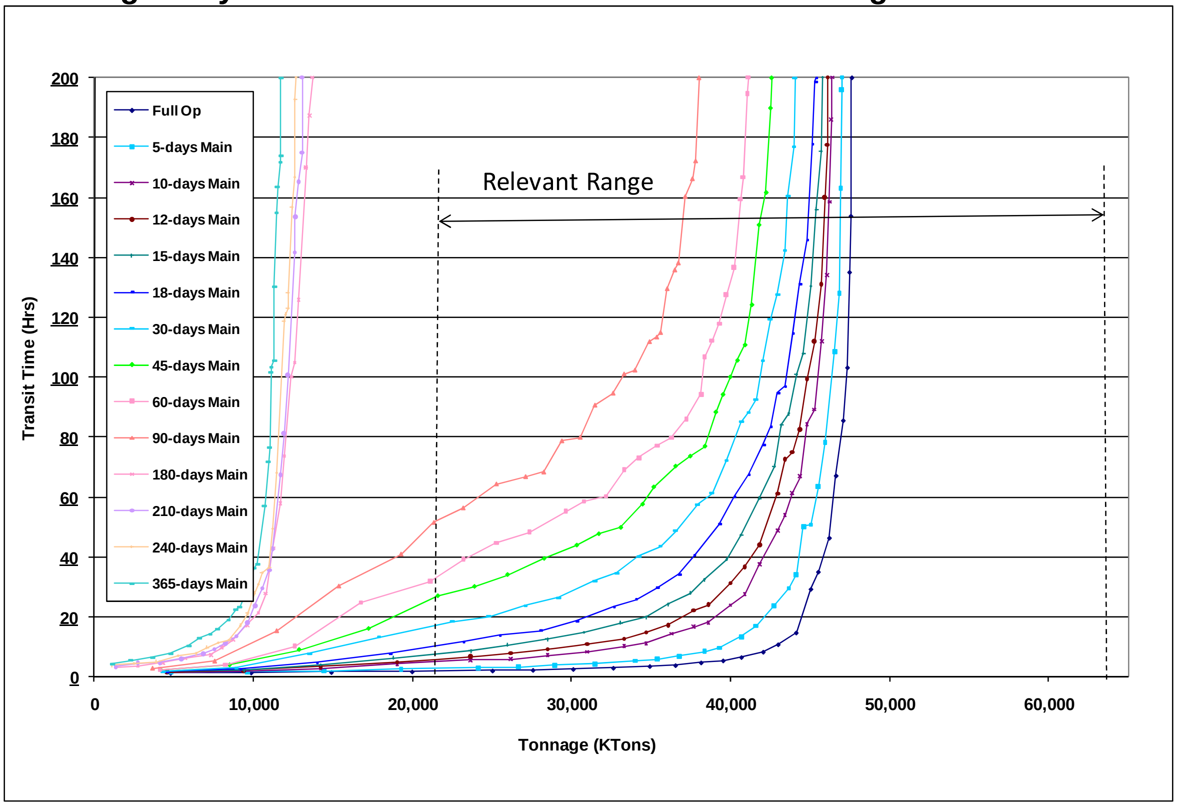


FIGURE A2- 144
Montgomery WOPC Main Chamber Closures – Future Fleet

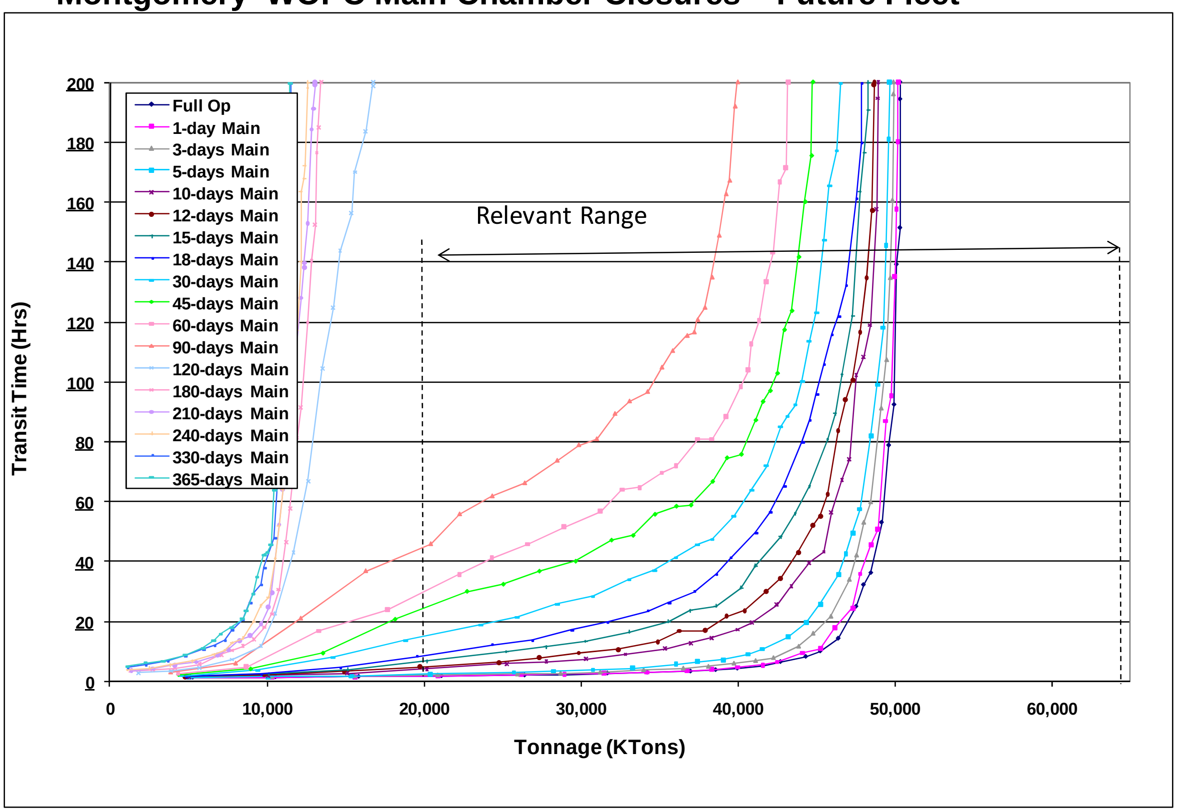


FIGURE A2- 145
Montgomery WOPC Auxiliary Chamber Closures – Existing Fleet

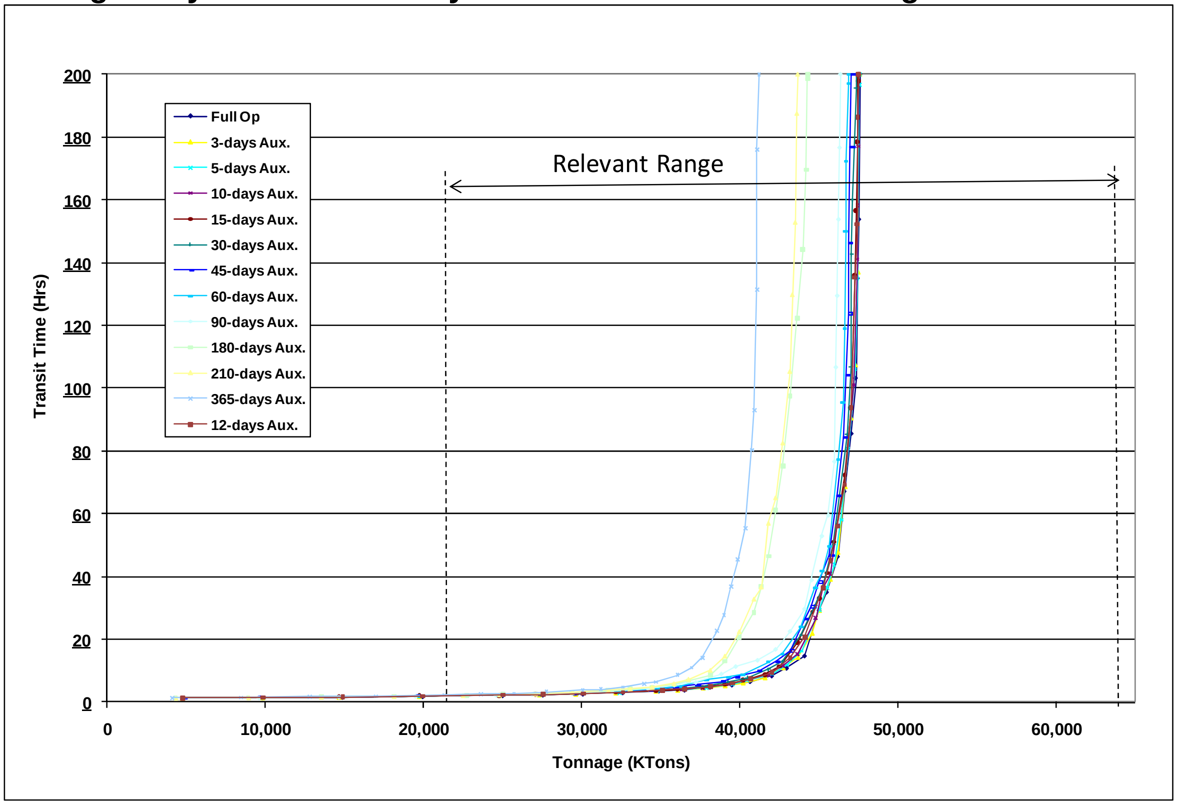


FIGURE A2- 146
Montgomery WOPC Auxiliary Chamber Closures – Future Fleet

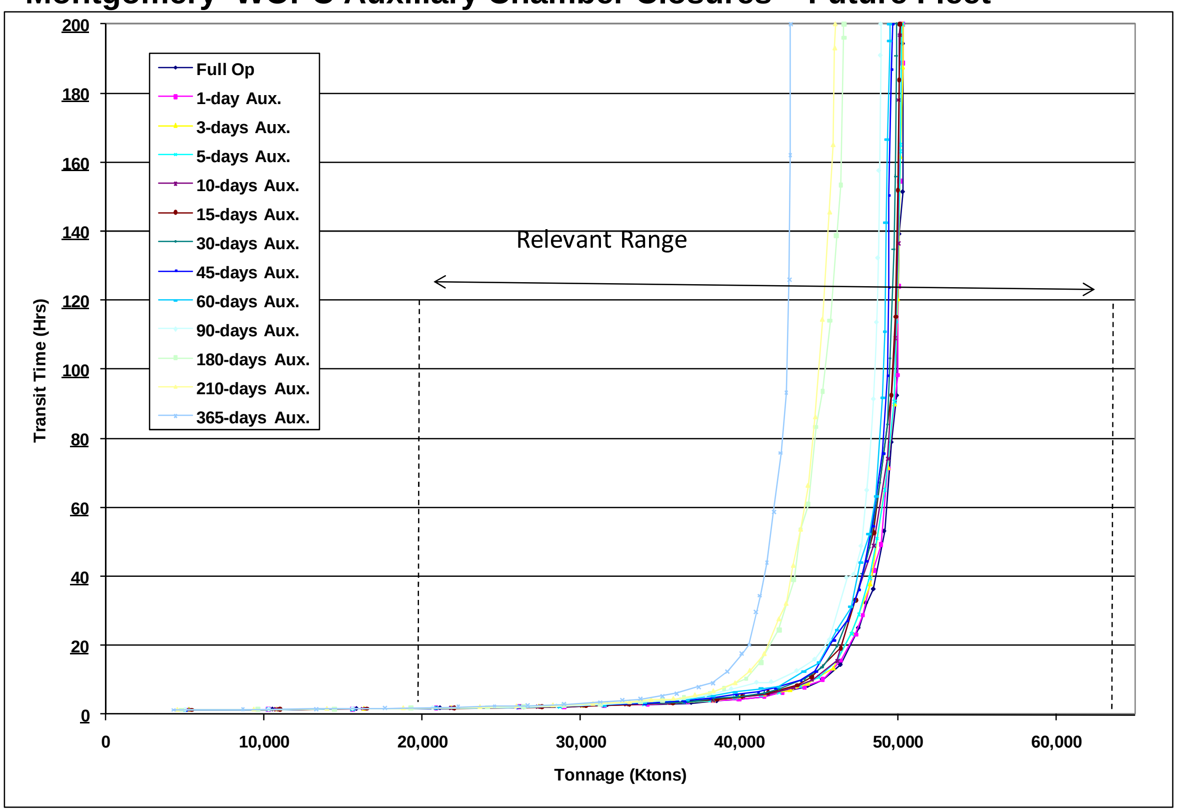


FIGURE A2- 147
Montgomery WOPC Main Chamber Half Speed Closures – Existing Fleet

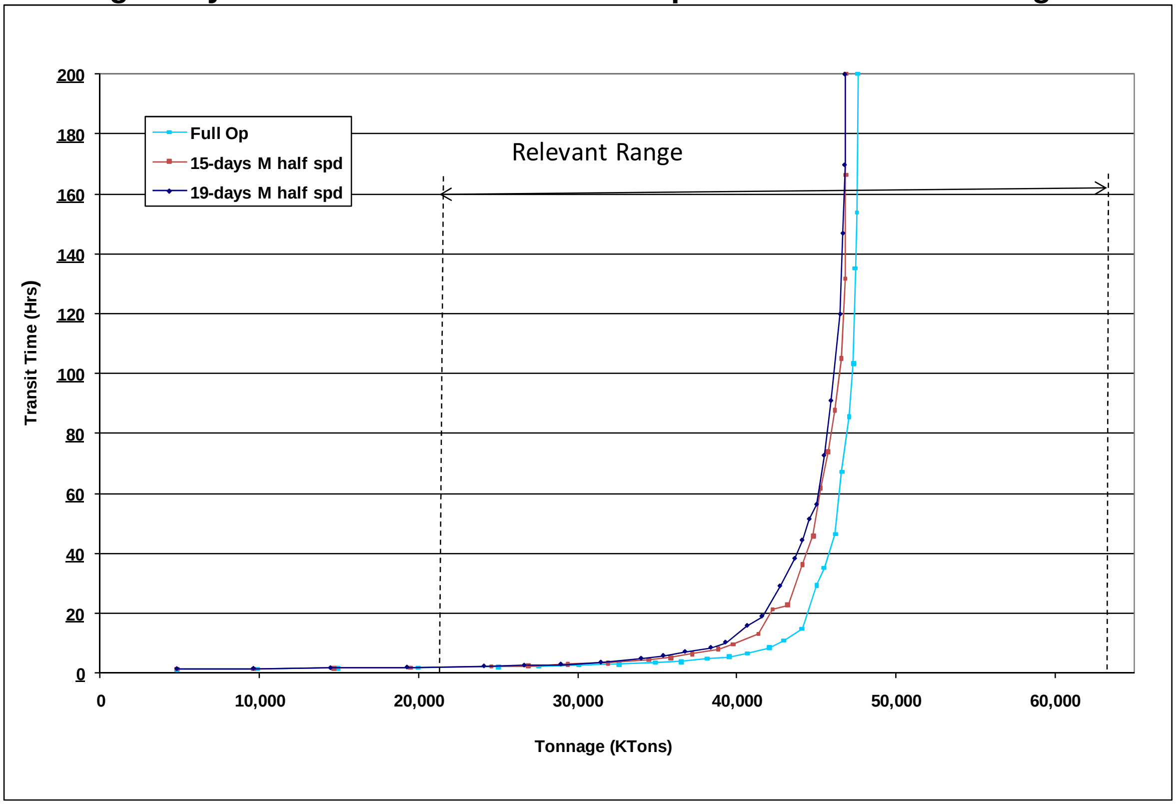


FIGURE A2- 148
Montgomery WOPC Main Chamber Half Speed Closures – Future Fleet

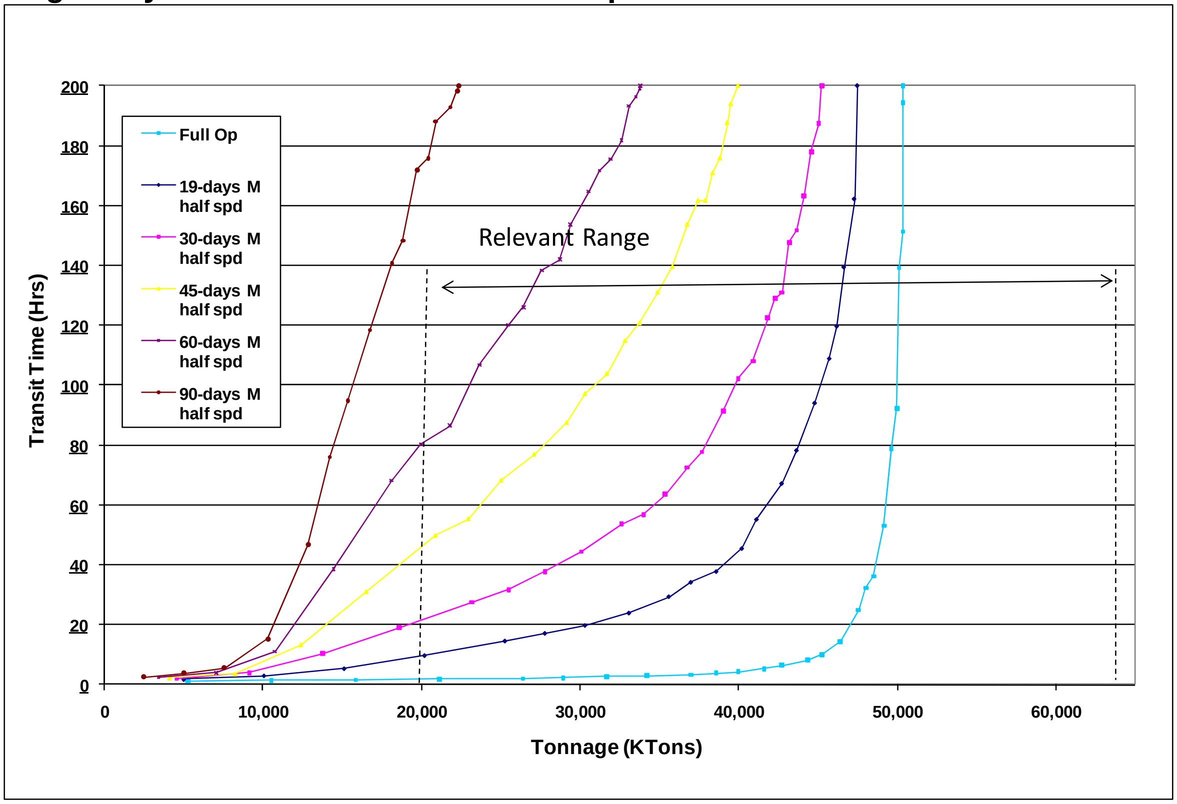


FIGURE A2- 149

Montgomery WOPC River Chamber Closures – Existing Fleet

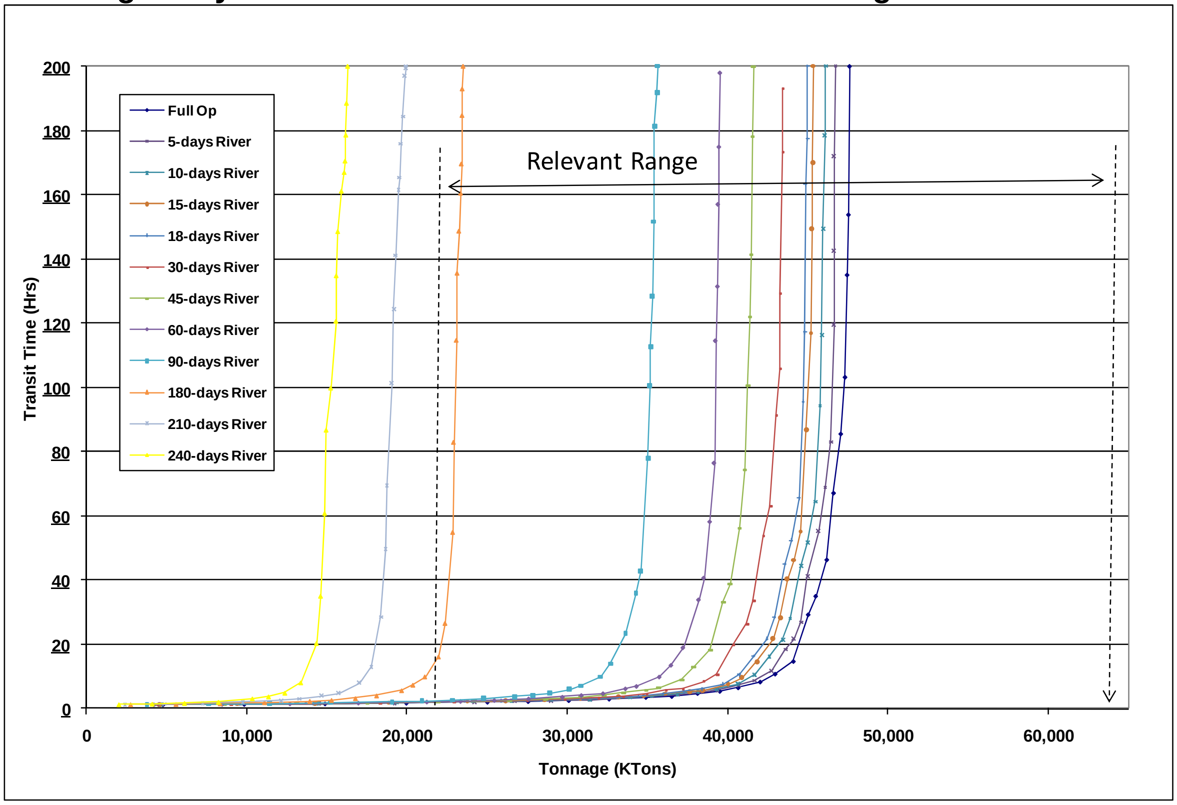
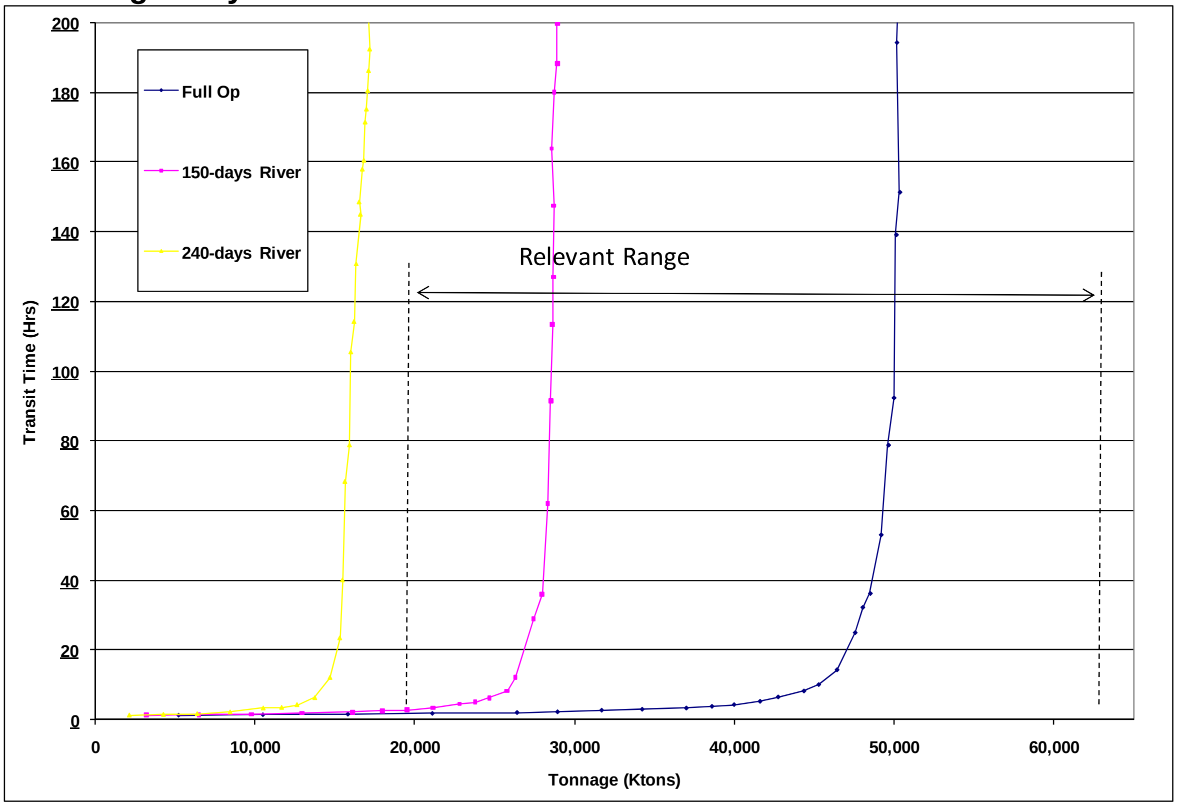


FIGURE A2- 150

Montgomery WOPC River Chamber Closures – Future Fleet



2.9.2 WPC

2.9.2.1 Emsworth Project Capacities and Processing Times

Table A2-171 and **Table A2-173** shows the Emsworth's With Project Condition capacities for the full operation, main and auxiliary chambers, and river closures for the existing versus the future fleet determined during this study. **Table A2-172** shows The capacity for the future fleet is approximately 3% higher than the existing fleet for the full op, main and auxiliary chamber closures.

The processing times for both the main and auxiliary chamber closures for all closure durations are 1% different for the existing vs future fleet.

Figure A2-151 through **A2-160** shows the With Project Condition capacity curves for the existing versus the future fleet for the main, auxiliary, and total river closures.

TABLE A2- 171
Emsworth New 600' & Old 600' Existing Fleet vs Future Fleet

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	Existing Fleet	Future Fleet	Existing Fleet	Future Fleet
No closures (normal operation)	75.3	77.8	71.5	72.2
1-day Main Chamber Closed	75.2	*	71.5	*
3-days Main Chamber Closed	74.9	*	71.5	*
5-days Main Chamber Closed	74.6	*	71.6	*
10-days Main Chamber Closed	73.9	76.0	71.5	*
12-days Main Chamber Closed	73.6	*	71.6	72.3
15-days Main Chamber Closed	73.1	75.6	71.5	72.3
18-days Main Chamber Closed	72.7	*	71.6	*
30-days Main Chamber Closed	71.3	*	71.7	*
45-days Main Chamber Closed	70.1	*	71.7	*
60-days Main Chamber Closed	68.4	*	71.7	*
90-days Main Chamber Closed	65.8	*	71.9	*
180-days Main Chamber Closed	43.7	*	72.0	*
210-days Main Chamber Closed	42.2	*	72.5	*
240-days Main Chamber Closed	41.1	*	72.8	*
365-days Main Chamber Closed	38.5	*	74.0	*
1-day Auxiliary Chamber Closed	75.2	77.6	71.5	72.2
3-days Auxiliary Chamber Closed	74.8	77.3	71.5	72.2
5-days Auxiliary Chamber Closed	74.5	77.1	71.5	72.3
10-days Auxiliary Chamber Closed	74.0	76.4	71.6	72.2
12-days Auxiliary Chamber Closed	73.7	76.1	71.6	72.2
15-days Auxiliary Chamber Closed	73.3	75.6	71.4	72.2
18-days Auxiliary Chamber Closed	*	75.2	*	72.3
30-days Auxiliary Chamber Closed	71.6	73.9	71.5	72.4
45-days Auxiliary Chamber Closed	70.2	72.6	71.6	72.4
60-days Auxiliary Chamber Closed	68.9	71.0	71.7	72.3
90-days Auxiliary Chamber Closed	66.7	68.6	71.8	72.4
120-days Auxiliary Chamber Closed	*	55.2	*	72.3
150-days Auxiliary Chamber Closed	*	52.0	*	72.3
180-days Auxiliary Chamber Closed	*	49.7	*	72.4
210-days Auxiliary Chamber Closed	46.5	48.2	71.8	72.5
240-days Auxiliary Chamber Closed	*	46.9	*	72.6
365-days Auxiliary Chamber Closed	41.8	43.1	72.1	72.5
19-days Main Chamber ½ speed	*	74.9	*	72.3
30-days Main Chamber ½ speed	73.7	*	72.5	*
19-days Aux Chamber ½ speed	74.6	*	72.0	*
30-days Aux Chamber ½ speed	*	73.2	*	72.3

** No WAM Capacity Curves*

TABLE A2- 172
Emsworth New 600’ & Old 600’ Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
No closures (normal operation)	3.3%	1.0%
1-day Main Chamber Closed	*	*
3-days Main Chamber Closed	*	*
5-days Main Chamber Closed	*	*
10-days Main Chamber Closed	2.9%	
12-days Main Chamber Closed	*	1.0%
15-days Main Chamber Closed	3.4%	1.1%
18-days Main Chamber Closed	*	*
30-days Main Chamber Closed	*	*
45-days Main Chamber Closed	*	*
60-days Main Chamber Closed	*	*
90-days Main Chamber Closed	*	*
180-days Main Chamber Closed	*	*
210-days Main Chamber Closed	*	*
240-days Main Chamber Closed	*	*
365-days Main Chamber Closed	*	*
1-day Auxiliary Chamber Closed	3.2%	1.0%
3-days Auxiliary Chamber Closed	3.3%	1.0%
5-days Auxiliary Chamber Closed	3.4%	1.1%
10-days Auxiliary Chamber Closed	3.2%	0.9%
12-days Auxiliary Chamber Closed	3.2%	0.9%
15-days Auxiliary Chamber Closed	3.2%	1.1%
18-days Auxiliary Chamber Closed	*	*
30-days Auxiliary Chamber Closed	3.3%	1.2%
45-days Auxiliary Chamber Closed	3.4%	1.1%
60-days Auxiliary Chamber Closed	3.1%	0.9%
90-days Auxiliary Chamber Closed	2.9%	0.9%
120-days Auxiliary Chamber Closed	*	*
150-days Auxiliary Chamber Closed	*	*
180-days Auxiliary Chamber Closed	*	*
210-days Auxiliary Chamber Closed	3.7%	1.0%
240-days Auxiliary Chamber Closed	*	*
365-days Auxiliary Chamber Closed	3.1%	0.5%
19-days Main Chamber ½ speed	*	*
30-days Main Chamber ½ speed	*	*
19-days Aux Chamber ½ speed	*	*
30-days Aux Chamber ½ speed	*	*

** No WAM capacity curves for both existing & futute fleets*

TABLE A2- 173
Emsworth New 600' & Old 600' Existing Fleet vs Future Fleet – River

Project/Scenario	Capacity (Millions of Tons) Existing Fleet	Capacity (Millions of Tons) Future Fleet	Avg. Processing Time (min/tow) Existing Fleet	Avg. Processing Time (min/tow) Future Fleet
5-days River Closure	73.8	*	71.5	*
10-days River Closure	72.7	*	71.5	*
15-days River Closure	71.6	*	71.6	*
18-days River Closure	71.0	*	71.6	*
30-days River Closure	68.5	*	71.6	*
42-days River Closure	*	39.2		71.7
45-days River Closure	65.6	*	71.7	*
60-days River Closure	62.3	*	71.6	*
90-days River Closure	55.9		71.6	*
150-days River Closure	*	25.2	*	71.4
180-days River Closure	37.8	*	71.3	*
210-days River Closure	32.1	*	71.6	*
240-days River Closure	26.2	14.2	71.5	71.3
365-days River Closure	0.0	*	0.0	*

** No WAM Capacity Curves*

FIGURE A2- 151

Emsworth New 600' & Old 600' Main Chamber Closures – Existing Fleet

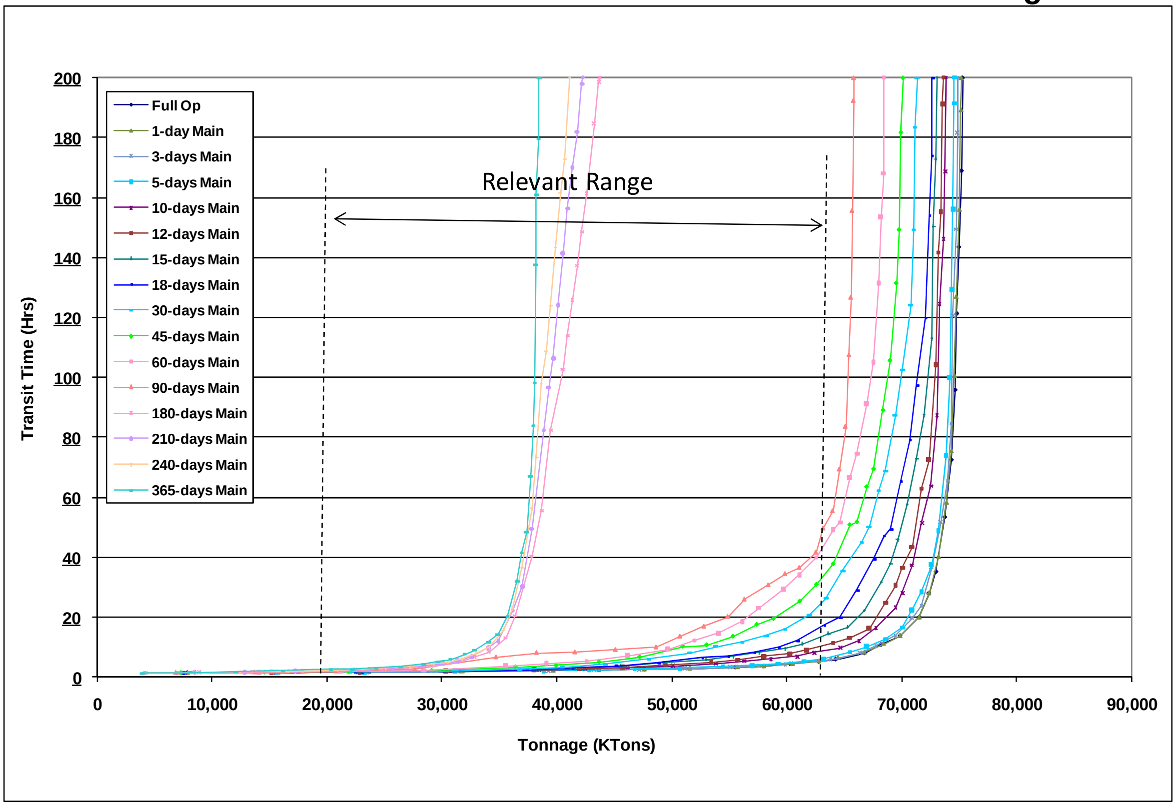


FIGURE A2- 152

Emsworth New 600' & Old 600' Main Chamber Closures – Future Fleet

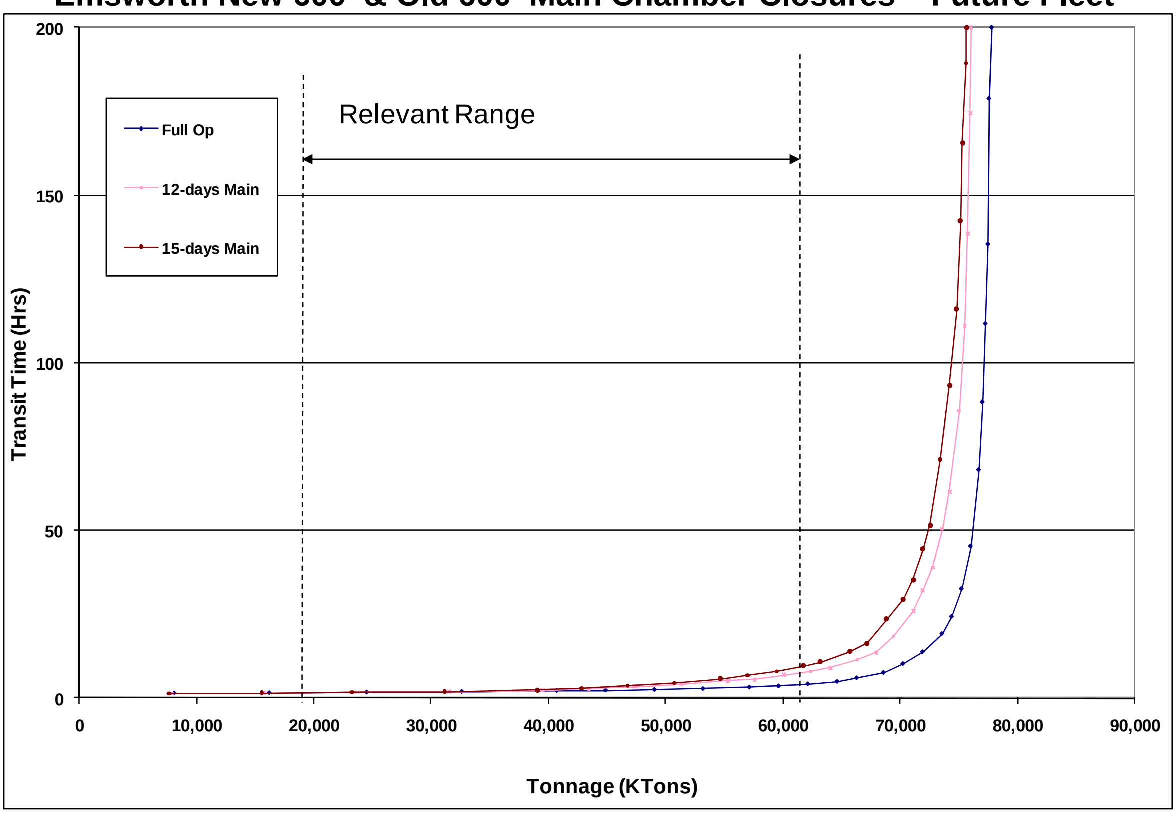


FIGURE A2- 153

Emsworth New 600' & Old 600' Auxiliary Chamber Closures – Existing Fleet

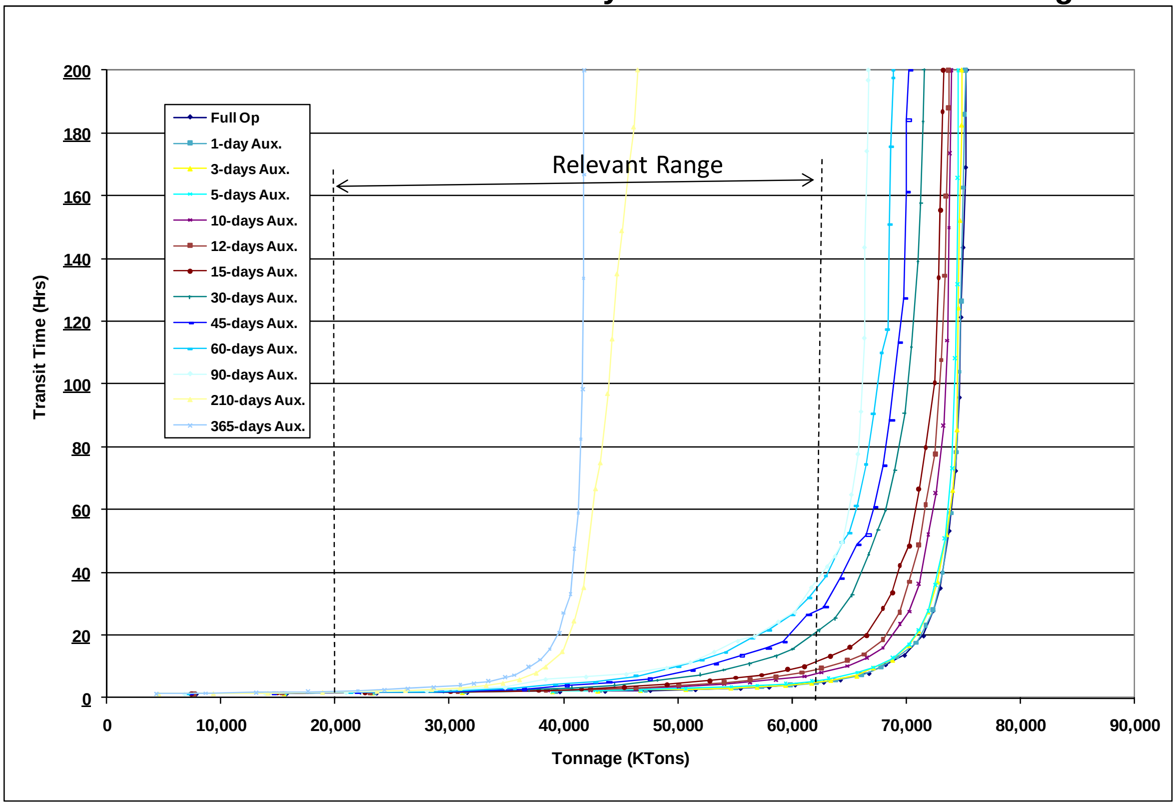


FIGURE A2- 154

Emsworth New 600' & Old 600' Auxiliary Chamber Closures – Future Fleet

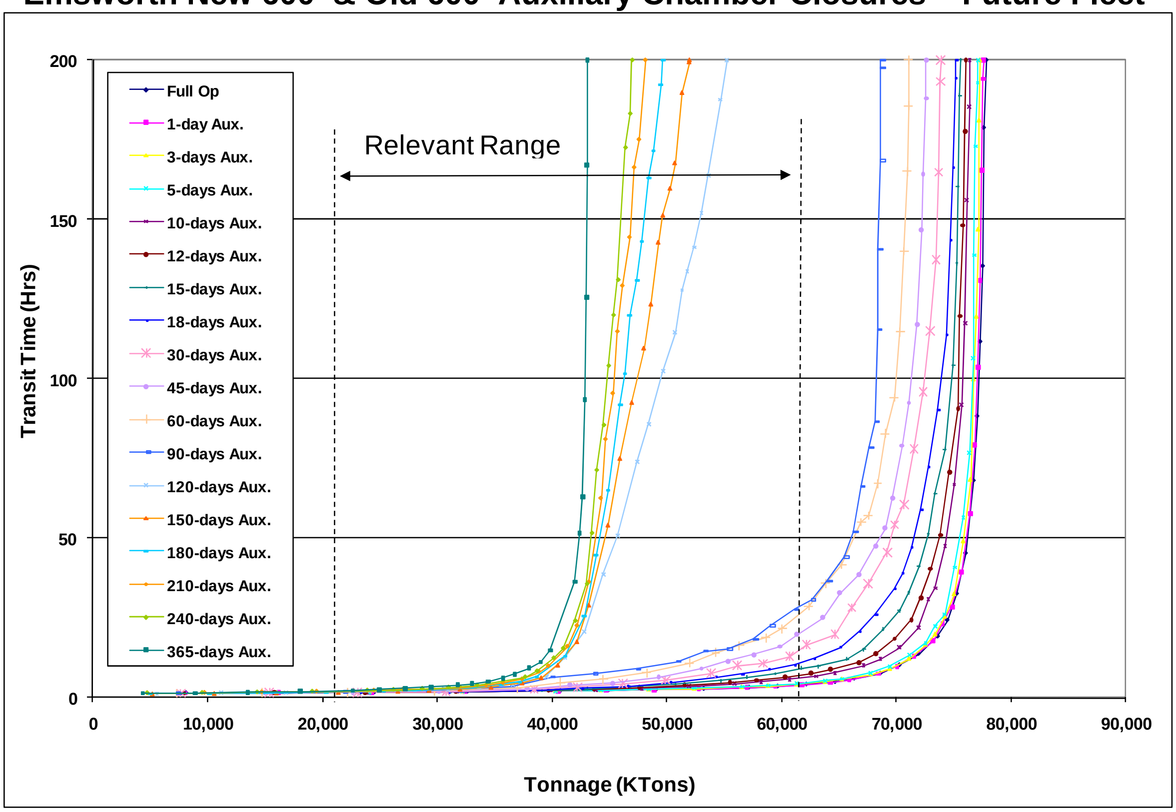


FIGURE A2- 155
Emsworth New 600' & Old 600' Main Chamber Half Speeds – Existing Fleet

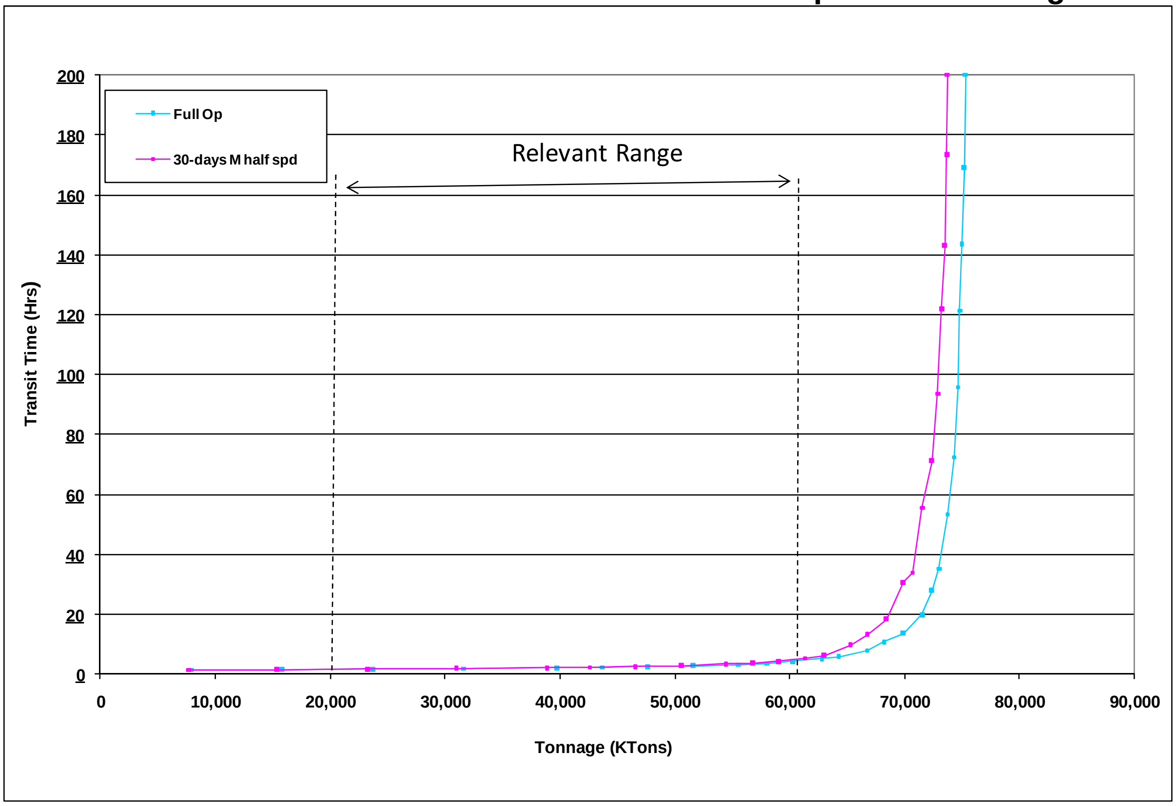


FIGURE A2- 156
Emsworth New 600' & Old 600' Main Chamber Half Speeds – Future Fleet

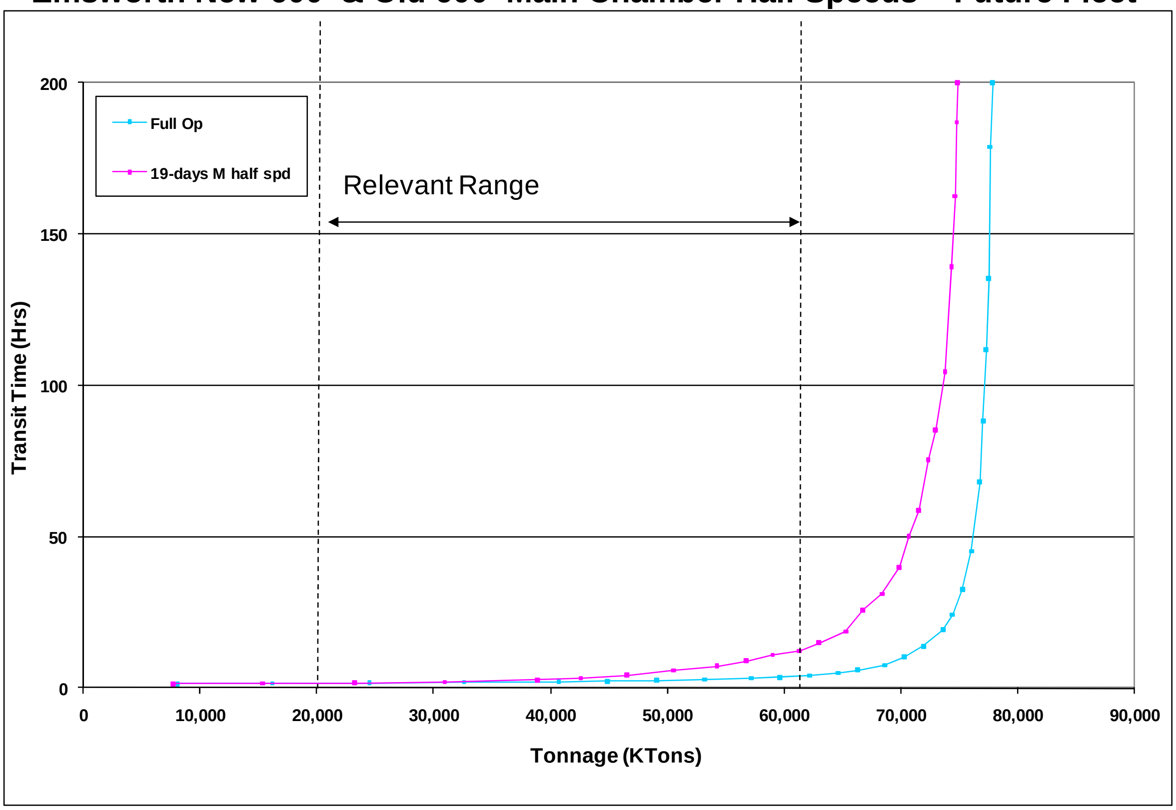


FIGURE A2- 157
Emsworth New 600' & Old 600' Auxiliary Half Speeds – Existing Fleet

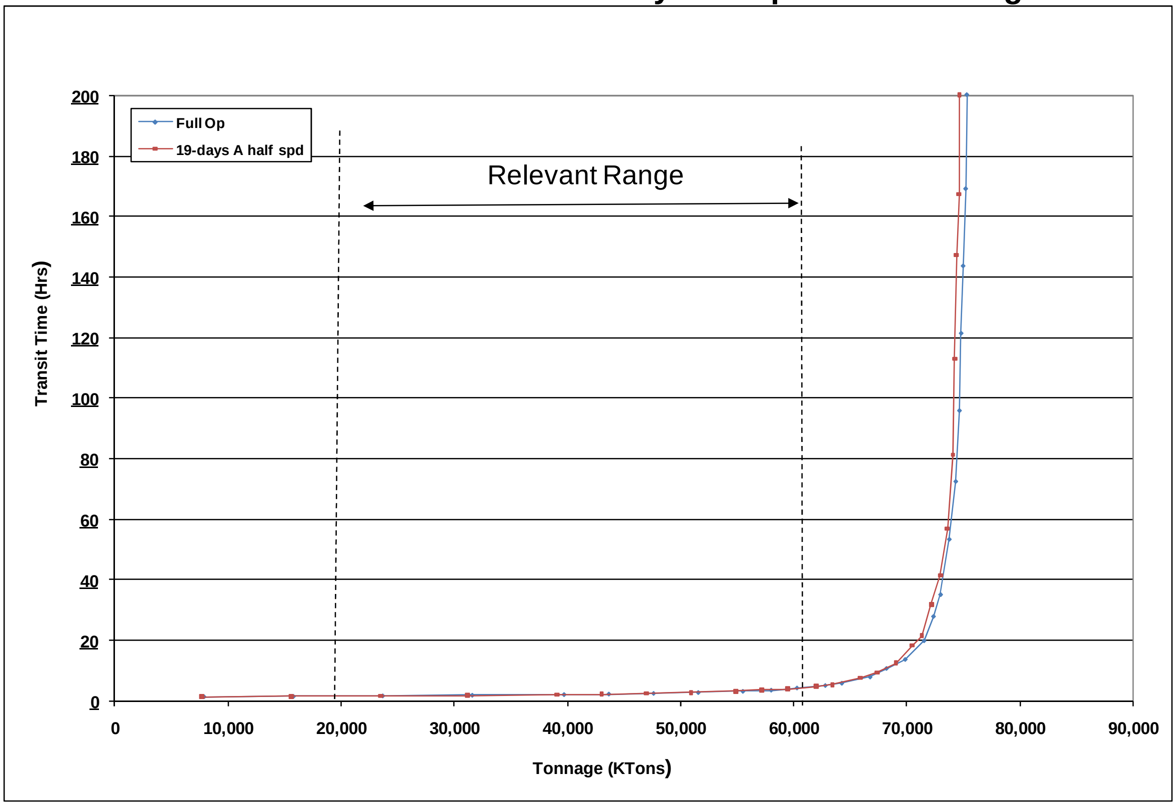


FIGURE A2- 158
Emsworth New 600' & Old 600' Auxiliary Half Speeds – Future Fleet

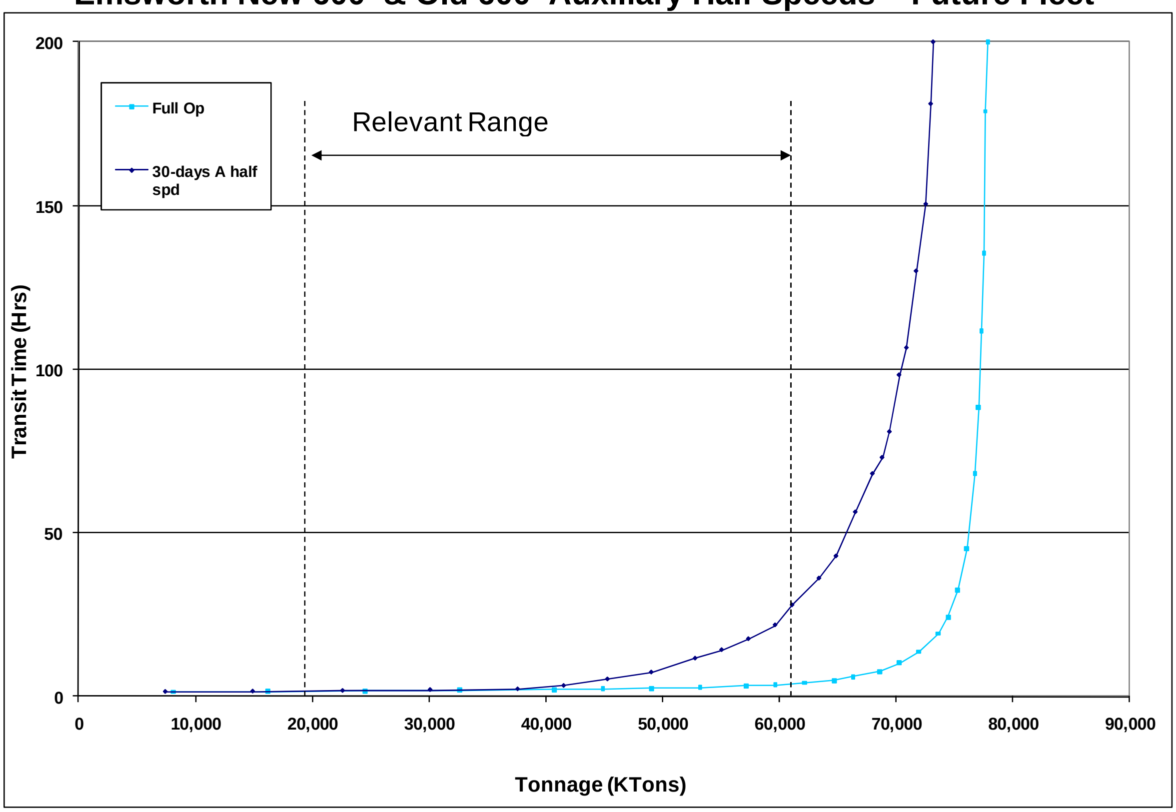


FIGURE A2- 159
Emsworth New 600' & Old 600' River Chamber – Existing Fleet

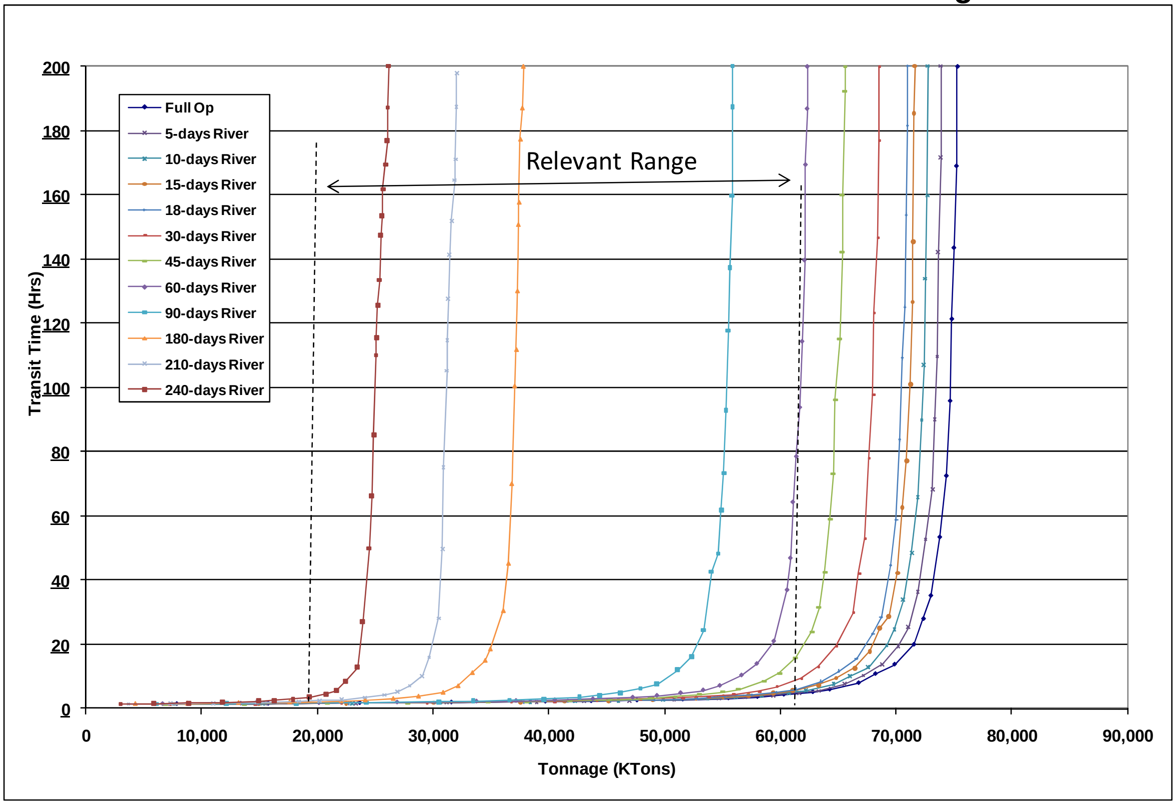
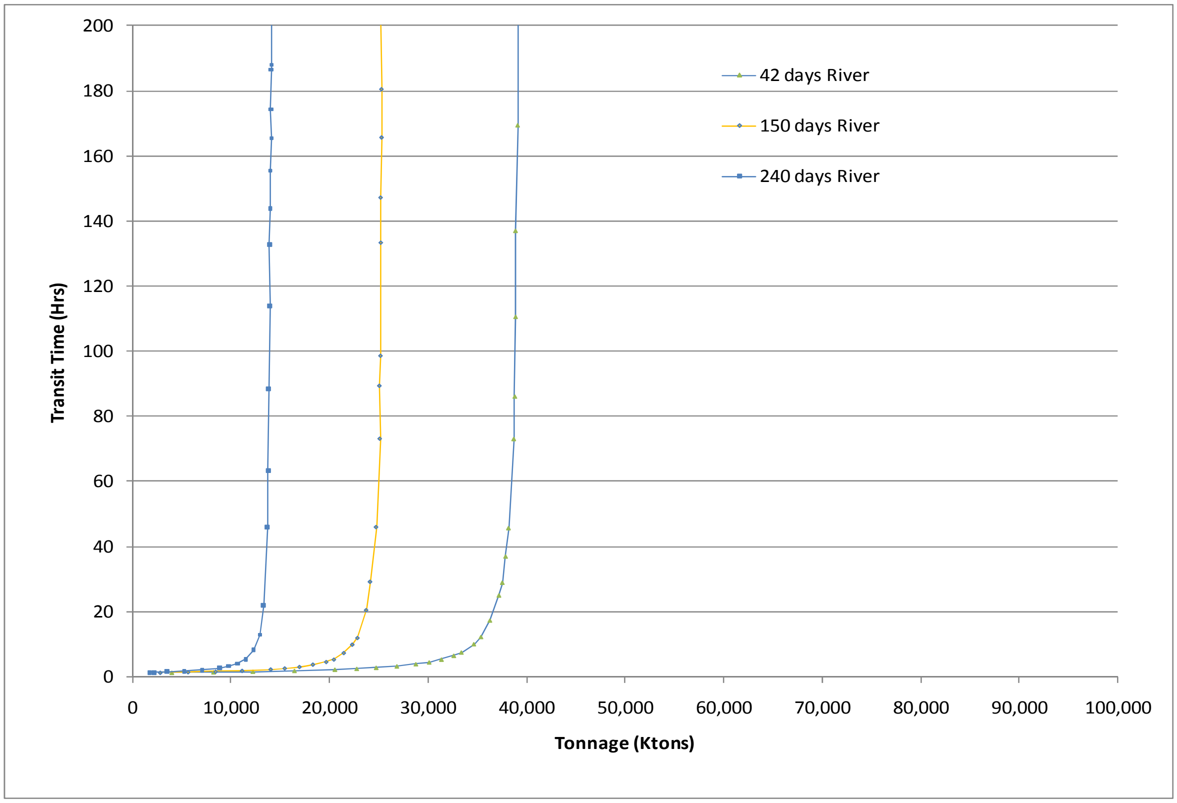


FIGURE A2- 160
Emsworth New 600' & Old 600' River Chamber – Future Fleet



2.9.2.2 Dashields Project Capacities and Processing Times

Table A2-174 and **Table A2-176** shows the Dashield's With Project Condition capacities for the full operation, main and auxiliary chambers, and river closures for the existing versus the future fleet determined during this study. **Table A2-175** shows the capacity for the full op, main chamber, and auxiliary chamber closures using the future fleet is approximately 3.5% higher than the existing fleet except for the 365 day main chamber which is 5% higher using the future fleet. The processing times are less than 0.5% lower for the future fleet.

The processing times for the existing versus future fleet are within 0.5% different for both the main and auxiliary chambers for all closure durations.

Figure A2-161 through **A2-170** shows the With Project Condition capacity curves for the existing versus the future fleet for the main, auxiliary, and total river closures.

TABLE A2- 174
Dashields New 600' & Old 600' Existing Fleet vs Future Fleet

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	Existing Fleet	Future Fleet	Existing Fleet	Future Fleet
No closures (normal operation)	87.5	90.7	60.8	60.6
1-days Main Chamber Closed	87.3	*	60.8	*
3-days Main Chamber Closed	87.0	*	60.9	*
5-days Main Chamber Closed	86.6	*	60.7	*
10-days Main Chamber Closed	85.8	*	60.9	*
12-days Main Chamber Closed	85.5	88.6	60.9	60.7
15-days Main Chamber Closed	84.8	88.0	61.0	60.7
18-days Main Chamber Closed	84.4	*	61.0	*
30-days Main Chamber Closed	82.9	*	60.9	*
45-days Main Chamber Closed	81.5	*	61.0	*
60-days Main Chamber Closed	79.8	*	61.0	*
90-days Main Chamber Closed	76.7	*	61.0	*
120-days Main Chamber Closed	58.6	*	62.1	*
150-days Main Chamber Closed	*	*	*	*
180-days Main Chamber Closed	51.4	*	62.3	*
210-days Main Chamber Closed	49.6	*	62.3	*
240-days Main Chamber Closed	48.4	*	62.3	*
365-days Main Chamber Closed	45.4	*	61.9	*
1-day Auxiliary Chamber Closed	87.5	90.4	60.8	60.6
3-days Auxiliary Chamber Closed	87.0	90.2	60.8	60.6
5-days Auxiliary Chamber Closed	86.7	89.8	60.9	60.6
10-days Auxiliary Chamber Closed	85.9	88.9	60.9	60.7
12-days Auxiliary Chamber Closed	85.5	88.6	60.9	60.7
15-days Auxiliary Chamber Closed	84.9	88.1	60.9	60.7
30-days Auxiliary Chamber Closed	83.2	86.1	61.0	60.7
45-days Auxiliary Chamber Closed	81.6	84.4	61.0	60.8
60-days Auxiliary Chamber Closed	79.9	82.7	61.1	60.9
90-days Auxiliary Chamber Closed	77.3	79.8	61.0	60.8
120-days Auxiliary Chamber Closed	*	62.7	*	61.8
150-days Auxiliary Chamber Closed	*	58.4	*	61.9
180-days Auxiliary Chamber Closed	53.8	55.8	62.1	61.9
210-days Auxiliary Chamber Closed	52.1	53.9	61.9	61.8
240-days Auxiliary Chamber Closed	*	52.8	*	61.5
365-days Auxiliary Chamber Closed	47.4	49.6	61.1	61.5
19-days Main Chamber ½ speed	86.5	87.1	61.3	61.5
19-days Aux Chamber ½ speed	86.8	87.3	61.0	60.7
** No WAM Capacity Curves*				

TABLE A2- 175
Dashields New 600’ & Old 600’ Existing Fleet vs Future Fleet

Project/Scenario	% Difference Capacity	% Difference Processing Time
No closures (normal operation)	3.6%	-0.3%
1-days Main Chamber Closed	*	*
3-days Main Chamber Closed	*	*
5-days Main Chamber Closed	*	*
10-days Main Chamber Closed	*	*
12-days Main Chamber Closed	3.6%	-0.3%
15-days Main Chamber Closed	3.8%	-0.4%
18-days Main Chamber Closed	*	
30-days Main Chamber Closed	*	*
45-days Main Chamber Closed	*	*
60-days Main Chamber Closed	*	*
90-days Main Chamber Closed	*	*
120-days Main Chamber Closed	*	*
150-days Main Chamber Closed	*	*
180-days Main Chamber Closed	*	*
210-days Main Chamber Closed	*	*
240-days Main Chamber Closed	*	*
365-days Main Chamber Closed	*	*
1-day Auxiliary Chamber Closed	3.3%	-0.3%
3-days Auxiliary Chamber Closed	3.6%	-0.3%
5-days Auxiliary Chamber Closed	3.5%	-0.5%
10-days Auxiliary Chamber Closed	3.5%	-0.3%
12-days Auxiliary Chamber Closed	3.7%	-0.4%
15-days Auxiliary Chamber Closed	3.8%	-0.4%
30-days Auxiliary Chamber Closed	3.6%	-0.4%
45-days Auxiliary Chamber Closed	3.5%	-0.4%
60-days Auxiliary Chamber Closed	3.4%	-0.3%
90-days Auxiliary Chamber Closed	3.3%	-0.4%
120-days Auxiliary Chamber Closed	*	*
150-days Auxiliary Chamber Closed	*	*
180-days Auxiliary Chamber Closed	3.7%	-0.2%
210-days Auxiliary Chamber Closed	3.4%	-0.2%
240-days Auxiliary Chamber Closed	*	*
365-days Auxiliary Chamber Closed	4.7%	0.7%
19-days Main Chamber ½ speed	0.6%	0.4%
19-days Aux Chamber ½ speed	0.5%	-0.6%

** No WAM capacity curves for both existing & futute fleets*

TABLE A2- 176
Dashields New 600’ & Old 600’ Existing Fleet vs Future Fleet – River

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	Existing Fleet	Future Fleet	Existing Fleet	Future Fleet
5-days River Closure	85.9	*	60.8	*
10-days River Closure	84.7	*	60.8	*
15-days River Closure	83.4	*	60.8	*
18-days River Closure	82.7	*	60.9	*
30-days River Closure	79.7	*	60.9	*
45-days River Closure	76.0	*	60.9	*
60-days River Closure	72.5	*	60.9	*
90-days River Closure	64.9	*	61.0	*
150-days River Closure	*	28.8	*	63.3
180-days River Closure	43.9	*	60.7	*
210-days River Closure	37.4	*	60.7	*
240-days River Closure	30.6	16.2	60.5	63.4
365-days River Closure	0.0	*	0.0	*

** No WAM Capacity Curves*

FIGURE A2- 161
Dashields New 600’ & Old 600’ Main Chamber Closures – Existing Fleet

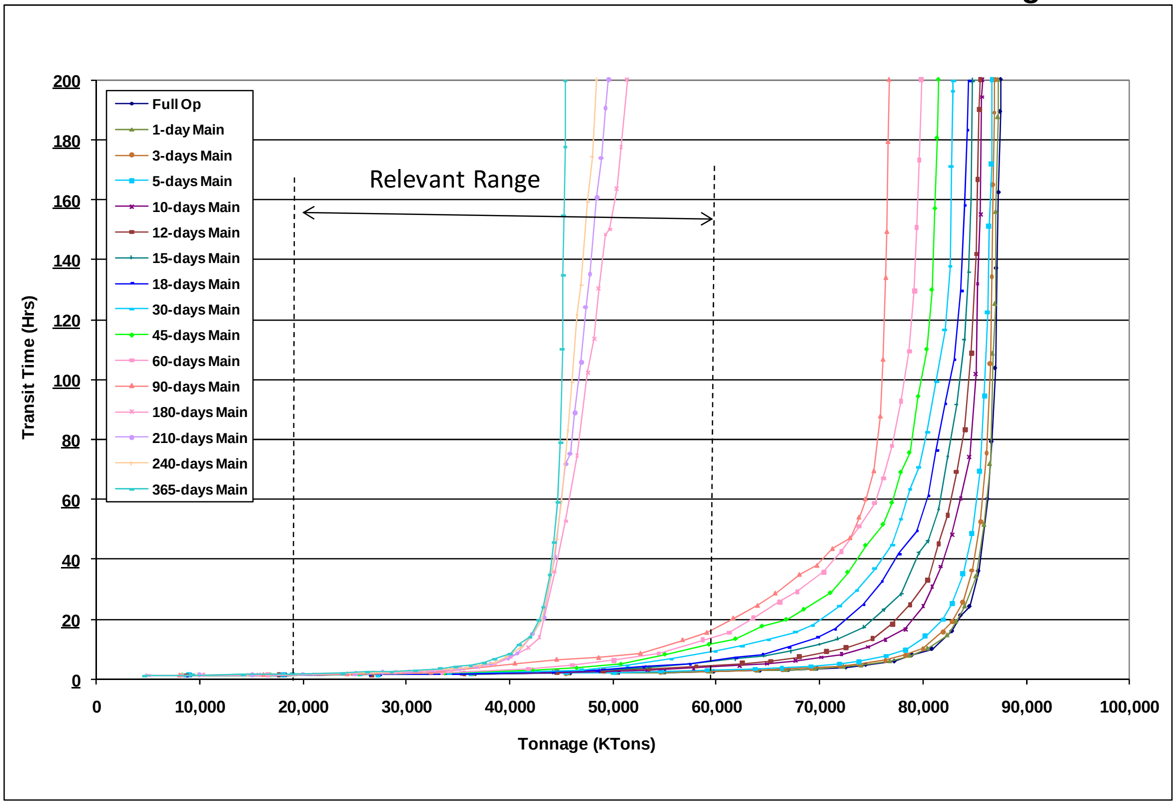


FIGURE A2- 162
Dashields New 600’ & Old 600’ Main Chamber Closures – Future Fleet

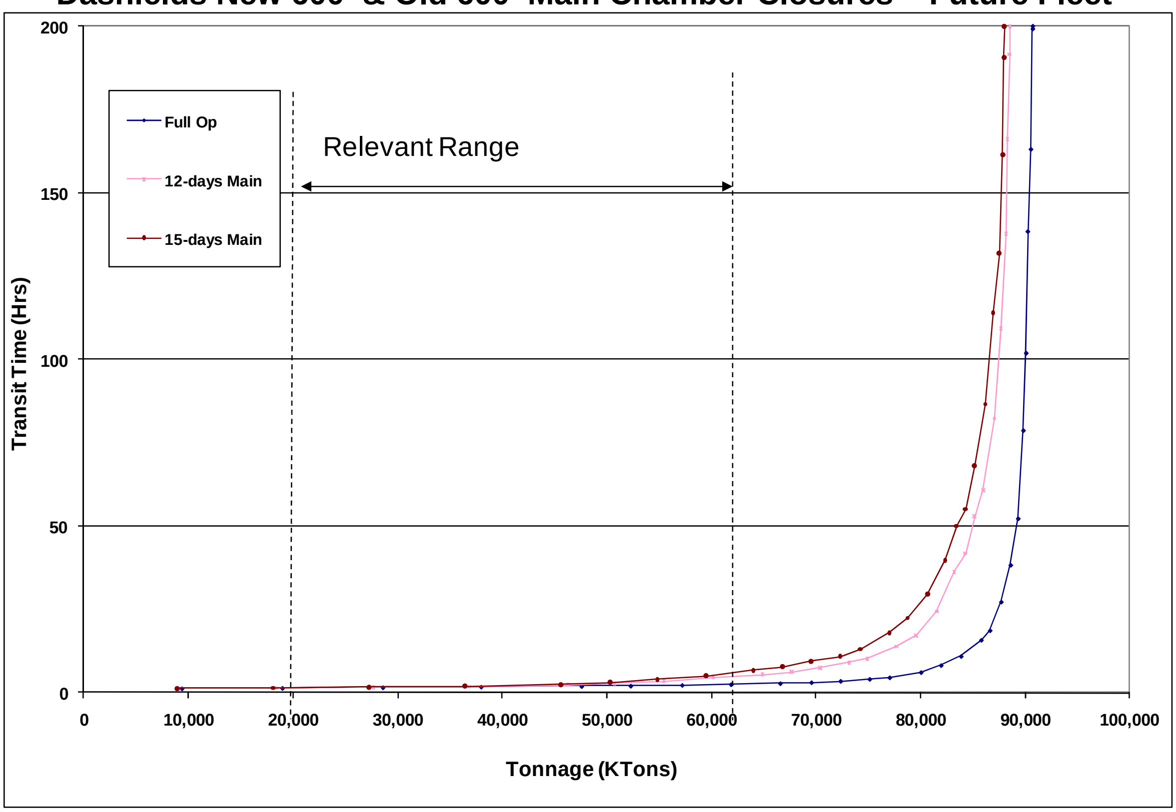


FIGURE A2- 163
Dashields New 600' & Old 600' Auxiliary Chamber Closures – Existing Fleet

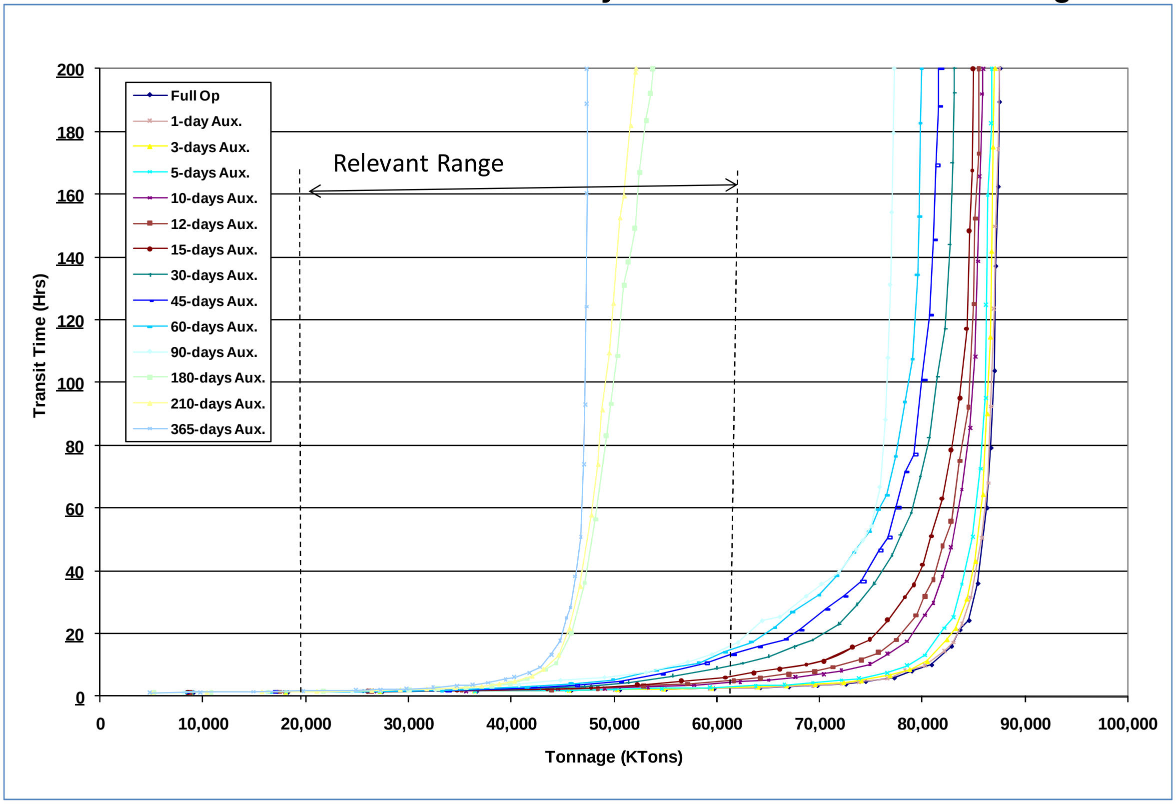


FIGURE A2- 164
Dashields New 600' & Old 600' Auxiliary Chamber Closures – Future Fleet

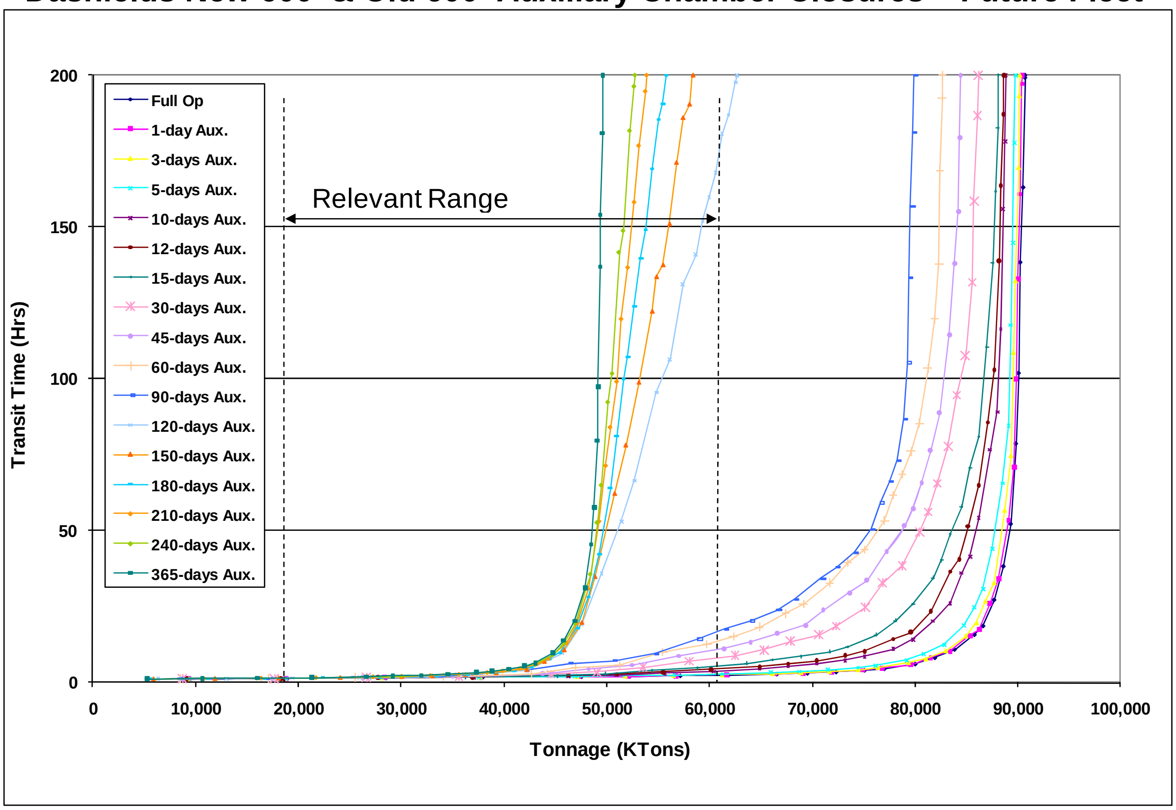


FIGURE A2- 165
Dashields New 600' & Old 600' Main Chamber Half Speeds – Existing Fleet

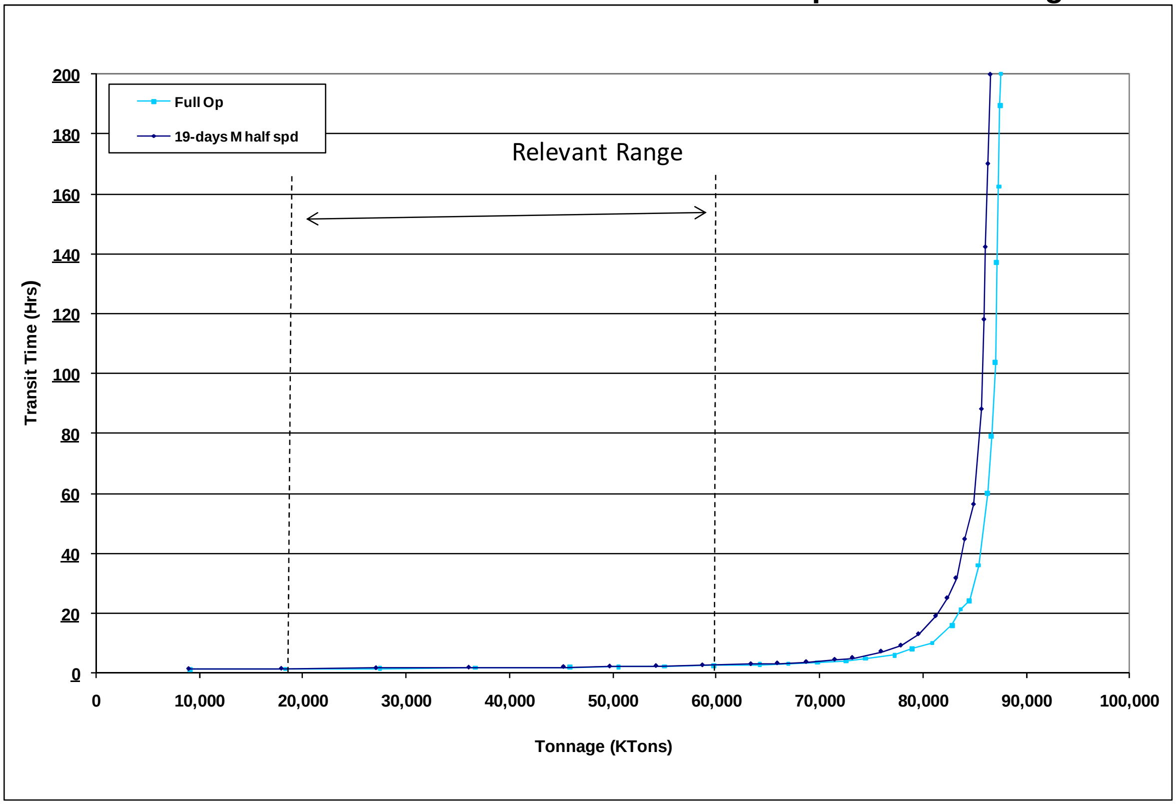


FIGURE A2- 166
Dashields New 600' & Old 600' Main Chamber Half Speeds – Future Fleet

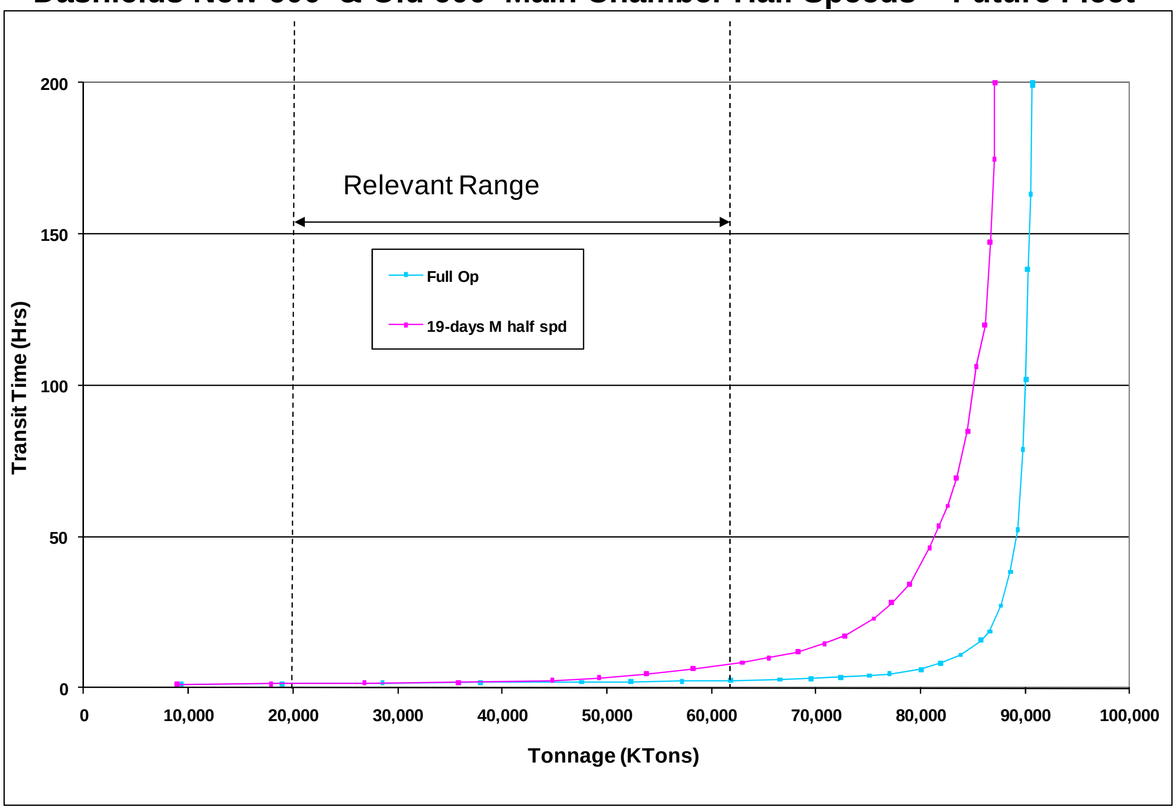


FIGURE A2- 167
Dashields New 600' & Old 600' Aux Chamber Half Speeds – Existing Fleet

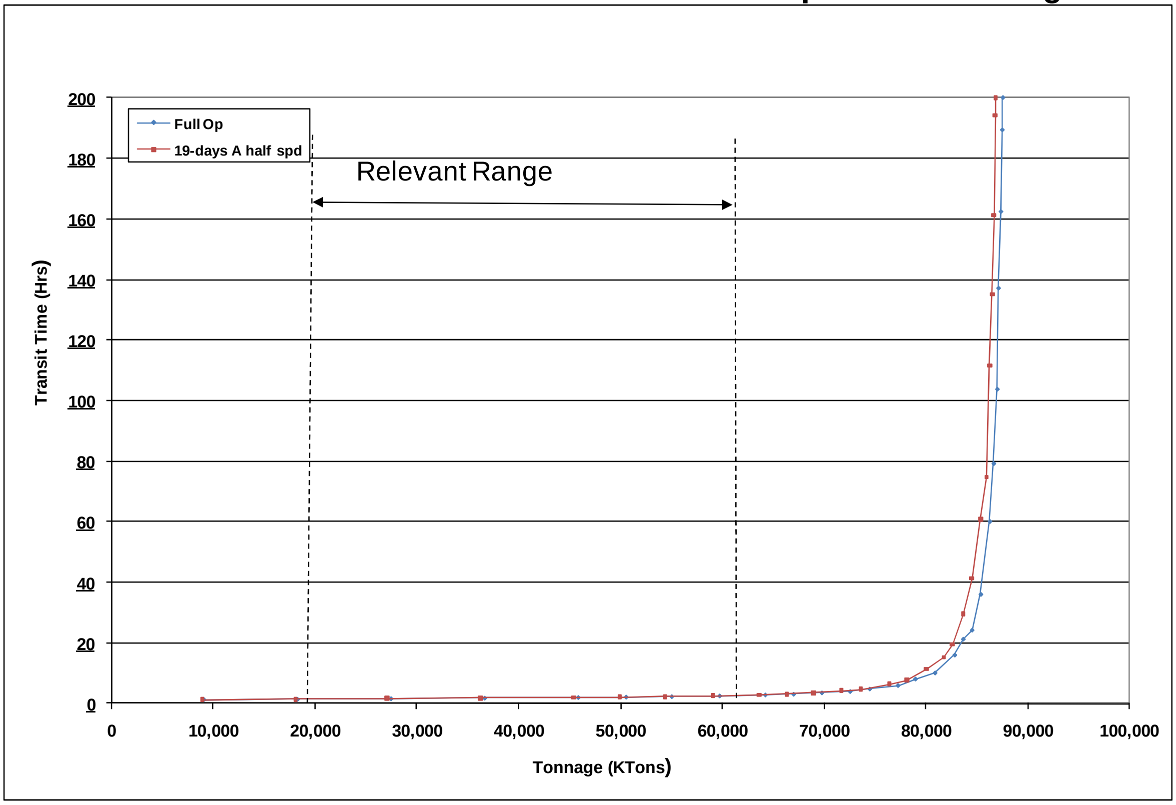


FIGURE A2- 168
Dashields New 600' & Old 600' Aux Chamber Half Speeds – Future Fleet

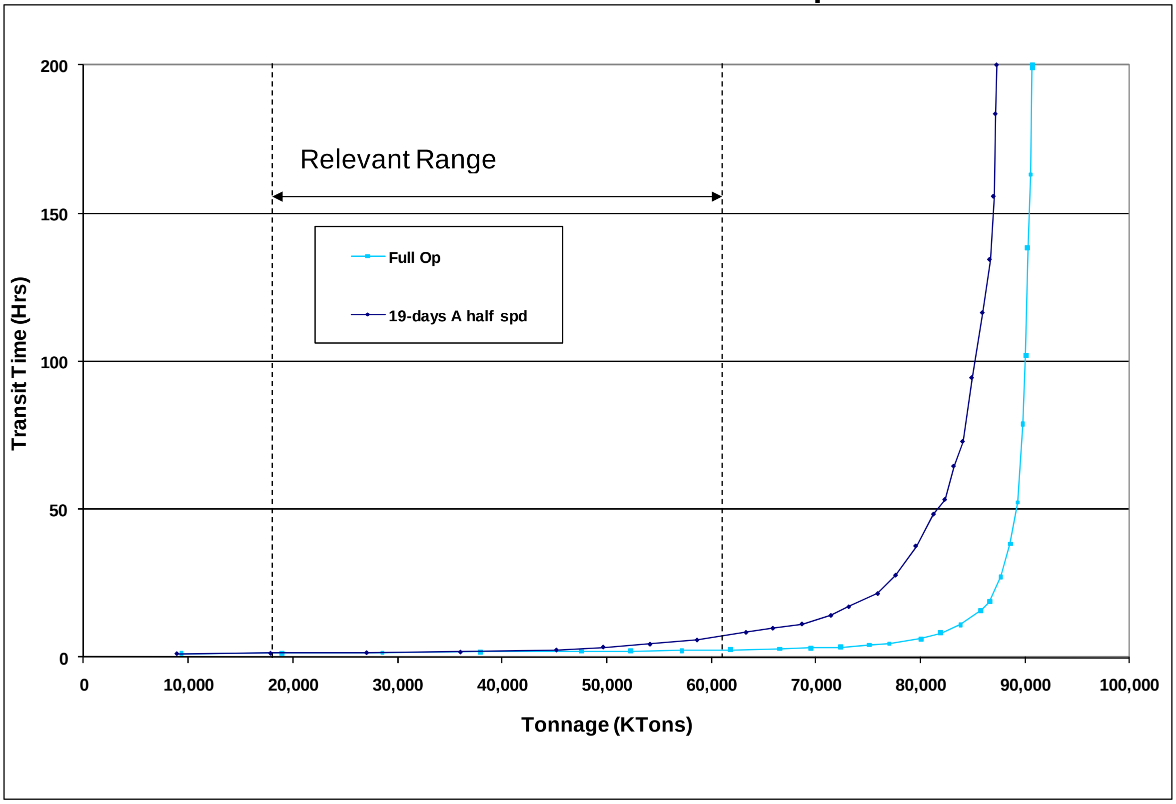


FIGURE A2- 169
Dashields New 600' & Old 600' River Chamber – Existing Fleet

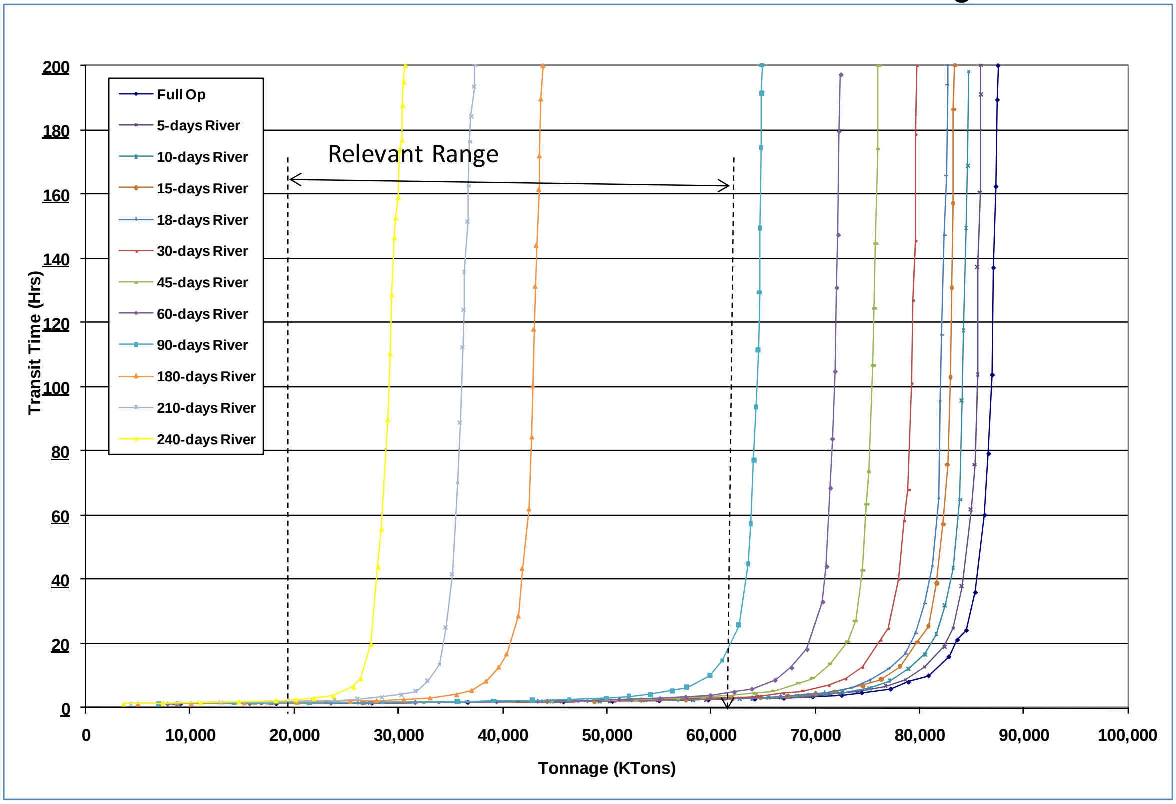
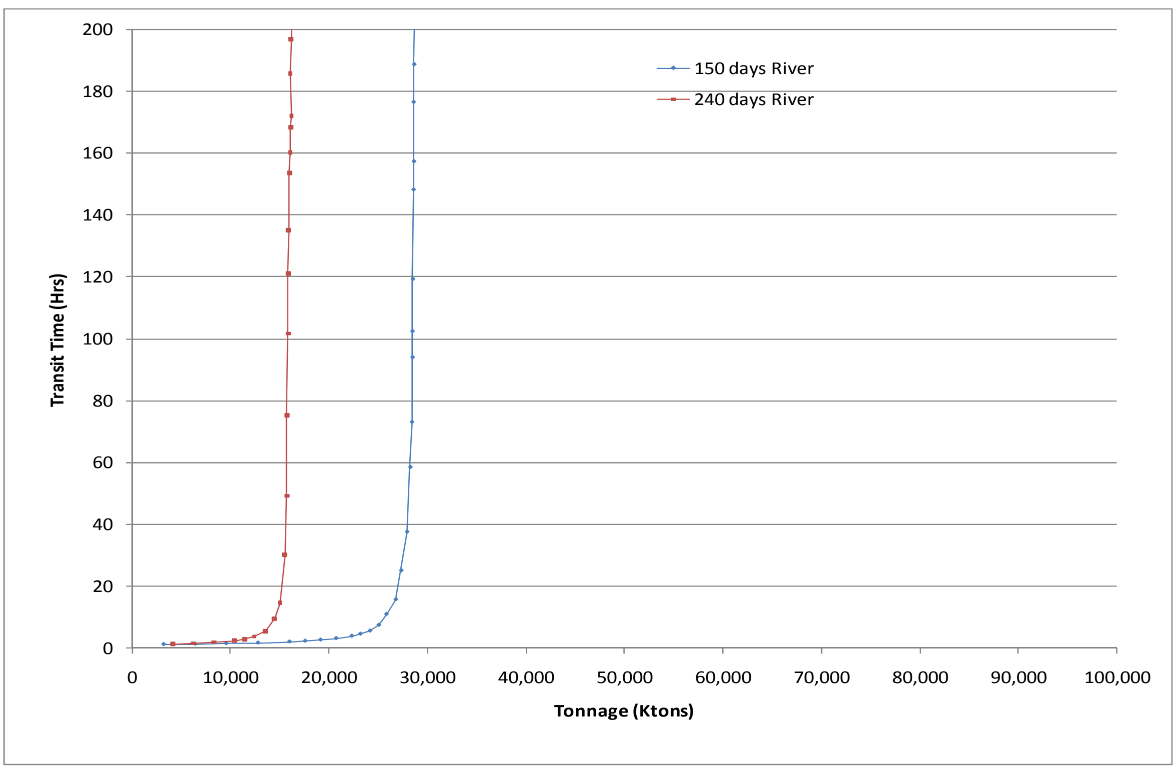


FIGURE A2- 170
Dashields New 600' & Old 600' River Chamber – Future Fleet



2.9.2.3 Montgomery Project Capacities and Processing Times

Table A2-177 and **Table A2-179** shows the Montgomery's With Project Condition capacities for the full operation, main and auxiliary chambers, and river closures for the existing versus the future fleet determined during this study. **Table A2-178** shows the capacity for the full op, main chamber, and auxiliary chamber closures using the future fleet is approximately 3% higher than the existing fleet. The auxiliary chamber 365 day closure is 6% higher using the future fleet. The capacity for the half speed closures are less than 1% higher for the future fleet.

The processing times are 2% lower for the future fleet for both the main and auxiliary chamber closures for all closure durations.

Figure A2-171 through **A2-180** shows the With Project Condition capacity curves for the existing versus the future fleet for the main, auxiliary, and total river closures.

TABLE A2- 177
Montgomery New 600' & Old 600' Existing Fleet vs Future Fleet

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	Existing Fleet	Future Fleet	Existing Fleet	Future Fleet
No closures (normal operation)	77.6	79.8	68.4	66.9
1-day Main Chamber Closed	77.5	*	68.4	*
3-days Main Chamber Closed	77.2	*	68.4	*
5-days Main Chamber Closed	77.0	*	68.4	*
10-days Main Chamber Closed	76.3	*	68.5	*
12-days Main Chamber Closed	76.2	78.2	68.4	67.0
15-days Main Chamber Closed	75.7	77.9	68.5	67.0
18-days Main Chamber Closed	75.3	*	68.5	*
30-days Main Chamber Closed	74.1	*	68.5	*
45-days Main Chamber Closed	72.5	*	68.5	*
60-days Main Chamber Closed	70.9	*	68.5	*
90-days Main Chamber Closed	67.9	*	68.7	*
120-days Main Chamber Closed	*	*	*	*
180-days Main Chamber Closed	46.2	*	69.4	*
210-days Main Chamber Closed	44.8	*	69.5	*
240-days Main Chamber Closed	43.8	*	69.7	*
365-days Main Chamber Closed	39.9	*	69.8	*
1-day Auxiliary Chamber Closed	77.5	79.7	68.4	66.9
3-days Auxiliary Chamber Closed	77.3	79.3	68.4	67.0
5-days Auxiliary Chamber Closed	76.9	79.1	68.4	67.0
10-days Auxiliary Chamber Closed	76.4	78.5	68.4	66.9
12-days Auxiliary Chamber Closed	76.1	78.2	68.4	67.0
15-days Auxiliary Chamber Closed	75.8	77.9	68.5	67.0
30-days Auxiliary Chamber Closed	74.2	76.2	68.5	67.0
45-days Auxiliary Chamber Closed	72.6	74.6	68.6	67.0
60-days Auxiliary Chamber Closed	71.2	73.0	68.6	67.1
90-days Auxiliary Chamber Closed	68.1	70.4	68.6	67.1
120-days Auxiliary Chamber Closed	*	55.0	*	67.7
150-days Auxiliary Chamber Closed	*	51.4	*	67.8
180-days Auxiliary Chamber Closed	47.9	49.1	69.3	67.8
210-days Auxiliary Chamber Closed	46.4	47.7	69.5	67.8
240-days Auxiliary Chamber Closed	*	46.6	*	67.7
365-days Auxiliary Chamber Closed	41.3	43.7	68.9	67.6
19-days Main Chamber ½ speed	76.7	77.2	69.07	67.0
19-days Aux Chamber ½ speed	77.1	77.3	68.75	66.9

** No WAM Capacity Curves*

TABLE A2- 178
Montgomery New 600' & Old 600' Existing Fleet vs Future Fl

Project/Scenario	% Difference Capacity	% Difference Processing Time
No closures (normal operation)	2.8%	-2.3%
1-day Main Chamber Closed	*	*
3-days Main Chamber Closed	*	*
5-days Main Chamber Closed	*	*
10-days Main Chamber Closed	*	*
12-days Main Chamber Closed	2.7%	-2.0%
15-days Main Chamber Closed	2.9%	-2.1%
18-days Main Chamber Closed	*	*
30-days Main Chamber Closed	*	*
45-days Main Chamber Closed	*	*
60-days Main Chamber Closed	*	*
90-days Main Chamber Closed	*	*
120-days Main Chamber Closed	*	*
180-days Main Chamber Closed	*	*
210-days Main Chamber Closed	*	*
240-days Main Chamber Closed	*	*
365-days Main Chamber Closed	*	*
1-day Auxiliary Chamber Closed	2.8%	-2.3%
3-days Auxiliary Chamber Closed	2.6%	-2.1%
5-days Auxiliary Chamber Closed	2.8%	-2.2%
10-days Auxiliary Chamber Closed	2.7%	-2.2%
12-days Auxiliary Chamber Closed	2.7%	-2.1%
15-days Auxiliary Chamber Closed	2.7%	-2.2%
30-days Auxiliary Chamber Closed	2.7%	-2.1%
45-days Auxiliary Chamber Closed	2.8%	-2.2%
60-days Auxiliary Chamber Closed	2.6%	-2.2%
90-days Auxiliary Chamber Closed	3.5%	-2.2%
120-days Auxiliary Chamber Closed	*	*
150-days Auxiliary Chamber Closed	*	*
180-days Auxiliary Chamber Closed	2.5%	-2.2%
210-days Auxiliary Chamber Closed	2.8%	-2.4%
240-days Auxiliary Chamber Closed	*	*
365-days Auxiliary Chamber Closed	5.9%	-1.8%
19-days Main Chamber ½ speed	0.6%	-3.0%
19-days Aux Chamber ½ speed	0.3%	-2.7%

** No WAM capacity curves for both existing & futute fleets*

TABLE A2- 179
Montgomery New 600' & Old 600' Existing Fleet vs Future Fleet - River

	Capacity (Millions of Tons)		Avg. Processing Time (min/tow)	
Project/Scenario	**Existing Fleet**	**Future Fleet**	**Existing Fleet**	**Future Fleet**
5-days River Closure	76.3	*	68.5	*
10-days River Closure	75.2	*	68.5	*
15-days River Closure	74.1	*	68.4	*
18-days River Closure	73.4	*	68.4	*
30-days River Closure	70.9	*	68.4	*
45-days River Closure	68.0	*	68.6	*
60-days River Closure	64.8	*	68.5	*
90-days River Closure	58.0	*	68.3	*
150-days River Closure	*	25.6		68.3
180-days River Closure	38.3	*	68.1	*
210-days River Closure	32.1	*	68.1	*
240-days River Closure	26.2	14.4	68.1	68.2
365-days River Closure	0.0	*	0.0	*

** No WAM Capacity Curves*

FIGURE A2- 171

Montgomery New 600' & Old 600' Main Chamber Closures – Existing Fleet

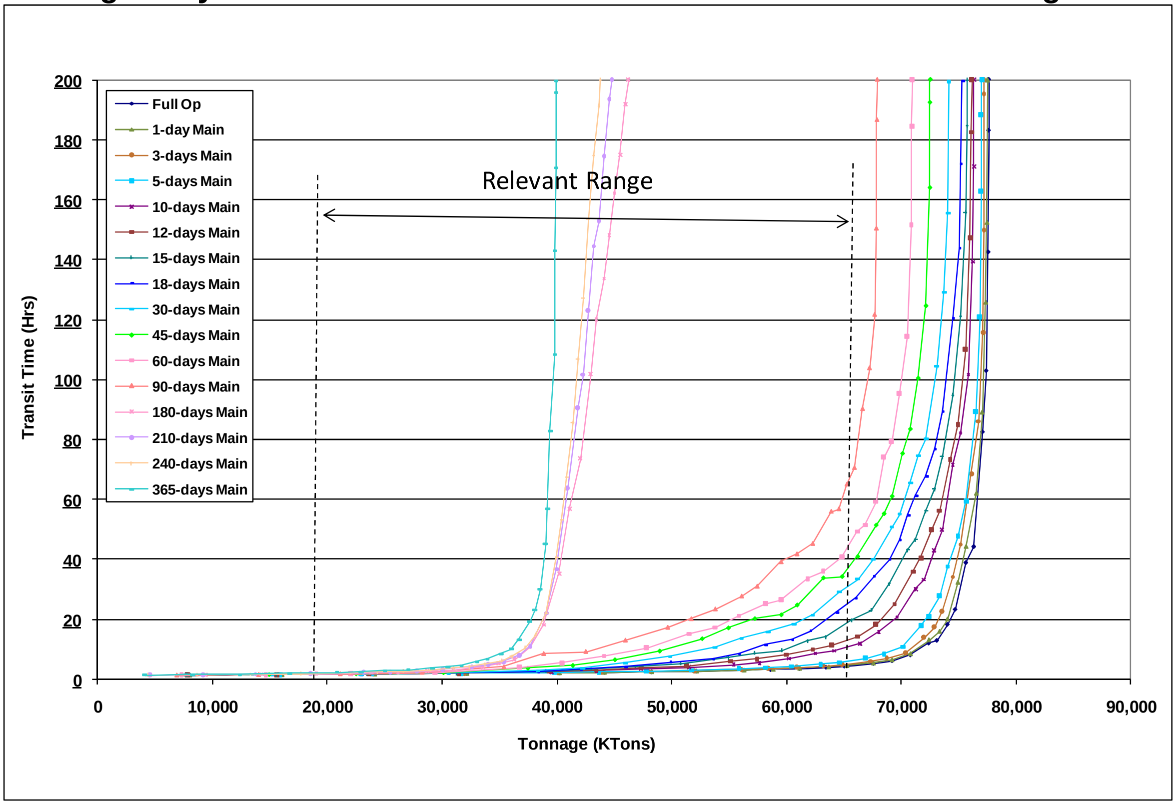


FIGURE A2- 172

Montgomery New 600' & Old 600' Main Chamber Closures – Future Fleet

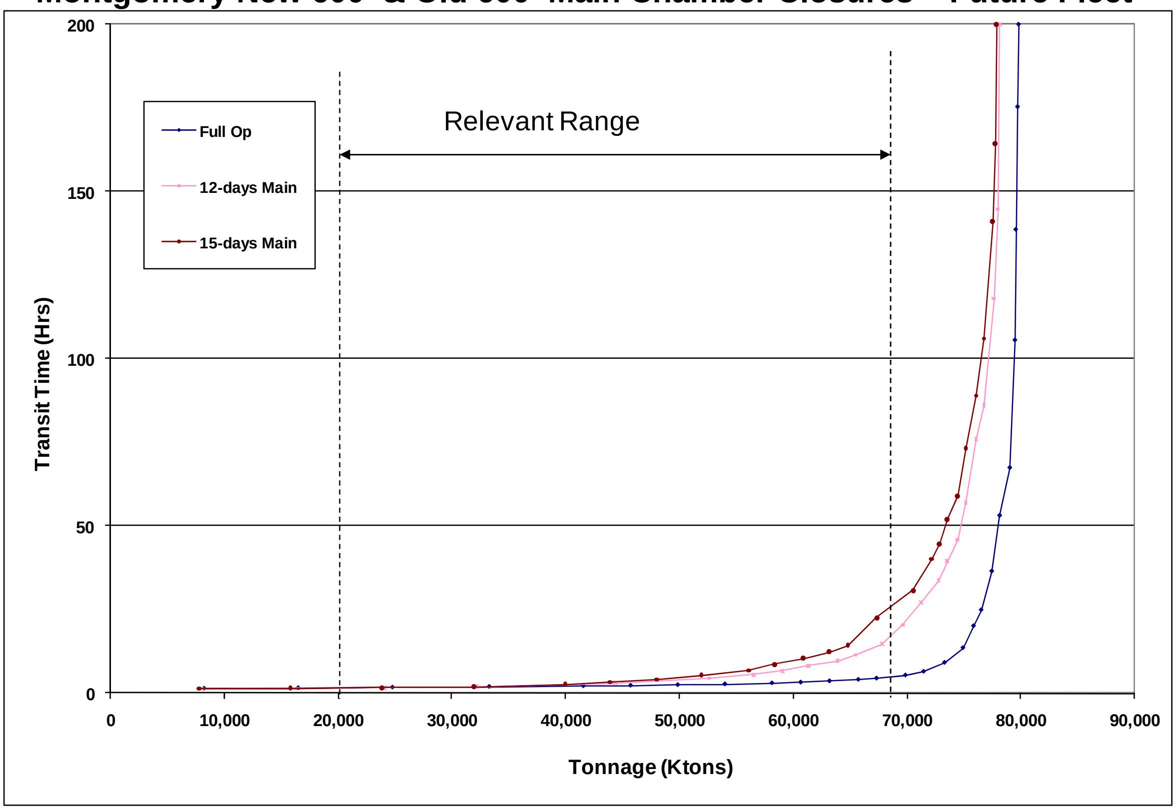


FIGURE A2- 173
Montgomery New 600' & Old 600' Auxiliary Chamber – Existing Fleet

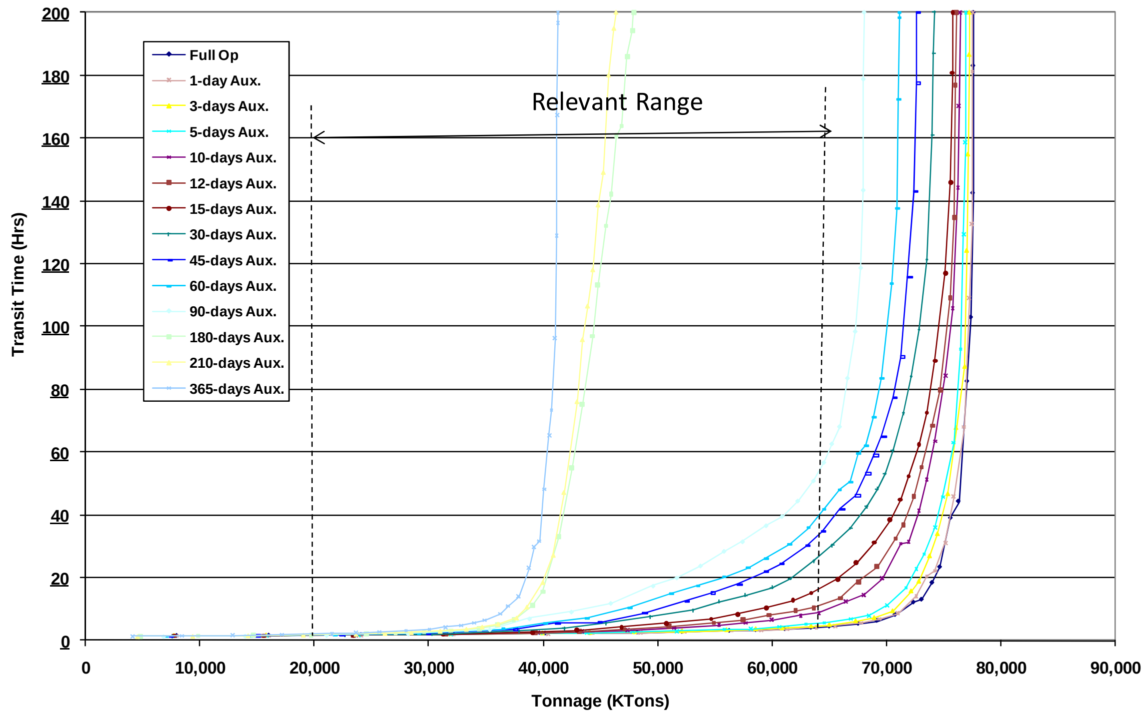


FIGURE A2- 174
Montgomery New 600' & Old 600' Auxiliary Chamber Closures – Future Fleet

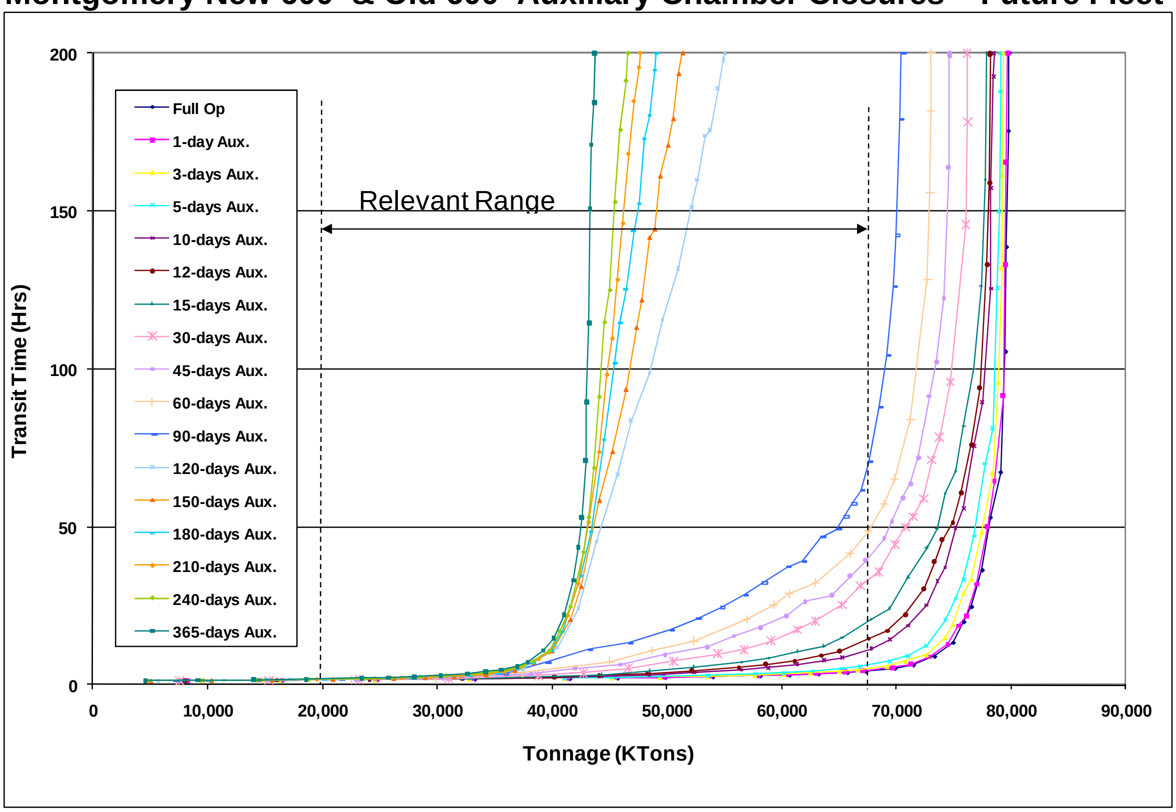


FIGURE A2- 175

Montgomery New 600' & Old 600' Main Chamber Half Speeds – Existing Fleet

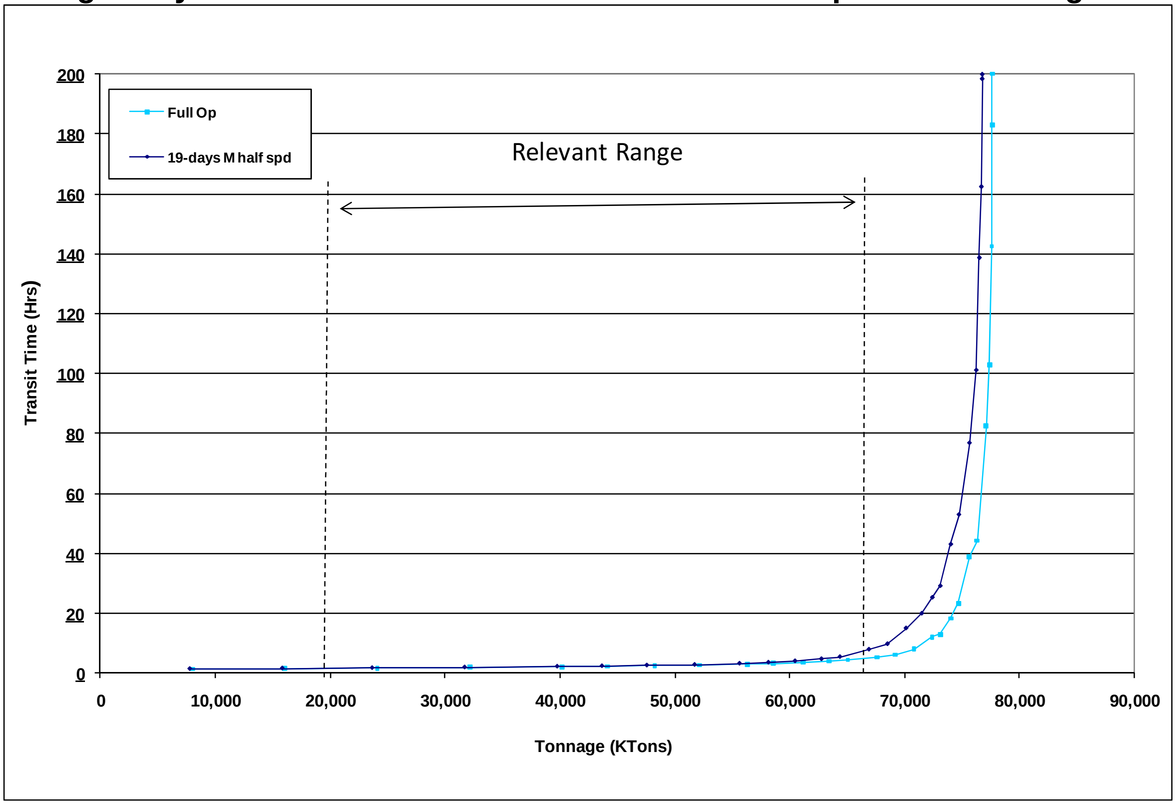


FIGURE A2- 176

Montgomery New 600' & Old 600' Main Chamber Half Speeds – Future Fleet

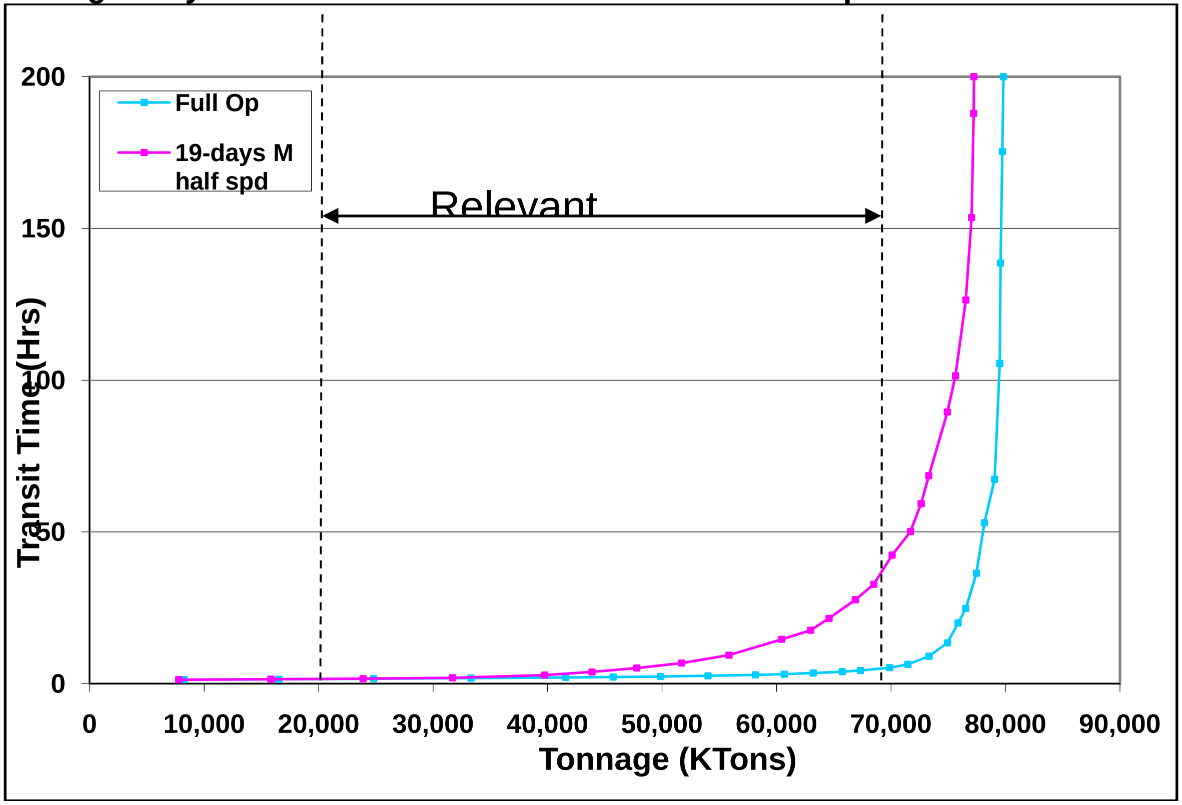


FIGURE A2- 177
Montgomery New 600' & Old 600' Aux Chamber Half Speeds – Existing Fleet

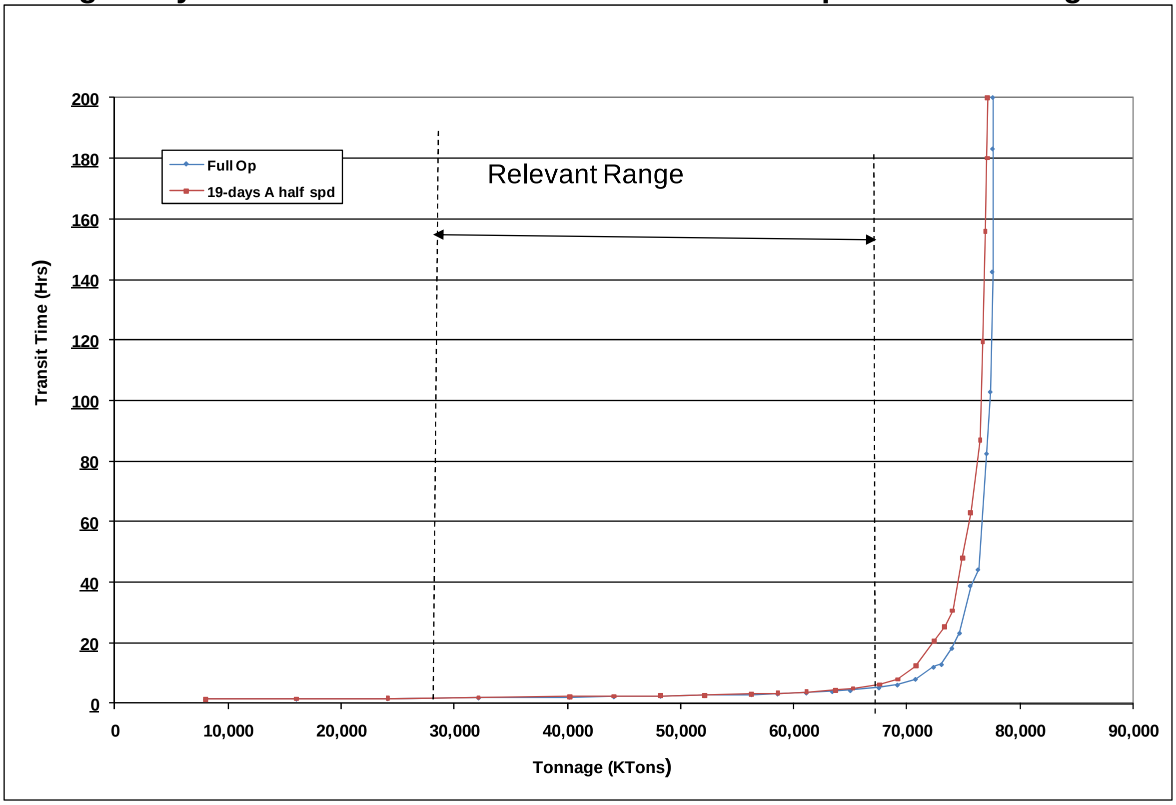


FIGURE A2- 178
Montgomery New 600' & Old 600' Aux Chamber Half Speeds – Future Fleet

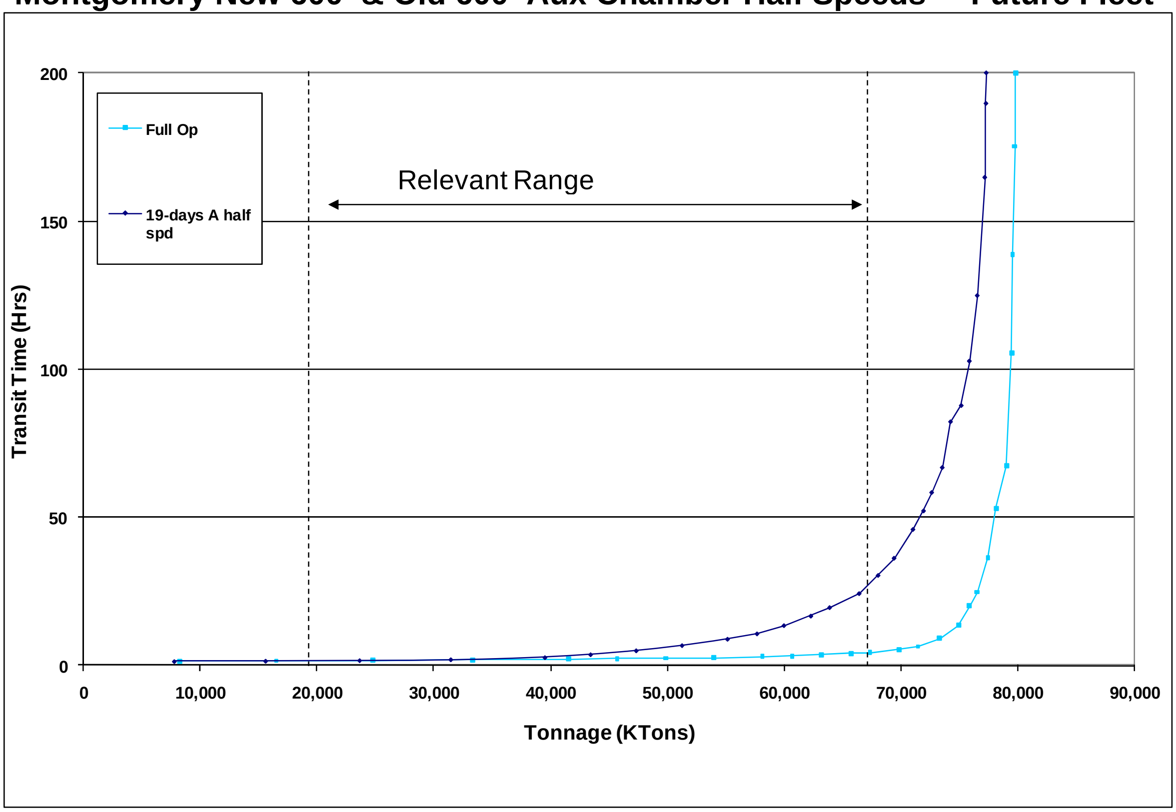


FIGURE A2- 179
Montgomery New 600' & Old 600' River Chamber – Existing Fleet

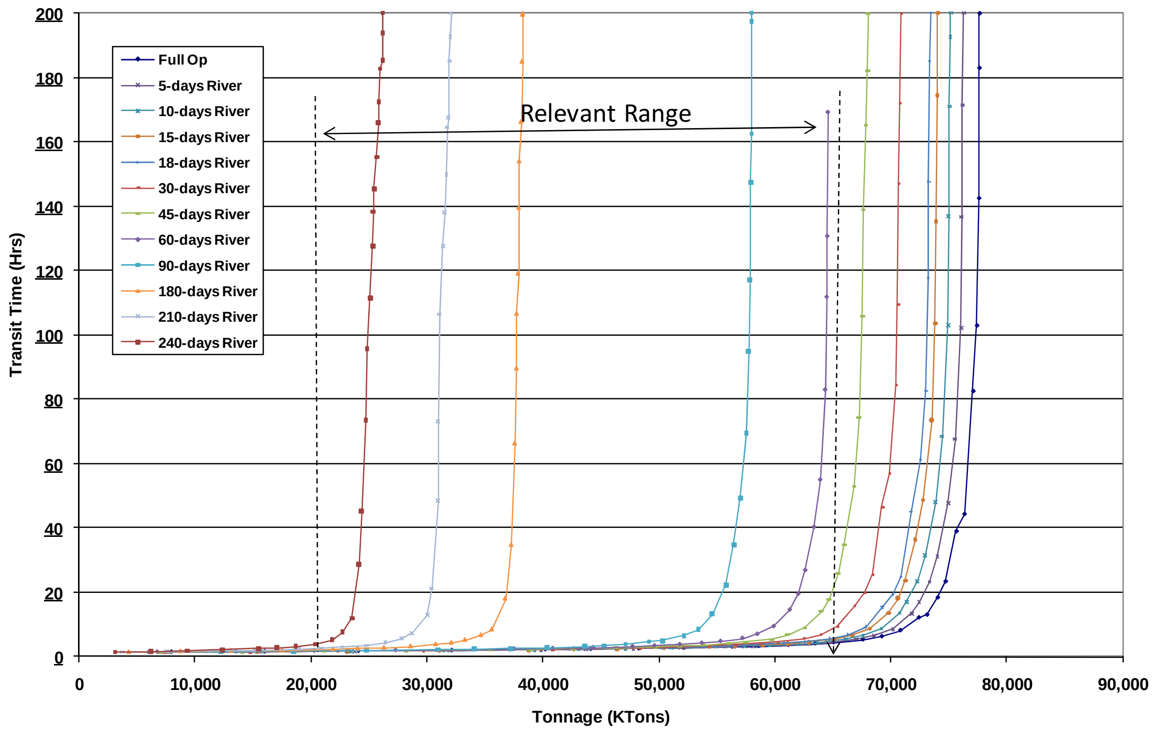
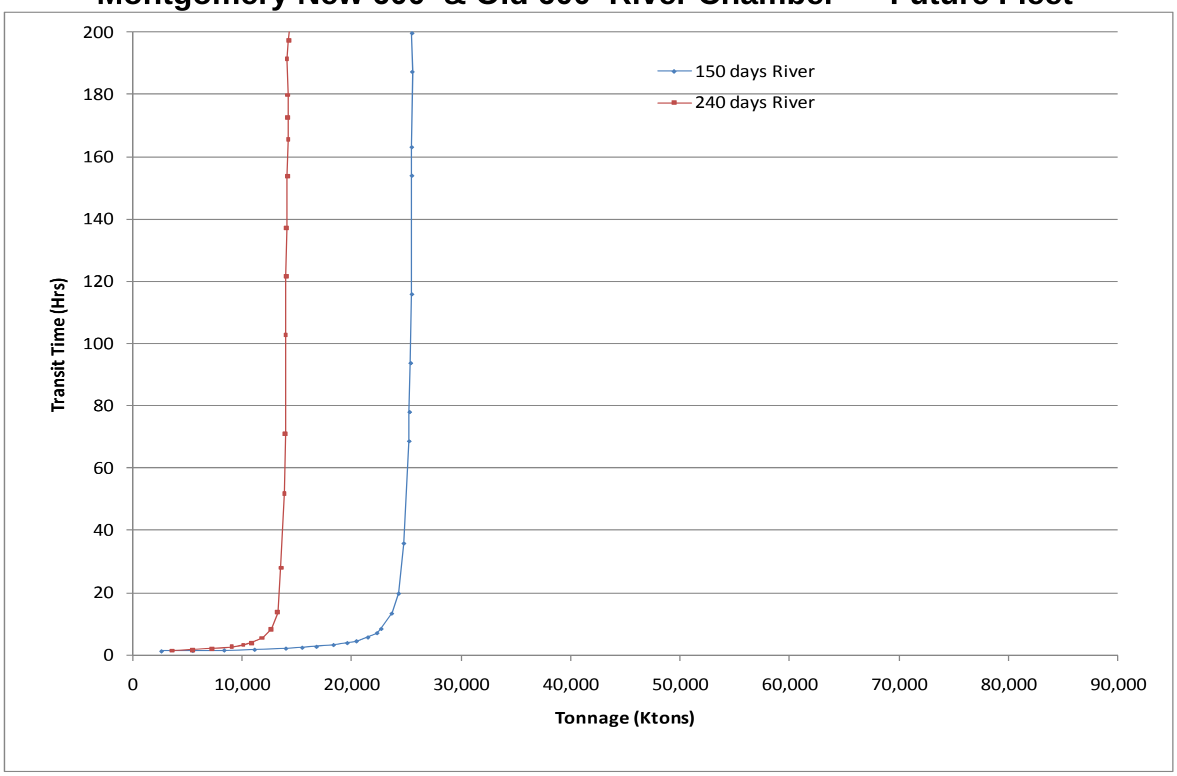


FIGURE A2- 180
Montgomery New 600' & Old 600' River Chamber – Future Fleet



Forecast of Coal and Sorbent Materials Traffic Demands for the Ohio River Navigation System

Phase 1 Report

Final Report
September 22, 2009

U.S. Army Corps of Engineers

Contract No. W91237-08-C-0010

Prepared By:

Leonardo Technologies, Inc.

Executive Summary

The primary purpose of this study effort is to generate forecasts of coal and coke traffic demands for the Ohio River Navigation System (ORS). Most of the effort is devoted to forecasting utility steam coal, since the utility coal dominates the traffic picture on the ORS. Separate forecasts are also developed for coking coal, industrial coal and export coal, as well as coal moving to coal-to-liquids plants. Special attention was devoted, as well, to forecasts of sorbent materials traffic. Sorbent materials are the materials used in coal desulfurization and comprise mainly lime and limestone. The ORS currently handles around 270 million tons (mmt) of commodity traffic, over half of which is coal and coke traffic. The major recipients of coal traffic on this navigation system are waterside electric utility plants.

This report was prepared for the U.S. Department of the Army, Corps of Engineers (USACE), Huntington District, Huntington, West Virginia under contract number W01237-080C-0010. The contract title is "Forecast of Coal and Sorbent Materials Traffic Demands for the Ohio River and Great Lakes Navigation System." This report covers Phase 1 which is limited to the ORS.

The forecasts of ORS coal and sorbent materials traffic demands were developed under a structure of three forecast scenarios developed in coordination with USACE personnel. In addition to a base case, alternative forecasts (High ORS Traffic Demand case and Low ORS Traffic Demand case) were developed. These forecasts are displayed in 5-year increments. The various databases resulting from this work display the year of the forecasts, off-waterway origin (general origin), mode to the waterway, river dock of origin, mode away from the water if appropriate, a destination plant and waterborne tonnage, and the total (waterborne and overland) coal/sorbent materials received at the plant. In a subsequent step, the forecasts were further refined by USACE based on the historic origin-destination patterns reflected in the Waterborne Commerce Data.

The demand for coking (metallurgical) coal, industrial use coal, and export coal was projected independent of the modeling incorporated in this project. These non-utility coal forecasts then were used as exogenous inputs to the modeling for the purpose of simulating appropriate overall supply/demand balances.

The Greenmont Energy Model (GEM™) was used to run the forecast. The GEM™ model is an optimization model which calculates the unique combination of a large number of parameters which achieves the lowest cost of electricity generation in the United States for a given amount of electricity demand. The model uses both Linear Programming (LP) and Mixed Integer Programming (MIP) optimization techniques and thus can be characterized as an LP/MIP optimization model. GEM™ modeling software optimizes coal and electricity supply and demand price balances as they are likely to operate in a free market. The GEM™ model minimizes the total system cost of U.S. electricity production and distribution and includes all power plants in the United States and Canada, regardless of fuel type. The

demand zones or areas, together with load curves, are given and connected via a transmission network. The GEM™ model provided the following results:

- In the Base Case, total U.S. demand for coal to satisfy domestic usage rises 46% from 2008 to 2070. Reflecting continued depletion of the lower cost, higher quality coal reserves, Base Case forecasted production of Central Appalachian (CAPP) coal declines in the latter stages of the forecast period. Also in the later years, a shift away from the highest sulfur coals is reflected in the projected Base Case coal production totals for the Illinois Basin and for Northern Appalachia, both of which rise strongly due to new scrubbers until the early 2020's and then begin losing tonnage. Powder River Basin (PRB) coal grows relatively unabated throughout the Base Case forecast. This strong growth is the factor that keeps overall U.S. tonnage rising in the face of some shifting away from higher sulfur coals in later years. However, coal does not grow as fast as electricity production, and coal's share of generation falls from a fairly steady level of 54%-56% in 2010-2030 to be only 43% in 2070. Gas-fired generation grows about as fast as overall generation, and the natural gas share of overall generation stays relatively flat throughout the Base Case forecast. The falling coal share is picked up by rising nuclear generation. In addition, construction of environmental clean-up equipment is very strong in the early years of the Base Case forecast.

- In the Low Traffic Demand Case, the imposition of carbon dioxide (CO_2) emission limits is the big driving force on coal tonnage. In this Low Case, total U.S. demand for use and exports runs generally lower than levels of the Base Case. Regionally, the PRB and Central Appalachia suffer the most in the first 20-30 years. This is logically consistent since these coals are the better quality coals in the Nation with a substantial portion of their demand driven by how tightly emissions from overall coal burn are pressing against the sulfur dioxide (SO_2) (and, to a lesser extent, nitrous oxide (NO_x)) limits. Entirely consistent with this PRB tonnage drop is the fact that the use of scrubbers and selective catalytic reduction (SCR) equipment in the Low Case remains very close to the Base Case levels until the very end of the time frame. Finally, in the Low Case both nuclear plants and gas-fired plants generally are built at a faster rate than in the Base Case, at least in the early years of the forecast time frame. This result is entirely expected, since both nuclear and gas help to lower the CO_2 emissions from a predominantly coal-fired electric generating industry.

- In the High Traffic Demand Case, higher economic growth (with accompanying higher domestic metallurgical coal demand, industrial steam coal demand, and coal export demand) along with an assumption of difficulties in the permitting and construction of nuclear plants, drives the overall U.S. coal demand gradually higher above the Base Case. Although the High Case regional tonnages in Central Appalachian, the Illinois Basin, and the PRB are marginally above those of the Base Case, the "shape" of the growth/decline curves remains about the same as in the Base Case for those regions. Finally, the demand for electricity is so strong in the High

Case that new construction of pulverized coal (PC), combined cycle (CC), and nuclear units maxes out against the limits in the model of the amount of new capacity of each type that could reasonably be built on an annually sustainable basis.

Acknowledgement

This report was developed by Leonardo Technologies, Inc. (LTI), under U.S. Department of Army, Corps of Engineers (USACE) Huntington District contract number W91237-08-C-0010. The work by LTI would not have been possible without support and guidance by the USACE Contracting Officer's Representative, Dale Kelz, and Mr. Kelz's supervisor, Mr. Wes Walker. In addition to Messrs. Kelz and Walker's direction and guidance throughout the project, LTI acknowledges the valuable input and critiques of Bill Freccione of the USACE Pittsburgh District office, Mark Hammond of the USACE Huntington District office, Kevin Logan of the USACE Pittsburgh District office, and Rebecca Moyer of the Great Lakes and Ohio River Division.

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Introduction and Background

Commercial navigation on the ORS serves portions of eight states in the industrial Midwest and the Southeast. The ORS currently handles around 270 mmt of commodity traffic, over half of which is coal and coke traffic. The major recipient of coal traffic on the ORS is waterside electric utility plants.

Investment decisions on the inland waterways are guided, in large part, by timely and accurate traffic demand forecasts. Traffic demand forecasts, in turn, are a major input to navigation systems modeling. Navigation systems modeling guides the timing and scale of investments in navigation infrastructure.

The purpose of this study is to generate forecasts of utility steam coal, coking coal, industrial coal, export coal, and sorbent materials (largely limestone and lime used in coal desulfurization) traffic demands on the ORS. The forecast of U.S. coal demand and demand for sorbent materials was developed under a structure of three forecast scenarios. In addition to a Base Case, alternative forecasts (High ORS Traffic Demand case and Low ORS Traffic Demand case) were developed. The utility steam coal forecasts were based on: (1) a thorough assessment of long-term electricity demands for much of the Eastern United States, (2) the satisfaction of these demands in a least-cost fashion on a plant-by-plant (or unit-by-unit) basis considering resource (especially coal) constraints and regional emission constraints under current and proposed environmental regulations, and (3) transmission system limitations. In addition to this report, the primary product from this study effort is a set of databases showing the detailed forecasts under the base and alternative forecast scenarios. For this report, summary forecasts are displayed in 5-year increments. The databases display the year of the forecasts, off-waterway origin (general origin), mode to the waterway, river dock of origin, mode away from the water if appropriate, a destination plant and waterborne tonnage, and the total (waterborne and overland) coal/sorbent materials received at the plant. Forecast data were subsequently refined by USACE based on specific historic origin-destination traffic data contained in the Waterborne Commerce Statistics.

The primary study area for this Phase 1 effort includes all or portions of eight states in the industrial Midwest and the Southeast. Specifically, the primary study area includes all or portions of Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee, and West Virginia. Each of these states has waterside coal-fired electric generating facilities that are served directly by the ORS. In this instance, the ORS includes the mainstem Ohio River and all of its navigable tributaries to include the Allegheny, the Monongahela, the Kanawha, the Green, the Tennessee, and the Cumberland rivers.

In addition to the primary study area, a number of utility systems operating coal-fired power plants, largely waterside, located outside of the primary study area were included in the study. This is due to their receiving coal that transits portions of the ORS.

For the purposes of coal supply analysis, it is important to note that the Ohio River Basin, which is largely a subregion of the primary study area, contains nearly the entire Appalachian coal producing region, as well as a large portion of the Illinois Basin coal producing region. Coal from these producing regions forms the bulk of coal traffic on the ORS. In recent years, because of more stringent environmental regulations, greatly increased volumes of western coal, primarily from the PRB, are moving on the system.

For coking coal and industrial coal, the primary areas of concern are the waterside origins and destinations of these commodities, largely inside of the ORS. The ORS has regional concentrations of iron and steel producers, as well as other major industrial coal consumers. Exports of U.S. coal, especially from Central Appalachia and the Illinois Basin, also provide traffic on the ORS toward the Gulf of Mexico. However, the larger share of the dominant Central Appalachian export tonnage moves directly by rail to Atlantic seaboard ports.

Forecasting

The forecasts developed under this contract are for river traffic demand, meaning that the forecasts did not consider transportation system constraints. Both the waterway and overland transportation system are considered to be reliable and efficient and capable of handling future traffic demands.

Navigation projects in the USACE are typically evaluated using a 50-year period of analysis, which is considerably beyond the forecasting horizon of most forecasting models. For the purposes of the current forecasting effort, the forecasting horizon extended to year 2070. This result was achieved through model runs of the GEM™. This forecasting effort began with forecasts of U.S. national electricity demands based on forecasts of Gross Domestic Product (GDP) and other factors such as electric intensity.

Once a national forecast of electricity demands was generated, an allocation of those demands to relevant U.S. subregions was made. The relevant primary subregions for this forecast effort are those regions that include waterside coal-fired electric generating facilities that either currently receive ORS coal or are expected to receive ORS coal in some future period. In this instance, ORS coal signifies coal that transits the ORS for all or part of its routing.

After determining the regional generation requirements, a forecast of generation for these regions by type of generation was developed. The types of generation included coal, gas, oil, nuclear, hydropower, and other renewables, along with generation by non-utility generators and independent power producers. Within the subregions, least-cost strategies for meeting the generation requirements were determined considering regional emission limits on SO_2, NO_x, mercury (Hg), CO_2, and particulates. The forecast of generation by type was determined for individual plants within the relevant subregions, again considering the environmental constraints of each plant and the need to pursue least-cost strategies. As potential strategies for meeting regional generation requirements, regional power transfers (purchases/sales) and addition of new generating capacity were considered. All additions of generating capacity were identified by type, e.g., nuclear, super critical PC, Integrated Gasification Combined Cycle (IGCC), etc.

Forecast of Coal Consumption/Sourcing by Coal-Fired Plants

The forecast of generation by coal-fired plants within the relevant subregions was determined in the context of the least-cost strategy for the coal-fired plants to meet their generation requirements within the constraints of the environmental regulations. Strategies included blending, fuel switching, addition of clean-up equipment, and allowance trading.

Coal sourcing and coal consumptions for the relevant coal-fired plants over the forecast horizon were determined based on the preceding analyses of generation and compliance strategies. Coal sourcing was based on equilibrium freight on board (FOB) mine price, coal transportation cost to the plant, and coal quality, including, but not limited to British thermal unit (Btu), ash, and moisture content, as well as sulfur, mercury, and other pollutant content. Coal imports were also considered.

Resource Depletion/Constraints

Coal sourcing was part of a least-cost strategy for coal-fired electric generating facilities to generate the needed electricity. As a part of the coal sourcing forecast, regional coal supply depletion, production costs, and other supply constraints were evaluated, as well as new resource development over the forecast horizon.

Sorbent Materials

In addition to the utility steam coal forecasts, this effort included forecasts of sorbent materials (including lime, limestone, and other materials used in coal emission desulfurization) consumption and sourcing for scrubbed waterside facilities on the ORS. In this instance, the primary area of interest is the forecast of future waterborne movements of sorbent materials that will utilize the ORS. The volume of sorbent material consumption was keyed to coal consumption and quality at scrubbed units at waterside facilities. The type of sorbent material used was the material considered most likely to be used at individual facilities given the existing or expected future flue gas desulfurization (FGD) technology at the facility. Over the forecast horizon, as scrubbers are added to waterside plants, sorbent material consumption/movement was forecasted beginning in the year of installation of the scrubbers.

Alternative Scenarios - Utility Steam Coal

Potential waterway infrastructure improvements are evaluated under conditions of forecasting uncertainty. For the purposes of project sensitivity analyses, the Corps of Engineers has a need for alternative forecast scenarios that capture the reasonable range of utility steam coal consumption/traffic possibilities. The ultimate goal, in this instance, is generally to develop a range of traffic demand forecasts sufficiently differentiated to be useful in sensitive analyses of navigation improvements.

LTI developed three alternative forecast scenarios for utility steam coal and sorbent materials that resulted in high, medium, and low traffic forecasts. The specific forecast scenarios were formulated in consultation with the USACE Contracting Officer's Representative (COR) and other Corps personnel identified by the COR. The Base Case scenario was predicated upon a continuation of the Clean Air Interstate Rule (CAIR), and the Clean Air Visibility Rule (CAVR) plus a Mercury Maximum Achievable Control Technology (MACT) limitation substituting for the court-vacated Clean Air Mercury Rule (CAMR). The Low Traffic Demand scenario was based on strict CO_2 emissions limitations as proposed in the current (as of May 2009) Markey-Waxman bill, since it is considered likely that strict CO_2 emissions limitations would result in greatly reduced coal consumption and coal traffic, at least until effective carbon capture technologies are developed and implemented. A slightly lower growth in U.S. GDP was also used in the Low Traffic Demand Case. The High Traffic Demand Case was based primarily on stronger GDP growth coupled with limitations on nuclear power development.

Coking, Export, and Industrial Coal Forecasts

In addition to the utility steam coal and sorbent materials, demand forecasts were prepared for industrial coal, coking coal, and export coal. As noted above, these forecasts were prepared independent of the GEM™ model and served as inputs to the modeling to assure overall supply/demand balances. Since utility steam coal is a major driving commodity on the ORS, the bulk of the attention in this forecasting effort was devoted to generating the utility steam coal forecasts. Industrial coal and coking coal each form a much smaller share of total traffic on both systems and, therefore, the level of effort devoted to these commodities was lower than that afforded to the electric generation tonnage.

Analytical Approach

The databases created by this effort provide detailed forecasts of coal and sorbent demand on the ORS through the year 2070. From this year-by-year forecast, a summary for ORS utility "plants of interest" in 5-year increments was prepared and reported. The forecasts included a Base Case projection as well as alternative demand scenarios (high and low).

This effort utilized waterways traffic data provided by the USACE, as well as other recognized sources, including but not limited to:

- Energy Information Agency (EIA) Electricity Database Files,
- USACE/Bureau of Transportation Statistics (BTS) Waterway Database,
- EIA Form 423 database and the Mine Safety and Health Administration (MSHA) productivity database,
- Environmental Protection Agency (EPA) Emissions and Generation Resource Integrated Database (eGRID),
- EPA National Allowance Database (NADB),
- Bureau of Economic Analysis' North American Industry Classification System (NAICS)/GDP database, and
- U.S. Department of Transportation's National Transportation Atlas Database (NTAD).

The necessary input data were compiled, then used to formulate the basis of the projection. The proprietary GEM™ model was used to run the forecasts, the outputs of which were analyzed for reporting. Model outputs were analyzed and tabulated.

Traffic density projections are driven by the energy commodity demand. This study forecasted changing future electricity intensity (Megawatt-hour [MWh] of generation per dollar of GDP, coupled with a forecast of Heat Rate efficiency gains, to arrive at a growth rate of Btu's. A forecast of U.S. GDP growth by year was regionalized using Bureau of Census established regions. This provided a growth of Btu's needed for electricity generation in each region, expressed as a percentage above the amount generated in the "base year." This base year determination served as a platform from which the forecast was launched.

The growth percentage of Btu's needed for the regional generation of electricity was applied to modeling generation areas which are very similar to – but more specific than – the traditional North America Electric Reliability Corporation (NERC) control areas. For the majority of the country, these correspond to classical utility areas. The generation areas tend to be geographically contiguous service areas for classical generating companies, before the recent deregulation mergers.

Modeling the multiple parameters and their interdependent relationships requires a sophisticated capability. The GEM™ model was used for several reasons. A major benefit is that the split of total generation, even within a single generation area, by type of generation is not pre-determined. That is, it was not assumed that coal-fired generation drops to 49% for a given year based on conjecture. Rather, the model lets the economic competition on the dispatch grid "play out" year-by-year, with the splits by type of generation then being outputs instead of *a priori* inputs. This is significantly different than the approach taken by many others who attempt to model the electric sector into the future simply by making generalizations or estimates of key results, especially in out years.

In the course of modeling the economic competition (described above) on the dispatch grid, the GEM™ model simultaneously optimized both the coal choices for coal-fired units, as well as their optimal compliance strategies such as installing cleanup equipment versus purchasing emission allowances. Worthy of note is that by using this model, it was possible to make determinations at the unit level, not the plant level, providing a much more granular analysis which generated significantly better results. The GEM™ model is the only model available which provides such unit level specificity.

This interactive optimization of coal sourcing by unit provided a very detailed forecast of specific coal movements from narrow sourcing areas to each coal-fired unit. Both amount and route of each coal source to each coal-fired unit was projected for each year of the forecast. These results for the base forecast, plus the high and low alternative forecasts, all run through the year 2070, are included in the databases described above which are in addition to this report.

This effort interactively determined the optimal installations of cleanup equipment by year, as well as kept track of previously installed cleanup equipment. The combination of coal quality received and use of existing or newly-installed scrubbers determined point-specific (by location of coal-fired unit) demand for FGD sorbent materials. Determining this on a unit level, as opposed to a plant level, resulted in a more granular and quantitatively superior modeling output for sorbent demand as it does for coal demand. This point-specific demand for FGD sorbents was then optimally sourced from suppliers of the sorbent materials in a manner similar to that used for the coal flows. Again, the GEM™ model is the only one available with this unit level specificity.

As part of the work, future demand for coking (metallurgical) coal, industrial use coal, and export coal was projected independent of the GEM Model and then used as an exogenous input to the modeling for the purpose of simulating appropriate overall supply/demand balances. For determining river traffic demand, these projections were broken out and elucidated individually under this project in a manner most beneficial to the USACE.

Methodology

Greenmont Energy Model

The GEM™ is an optimization model which calculates the unique combination of a large number of parameters that achieves the lowest cost of electricity generation in the United States for a given amount of electricity demand. The model uses both LP and MIP optimization techniques and thus can be characterized as an LP/MIP optimization model. GEM™ simultaneously solves 84 time blocks for a single year (six seasons times 14 time zone combinations for time-of-day load distribution). Since all this is done simultaneously, it means that in one single module of computation, optimal co-dependent values are determined for all of the varying parameters including, among others:

- amount and type of coal choice by unit;
- level of each unit's dispatch;
- environmental clean-up decisions between new equipment, fuel switching, and allowance purchasing;
- location, amount, and type of new generation capacity;
- retirement of existing units;
- amount of economically justified mining capacity expansion for each cost level for each type of coal;
- FOB coal mine prices;
- wholesale electricity prices; and
- pollutant allowance prices.

The model carries forward results from each previous year, so that in a succeeding year, the correct amount of (1) generation capacity by type, (2) mining capacity and remaining reserves by type and cost level, and (3) clean-up capacity for each pollutant are available. All of the varying parameters are output by the model in database tables. Many of the key outputs are aggregated upward to regional and national totals which are automatically graphed across years.

GEM™ modeling software optimizes steam, coal, and electricity supply, and demand price balances as they are likely to operate in a free market. The model contains highly sophisticated methods and algorithms for dealing with air emission limitations under various future scenarios. For example, the EPA's CAIR, as well as proposed Mercury and Greenhouse Gas (GHG) environmental rules, are explicitly accounted for, as these will have a significant impact on the distribution of types of coal being supplied over the coal transportation network in the United States. Due to its robust design and flexibility, GEM™

is able to accommodate the modeling of a carbon constrained economy. It also models the market for the emission allowances for the various regulated pollutants.

GEM™ includes a subsidiary transportation model called the Greenmont Transportation Model (GTM™) that models all rail and barge transportation routes for coal and sorbents with the capability to model all commodities in the United States with specialized algorithms for transportation beyond the United States, including Canada. This allows a fine level of prediction of the routes and economics of transportation of any commodity including coal and sorbents for any scenario.

The GEM™ model minimizes total system cost of U.S. electricity production and distribution and includes all power plants, regardless of fuel type, in the United States and Canada. The demand zones or areas, together with load curves, are given and connected via a transmission network. Power plants supply energy into this network. A power plant is assigned to a particular demand area, based on its location. For power plants not fired by coal or gas, a simplified generation cost and emission rate is applied. For gas-fired plants, the generation cost is based on a gas supply curve reflecting elasticity assumptions. A transportation sub-model (GTM™) optimizes coal routes.

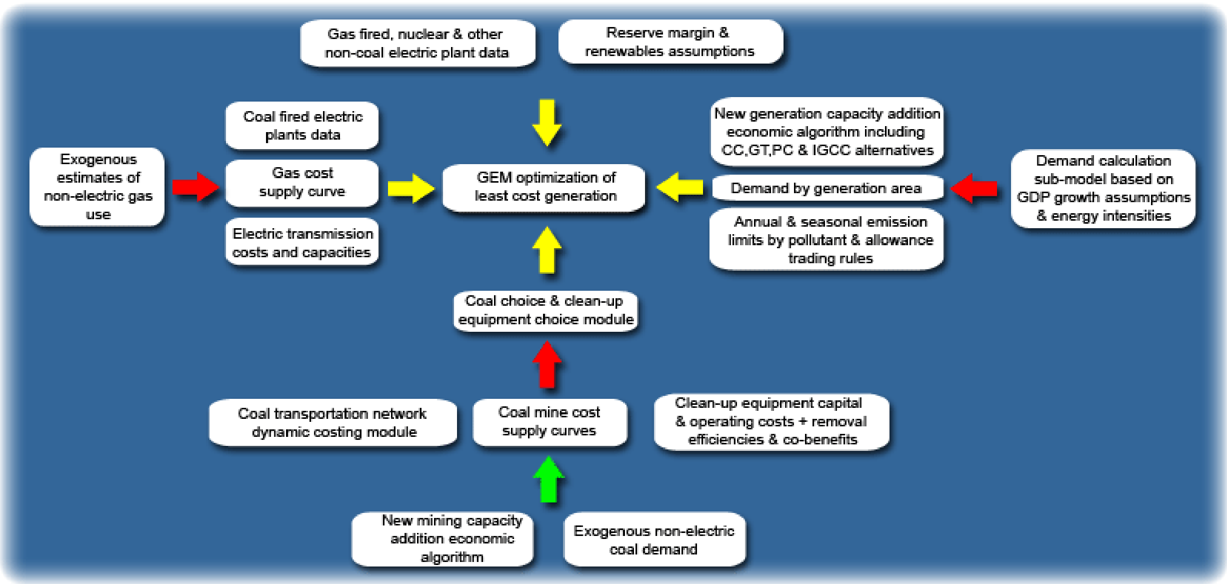
However, when it comes to coal-fired power plants, the model level of detail is unique. Coal-fired power plants, which play an important role in today's energy system, are modeled at a very detailed level. The coal-fired plants are modeled on a unit-by-unit basis with every boiler of every coal-fired power plant in the United States represented separately in the GEM™ model. Pollution abatement technology also plays a major role in the GEM™ model. Coal-fired power plants can invest or use already-installed abatement technology capacity to reduce the emission rates for all major pollutants. In addition, they can buy emission allowances from other emitters (if permitted in the scenario setup). The coal-fired power plants also have complete freedom of choice in the quality of coal to use. All coals are available to every coal-fired unit (except for coals that would be technically infeasible to burn in the unit). The delivered cost of coal is determined for each plant by a coal price which is drawn from the marginal point of production on a set of detailed mine cost supply curves and by a transportation cost estimate from the GTM™ sub-model. Additional cost modules of the GEM™ model are:

- cost of wheeling of power;
- cost for constructing a new plant of a certain type;
- generation cost; and
- cost for construction of new mining capacity (for each type of coal).

In addition to generating power with existing power plant capacity, the model can also build new, or extend existing, power plants and increase coal mining capacity to satisfy growing energy demand. However, new capacity of either type must meet economic criteria which are inputs to the model before the new capacity can be built. If the economic criteria are not met, then the additional capacity is not built, and energy commodity prices keep rising until the economics favor building new capacity.

GEM™ Components

Figure 1. GEM™ Components



<u>Typical Inputs</u>

- Electricity demand by generation area;
- bidirectional transmission capabilities between generation areas;
- gas basis differential from the Henry Hub;
- a gas price-elasticity curve based on Henry Hub prices;
- proprietary coal specific mine cost curves;

- coal Transportation Costing Module determining costs via network algorithms which allow all coals to be bid into all plants simultaneously and also allow quick and easy updating of transport mils/ton-mile rates;

- coal-fired boiler level data;

- all electric generating plants' data, included for both the United States and Canada;

- user-determined discounted cash flow internal rate of return (IRR) input as a minimum criterion for coal mine and electric plant new capacity additions;

- capital and operating cost assumptions for new generation by plant type (gas-fired CC, gas turbine (GT), PC, coal-fired IGCC, nuclear, and renewable – based on wind power costs);

- multi-pollutant allowance trading capability for any number of pollutants and/or trading regions;

- NO_x State Implementation Plant (SIP) call, CAIR, CAMR and CO_2 restrictions at annual and strict ozone season levels (i.e., SO_2, NO_x, Hg, and CO_2 limits by region, by year, and/or by season);

- coal plant turn down rate at unit level;

- capital and operating cost of clean-up equipment;

- current and announced clean-up equipment installations at existing plants for all pollutants;

- 104 modeled coal types reflecting both domestic and international coals;

- Details: Includes all domestic regions in addition to Australia, Canada, Poland, Russia, Indonesia, Colombia, and Venezuela;

- plus the ability to co-fire natural gas in each coal-fired boiler;

- 123 modeled generation areas; and

- specific mine capacity, cash mining cost estimate, reserves and expandability.

Typical Outputs

- Projected FOB Mine Prices by specific coal and year;
- projected production by specific coal and year;
- projected gas prices and volume;
- electricity wholesale prices by time of day, season, and generation area;
- electricity generation by coal-fired unit and by plant for all U.S. and Canadian plants by year;
- dispatch curves by generation area from unit level costs, by year;
- projected SO_2, NO_x, Hg, CO_2 allowances priced by year;
- projected annual new generation by plant type and location;
- coal choices by unit by year;
- optimized clean-up equipment installations by unit and year of installation; and
- generation capacity using each type of clean-up equipment by year.

ORS COAL POWER PLANT LIMESTONE-LIME SORBENT DEMAND AND SOURCING

Dry Creek Resources, Inc. (DCR) was subcontracted by LTI to work with coal and scrubber usage output from the GEM™ model to produce a forecast of annual sorbents tonnages used to clean sulfur emissions from coal burning power plants in the ORS area and to identify likely sources of sorbent material. The coal forecasts for the ORS area power plants included Base, Low, and High cases produced by the GEM™ model. These forecasts also included several specifications for each power plant to be used by DCR:

- plant name, ID number, unit designations, and physical land and river location;
- coal source and coal tons consumed in each Unit number in each forecast year from 2006 for the next 70 years;
- identification of the sulfur content of each coal used;

- sulfur removal assumptions inherent in the GEM™ model coal use forecast for each coal and power plant/unit;
- scrubbing technology specified or to be assumed; and
- an indication of which plants had likely docks with water access for barge delivery of sorbents.

LTI supplied the above for all power plants within, around, and beyond the ORS. The data files were very large and had to be substantially modified to make all data uniform for relational database use. The power plants evaluated for sorbent consumption were limited to a subset of the latter power plants that had:

- access to water and/or,
- a “high interest” from the USACE, and/or
- a historical water delivered use of sorbents to clean coal, and/or
- coal sulfur emission reduction requirements from the GEM™ model forecasts.

DCR’s forecast work was divided between determining the expected sorbent consumption at each unit and plant and then identifying the likely source of the sorbent by geographical area along the ORS.

USACE Base Case Scenario

In order to provide a benchmark for comparison purposes, most of the modeling inputs for this present Base Case were aligned with the inputs published by the Department of Energy (DOE) for their 2008 version of the Annual Energy Outlook (AEO 2008). However, from the beginning it was recognized that the resulting outputs from the similar inputs would be somewhat different because of the greatly differing methodologies between the federal government’s National Energy Modeling System (NEMS) model, which produces the AEO, and the private GEM™ model which is used in this current analysis.

Although many factors that strongly drive coal supply and demand in the United States are currently in a state of flux, the Base Case is designed to provide a “business as usual” scenario in the sense that issues which could break one way or the other in the future are modeled in this scenario as falling into a more “traditional” (or without any fundamental shift in direction) sense. Thus, it would probably be erroneous to attach to this Base Case the term "most likely scenario" since, particularly on the environmental regulatory front, it seems that some fundamental shifts in direction may very well occur in the form of climate change legislation and/or even more strict limits on SO_2, NO_x, and Hg than those in the CAIR and the CAMR that have now been vacated by the courts. Rather, this Base Case is more of a "middle of the road" scenario against which the later Low River Traffic Demand Case and the High River Traffic Demand Case can be compared. This present analysis does not attempt to assign probabilities to the three cases presented – it simply provides the input assumptions and logic behind each distinct scenario, along with the forecast of the future under such assumptions as derived from the modeling effort.

A full description of the quantitative input assumptions for the Base Case is provided in the following section, along with comparisons to the published modeling inputs for DOE's AEO 2008, where appropriate. There were instances where those quantitative inputs should differ from the AEO 2008 values.

First, the AEO process does not use a natural gas cost-supply curve, but rather has a separate modeling module to determine supply/demand/price. Therefore, this modeling effort used a gas supply curve based upon modeling done by the EPA using their Integrated Planning Model (IPM). Specifically, the EPA-IPM 2006 Base Case was used with costs adjusted to the early-2008 market. The derived curve used in this GEM™ modeling represents only the portion of the total gas supply curve that was used for the electricity sector.

Second, AEO 2008 assumed various coal mining productivity growth rates by mining region, some of which were zero or negative. Rather than suffer the effects of compounding of a negative growth rate for decades into the future, this present analysis uses the small (much lower than the long-term average trend of the last few decades) but still positive mining productivity growth rates shown in the Assumptions section below.

Third, AEO 2008 models both CAIR and CAMR, which have now been vacated by the courts. In the absence of replacement regulations or legislation, CAIR is also modeled in this current analysis, matching AEO 2008 (and, in fact, with the NO_x planning void that occurred at the start of 2009, the initial year of CAIR's NO_x rules, both sides of the lawsuit that resulted in CAIR vacatur petitioned the court to rescind that portion of the vacatur and reinstate the NO_x rules as written). However, it was decided for this present analysis that the CAMR vacatur was likely to stand, and this Base Case assumes that the court-vacated CAMR rules are replaced with a mercury MACT logic interpreted as: (1) existing coal-fired units must remove 85% of the Hg entering in the coal, and (2) newly constructed units must remove 90% of the Hg based on the amount in the feed coal.

Fourth, AEO 2008 and this present Base Case both assume no nationwide GHG legislation. However, the Base Case of this analysis differs from AEO 2008 by modeling the fact that at the regional level, northeastern states, as well as some mid-Atlantic ones, have adopted their own initiative which is now in place for reducing GHG emissions: the Regional Greenhouse Gas Initiative (RGGI). This program began in January 2009 and calls for signatory states to stabilize power sector CO_2 emissions over the first 6 years of program implementation (2009-2014) at a level roughly equal to current emissions, before initiating an emissions decline of 2.5% per year for the 4 years 2015 through 2018. This difference from AEO 2008 was adopted because the initiative was already in place at the time of modeling and thus forms a part of the "existing framework."

Apart from AEO comparisons, there are a few additional parameters that merit consideration in discussion of the setup of the Base Case. Since the GEM™ model has been developed to treat the maximum number of variables as endogenously determined outputs instead of exogenously determined inputs, much of the following discussion does not center as much on specific quantitative inputs as on underlying assumptions that are incorporated *de facto* into the methodology of the model's operation. For example, in the Base Case, it is not assumed that mine permitting problems such as valley fill restrictions (often called "mountaintop removal" restrictions, although affecting all surface mining and possibly even refuse material from coal washing plants) will become a resource constraint with regard to the supply of coal. In the GEM™ model structure, that assumption of no valley fill effect is reflected by an absence of change in (a) the new mine construction costs, (b) the current mine operating costs, and (c) the timing and discounted cash flow IRR required to build new mines.

Similarly, the model endogenously determines the optimum mix of future new capacity between coal-fired, gas-fired, nuclear, and renewable generation units. However, a practical limit was placed on the earliest time at which a currently unplanned unit of each type could be built (e.g., it would take longer to permit and construct a currently unplanned nuclear plant than it would a currently unplanned coal-fired plant), and on the total amount in any given year of some capacity types. For example, it is assumed that for various societal and political reasons, no more than 2,200 megawatts per year of new nuclear capacity could be permitted and built initially, with that annual limit gradually increasing to 3,000 megawatts per year by 2022 and on up to 4,000 megawatts per year by 2032 and holding at that level thereafter. Having such a limit in the model does not force that amount of new nuclear capacity to be built – it simply places an upper limit on the amount that could be built in the event that the optimization determines that nuclear is highly desirable.

Assumptions

The following provides a discussion of selected modeling assumptions used in the GEM™ model for the Base Case. For comparison, DOE's AEO 2008 assumptions are also indicated.

Note, the GEM™ input assumptions shown can be modified, and some are in the alternate cases. In some instances the inputs shown only go to 2050. This is for illustrative purposes only. The GEM™ model is designed to go as far as 2100, and this forecast went through 2070.

Gross Domestic Product

AEO 2008 reference case assumes real GDP growth at an average annual rate of 2.4% from 2006 to 2030. Thus, the proposed GEM™ input for the USACE base case scenario is:

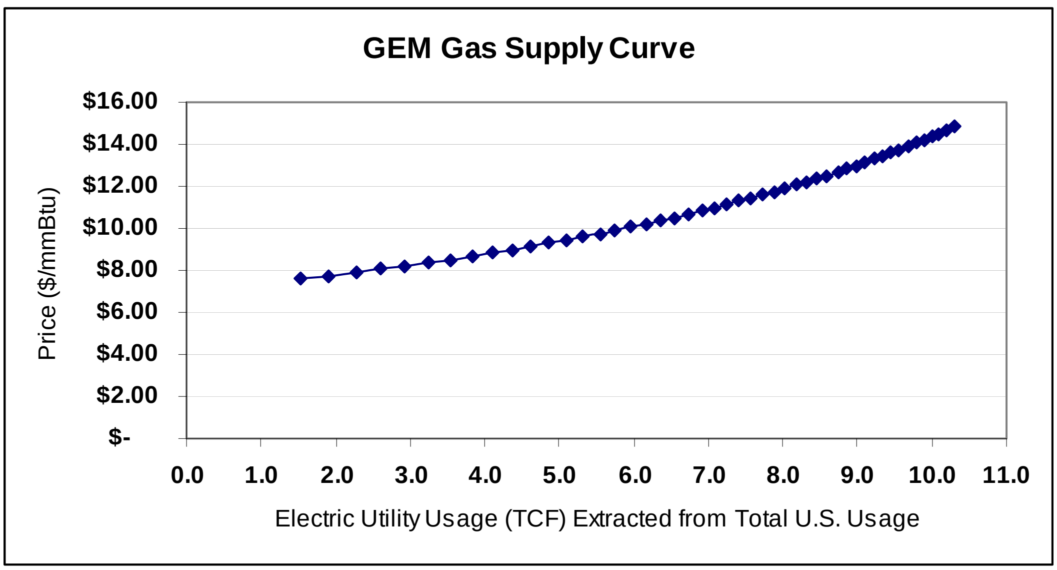
Year	GDP growth ratio
2006	1.000
2007	1.0218
2008	1.024
2009	1.024
2010	1.024
2011	1.024
2012	1.024
2013	1.024
2014	1.024
2015	1.024
2016	1.024
2017	1.024
2018	1.024
2019	1.024
2020	1.024
2021-2070	1.024

To provide a more accurate forecast, the GEM™ model uses regionalized GDP. Regional GDP values are determined by applying a Regional Growth Ratio to the national GDP. The ratio of regional GDP growth to U.S. GDP growth is determined by taking actual data that covers a recent 5-year period and calculating the regional growth ratio. These values are shown in the following table:

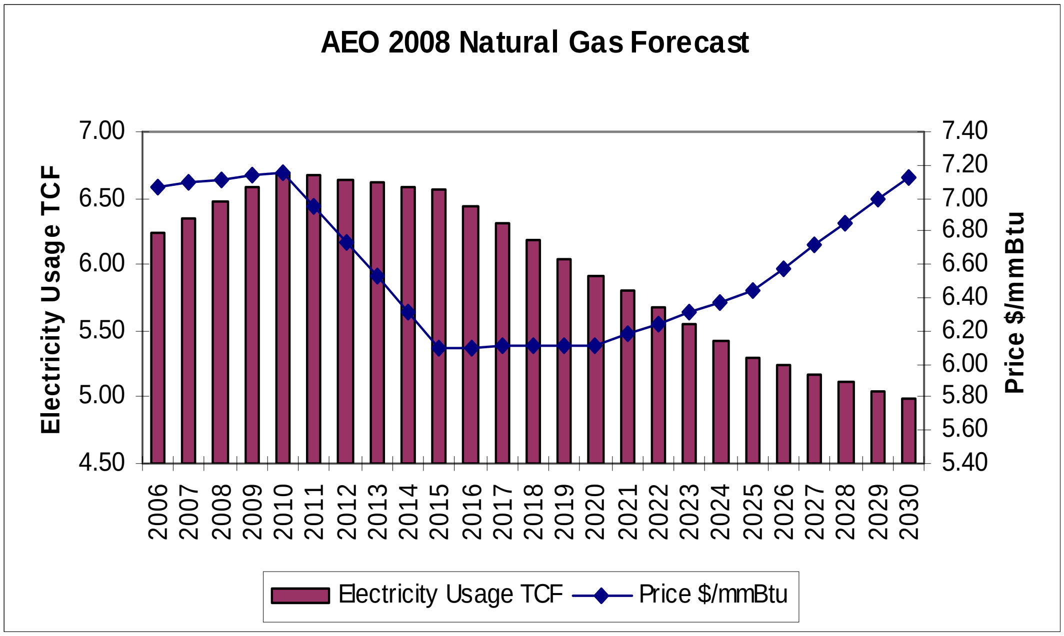
CENSUS_REG	Avg. GDP Growth	Regional Growth Ratio
NE	2.03%	83.17%
MAT	2.35%	96.30%
SAT	3.29%	134.80%
ENC	1.09%	44.72%
ESC	2.90%	119.11%
WNC	2.24%	91.74%
WSC	2.26%	92.78%
MTN	3.45%	141.56%
PAC	2.68%	109.90%
US	2.44%	100.00%

Natural Gas Supply Curve Assumption in GEM™

The following supply curve is based on EPA-IPM 2006 Base Case with costs adjusted to reflect current markets. The curve used in GEM™ represents only the portion of the total gas supply curve that was used for the electricity sector.



AEO does not use a gas cost-supply curve, but rather has a separate modeling module to determine supply/demand/price. However, the AEO output of final electric sector gas usage and gas price was able to be plotted (as shown below). The AEO natural gas forecast graph includes linear interpolation since AEO only lists data points for 2006, 2010, 2015, 2020, 2025, and 2030. While listed here for illustrative purposes, the AEO natural gas forecast is not comparable to the GEM™ natural gas cost curve. As noted above, the gas cost curve used in this forecasting is an updated form of one used by EPA in their 2006 Base Case.



U.S. Metallurgical Coal, Industrial, Metallurgical Coal Export and Steam Coal Export

The following two tables present a comparison of AEO 2008 and GEM inputs for metallurgical, export, industrial, and coal-to-liquid tonnages. In order to directly compare the inputs, the following is noted:

- the coke plants entry in the AEO table is comparable to U.S metallurgical (USMET) in the GEM™ table,
- the other industrial entry in the AEO table is comparable to industrial (INDUS) in the GEM™ table,
- the combined coal-to-liquids entry is comparable in both tables, and
- the export entry in the AEO table is comparable to the sum of metallurgical coal export (METEX) and steam coal export (STEAMEX) in the GEM™ table.

AEO 2008 Appendix A – Table A15 (million short tons)

	2006	2010	2015	2020	2025	2030
Coke Plants	23	23	21	20	20	18
Other Industrial	61	64	60	59	58	58
Combined Coal-to- Liquids	0	0	17	42	46	64
Exports	50	71	45	34	35	35

The projections of U.S. coal exports, both for metallurgical and steam purposes, were derived independent of the GEM™ Model. The projections were derived from international markets with U.S. producers being suppliers of last resort. The very early year projections reflect the 2000-2008 surge in U.S. exports arising from a confluence of international supply and demand factors, including strong demand growth in China and India coupled with supply difficulties in several different countries, especially Australia and South Africa. However, as time progresses in the forecast, the projections for later years reflect the fact that the United States is almost always the "supplier of last resort" in the international market and, except for relatively brief periods, other supply sources usually expand to absorb demand increases, leaving the United States to supply its traditional specialty niche international markets.

As indicated by the tables above and below, use of this methodology yielded results that were a close match to the DOE AEO 2008 declining trend for coal exports in the longer term.

GEM™ Inputs (thousand short tons)

	USMET	INDUS	METEX	STEAMEX	COAL-TO- LIQUIDS
2008	22,500	63,231	45,000	28,500	
2009	22,000	63,538	43,000	28,500	
2010	22,500	63,846	42,500	28,500	
2011	23,000	64,154	39,000	24,000	
2012	23,000	63,000	36,000	21,000	
2013	22,000	62,000	34,000	19,000	3,000
2014	22,000	61,000	32,000	17,000	10,000
2015	21,000	60,000	30,000	15,000	17,000
2016	21,000	60,000	28,000	15,000	20,000
2017	20,500	59,500	26,000	14,000	25,000
2018	20,500	59,500	24,000	14,000	30,000
2019	20,500	59,500	22,000	13,500	35,000
2020	20,000	59,000	21,000	13,000	42,000
2021	20,000	59,000	21,000	14,000	43,000
2022	20,000	59,000	21,000	14,000	44,000
2023	20,000	58,500	21,000	14,000	45,000

	USMET	INDUS	METEX	STEAMEX	COAL-TO- LIQUIDS
2024	20,000	58,500	21,000	14,000	45,500
2025	20,000	58,000	21,000	14,000	46,000
2026	19,000	58,000	21,000	14,000	49,000
2027	19,000	58,000	21,000	14,000	53,000
2028	19,000	58,000	21,000	14,000	57,000
2029	18,000	58,000	21,000	14,000	60,000
2030	18,000	58,000	21,000	14,000	64,000
2031	18,000	58,000	21,000	14,000	64,000
2032	18,000	58,000	21,000	14,000	64,000
2033	18,000	58,000	21,000	14,000	64,000
2034	18,000	58,000	21,000	14,000	64,000
2035	18,000	58,000	21,000	14,000	64,000
2036	18,000	58,000	21,000	14,000	64,000
2037	18,000	58,000	21,000	14,000	64,000
2038	18,000	58,000	21,000	14,000	64,000
2039	18,000	58,000	21,000	14,000	64,000
2040	18,000	58,000	21,000	14,000	64,000
2041	18,000	58,000	21,000	14,000	64,000
2042	18,000	58,000	21,000	14,000	64,000
2043	18,000	58,000	21,000	14,000	64,000
2044	18,000	58,000	21,000	14,000	64,000
2045	18,000	58,000	21,000	14,000	64,000
2046	18,000	58,000	21,000	14,000	64,000
2047	18,000	58,000	21,000	14,000	64,000
2048	18,000	58,000	21,000	14,000	64,000
2049	18,000	58,000	21,000	14,000	64,000
2050	18,000	58,000	21,000	14,000	64,000
2051-2070	18,000	58,000	21,000	14,000	64,000

U.S. Metallurgical Coal

As discussed earlier, it was desired to have this project's forecast basis be as close to DOE's AEO 2008 as was reasonable. The previous two tables show that the future U.S. metallurgical coal tonnage used as an exogenous input in this project matches closely with the AEO 2008 statement of metallurgical coal demand. The following table provides a more complete picture of the likely steel/pig iron/coke production that would lead to these met coal demand numbers.

U.S. Domestic Metallurgical Coal Demand Forecast

Year	Crude Steel Production	Pig Iron	Coke Consumption	Net Coke Imports	Coke Stock Change	Coke Production	Domestic Demand Coking Coal
2000	111,983	52,666	23,242	2,635	201	20,808	28,939
2001	99,114	46,318	20,202	1,180	-73	18,949	26,075
2002	100,746	44,248	19,603	2,450	-375	16,778	23,656
2003	103,045	44,708	19,437	2,037	-227	17,173	24,248
2004	109,649	46,520	22,491	5,554	-28	16,909	23,670
2005	104,387	40,944	18,238	1,782	263	16,719	23,434
2006	108,413	41,693	18,785	2,452	71	16,404	22,957
2007	106,933	39,292	17,269	1,016	-52	16,201	22,715
2008	101,000	38,885	17,304	1,232	0	16,071	22,500
2009	100,000	38,500	17,133	1,418	0	15,714	22,000
2010	102,000	39,270	17,475	1,404	0	16,071	22,500
2011	103,000	39,655	17,646	1,218	0	16,429	23,000
2012	103,000	39,655	17,646	1,218	0	16,429	23,000
2013	103,000	39,655	17,646	1,932	0	15,714	22,000
2014	103,000	39,655	17,646	1,932	0	15,714	22,000
2015	103,000	39,655	17,646	2,646	0	15,000	21,000
2016	103,000	39,655	17,646	2,646	0	15,000	21,000
2017	103,000	39,655	17,646	3,004	0	14,643	20,500
2018	103,000	39,655	17,646	3,004	0	14,643	20,500
2019	103,000	39,655	17,646	3,004	0	14,643	20,500
2020	103,000	39,655	17,646	3,361	0	14,286	20,000
2021	103,500	39,848	17,732	3,446	0	14,286	20,000
2022	103,500	39,848	17,732	3,446	0	14,286	20,000
2023	103,500	39,848	17,732	3,446	0	14,286	20,000
2024	103,500	39,848	17,732	3,446	0	14,286	20,000
2025	103,500	39,848	17,732	3,446	0	14,286	20,000
2026	103,500	39,848	17,732	4,161	0	13,571	19,000
2027	103,500	39,848	17,732	4,161	0	13,571	19,000
2028	103,500	39,848	17,732	4,161	0	13,571	19,000
2029	103,500	39,848	17,732	4,875	0	12,857	18,000

2030	103,500	39,848	17,732	4,875	0	12,857	18,000
2031	104,000	40,040	17,818	4,961	0	12,857	18,000
2032	104,000	40,040	17,818	4,961	0	12,857	18,000
2033	104,000	40,040	17,818	4,961	0	12,857	18,000
2034	104,000	40,040	17,818	4,961	0	12,857	18,000
2035	104,000	40,040	17,818	4,961	0	12,857	18,000
2036	104,000	40,040	17,818	4,961	0	12,857	18,000
2037	104,000	40,040	17,818	4,961	0	12,857	18,000
2038	104,000	40,040	17,818	4,961	0	12,857	18,000
2039	104,000	40,040	17,818	4,961	0	12,857	18,000
2040	104,000	40,040	17,818	4,961	0	12,857	18,000
2041	104,500	40,233	17,903	5,046	0	12,857	18,000
2042	104,500	40,233	17,903	5,046	0	12,857	18,000
2043	104,500	40,233	17,903	5,046	0	12,857	18,000
2044	104,500	40,233	17,903	5,046	0	12,857	18,000
2045	104,500	40,233	17,903	5,046	0	12,857	18,000
2046	104,500	40,233	17,903	5,046	0	12,857	18,000
2047	104,500	40,233	17,903	5,046	0	12,857	18,000
2048	104,500	40,233	17,903	5,046	0	12,857	18,000
2049	104,500	40,233	17,903	5,046	0	12,857	18,000
2050	104,500	40,233	17,903	5,046	0	12,857	18,000
2051	105,000	40,425	17,989	5,132	0	12,857	18,000
2052	105,000	40,425	17,989	5,132	0	12,857	18,000
2053	105,000	40,425	17,989	5,132	0	12,857	18,000
2054	105,000	40,425	17,989	5,132	0	12,857	18,000
2055	105,000	40,425	17,989	5,132	0	12,857	18,000
2056	105,000	40,425	17,989	5,132	0	12,857	18,000
2057	105,000	40,425	17,989	5,132	0	12,857	18,000
2058	105,000	40,425	17,989	5,132	0	12,857	18,000
2059	105,000	40,425	17,989	5,132	0	12,857	18,000
2060	105,000	40,425	17,989	5,132	0	12,857	18,000
2061	105,500	40,618	18,075	5,218	0	12,857	18,000
2062	105,500	40,618	18,075	5,218	0	12,857	18,000
2063	105,500	40,618	18,075	5,218	0	12,857	18,000
2064	105,500	40,618	18,075	5,218	0	12,857	18,000
2065	105,500	40,618	18,075	5,218	0	12,857	18,000
2066	105,500	40,618	18,075	5,218	0	12,857	18,000
2067	105,500	40,618	18,075	5,218	0	12,857	18,000
2068	105,500	40,618	18,075	5,218	0	12,857	18,000
2069	105,500	40,618	18,075	5,218	0	12,857	18,000
2070	105,500	40,618	18,075	5,218	0	12,857	18,000

The table illustrates that with fairly flat or minimally growing crude steel production in the United States, a rising amount of coke imports would be likely as coke oven capacity does not increase and, in fact, declines over time. The fundamental rationale behind this lack of investment capital into U.S. coke oven capacity is a combination of economics and environmental challenge. It has been demonstrated in recent years that because of these two factors, expansion of overseas coking capacity is much more likely than expansion in the United States.

Since U.S. domestic metallurgical (met) coal is a very small slice of the total tonnage and fits only a few types of the coals, it was not made part of the external demand directly dependent on the U.S. GDP growth of each scenario. However, as stated earlier, all MEIO (domestic Met coal, Export coal of both the steam and met varieties, Industrial steam coal, and "Other" – indicating primarily Coal-To-Liquids plants) categories were raised, including U.S. domestic met coal usage, in the High Case by 5 mmtpy.

New Generation Capacity

New Plant Overnight Capital and Operations and Maintenance (O&M) Building Costs by Plant Type and earliest year plant can be built as a result of model optimization (units stated in 2006 $/kilowatt (kW) to compare with AEO 2008, although GEM™ operated in 2008$) are listed below for AEO 2008 and GEM™.

Excerpt from AEO 2008 (Table 38: Cost and Performance Characteristics of New Central Station Electricity Generating Technologies)

Technology	Online Year	Base* Overnight Cost in 2007 ($2006/kW)	Heat Rate (Btu/KWh)
Conv. Combustion Turbine	2009	$ 476	10,450
Conv. Gas/Oil Comb Cycle	2011	$ 683	6,800
Coal New	2011	$ 1,434	8,740
IGCC	2011	$ 1,657	7,450
Advanced Nuclear	2016	$ 2,143	10,400
Wind	2010	$ 1,340	10,022

*Base overnight costs do not include AEO's "project contingency factor" and "technological optimism factor" which AEO uses to effectively raise or lower their stated costs.

The table below lists the similar GEM™ input capital costs which are drawn from extensive project work with GEM™ for DOE and which reflect the extensive studies recently performed by DOE's National Energy Technology Laboratory (NETL) and reported in "Cost and Performance Baseline for Fossil Energy Plants" (DOE/NETL-2007/1281).

Plant type	Step 1 (first 1000 MW)	Step 2 (Additional 3000 MW)	Step 3 (Additional 4000 MW)	Step 4 (Additional 4000 MW)	Step 5 (Additional 3000 MW)	Step 6 (Additional 5000 MW)	O&M Adder	Start year	Heat Rate (Btu/KWh)
Gas Turbine	407	412	417	422	462	612	3.25	2008**	10,000
Combined Cycle	549	554	559	563	596	737	2.25	2011	7,000
Pulverized Coal	1556	1562	1568	1574	1880	2316	1.75	2011	10,000
IGCC	1835	1841	1847	1854	1885	2292	2.25	2011	9,200
Nuclear	2073	2081	2089	2098	2504	3085	0.45	2014	-
Renewables (wind costs assumed)	1167	1172	1176	1181	1410	1737	0.1	2008***	-

** must be allowed to be built in 2008 for reserve margin requirements
*** must be allowed to be built in 2008 for Renewable Portfolio Standard (RPS) requirements

All costs steps used in GEM™ are subject to a cost learning curve to reflect that with the advancement of technology, overnight building costs will decrease over time. AEO 2008 also has "learning curve" adjustments downward in costs over time, but we do not compare those here. The GEM™ learning curve values are:

Plant Type / $/kW reduction from original capital cost	2011-2014	2015-2019	2020-2024	2025-2029	2030-2070
PC All Steps	-16	-32	-50	-65	-78
CC All Steps	-8	-15	-22	-29	-37
GT All Steps	-5	-10	-15	-20	-26
IG All Steps	-29	-58	-104	-179	-254
NUC All Steps	-50	-101	-182	-232	-281
REN	0	0	0	0	0

Seasonal Availability of Fuel Types (Capacity Factors)

Although AEO does not list any information on assumed seasonal availability of units, the GEM™ model seasonal availabilities, which reflect industry-wide typical down times for both scheduled and unscheduled maintenance, are listed since they are key inputs determining the maximum allowed usage of any generating unit.

Primary Fuel	Summer	Winter	Spring1	Spring2	Fall1	Fall2
COAL	0.940	0.940	0.760	0.790	0.820	0.850
GAS	0.950	0.880	0.920	0.950	0.950	0.920
GEO	0.980	0.980	0.980	0.980	0.980	0.980
HY	0.850	0.600	0.800	0.950	0.800	0.750

Primary Fuel	Summer	Winter	Spring1	Spring2	Fall1	Fall2
NUC	0.890	0.890	0.890	0.890	0.890	0.890
OIL	0.950	0.880	0.920	0.950	0.950	0.920
WND	0.850	0.850	0.850	0.850	0.850	0.850
WOOD	0.940	0.700	0.850	0.940	0.940	0.850
REN	0.850	0.850	0.850	0.850	0.850	0.850

Mine Productivity Gain by Coal Region

The table below compares AEO 2008 and GEM™ annual average mine productivity growth. GEM™ mine productivity assumptions are at the coal type level (104 types of coal) but were aggregated back up to the basin level for comparative purposes.

Coal Region	AEO Average Annual Productivity Growth 06-30	GEM Average Annual Productivity Growth 06-30
Northern Appalachia	0.10%	0.3%-1.0%*
Central Appalachia	-0.90%	0.2%-0.5%*
Southern Appalachia	-1.00%	1.50%
Eastern Interior	0.20%	1.00%
Western Interior	0.00%	0.10%
Gulf Lignite	-0.50%	0.30%
Dakota Lignite	0.50%	0.50%
Wyoming, Northern PRB	-0.10%	3.00%
Wyoming, Southern PRB	-0.50%	3.00%
Rocky Mountain	0.10%	0.5%-1.5%*
Arizona/New Mexico	0.20%	2.0%-3.0%*
Alaska/Washington	0.00%	0.30%

* Because GEM™ includes 104 types of coal, there are instances where there is more than one mine productivity growth level per coal region. In those instances a range is listed in the table above.

This assumption is one of the few areas where the GEM's™ inputs were not adjusted to match the AEO 2008 assumptions, since the GEM™ values are believed to be much more carefully researched from mine-by-mine MSHA quarterly production and manpower records to reflect the reality in the coal mining areas.

Coal Specifications Modeled

AEO models only 14 coal supply regions in NEMS whereas the GEM™ model uses 104 unique types of coal. This is one facet of the greater granularity of the GEM™ model described above. The 104 coal types, with their respective characteristics, used in GEM™ are listed below:

Basin	Coal Area	Coal Type	Btu	% Sulfur	#SO_2	CO_2 Rate (lbs/mmBtu)	HG lbs/TTBtu
SAPP	Alabama	Compliance	11,830	0.70	1.18	205.50	6.4699
SAPP	Alabama	High-Sulfur	11,460	2.40	4.19	205.50	9.4699
SAPP	Alabama	Mid-Sulfur	11,800	1.70	2.88	205.50	8.4699
SAPP	Alabama	Near-Compliance	12,000	1.10	1.83	205.50	7.4699
ANT	Anthracite	Near-Compliance	6,250	0.49	1.57	227.40	17.8222
SOW	Arizona	Super-Compliance	10,900	0.50	0.92	209.70	3.1271
OIMP	Australia	Super-Compliance	11,750	0.45	0.76	213.40	8.0000
CAPP	Blue Gem	Near-Compliance	12,500	1.10	1.76	204.80	4.7286
OIMP	Canada	Super-Compliance	11,920	0.48	0.81	213.40	8.0000
COLO	Colorado-Green River-High Btu	Super-Compliance	11,400	0.45	0.79	206.20	2.0433
COLO	Colorado-Green River-Mid Btu	Super-Compliance	10,500	0.45	0.86	206.20	2.0433
NAPP	Central Pennsylvania	Compliance	11,200	0.62	1.11	205.70	16.8222
NAPP	Central Pennsylvania	High-Sulfur	10,000	3.20	6.40	205.70	19.8222
NAPP	Central Pennsylvania	Mid-Sulfur	11,990	1.89	3.15	205.70	18.8222
NAPP	Central Pennsylvania	Near-Compliance	11,980	1.28	2.14	205.70	17.8222
COLO	Colorado-Uinta-High Btu	Super-Compliance	11,900	0.48	0.81	206.20	3.5330
COLO	Colorado-Uinta-Mid Btu	Super-Compliance	10,000	0.48	0.96	206.20	3.5330
GLF	Gulf Coast- San Miguel	High-Sulfur	5,200	1.98	7.62	213.50	20.0000
GLF	Gulf Coast- Sandow	High-Sulfur	5,900	1.40	4.75	213.50	20.0000
GLF	Gulf Coast- Calvert	Mid-Sulfur	6,700	0.98	2.93	213.50	18.0000
GLF	Gulf Coast- Jewett	Mid-Sulfur	6,500	0.84	2.58	213.50	18.0000
GLF	Gulf Coast- Big Brown	Near-Compliance	7,000	0.86	2.46	213.50	17.0000
GLF	Gulf Coast- Darco (Dolet Hills & Oxbow)	Mid-Sulfur	6,800	1.07	3.15	213.50	18.0000
GLF	Gulf Coast- Monticello	Compliance	7,100	0.40	1.13	213.50	16.0000
GLF	Gulf Coast- Martinslake	High-Sulfur	6,900	1.78	5.16	213.50	20.0000
GLF	Gulf Coast- S.Hallsville	Mid-Sulfur	6,500	1.14	3.51	213.50	18.0000
GLF	Gulf Coast- Gibbons Creek	High-Sulfur	4,800	1.55	6.45	213.50	16.0000

Basin	Coal Area	Coal Type	Btu	% Sulfur	$\#SO_2$	CO_2 Rate (lbs/mmBtu)	HG lbs/TTBtu
GLF	Gulf Coast- Twin Oaks	Mid-Sulfur	6,700	0.98	2.93	213.50	18.0000
ILB	Illinois	High-Sulfur	11,350	3.10	5.46	203.50	6.8718
ILB	Illinois	Mid-Sulfur	11,100	1.65	2.97	203.50	5.8718
ILB	Illinois	Near-Compliance	11,000	1.00	1.82	203.50	4.8718
ILB	Indiana	Compliance	10,940	0.60	1.10	203.60	5.9694
ILB	Indiana	High-Sulfur	11,250	3.18	5.65	203.60	6.9694
ILB	Indiana	Mid-Sulfur	11,100	1.69	3.05	203.60	5.9694
ILB	Indiana	Near-Compliance	11,100	1.09	1.96	203.60	6.1747
INDO	Indonesia-High Btu	Super-Compliance	11,100	0.50	0.90	213.40	7.1747
INDO	Indonesia-Mid Btu	Ultra-Compliance	9,400	0.10	0.21	213.40	7.1747
CAPP	Eastern Kentucky-High Btu-CSX	Super-Compliance	12,900	0.61	0.95	204.80	2.7286
CAPP	Eastern Kentucky-High Btu-NS	Super-Compliance	12,600	0.60	0.95	204.80	2.7286
CAPP	Eastern Kentucky-Mid Btu-CSX	Compliance	12,390	0.73	1.18	204.80	3.7286
CAPP	Eastern Kentucky-Mid Btu-CSX	Mid-Sulfur	12,400	1.73	2.79	204.80	5.7286
CAPP	Eastern Kentucky-Mid Btu-CSX	Near-Compliance	12,360	1.05	1.70	204.80	3.7286
CAPP	Eastern Kentucky-Mid Btu-NS	Compliance	12,600	0.71	1.13	204.80	3.7286
CAPP	Eastern Kentucky-Mid Btu-NS	Mid-Sulfur	11,932	1.72	2.88	204.80	5.7286
CAPP	Eastern Kentucky-Mid Btu-NS	Near-Compliance	12,240	1.04	1.70	204.80	6.1747
LATA	Latin America-High Btu	Compliance	12,820	0.67	1.05	213.40	7.1747
LATA	Latin America-Mid Btu	Super-Compliance	11,700	0.55	0.94	213.40	7.1747
NAPP	Maryland	Mid-Sulfur	12,360	1.76	2.85	210.20	16.7323
NAPP	Maryland	Near-Compliance	12,820	1.30	2.03	210.20	15.7323
MWI	Midwest Interior	High-Sulfur	11,370	3.90	6.86	205.90	20.0000
NDL	North Dakota-Savage	Near-Compliance	6,600	0.57	1.73	218.80	6.9794
NDL	North Dakota-Freedom	Near-Compliance	6,600	0.64	1.94	218.80	6.9794
NDL	North Dakota-Falkirk	Near-Compliance	6,300	0.60	1.90	218.80	6.9794
NDL	North Dakota-Center	Mid-Sulfur	6,700	0.85	2.54	218.80	7.9794
NDL	North Dakota-Coyote	Mid-Sulfur	6,950	1.09	3.14	218.80	7.9794
NDL	North Dakota-Heskett	Near-Compliance	7,300	0.71	1.95	218.80	6.9794
SOW	New Mexico	Near-Compliance	9,250	0.80	1.73	205.70	7.2349
SOW	New Mexico	Super-Compliance	9,830	0.45	0.92	205.70	5.2349
NAPP	Northern West Virginia	Compliance	12,400	0.71	1.15	207.10	8.1645
NAPP	Northern West Virginia	High-Sulfur	12,200	3.39	5.56	207.10	11.1645

Basin	Coal Area	Coal Type	Btu	% Sulfur	#SO_2	CO_2 Rate (lbs/mmBtu)	HG lbs/TTBtu
NAPP	Northern West Virginia	Mid-Sulfur	12,700	2.04	3.21	207.10	10.1645
NAPP	Northern West Virginia	Near-Compliance	12,300	1.01	1.64	207.10	9.1645
NAPP	Ohio	High-Sulfur	12,200	3.75	6.15	202.80	16.6119
NAPP	Ohio	Mid-Sulfur	12,300	2.25	3.66	202.80	15.6119
NAPP	Ohio	Near-Compliance	12,285	1.20	1.95	202.80	14.6119
PET	Pet Coke	High-Sulfur	14,000	5.19	7.41	227.40	8.0000
PRB	PRB-Montana	Near-Compliance	8,650	0.66	1.53	213.40	5.1077
PRB	PRB-Montana	Super-Compliance	9,360	0.35	0.75	213.40	3.1077
PRB	PRB-North Gillette	Compliance	8,100	0.44	1.09	213.40	8.9057
PRB	PRB-North Wright	Super-Compliance	8,800	0.33	0.75	212.70	5.1077
CAPP	Pocahontas	Compliance	13,800	0.78	1.13	207.10	4.3054
OIMP	Poland	Super-Compliance	12,125	0.52	0.86	213.40	8.0000
PRB	PRB-South Gillette	Super-Compliance	8,500	0.33	0.78	212.70	5.1077
PRB	PRB-South Wright	Ultra-Compliance	8,800	0.21	0.48	212.70	4.1077
CAPP	Southern West Virginia-High Btu-CSX	Super-Compliance	12,500	0.61	0.98	207.10	6.1645
CAPP	Southern West Virginia-High Btu-NS	Super-Compliance	12,000	0.57	0.95	207.10	6.1645
CAPP	Southern West Virginia-Mid Btu-CSX	Compliance	12,300	0.69	1.12	207.10	7.1645
CAPP	Southern West Virginia-Mid Btu-CSX	Mid-Sulfur	12,900	1.68	2.60	207.10	9.1645
CAPP	Southern West Virginia-Mid Btu-CSX	Near-Compliance	11,500	0.83	1.44	207.10	8.1645
CAPP	Southern West Virginia-Mid Btu-NS	Compliance	12,400	0.70	1.13	207.10	7.1645
CAPP	Southern West Virginia-Mid Btu-NS	Mid-Sulfur	13,100	2.01	3.07	207.10	9.1645
CAPP	Southern West Virginia-Mid Btu-NS	Near-Compliance	12,400	0.80	1.29	207.10	8.1645
SOW	Raton Basin	Super-Compliance	10,100	0.44	0.87	205.70	2.0433
OIMP	Russia	Super-Compliance	11,685	0.50	0.85	213.40	7.0000
SWY	Southern Wyoming	Near-Compliance	9,700	0.84	1.73	206.50	5.6991
SWY	Southern Wyoming	Super-Compliance	9,500	0.43	0.91	206.50	4.6991
CAPP	Tennessee	Compliance	12,800	0.73	1.14	204.80	5.2468
CAPP	Tennessee	Mid-Sulfur	12,200	1.96	3.21	204.80	7.2468
CAPP	Tennessee	Near-Compliance	12,700	1.16	1.83	204.80	6.2468
TRA	Waste Coal	Mid-Sulfur	6,600	1.28	3.88	203.60	2.0000
UTA	Utah	Near-Compliance	11,900	0.96	1.61	204.10	4.3334
UTA	Utah	Super-Compliance	11,300	0.48	0.85	204.10	2.3334
CAPP	Virginia	Compliance	12,850	0.72	1.12	206.20	4.3054

Basin	Coal Area	Coal Type	Btu	% Sulfur	#SO_2	CO_2 Rate (lbs/mmBtu)	HG lbs/TTBtu
CAPP	Virginia	Mid-Sulfur	12,500	1.81	2.90	206.20	6.3054
CAPP	Virginia	Near-Compliance	12,600	0.96	1.52	206.20	5.3054
CAPP	Virginia	Super-Compliance	13,000	0.61	0.94	206.20	3.3054
WAS	Washington	Near-Compliance	7,800	0.91	2.33	203.60	6.4535
ILB	Western Kentucky	High-Sulfur	11,200	3.30	5.89	203.20	7.4535
ILB	Western Kentucky	Mid-Sulfur	12,600	2.40	3.81	203.20	6.7286
ILB	Western Kentucky	Near-Compliance	11,000	1.00	1.82	203.20	4.8718
NAPP	Western Pennsylvania	Compliance	12,300	0.69	1.12	205.70	16.8222
NAPP	Western Pennsylvania	High-Sulfur	12,100	2.97	4.91	205.70	19.8222
NAPP	Western Pennsylvania	Mid-Sulfur	13,000	2.07	3.18	205.70	18.8222
NAPP	Western Pennsylvania	Near-Compliance	13,000	1.41	2.17	205.70	17.8222

Miscellaneous Assumed Inputs

For “other” capital such as clean-up equipment (i.e., those capital cost items in the model that are not IRR-driven in the methodology, as new plant and new mine construction are):

Discount period: 20 years
Discount rate: 10%

For electric transmission:

Line loss penalty for wheeled power: 4%

Mercury Emission Regulations

On February 8, 2008, the Circuit Court of Appeals of the District of Columbia vacated the CAMR, siding with several states and environmental groups who sued EPA (State of New Jersey vs. EPA, No. 05-1097, *et al.*). The court ruled that EPA lacks the authority to remove electric utility steam generating units (EGU’s) from the list of regulated source categories subject to stringent MACT standards under section 112 of the Clean Air Act (CAA) except by applying the delisting criteria specified in the Act.

Those delisting criteria require that EPA demonstrate that no EGU emits mercury in an amount which would exceed a level adequate to protect health with ample margin of safety and that no adverse environmental effect will result from those emissions. Under such an extreme burden of proof, it seems unlikely that EPA would be able to implement any program which removes EGU's from the section 112 MACT requirement and places them in a section 111 (New Source Performance Standard) cap-and-trade program with free market allowance trading.

Since EPA's own interpretation of the CAA stated that EGU's must first be removed from the MACT standards (section 112 of the Act) before they could be controlled under any cap-and-trade program (such as CAMR) implemented under a different section (section 111 of the Act), the court ruled that disallowing the delisting necessarily means that CAMR must be vacated. Thus, any effort to project the future must deal with the fact that (a) no federal mercury regulations are technically in existence since the EGU's technically revert back to being under MACT restrictions and no specific set of MACT rules has been promulgated, and (b) any future mercury rules must either be MACT-oriented or be a court-approved settlement among the parties of some [presumably much stricter] set of cap-and-trade rules.

Until EPA promulgates a new rule, existing power plants will be subject only to state regulations for mercury (several states have adopted rules), and (pursuant to section 112(g)) new power plants are required to obtain case-by-case MACT determinations from state permitting authorities. However, for the purposes of this project we assumed nationwide MACT limits as discussed below.

AEO 2008 models CAMR which has since been vacated and is no longer relevant. In the modeling for this project, we assume that the court-vacated CAMR rules are replaced with a MACT logic interpreted as: (1) Existing coal-fired units must remove 85% of the Hg entering in the coal. (2) Newly constructed units must remove 90% of the Hg based on the amount in the feed coal.

Greenhouse Gas Emission Regulations

S. 2191, the Lieberman-Warner bill, was the first climate change legislation to emerge from the Senate Environment & Public Works Committee and be sent to the Senate floor for debate. Renumbered S. 3036, and substantially revised by Chairman Boxer's "Substitute Amendment," the bill remained on the floor for less than 1 week before being pulled by the Democratic leadership.

The bill was relatively stringent, as compared to other recent climate change bills, and was comprehensive. Oil and gas were regulated "upstream" at points of origin (refineries, natural gas processing plants); coal was regulated "downstream" at major users, like power plants. Non-CO_2 Greenhouse Gases (GHGs) were also covered, although certain agricultural emissions were not covered. Regulated entities were required to submit one GHG allowance for each ton of CO_2 emitted (or potential emissions in the case of oil and gas). The overall emission cap began at 5.775 billion tons per year (tpy) in 2012, and declined to 1.732 billion tpy in 2050.

The major change in the final bill as it emerged on the Senate floor was not in the targets and timetables for GHG emission reductions, but rather in the distribution of “free” allowances and revenues from government-auctioned allowances to fund favored activities. For example, significant amounts of allowances were directed to certain classes of major GHG emitters, although this distribution generally declined to zero over time. Certain low GHG emitting technologies received either allowances or dollars from the auction of allowances. Carbon capture and storage (CCS) technologies received both “Bonus Allowances” and revenues for early deployment, totaling about $200 billion over the life of these programs, assuming allowance prices consistent with EPA projections. Other activities intended to offset the economic impact of regulation (retraining of displaced workers), or the environmental impact of emissions (wildlife adaptation), consumed large quantities of the roughly $10 trillion in allowance value (total estimated allowance values vary).

A number of government agencies and private sector groups performed computer simulations of the cost and energy impacts of the bill. Results varied widely, but a general theme was that most reductions, at least in early years, derived from “offset projects” such as agricultural and forestry projects to reduce GHG emissions through increased carbon sinks, and through changes in the electric power sector (replacement of coal-fired power plants with lower-emitting natural gas, nuclear, or renewable energy units, or new coal units equipped with CCS). The key to all of these analyses is their estimate of capital costs for new power systems, and the future price of natural gas – both of which are changing rapidly. In the long term, some solution for transportation sector GHG emissions must also be deployed and these analyses tend to concur that we do not yet have such technology.

From a USACE perspective, two important factors related to climate change mitigation are apparent:

- fuel switching away from coal would have obvious impacts on coal transportation needs, and
- use of CCS has both large parasitic power requirements and, for PC units, large new cooling water requirements that would impact water withdrawals and affect cooling water intake structure needs.

At the regional level, northeastern states, as well as some mid-Atlantic ones, have adopted their own initiative which is now in place for reducing GHG emissions: the RGGI. This program calls for signatory states to stabilize power sector CO_2 emissions over the first 6 years of program implementation (2009-2014) at a level roughly equal to current emissions, before initiating an emissions decline of 2.5% per year for the 4 years 2015 through 2018.

Also, the RGGI apportions CO_2 allowances among signatory states through a process that was based on historical emissions and negotiations among the signatory states. Together, the emissions budgets of each signatory state comprise the regional emissions budget, or RGGI cap. The following are the Regional Annual CO_2 emissions Budgets (short tons):

2009-2014:	188,076,976
2015:	183,375,052
2016:	178,673,127
2017:	173,971,203
2018:	169,269,278

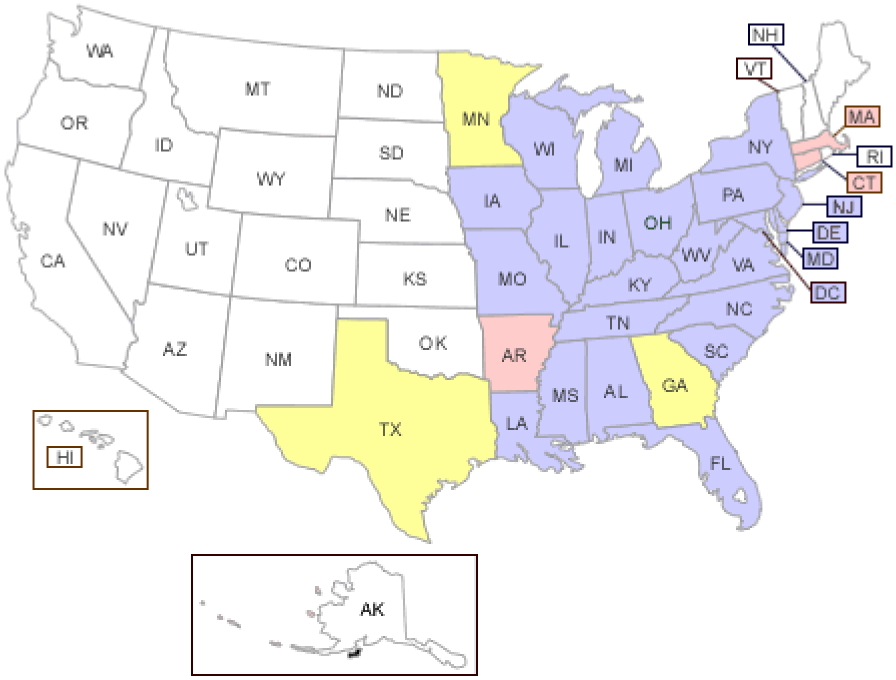
AEO 2008 Base Case assumes no limitations on GHG emissions. The USACE Base Case modeled the RGGI as described above. However, beyond this regional instance, the USACE Base Case did not model any nationwide GHG restrictions.

Implications of the Clean Air Interstate Rule Vacatur

The CAIR was promulgated by EPA on March 10, 2005. The rulemaking covered emissions of NO_x and SO_2 from electric generating units (power plants) in the eastern half of the United States (see Figure 2).[1] The purpose of the rule was to reduce emissions contributing significantly to non-attainment of the fine particulate matter ($PM_{2.5}$) and Ozone National Ambient Air Quality Standards (NAAQS) in the East.

[1] Technically, the rule did not require reductions from power plants; states could achieve the required tonnage targets in any manner they chose. However, regulation of power plants is the only pragmatic approach to achieve the vast majority of the required reductions.

Figure 2. States Covered by Clean Air Interstate Rule



Key: States are colored according to whether reductions are needed for the Ozone or PM NAAQS. Blue = Both; Pink = Ozone; Yellow = PM; White = Not covered by CAIR.

From an air quality perspective, EPA identified 129 areas that did not meet either the $PM_{2.5}$ or Ozone NAAQS in 2005. CAIR would have reduced this number by 106 areas in 2020, and some of the remaining areas were in western states not covered by CAIR. Reductions in the cost of achieving the emission reductions prescribed by CAIR were facilitated by the use of a "cap and trade" program similar to the program established for acid rain mitigation in the 1990 CAA Amendments, and to the earlier EPA "NO_x SIP Call" regulations.

From a technology retrofit perspective, EPA projected that the amount of coal-fired generating capacity retrofit with SCR for NO_x, or FGD for SO_2, would increase significantly between 2004 (before CAIR) and 2020. SCR capacity would roughly double (to nearly 2/3 of total coal capacity), although some of the added systems were attributable to pre-CAIR rules or new source requirements. FGD capacity would more than double from about 100 gigawatts (GW) to 230 GW, again with some of the added hardware attributable to non-CAIR regulations.

Following the promulgation of CAIR in 2005, several states and electric utilities challenged the legality of various provisions of the rule. Jurisdiction for such challenges rests with the DC Circuit Court of Appeals, which has vacated several recent air quality protection rulemakings, including rules on New Source Review and mercury (CAMR). On July 11, 2008, the Court ruled against EPA.[2] A vacatur means that EPA must start over from scratch: propose alternative regulations to achieve their statutory requirements, take public comment, and promulgate new rules. This process normally requires several years for issues as complex as those CAIR addressed.

Implications of Vacatur on Shipments of Coal

In contrast to the discussion of what *has* happened regarding the CAIR vacatur, a discussion of what *will* happen if the vacatur stands and is not stayed is by its nature conjectural. The reader is cautioned to recognize that the following discussion is, at best, informed opinion.

The primary impacts on coal shipping from the CAIR vacatur are related to both a change in the amount of coal used in general (e.g., less regulation might imply more coal use); and a shift in the balance between use of low sulfur coal versus FGD to achieve SO_2 requirements. Low sulfur coal is dominated by western subbituminous coal and eastern bituminous coal from Central Appalachia. Less FGD would imply more coal shipments from these low sulfur coal regions, and less from higher sulfur coal regions like the Midwest.

There are two "tensions" which are apt to define the impact of the vacatur on coal shipments in the United States. The first, and more dominant, is the tension between compliance with current rules using capital intensive hardware (e.g., FGD) versus lower sulfur content coal. In general, low sulfur coal is a less costly way to reduce SO_2 emissions than use of FGD, but low sulfur coal is not capable of meeting extremely low emission levels. Under CAIR, the use of FGD was projected to expand from a little under one-third of U.S. coal-fired capacity, to a little over two-thirds of total capacity. EPA projected the addition of about 50 GW of new FGD capacity to augment the existing 100 GW of capacity by 2010. They projected another 80 GW of FGD capacity to be added between 2010 and 2020.[3]

Most observers agree that any FGDs built or nearly built will be used, so the important issue is: what happens to the roughly 80 GW of new FGD capacity not yet under construction? There are two schools of thought on this matter. The first is that most of it will still be built. The logic supporting this view is that the permitting and Public Utility Commission (PUC)

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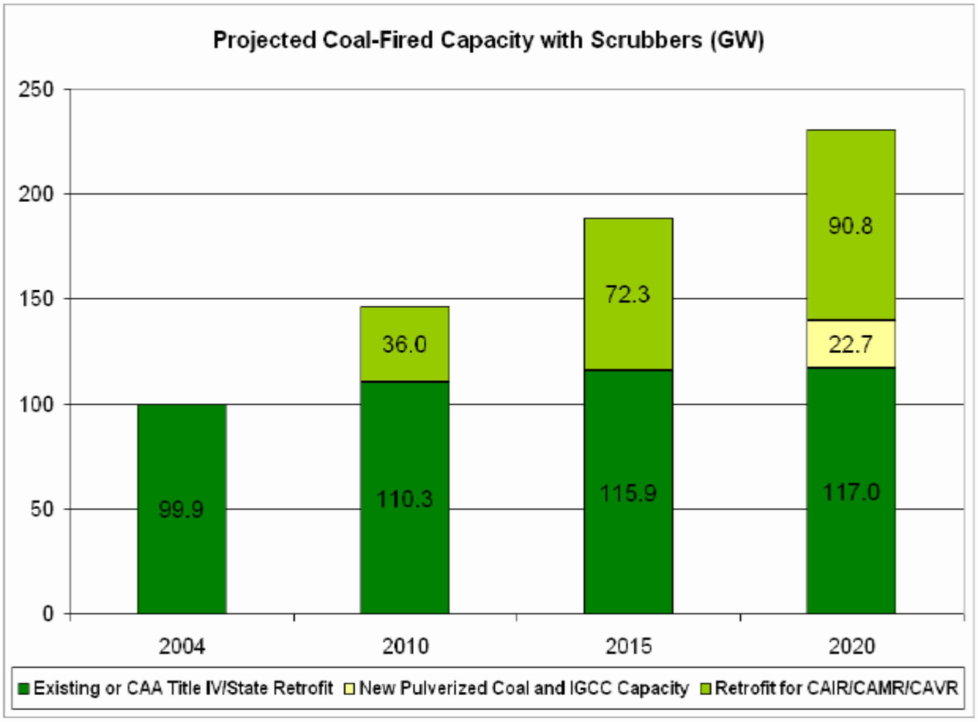
[2] *State of North Carolina v. EPA,* U.S. Court of Appeals for the District of Columbia Circuit, Case No. 05-1244, decided July 11, 2008.
[3] Contributions of CAIR/CAMR/CAVR to NAAQS Attainment: Focus on Control Technologies and Emission Reductions in the Electric Power Sector, Office of Air and Radiation, US EPA, April 18, 2006.

approval for this next wave of hardware is already underway or completed, and that utilities recognize that emission reductions will eventually be required by regulation. Under this line of thinking, disrupting the construction program would simply add cost and create unproductive criticism. Additionally, rules for mercury reduction and visibility improvement may also drive the installation of these FGD systems. However, the 23 GW of FGD associated with new power plants may depend more on other issues than the CAIR rule (for example, climate change legislation and regulations).

Figure 3. EPA Projected Addition of Flue Gas Desulfurization Capacity



A second school of thought is that many, if not most, of these future FGD units will be delayed until rules are clearer. Under a "CAIR-2" rule, for example, requirements may be more aggressive and greater reductions may be needed, based on EPA's 2006 revision to the NAAQS. Climate rules could also be imposed on these units. These requirements might lead utilities to decide to retire some coal capacity, making compliance with a "cap" easier for those remaining units. An "easier" cap would imply more use of low sulfur coal, less total coal use, and less use of FGD. In the period until rules are adopted, it seems likely that use of low sulfur coal would receive greater emphasis because it is a relatively low cost way to reduce emissions, and it does not require commitment of capital – so a utility can preserve its options. Supporting this line of reasoning is the near collapse of the SO_2 allowance market. SO_2 allowances selling for over $500/ton in December 2007 were selling after the vacatur for about $135/ton – much less than the annualized cost of building and operating an FGD unit. Finally, in the absence of operative rules requiring emission reductions, some PUC's might challenge further FGD builds as not "used and useful" for rate-setting purposes.

Without resolving the FGD-low sulfur coal tension, we should consider the second tension: the combined impact of CAIR decision making and anticipatory climate change decision making. The prospect for climate change legislation (or regulation under current law) makes planning for coal systems very complicated. Coal-fired power generation appears to be the only major GHG emitting sector which is amenable to large emission reductions.[4] Different aspects of the same driver (climate rules) could lead to either more or less retirement of existing capacity, and more or less new coal capacity. Generally speaking, climate change requirements leading to less existing coal-based capacity favors use of low sulfur coal, but all new coal-based capacity is required to have FGD or equivalent systems. And more capacity in general means more coal use. Moreover, current capture systems for CO_2 are very energy intensive, lowering a power plant's efficiency by as much as 30% and therefore requiring more coal to make the same power. This may all seem somewhat separate from consideration of the CAIR vacatur, but climate change is part of the economic context in which decisions about utility capital investments must now be made. A conservative perspective would clearly favor not making capital investments that would "lock-in" a future commitment to coal, and favor use of low sulfur coal over investments in FGD capacity. It might also lead to more use of low sulfur coal to increase "banks" of excess emission reductions for later use. However, if climate restraints are viewed as reducing future coal use overall, then the value of banked SO_2 emission reductions may decrease sharply, making such banking imprudent. Moreover, the potential climate change rules for existing units and new units are apt to be vastly different in nature, and could have the perverse effect of making retention of existing capacity very desirable to electric utilities. The best path forward is not clear. Indeed, some environmentalists might see today's regulatory confusion as an opportunity to persuade utilities or utility regulators to abandon coal units, rather than invest more capital in the face of coming climate change rules.

The recommended approach to reflect these tensions and uncertainties is to conduct sensitivity analysis. In the Base Case modeled under this contract, a continuation of the CAIR rules is assumed, based on the logic of Congress acting to legislatively impose the rules as a substitute for the administrative regulatory approach. However, in alternate modeling

[4] The transportation sector is the second largest GHG emission source in the United States and may seem ripe for climate policies. However, higher efficiency in transportation is likely to be offset by increases in transportation use (due to population increases and economic growth). Use of renewable transportation fuels has been shown to actually increase GHG emissions, due to GHG emissions associated with land clearing necessary to grow renewable crops.

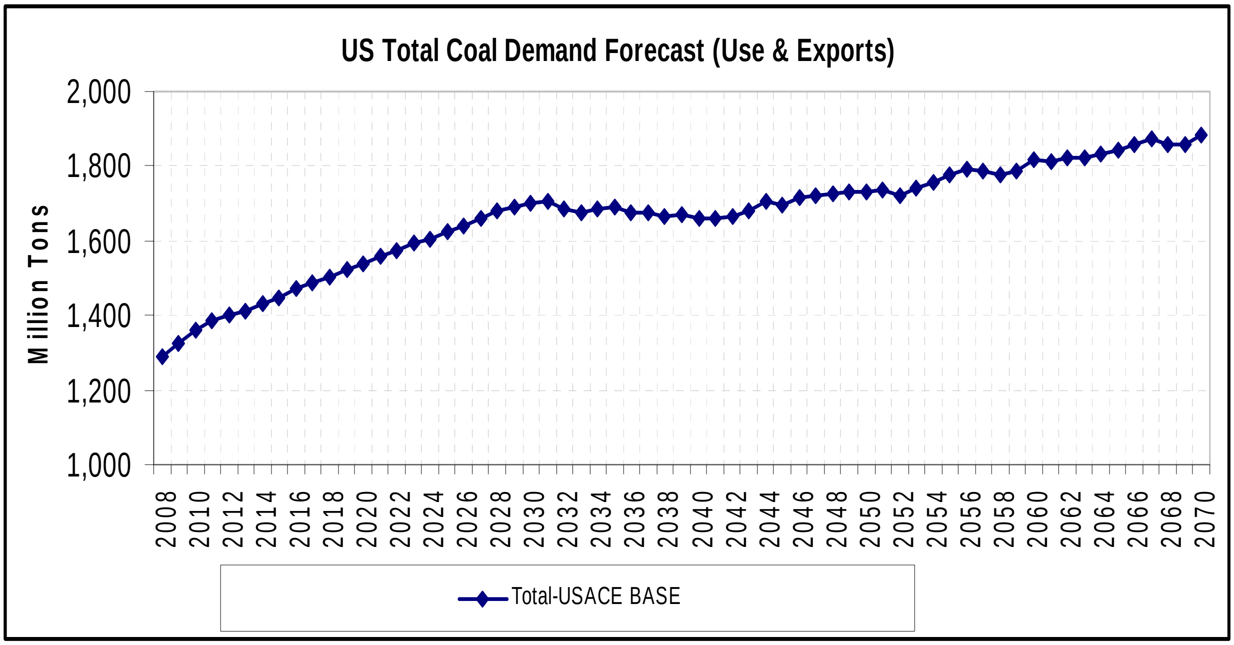
scenarios, the sensitivity analysis suggested here is incorporated as part of the set up of the scenarios.

Base Case Results

Total Coal for Use and Export

The following graph of total U.S. coal includes not only U.S. coal production for domestic use and for exports, but also includes imports which augment the U.S. production to satisfy total domestic use.

Figure 4. U.S. Total Coal Demand Forecast (Use & Exports)

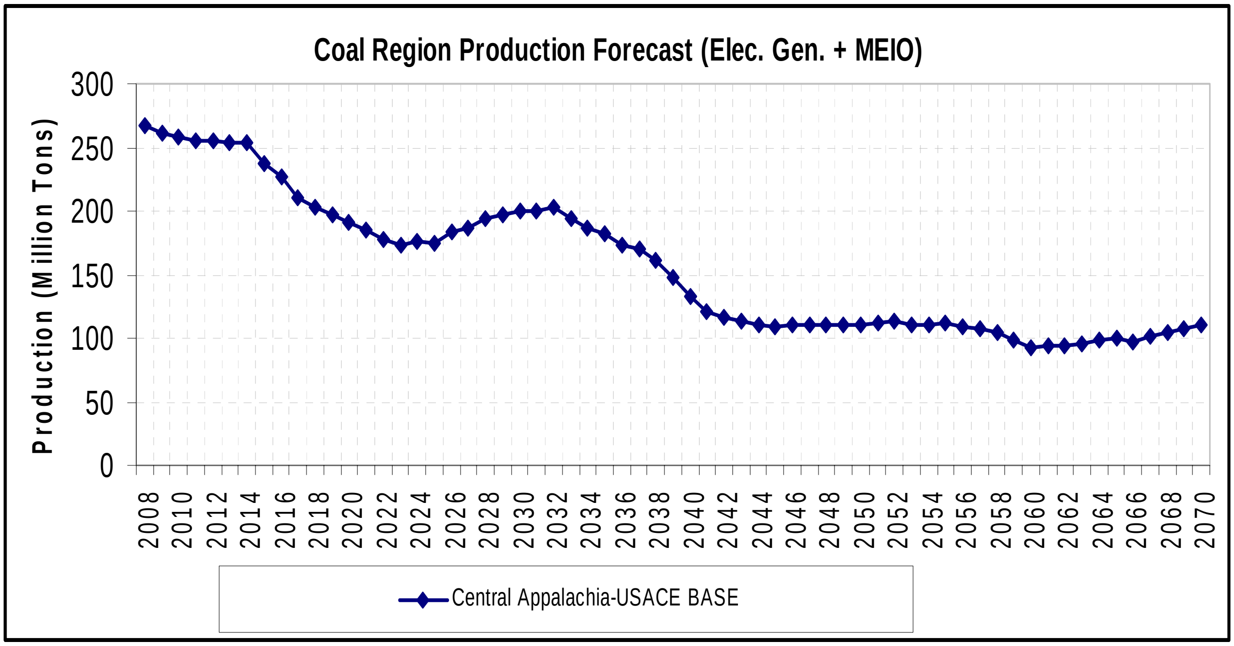


The growth in U.S. coal demand continues to grow across the entire forecast period. Total coal demand grows from roughly 1.29 billion tons in 2008 to 1.88 billion tons in 2070. There is strong growth from 2008 through about 2030, after which there is somewhat of a plateau from 2030-2045, and finally another period of growth from 2045 through 2070, albeit at a slower rate than in the period before 2030. The compound annual rate of growth from 2008 to 2030 is about 1.27% per year, and from 2045 to 2070 it is 0.43% per year. The period 2030-2045 has some fluctuations by year, but basically remains at the same level. To understand the driving forces behind this pattern of overall coal growth, the following discussion looks at tonnage coming from key coal basins and at the causes of their production's rise or fall.

Central Appalachian Coal Production

The following graph depicts forecasted coal production for CAPP.

Figure 5. Coal Region Forecast (Elec. Gen. + MEIO) – Central Appalachia



The continuing depletion of the higher quality coal reserves in CAPP is a well-known phenomenon. This trend is demonstrated in the forecast, as tonnage from this production region declines from more than 250 million tons per year (mmtpy) to level off at only around 100 mmtpy in the latter stages of the forecast.

However, it is important to note that CAPP is not running out of coal in the ground. It is running out of *economically competitive* coal of the higher quality levels. If circumstances change regarding the economic competitive factors, then this coal is still in the ground at higher cost levels to be produced in CAPP. This situation is witnessed by the "bump" between 2025 and 2035 in the CAPP production forecast. The cause of this bump lies in having primarily fixed caps on pollutants (at least for SO_2 and NO_x) while the demand for electricity keeps rising each year. In a cumulative sense, emission levels keep pressing harder against the pollutant caps until, in order to stay in compliance, both cleaning equipment (e.g., scrubbers) and stepping to a bit lower sulfur coal is needed.

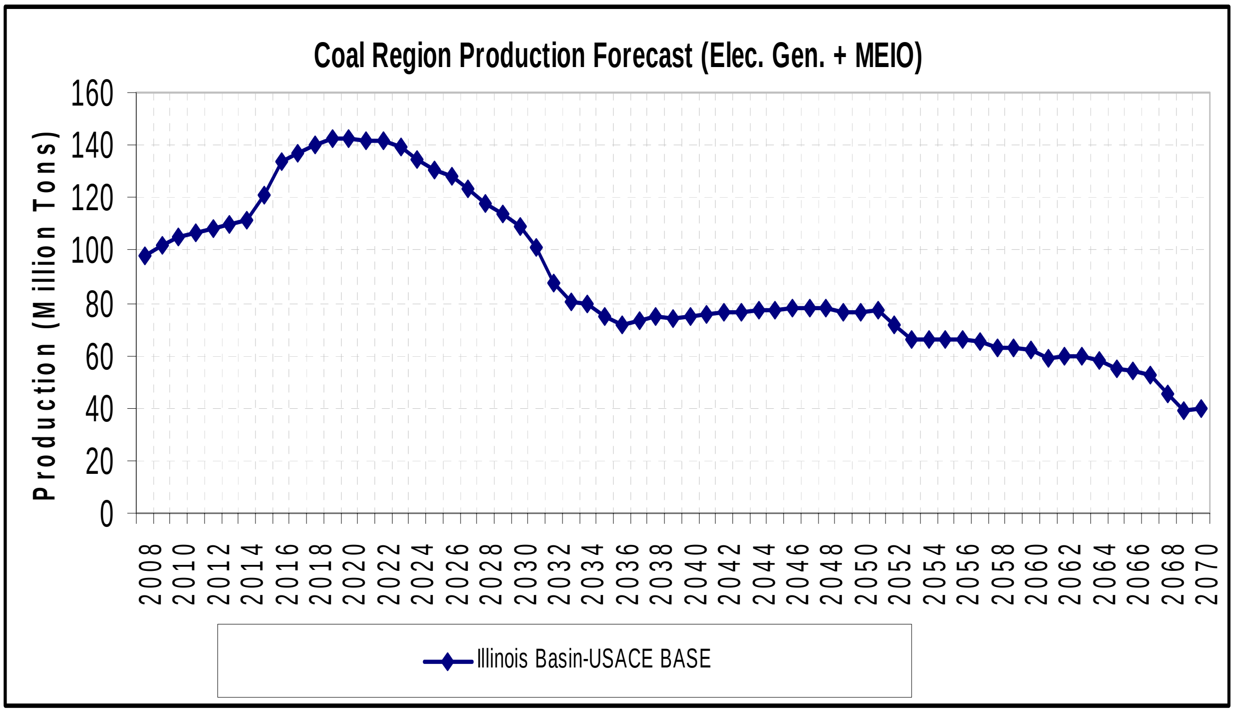
As will be seen in later discussion about some of the higher sulfur coal producing areas, the demand for Btu's is somewhat of a zero-sum game. When the demand for the higher sulfur coals declines due to the cumulative effect described above, the Btu's to generate electricity begin to originate more from lower sulfur coal areas. These areas may not have been able to compete as strongly on a purely economic basis. However, they now can fill some of the void left by the inability to continue using as much of the highest sulfur coals, even with scrubbing. CAPP coal is one of the beneficiaries of this trade-off and, for a while, the decline in CAPP production reverses as the need for better quality coals becomes stronger.

However, as electricity demand continues even higher, even CAPP's remaining higher quality coals become (a) more expensive to mine as reserve depletion continues, and (b) not as attractive as the truly lowest sulfur coals from the West. Because of this, CAPP coal again starts declining after the 2025-2035 "bump."

Illinois Basin Coal Production

When looking at a traditionally high sulfur coal producing region such as the Illinois Basin (Figure 6), an inverse picture to the CAPP picture is witnessed, at least in the early years.

Figure 6. Coal Region Production Forecast (Elec. Gen. + MEIO) – Illinois Basin



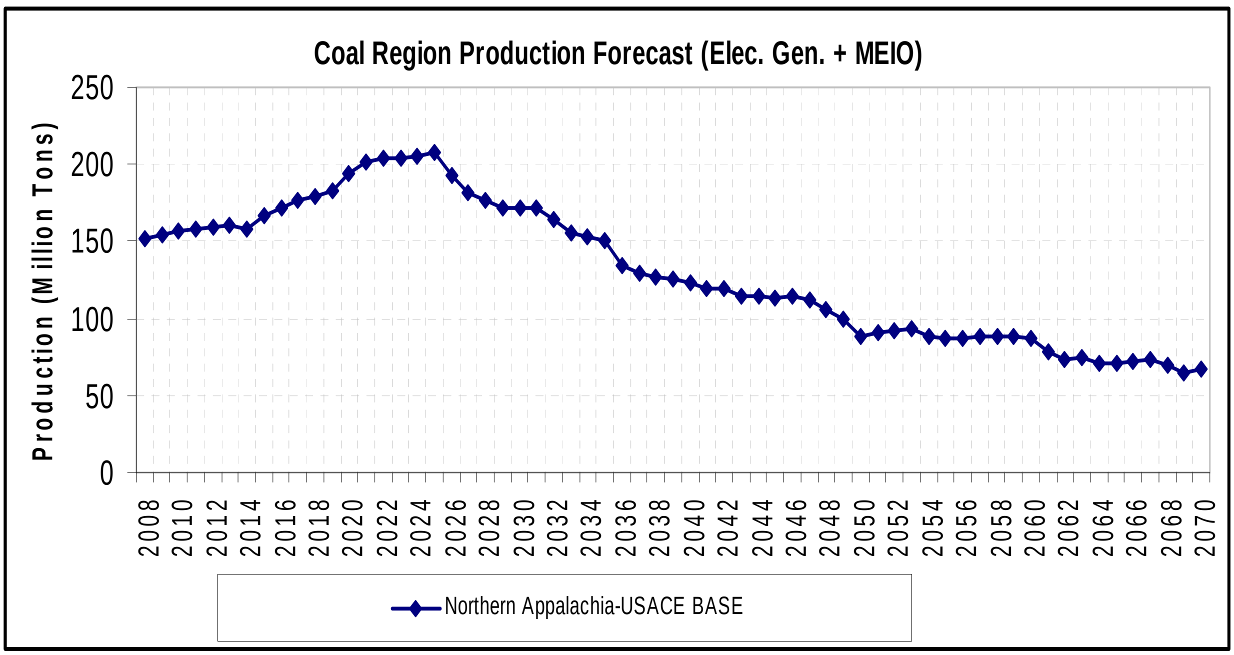
Through 2014, there is growth in Illinois Basin tonnage, driven primarily by the demand from units that added scrubbers for Phase I of CAIR. Then, in 2015-2020, there is an acceleration of this growth as CAIR Phase II kicks in and the amount of scrubbing increases even more. However, as discussed earlier, the cumulative build-up of emissions, as electric load growth continues, finally starts pressing so tightly against fixed cap limits in the early to mid 2020's that both cleanup equipment and a moderation of sulfur in the incoming coal are needed. The Illinois Basin is one of the first areas to feel this effect, and demand begins to decline around 2023.

Around 2035, Illinois Basin coals reach a place of competitive stability which keeps the annual tonnage level roughly constant at about 80 mmtpy. This balance remains until the early 2050's when demand again starts declining, and production falls to the 40 mmtpy level by the end of the forecast.

Northern Appalachian (NAPP) Coal Production

Shifting to another coal producing area with predominantly mid to high sulfur coals, NAPP has a similar scrubber-fed strong growth pattern through the early 2020's, with growth accelerating when CAIR Phase II begins in 2015.

Figure 7. Coal Region Production Forecast (Elec. Gen. + MEIO) – Northern Appalachia



These NAPP results do not show the conventional wisdom that the CAIR-driven strong growth in scrubbing produces an indefinite upward trend for NAPP's coals, which are generally higher in sulfur. In other words, this is not a one-dimensional situation in which increased scrubbing must necessarily pull NAPP production higher into the indefinite future. Rather, as pointed out above, there comes a point at which the fixed cap on sulfur emissions eventually requires both scrubbing (but not at all units, which shall be mentioned later) and also shifting to coals that are not high in sulfur. The graph shows that, for NAPP, this turnaround occurs in 2025 with declining tonnage thereafter.

In addition to the sulfur effects, NAPP has another negative aspect, which is a contributing factor to its ultimate decline in production. NAPP contains coal with the highest Hg content in the Nation. These contents often are double or triple the mercury content of other areas.

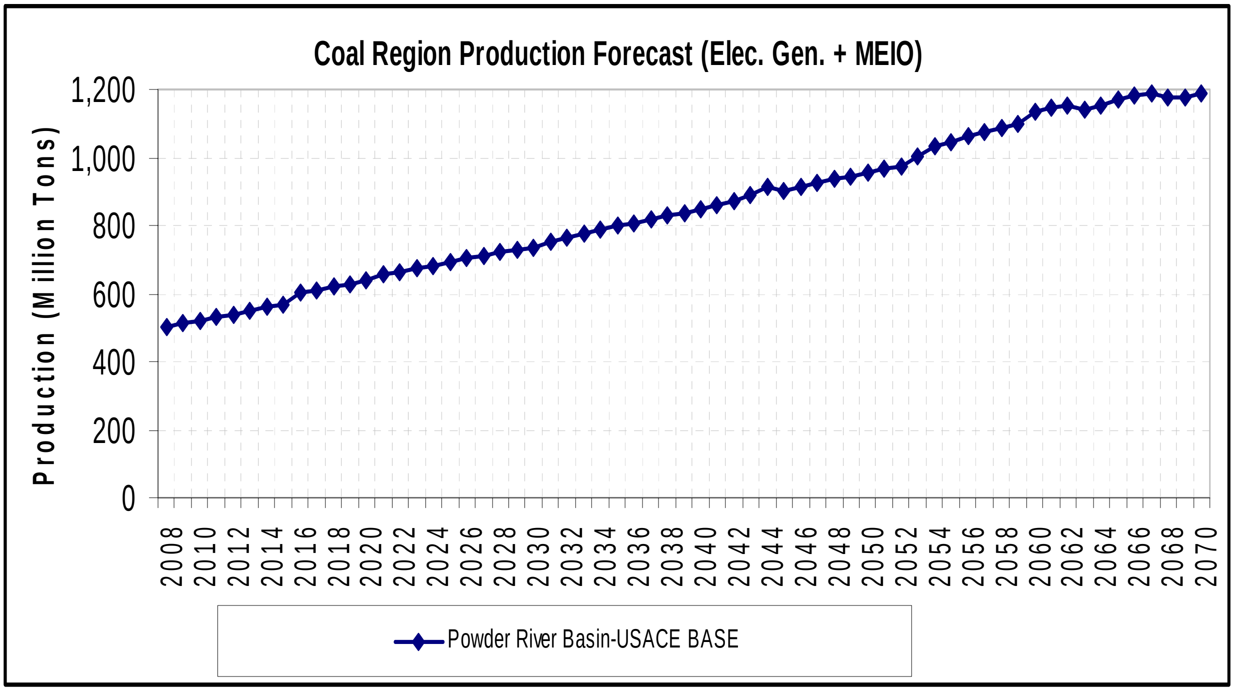
This negative mercury impact is somewhat ameliorated by the court's vacatur of the CAMR rules with its fixed emission limits (which would tend to work exactly like the fixed cap sulfur limits). However, it is still true that even under a MACT Hg emission limitation interpreted as a fixed percentage removal at each unit, it is more costly to remove, say, 85% of the Hg in a coal with 16 pounds Hg per trillion Btu than to remove that same percentage from a coal running 5 pounds Hg per trillion Btu. Thus, the added cost burden of NAPP's generally high Hg content is another factor in its eventual turnaround and decline.

In the final decade of the forecast period, NAPP's coal production seems to level out at around 70-75 mmtpy, or about one-third of its peak values in the early 2020's.

Powder River Basin Coal Production

To this point of this evaluation, overall U.S. total coal production (Figure 4) continued to rise to 2070 with CAPP, Illinois Basin and NAPP tonnage all eventually declining. These seemingly contradictory trends are explained by the following graph (Figure 8).

Figure 8. Coal Region Production Forecast (Elec. Gen. + MEIO) – Powder River Basin

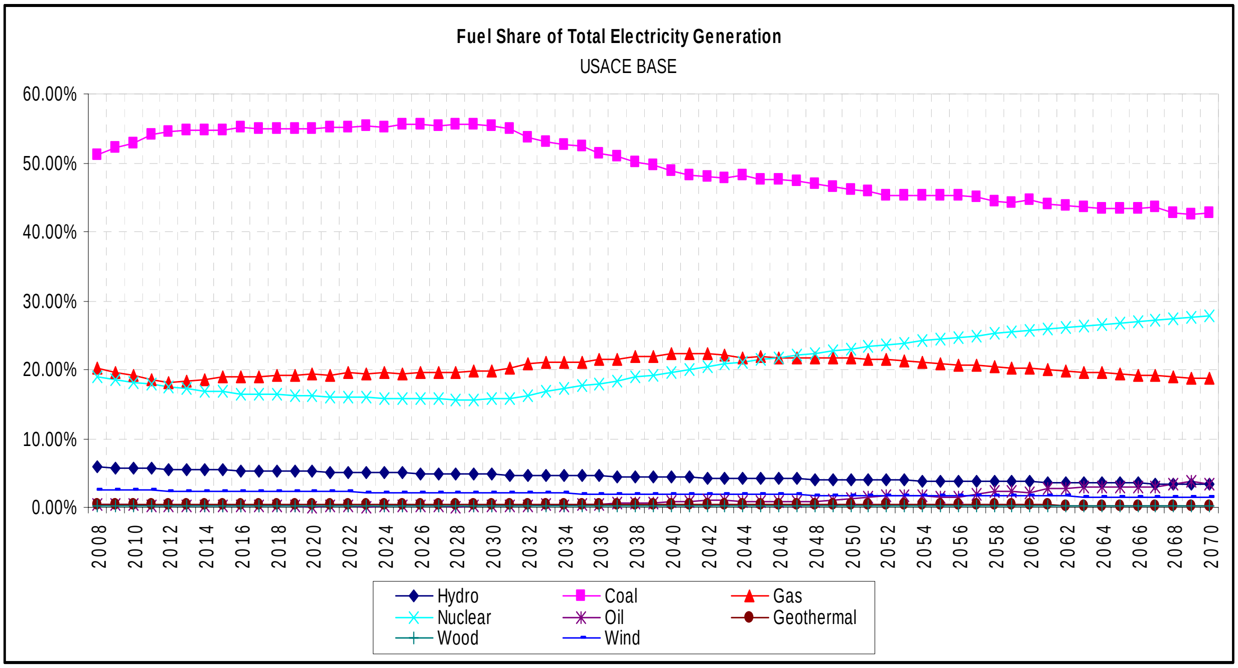


As depicted by Figure 8, PRB coal grows from around 500 mmtpy at the beginning of the forecast period (or about 39% of U.S. Total Use and Export) to nearly 1.2 billion tons in 2070 (or about 64% of U.S. Total Use and Export). This compound growth rate of over 1.4% per year makes PRB coal the fastest growing coal in the Nation over the entire 62 year forecast period. Although overall U.S. coal does not grow as rapidly as the growth in electricity demand, it does still experience positive growth, primarily due to the ability of PRB coals to be both economically and environmentally attractive.

Fuel Shares of Electric Generation

Since total U.S. coal does not grow as fast as the demand for electricity, Figure 9 indicates that coal's share of electricity generation, after holding steady at 54%-56% from 2010 to 2030, declines steadily thereafter to be just below 43% in 2070.

Figure 9. Fuel Share of Total Electricity Generation

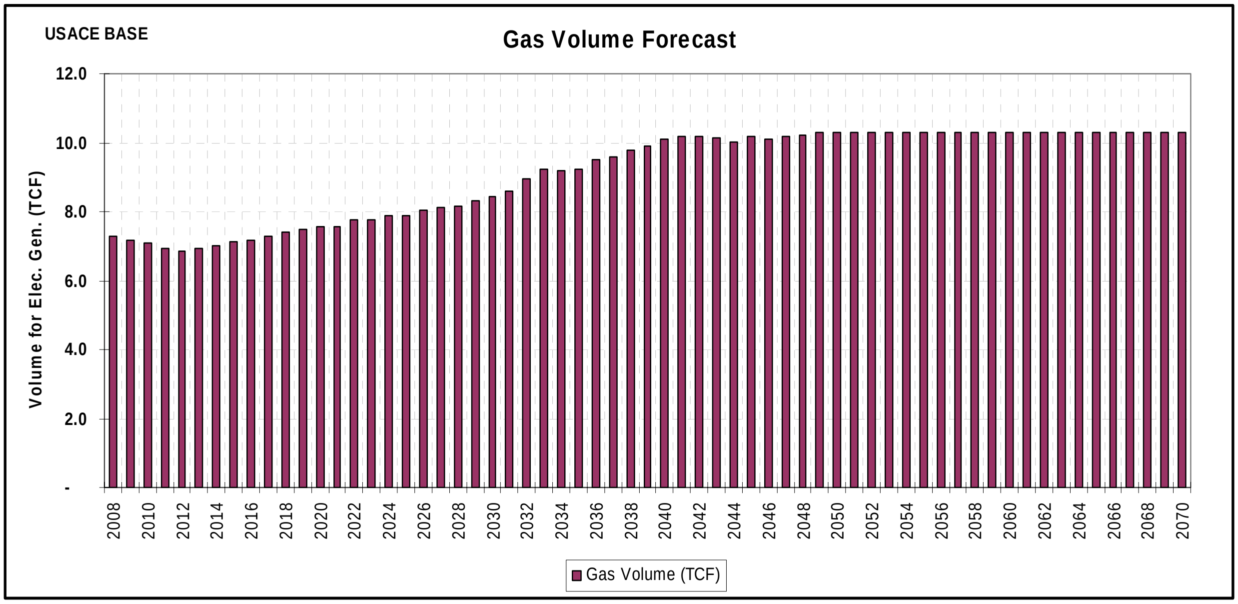


Offsetting the decline in coal's share during the 2030-2070 period is the growth in fuel share of electricity generation from nuclear. Nuclear grows from around 16% to nearly 28% over this period.

The fact that the natural gas share of generation stays relatively flat at 18%-22% throughout the entire forecast period is a little misleading, since this means that gas-fired generation is actually growing at about the same rate as overall electricity demand. The next graph looks more closely at this natural gas growth.

Gas Use by Electric Utilities and Price Forecast

Figure 10. Gas Volume Forecast



As shown in Figure 10, the volume of natural gas used for electric generation grows from the 6-7 trillion cubic feet (TCF) level each year in the 2008-2015 period to be a little over 10 TCF per year in 2040. Thereafter, the use of natural gas flattens for the remainder of the forecast period. However, even this flat level of gas use for generation in the final 30 years of the forecast is strong enough, when coupled with growing non-generation use of natural gas, to place a strong pull on total gas supply over the period.

Model-generated New Electric Generation Capacity

The fuel usage trends discussed to this point are reflected in the next series of graphs which show the model-optimized new construction of electric generation capacity by type of plant.

Figure 11. New Generation by Plant Type – Pulverized Coal

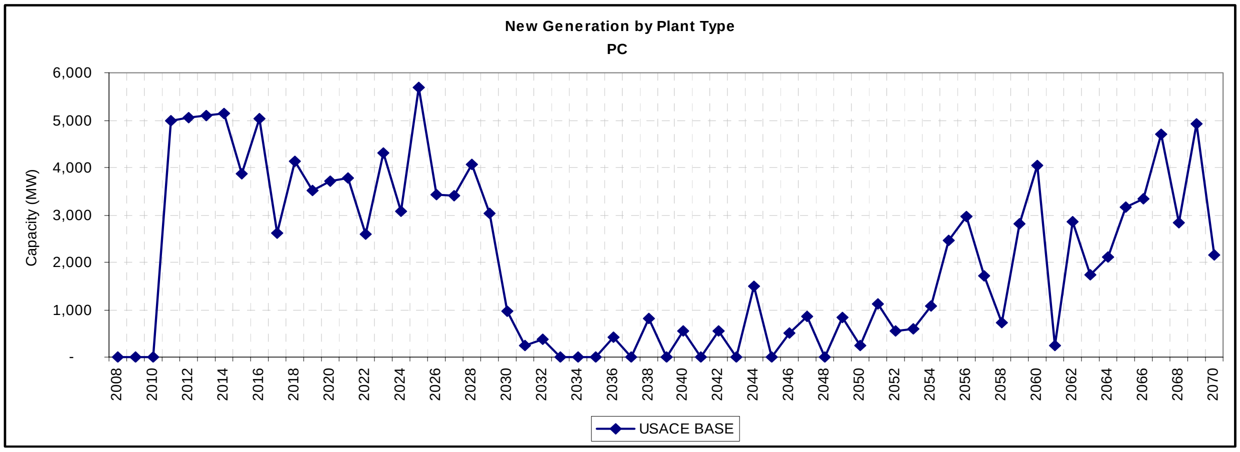
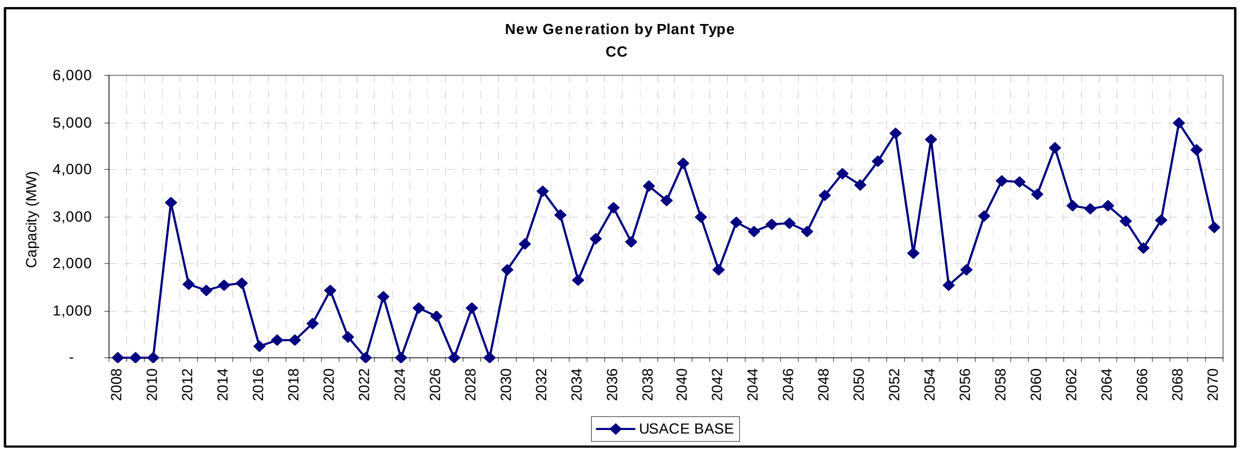


Figure 12. New Generation by Plant Type – Gas-Fired Combined Cycle



There are two structural things to note about these graphs:

For the first few years of modeling, any new capacity being built is that capacity that has already been announced by the electric utilities and has had all of the steel ordered, permits approved, etc., and those new units do NOT appear in these graphs. Rather, these graphs show only the new capacity that arises from the model's recognition that, in order to meet electricity demand, new units are needed even beyond those which have already been announced and are under construction. The model optimizes how many of each type of unit should be built each year and their optimal locations, which can change each year (although once built, those particular units obviously stay at the location of their construction). These "model-optimized" units are the only ones shown in these graphs and the ones that follow.

The graphs presented are not cumulative. Rather, they show the amount of each type of new capacity built in each year. In order to arrive at a cumulative amount of new capacity of a certain type built and running by 2030, for example, it would be necessary to add together the previous years' numbers and also add in the amount of previously announced new capacity actually permitted and mostly under construction at the start of modeling (i.e., not added as model-optimized).

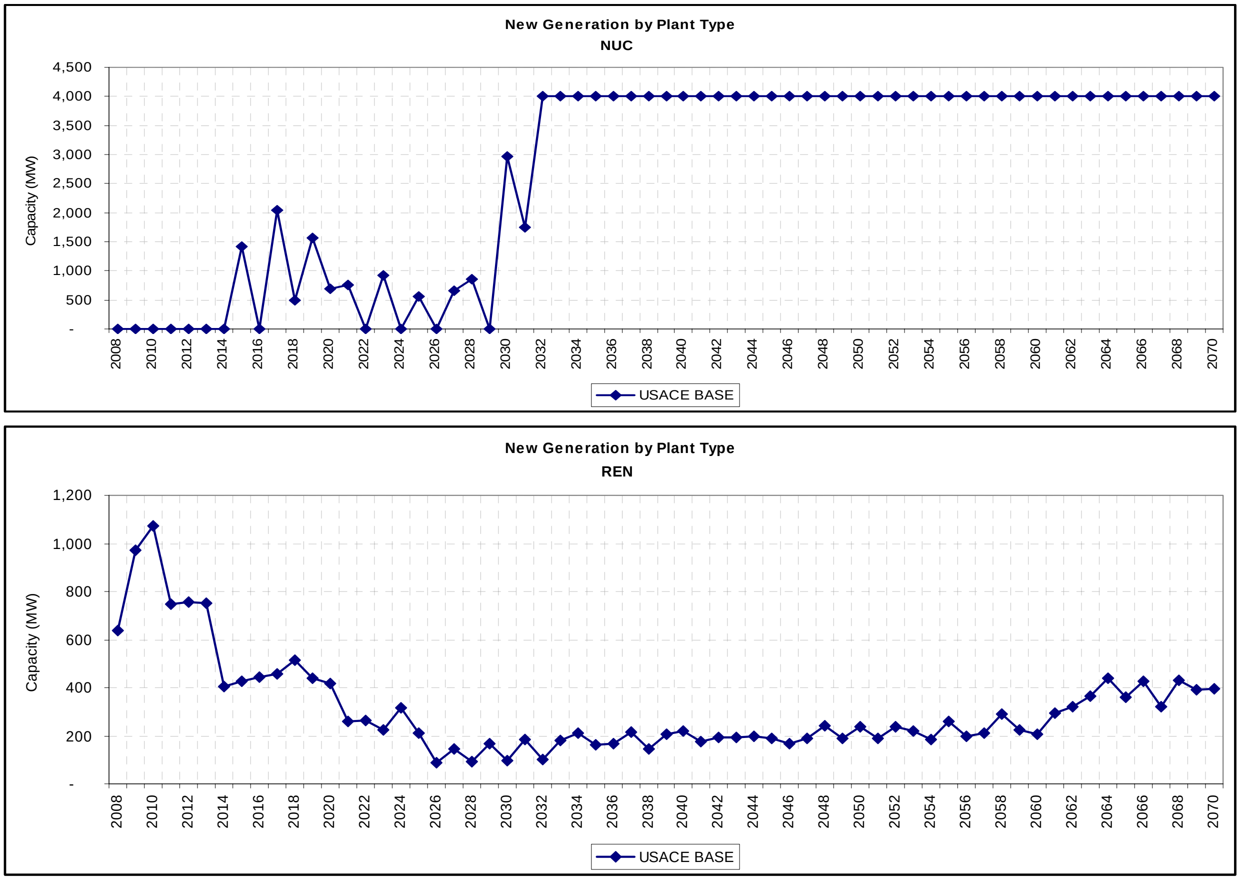
In the upper graph of new PC capacity, Figure 11, we see a close parallel to the tonnage discussion above. That is, while demand for coal of several types is growing strongly into the mid to late 2020's, the construction of new PC units is also strong, adding as much as 4,000-5,000 MW in many years. Then, as CAPP resumes its decline post-2030 and both NAPP and Illinois Basin are in strong decline, the building of new PC units stagnates for about 20 years until there is some modest resurgence post-2050.

In the lower graph, Figure 12, we see that the construction of new gas-fired CC units surges at exactly the point where the building of new PC capacity drops in 2030. Roughly 3,000 MW of new CC capacity is constructed each year thereafter, with some years going over 4,000 MW. The continuation of this rate of capacity expansion even in the later years of the forecast period allows natural gas to maintain its market share of electricity generation (discussed above) even while coal's share is falling. In other words, the coal unit construction in the later years of the forecast period is not sufficient to maintain coal's share of generation but only serves to slow its decline.

Model-generated New Capacity

Perhaps the strongest indication of the threshold effect in which all "slack" under the fixed cap pollutant limits is finally used up, is the pattern of nuclear plant construction as shown in Figure 13.

Figure 13. New Generation by Plant Type - Nuclear and Renewable



Due to the long lead times for permitting, actual construction, and certification of a new nuclear plant, we do not allow any new model-optimized nuclear units to come on-line before 2014. Thereafter, there is some nuclear plant construction, but the rate of construction strongly surges post-2030 as coal's share of generation begins to decline and natural gas merely maintains its market share. In fact, nuclear would grow even faster in the modeled scenario except for the fact that annual expansion limits were included representing a judgment of the maximum ability of the regulation and permitting system, as well as the ability of the engineering and construction firms, to actually bring on new nuclear capacity each year. It is obvious from the graph that this annual expansion limit was set at 4,000 MW in any single year, and the model's optimum response to this limit is to bring on a full 4,000 MW every year for the indefinite future after about 2031. Clearly, the growth of electricity in the latter decades is being provided by the construction of new nuclear generation.

The final graph of this set shows the building of model-optimized new renewable capacity (which in this modeling is completely based on wind generation costs). As the years arrive in which various states have announced the upcoming implementation of a RPS, the building of renewables is witnessed as running as high as several hundred MW per year. However, by the mid 2020's to early 2030's this rate of renewables construction levels out to around 200 MW per year which is necessary to keep up with growth in total generation and maintain the RPS-mandated percentage of generation from renewables. The reader should note that there is no nationwide RPS assumed in this scenario, and only those states with currently existing or announced RPS standards are modeled with RPS restrictions.

Percentage of Scrubbed Coal per Year

Finally, the modeling results regarding usage of environmental clean-up equipment completes the picture of the Base Case scenario.

Figure 14. Percentage of Scrubbed Coal per Year

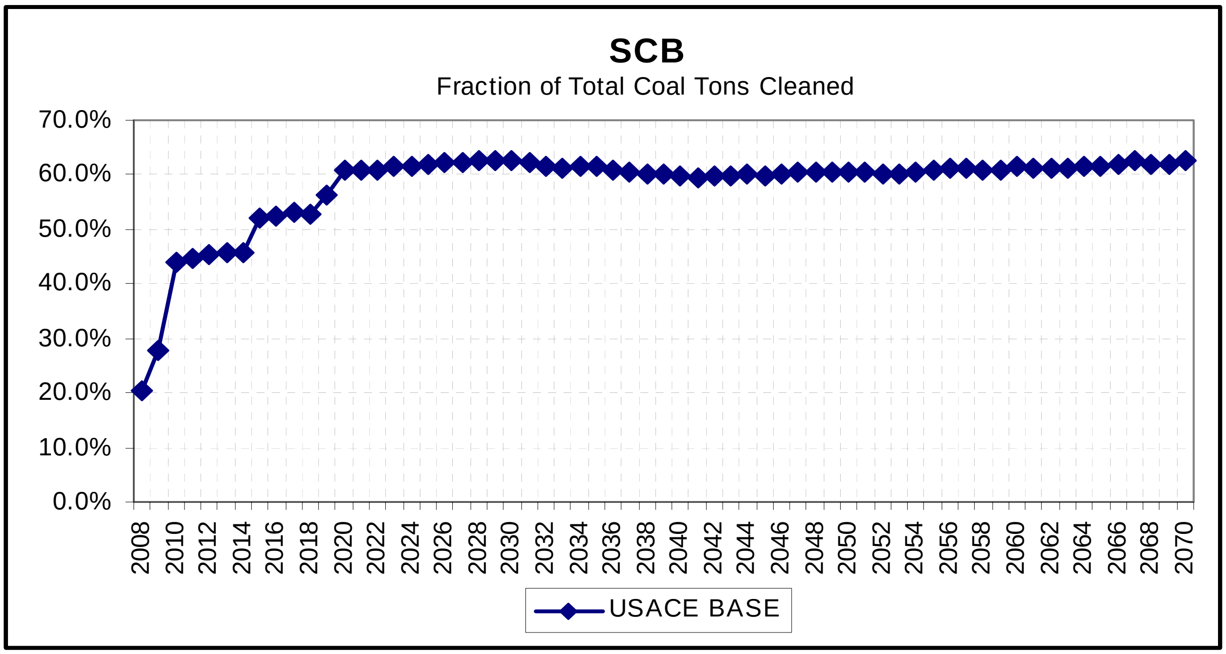


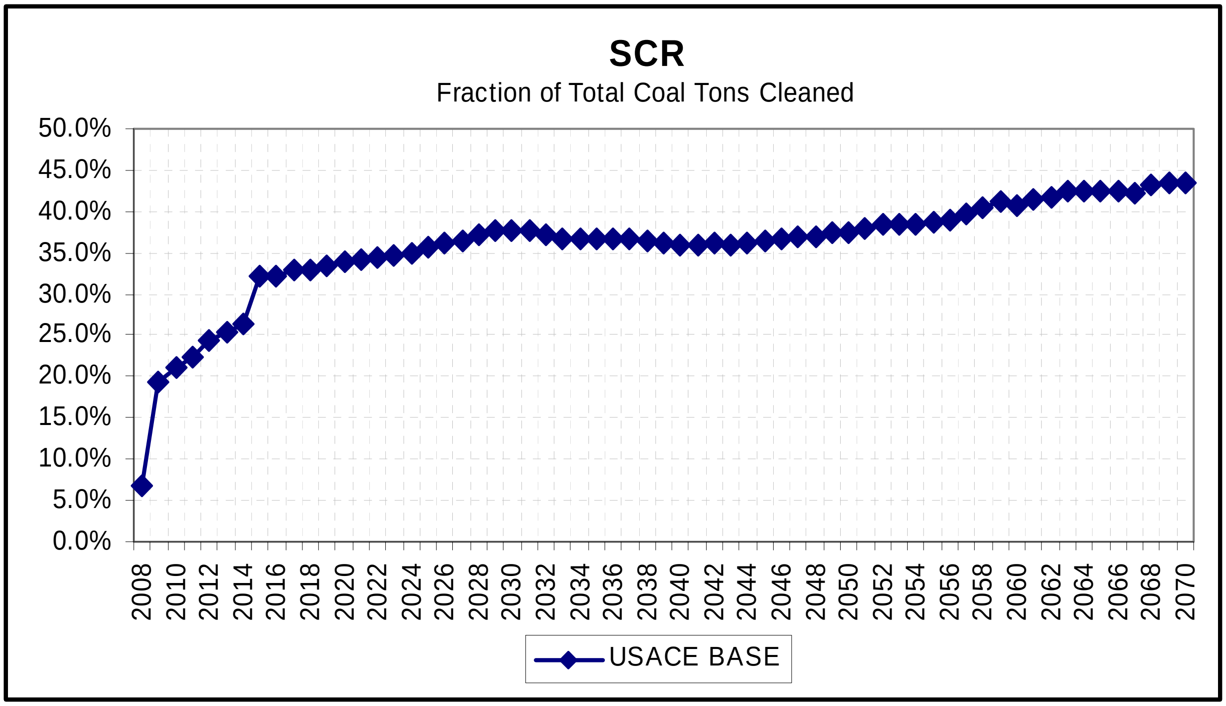
Figure 14 presents the fraction of total coal that is burned in scrubbed units in the modeled scenario. From a starting point of about 20% of coal scrubbed in 2008, the use of scrubbing jumps dramatically as CAIR Phase 1 starts in 2010 to a level of around 44%. Then, as CAIR Phase 2 begins in 2015, the level jumps up again to the point where about 52% of all coal is scrubbed.

A final upward impetus to coal scrubbing is the co-benefit for mercury removal that occurs with scrubbing. Although this Base Case scenario replaces the court-vacated CAMR rules with a percentage removal at all units under a MACT philosophy, the modeling setup also included the requirement for all new units (constructed after 2008) to install some form of Activated Carbon Injection (ACI) by 2018. Since there is some co-benefit to operating this Hg removal equipment in tandem with a scrubber, we see in the scrubbing graph that several units which were just under the economic threshold of justifying installation of a scrubber on a sulfur basis alone, now have a little added value which causes them to be installed to complement the ACI equipment, in addition to removing sulfur. The final result is that scrubbing flat-lines at approximately 60%-62% of all coal burned throughout the remainder of the forecast period. Again, it should be stressed that this flat-lining in a percent-of-total sense does not mean zero growth – it indicates that new scrubbing is growing at the same rate as coal use is growing (see Figure 4 and discussion above of total U.S. coal growth).

Percentage of Coal with Selective Catalytic Reduction

CAIR Phase 1 NO_x limitations were scheduled to begin in 2009 (one year earlier than the Phase 1 SO_2 limits). In fact, limitations did commence in very early 2009 as the court was petitioned by both sides in the vacatur lawsuit to rescind the vacatur on the NO_x portion of CAIR to facilitate planning and implementation of NO_x strategies by electric generating companies.

Figure 15. Percentage of Coal with Selective Catalytic Reduction



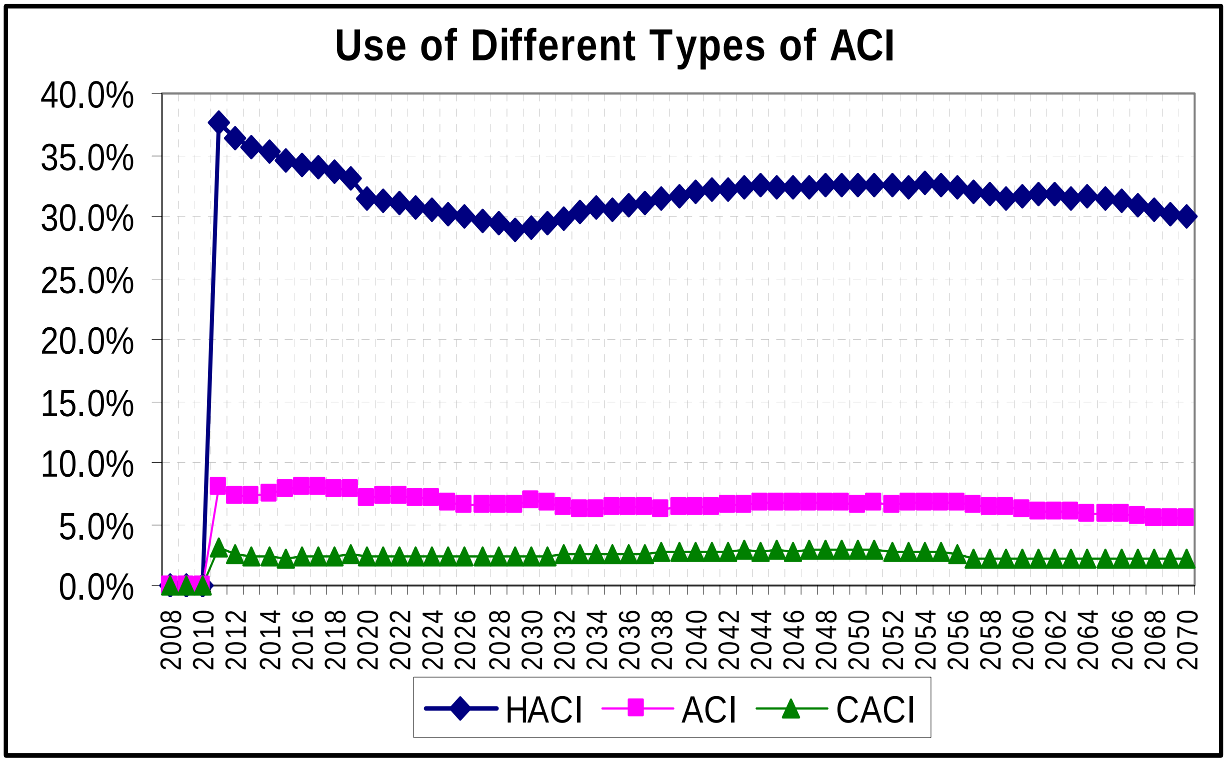
Thus, the graph in Figure 15 showing usage of SCR equipment for NO_x removal indicates a steep jump to around 20% of all coal in 2009 going into SCR-equipped units. This percentage climbs steadily for the next 5 years and then takes another steep jump as CAIR Phase 2 begins in 2015. Thereafter, this SCR usage graph closely tracks the total U.S. coal graph (Figure 4) with strong growth to about 2030 (reaching nearly 38% of all coal burned), a leveling off to the mid 2040's, and then the resumption of positive growth throughout the remainder of the forecast period, reaching 43.6% by 2070.

It is important to note that a switch to PRB coal involves an inherently lower NO_x emission rate due to avoidance inside the boiler of the temperature zone at which there is "fixation" of the atmospheric nitrogen in the air being drawn into the boiler. With the strong growth in PRB coal tonnage which was noted earlier, there is undoubtedly some dampening of demand for the SCR equipment that would have been required without the strong PRB growth.

Base Case Use of Activated Carbon Injection of Different Types

In the scenario setup, it was assumed that Hg MACT limitations begin in 2011. As seen in Figure 16, ACI of various types rises steeply in that year.

Figure 16. Use of Different Types of Activated Carbon Injection



Since the halogenated form of this equipment (HACI) is necessary for effective Hg removal from the burning of PRB coal (which is already more than 40% of the Nation's total and climbing), Figure 16 shows that HACI is the predominant form of Hg removal equipment installed.

At first glance, the use of HACI appears to decline in the period 2011-2030, but that is primarily because the graph is expressed as a percent of total coal. In fact, because of the installation of other non-Hg equipment which also has a co-benefit for Hg (see the discussion above concerning scrubbers), the absolute amount of coal going into HACI-treated units is very nearly constant over this time period. However, since total coal demand grows while this HACI portion remains constant, the graphed line showing percent of total actually goes down.

From 2030 to the mid 2050's more HACI is installed at a rate that is faster than the growth in total coal demand, and the percentage graph again rises. From 2055 through 2070, the absolute amount of coal undergoing HACI post-combustion treatment again holds steady.

This trend is depicted in the percent-of-total graph as a slow decline of a couple of percent as total coal continues a slow growth while HACI-treated coal remains constant.

The other non-halogenated forms of Hg-specific clean-up equipment are not negligible, but they are substantially lower in usage than HACI. These include plain ACI and the use of a Combined Hybrid Particle Collector (COHPAC) with ACI, frequently referred to as "CACI." The graph shows that plain ACI starts out in 2011 covering about 8% of total coal and, as total coal grows but plain ACI does not, this percentage drops to about 5.5% by the end of the forecast period. Lastly, CACI usage hovers between 2.2% and 3.0% of total coal for the entire forecast period after mercury rules hit in 2011.

USACE Alternate Case Scenarios

Assumptions

High ORS Traffic Demand Case

The High ORS Traffic Demand Case included several changed assumptions. These assumptions are as follows:

- U.S. GDP growth at 4.0% per year (i.e., higher than Base Case's 2.4% per year which matched DOE AEO 2008).

- Reduced ability for nuclear to grow – new unannounced nuclear could become available by the beginning of 2014 (same as Base Case) but only at the following maximum rates:

2014:	500 MW
2015:	750 MW
2016:	1,000 MW
2017:	1,250 MW
2018-2070:	1,500 MW per year

Note: This assumption compares to the Base Case rate of 2,200 MW in 2014, with the annual level increasing by 100 each year (2,300 in 2015, 2,400 in 2016, etc.) until it leveled off in 2032 at 4,000 MW per year and stayed at that maximum rate per year through 2070. The GEM™ model did not force the amount of nuclear to be built each year, but simply limited the *maximum* that could be built each year.

- A resumption of high natural gas prices (making natural gas less attractive and thus promoting higher overall coal use). Each step of the Henry Hub gas supply curve was raised $6.00 per million cubic feet (MCF) over that used in the Base Case, making the Henry Hub price of gas be approximately $10.75/MCF at the general current level of 6 TCF usage for electric generation purposes (as compared to the Base Case curve level of approximately $4.75 at the 6 TCF level of electric generation gas usage). This natural gas price differential is in line with the actual difference experience in pricing between mid-2008 and mid-2009.

- Across the board higher MEIO (domestic Met coal, Export coal of both the steam and met varieties, Industrial steam coal, and "Other" – indicating primarily Coal-To-Liquids plants) demand was also assumed. Each category was raised by 5 mmt (25 mmtpy total since there are two types of Export coal). In other words, compared to the Base Case, there was an additional 25 mmtpy of coal demand without regard for the demand from the electricity sector.

Low ORS Traffic Demand Case

As with the High ORS Traffic Demand Case, the Low ORS Traffic Demand Case used some assumptions that differed from the Base Case:

- U.S. GDP growth at 2.0% per year (i.e., lower than Base Case's 2.4%/yr).

- Increased ability for nuclear to grow – new unannounced nuclear could come on beginning in the same year (2014) as the Base and High cases, but could expand at the following maximum rates:

2014:	2,250 MW
2015:	2,500 MW
2016:	2,750 MW
2017:	3,000 MW
2018:	3,250 MW
2019:	3,500 MW
2020:	3,750 MW
2021:	4,000 MW
2022:	4,250 MW
2023:	4,500 MW
2024:	4,750 MW
2025:	5,000 MW

2026: 5,250 MW
2027-2070: 5,500 MW/yr

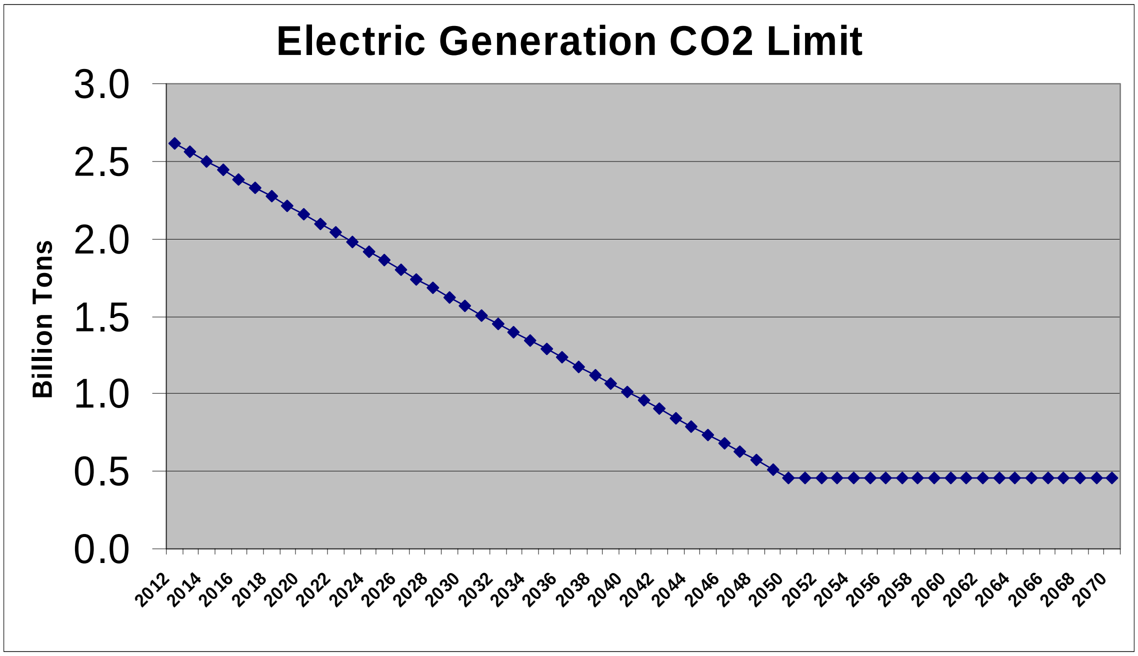
Note: These numbers are not cumulative, but represent the maximum amount of new nuclear capacity in each single year that could be added to the accumulated nuclear capacity from previous years. As was mentioned with the High ORS Traffic Demand Case assumption, the GEM™ model did not force the amount of nuclear to be built each year, it simply limited the *maximum* that could be built each year.

- CO_2 emission limits were assumed to begin in 2012 according to a pattern determined from the Waxman-Markey bill, H.R. 2454, introduced in Congress in early 2009. It was assumed for this current analysis that the electric generation sector would only bear its proportionate share of the percentage reduction limits stated in the bill, and that no offsets were available from international sources or from activities such as reforestation, etc. The emission limits used in the modeling are based upon the 2005 emission levels (as is done in the Waxman-Markey bill setup for overall U.S. emissions). Based upon 2005 CO_2 emission from electric generation of 2.696209 billion tons (EPA eGRID database 2007-V1_1), the specific limits used were:

Year	pct under 2005	util_CO_2_limit
2012	0.030000	2.615323
2013	0.051250	2.558028
2014	0.072500	2.500734
2015	0.093750	2.443439
2016	0.115000	2.386145
2017	0.136250	2.328851
2018	0.157500	2.271556
2019	0.178750	2.214262
2020	0.200000	2.156967
2021	0.222000	2.097651
2022	0.244000	2.038334
2023	0.266000	1.979017
2024	0.288000	1.919701
2025	0.310000	1.860384
2026	0.332000	1.801068
2027	0.354000	1.741751
2028	0.376000	1.682434
2029	0.398000	1.623118
2030	0.420000	1.563801
2031	0.440500	1.508529
2032	0.461000	1.453257
2033	0.481500	1.397984
2034	0.502000	1.342712
2035	0.522500	1.287440
2036	0.543000	1.232168
2037	0.563500	1.176895
2038	0.584000	1.121623
2039	0.604500	1.066351
2040	0.625000	1.011078
2041	0.645500	0.955806
2042	0.666000	0.900534
2043	0.686500	0.845262
2044	0.707000	0.789989
2045	0.727500	0.734717
2046	0.748000	0.679445
2047	0.768500	0.624172
2048	0.789000	0.568900
2049	0.809500	0.513628
2050-2070	0.830000	0.458356

This progressively declining emission limit is illustrated in the following graph:

Figure 17. Electric Generation Carbon Dioxide Limit



- It was also assumed for this case, in light of the CAIR vacatur by the courts, that even more strict SO_2 and NO_x limits than the CAIR limits would eventually be implemented. Accordingly, the regular initial CAIR limits were imposed (NO_x beginning in 2009 and SO_2 beginning in 2010), but in 2012 the SO_2 emission limit was reduced by 25% (new SO_2 limit = 75% of the 2010 CAIR SO_2 limit) and in 2015 the normal CAIR step-down in emissions was taken 25% further for both NO_x and SO_2 (new limit in 2015 = 75% of the old 2015 CAIR limit). This serves to make coal even less environmentally attractive and also hastens the need for even scrubbed plants to move away from the highest sulfur coals that comprise a substantial portion of ORS river traffic.

It should be noted the mercury MACT restrictions used in the Base Case remained the same for the alternative high and low cases.

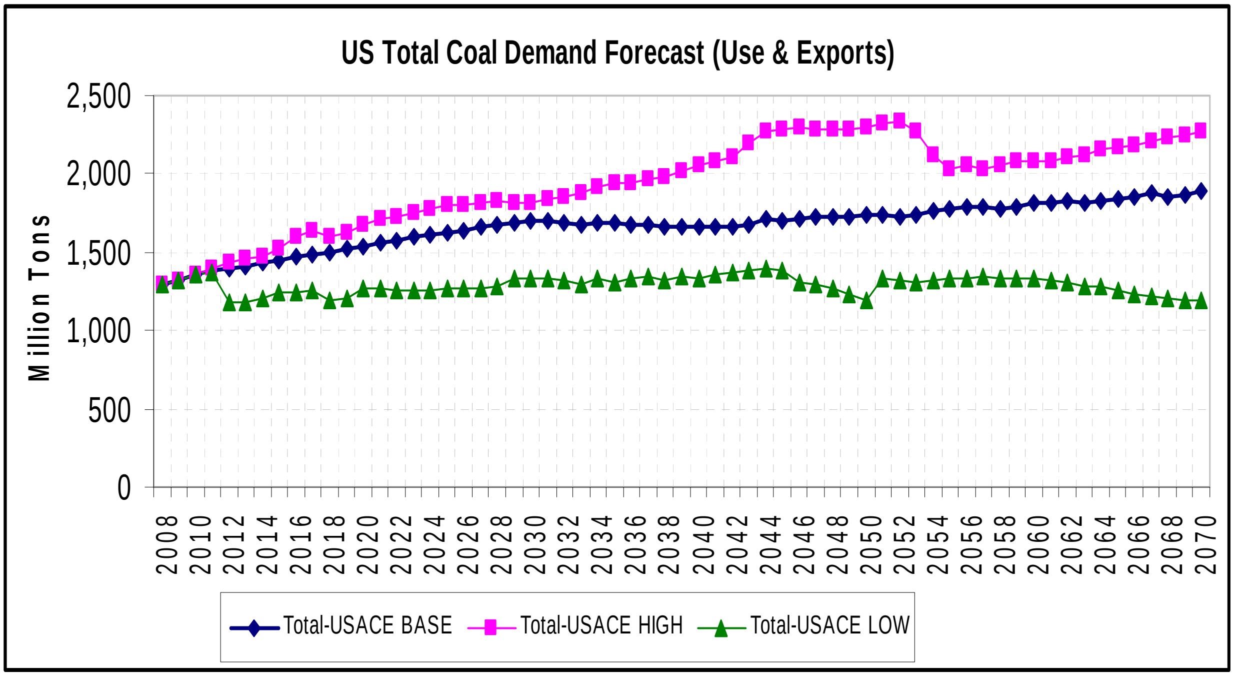
Results

Using the before mentioned assumptions, the following results were recorded.

Total Coal for Use and Export

Figure 18 presents overall U.S. demand for coal for both domestic use and export for all three scenarios of this study.

Figure 18. U.S. Total Coal Demand Forecast (Use & Exports) – All Scenarios



In the High ORS Traffic Demand Case, the combination of increased electricity demand (caused by higher GDP growth) and increased non-electric sector coal demand (i.e., MEIO demand) causes overall coal tonnage to gradually move higher than Base Case levels in the 2012-2030 period. Then, post-2030 when coal flattens and new nuclear construction comes on strongly in the Base Case, the High ORS Traffic Demand Case, by contrast, assumes that regulatory and environmental challenges place a tighter throttle on nuclear expansion, and coal is the primary beneficiary, growing at a faster pace.

As shown later in this report, this post-2030 growth surge is due primarily to strong growth in NAPP and in the PRB. However, in the face of the tight SO_2 emission restrictions of the CAIR rules (the same in both the Base and High ORS Traffic Demand cases), the expanded use of overall coal means that the portion of NAPP coal that expands the most strongly is the higher quality portion, with specific high-quality seams being economic to develop at the market prices for coal caused by the strong overall demand. In addition, much of the NAPP mid-sulfur coal is washed harder in the High scenario (again at a washing plant cost justified by a strong market) to bring it down into the upper end of the "near-compliance" range. A more detailed look at this Northern Appalachian quality phenomenon is presented later in this discussion.

Eventually, as happens earlier with CAPP coal, the NAPP reserves of better quality or economically washable coal begin to deplete, and around 2053 we see a decline begin in NAPP tonnage. This decline, coupled with the on-going declines in CAPP and Illinois Basin coal production, are enough to cause the overall U.S. tonnage to drop in the figure above by approximately 300 mmt, but it still remains more than 200 mmtpy above the Base Case levels in the mid-2050's period. Then, in approximately the last decade of the forecast time horizon, the High Case tonnage again pulls away from the Base Case tonnage, due to stronger demand for coal due to electric load growth. Throughout, the higher natural gas prices keep gas from stripping dispatch from coal, and the High Case scenario plays out as primarily a coal versus coal situation.

According to the Low Case in Figure 18, the start of CO_2 emission limits in 2012 immediately causes a drop in total U.S. coal demand of slightly over 200 mmt. Thereafter, total U.S. coal in the Low Case floats up and down between 1.2 billion tpy and 1.4 billion tpy throughout the rest of the forecast period while the total tonnage in the Base Case generally grows (see discussion of the Base Case results). The shortfall of Low Case tonnage versus Base Case expands to about 400 mmt in 2028, falls a bit to be just below 300 mmt in 2043, and then expands to be 685 mmtpy below the Base Case by 2070. This final figure represents a loss of about 36% of U.S. total coal demand.

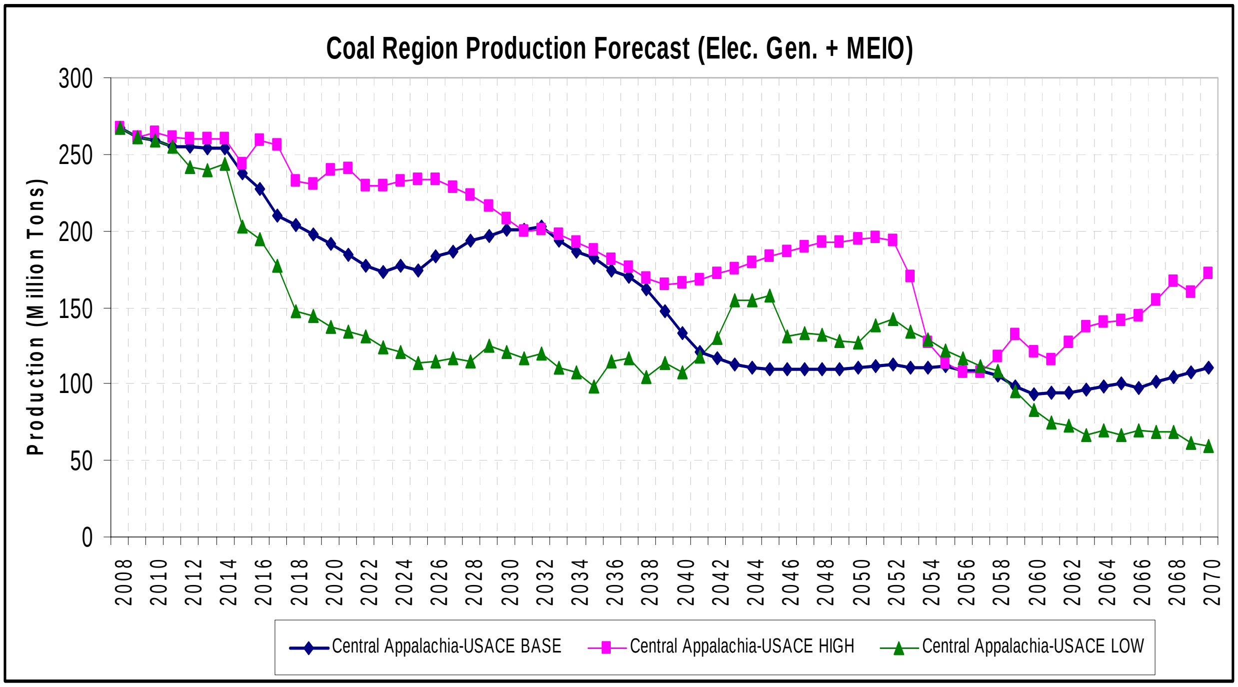
The general period between the early-2040's and the early-2050's presents some noticeable movements in the High and Low case curves, both strongly related to the PRB and the impact of its large tonnage on the total. Although the PRB will be discussed in more detail later, we note here how it affects the total tonnage shown in the figure above. In the High Case, the United States enters a period where the economics of continued strong demand growth cross a threshold that stimulates higher than usual expansion of PRB capacity. This expansion of the largest piece of the pie overwhelms the smaller movements in other major producing areas, some upward and some downward, to drive the U.S. total upward at a faster pace. However, in the Low Case during roughly this same period, the PRB does not cross such an economic threshold and remains virtually flat. Without any upward offset from the large block of PRB tonnage, the declines in CAPP, NAPP, and Illinois Basin tonnages cumulatively cause the U.S. total to dip down. Then, for several years after about 2053 in the Low Case, the PRB grows a bit more, and even a 5-10% cumulative rise in its large tonnage is enough to offset declines in other areas for about 10-12 years, keeping the U.S. total flat.

The following discussion focuses on the basin-level sub-pieces of the total tonnages discussed above.

Central Appalachian Coal Production

With regard to the CAPP production (Figure 19), a strong demonstration is observed of the point (mentioned prior) that the United States is not "running out of coal in the ground" in CAPP. Rather, the reference should always be to an economic level – the United States is running out of $35 cost-of-mining compliance coal, etc. – and this three-case comparison graph aptly illustrates this point.

Figure 19. Central Appalachian Coal Demand (Use & Exports) – All Scenarios



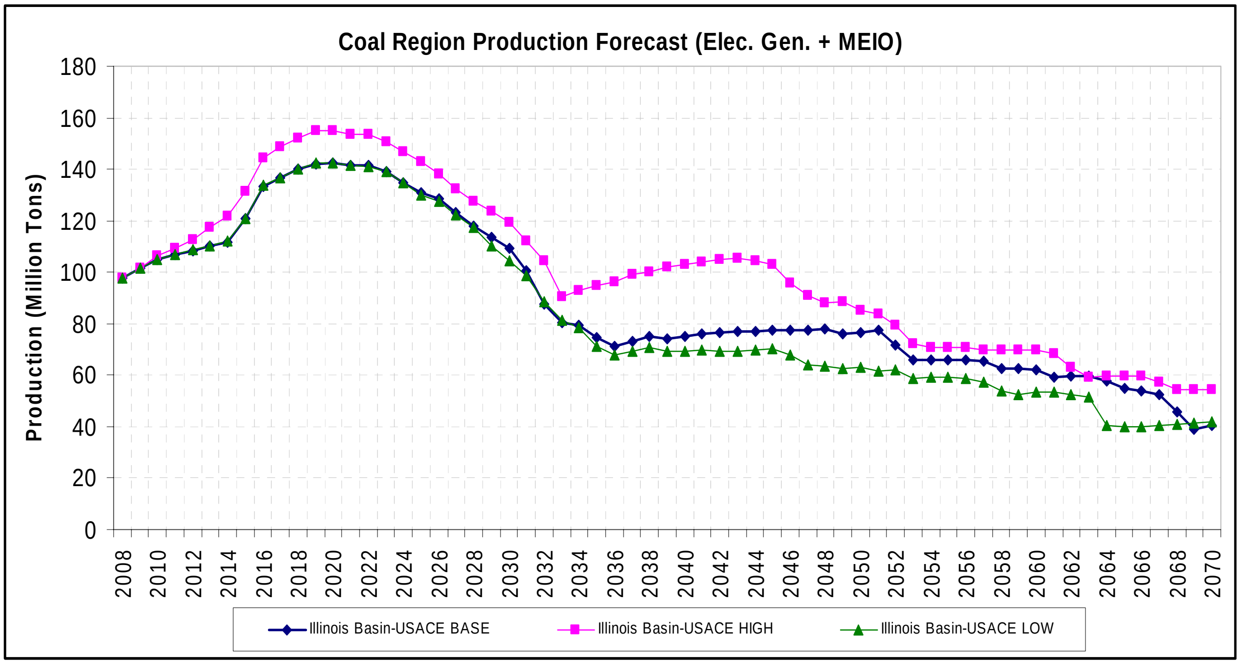
Specifically, in the High Case, market-clearing coal prices rise faster and cross a point where a "bubble" of coal reserves at a somewhat higher cost is economic to produce in the 2015-2025 time frame, while it is not economic to produce in the Base Case and the Low Case in that time frame. Then, as cumulatively more coal is produced in the Base Case and market prices reach the threshold point, this "bubble" of coal is produced in the Base Case in roughly the 2025-2035 time frame. Finally, with much lower overall demand in the Low Case, the United States does not reach the need for this block of high quality, but also higher cost, coal (the "bubble") until about the 2040-2055 time frame. The coal is always there waiting to be mined, but its time does not arrive until later in the lower demand scenarios.

In addition to the above, it should be noted that only in the High Case is the market strong enough to justify a second "bubble" of yet higher-cost coal to be produced in CAPP (2040-2052). It is still true that high-quality reserves at each new cost level will last only for a time, especially in the CAPP area where extensive previous mining has occurred, and these "bubbles" of new capacity only temporarily slow the inevitable slow decline.

Illinois Basin Coal Production

In addition to the overall discussion above, the Illinois Basin seems to be the area that is least impacted by the various differing assumptions across the three scenarios.

Figure 20. Illinois Basin Coal Demand (Use & Exports) – All Scenarios



In fact, for roughly the first half of the forecast, the Base Case and the Low Case virtually coincide with each other, with the High Case running at most 10%-15% above the Base Case level. The only period showing more divergence than this is the period of the early-2030's through the late-2040's during which the High Case Illinois Basin tonnage moderately grows while the Base Case and Low Case tonnages generally flatten out. However, after climbing to more than 25% above the Base Case level, the High Case tonnage then falls to be only marginally above the Base Case from about 2050 forward.

Northern Appalachian Coal Production

Northern Appalachia is the coal producing area that shows the strongest response to the High Case assumptions. From about 2025 forward, it is clear that the economic stimulus for strong NAPP production, which is missing in the Base and Low Cases, is available in the High Case. However, as mentioned in earlier discussion, this strong coal production is not the stereotypical high sulfur coal that is the image of today's NAPP production. In fact, looking below the Basin-level tonnage (Figure 21) and toward some specific coals within that region, Figures 22 and 23 show Northern West Virginia compliance coal and near-compliance coal tonnage, respectively, for the High Case.

Figure 21. Northern Appalachian Coal Demand (Use & Exports) – All Scenarios

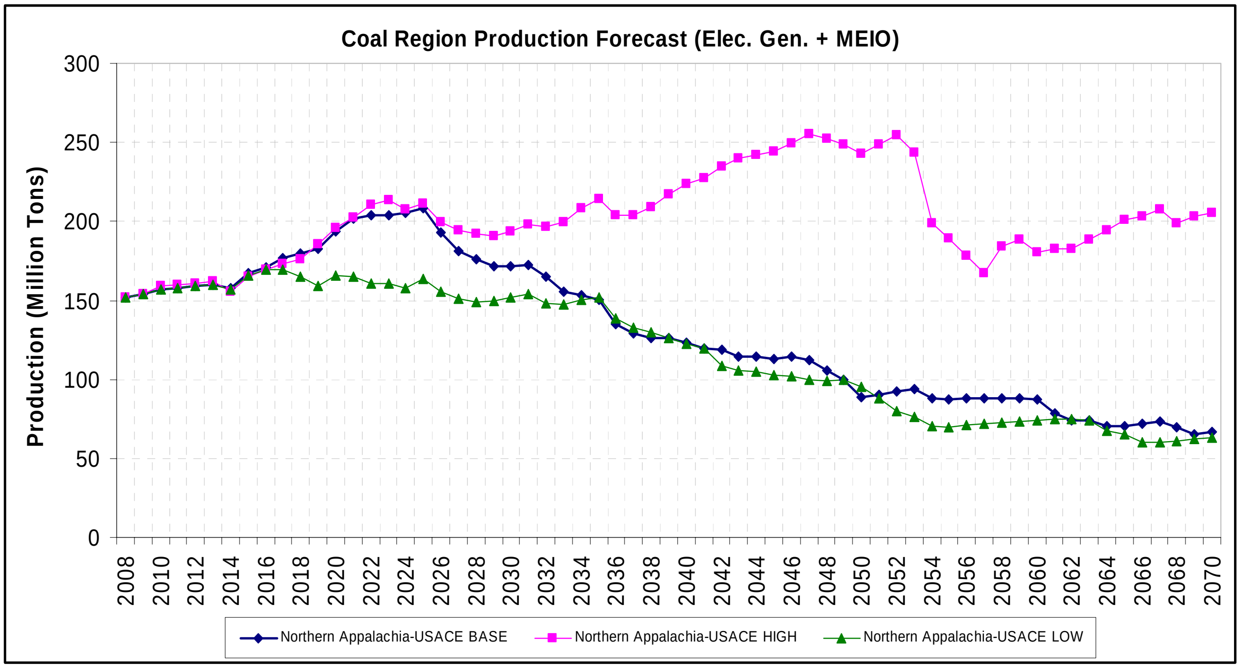


Figure 22. Northern West Virginia Compliance Coal Production – High Case

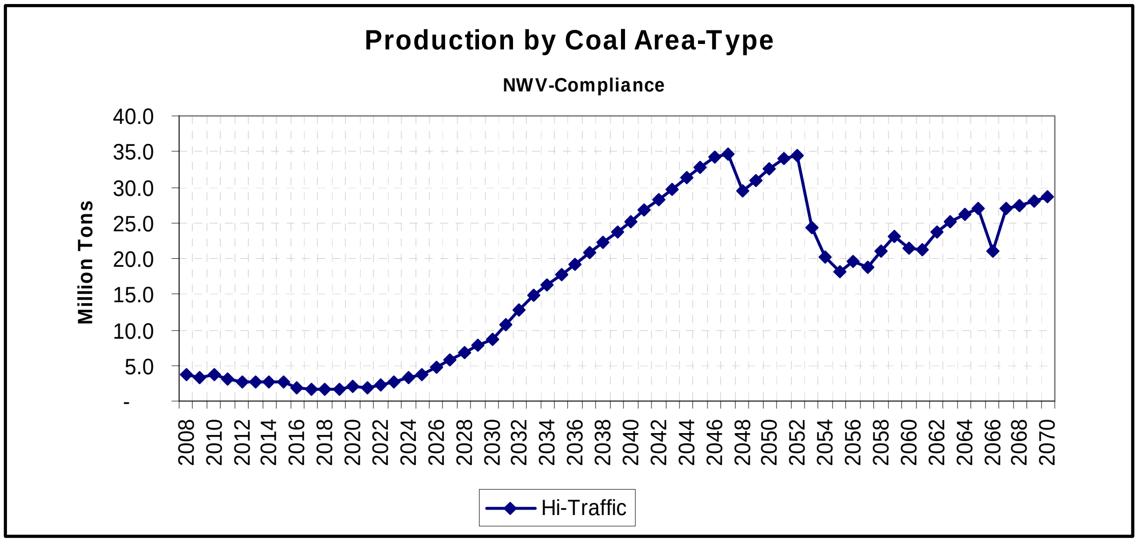
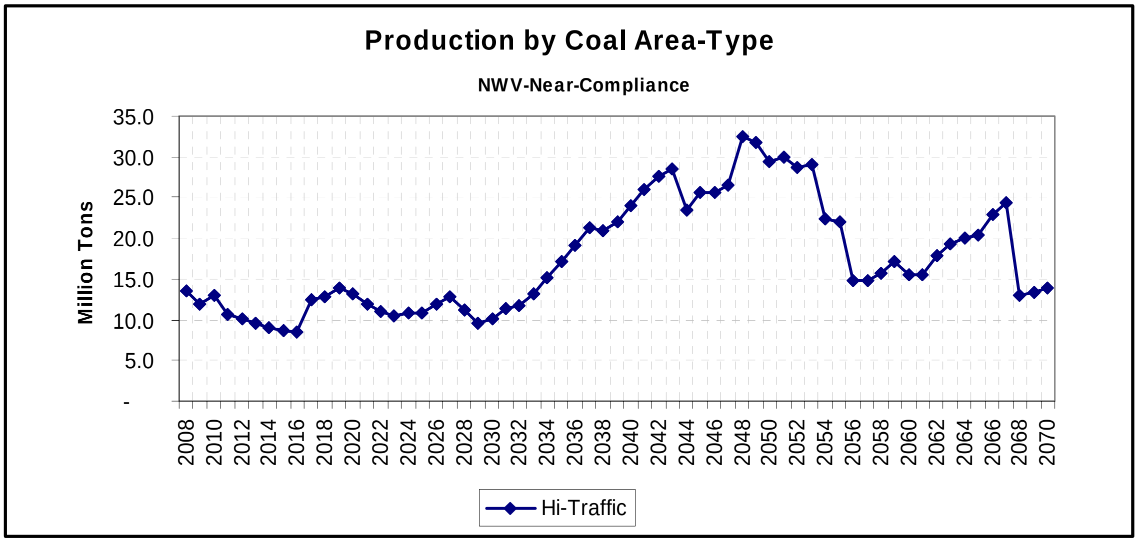


Figure 23. Northern West Virginia Near-compliance Coal Production – High Case

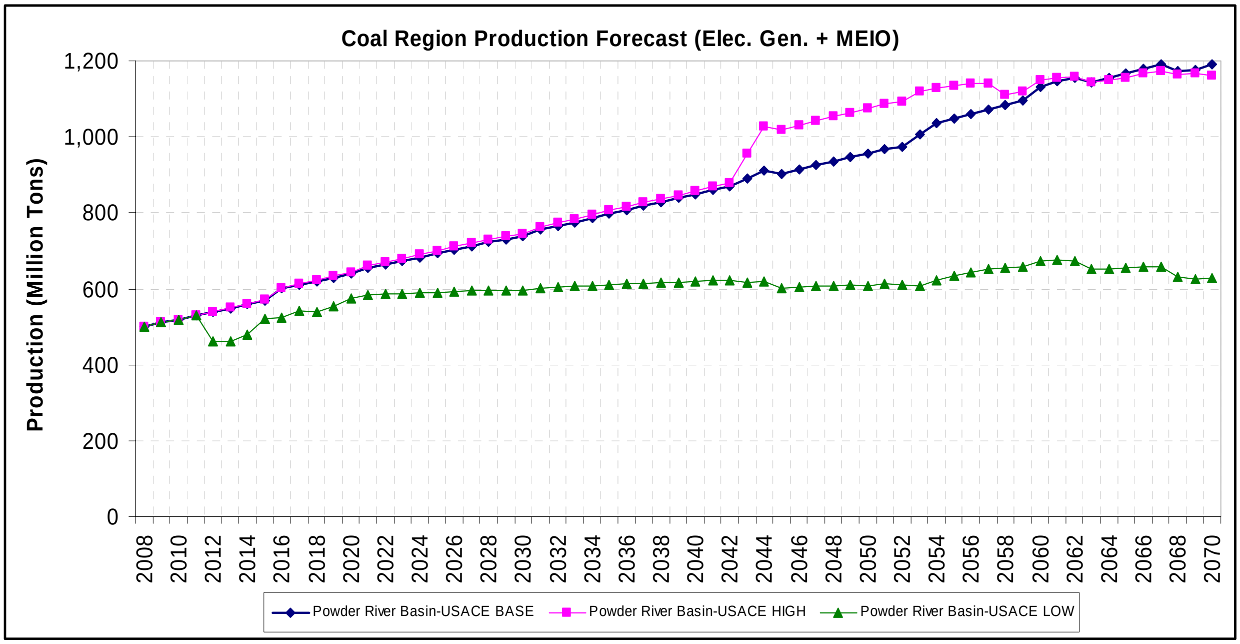


While the mid-sulfur and high-sulfur coals from this area still decline in the face of needing both scrubbing and lower sulfur coals against a fixed SO_2 emission cap (see discussion of the Base Case results), there is no longer the lower sulfur coals coming solely from outside NAPP. As discussed earlier, this production of lower sulfur coals in NAPP comes at a cost (both in mining of difficult seams and in higher reject washing of traditional seams), but with very strong market demand, the economic incentive exists to justify these costs.

Powder River Basin Coal Production

The final tonnage slide (Figure 24) shows the three-case comparison for PRB tonnage, which was discussed extensively above. However, it should be stressed that with the advent of CO_2 limits in 2012 in the Low Case, the PRB is one of the areas that feels a strong impact, initially losing about 80 mmt of annual production.

Figure 24. Powder River Basin Coal Demand (Use & Exports) – All Scenarios



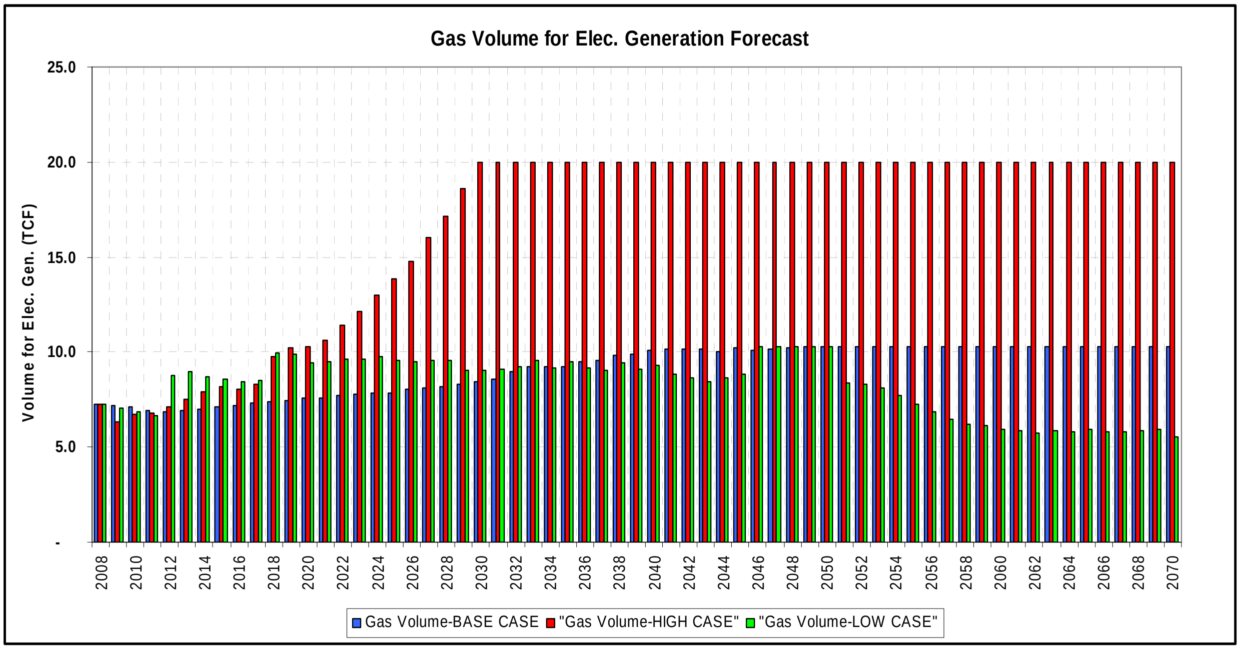
The PRB production recovers somewhat to grow at about the same rate (same slope of the curve) as in the Base and High Cases until about 2020, but after that time, it flattens out in production in the Low Case while the Base and High cases grow robustly. Clearly, in a mirror image to NAPP's High Case response, the PRB is the area that shows the most impact of the Low Case assumptions.

Gas Use by Electric Utilities Forecast

Given the other non-generation uses for natural gas, especially in a strongly growing economy, we placed an assumed upper limit on the amount of natural gas that could be used for electric generation in the High Case. That limit was 20 TCF per year, more than triple the typical current level of use. In the High Traffic Demand scenario, use of natural gas for electric generation grows steadily until it hits this maximum around 2030, and then it stays at that level. This is despite the input assumption of higher natural gas prices than in the Base

Case (see case assumptions above). The simple fact is that the strong growth in GDP and electricity demand causes a need for both coal-fired and gas-fired generation (as well as maximum nuclear, as is shown later).

Figure 25. Gas Volume for Electric Generation – All Scenarios

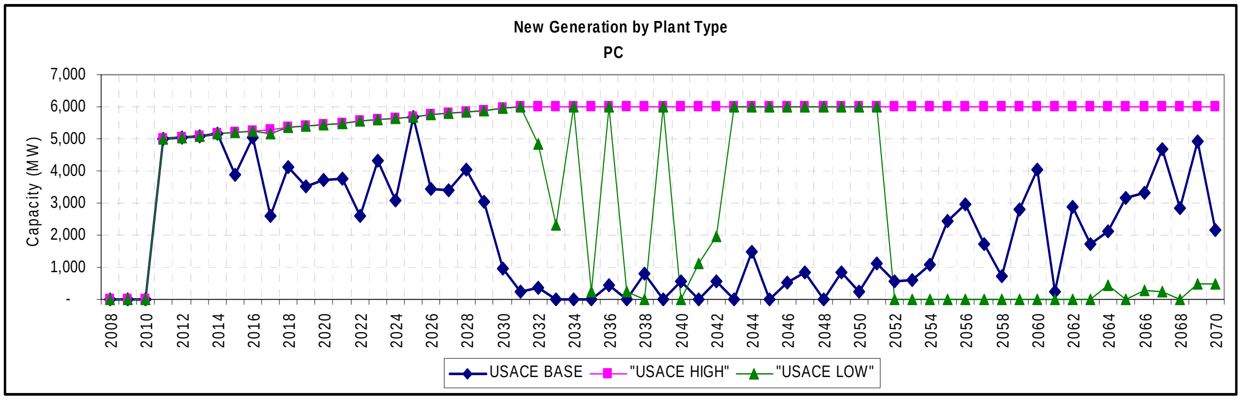


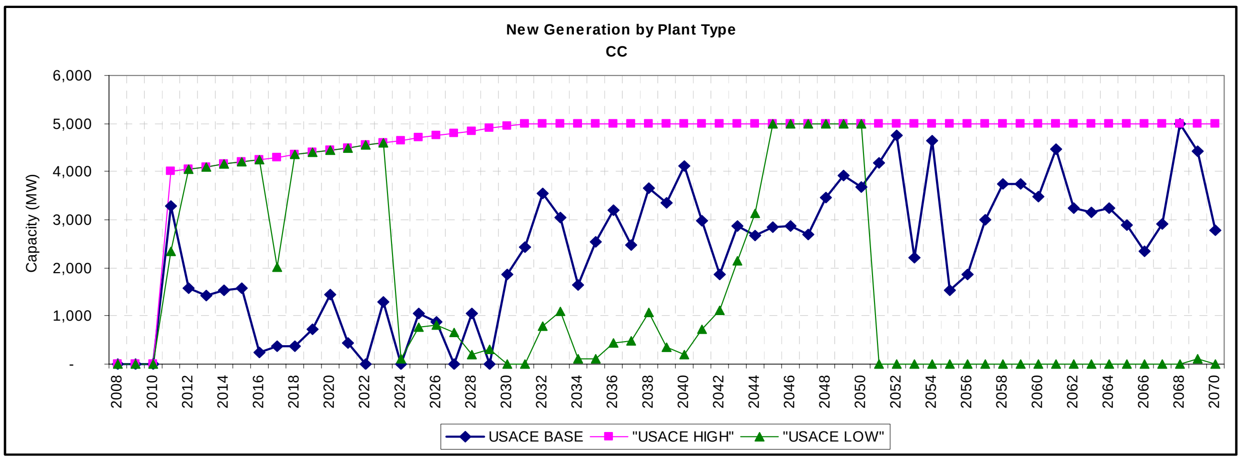
With the start of CO_2 emission limitations in 2012 in the Low Case, Figure 25 depicts a jump in gas use for electric generation from approximately 6.7 TCF to 8.7 TCF per year. Thereafter, use of gas for electric generation in the Low Case bounces up and down between about 8 and 10 TCF per year, finally beginning a downward trend in the last two decades of the forecast period and falling below 6 TCF per year.

Model Generated New Electrical Generation Capacity

Both new PC unit construction and new gas-fired CC unit construction tend to lock in on their assumed maximum rates in the early years of the forecast period in both the High Case and the Low Case. However, the driving forces for this are very different between the High and Low cases. In the High Case, the demand for electricity is simply so strong that enough additional capacity is needed to max out the build rates for these types of generation. Thus, as soon as new "generic" (i.e., model-optimized as opposed to announced and under construction) units are allowed in the model in 2011, the model chooses to build both coal-fired and gas-fired baseload units as fast as it can, and this continues unabated throughout the entire High Case forecast.

Figure 26. New Generation by Plant Type – Pulverized Coal and Combined Cycle – All Scenarios





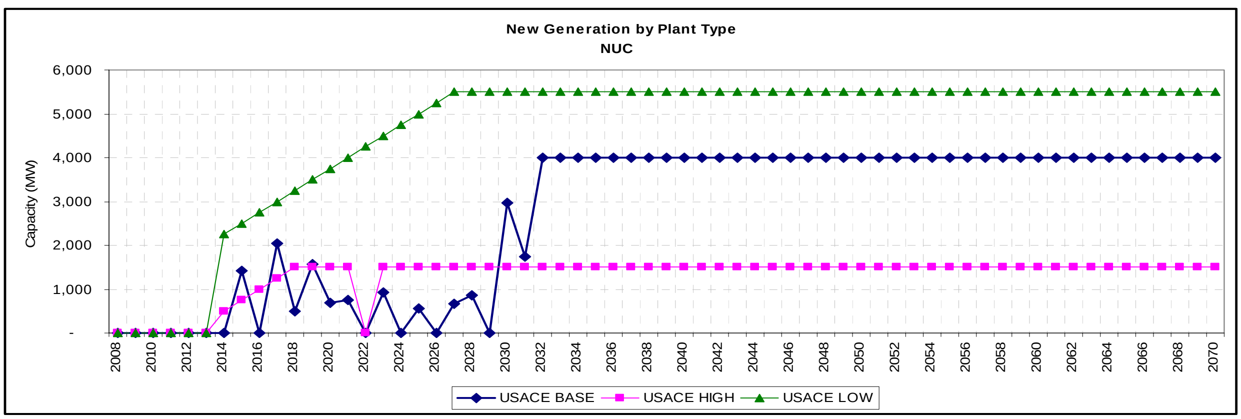
In the Low Case, however, electricity demand is growing at a much slower pace, but both PC construction and CC construction still tend generally to max out (PC construction until 2032 and CC construction until 2024), both significantly above the Base Case levels of new construction.

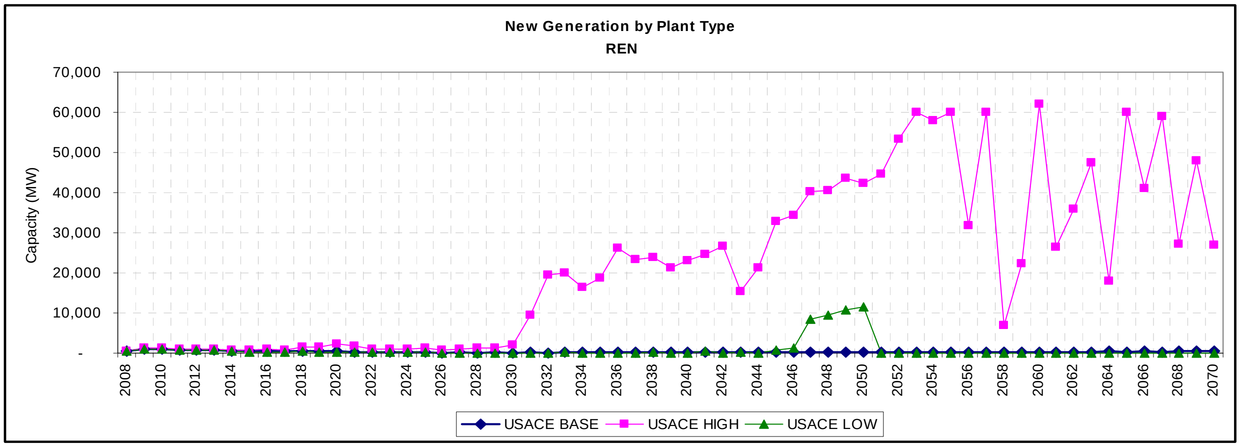
In this Low scenario, it is not electric load growth that is driving the new generation capacity construction – it is the imposition of CO_2 emission limits. The building of new PC's maxes out in 2011 simply because more capacity is needed in the next couple of years (i.e., even the Base Case maxes out 2011-2013 for PC construction). However, close examination of the CC graph for the Low Case reveals that it does not max out until 2012, the year of imposition of CO_2 limits. Both PC's and CC's are being built post-2014 at the maximum rate because they emit less CO_2 than existing units (new PC's because of their better assumed heat rate, and new CC's because of the lower carbon content in natural gas compared to coal, as well as the assumed lower heat rate for new CC units). Thus, basically the same result exists in the High and Low Cases (maxed out PC and CC construction, significantly higher than Base Case construction), but for a different reason in each scenario.

In the Low Case during the 2040's, both PC and CC new construction again max out for a few years. This time it is related to the decline in economic availability of higher quality eastern coals (see the discussion of tonnage graphs above). In other words, as it becomes harder and more expensive year-by-year to provide certain types of coal, a point is reached at which it is more economic to build new generating capacity with higher thermal efficiency and all of the latest clean-up equipment than to continue operating some of the older, less efficient units. Both coal-fired and gas-fired new capacity benefits from this economic threshold effect.

Both the nuclear and renewables new construction graphs listed below (Figure 27) illustrate the delicate nature of making scenario assumptions for running "what if" modeling cases.

Figure 27. New Generation by Plant Type – Nuclear and Renewables – All Scenarios





The nuclear new construction graph clearly shows that whether for keeping up with strong electric load growth (the High Case) or for providing low carbon emitting generation (the Low Case), nuclear power is highly desired. It reaches the limit in both the High and Low cases at the assumed maximum level, which purposely has been set at different values since nuclear availability is used as one of the driving forces between the scenarios.

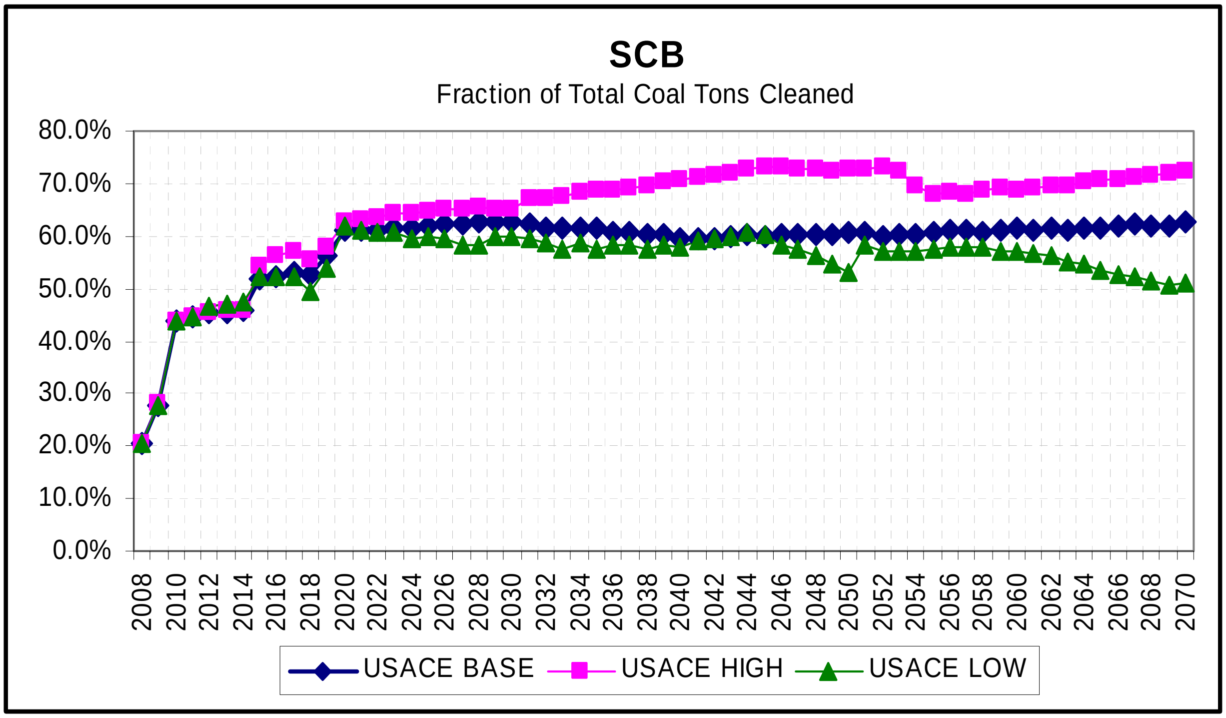
The renewables graph should be viewed as a "safety valve" graph in this situation, and directly related to the arbitrary level assumed for nuclear maximum build rate (as well as PC and CC assumed maximum build rates). This situation occurs because the renewables in the model are unconstrained in order to allow each state to always be able to construct enough renewable generation capacity to meet its RPS. When the other types of capacity building are not allowed by their assumed maximum construction rates to be sufficient to meet growing electricity demand (which is especially strong in the High Case), then the model turns to the only unconstrained source, renewables, and "fills the gap" with this new construction. Thus, these are "false" renewables that, given the tight environmental constraints, might best be viewed as additional nuclear capacity in the modeling.

In other words, if the High Case nuclear building rate constraint is relaxed from the highly restrictive 1,500 MW per year maximum to allow, say, 3,000 MW per year maximum, then cumulatively over a 10 year period there would be another 15,000 MW of nuclear (or over a 30 year period an extra 45,000 MW of nuclear), and the pressure to build the "false" renewables would be greatly alleviated.

Percentage of Coal that is Scrubbed per Year

In interpreting the following "percentage of clean-up" graphs, it is important to reflect back on the tonnage results presented earlier.

Figure 28. Percentage of Scrubbed Coal per Year – All Scenarios



The scrubbing graph shown in Figure 28 clearly shows that in the High Case with fixed CAIR SO_2 caps, but higher generation and higher tonnage than the Base Case (see Figure 18), there is an obvious need for a higher percentage of the coal-fired units to have scrubbers. Note that the upward steps in 2010, 2015, and the 2018-2020 period occur in all three scenarios, but the High Case scrubbing percentage simply needs to be a little higher due to more generation causing more SO_2 production.

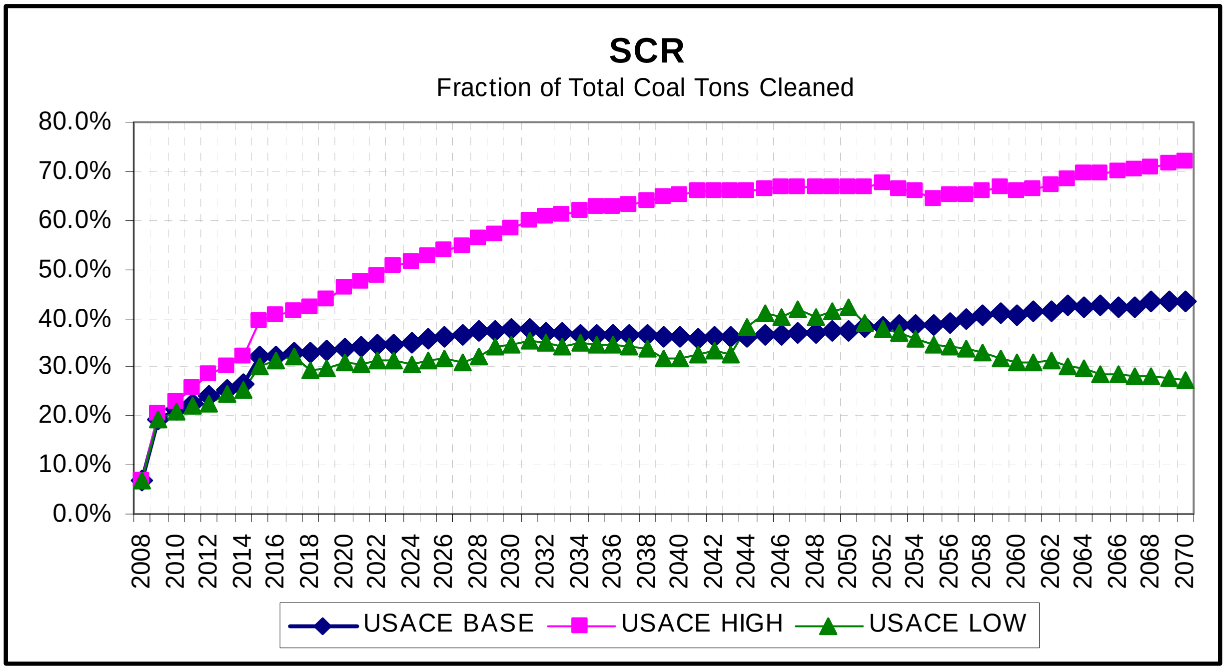
In the Low Case, two opposing driving forces exist which affect the percentage of units scrubbed. On the one hand, significantly lower coal tonnage is being used, due primarily to the imposition of CO_2 emission limits. All else being equal, this trend should cause a lowered percentage of coal being scrubbed against fixed SO_2 emission caps.

On the other hand, the emission caps have tightened in the Low Case, and with these more restrictive SO_2 caps there is pressure in the other direction for more scrubbing instead of less scrubbing. As the graph in Figure 28 depicts, the lowered overall tonnage has more impact, and the percentage of coal scrubbed in the Low Case is marginally below the Base Case until the tail-end of the forecast period when Low Case tonnage starts a decline.

Percentage of Coal with Selective Catalytic Reduction

The graph for SCR NO_x removal equipment shows the same pattern as the scrubbing graph for exactly the same reasons as just described.

Figure 29. Percentage of Coal with Selective Catalytic Reduction – All Scenarios

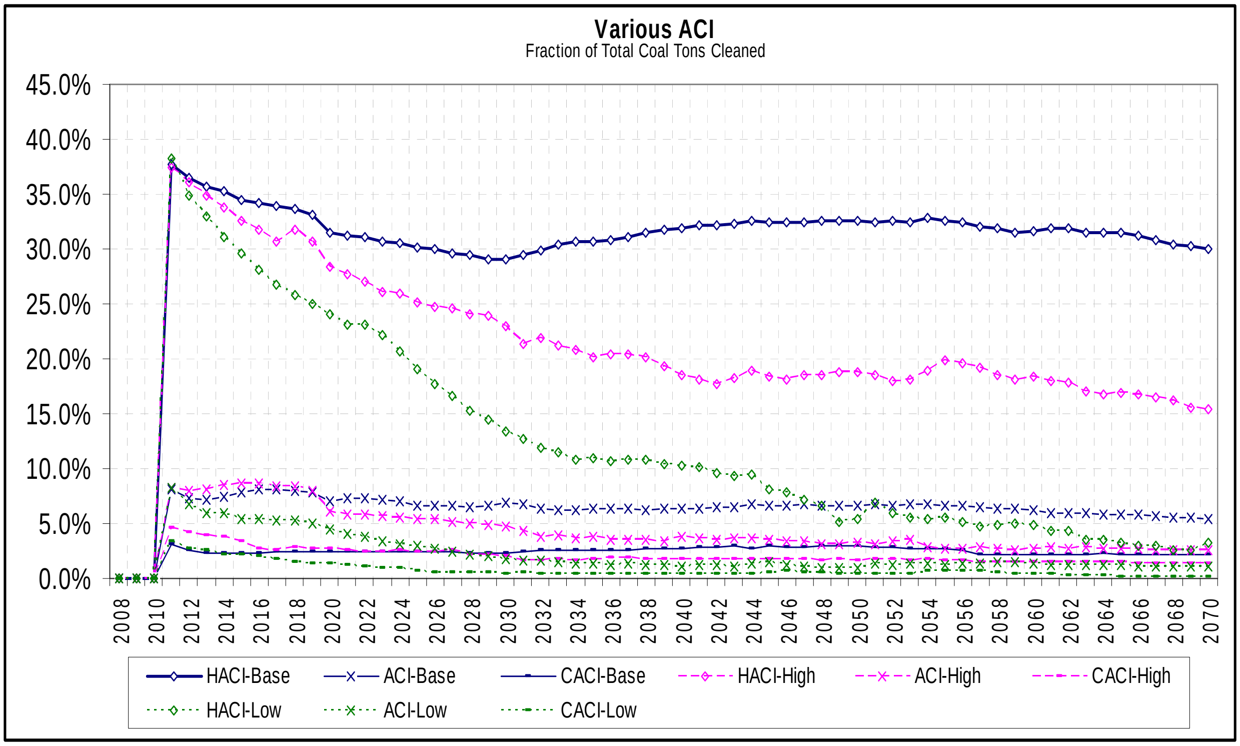


However, it can be noted that in the High Case, the NO_x situation seems more sensitive, and the gain in SCR percentage clean-up is more like 25%-30% over the Base Case instead of the roughly 10% gain we saw in the scrubbing situation.

Percentage of Coal with Various ACI

HACI is the most effective option for lower rank coals. With High Case PRB tonnage staying mostly the same as the Base Case (Figure 24*)* while total U.S. High Case tonnage increases significantly above the Base Case (Figure 18*)*, it is not surprising that the calculated percentage of total coal cleaned by HACI is lower in the High Case than in the Base Case.

Figure 30. Use of Different Types of Activated Carbon Injection – All Scenarios



Since there is not a fixed cap for Hg MACT (and these graphs are expressed as percentage of coal treated), not much of a corresponding increase exists in ACI and CACI as an "offset" to the reduced HACI in the High Case.

In the Low Case, both the total U.S. tonnage is lower (which would increase the percentage of total if the absolute amount of HACI held constant) and the PRB tonnage is substantially lower than the Base Case (which would tend to lower the percentage of total for HACI which is predominantly for PRB coal). Obviously, this second factor (lower PRB and lower HACI) is most important since the graphed results show that HACI clean-up percentage drops from over 35% to less than 5% in the Low Case.

CONCLUSIONS

Base Case

Total U.S. demand for coal to satisfy domestic usage (as well as exports) in the Base Case rises from 1.29 billion tons in 2008 to 1.88 billion tons in 2070. The growth is fastest in the

2008-2030 period at a compound rate of 1.27% per year, is basically stagnant in the 2030-2045 period, and climbs again at a 0.43% per year rate in 2045-2070.

Reflecting continued depletion of the lower cost, higher quality coal reserves, Base Case forecasted production of CAPP coal declines from more than 250 mmtpy to level off at approximately 100 mmtpy in the latter stages of the forecast period. There is some respite in the declining trend during the 2025-2035 period as higher sulfur coals begin to fall because the fixed cap under the CAIR SO_2 rules eventually requires both scrubbing and some shifting away from the highest sulfur coals.

This shift away from the highest sulfur coals in later years is reflected in the projected Base Case coal production totals for the Illinois Basin and for NAPP, both of which rise strongly due to new scrubbers until the early 2020's and then begin losing tonnage. The downward pressure on Northern Appalachian coal production is exacerbated by the fact that the coals in this region have the highest mercury content in the Nation.

PRB coal grows relatively unabated throughout the Base Case forecast, rising from approximately 500 mmtpy at the beginning of the forecast (or about 39% of U.S. total use and export) to nearly 1.2 billion tpy in 2070 (or about 64% of total use and export). This strong growth is the factor that keeps overall U.S. tonnage rising in the face of some shifting away from higher sulfur coals in later years.

However, coal does not grow as fast as electricity production, and coal's share of generation falls from a fairly steady level of 54%-56% in 2010-2030 to be only 43% in 2070. Gas-fired generation grows about as fast as overall generation, representing a solid growth in gas demand from the electric sector, and the natural gas share of overall generation stays relatively flat at 18%-22% throughout the Base Case forecast. The falling coal share is picked up by nuclear generation which rises from around 16% to nearly 28% by the end of the forecast.

These Base Case fuel share trends are reflected in the patterns of new electric plant construction, with coal-fired generation expanding early and stagnating later, while both gas-fired and nuclear begin their strongest growth at the point when construction of coal units begins to decline. After catching up with the RPS in various states, the building of new renewable generation is only strong enough to maintain the required RPS percentages each year.

Construction of environmental clean-up equipment is very strong in the early years of the Base Case forecast. Use of scrubbers climbs from about 20% of all coal burned at the beginning of the forecast to around 60% by 2020 when the second phase of CAIR has fully impacted and many coal-fired units are also seeking the mercury co-benefits of scrubbers.

This 60% level of all coal scrubbed holds for the rest of the forecast period, indicating more scrubbers are built as coal use increases. SCR for NO_x removal grows rapidly from just over 5% of all coal in 2008 to nearly 35% in 2020 and climbs more slowly thereafter, reaching about 44% in 2070. With the implementation of mercury MACT limits in 2011, ACI of various types is immediately implemented on roughly 40%-45% of all coal burned. The levels of each type remain fairly consistent, with HACI hovering between 30%-35% of all coal, ACI running 5%-8% of all coal, and CACI maintaining about 2%-3% of all coal burned.

Low Case

In the Low Traffic Demand Case, the imposition of CO_2 emission limits is the big driving force on coal tonnage, with additional impacts caused by making CAIR emission limits 25% more stringent and assuming GDP growth 0.4% per year lower than the Base Case growth. In this Low Case, total U.S. coal demand for use and exports runs generally 300-650 mmtpy lower than levels of the Base Case, with the difference climbing above the 400 mmtpy mark predominantly in the last two decades of the forecast (i.e., the 2050's and 2060's). Regionally, the PRB and CAPP suffer the most in the first 20-30 years, which is logically consistent since these coals are the better quality coals in the Nation with a substantial portion of their demand driven by how tightly emissions from overall coal burn are pressing against the SO_2 (and, to a lesser extent, NO_x) limits. As the overall demand for coal drops due to CO_2 limits, the remaining amount of burn presses less strongly against the SO_2/NO_x limits, and a portion of the economic premium for these better quality coals disappears, causing their demand to drop. After the late-2030's, almost all of the Low Case drop below the Base Case is due to the PRB which is as much as 600 mmtpy below its Base Case level.

Entirely consistent with this PRB tonnage drop is the fact that the use of scrubbers and SCR equipment in the Low Case remains very close to the Base Case levels until the very end of the time frame. In other words, it is more economic to continue to use Base Case levels of eastern and mid-western coal with the use of clean-up equipment than it is to move much of this usage to PRB coal under the CO_2 limits (and the 25% more strict CAIR limits). Of course, with PRB tonnage significantly below the Base Case, the use of HACI mercury removal equipment is very much lower in the Low Case since the HACI is predominantly used for the lower rank coals.

Finally, we see in the Low Case that both nuclear plants and gas-fired plants generally are built at a faster rate than in the Base Case, at least in the early years of the forecast time frame. This result is entirely expected, since both nuclear and gas help to lower the CO_2 emissions from a predominantly coal-fired electric generating industry. However, there also is an initial unexpected result of new coal units being built at a much faster pace in the Low Case than in the Base Case, at least in the early years where rapid nuclear and gas expansions were witnessed. Upon reflection, this result also is very logical as the newly-constructed coal-fired units are very much higher in thermal efficiency with lower heat rates than the much older coal-fired units that they generally are replacing. It is clear that these new units are replacing other older coal units since the overall total U.S. coal tonnage remains fairly flat and does not rise as these units are built.

High Case

In the High Traffic Demand Case, higher economic growth (with accompanying higher domestic met coal demand, industrial steam coal demand, and coal export demand) along with an assumption of difficulties in the permitting and construction of nuclear plants, drives the overall U.S. coal demand gradually higher above the Base Case. This differential of the High Case over the Base Case generally runs in the 100-150 mmtpy range until around 2030 when strong nuclear construction in the Base Case tends to suppress coal growth. Since this strong nuclear growth cannot occur in the High Case due to the assumption of permitting and construction difficulties, the coal tonnage continues a strong growth pattern and rises as high as 600 mmtpy above Base Case levels before the gap between the cases closes to a range of 250-400 mmtpy.

Although the High Case regional tonnages for CAPP, the Illinois Basin, and the PRB are marginally above those of the Base Case, the "shape" of the growth/decline curves remains about the same as in the Base Case for those regions. However, the NAPP tonnage shows a strikingly different pattern between the two cases. While the post-2025 need for a combination of both scrubbing and lower sulfur coals in the Base Case causes a drop in demand for the NAPP coals, the High Case demand is strong enough to cause an economic justification of producing some lower sulfur coals actually within NAPP. This occurs from a combination of deeper washing (with higher reject material) and the mining of more difficult, but higher quality reserves. Eventually, the economics wane slightly, and NAPP High Case tonnage, which had grown to be 150 mmtpy above the Base Case levels, falls back to a range of 75-100 mmtpy above the Base Case.

The use of clean-up equipment in the High Case directly flows from the tonnages described above. With significantly higher tonnage than in the Base Case, but with the same fixed CAIR SO_2 and NO_x caps, the use of scrubbers in the High Case grows to more than 70% of all coal burned, which is 10% higher than in the Base Case. Similarly, the use of SCR's in the High Case grows to 60% of all coal by 2030 (more than 20% over the Base Case's nearly 40% level) and to slightly over 70% of all coal by 2070 (nearly 30% over the Base Case). However, in a second-order domino effect, this higher use of scrubbers has a co-benefit effect in the High Case of removing more mercury. This effect causes somewhat less usage of all types of ACI in general, with the lowered HACI usage being most visible because of its high level in the Base Case.

Finally, the demand for electricity is so strong in the High Case that new construction of PC's, CC's, and nuclear units all max out against the limits in the model of the amount of new capacity of each type that could reasonably be built on an annually sustainable basis. In fact, with the throttled-back nuclear construction, the model builds unrealistic amounts of renewable generating capacity in the far later years of the forecast. This is stated as "unrealistic" because if any one of the other limits of annually sustainable permitting and construction capacity for coal-fired, gas-fired, or nuclear units were relaxed, then those units would be built instead of the renewable units. These excess renewable units are best interpreted as actually being nuclear capacity that would be built under a somewhat less-constrained set of model limits.

Calibration of the Model

There are very fundamental reasons why a model such as GEM™ will not match exactly in all points to the actual results in the real world, even when the model is run for a past year. For example, all of the model's logic is based upon solely economic driving forces (albeit with limits placed on certain constraining parameters), while in the real world decisions sometimes vary from the pure economic optimum due to other strategic and psychological considerations. Also, a model by its very nature makes some "generic" assumptions such as "typical" seasonal maximum availability of capacity for coal-fired electric generating units. In any historical period, however, there will always be the exception of a unit that ran at a non-typical very high capacity factor for that particular period, and model results should be expected to be somewhat different than the historical reality for this particular unit in that particular period.

Despite all of this, a robust and highly granular model such as GEM™ can be calibrated or "fine-tuned" by adjusting the input parameters, some slightly up and some slightly down from their nominal settings, until a very large number of model outputs match very closely to the historical reality when the model is run for a past year. For example, a nominal entry of summertime maximum availability of 90% for nuclear units and 95% for coal-fired units will be treated in a computer model as 90.0000% and 95.0000% respectively, even though the modeler is not thinking that he wants a nuclear entry between 89.9999% and 90.0001%. In fact, in the calibration, or "fine-tuning" process, the modeler may adjust the summertime nuclear availability to 89% and the coal unit availability to 94% because in combination with a large number of other fine-tuned inputs the entire array causes the plant-by-plant results to line up very closely with the actual historical results from a baseline year.

This type of calibration was done with the GEM™ model for this project. Using both 2006 and 2007 as dual "baseline" years for comparison, the input parameters were calibrated in small amounts to arrive at a fine-tuned set that brought plant-by-plant results into a close match for the ORS plants of interest, recognizing that it is impossible for even a highly granular model to ever achieve exact matching. The table below gives the comparison of model output to historical data for a set of ORS plants of interest for the years 2006 and 2007. Model results for 2008 and 2009 are also shown for comparison.

Plt_Name	Ktons Actual2006	Ktons Actual2007	Model MMT Total 2006	Model MMT Total 2007	Model MMT Total 2008	Model MMT Total 2009	2006 Pct. over / under	2007 Pct. over / under	2-Year Average
Barry	4,903.89	4,770.85	5.688706	5.777998	6.026009	6.026009	16.0%	21.1%	18.6%
Gorgas	3,334.45	3,139.00	3.468673	3.064339	3.305874	3.046155	4.0%	-2.4%	0.8%
Greene County	1,609.14	1,576.61	1.775061	1.616221	1.524353	1.533724	10.3%	2.5%	6.4%
Colbert	3,556.27	3,515.49	3.759953	3.100161	3.690979	3.747253	5.7%	-11.8%	-3.0%
Widows Creek	4,534.14	4,741.99	4.613367	4.960560	4.586425	4.588227	1.7%	4.6%	3.2%
Charles R Lowman	1,672.30	1,573.10	1.744173	1.547554	1.644303	1.653917	4.3%	-1.6%	1.3%
Clifty Creek	4,778.81	4,365.61	4.573666	4.396551	4.777455	4.777455	-4.3%	0.7%	-1.8%
Tanners Creek	2,687.63	2,858.13	2.666149	2.711577	2.402207	2.479608	-0.8%	-5.1%	-3.0%
R Gallagher	1,158.75	1,400.83	1.376515	1.387560	1.384493	1.384493	18.8%	-0.9%	8.9%
Culley	1,202.28	1,062.00	1.426909	1.426909	1.426909	1.420567	18.7%	34.4%	26.5%
Ghent	5,640.29	5,304.79	5.591443	5.364934	5.933826	6.041722	-0.9%	1.1%	0.1%
Green River	765.78	729.59	0.388763	0.482851	0.453271	0.460941	-49.2%	-33.8%	-41.5%
Mill Creek	4,469.50	4,819.01	4.425412	4.741512	4.740459	4.740459	-1.0%	-1.6%	-1.3%
Paradise	6,895.49	5,830.53	6.751729	5.785062	6.729142	6.729142	-2.1%	-0.8%	-1.4%
Shawnee	4,522.35	4,586.00	6.349531	7.562765	2.863662	3.503731	40.4%	64.9%	52.7%
Coleman	1,317.70	1,468.39	1.336758	1.344580	1.532762	1.377307	1.4%	-8.4%	-3.5%
New Madrid	4,226.95	4,530.00	3.558507	3.836998	3.836998	3.836998	-15.8%	-15.3%	-15.6%
Cardinal	4,675.36	4,469.77	4.498062	4.516717	4.418710	4.418988	-3.8%	1.1%	-1.4%
Walter C Beckjord	2,818.12	2,812.54	2.994824	2.927200	1.808214	1.808214	6.3%	4.1%	5.2%
Miami Fort	3,044.03	2,983.70	3.169385	2.949165	3.216117	3.241823	4.1%	-1.2%	1.5%
J M Stuart	6,187.29	6,384.54	5.921138	6.344076	5.784016	5.784016	-4.3%	-0.6%	-2.5%
R E Burger	847.20	832.20	0.925670	0.993672	0.817135	0.817135	9.3%	19.4%	14.3%
Sammis	7,608.40	7,446.22	7.943249	7.420231	6.699607	6.645682	4.4%	-0.3%	2.0%
Muskingum River	2,798.00	3,250.00	2.779081	3.235809	3.767598	3.817156	-0.7%	-0.4%	-0.6%
Kyger Creek	3,270.51	3,373.95	3.348087	3.336935	3.016625	3.016625	2.4%	-1.1%	0.6%
Elrama	912.40	913.57	1.098138	1.099893	1.115886	1.115055	20.4%	20.4%	20.4%
Hatfields Ferry	3,478.00	4,160.00	3.466442	4.023071	4.515174	3.740785	-0.3%	-3.3%	-1.8%
Mitchell (PA)	671.60	386.27	0.719029	0.463406	0.714592	0.714592	7.1%	20.0%	13.5%
Allen	2,925.25	2,937.54	2.979418	3.138900	3.145401	3.161511	1.9%	6.9%	4.4%
Cumberland	7,782.23	7,107.58	7.759611	7.178809	7.167972	7.167970	-0.3%	1.0%	0.4%
Gallatin	4,185.39	4,177.64	4.210034	4.210034	4.811468	4.811468	0.6%	0.8%	0.7%
Johnsonville	3,840.08	3,878.33	3.684695	3.810885	3.877303	4.539563	-4.0%	-1.7%	-2.9%
Amos	8,228.30	8,088.00	8.595907	8.376406	5.912757	5.912757	4.5%	3.6%	4.0%
Kanawha River	815.93	884.70	1.003052	0.931406	0.996199	0.996199	22.9%	5.3%	14.1%
Phil Sporn	2,096.41	2,538.74	2.275909	2.374563	2.275909	2.275909	8.6%	-6.5%	1.0%
Fort Martin Power St	3,311.55	2,979.27	3.210857	3.170275	3.195155	3.195155	-3.0%	6.4%	1.7%
Rivesville	93.59	124.00	0.429866	0.379610	0.343548	0.442611	359.3%	206.1%	282.7%
Willow Island Power	395.55	419.14	0.391252	0.380982	0.388219	0.388219	-1.1%	-9.1%	-5.1%
Kammer	1,347.67	1,655.54	1.441258	1.555664	1.507631	1.509763	6.9%	-6.0%	0.5%
Mitchell (WV)	2,973.95	3,285.00	2.953934	3.275652	4.303235	4.303235	-0.7%	-0.3%	-0.5%
Miller (ALA)	12,542.23	12,557.00	11.931833	11.931833	11.931833	9.675153	-4.9%	-5.0%	-4.9%
Pleasants	3,487.97	3,197.39	3.708261	3.244729	3.313300	3.313300	6.3%	1.5%	3.9%
East Bend	2,125.22	1,684.40	2.172275	1.605024	1.878931	1.878931	2.2%	-4.7%	-1.2%
W H Zimmer	3,768.98	3,291.21	3.788781	3.195068	3.987827	4.005691	0.5%	-2.9%	-1.2%
Killen Station	1,752.54	1,747.13	1.627629	1.674566	1.494152	1.494152	-7.1%	-4.2%	-5.6%
Spurlock	3,379.94	3,497.12	3.227942	3.230533	3.260055	4.118834	-4.5%	-7.6%	-6.1%
Big Cajun	8,087.00	7,765.00	8.016980	7.812262	6.893172	6.893172	-0.9%	0.6%	-0.1%
Trimble County	1,787.71	1,553.10	1.868413	1.711800	1.747350	1.747350	4.5%	10.2%	7.4%
Bruce Mansfield	7,378.80	7,047.87	6.344244	6.351804	6.262253	6.262253	-14.0%	-9.9%	-11.9%
Brown (SIGE)	1,816.47	1,428.00	1.821525	1.821525	1.813429	1.813429	0.3%	27.6%	13.9%
Rush Island	6,073.74	4,479.70	4.847048	4.445436	4.637048	4.637048	-20.2%	-0.8%	-10.5%
Rockport	10,418.83	8,832.37	10.246230	8.869929	10.007042	10.007042	-1.7%	0.4%	-0.6%
Mountaineer	2,969.73	3,736.05	2.544404	3.644137	3.868570	3.868570	-14.3%	-2.5%	-8.4%
R D Green	1,801.90	1,622.03	1.814286	1.734256	1.752832	1.752832	0.7%	6.9%	3.8%
Warrick	476.71	2,673.00	0.454112	2.625438	2.276114	2.280318	-4.7%	-1.8%	-3.3%
D B Wilson	1,810.04	1,469.76	1.872711	1.572246	1.084308	1.080921	3.5%	7.0%	5.2%
Richard Gorsuch	646.85	764.80	0.642999	0.699008	0.650348	0.777098	-0.6%	-8.6%	-4.6%
Gavin	6,586.29	7,348.09	6.355863	7.219666	8.153448	8.155353	-3.5%	-1.7%	-2.6%
Cheswick	1,042.80	1,189.02	1.040459	1.068075	0.926225	0.926225	-0.2%	-10.2%	-5.2%
Totals	209,536.28	207,243.20	209.620211	209.658828	206.595836	205.859811	0.0%	1.2%	0.6%

The 2-year average deviation column shows that 46 out of the 59 plants had a deviation of less than 10% up or down, while another 9 out of the 59 plants had a deviation in the range 10%-21%. Only 4 plants were outside this 21% band (Culley and Green River in the 21%-50% range, and Rivesville and Shawnee greater than 50%). Of course, using a percentage deviation measurement means that a plant with smaller coal burn can show a large percentage variance even though the absolute tonnage difference is moderate. The total tonnage across the entire set of the plants of interest shows a deviation of around 1% or less.

Although not presented here, the data in the Appendix show that the types of coal taken at each of these plants also match quite well with their historical selection in the real world during these 2 years. On both the dispatch level (as evidenced by total coal burn at the plant) and the level of economic competition among the various coals to each plant, this was considered to be very good calibration of the model to reality.

Preliminary Coal Traffic Demand for ORS Plants of Interest

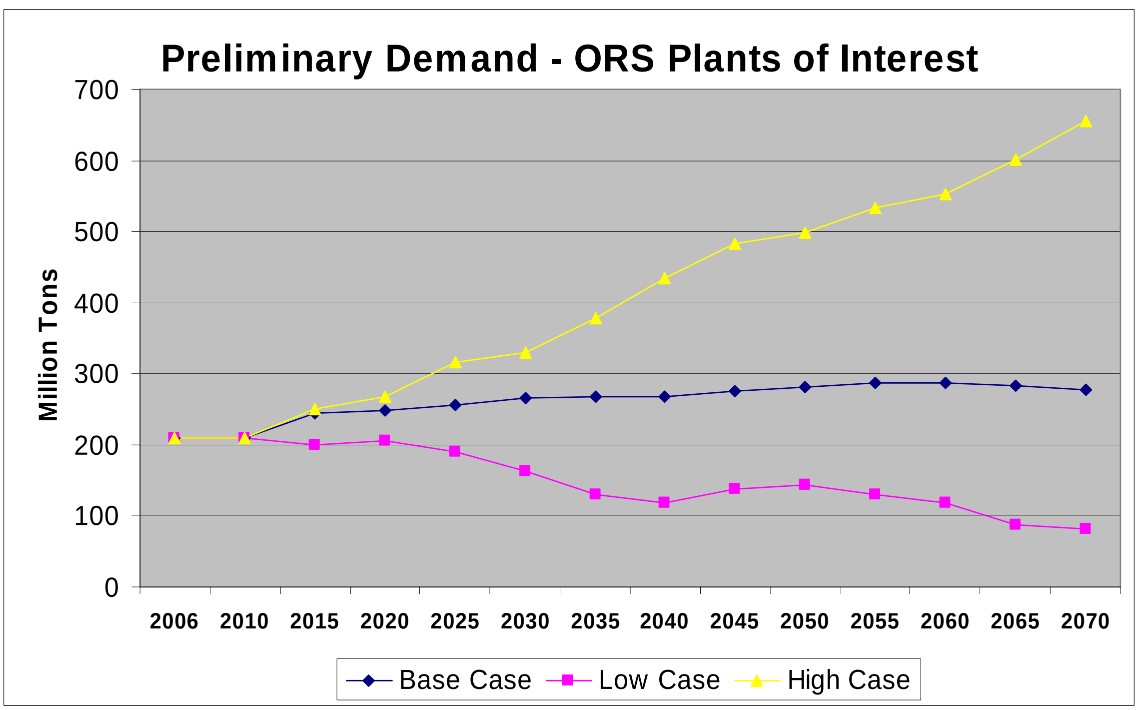
Although the GEM™ model's set of 104 coal "sources," each representing a unique type of coal, is much more granular than most other national models, a decision was reached midway through the project to differentiate the sourcing even further after model demand tonnages by plant were determined. This is accomplished via internal USACE calculations based upon very specific dock-by-dock sourcing and delivery patterns which can be derived from the waterways historical data. That internal USACE further differentiation of coal flow is outside the scope of this project and is not included in this report.

Accordingly, the material presented here is a discussion of the summation of the coal traffic demand (by all modes of transportation, before being further refined by USACE) for that set of plants defined earlier in this report as forming the basis for the calibration of the GEM™ model and referred to as "ORS Plants of Interest." Just as it did in the model calibration, the summation of coal demand across those 59 plants provides a very good preliminary look at the growth in ultimate coal river traffic demand for each scenario of this project. The table below presents the total coal tonnage demand, in millions of tons, for this set of ORS Plants of Interest.

Year	ORS Plants Base Case	ORS Plants Low Case	ORS Plants High Case
2006	209.6	209.6	209.6
2010	210.1	210.3	209.1
2015	244.5	199.7	250.4
2020	247.4	206.1	267.1
2025	255.7	190.9	315.8
2030	264.8	163.8	328.9
2035	266.8	129.4	378.6
2040	268.4	117.5	433.5
2045	274.6	137.8	483.5
2050	281.1	142.8	499.0
2055	286.6	130.1	532.7
2060	286.0	118.2	552.7
2065	282.3	86.8	600.4
2070	276.5	82.4	656.3

In Figure 31 below these results for each scenario are plotted, presenting a more visual image of the divergence between the cases.

Figure 31 – Total Coal Demand by Case for ORS Plants of Interest



The compound annual growth rate from 2010 to 2070 in the Base Case is 0.46% per year, although most of this growth occurs in the first 40 years leading up to about 2050 (a growth rate over this earlier period of 0.73% per year), with the last 20 years of the forecast time horizon remaining relatively stagnant.

By contrast, the overall coal demand at this set of ORS Plants of Interest grows fairly monotonically between 2010 and 2070 in the High Case at an average annual compounded rate of growth of 1.92% per year. This sustained rate of growth over such a long period results in the tonnage for this set of plants being about 656 mmt in 2070, more than double the Base Case level of 276 mmt.

Finally, in the Low Case, except for a bit of life in the 2040-2050 time period (see discussion earlier in this report of the Central Appalachian "bubble" for this time period in the Low Case), we see a declining pattern of coal use at the ORS Plants of Interest. Instead of positive growth, we see a calculated compound rate of decline of -1.55% per year for 2010-2070, leaving the total coal demand at these plants at 82.4 mmt in the final year of the forecast.

In summary, we see a spread of coal demand between the Low and High cases which exceeds 500 million annual tons, indicating a wide diversity of planning needs, depending on the assumptions for the future.

Sorbent Consumption Results and Conclusions

In all of the following discussion, the term "total tonnage" refers to a total of the pre-identified set of plants of interest regarding ORS water movement. The term is not intended to be interpreted as a U.S. total. The following table lists the plants of interest.

Plant ID	Name	Sorb POI	POI	ORS	River	Milepost	Comment	Interest	Water Pct	Origin	Water Pct Lime	Origin Lime
3	Barry	0	1	1	TB		Mobile, AL		0.0	9	0.0	9
8	Gorgas	0	1	1	BW	397		Low	0.0	9	0.0	9
10	Greene County	1	1	1	BW		Fork BW TB, AL	High	0.0	9	0.0	9
47	Colbert	1	1	1	TN	245		High	0.0	9	0.0	9
50	Widows Creek	1	1	1	TN	407		High	0.0	9	0.0	9
1000126	Widows Creek Generic	1			TN	407			0.0	9	0.0	9
1000250	Widows Creek Generic	1			TN	407			0.0	9	0.0	9
56	Charles R Lowman	0	1	1	TB	87		Medium	0.0	9	0.0	9
1000129	Charles R Lowman Generic	0			TB	87			0.0	9	0.0	9
1000253	Charles R Lowman Generic	0			TB	87			0.0	9	0.0	9
136	Seminole (136)	0	0	0					0.0	9	0.0	9
207	St. Johns River Powe	0	0	0					0.0	9	0.0	9
602	Brandon Shores	0	0	0					0.0	9	0.0	9
628	Crystal River	0	1	1				Medium	0.0	9	0.0	9
641	Crist Electric Gener	0	0	0			FL/AL border	Medium	0.0	9	0.0	9
643	Lansing Smith Genera	0	1	1			FL	Medium	0.0	9	0.0	9
645	Big Bend	0	1	1			Tampa, FL	Medium	0.0	9	0.0	9
676	CD McIntosh Jr.	0	0	0					0.0	9	0.0	9
887	Joppa Steam	1	1	1	OH	952			1.0	1	1.0	1
1000172	Joppa Steam Generic	1			OH	952			1.0	1	1.0	1
1000296	Joppa Steam Generic	1			OH	952			1.0	1	1.0	1
891	Havana	0	0	0					0.0	9	0.0	9
892	Hennepin Power Stati	0	0	0				Low	0.0	9	0.0	9
898	Wood River Power Sta	1	1	1	UM		east alton il		1.0	1	1.0	1
983	Clifty Creek	1	1	1	OH	560		High	1.0	3	1.0	3
1000179	Clifty Creek Generic	1			OH	560			1.0	3	1.0	3
1000303	Clifty Creek Generic	1			OH	560			1.0	3	1.0	3
988	Tanners Creek	1	1	1	OH	493		High	1.0	3	1.0	3
1004	Edwardsport	0	0	0					0.0	9	0.0	9
1008	R Gallagher	1	1	1	OH	610		High	0.0	3	0.0	3
1012	F B Culley Generatin	1	1	1	OH	779			1.0	3	1.0	3
1046	Dubuque	0	1	1			iowa		0.0	9	0.0	9
1047	Lansing	0	1	1			iowa		0.0	9	0.0	9
1048	Milton L Kapp	0	1	1			iowa		0.0	9	0.0	9
1104	Burlington	0	1	1			iowa		0.0	9	0.0	9
1167	Muscatine	0	1	1			iowa		0.0	9	0.0	9
1218	Fair	0	1	1			iowa	Low	0.0	9	0.0	9
1355	E W Brown	0	0	0			ky		0.0	9	0.0	9
1356	Ghent	1	1	1	OH	535		High	1.0	3	1.0	3
300001	Ghent Generic	1			OH	535			1.0	4	1.0	4
1357	Green River	1	1	0				High	1.0	3	1.0	3
300002	Green River Generic	1							1.0	3	1.0	3
300003	Green River Generic	1							1.0	3	1.0	3
1363	Cane Run	1	1	0	OH	617			1.0	3	1.0	3
1000191	Cane Run Generic	1			OH	617			1.0	3	1.0	3
1000315	Cane Run Generic	1			OH	617			1.0	3	1.0	3
1364	Mill Creek	1	1	1	OH	627		High	1.0	4	1.0	3
1372	Henderson	1	1	1	Green	42		High	1.0	3	1.0	3
1374	Elmer Smith	1	1	0			Ky davies	High	0.0	9	0.0	9
1378	Paradise	1	1	1	Green	100		High	0.0	2	0.1	2
1379	Shawnee	1	1	1	OH	946			1.0	1	1.0	1
1381	Coleman	1	1	1	OH	729		High	1.0	1	1.0	1
1383	Reid Henderson	1	1	0				High	0.0	9	0.0	9
1554	Herbert A Wagner	0	0	0					0.0	9	0.0	9
1613	Somerset	0	0	0					0.0	9	0.0	9
1619	Brayton Point	0	0	0					0.0	9	0.0	9
1626	Salem Harbor	0	0	0					0.0	9	0.0	9
1912	High Bridge	0	1	1			MN		0.0	9	0.0	9
1927	Riverside	0	0	0					0.0	9	0.0	9
2049	Jack Watson	0	1	1			ms	Medium	0.0	9	0.0	9
2104	Meramec	1	1	1					0.0	9	0.0	9
2107	Sioux	0	1	1			st charles, mo	Low	1.0	1	1.0	1
2167	New Madrid	1	1	1					1.0	1	1.0	1
2367	Schiller	0	0	0					0.0	9	0.0	9
2403	Hudson	0	0	0					0.0	9	0.0	9
2480	Dynegy Danskammer	0	0	0					0.0	9	0.0	9
2828	Cardinal	1	1	1	OH	77		High	1.0	3	1.0	3
2830	Walter C Beckjord	1	1	1	OH	453		High	1.0	3	1.0	4

2832	Miami Fort	1	1	1	OH	490		High	1.0	3	1.0	3
2850	J M Stuart	1	1	1	OH	405		High	1.0	3	1.0	3
2864	R E Burger	1	1	1	OH	103		High	1.0	3	1.0	4
2866	W H Sammis	1	1	1	OH	53		High	1.0	4	1.0	4
2872	Muskingum River	1	1	0				Medium	1.0	4	1.0	4
2876	Kyger Creek	1	1	1	OH	259		High	1.0	4	1.0	4
3098	Elrama	1	1	1	Mon	25	Pittsburgh	High	1.0	5	0.0	9
3161	Eddystone	0	0	0					0.0	9	0.0	9
3179	Hatfields Ferry Powe	1	1	1	Mon	79		High	1.0	5	1.0	5
300016	Hatsfields Ferry Generic	1			Mon	79			1.0	5	1.0	5
3181	Mitchell Power Station	1	1	1	Mon	29		High	1.0	5	0.0	9
3393	Allen	0	1	1	LM		Near Memphis	High	1.0	1	1.0	1
3396	Bull Run	0	0	0					0.0	9	0.0	9
3399	Cumberland	1	1	1	CU	103		High	1.0	2	1.0	2
3403	Gallatin	1	1	1	CU	240		High	1.0	2	1.0	2
3406	Johnsonville	1	1	1	TN	99		High	1.0	2	1.0	2
3407	Kingston	0	0	0					0.0	9	0.0	9
3803	Chesapeake	0	0	0					0.0	9	0.0	9
3809	Yorktown	0	0	0					0.0	9	0.0	9
3935	John E Amos	1	1	1	Kan	39		High	1.0	4	1.0	4
3936	Kanawha River	1	1	1	Kan	78		High	1.0	4	1.0	4
3938	Phil Sporn	1	1	1	OH	244		High	1.0	4	1.0	4
3943	Fort Martin Power St	1	1	1	Mon	92		High	1.0	5	1.0	5
3945	Rivesville Power Sta	1	1	1	Mon	120			0.0	5	0.0	5
3946	Willow Island Power	1	1	1	OH	160		High	1.0	4	1.0	4
3947	Kammer	1	1	1	OH	112		High	1.0	4	1.0	4
3948	Mitchell	1	1	1	OH	101		High	1.0	4	1.0	4
4054	Nelson Dewey	0	1	1			WI		0.0	9	0.0	9
4140	Alma	0	1	1			Upper MS	Low	1.0	9	1.0	9
4143	Genoa	0	1	1			WI	Low	0.0	9	0.0	9
4271	J.P. Madgett	0	1	1			WI		0.0	9	0.0	9
6002	Miller	0	1	1	BW		next to Gorgas		0.0	9	0.0	9
6004	Pleasants Power Stat	1	1	1	OH	161		High	1.0	3	1.0	3
6018	East Bend	1	1	1	OH	511		High	1.0	3	1.0	3
6019	W H Zimmer	1	1	1	OH	445		High	1.0	3	1.0	3
6031	Killen Station	1	1	1	OH	391		High	1.0	3	1.0	3
6040	Beaver Valley	0	0	0					0.0	9	0.0	9
6041	H L Spurlock	1	1	1	OH	414		High	1.0	3	1.0	3
1000224	HL Spurlock Generic	1		1	OH	414			1.0	3	1.0	3
1000348	HL Spurlock Generic	1		1	OH	414			1.0	3	1.0	3
6055	Big Cajun 2	1	1	1			LA	Low	0.0	9	0.0	9
6071	Trimble County	1	1	1	OH	572	KY	High	1.0	4	1.0	3
6073	Victor J Daniel Jr	1	0	0			Jackson MS		0.0	9	0.0	9
6094	Bruce Mansfield	1	1	1	OH	33	PA	High	1.0	3	0.0	9
6113	Gibson	1	0	0			Mt Carmel IN		0.0	9	0.0	9
6137	A B Brown Generating	1	1	1	OH	831	Mt Vernon IN		0.5	1	0.5	1
1000180	AB Brown Generic	1		1	OH	831			0.5	1	0.5	1
1000304	AB Brown Generic	1		1	OH	831			0.5	1	0.5	1
6155	Rush Island	0	1	1	LM		40mi S St.Louis	Low	0.0	9	0.0	9
1000170	Rush Island Generic	0		1	LM				0.0	9	0.0	9
1000294	Rush Island Generic	0		1	LM				0.0	9	0.0	9
6166	Rockport	1	1	1	OH	744		High	1.0	1	1.0	2
6264	Mountaineer	1	1	1	OH	242		High	1.0	4	1.0	4
6639	R D Green	1	1	1	Green	41		High	1.0	1	1.0	1
6705	Warrick	1	1	1	OH	784		High	1.0	1	1.0	3
6823	D B Wilson	1	1	1	Green	73		High	1.0	2	1.0	2
1000192	DB Wilson Generic	1			Green	73			1.0	2	1.0	2
1000316	DB Wilson Generic	1			Green	73			1.0	2	1.0	2
7242	Polk	0	0	0				Medium	0.0	9	0.0	9
7286	Richard Gorsuch	1	1	1	OH	177	Marietta, OH	High	1.0	4	1.0	4
8102	Gavin	1	1	1	OH	258		High	1.0	3	1.0	3
1000176	Gavin Generic	1			OH	258			1.0	3	1.0	3
1000300	Gavin Generic	1			OH	258			1.0	3	1.0	3
8226	Cheswick	1	1	1	Alleg	15	Pittsburgh	High	1.0	5	1.0	5
10075	Taconite Harbor Energy Cen	0	0	0					0.0	9	0.0	9
10675	Thames	0	0	0			CT		0.0	9	0.0	9
50130	G F Weaton Power Station	1	0	0			Beaver, PA		0.0	9	0.0	9

The sorbent consumption results for limestone and lime are shown in the next four line graphs. The first line graph for each commodity shows total tonnage consumed and the second line graph shows that portion of the total tonnage consumed that was likely to have been shipped over some portion of the ORS.

Figure 32. Limestone Total Tonnage – All Scenarios

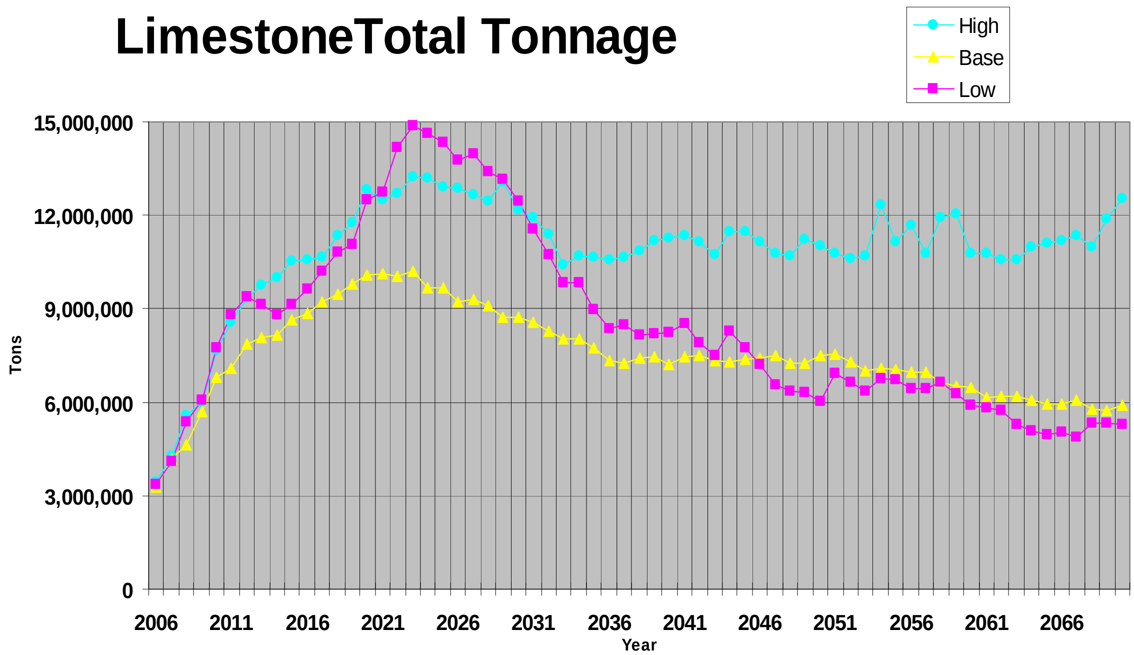
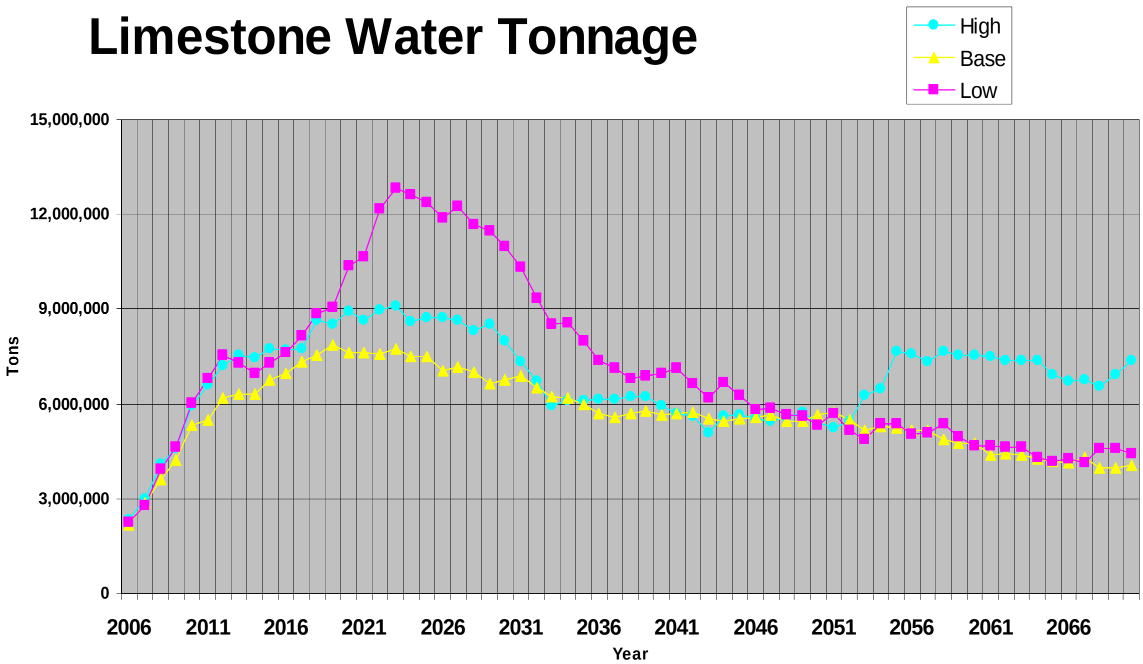


Figure 33. Limestone Water Tonnage – All Scenarios



The following table displays actual numbers used for the graph above and below.

Sorbent Totals for ORS "Plants of Interest" (not U.S. totals)						
	Limestone Total Tonnage			**Limestone Water Delivered Tonnage**		
Year	**Low**	**Base**	**High**	**Low**	**Base**	**High**
2006	3,349,624	3,294,496	3,442,977	2,083,228	2,028,161	2,176,582
2010	7,730,897	6,822,123	7,645,601	5,851,752	5,141,327	5,780,385
2015	9,146,786	8,656,052	10,545,225	7,115,007	6,609,174	7,558,336
2020	12,494,845	10,084,463	12,817,292	10,176,383	7,415,055	8,768,090
2025	14,332,522	9,688,465	12,918,168	12,268,047	7,330,611	8,566,171
2030	12,452,408	8,725,607	12,174,718	10,897,026	6,590,244	7,851,685
2035	8,983,829	7,735,956	10,661,010	7,949,910	5,931,272	6,079,669
2040	8,228,616	7,209,060	11,251,918	6,980,207	5,609,207	5,854,885
2045	7,757,598	7,374,115	11,481,588	6,253,947	5,530,712	5,587,876
2050	6,017,686	7,489,512	11,019,108	5,320,605	5,639,517	5,350,218
2055	6,703,085	7,069,341	11,147,216	5,364,425	5,240,022	7,613,032
2060	5,910,984	6,487,297	10,763,210	4,686,668	4,715,245	7,418,502
2065	4,954,508	5,946,703	11,093,261	4,187,953	4,165,737	6,830,508
2070	5,275,905	5,901,819	12,522,741	4,422,491	4,032,067	7,286,023
	Lime Total Tonnage			**Lime Water Delivered Tonnage**		
Year	**Low**	**Base**	**High**	**Low**	**Base**	**High**
2006	1,692,055	1,366,092	1,664,079	1,511,384	1,185,421	1,483,408
2010	1,701,966	1,312,961	1,766,103	1,543,375	1,154,371	1,607,513
2015	909,098	969,549	1,267,997	687,882	717,397	1,015,846
2020	1,283,147	1,081,638	1,341,203	1,062,949	829,486	1,089,051
2025	981,229	1,219,650	1,310,389	911,941	967,498	1,122,711
2030	511,711	962,035	954,555	511,711	709,884	793,707
2035	341,748	866,181	899,984	341,748	644,837	752,077
2040	418,535	740,097	718,163	418,535	525,115	629,426
2045	314,731	953,804	642,958	314,731	762,296	539,952
2050	313,164	930,575	576,783	313,164	743,428	509,101
2055	401,939	782,870	1,157,263	401,939	601,922	1,015,757
2060	465,466	737,601	1,200,664	465,466	553,720	1,026,004
2065	293,754	781,532	1,113,178	293,754	613,932	995,609
2070	358,415	588,959	1,088,561	358,415	558,910	987,529

Figure 34. Lime Total Tonnage – All Scenarios

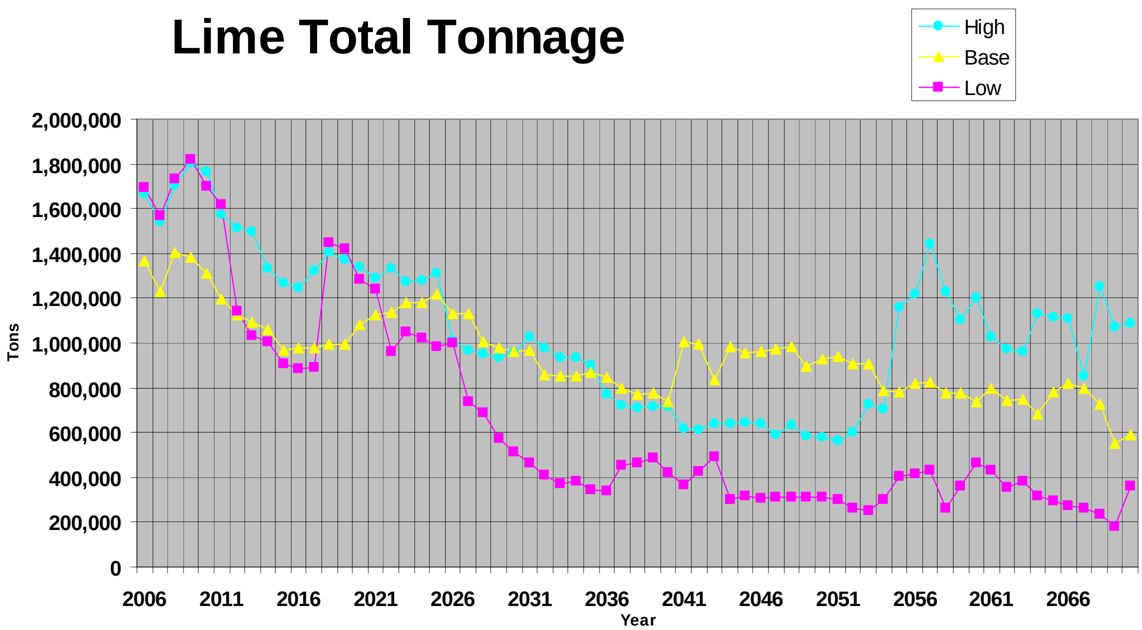
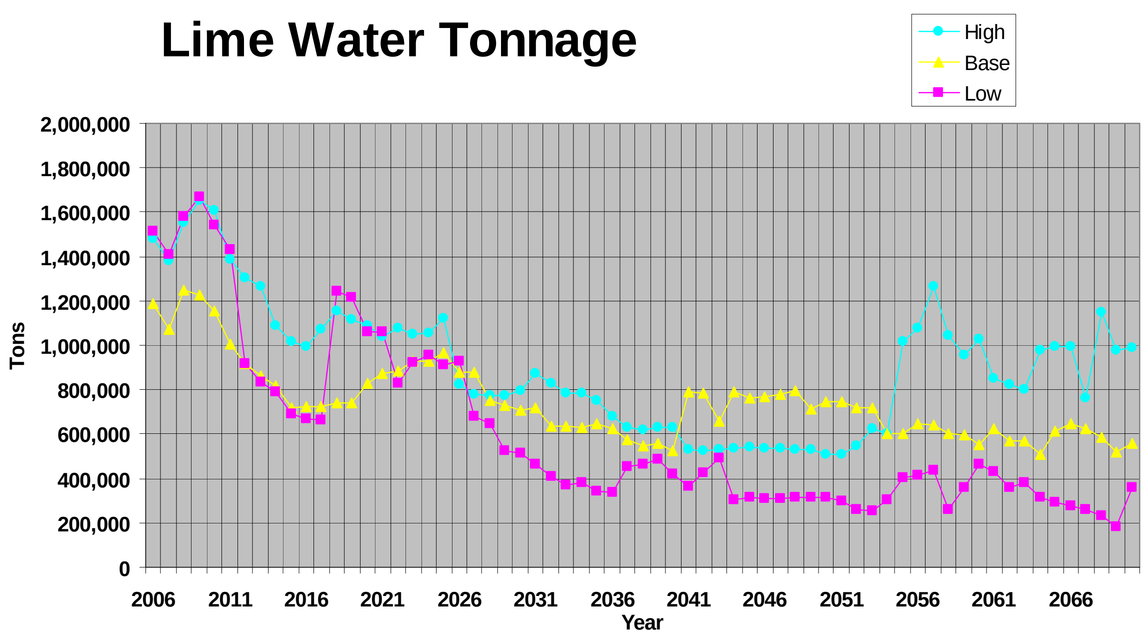


Figure 35. Lime Water Tonnage – All Scenarios



The results from a lime or limestone producer's perspective are remarkable in that the case labels seem to be misleading. For example, while the "High" Case (from a coal perspective) for the GEM™ model projections involves higher tonnages of annual coal consumption, its inherent assumptions cause the Low Case to sometimes have a higher limestone tonnage consumed than the High Case.

This latter "non trend" result is not anomalous if one considers coal power plant cost, utility profit decision making, and the availability of coals used by the GEM™ model. While this was not part of DCR's work, the results of such work from the GEM™ modeling show that while some power plants may use the same overall coal tonnage in a high or low case, the coal types fluctuate between 0.83% and 3.75% sulfur respectively. Similarly, a low coal case may use lower quantities of coal, but a higher sulfur coal, and therefore consume more limestone in the Low Case than in the High Case. These examples explain some of the counter intuitive trends seen in the subsequent tables and graphs on lime and limestone sorbent use.

Sorbent consumption for power plant sulfur emission reduction is a function of:

- the plant/unit technology installed to clean coal emissions;
- the sorbent feedstock quality; and
- sorbent alternative supply sources.

The GEM™ modeling work included cost considerations in many factors including federal government carbon emission policies, overall regional power production/consumption levels, power production and distribution versus purchasing between plants and companies, alternative coals (+100) and their respective delivered costs (whether by mine mouth, water, truck, or rail) and sulfur contents (0.35% – 5.00%) versus other energy equivalent costs from other plants as well as all of the typical internal power plant operating and capital cost assessment decision making. Previous GEM™ modeling work was reviewed and found to be sufficiently detailed and accurate to rely upon for subsequent ancillary work such as sorbent forecasting. As a result, significant "sorbent" forecast work determining coal type use at each plant is completed. This work focused on the above three items to develop sorbent forecast results.

The sorbent technologies considered are simplified by using three sorbent categories: alkali, lime, and limestone. Obviously, the type of coal sulfur cleaning technology utilized dictates the type of feedstock purchased and delivered to the power plant. Each feedstock has its own different handling, preparation, and delivery requirements making the type of technology used a forecast constraint. Based on the sorbent technologies received from GEM™ modeling input files, three sorbent technology classifications can be identified:

- the alkali technologies are limited in application and locations and are therefore not considered;

- current coal burning power plants with lime and limestone sorbent technologies already installed are assumed to not change their technologies and to continue to use and consume lime and limestone as required by their coal consumption forecast; and

- all new future cleaning technologies built and installed at coal burning power plants are assumed to be limestone. Some such assumption is required because many technologies are identified in the official EPA databases as "#N/A" or "Other" or "Unknown." Some plants were researched to identify their likely sorbent technologies. Other plants were noted to have had limestone sorbent based technologies installed in one or more future years or simply identified the sulfur reduction efficiency. When the latter cases were identified, the intervening years were identified and assigned limestone sorbent technologies. If the sorbent technology was still not clear, it was assigned a limestone technology. This latter assumption was based on the detailed cost modeling and resultant coal forecast work with the GEM™ model warranting such a conclusion. Delivered lime is 5-10 times more expensive than limestone on a $/tn basis, but offers reduced plant equipment/capital. Current expectations from the GEM™ modeling work are that the net cost result favors the installation of only limestone scrubbing technologies in the forecast time period.

Sorbent chemistry and chemical reaction yields are important. Ideally, or stoichiometrically, it takes 3.125 tons of limestone to remove 1.0 ton of sulfur from coal combustion products at a power plant. If typical process efficiencies of 95-98% and good quality rock efficacies of 95% are recognized, then the process chemistry results in 3.36 – 3.46 tons of limestone per ton of sulfur removed. Engineers typically see these latter chemistry and rock yields as somewhat constant. Indeed, commercial results attain these efficiencies and are used in this project's forecast modeling work. However, field work with power plants obtaining sorbent technologies and sorbent feedstocks recognize that significant testing and result confirmation are required to attain the nearly "constant" yields desired. Where known, such field differences were incorporated in this work, recognizing differences in limestone's efficacy or the plant scrubbing technology's sulfur removal efficiencies.

No two limestones are alike. Many limestone characteristics sometimes can be ignored as sorbent process technologies "force" limestone through chemistry, pressure, temperature, or catalysts to remove the sulfur. However, limestone efficacies can range from 24% to 99%. This means that it is important to quickly screen limestones before even expensive bench scale testing is done and to recognize that widespread distribution of surface limestones does not mean suitable limestone is available for power plant sulfur scrubbing. Limestone screening is accomplished by considering what limestone qualities correlate highly with >90% rock efficacies in sorbent technologies. These rock qualities are discussed below and then used to identify the likely areas in the ORS where such rocks are being or could be found and/or are produced to supply suitable sorbent limestones to the project's power plants of interest.

Optimizing coal cleaning costs obviously favors less limestone consumed per ton of sulfur, which in turn limits limestone sources and likely producers to those in unique and selected limestone geographical areas of the ORS. There are sufficient geologic areas with sufficient producers to offer varied competitors and supplies to support the assumption of new future power plant scrubbers being limited to limestone feedstocks.

A minor and often ignored issue is the sulfur that comes not in the coal organic matter, but in the coal mineral matter. This latter sulfur is 0.0% to 5.0% of the total coal sulfur and is often not susceptible to scrubbing technologies. As this coal sulfur amount is minor, this "type" of sulfur is ignored in this work.

The following two tables demonstrate how the sorbent consumption was calculated for 2012, Ghent power plant, Ghent, KY, Ohio River, Milepost 535 and ***only*** for the Indiana High-Sulfur coal (INDHIS). However, it is important to note that for each year and each unit and each coal, the "Sorb Tn" or tons of limestone, in this case, were identified and calculated. These calculations for sorbent use for all coals used by each power plant boiler or unit were then summed for each boiler or unit. The sum of such calculations for all boilers or units at a power plant for each year identifies the sorbent used in that year for that power plant. The second table shows the calculations and assumptions for 105,850 tons per year in 2012 for unit 1 using 1,352,580 tons of INDHIS coal with 3.18% sulfur.

Year	Plant ID	Unit ID	Name	CS MM Tn	Scrub On	Coal ID	Pct S	ScrEff	Scrubber	Rock Eff	Stoich	Sorb Tn
2012	1356	1	Ghent	0.068965672	1	OHOHIS	3.75	0.75	Wet Limestone	1.05	3.125	6,365
2012	1356	1	Ghent	0.074130502	1	ILLHIS	3.1	0.75	Wet Limestone	1.05	3.125	5,655
2012	1356	1	Ghent	1.352580993	1	INDHIS	3.18	0.75	Wet Limestone	1.05	3.125	105,850
2012	1356	1	Ghent	0.196711693	1	WKYHIS	3.3	0.75	Wet Limestone	1.05	3.125	15,975
2012	1356	2	Ghent	1.126632469	1	QMCNCP	0.83	0.98	Wet Limestone 2	1.05	3.125	30,066
2012	1356	2	Ghent	0.06724854	1	NWVHIS	3.39	0.98	Wet Limestone 2	1.05	3.125	7,330
2012	1356	2	Ghent	0.06724854	1	OHOHIS	3.75	0.98	Wet Limestone 2	1.05	3.125	8,108
2012	1356	2	Ghent	0.072284774	1	ILLHIS	3.1	0.98	Wet Limestone 2	1.05	3.125	7,205
2012	1356	2	Ghent	0.072927306	1	INDHIS	3.18	0.98	Wet Limestone 2	1.05	3.125	7,457
2012	1356	2	Ghent	0.286542798	1	WKYHIS	3.3	0.98	Wet Limestone 2	1.05	3.125	30,404
2012	1356	3	Ghent	1.182323736	1	QMCNCP	0.83	0.98	Wet Limestone	1.05	3.125	31,553
2012	1356	3	Ghent	0.070572744	1	NWVHIS	3.39	0.98	Wet Limestone	1.05	3.125	7,692
2012	1356	3	Ghent	0.070572744	1	OHOHIS	3.75	0.98	Wet Limestone	1.05	3.125	8,509
2012	1356	3	Ghent	0.075857928	1	ILLHIS	3.1	0.98	Wet Limestone	1.05	3.125	7,561
2012	1356	3	Ghent	0.07653222	1	INDHIS	3.18	0.98	Wet Limestone	1.05	3.125	7,825
2012	1356	3	Ghent	0.300707073	1	WKYHIS	3.3	0.98	Wet Limestone	1.05	3.125	31,906
2012	1356	4	Ghent	1.410435555	1	QMCNCP	0.83	0.98	Wet Limestone	1.05	3.125	37,640
2012	1356	4	Ghent	0.071082655	1	NWVHIS	3.39	0.98	Wet Limestone	1.05	3.125	7,748
2012	1356	4	Ghent	0.071082655	1	OHOHIS	3.75	0.98	Wet Limestone	1.05	3.125	8,571
2012	1356	4	Ghent	0.076406026	1	ILLHIS	3.1	0.98	Wet Limestone	1.05	3.125	7,616
2012	1356	4	Ghent	0.077085191	1	INDHIS	3.18	0.98	Wet Limestone	1.05	3.125	7,882
2012	1356	4	Ghent	0.077429321	1	WKYHIS	3.3	0.98	Wet Limestone	1.05	3.125	8,216

Powerplant Limestone/Lime Demand and Waste Calculations

Chemistry	**Molecular Wt**	**Limestone $CaCO_3$**	**Lime CaO**	**SO_2**	**Sulfur**	**$CaSO_4$**
calcium	40	40	40			40
carbon	12	12				
oxygen	16	48	16	32		64
sulfur	32			32	32	32
Total		100	56	64	32	136

Limestone to SO2	100/64 =	**1.5625**	tons limestone to remove 1 ton SO2
Limestone to S	100/32 =	**3.1250**	tons limestone to remove 1 ton sulfur
Limestone to Lime	100/56 =	**1.7857**	tons limestone to make 1 ton lime
Lime to S	56/32 =	**1.7500**	tons lime to remove 1 ton sulfur
Limestone to Lime to S	(100/56)(56/32) =	**3.1250**	tons limestone to make 1 ton lime to remove 1 ton sulfur

Note:

1) Some sulfur is retained unreacted in the ash and/or is scrubbed by coal ash calcium.

2) The ideal limestone amount needed will be 100-120% of amount chemistry suggests.

3) The only difference between limestone and lime is not the amount of limestone but the source of the material used: limestone quarry or lime kiln plant.

If the product is limestone, though, then 3.125/1.75 or 1.785 times more material than lime is shipped.

Limestone Example: Ghent, KY Ohio River MP 535 2012 Unit 1 INDHIS coal

coal tons/year	1,352,580.993	**forecast**
coal sulfur weight %	3.18%	**forecast**
ash weight %		**forecast**
scrubber efficiency	75.0%	**forecast**
% sulfur retained in ash	0.00%	**forecast**
sulfur % scrubbed	75.0%	calculated

limestone efficiency	105.00%	**forecast**	105.00%	of theoretical limestone amount needed
Coal Total Sulfur Tons/Yr	43,012.076	calculated	= tns/yr * coal sulfur content %	
Sulfur Air Emitted Tons/Yr	10,753	**calculated**	1-Process Efficiency times total coal sulfur tons	
Sulfur Ash Retained Tons/Yr	0	**forecast**	Percent Ash Retained times total coal sulfur tons	
Sulfur Removed Tons/Yr	32,259.057	**Creates Limestone/Lime/Sorbent Demand**		

How much Sulfur must be removed per ton of coal?

= (coal sulfur scrubbed %)*(coal sulfur wt%)*(2,000 lb/tn)

= (75.0%) * (3.18%) * (2,000)

= 47.70 lb Sulfur/ton of coal to be removed by the sorbent

How many lbs of limestone per ton of coal?

= (1/limestone efficiency) * (molecular weight ratio limestone/sulfur) * (lb sulfur/tn)

= 105% * 3.125 * 47.70

= 156.52 lb of limestone per ton of coal burned

How many tons/yr of limestone at the plant? (If actual LS tons known, calculate limestone efficiency.)

= (tons of coal) * (lbs limestone/ton of coal)

= (1,352,581 tpy coal)*(156.91 lb limestone/tn of coal)/(2000lb/tn)

= 105,850 tons per year of limestone sales

How many tons of limestone per ton of S?

= (tons of limestone) / (tons of S)

= 498,354 / 151,500

= 3.28

Sorbent Power Plant Use Technology

This summary of equipment and technology used to clean coal sulfur emissions is a very simplified review of what equipment is being used and how it relates to the type of material used as feedstock to remove the coal sulfur combustion products. Most (79%) of the original scrubbing technologies in the late 1900's were calcium wet scrubbing systems with half based on lime and half based on limestone. The remaining 21% were based on sodium or lime based slurry dry scrubbing. Each system had its share of operating issues. When the second and third generation technologies began being designed, built, and operated towards the end of the 1990's and into the 2000's, the scrubbing technologies were dominated by wet limestone FGD systems. (GEM™ model usage conclusions from this project and "Is It Time to Rethink SO_2 Control Technology Selection," Jim Dickerman, P.E. 12/26/08.) Dickerman concluded, as noted previously, that while the capital costs for limestone systems are generally 10-15% higher than the capital costs for lime based systems, the overall lower limestone operating costs have resulted in the economic selection of wet limestone based systems. Virtually no wet lime systems are being selected for new installations especially those power plants using higher sulfur coals.

Nolan ("Flue Gas Desulfurization Technologies for Coal Fired Power Plants," Paul Nolan, Babcock & Wilcox Company, Coal Tech 2000 International Conference, Jakarta, Indonesia, BR-1709) notes that the breakthrough for wet limestone technologies resulted from the forced air blown into the reaction which prevented scaling and enhanced oxidation of the calcium carbonate ($CaCO_3$) towards 100%. The latter process is referred to as the Limestone Forced Oxidation (LSFO) system and is the dominant system in the Ohio River Valley according to Nolan.

The wet systems refer to a technology where lime or limestone is mixed in a water solution and then brought into direct contact with the SO_2 produced by coal combustion and in the flue gas. The dry systems, mostly lime, rely upon atomizing the sorbent in a water solution into a reactive chamber requiring a particulate collector. This system requires a very fine material and hence lime products are more suitable than limestone. The dry systems have been generally considered when making low efficiency recoveries from low sulfur coals. However, now that low sulfur coals must also have higher sulfur recoveries, the limestone systems again seem to be more favorable.

The alkali based systems sometimes use lime, but are mostly based on local sources of sodium based minerals which are not found in the ORS as they are in other U.S. areas.

Ohio River System Regional Limestone Rocks

Rock Testing

Limestone scrubbing research noted earlier demonstrated that there can be a 400% difference in SO_2 absorption capacity from different limestone rocks. "Bad," ineffective, or less reactive limestone rock or non-limestone rock content can plug power plant filters, increase grinding costs, increase waste by-products impacting land use and dewatering costs as well as internal plant equipment abrasion and increased costs. It is important for a power plant to select the appropriate limestone to reduce these costs. If a quarry operator has a desirable limestone, the least that will be achieved is market share and the most that could be achieved would be market share and a sorbent price premium because of the limestone's sorbent use advantages.

While limestones must and are evaluated for their ability to remove sulfur combustion products from coal burning power plant units, there is no standardized test or set of tests to identify the optimal or appropriate limestone to be used. Optimal means that either or both less limestone per ton of sulfur is used or that a limestone results in reduced overall sulfur removal costs at the power plant.

Past limestone for FGD assessment efforts have focused on:

- $CaCO_3$ content — This is the chemical molecule needed to remove sulfur. It takes a minimum of 3.125 tons and has been as high as 5.0 tons of $CaCO_3$ to remove 1 ton of sulfur. DCR used 3.36-3.46 in this work. If one limestone shows that less is required than another limestone, than this first limestone is better as it will reduce associated purchase, transport, and handling costs.

- Free Magnesium — Some minimal amount of free magnesium (Mg) is thought to help "fracture" the limestone rock's chemical reactions during combustion product processing. Too much Mg is known to inhibit the calcium and sulfur related reactions. Inter-crystalline Mg is good as this means "free" Mg crystals or molecules in limestone fractures and joints. Mg as dolomite is bad as it is chemically bound to the calcium and other minerals and takes excess process energy to free such Mg. Generally < 5% Mg in a limestone rock is considered good and >5% is considered bad.

- Crystallinity — Different limestones have different rock structures considered "massive" where the crystal structure of $CaCO_3$ is not present. More crystalline limestone rocks show more of the crystal structure physically or geologically known for limestone. More limestone rock crystalline structure sometimes means faster reactions combining sulfur with calcium oxide which means greater process efficiencies and lower costs.

- Grindability — The easier it is to grind the limestone, the less costly it is to prepare for use in the power plant's sorbent technology process.

- Bond Work Index — This engineering index relates to grindability and processing costs.

- Pore Size — Smaller limestone rock pore size means faster reactions, but lower total sulfur removal.

- Solubility — Carbonate rocks are soluble in acid so that the higher this value, the more likely the limestone rock is good. Non-carbonate rocks plug rock fissures, fractures, and joints and decrease sulfur and $CaCO_3$ reaction times.

The ORS various state geological surveys have each addressed the implications of using local high sulfur coals and then local limestone rocks to remove the sulfur combustion products at each local power plant. The obvious reasons for such work are to encourage the use of local coals and limestone rocks to enhance each state's local economy. The Indiana Geological Survey has done notable work on identifying the key characteristics to identify a good or optimal limestone rock. Their work is highlighted as it included extensive rock sampling, testing, and benchscale power plant testing with Indiana Power and Light (IPL). The documented results were obtained and reviewed, but are somewhat indecipherable from a lay person's perspective. A FGD technological model from the Electric Power Research Institute (EPRI), called PRISM, was used. All of the work done by Indiana Geological Survey resulted in three abbreviated tests to avoid doing the above tests or limit the use of EPRI's PRISM model to limit time, costs, and still have confidence in the results:

- Dissolution — The ability to dissolve the limestone rock simulates grindability, solubility, crystallinity, and $CaCO_3$ content.

- Calcium/Magnesium Ratio — This ratio is set to limit the Mg content and emphasize high $CaC0_3$ content. Inherent in the ratio values is the recognition that some Mg < 5% is desired, but primarily high >95% $CaCO_3$

is known to represent the good or optimal limestone rock for power plant coal sulfur reduction.

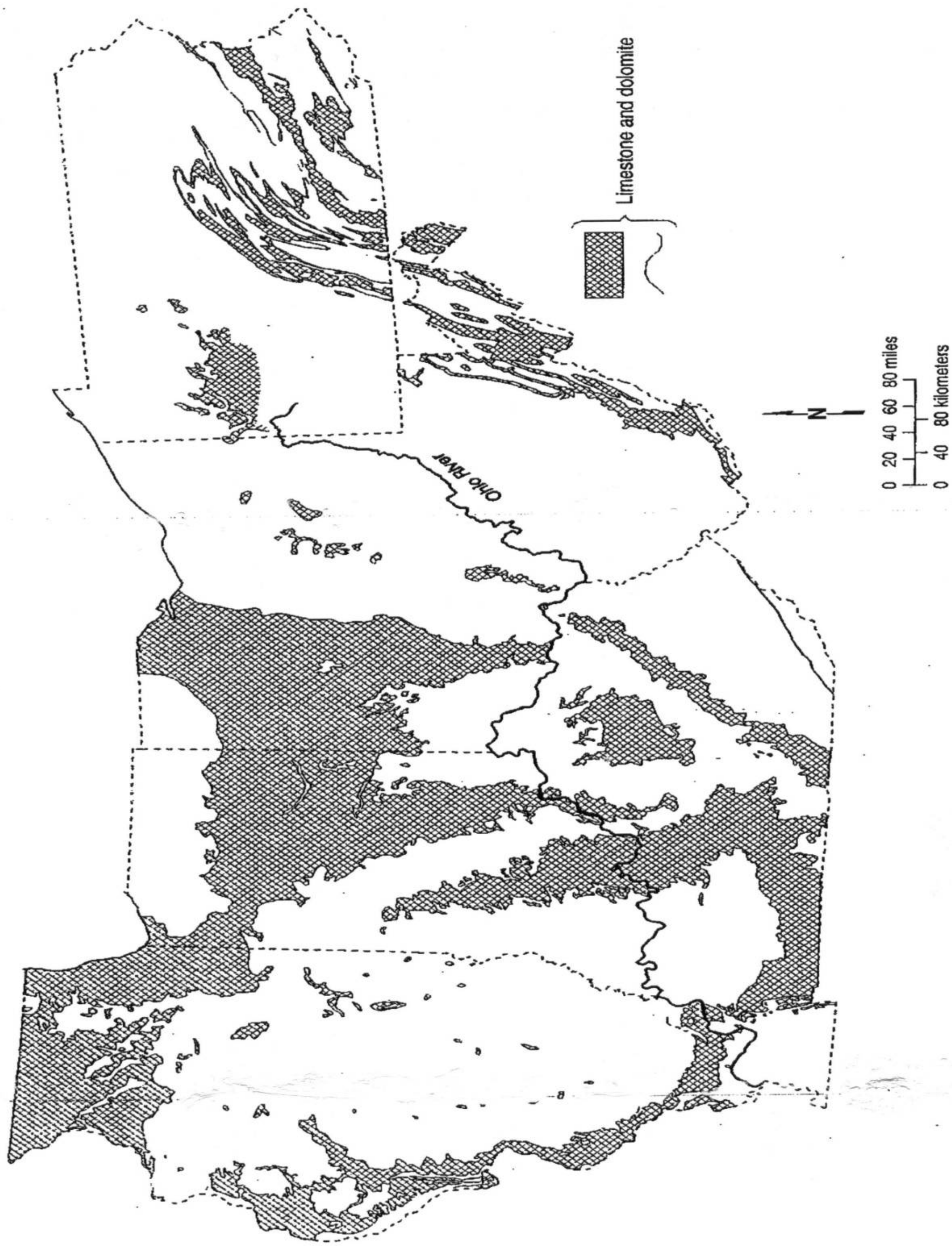
- Rock Geological Unit — Rocks of a similar type and age are identified in geology as a unit that was created at the same time with the same general material. When one rock unit is known to produce a good or optimal limestone rock for power plant sulfur reduction, it has been found that the same rock unit found elsewhere often behaves in the same manner. Therefore, there is very high correlation coefficient between a limestone rock's "rock geological unit" and knowing the power plant sulfur reduction results from that limestone rock.

The dissolution test is not a standard "American Society for Testing and Materials" (ASTM) test and proper controls need to be established for its use for standardized results. The Indiana Geological Survey, located in Bloomington, has dissolution testing equipment, and is interested in such "outside" work so long as they don't compete with other labs. Determining the calcium and Mg content are standard ASTM tests. The rock geological unit is usually a matter of record and is a ***subjective*** correlation. For example, good rock units include Paoli, St. Genevieve, and Salem according to one of the research principals in Bloomington. In general, the oolitic or chalk type rocks work best, but work has shown that many other limestones can have comparable performance. "Suitable" additional rock units could also include Silurian Wabash Rocks, Devonian of the Muscatatuck Group; and Sanders, Blue River, West Baden, and Stephensport groups of Mississippian age.

State Sources of "Good" Limestone Sorbent

The six states bordering the Ohio River (Illinois, Indiana, Ohio, Pennsylvania, West Virginia, and Kentucky) have abundant carbonate rocks (limestone and dolomite) of varied purities. These carbonate rocks are located where geology dictated, which makes the locations likely to supply sorbent rock for this study somewhat definable. This work identifies likely origins of the sorbent used at a power plant for this project. It is important to consider the depth and ability to practically and economically mine the limestone rock when looking for a source of good limestone rock. Typically, if the limestone rock is at a depth greater than 50 feet, it requires an underground mine. While underground mines exist and will be built, it is prudent to consider that most sorbent materials will be supplied, in general, from a surface deposit expression or ***outcrop*** and mine operation.

First, the following map labeled "Outcrop areas of limestone and dolomite in the Ohio River Valley" shows the areas where carbonate rocks outcrop. (The two maps shown below are from: Ohio Geological Survey, Information Circular 59, "Limestone and Dolomite Availability in the Ohio River System for Sulfur Sorbent Use, With Observations on Obtaining Reliable Chemical Analyses," 1997.) There are limited underground carbonate mines in the area, but the vast majority of carbonate producers are surface quarries. In general, surface outcrops are easier to construct, finance, and operate than underground mines. This map, therefore, shows the first level of screening as to where limestone sorbents and lime can be found or are produced in the study area. Since subsurface good limestone is included at great depth, this work identifies both likely surface and underground mine locations.



Outcrop area of limestone and dolomite in the Ohio River Valley.

Second, based on previous conclusions regarding the differences between free magnesium and magnesium present as dolomite, the dolomite outcrops and high purity dolomite sources are excluded from consideration for this project. Separate isopach maps (maps showing areas of equal values) are available showing "mineable" thicknesses of high purity limestone at >85%, >90%, and >95% $CaCO_3$. Mineable in this 1997 reference is defined as <25' of overburden which is not unreasonable today. Considering the previous quality comments, the map labeled "Outcrop area of formations containing mineable thicknesses of limestone with >85% $CaCO_3$" is displayed, which incorporates both the areas of >85% and >90% $CaCO_3$. However, this does not mean that a mine won't be built underground to take advantage of some known large high quality limestone rock deposit. This might be done at some unexpected location to take advantage of some likely limestone rock sale's price premium due to the limestone's quality efficacy or location reducing transportation costs to a power plant. Underground mines depend upon coring and interpreting what cannot be seen and hence often carry greater development risks than a surface limestone rock deposit.

While isopach maps showing concentrated areas of desired material are helpful, geology is as much an art as other sciences. There is always a good probability of finding a 95% $CaCO_3$ rock deposit in the >85% $CaCO_3$ areas and vice versa. This is the purpose of geological exploration and understanding that no two limestone deposits are the same. Further, most Midwest limestone rock deposits are not thick homogeneous deposits, but instead have multiple layers, formations, or ledges with each layer, formation, or ledge having a different $CaCO_3$ content and even being a different rock type with different sorbent chemistry. Further, quarries can mine from different ledges and blend to produce a more desirable or even less desirable sorbent feedstock product. The former can result in a more reactive limestone and/or a lower delivered price.

For the above reasons, as well as to consider likely underground limestone mines, the 85% $CaCO_3$ isopach map was used and shown. U.S. quarry operators are numerous and clever. If there is a >250,000 tpy market, operators will open new quarries or realize that one of their ledges in an existing quarry could be selectively mined and marketed to the ORS power plant coal sorbent market. One should favor the areas identified with the >95% $CaCO_3$ (not shown separately), but not discount the areas with >85% $CaCO_3$. In all cases, as noted, the dolomite locations are ignored due to the low rock efficacy of dolomite in power plant sorbent chemical reactions.

In general, then, this prior geological field work was used to define likely locations to identify current suitable limestone rock sorbent producers and where likely future producers of suitable sorbent quality material might occur. These good limestone rock geological areas are generalized in six areas for this project and function as the sources for sorbent rock to all of the ORS power plants of interest:

- the Mississippi River about 100 miles north and south of where the Ohio River enters the Mississippi River;

- the Green River and Kentucky River areas in western Kentucky and the extreme southeast tip limited area of Illinois;

- southeast Indiana to east of Cincinnati essentially from the Cannelton Locks to the area on the Ohio River north of Maysville, KY;

- the Greenup Locks to Willow Island Locks and further to the northeast along and north of the Ohio River in the southern and southeast part of Ohio;

- the Monongahela River south of Pittsburgh, PA; and

- any other sorbent source not "directly" or "economically" on or susceptible to using barge transportation on any ORS waterway. (Note that areas 6 through 8 were left open in case other areas or suppliers were eventually identified in the study. Had the latter occurred, they would have been noted as area 6, 7, or 8.)

Each power plant sorbent used were assigned a likely origin based on their proximity to one of these six areas or were assigned an origin based on existing historical, current, or planned shipment information. Power plant reclamation and air permits were often identified as these documents contained indications of where power plant materials such as limestone or lime would be obtained as they impacted trucking through local communities. An example of the latter would be Tennessee Valley Authority's (TVA) Paradise plant where two of the three units use limestone and the other unit uses lime. The limestone deliveries by truck were noted in the permit hearings as currently supplied and expected to be supplied by truck from nearby quarries operated by Martin Marietta and Rogers Group. Both of the latter quarries were examined by DCR in past work.

The following discussion of sorbent material deposits effectively indicates how and why these six sourcing zones were defined. The reader is encouraged to refer back to these definitions of the six sourcing zones while reading the following.

State Limestone and Lime Data

The limestone $CaCO_3$ content, deposit thicknesses, surface availability, depth to the "good" rock, and access to transportation vary between and within all of the states considered in this project.

The lime data is somewhat simpler in that the existing lime plants are known to be located at three primary locations south of the Ohio River entrance to the Mississippi River, north central Kentucky along the Ohio River, and east of the Monongahela River southeast of Pittsburgh, PA. No new lime plants are considered because of the assumed sorbent technology favoring limestone for all future scrubbers and because all initial project results did not demonstrate the large growth rates in sorbent demand typically associated with future massive coal burning sulfur controls.

LIMESTONE

Pennsylvania

Pennsylvania mainly has narrow, folded bands of steeply dipping Cambrian to Devonian rocks in the southeastern, central, and south central parts of the state along with some flat lying Pennsylvanian limestone in the western part of the state. For this work, sources are limited to the latter as source number "5." The Pennsylvania Department of Geology lists ten quarries that currently supply limestone sorbent rock. None of these sorbent limestone producers are along the Monongahela River in western Pennsylvania. If producers do not avail themselves to this power plant sorbent market identified for power plants located along this river, then the limestones sourced from this area 5 would be reassigned to area 3 from Maysville, KY through southeast Indiana.

West Virginia

West Virginia has steeply dipping good quality limestone rocks in narrow folded bands in the eastern and southeastern parts of the state. The eastern and southeastern parts of the state have minor thin flat Pennsylvanian age limestones, but any likely commercial carbonates in western West Virginia would be underground and the depths are such that *West Virginia is considered to have no likely suppliers of sorbent material for this project's forecast time period*. This conclusion was confirmed through personal communications with the state's geological survey personnel.

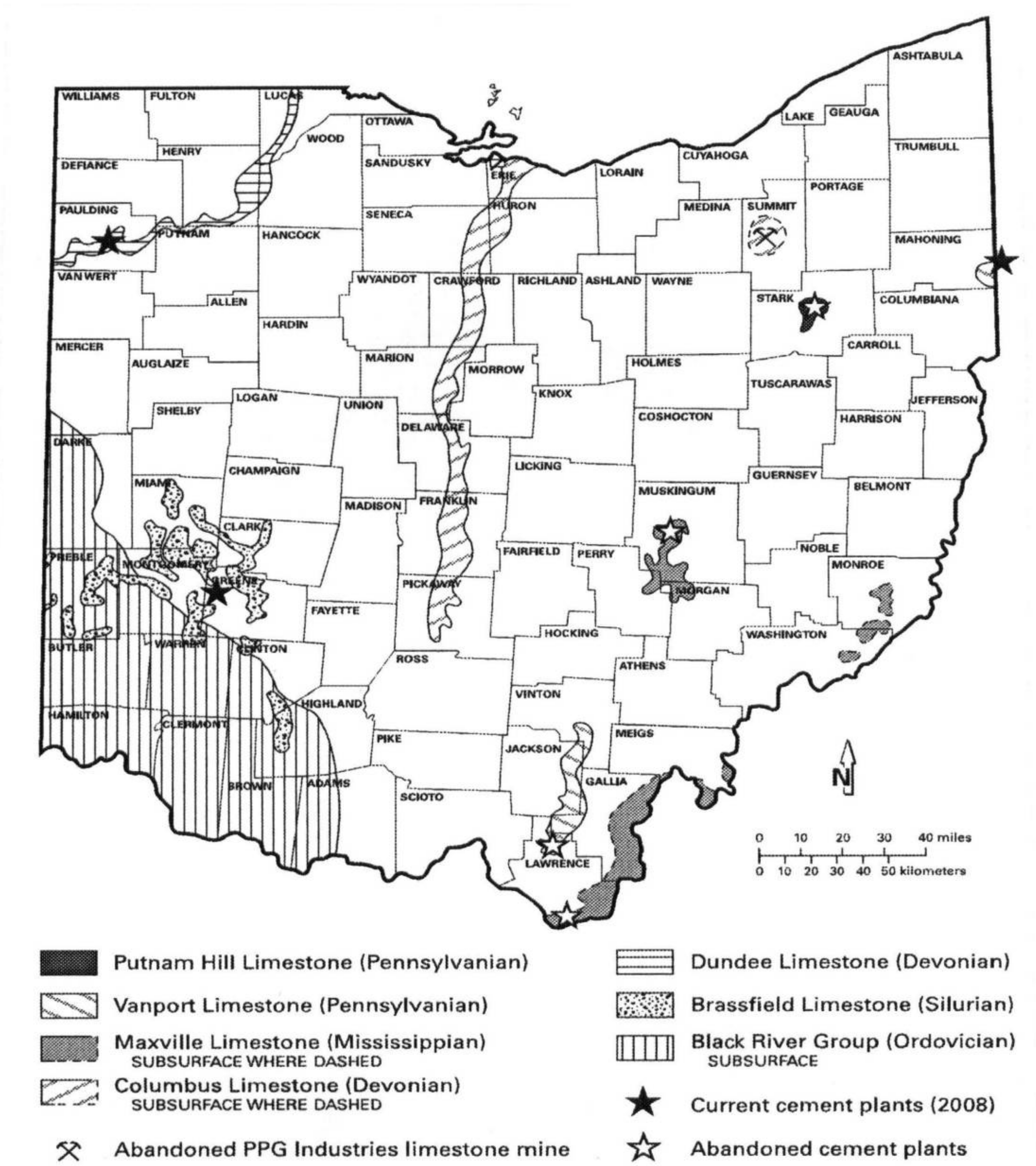
Ohio

The western half of Ohio contains extensive flat deposits of Silurian age dolomite and lesser amounts of Devonian age limestone and dolomitic limestones. Comments refer to the following Ohio carbonate geology map. Eastern Ohio contains minor amounts of thin flat Pennsylvanian age limestone such as the Putnam Hill limestone land locked in northeast Ohio. The Vanport limestone is also Pennsylvanian in age. This source is 25' thick, has been mined for cement production, and has existing quarries in Lawrence County on the Ohio River. The Maxville Limestone is Upper Mississippian age and is 40' thick in central southeast Ohio and +100' thick following the Ohio River from Lawrence County, through Gallia County and into Meigs County. The chemistry is good. The problem is that these limestone deposits have extensive overburden depths varying from 97' to 1,900' and 475' at one mine in Lawrence County along the Ohio River. The Columbus limestone is Devonian in age and runs from Columbus to Lake Erie north.

It is 40-65' thick with good chemistry and has been mined underground at great depth for specialty glass uses. Essentially, it is too deep and too far from the ORS to consider for selling limestone sorbent rock on the ORS. The Dundee limestone is Devonian in age in the extreme northwest part of the state. It is also subsurface at 900' depths, but has good chemistry and has a 20-60' thickness but is considered too remote for this project. The Brassfield limestone is Silurian in age and has inconsistent layers of limestone, dolomite, and shale. Its thickness is 11-50' and has >95% $CaCO_3$, but is located 1-2 counties inland from the ORS, making its consideration possible, but not likely. The Black River Group is Ordovician in age, has super chemistry with 98% $CaCO_3$, covers ALL of southwest Ohio, is 400-500' thick, but is at depths of 700-2,000' deep. One of its units, the Carntown unit, was mined in 2006 along the Ohio River at a lime plant. It was 34' thick with 95.1% $CaCO_3$. This limestone source could develop a good project underground mine.

The relevant sources along the Ohio River are the Carntown unit, the Black River Group near Cincinnati, and the Maxville near Lawrence County. The Carntown unit is part of source "3" and the Maxville is source "4." Both are thick, good chemistry, good river locations, but at significant depths.

OHIO CARBONATE ROCKS (OH GEOLOGICAL SURVEY (Geofacts No. 25)



Surface or near-surface geologic units that contain potentially mineable high-calcium limestone.

Indiana

South central and southeast Indiana has extensive flat Mississippian age limestone outcrops. The northern, eastern, and southeastern area has Silurian and Devonian age dolomite with isolated patches of limestone. There's a large structural geological arch across this entire area that brings the good limestone rocks to the surface through central and southern Indiana and north central Kentucky running north to south, as shown in previous maps with good limestone isopachs or areas.

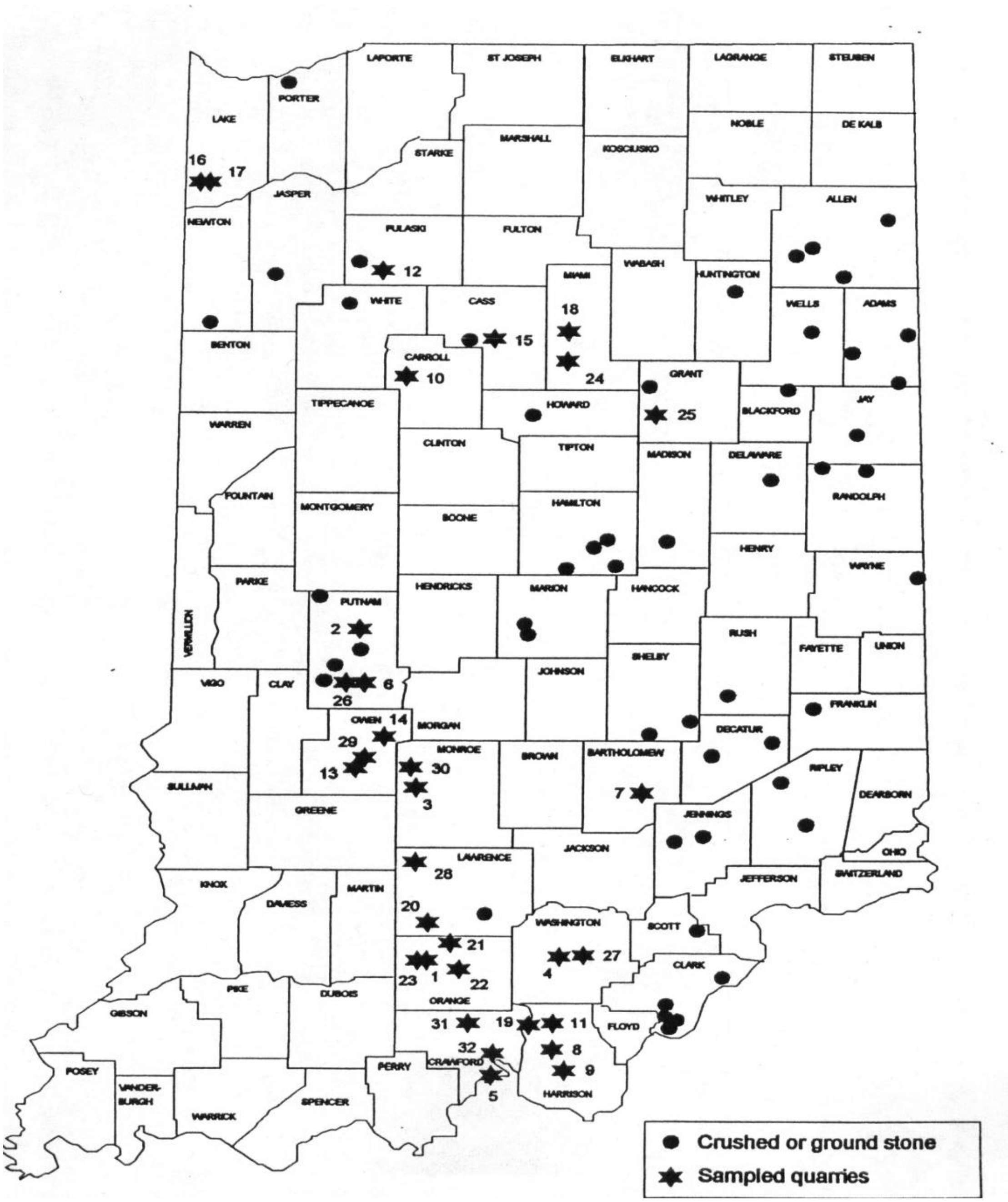
The Indiana Geological Survey obtained several hundred limestone samples from within 30 active Indiana quarries. Rocks from the Paoli, Ste. Genevieve, Salem, North Vernon, Jeffersonville, Louisville, Wabash, and West Baden formations/groups were tested. The most promising rock sources are in the south central portion of the state as shown in the following map with >90% $CaCO_3$. Thirty-two (32) of 95 operating quarries were sampled. Sample characteristics varied:

Specific Gravity:	2.00-2.71
Absorption:	0.4-11.8
Grindability:	7.2-21.7
Insoluble Residues:	0.3-35.4%
Dissolution Rates:	1-100 times different
SO_2 removal:	89-98%
Rock utilization:	91-93%
Ca/Mg:	1-94

The best reactivity or dissolution rates were obtained from Ste. Genevieve rock at >90% and Salem rock at 94% $CaCO_3$ contents. These two rocks were noted to be easy to grind with low insoluble residues <1%.

Limestone quarries exist along the entire length of the Ohio River in southern Indiana (four known quarries west of the selected sorbent area "3" towards Mt. Vernon, IN). However, the Indiana part of area "3" of importance is demonstrated with the following map of known Indiana quarries. The location of these quarries is based, of course, on markets, but geologically are a function of the surface exposure of good limestone bedrock due to the structural arch, glaciation, and the existence of good limestone rock in the bedrock.

Quarry Sample Sites from Indiana Geological Survey Work
(Source: Indiana Geological Survey, Bloomington, IN)

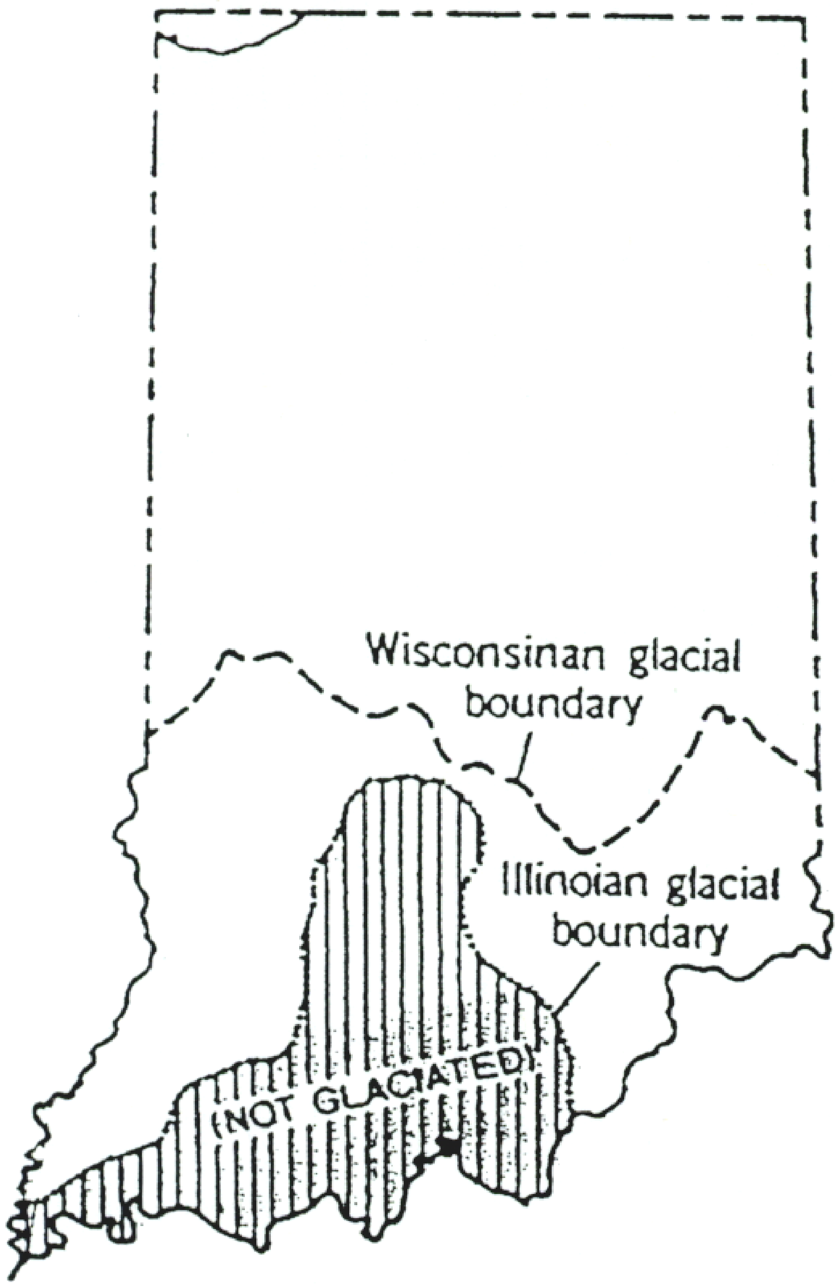


In addition to the geological structural arch pushing the good limestone rock towards the surface, glaciers helped push undesired overburden off of these good limestone bedrock rocks. This is one of the key differences between the geology of southeast Indiana and southwest Indiana. Southeast Indiana was glaciated and essentially southwest Indiana was not. (See the following Indiana map on Glaciers.) This means that when the glaciers advanced south during a recent ice age, the southeast portion of Indiana was glaciated. Glaciers advanced and scrapped surface material off of the limestone rocks exposing them and making these deposits outcrop. The limestone rocks in southwest Indiana were not exposed to such glacial activity and hence are likely to have greater overburden depths and be less likely to have suitable limestone rock producing quarries. Underground quarries could be developed and the glaciated area did come close to the Ohio River in the extreme southwest portion of the state. Further, where sand and gravel operations have mined down to the limestone rock bedrock, limestone quarries have been developed and are operating. The latter is another example of how a quarry could be developed where it is not expected.

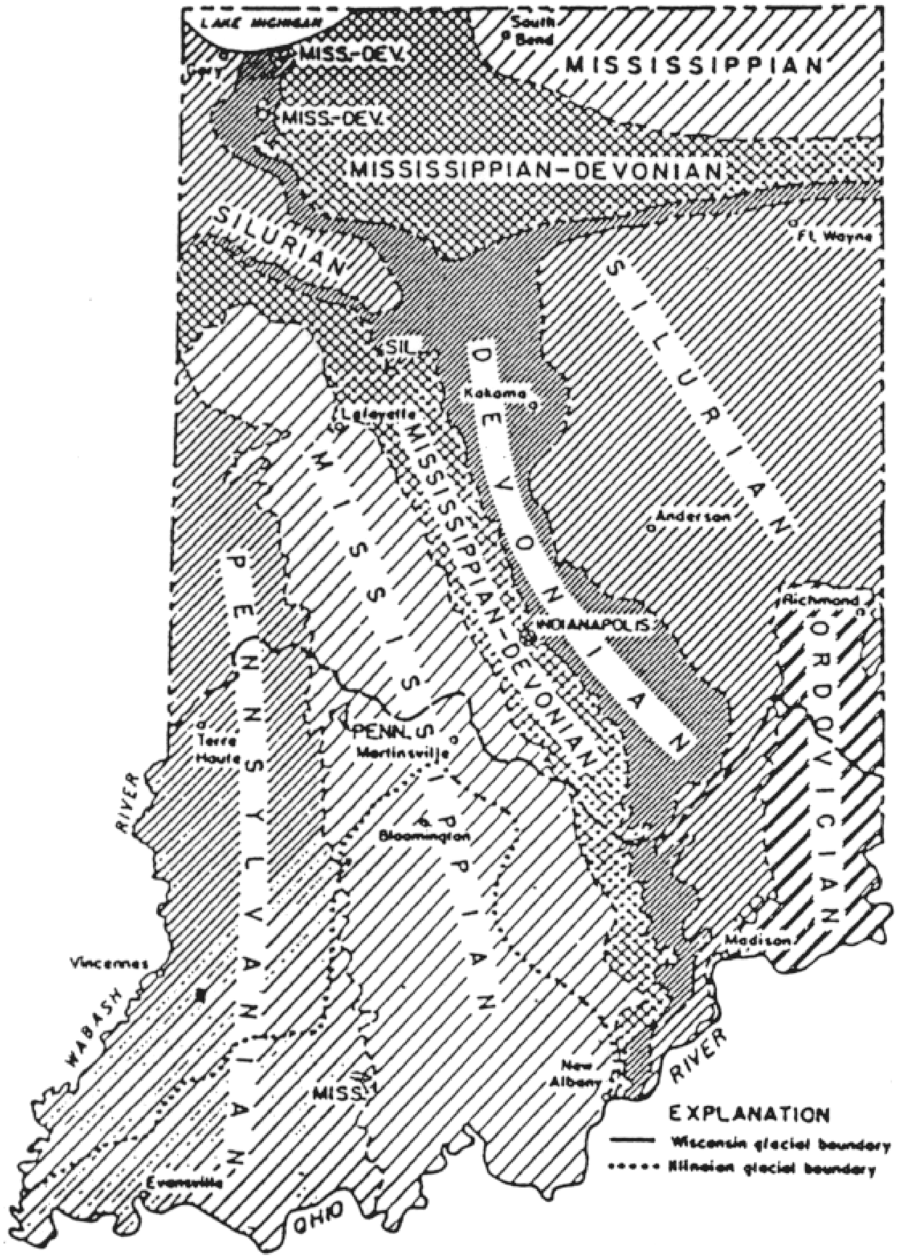
Those rocks identified in the quarries in this southern portion of the state are typically produced from limestone bedrock rocks of Mississippian, Devonian, and Silurian Ages. During these time periods, thick deposits of high grade limestone were formed. Limestone rocks formed during other time periods are either not accessible to mine or do not have good quality for power plant sorbent or even construction use. A map is included showing the distribution of southern Indiana limestone rocks by age.

Southern Boundaries of Glaciers which Moved into Indiana

(Source: Indiana Department of Transportation)



Indiana Bedrock Distribution by Age
(Source: Indiana Department of Transportation)



Illinois

The northern third of the state is primarily Ordovician and Silurian age dolomites with smaller areas of Mississippian age limestone and Ordovician – Silurian − Devonian age limestone rocks along the Mississippi River and the Ohio River. The dolomites and northern locations are of no interest to this project. No readily available limestone deposit or depositional age map could be identified, but the Illinois Geological Survey data reviewed supports the initial regional map showing suitable high $CaCO_3$ rock deposits on the extreme tip of Illinois, southeast part of the tip adjacent to the Ohio River, and the southwestern part of the state along the Mississippi River. However, the following map showing limestone quarry producer locations in southern Illinois along the Ohio and Mississippi Rivers confirms the previous regional maps showing limestone deposits. The area along the Mississippi River forms part of sorbent source "1" along with Missouri limestone deposits. The limited southeast Illinois area is part of area source "2."

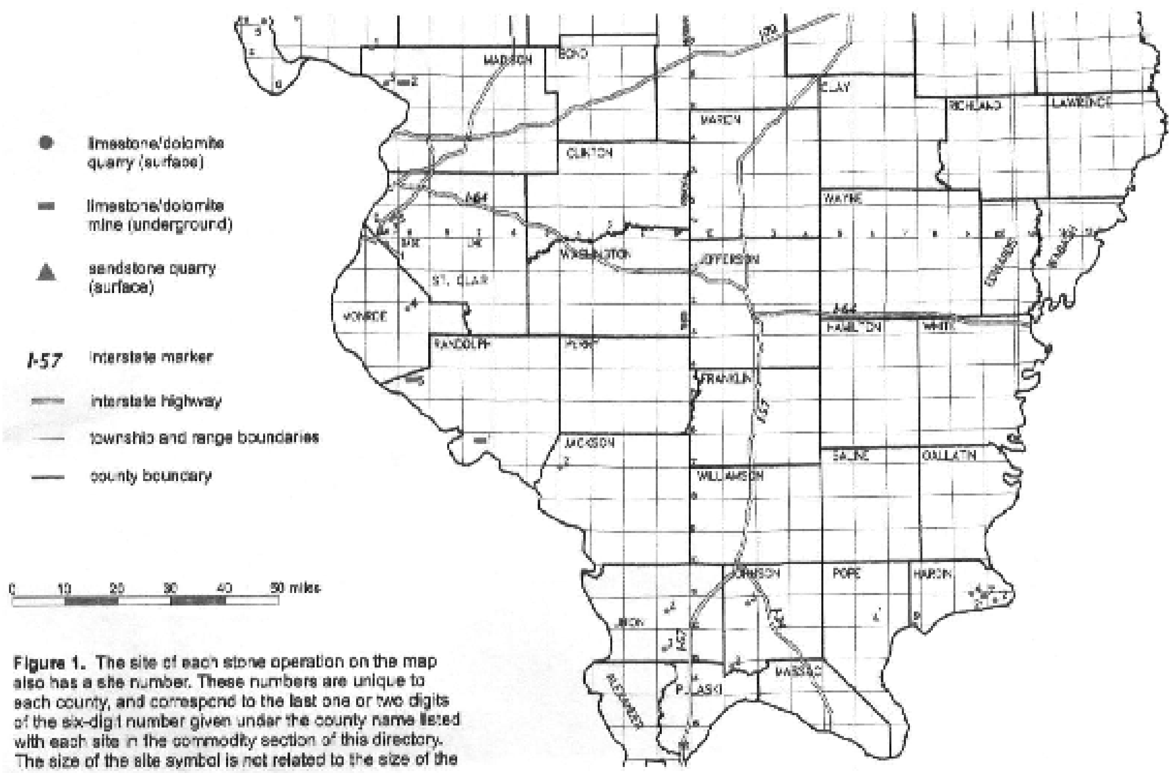
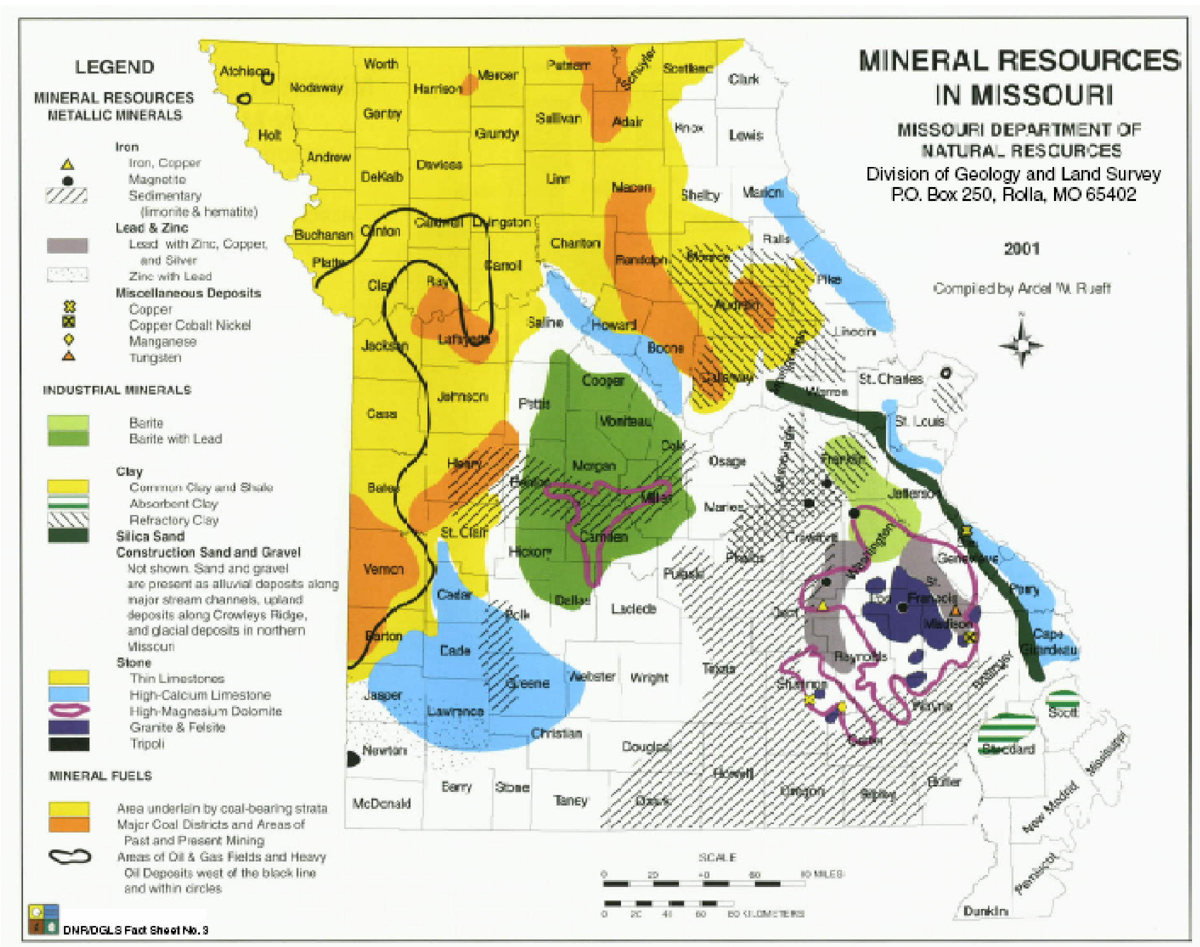


Figure 1. The site of each stone operation on the map also has a site number. These numbers are unique to each county, and correspond to the last one or two digits of the six-digit number given under the county name listed with each site in the commodity section of this directory. The size of the site symbol is not related to the size of the

Missouri

The following map highlights limited areas marked with a sky blue color in Missouri containing high $CaCO_3$ limestone deposits. Obvious areas along the Mississippi River both north and south of St. Louis can be seen. The notable area supplying both lime and limestone up the Ohio River is from St. Genevieve county 80 miles south of St. Louis where both several high $CaCO_3$ quarries operate as well as one of the three project lime plants operates.

The high calcium limestone rocks are again associated with Mississippian, Devonian, and Middle Ordovician age rocks. The deposit locations described comprise the Missouri portion of sorbent source "1."



Kentucky
As previous maps have shown, Kentucky has large plentiful deposits of mineable limestone rock, both surface and underground. There are notable locations in Western Kentucky along the Green River and Kentucky River, and opposite the same section previously highlighted in south central and southeast Indiana west of Louisville, KY. This area of similar Mississippian rocks can be seen in the following Kentucky geological map.

The arch described in Indiana extends into Kentucky which forced certain limestone formations to the surface in northwest central Kentucky suitable for surface mining. The limestone deposits east of the arch, however, are too thin and varied in quality to be suitable for sorbent and even construction uses. This means, however, that some inland limestone rock deposits and quarries on and west of the arch have a likelihood of being mined and trucked to power plants along the ORS. There could be deposits on or near the Ohio River north of the locations in south central Kentucky and northeastern Kentucky opposite southwest Ohio. However, again these latter Kentucky areas are known for thin limestone rock deposits from both their original formation as well as subsequent erosion. Finding suitable thicknesses to mine is difficult.

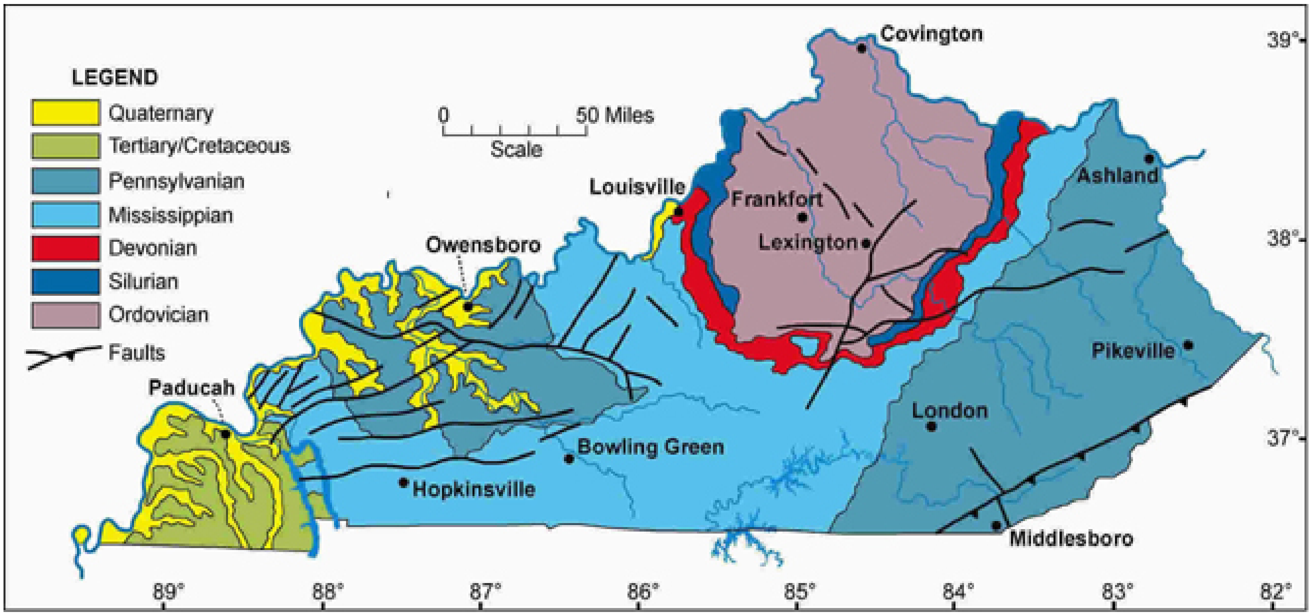
Kentucky has extensive Mississippian age limestone deposits in the western, south central, east central, and southeastern areas. Ordovician age limestone and dolomite and Silurian age dolomites are quarried in the central area. The Ste. Genevieve formation limestone is mined from the western part of the state and is used readily in power plant sorbent scrubber applications as is the Ordovician age limestone from the north central area.

Two mines are along the Ohio River in north central Kentucky in the Camp Nelson limestone producing low Mg high $CaCO_3$ limes being used in power plant scrubbing operations. This is the Maysville area lime plant.

Western Kentucky rock formations with high $CaCO_3$ rock from Bowling Green in Warren County to Smithland in Livingston County include a small interval in the lower part of the Upper St. Louis formation and St. Genevieve. While the St. Genevieve formation covers much of western Kentucky, finding surface or mineable deposits near waterways is difficult. Part of the St. Genevieve outcrops near Princeton where two quarries operate that truck suitable sorbent material to the Paradise TVA power plant. Such good quality limestone rock coming from two large quarries by truck is expected to preclude water delivered limestone to such plants as TVA's Paradise power plant.

There are known limestone deposits of high $CaCO_3$ content in eastern south central Kentucky which continues to emphasize the prevalence of carbonate rocks. (This is also seen by noting that of the 6,000 or so U.S. quarries, better than two-thirds are carbonate.) These and other rocks in other states address the needs of other power plants of interest in this project further to the south in Kentucky, as well as into Tennessee, Alabama, Georgia, and Mississippi. The St. Louis and St. Genevieve limestone rocks of Mississippian age can be found and outcrop in this area of Kentucky. There are several mines producing high $CaCO_3$ limestone rocks.

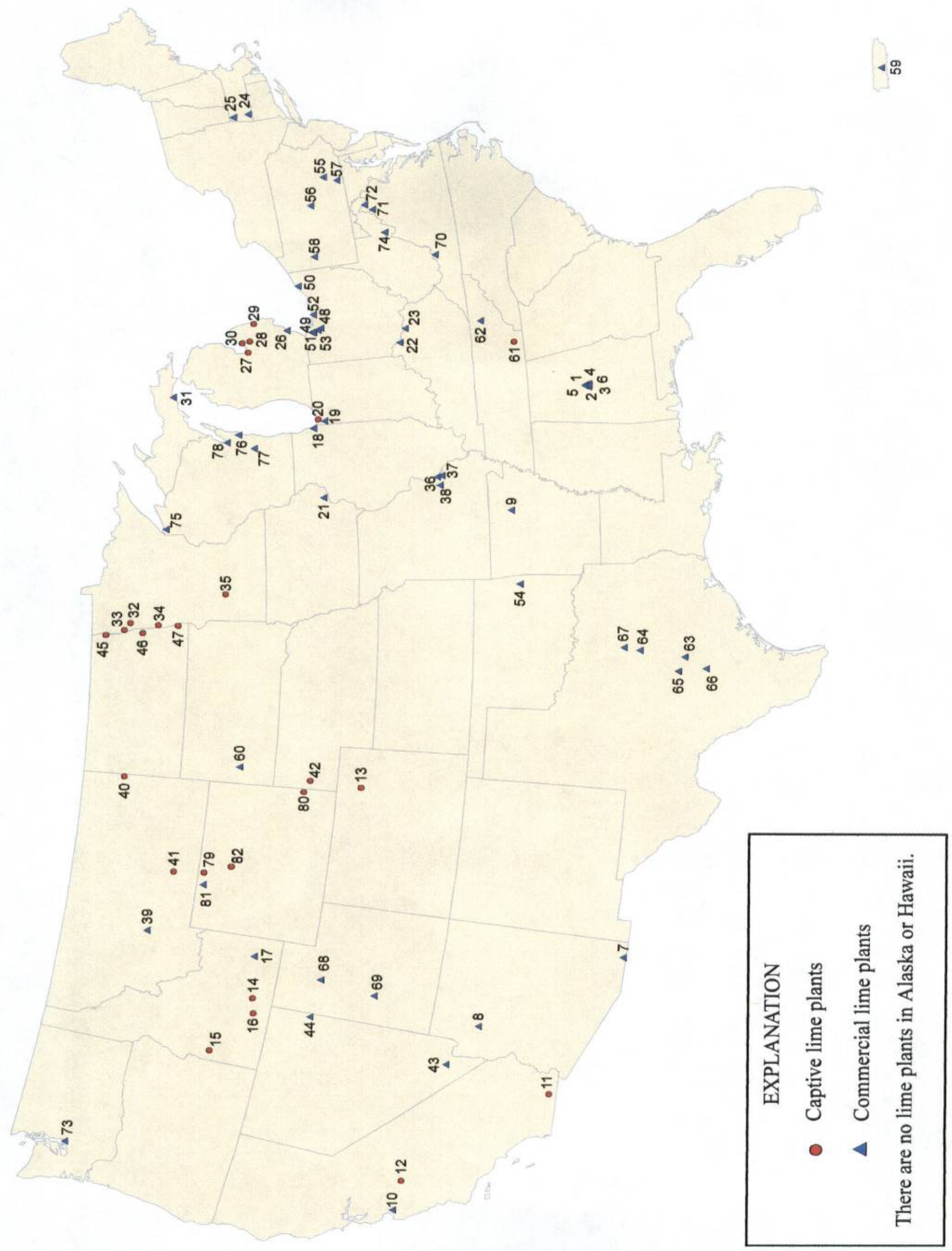
Geology of Kentucky
(Source: Kentucky Geological Survey)



LIME PRODUCERS

There are 82 lime plants in the United States. The ORS has three areas with lime plants coinciding with source areas 1, 3, and 5. The coincidence of the high $CaCO_3$ limestone and lime plants should be obvious as lime producers must have high $CaCO_3$ rock to produce lime products (CaO) from limestone or $CaCO_3$. The producers and their locations are identified in the following map and producer list from the USGS for 2007.

—Lime plants in the United States active as of December 31, 2007



LEGEND

ALABAMA
1 LONGVIEW LIME PLANT - *CARMEUSE LIME*
2 MONTEVALLO PLANT - *CHEMICAL LIME CO*
3 ALABASTER PLANT - *CHEMICAL LIME CO*
4 O'NEAL LIME PLANT - *CHEMICAL LIME CO*
5 LANDMARK LIME PLANT - *CHENEY LIME & CEMENT CO*
6 ROBERTA LIME PLANT - *SOUTHERN LIME CO*

ARIZONA
7 DOUGLAS LIME PLANT - *CHEMICAL LIME CO*
8 NELSON LIME PLANT - *CHEMICAL LIME CO*

ARKANSAS
9 BATESVILLE LIME PLANT - *US LIME & MINERALS - ARKANSAS LIME CO*

CALIFORNIA
10 NATIVIDAD LIME PLANT - *CHEMICAL LIME CO*
11 BRAWLEY LIMEKILN - *SPRECKELS SUGAR CO*
12 MENDOTA LIMEKILN - *SPRECKELS SUGAR CO*

COLORADO
13 FORT MORGAN LIMEKILN - *WESTERN SUGAR CO*

IDAHO
14 MINI-CASSIA LIMEKILN - *AMALGAMATED SUGAR CO*
15 NAMPA LIMEKILN - *AMALGAMATED SUGAR CO*
16 TWIN FALLS LIMEKILN - *AMALGAMATED SUGAR CO*
17 TEN MILE PLANT - *CHEMICAL LIME CO*

ILLINOIS
18 SOUTH CHICAGO LIME PLANT - *CARMEUSE LIME*

INDIANA
19 BUFFINGTON LIME PLANT - *CARMEUSE LIME*
20 INDIANA HARBOR WORKS LIMEKILN - *MITTAL STEEL USA*

IOWA
21 LINWOOD LIME PLANT - *LINWOOD MINING & MINERALS CORP*

KENTUCKY
22 BLACK RIVER LIME PLANT - *CARMEUSE LIME*
23 MAYSVILLE LIME PLANT - *CARMEUSE LIME*

MASSACHUSETTS
24 LEE LIME PLANT - *OLD CASTLE INDUSTRIAL MINERALS INC*
25 ADAMS LIME PLANT - *SPECIALTY MINERALS INC*

MICHIGAN
26 RIVER ROUGE LIME PLANT - *CARMEUSE LIME*
27 BAY CITY LIMEKILN - *MICHIGAN SUGAR CO*
28 CARO LIMEKILN - *MICHIGAN SUGAR CO*
29 CROSWELL LIMEKILN - *MICHIGAN SUGAR CO*
30 SEBEWAING LIMEKILN - *MICHIGAN SUGAR CO*
31 PORT INLAND LIME PLANT - *WESTERN LIME CORP*

MINNESOTA
32 CROOKSTON LIMEKILN - *AMERICAN CRYSTAL SUGAR CO*
33 EAST GRAND FORKS LIMEKILN - *AMERICAN CRYSTAL SUGAR CO*
34 MOORHEAD LIMEKILN - *AMERICAN CRYSTAL SUGAR CO*
35 RENVILLE LIMEKILN - *SOUTHERN MINNESOTA SUGAR CORP*

MISSOURI
36 STE GENEVIEVE PLANT - *CHEMICAL LIME CO*
37 STE GENEVIEVE LIME PLANT - *MISSISSIPPI LIME CO*
38 BONNE TERRE LIME PLANT - *VESSELL MINERAL PRODUCTS CO*

MONTANA
39 INDIAN CREEK LIME PLANT - *GRAYMONT WESTERN US INC*
40 SIDNEY LIMEKILN - *SIDNEY SUGARS INC*
41 BILLINGS LIMEKILN - *WESTERN SUGAR CO*

NEBRASKA
42 SCOTTSBLUFF LIMEKILN - *WESTERN SUGAR CO*

NEVADA
43 APEX LIME PLANT - *CHEMICAL LIME CO*
44 PILOT PEAK LIME PLANT - *GRAYMONT WESTERN US INC*

NORTH DAKOTA
45 DRAYTON LIMEKILN - *AMERICAN CRYSTAL SUGAR CO*
46 HILLSBORO LIMEKILN - *AMERICAN CRYSTAL SUGAR CO*
47 MINN-DAK LIMEKILN - *MINN-DAK FARMERS COOPERATIVE*

OHIO
49 MAPLE GROVE LIME PLANT - *CARMEUSE LIME*
48 MILLERSVILLE LIME PLANT - *CARMEUSE LIME*
50 GRAND RIVER LIME PLANT - *CARMEUSE LIME*
51 GENOA LIME PLANT - *GRAYMONT DOLIME (OH) INC*
52 HURON LIME PLANT - *HURON LIME CO*
53 WOODVILLE LIME PLANT - *MARTIN MARIETTA MAGNESIA SPECIALTIES*

OKLAHOMA
54 MARBLE CITY LIME PLANT - *US LIME CO - ST CLAIR*

PENNSYLVANIA
55 ANNVILLE LIME PLANT - *CARMEUSE LIME*
56 PLEASANT GAP LIME PLANT - *GRAYMONT (PA) INC*
57 YORK LIME PLANT - *LWB REFRACTORIES CO*
58 BRANCHTON LIME PLANT - *MERCER LIME AND STONE CO*

PUERTO RICO
59 PONCE LIMEKILN - *FLORIDA LIME CORP*

SOUTH DAKOTA
60 RAPID CITY LIME PLANT - *PETE LIEN & SONS INC*

TENNESSEE
61 CALHOUN LIME PLANT - *BOWATER SOUTHERN PAPER CORP*
62 LUTTRELL LIME PLANT - *O-N MINERALS*

TEXAS
63 MCNEIL LIME PLANT - *AUSTIN WHITE LIME CO*
64 CLIFTON LIME PLANT - *CHEMICAL LIME CO*
65 MARBLE FALLS LIME PLANT - *CHEMICAL LIME CO*
66 NEW BRAUNFELS LIME PLANT - *CHEMICAL LIME CO*
67 CLEBURNE LIME PLANT - *US LIME & MINERALS - TEXAS LIME CO*

UTAH
68 GRANTSVILLE LIME PLANT - *CHEMICAL LIME CO*
69 CRICKET MOUNTAIN PLANT - *GRAYMONT WESTERN US INC*

VIRGINIA
70 LIME PLANT #1 - *CHEMICAL LIME CO*
71 STRASBURG LIME PLANT - *O-N MINERALS*
72 WINCHESTER LIME PLANT - *O-N MINERALS*

WASHINGTON
73 TACOMA LIME PLANT - *GRAYMONT WESTERN US INC*

WEST VIRGINIA
74 RIVERTON LIME PLANT - *GREER LIME CO*

WISCONSIN
75 GRAYMONT SUPERIOR LIME PLANT - *GRAYMONT WESTERN US INC*
76 MANITOWOC LIME PLANT - *ROCKWELL LIME CO - CARMEUSE LIME*
77 EDEN LIME PLANT - *WESTERN LIME CORP*
78 GREEN BAY LIME PLANT - *WESTERN LIME CORP*

WYOMING
79 LOVELL LIMEKILN - *WESTERN SUGAR CO*
80 TORRINGTON LIMEKILN - *WESTERN SUGAR CO*
81 FRANNIE LIME PLANT - *WYOMING LIME PRODUCERS*
82 WORLAND LIMEKILN - *WYOMING SUGAR CO LLC*

Based on all of the analysis discussed above of likely future sources of sorbent material, the detailed plant-by-plant sorbent forecast was prepared. The overall aggregated results of this detailed forecast are shown at the start of this section in Figures 32-35.

TIMES SERIES FORECASTS
OF
OHIO RIVER TRAFFIC

Final Report

July 2009

by

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1. EXECUTIVE SUMMARY AND INTRODUCTION

Commercial Navigation on the Ohio River System is central to the region and to the nation. The system is comprised of the Ohio, Monongahela, Allegheny, Kanawha, Green, Tennessee and Cumberland rivers and a number of tributaries. These rivers and tributaries are largely contained within an eight state region, which includes Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee and West Virginia. But, portions of the basin reach, as well, into parts of Georgia, Mississippi, New York, North Carolina and Virginia. Further, while the majority of traffic both originates and terminates within the system, there are significant quantities that originate or terminate outside the System. Hence, the system is important not only to the industrial Midwest and southeast but also to the rest of the United States.

The volume of traffic that moves over the ORS is significant. In recent years, the ORS has handled approximately 270-280 million tons per year. Further, over the last 20 years, traffic has grown from about 200 million tons in 1985 to as much as 280 million in 2005; an increase of about 40 percent. This level of traffic, which will continue to grow, cannot be accommodated without investments in the waterway system. Originally, investments were made to make the river navigable, but continued investments are necessary to maintain and expand the capacity of the waterway. Investments are the result of the legislative process, and are guided, in part, by cost/benefit studies. These studies require timely and accurate traffic demand forecasts. In particular, forecasts for future river traffic are used as an input to simulation models that estimate the benefits of alternative investments. Hence, these models guide the timing and scale of investments in navigation infrastructure.

The purpose of this report is to generate traffic forecasts for commodities shipped on the ORS. There are many different strategies that can be used for forecasting, and this report uses time series techniques to forecast river traffic. To this end, there is a detailed review of alternative time series methods and their applicability to forecasting river traffic. These are provided in Appendix A. To frame the forecasts, an in depth description of the waterway is given in section 2; section 3 provides a discussion of the theoretical basis on which our forecasts are framed along with a discussion of the procedures and results. Section 4 summarizes the report. A brief discussion of findings is given below:

- Since 1985, total traffic in the ORS has increased from about 200 million tons in 1985 to over 280 million tons in 2005 and 270 million tons in 2006.
- Most of the growth in tonnages occurred prior to 1995. Since the mid-1990s, tonnages have remained relatively stable, fluctuating between about 260 and 280 million tons.
- Since 1985, over 60 percent of traffic both originates and terminates in the ORS, and the percentage has increased slightly from about 63 percent in 1985 to about 68 percent in 2005 and 67 percent in 2006.
- Coal is dominant in the ORS. Over 50 percent of all traffic is coal, and most of the coal is from mines to coal-fired electricity plants. Construction products e.g., sand-gravel represent the second largest commodity group with about 19 percent of 2006 tonnage.

- The purpose of this analysis is to provide time series forecasts of non-electric coal and coke movements. But, for completeness, estimates of electricity related movements of coal, lime and limestone are also presented. To accomplish the general purpose, a variety of time series models were examined. A Box-Jenkins approach was used to specify three different time series models, and these three models were used to generate forecasts for three different levels of traffic aggregations.
- Section 3 summarizes the empirical work. First, the theoretical underpinning of the time series models used to generate forecasts is presented. Second, the specifics of the Box-Jenkins methodology used to develop the forecasts in this report are presented. It is noteworthy that while the Box-Jenkins methodology is used to specify the ARIMA models used for the forecasts, there are a variety of other time series models that might have been used instead. These alternatives along with the pros and cons of each approach are summarized in Appendix A. Third, a summary of the results is from the three estimation alternatives and various levels of data aggregation is presented. The data work and the number of forecasts are both quite voluminous, and that precludes a detailed discussion in the text. However, this is provided in appendices (C-K).
- Forecasts are provided for three different types of time series models. Each model is specified using a Box-Jenkins approach. The models are: 1. A declining growth-deterministic trend model (DG-DT); 2. A constant growth-deterministic trend model (CG-DT); and 3. A constant growth-stochastic trend model (CG-ST). For each model type, nine different sets of autoregressive (AR) and moving average (MA) specifications are examined. From these, the one that best fits the data is chosen. This identifies the "best" model in the ARMA class for each series.
- Forecasts are provided at three different levels of aggregation. These include commodity group system aggregates, destination reach-commodity aggregates, and origin-destination-commodity aggregates. Thus, there are nine different sets of forecasts (three different time series models and three different levels of aggregation). Each is provided in Appendices C-K.
- The purpose of the models is to forecast tonnages. The dependent variable is the quantity of tons in a year for the DG-DT model, the log of tons for the CG-DT model, and the log of tons differenced or the CG-ST model. These variables are explained by the ARMA terms as described above, a trend, and a set of variables based on a model of trade between regions of the type first developed by Samuelson (1952) and more recently in Anderson and Wilson (2007).
- A number of alternative explanatory variables were considered. These include demand variables in the receiving region such as real personal income, per-capita income, population, etc. as well as supply variables such as the average real wage and employment levels. All of the data are from the Bureau of Economic Analysis website and represent BEA economic region levels and/or aggregations thereof.
- The time-series techniques were applied to data constructed from Waterborne Commerce data (WBC) files provided by ACE. These data provide flows from an origin dock to a destination dock of a specific commodity and are available from 1985-2006 in two different data sets. These were combined with dock directory,

location codes, commodity codes, and BEA data to form the data used in the analysis. A description of the data is provided in Section 2 and in Appendix B.

- Forecasts are provided for 13 different commodity groups. Specifically, there are 11 different commodity groups, with further delineations of shipments of coal and coke, and lime and limestone to locations that are dominated by flows to electricity plants. Throughout the report, these are described as "commodity groups".
- There are nine regions in the report. These include the Upper, Middle, and Lower Ohio, as well as separate treatment for major tributaries, including the Monongahela/Allegheny, Kanawha, Big Sandy, Green River, and Tennessee/Cumberland. These were defined by commonality of flows in conjunction with ACE.
- Three different levels of aggregations were analyzed. These include 1. System-wide commodity group aggregations; 2. Destination Reach-Commodity aggregations; and 3. Origin-Destination-Commodity aggregations.
- The system-wide commodity group data allowed forecasts using 22 years of data (1985-2006) for 11 of the 13 different commodity groups. For the remaining two groups (metals and industrial chemicals), there are 17 years of data used (1990-2006). In the case of these latter two groups, there was a commodity reclassification which did not allow consistent time series to be identified.
- The commodity-destination reach aggregations are derived by aggregating data over origins. This gives a total of 117 possible (9*13) markets, and forecasts are made for commodity group for the 9 different regions. Some regions do not import commodity groups, and still others import only very small amounts and only for limited time periods and these observations are excluded. Indeed, in the data there are 109 markets in which flows occurred for at least one time period leaving 8 markets with no flows in any time period. In addition, as with the larger sample, all of the markets were required to have a minimum of 15 time periods with observed positive flows in order to ensure that sufficient degrees of freedom are available for estimation. In the results reported, there were 17 markets with less than 15 time periods. As a result, there are forecasts for 92 markets of the 109 markets. These 92 markets account for about 99 percent or more of all ORS traffic in every year.
- The commodity-origin-destination data are aggregations into 13 different commodity groups, 9 origin regions and 9 destination regions. The result gives a total of 9*9*13=1053 possible markets. However, over the entire time period, flows in at least one time period occurred in only 671 of the markets. Of the 671 markets in which flows appear for at least one time period, forecasts were formed for 333 of them. The remainder had less than 15 periods in which flows occurred and those were dropped to ensure that there is enough data to estimate the growth rate reliably. Generally, of those omitted, the flows tended to be quite small. Indeed, in all years, the 333 markets where forecasts are made, in total, contain 97 percent or more of total system traffic.
- The estimation produces a large number of different estimated growth rates and forecasts. Specifically, there are a total of nine different sets of estimates, encompassing three different empirical specifications (constant growth with a deterministic trend, constant growth with a stochastic trend, and a declining

growth model with a deterministic trend) which were estimated on three different data sets (commodity aggregates for the system, commodity aggregates for nine receiving regions, and commodity aggregates for nine receiving regions from nine originating regions). All growth rates and forecasts are provided in Appendices C-K for the commodity-system aggregates (C, D and E), the commodity-receiving region aggregates (F, G, and H), and the commodity-origination-receiving regions (I, J, K), respectively. Given the large number of estimates, the "best" forecast for each series and the associated growth i.e., a choice of DG-DT, CG-DT, and CG-ST is made on the basis of in-sample forecast errors. Appendix L provides these results and various aggregations are used to summarize the results in Section 3.4.

- A summary of the aggregated results is as follows:

    1. The different procedures and aggregations provide a range of different estimates. Certainly, there is considerable correspondence across different estimation procedures, but there are also a number of cases where the forecasts from the different models are considerably different. Generally, growth rates increase with the level of data disaggregation and the growth rate for the declining growth model (with growth rates measured from 2007 to 2070) are lower than for the constant growth rate models.
    2. For system aggregates (weighted by 2006 tonnages), the results point to relatively modest growth in waterway traffic. In particular, system wide estimates range from -.128 to 4.688 depending on the model and data aggregation. For estimates based on the DG-DT model, the estimates based on the commodity (C), destination-commodity (DC), and origin-destination commodity (ODC) are .873, 1.034 and 1.132. For estimates based on the CG-DT model, the estimates are -0.128, 2.296, and 2.985 for C, DC, and ODC aggregates, respectively. Finally, for the CG-ST model, the estimates are 1.606, 2.296 and 4.688, for C, DC, and ODC aggregates, respectively. Generally, the DG-DT model gives more conservative and more consistent results than the other models.
    3. "Best" model aggregations yield more systematic estimates. The commodity level aggregates yield a system estimate of 0.615 percent, the destination-commodity aggregates yield a system estimate of 1.65 percent, and the origin-destination-commodity aggregates yield an estimate of 3.27 percent. As indicated, the system growth rate decreases with the level of aggregation.
    4. At the commodity level, there is considerable variation across commodity groups, and in some cases, across estimation procedures and the level of aggregation. Looking across the three estimation procedures, there are 13 commodity groups. In seven groups, the growth rates for the group are uniformly positive across time series models, while in six groups there is at least one estimate that is negative. In terms of best estimates chosen as above, there are three sets of estimates by commodity. A summary of those is as follows:

   a. Commodity-system: There are 10 positive and 3 negative growth rates. The largest growth rates are observed for Electric Lime/Limestone (1.997), Other (1.819), and Metals (1.76). The negative growth rates are for Non-electric Coal and Coke (-2.971), Crude Petroleum (-2.630), and Petroleum Products (-0.35). The largest market share commodity, Electric Coal, has a growth rate of about 0.878 per year.
   b. Destination Reach-Commodity: There are 11 positive and 2 negative growth rates. The largest growth rates are observed for Metals (4.606), Non-Metallic Minerals (2.378), Electric Coal (1.873) and Electric Lime/Limestone (1.704). The two negative growth rates are for Crude Petroelum (-7.33) and Other (-1.444).
   c. Origin-Destination Reach-Commodity: There are 12 positive and one negative growth rate. The largest growth rates are observed for Forest Products (8.225), Electric Lime and Limestone (6.193) and for Metals (5.556). The smallest growth rates are observed for Crude Petroleum (-1.870) and Non-Electric Coal and Coke (0.033). Electric Coal has a growth rate of 4.403.
5. Two of the three data aggregations (Destination-Commodity and Origin-Destination-Commodity) allow estimates by destination (receiving) reach. There are nine reaches, and in both specifications, the estimated growth rates for all nine regions are positive i.e., there is no destination reach that has negative growth. Further, in both specifications, the Big Sandy is a primary growth market with growth rate estimates of about 15 percent per year. The other estimates are described by data aggregation.
   a. Destination-Commodity: As noted, the Big Sandy has a large growth rate (15.132). The others are much more modest. The Green River (2.328), the Kanawha (2.920), and the Middle Ohio (2.834) have growth rates larger than 2 percent a year; the Lower Ohio (1.224), the Tennessee/Cumberland (1.341), and the Upper Ohio (1.61) have growth rates larger than 1 percent a year; and the Monongahela/Allegheny and "Other" have growth rates of less than 1 percent a year.
   b. Origin-Destination-Commodity: Again, as noted, the Big Sandy has a large growth rate (15.099) percent per year. The Green River has a growth rate in excess of 28 percent. The others are more modest. The Middle Ohio (3.630), the Tennessee/Cumberland, and the Upper Ohio (3.266) have growth rates between 3 and 5 percent. The Lower Ohio (2.472) has a growth rate large than 2 percent, while the Kanawha (1.16), Monongahela/Allegheny (1.147) and "Other" .399 each has a growth rates of less than 2 percent.
6. The Origin-Destination-Commodity aggregation also allows growth estimates to be summarized by origin reach. All origin reaches have

positive growth rates. The Green River (12.428) has the largest growth rates. The Upper Ohio (5.047) and the Big Sandy (4.858) are each growing about 5 percent per year. Other origins (3.6940) and the Tennesse/Cumberland (3.113) are each growing in excess of 3 percent per year. The Kanawha (2.926) and the Middle Ohio (2.519) have growth rates in excess of 2 percent, while the Lower Ohio (1.902) and Monongahela/Allegheny are growing at less than 2 percent per year.

- Overall, the results are similar across the different estimation techniques and commodity aggregations. Generally, the constant growth models (whether deterministic or stochastic trends) tend to yield larger growth rates than the declining growth models. Further, the overall growth rates tend to be larger and more variable as the more disaggregate data are used. This likely reflects idiosyncratic circumstances of different markets, while in the more aggregated data such circumstances are masked in the aggregation.

2. DESCRIPTION OF OHIO RIVER SYSTEM

The primary study area is the Ohio River Basin, which is largely contained within the states of Alabama, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Tennessee and West Virginia. Portions of the basin reach, as well, into parts of Georgia, Mississippi, New York, North Carolina and Virginia. This forecasting effort involves commodity traffic moving on ORS, meaning the Ohio River or any of its navigable tributaries, including the Monongahela, Allegheny, Kanawha, Green, Tennessee and Cumberland rivers. In 2006, the ORS handled approximately 270 million tons of commodity traffic. Approximately two-thirds of this traffic was (and typically is) internal to the ORS, meaning that both the origin and destination of the commodity movements are on the ORS itself.

Aside from the internal traffic, traffic moving on the ORS also originates in or is destined for areas outside of the ORS. Commodity traffic moves to/from parts of the Upper Midwest by way of the Upper Mississippi and Illinois Waterway, as well as parts of the Southeast, and to export markets by way of the Lower Mississippi, the Tennessee Tombigbee Waterway and the Gulf Intercoastal Waterway (East and West). Accordingly, the forecasting process also necessarily deals with areas outside of the ORB.

For the immediate purposes, the Army Corps (ACE) provided Waterborne Commerce Statistics data. These data were received in two files. The first file contains data from 1990-06, while the second file consists of data from 1980-1989.[1] A record or observation in the 1990-06 data file is a movement from one dock to another dock of a five digit defined[2] commodity flowing through a common set of locks (i.e., a routing). A record in the 1980-89 data is the movement from one dock to another of a four digit commodity regardless of routing. These two data sets were combined to form the data available for use in the study. More information is provided in Appendix B on the data employed and the steps taken to organize the data. On inspection and review, the data from 1980-1984 were excluded owing to measurement issues.[3] Further, a definition of a commodity (alumina) in 1990 affected commodity groups (defined below) and negated the use of data for two of these groups (Industrial Chemicals and Metals) for periods before 1990.

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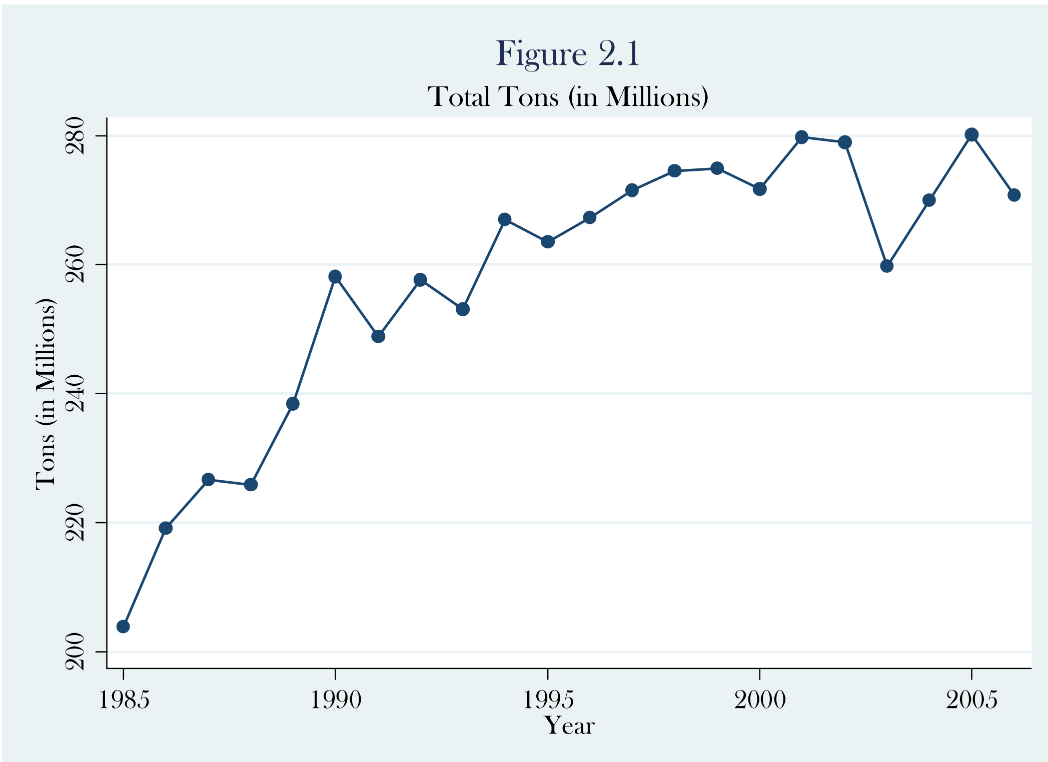
[1] The 1980-9 data were added in to increase the number of observations used in the time-series analysis. There are a number of potential issues. On the positive side, a longer time series does indeed increase the number of observations (degrees of freedom) and, generally, increases the precision of estimates. On the negative side, most econometric techniques rest on stable structures. If there is structural change in the system e.g., a change in demand that is not observed, the added time component may not be useful. For example, a close examination of crude petroleum over time indicates a major structural change when pipelines were added in 1974. After pipelines were developed, a major flow dropped substantially. A second factor is that over time there have been improvements in data collection and quality control checks. In short, if there is no structural change and the data added do not suffer in quality, the additional observations are indeed a major benefit to the forecasting effort. In this study, we scrutinized each time series employed to identify problems of this type.

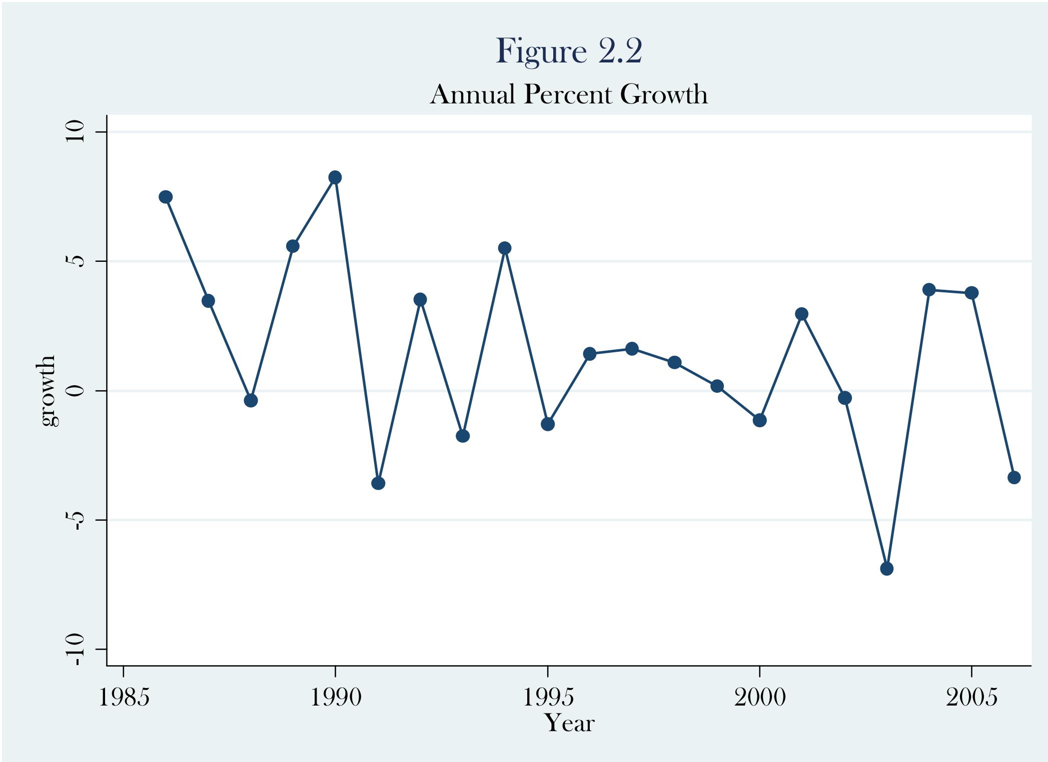
[2] The waterborne commerce data have a set of codes to delineate commodity groups. In the 1990-06 data, these codes are at the five digit level, while in the 1980-9 data; these codes are at a four digit level.

[3] In particular, in the early 1980s the Waterborne Commerce Data underestimated total river tonnages. There was no obvious corrections to the disaggregate data used throughout the analysis, and therefore, after discussion with ACE, the 1980-84 data were excluded.

Both datasets were collapsed by time to yield total tonnages. Figure 2.1 presents the data over time. This figure illustrates that tonnages range from about 200 million tons in 1983 to about 280 million in 2005 and 270 million in 2006. From low to high this represents only about a 80 million ton difference (about 40 percent). It is also clear that much of the growth occurred from 1985 to about 1994. Since then tonnages have increased, but only modestly.



The annual percentage change in tonnages $(tons_t - tons_{t-1})/tons_{t-1}$ is presented in Figure 2.2. The average annual percentage change over the span of the data is about 1.43 percent per year, with a range from -6.9 percent in 2003 to 8.26 in 1990. Statistically, the average change rate is not different from zero, and by inspection of the data in Figure 2.2, the percentage change in tonnages has become smaller in magnitude over time.



The overall traffic growth rate suggests a low to moderate growth with relatively stable tonnages. The traffic itself, however, consists of a large number of different commodities. In particular, there are 306 different commodities (five digit waterborne commerce codes), and this fact alone points to the considerable heterogeneity in transportation markets.

At the four digit level, the number is far more manageable with 130 unique four digit codes. In concert with the Army Corps of Engineers, these 130 different commodity codes were used to define 11 different commodity groups for purposes of forecasting. Two additional categories were added to reflect differences in demanders. In particular, ACE identified locations of electricity docks, which were then used along with the commodity designations to define coal and coke movements and also lime and limestone movements to electricity plants. These were assigned group numbers 12 and 13. The four digit WCSC codes, descriptions, and aggregations are summarized in Table 2.1.

Table 2.1: Commodity Aggregations

Group Number	Group Name	"Old" WCSC 4-Digit Code	"Old" WCSC 4-Digit Description
1	Coal and Coke	1121	COAL
		2920	COKE
2	Crude Petroleum	1311	CRUDE PETROL
3	Petroleum Products	2911	GASOLINE
		2912	JET FUEL
		2913	KEROSENE
		2914	DIST.FUELOIL

		2915	RESD FUELOIL
		2916	LUBRIC. OILS
		2917	SOLVENTS,NEC
		2921	LIQ PETR GAS
		2991	PETROL PROD.
4	Agricultural Chemicals	1479	FERTILIZERNC
		2871	NITROG. FERT
		2872	POTASS.FERT.
		2873	PHOSPHATFERT
		2879	FERTILIZERS
5	Industrial Chemicals	1493	SULPHUR, LIQ
		2810	SODIUM HYDRX
		2811	CRUDE PROD
		2812	DYES
		2813	ALCOHOLS
		2816	RADIOACT MAT
		2817	BENZENE
		2818	SULPHURIC AC
		2819	BASIC CHEM.
		2821	PLASTIC MAT.
		2831	DRUGS
		2841	SOAPS
		2851	PAINTS
		2861	WOOD CHEM.
		2876	INSECTICIDES
		2891	MISC.CHEMPRD
6	Forest Products	841	CRUDE RUBBER
		861	FOR.PROD,NEC
		2411	Logs
		2413	FUEL WOOD
		2414	TIMBER
		2415	Pulpwood Logs
		2416	WOOD CHIPS
		2421	LUMBER
		2431	VENEER-PLYWD
		2491	WD.MANF.,NEC
		2611	PULP
		2621	NEWSPRNT PPR
		2631	PAPER
		2691	PAPER ,NEC
		4024	PAPER SCRAP
7	Non-Metallic Minerals	931	MARINE SHELL
		1451	CLAY
		1471	PHOSPHATES
		1491	SALT
		1492	SULPHUR, DRY
		1494	GYPSUM

		1499	NONMET MN,NC
		2951	ASPHALT MAT.
		3211	GLASS PROD.
		3251	STRCCLAY PRD
		3271	LIME
		3281	STONE PROD
		3291	NONMETALPROD
		3312	SLAG
		4118	GOV.MATERIAL
8	Metals	1011	IRON ORE
		1021	COPPER ORE
		1051	BAUXITE ORE
		1061	MANGANESEORE
		1091	NONFERORENEC
		3311	PIG IRON
		3314	IRON-STL ING
		3315	IRON-STL BAR
		3316	IRON-STL PLT
		3317	IRON-STL PIP
		3318	FERROALLOYS
		3319	IRON-STL NEC
		3319	FERROALLOYS
		3321	NONFER.METAL
		3322	COPPER
		3323	LEAD-ZINC UW
		3324	ALUMINUM UW
		3411	FABMET.EXORD
		4011	IRON-STLSCRP
		4012	NONFER.METSP
9	Farm Products	101	COTTON
		102	BARLEY - RYE
		103	CORN
		104	OATS
		105	RICE
		106	SORGHUM
		107	WHEAT
		111	SOYBEANS
		119	OILSEED,NEC
		121	TOBACCO,LEAF
		122	HAY - FODDER
		129	FLD.CRPS,NEC
		141	FF VEGETABLE
		161	ANIMALS,NEC
		191	MISCFARMPROD
		911	FRESH FISH
		2014	TALLOW
		2031	FISH

		2041	WHEAT FLOUR
		2042	ANIMAL FEEDS
		2049	GRA.MILL,NEC
		2061	SUGAR
		2062	MOLASSES
		2081	ALCOHOL BEV.
		2091	VEGET. OILS
		2099	MISC.FD.PROD
10	Other	1911	ORDNANCE
		2211	BASICTEXPROD
		2511	FURNITURE
		2822	SYNTH. RUBBR
		3011	RUBBER PROD.
		3511	MACH.EX.ELEC
		3611	ELECT MACHIN
		3711	MOTOR VEHIC.
		3721	AIRCRAFT
		3731	SHIPS- BOATS
		3791	MISC TRAN EQ
		3911	MISC.PROD MF
		4022	TEXTILESCRAP
		4029	SCRAP,NEC
		4111	WATER
		4112	MISC. SHIPM.
		4119	MT CONTAINER
11	Construction	1411	LIMESTONE
		1412	BUILDING STN
		1442	SAND- GRAVEL
		2918	ASPHALT
		3241	BUILD CEMENT
12	Electric Coal-Coke	1121	COAL
		2920	COKE
13	Electric Lime/Limestone	1411	LIMESTONE
		3271	LIME

These commodity groups vary dramatically in total tonnages as indicated by the 2006 statistics presented in Table 2.2. For example, in 2006 there were a total of about 271 million tons transported in the ORS. Coal movements by electricity companies dominate the tonnages with about 47 percent of the total movement. Construction represents about 18 percent of the total movement. Of the remainder, non-electric Coal and Coke movements represent about 9 percent of the total tonnage, while metals, farm products and petroleum products each represent about 5 to 7 percent. The remaining groups, Crude Petroleum, Agricultural Chemicals, Industrial Chemicals, Forest products, non-metallic minerals and other commodities each represent less than five percent of the total tonnage.

As might be expected, there are considerable differences in growth rates across the markets. As indicated in Table 2.2, electric lime/limestone has marked growth. Metals and construction are also high growth markets. Electric coal and forest products have moderate growth, while industrial chemicals, non-metallic minerals, petroleum products, farm products and agricultural chemicals are at about the same level as in 1985. "Default" or non-electric Coal and Coke, crude petroleum and other products have substantially lower tonnages than in 1985.

Table 2.2: Commodity Groups, Tons, Market Shares and Growth

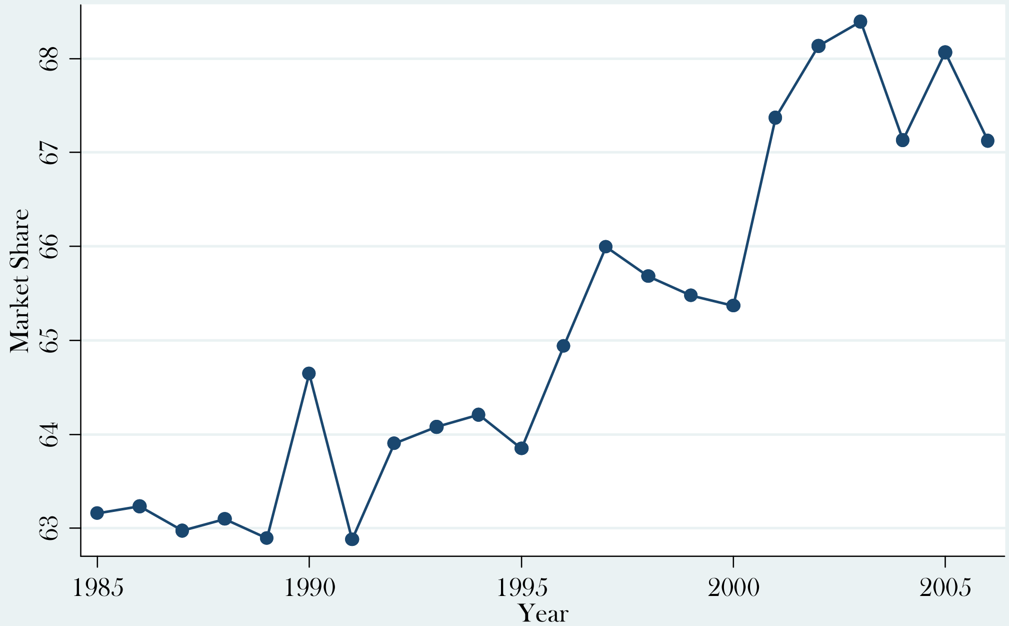
Group Number	Group Name	Tons (millions)	Market Share	Percent of 1985 Tons
1	Coal and Coke	23.91	8.83	70.17
2	Crude Petroleum	0.65	0.24	75.68
3	Petroleum Products	13.55	5.00	106.50
4	Agricultural Chemicals	2.63	0.97	93.65
5	Industrial Chemicals	8.01	2.96	115.28
6	Forest Products	1.03	0.38	140.14
7	Non-Metallic Minerals	8.15	3.01	113.41
8	Metals	18.39	6.79	177.95
9	Farm Products	15.39	5.68	100.08
10	Other	0.08	0.03	67.03
11	Construction	48.29	17.83	170.60
12	Electric Coal	127.10	46.94	150.07
13	Electric Lime/Limestone	3.58	1.32	355.12
	Total	270.75	100.00	132.82

Note: Group numbers 5 and 8 have growth numbers based on 1990 tons because of a commodity redefinition.

In addition to commodities, the location of economic activity and entrances/exits from the waterway are important to framing forecasts. In particular, it is often noted that much of the traffic in the Ohio system both originates and terminates in the same system. Indeed, movements on the river are dominated by such traffic, and, as indicated in Figure 2.3, the extent of this containment has only grown slightly since the mid-1980s. In 1985, it was about 63 percent, it increased to 67 percent in 2001, and has been relatively stable since.

Figure 3.3

Share of Traffic that Originates and Terminates in ORS



The Ohio River Waterway consists of the Ohio River and several tributaries. Table 2.3 presents all of the rivers (and other origin/termination dock locations) that appear in the data and assigns them a category (Ohio, Ohio Tributary, and Not in Ohio). It is noted that there are 58 different rivers and other origin/destination dock locations in the data. This includes the Ohio, 13 different rivers that are titled Ohio Tributaries, and a group of 44 other rivers that either originate or terminate flows into the Ohio. Table 2.3 also shows the originating and terminating tonnages by river. Clearly, the Ohio Waterway system is dominated by traffic that originates and terminates on the Ohio River. But, there are also significant tonnages that originate (34%) and terminate (29%) from the tributaries, and that originate (16%) and terminate (17%) from outside the system. Primary originations among the tributaries are: the Big Sandy (6.5%), the Kanawha River (5.73%), the Monongahela River (6.82%), and the Tennessee River (9.02%). Primary destinations among the tributaries are: The Cumberland River (7.25%), the Monongahela River (6.75%), and the Tennessee River (7.81%). Finally, the primary origination and termination points outside the Ohio Waterway are on the Mississippi and account for 12% of originations and 11% of destinations for tonnages that touch the Ohio.

Table 2.3: River System, River and 2006 Tonnages

River Group	River	River Name	Originating Tons	Share	Terminating Tons	Share
OHIO	OH	OHIO	135,600,000	50.077	147,500,000	54.475
OHIO-TRIBUTARY	AG	ALLEGHENY	1,455,067	0.537	2,735,591	1.010

	BS	BIG SANDY	17,631,609	6.513	3,095,550	1.143
	CL	CLINCH/EMORY	0	0.000	229	0.000
	CU	CUMBERLAND	6,287,872	2.323	19,641,844	7.255
	FB	FRENCH BROAD	38,893	0.014	163,706	0.060
	GB	GREEN	6,898,227	2.548	5,707,288	2.108
	HI	HIWASSEE	66,900	0.025	378,489	0.140
	KA	KANAWHA	15,510,833	5.729	5,363,928	1.981
	KY	KENTUCKY	3,422	0.001	1,872	0.001
	LI	LICKING	402,102	0.149	1,272,766	0.470
	LK	LITTLE KANAWHA	6,274	0.002	68,231	0.025
	MN	MONONGAHELA	18,468,401	6.822	18,282,318	6.753
	TN	TENNESSEE	24,413,782	9.018	21,136,655	7.807
NON-ORS	AC	ATLANTIC COAST	0	0.000	0	0.000
	AL	ALABAMA	0	0.000	0	0.000
	AP	APALACHICOLA	0	0.000	0	0.000
	AT	ATCHAFALAYS	172,117	0.064	76,501	0.028
	BA	BAYOU TERRBONNE	0	0.000	0	0.000
	BB	BAYOU BARATARIA	0	0.000	1,839	0.001
	BL	BAYOU LAFOURCHE	1,400	0.001	52,784	0.019
	BR	BLACKWATER RIVER	0	0.000	0	0.000
	BT	BAYOU TECHE	1,502	0.001	269,377	0.100
	BW	BLACK WARRIOR TOMBIGBEE	232,502	0.086	1,172,868	0.433
	CA	CALCASIEU	561,364	0.207	1,048,251	0.387
	CC	CHICAGO	273,205	0.101	189,624	0.070
	CO	CORPUS CHRISTI, TX	775,396	0.286	0	0.000
	CS	CALUMET	293,977	0.109	250,127	0.092
	GC	GULF COAST	696,932	0.257	1,473,402	0.544
	GI	GIWW	2,051,789	0.758	2,045,078	0.755
	GL	GREAT LAKES	164,085	0.061	647,525	0.239
	HS	HOUSTON SHIP CHANNEL	1,589,263	0.587	693,318	0.256
	IH	INNER HARBOR	0	0.000	819,513	0.303
	IL	ILLINOIS	917,057	0.339	594,441	0.220
	KK	KASKASKIA	1,640	0.001	1,409	0.001
	LP	LAKE PONCHARTRAIN	0	0.000	0	0.000
	MA	MATAGORDA SHIP CHANNEL	884,263	0.327	1,491	0.001
	ME	MINNESOTA	90,889	0.034	0	0.000
	MG	MISSISSIPPI GULF OUTLET	0	0.000	0	0.000
	MI	MISSISSIPPI	32,879,129	12.145	30,534,366	11.279
	MK	ARKANSAS	310,655	0.115	674,012	0.249
	MR	MISSOURI	21,356	0.008	98,697	0.036
	MS	MOBILE HARBOR	229,726	0.085	658,858	0.243
	NR	NECHES RIVER	163,475	0.060	284,687	0.105
	OB	OUACHITA/BLACK/RED RIVERS	24,751	0.009	1,603,221	0.592

	PA	PORT ALLEN	61,504	0.023	0	0.000
	PC	PACIFIC COAST	0	0.000	0	0.000
	PE	EAST PEARL RIVER	1,635	0.001	189,724	0.070
	PR	WEST PEARL RIVER	1,498	0.001	326,748	0.121
	PT	PETITE ANSE	594,852	0.220	106,883	0.039
	SA	SABINE LAKE	1,246	0.000	205,048	0.076
	SR	WHITE	0	0.000	0	0.000
	TC	TEXAS CITY	273,392	0.101	524,063	0.194
	TR	TRINITY BAY	0	0.000	0	0.000
	TT	TENNESSEE TOMBIGBEE	665,372	0.246	385,465	0.142
	VB	VERMILLION BAY	0	0.000	424,732	0.157
	YA	YAZOO	34,209	0.013	45,990	0.017
	SB	SAN BERNARD	2,370	0.001	0	0.000

For the purposes of forecasting, the individual locations were aggregated into 9 nine groups. These groups include all points on the Big Sandy river, Green River, Kanawha river, Monongahela and Allegheny rivers, the Tennessee and Cumberland Rivers, the Upper Ohio (river miles 0-237.5), the Middle Ohio (river miles 237.5-580), the Lower Ohio (river miles 580-), and all points outside of the ORS. These distinctions were made in conjunction with ACE and reflect plausible differences in economic base and location.

Table 2.4, presents the movements received by each region and from each region for the year 2006. As noted in the table, the primary destination is the Ohio River, with the Upper, Middle and Lower portions, receiving 14, 26 and 14 percent respectively. The Tennessee/Cumberland and Other regions receive 15 and 16 percent, respectively. The remainder is received in smaller proportions by the Monongahela/Allegheny (8%), the Kanawha (2%), Green (2%), and Big Sandy (1%).

Also as noted in table 2.4, there are significant differences in the origin of movements across the destination regions. A brief summary is:

1. Locations on the Big Sandy received over 3 million tons in 2006. Most of that originates from outside the ORS or the Middle Ohio.
2. Locations on the Green River received about 5.7 million tons in 2006. Most originates from the Green River itself (33%), the Lower Ohio (28%) and locations outside the ORS (31%).
3. Locations on the Kanawha received about 5.3 million tons in 2006. Most of this tonnage originates from the Lower Ohio (34%), the Middle Ohio (35%), and, to a lesser degree, locations outside the ORS (14%).
4. Locations in the Lower Ohio received about 38 million tons in 2006. Most originates from the Lower Ohio itself (50%), and, to a lesser degree from the Middle Ohio (14%) and locations outside the ORS (19%).
5. Locations in the Middle Ohio receive about 73 million tons a year. Unlike the others, the Middle Ohio is far more balanced in origins. It receives the most from locations in the Upper Ohio (20%), the Middle

Ohio (19%) and from locations outside the ORS (18%). But, it also receives significant tonnages from locations on the Big Sandy (12%), the Kanawha (11%) and the Lower Ohio 12(%).

6. Locations on the Monongahela/Allegheny Rivers received about 21 million tons in 2006. The bulk of the tonnage originates from other locations on these rivers (51%), but also the Upper Ohio (13%) and the Middle Ohio (24%).
7. Locations on the Tennessee/Cumberland receive about 41 million tons. These tons originate from primarily three different regions. These include the Tennessee/Cumberland and tributaries (33%), the lower Ohio (32%) and locations outside of the ORS (26%).
8. The Upper Ohio received about 38 million tons in 2006. Most of the tonnages originated from locations within the Upper Ohio (32%), the Middle Ohio (19%), the Monongahela/Allegheny (11%) and locations from outside the ORS (20%).
9. Locations outside the ORS received about 45 million tons in 2006. Most of the tonnages originated in the Lower Ohio (41%), the Tennessee/Cumberland (35%), and the Middle Ohio (11%).

From this set of figures, it is clear that locality plays a big role in the origination of freight. For virtually all reaches, sizable proportions of incoming freight originated from locations within the same reach or a neighboring reach.

Table 2.4: Major Destinations and Origins of River Traffic

DESTINATION	ORIGIN	TONS	Reach Share	System Share
BIG SANDY	BIG SANDY	351,731	11.36	0.13
BIG SANDY	GREEN RIVER	0	0.00	0.00
BIG SANDY	KANAWHA	8,498	0.27	0.00
BIG SANDY	LOWER OHIO	48,469	1.57	0.02
BIG SANDY	MIDDLE OHIO	700,723	22.64	0.26
BIG SANDY	MONONGAHELA/ALLEGHENY	167,690	5.42	0.06
BIG SANDY	OTHER	1,554,234	50.21	0.57
BIG SANDY	TENNESSEE/CUMBERLAND	62,078	2.01	0.02
BIG SANDY	UPPER OHIO	202,127	6.53	0.07
TOTAL		3,095,550	100.00	1.14
GREEN RIVER	BIG SANDY	0	0.00	0.00
GREEN RIVER	GREEN RIVER	1,900,648	33.30	0.70
GREEN RIVER	KANAWHA	0	0.00	0.00
GREEN RIVER	LOWER OHIO	1,592,420	27.90	0.59
GREEN RIVER	MIDDLE OHIO	9,499	0.17	0.00
GREEN RIVER	MONONGAHELA/ALLEGHENY	0	0.00	0.00
GREEN RIVER	OTHER	1,771,733	31.04	0.65
GREEN RIVER	TENNESSEE/CUMBERLAND	420,717	7.37	0.16
GREEN RIVER	UPPER OHIO	12,271	0.22	0.00

TOTAL		5,707,288	100.00	2.11
KANAWHA	BIG SANDY	73,695	1.37	0.03
KANAWHA	GREEN RIVER	0	0.00	0.00
KANAWHA	KANAWHA	313,564	5.85	0.12
KANAWHA	LOWER OHIO	1,822,546	33.98	0.67
KANAWHA	MIDDLE OHIO	1,892,264	35.28	0.70
KANAWHA	MONONGAHELA/ALLEGHENY	54,650	1.02	0.02
KANAWHA	OTHER	761,947	14.21	0.28
KANAWHA	TENNESSEE/CUMBERLAND	29,266	0.55	0.01
KANAWHA	UPPER OHIO	415,996	7.76	0.15
TOTAL		5,363,928	100.00	1.98
LOWER OHIO	BIG SANDY	2,149,094	5.64	0.79
LOWER OHIO	GREEN RIVER	3,463,163	9.08	1.28
LOWER OHIO	KANAWHA	321,448	0.84	0.12
LOWER OHIO	LOWER OHIO	18,861,041	49.47	6.97
LOWER OHIO	MIDDLE OHIO	5,430,836	14.24	2.01
LOWER OHIO	MONONGAHELA/ALLEGHENY	198,597	0.52	0.07
LOWER OHIO	OTHER	7,122,384	18.68	2.63
LOWER OHIO	TENNESSEE/CUMBERLAND	85,502	0.22	0.03
LOWER OHIO	UPPER OHIO	497,794	1.31	0.18
TOTAL		38,129,859	100.00	14.08
MIDDLE OHIO	BIG SANDY	8,983,751	12.31	3.32
MIDDLE OHIO	GREEN RIVER	1,019,809	1.40	0.38
MIDDLE OHIO	KANAWHA	9,831,933	13.47	3.63
MIDDLE OHIO	LOWER OHIO	8,085,884	11.08	2.99
MIDDLE OHIO	MIDDLE OHIO	14,216,642	19.48	5.25
MIDDLE OHIO	MONONGAHELA/ALLEGHENY	2,470,336	3.38	0.91
MIDDLE OHIO	OTHER	13,174,451	18.05	4.87
MIDDLE OHIO	TENNESSEE/CUMBERLAND	592,761	0.81	0.22
MIDDLE OHIO	UPPER OHIO	14,608,531	20.02	5.40
TOTAL		72,984,098	100.00	26.96
MONONGAHELA/ALLEGHENY	BIG SANDY	125,199	0.60	0.05
MONONGAHELA/ALLEGHENY	GREEN RIVER	0	0.00	0.00
MONONGAHELA/ALLEGHENY	KANAWHA	1,288,657	6.13	0.48
MONONGAHELA/ALLEGHENY	LOWER OHIO	0	0.00	0.00
MONONGAHELA/ALLEGHENY	MIDDLE OHIO	5,114,353	24.33	1.89
MONONGAHELA/ALLEGHENY	MONONGAHELA/ALLEGHENY	10,766,912	51.23	3.98
MONONGAHELA/ALLEGHENY	OTHER	901,104	4.29	0.33
MONONGAHELA/ALLEGHENY	TENNESSEE/CUMBERLAND	13,061	0.06	0.00
MONONGAHELA/ALLEGHENY	UPPER OHIO	2,808,623	13.36	1.04
TOTAL		21,017,909	100.00	7.76
OTHER	BIG SANDY	1,938,628	4.27	0.72
OTHER	GREEN RIVER	514,607	1.13	0.19
OTHER	KANAWHA	1,276,648	2.81	0.47

OTHER	LOWER OHIO	18,545,809	40.85	6.85
OTHER	MIDDLE OHIO	4,907,123	10.81	1.81
OTHER	MONONGAHELA/ALLEGHENY	599,669	1.32	0.22
OTHER	OTHER	378,208	0.83	0.14
OTHER	TENNESSEE/CUMBERLAND	15,830,474	34.87	5.85
OTHER	UPPER OHIO	1,408,876	3.10	0.52
TOTAL		45,400,042	100.00	16.77
TENNESSEE/CUMBERLAND	BIG SANDY	1,038,188	2.51	0.38
TENNESSEE/CUMBERLAND	GREEN RIVER	0	0.00	0.00
TENNESSEE/CUMBERLAND	KANAWHA	0	0.00	0.00
TENNESSEE/CUMBERLAND	LOWER OHIO	13,311,342	32.21	4.92
TENNESSEE/CUMBERLAND	MIDDLE OHIO	689,987	1.67	0.25
TENNESSEE/CUMBERLAND	MONONGAHELA/ALLEGHENY	1,387,774	3.36	0.51
TENNESSEE/CUMBERLAND	OTHER	10,853,001	26.27	4.01
TENNESSEE/CUMBERLAND	TENNESSEE/CUMBERLAND	13,688,114	33.13	5.06
TENNESSEE/CUMBERLAND	UPPER OHIO	352,517	0.85	0.13
TOTAL		41,320,923	100.00	15.26
UPPER OHIO	BIG SANDY	2,971,323	7.88	1.10
UPPER OHIO	GREEN RIVER	0	0.00	0.00
UPPER OHIO	KANAWHA	2,470,085	6.55	0.91
UPPER OHIO	LOWER OHIO	1,283,691	3.40	0.47
UPPER OHIO	MIDDLE OHIO	7,047,360	18.69	2.60
UPPER OHIO	MONONGAHELA/ALLEGHENY	4,277,840	11.35	1.58
UPPER OHIO	OTHER	7,455,489	19.77	2.75
UPPER OHIO	TENNESSEE/CUMBERLAND	85,474	0.23	0.03
UPPER OHIO	UPPER OHIO	12,115,254	32.13	4.48
TOTAL		37,706,516	100.00	13.93
TOTAL ORS		270,726,113	N.A.	100

Table 2.5 provides the total tons (in millions) by reach. As indicated, the lower Ohio originates the largest share of freight followed by locations outside of the ORS, the Middle Ohio, the Upper and the Tennessee/Cumberland.

Table 2.5: Origins of River Traffic by Reach (2006)		
Reach	**Tons (mil)**	**Share**
BIG SANDY	17.63	6.51
GREEN RIVER	6.90	2.55
KANAWHA	15.51	5.73
LOWER OHIO	63.55	23.47
MIDDLE OHIO	40.01	14.78
MONONGAHELA/ALLEGHENY	19.92	7.36
OTHER	43.97	16.24
TENNESSEE/CUMBERLAND	30.81	11.38

UPPER OHIO	32.42	11.98
TOTAL	270.73	100

Within each of these reaches there are a variety of products. Table 2.6 presents a summary of the products originated by each reach. The table provides tons (000) along with the share of the reach's total, the share of the total ORS system, and the cumulative reach share. As indicated, with the exception of the Tennessee/Cumberland and locations outside of the ORS, the number one commodity is coal. Indeed, the top two commodity groups, in most instances, are coal and coke for electricity plants and "default" coal and coke. In the Tennessee/Cumberland construction aggregates have the largest share of tonnages. Further, with the exception of locations outside of the ORS, the top five commodity groups account for over 90 percent of the traffic in each of the reaches.

Table 2.6: Origin Reaches and Commodities

Reach	Commodity	Tons (000)	Reach Share	ORS Share	Cum. Reach Share
BIG SANDY	Electric Coal	13530	76.74	5.00	76.74
	Coal and Coke	2042	11.58	0.75	88.32
	Construction	1192	6.76	0.44	95.08
	Petroleum Products	512	2.90	0.19	97.98
	Industrial Chemicals	263	1.49	0.10	99.47
	Crude Petroleum	85	0.48	0.03	99.95
	Non-Metallic Minerals	7	0.04	0.00	100.00
	Other	1	0.00	0.00	100.00
	Metals	0	0.00	0.00	100.00
	Electric Lime/Limestone	0	0.00	0.00	100.00
	Farm Products	0	0.00	0.00	100.00
	Forest Products	0	0.00	0.00	100.00
	Agricultural Chemicals	0	0.00	0.00	100.00
Total		17632	100.00	6.51	
GREEN RIVER	Electric Coal	6372	92.37	2.35	92.37
	Coal and Coke	494	7.16	0.18	99.53
	Farm Products	33	0.47	0.01	100.00
	Forest Products	0	0.00	0.00	100.00
	Construction	0	0.00	0.00	100.00
	Electric Lime/Limestone	0	0.00	0.00	100.00
	Crude Petroleum	0	0.00	0.00	100.00
	Other	0	0.00	0.00	100.00
	Industrial Chemicals	0	0.00	0.00	100.00
	Non-Metallic Minerals	0	0.00	0.00	100.00
	Metals	0	0.00	0.00	100.00
	Agricultural Chemicals	0	0.00	0.00	100.00
	Petroleum Products	0	0.00	0.00	100.00

Total		6898	100.00	2.55	
KANAWHA	Electric Coal	13208	85.15	4.88	85.15
	Coal and Coke	2201	14.19	0.81	99.34
	Industrial Chemicals	78	0.51	0.03	99.85
	Other	17	0.11	0.01	99.96
	Metals	4	0.03	0.00	99.99
	Construction	2	0.01	0.00	100.00
	Electric Lime/Limestone	0	0.00	0.00	100.00
	Petroleum Products	0	0.00	0.00	100.00
	Agricultural Chemicals	0	0.00	0.00	100.00
	Crude Petroleum	0	0.00	0.00	100.00
	Farm Products	0	0.00	0.00	100.00
	Non-Metallic Minerals	0	0.00	0.00	100.00
	Forest Products	0	0.00	0.00	100.00
Total		15511	100.00	5.73	
LOWER OHIO	Electric Coal	26140	40.58	9.66	40.58
	Construction	21588	33.51	7.97	74.09
	Farm Products	9043	14.04	3.34	88.13
	Coal and Coke	2493	3.87	0.92	92.00
	Non-Metallic Minerals	1679	2.61	0.62	94.61
	Petroleum Products	1301	2.02	0.48	96.63
	Electric Lime/Limestone	766	1.19	0.28	97.82
	Metals	715	1.11	0.26	98.93
	Agricultural Chemicals	514	0.80	0.19	99.73
	Industrial Chemicals	104	0.16	0.04	99.89
	Other	32	0.05	0.01	99.94
	Crude Petroleum	24	0.04	0.01	99.97
	Forest Products	17	0.03	0.01	100.00
Total		64414	100.00	23.79	
MIDDLE OHIO	Electric Coal	11705	29.90	4.32	29.90
	Coal and Coke	8398	21.45	3.10	51.35
	Petroleum Products	6131	15.66	2.26	67.02
	Construction	6025	15.39	2.23	82.41
	Farm Products	3065	7.83	1.13	90.24
	Electric Lime/Limestone	1803	4.61	0.67	94.85
	Metals	945	2.41	0.35	97.26
	Non-Metallic Minerals	797	2.04	0.29	99.30
	Forest Products	159	0.40	0.06	99.70
	Industrial Chemicals	115	0.29	0.04	100.00
	Other	2	0.00	0.00	100.00
	Agricultural Chemicals	0	0.00	0.00	100.00
	Crude Petroleum	0	0.00	0.00	100.00
Total		39145	100.00	14.46	
MONONGAHELA/ALLEGHENY	Electric Coal	13226	66.38	4.89	66.38

	Coal and Coke	3075	15.44	1.14	81.82
	Construction	2390	12.00	0.88	93.81
	Non-Metallic Minerals	600	3.01	0.22	96.83
	Metals	478	2.40	0.18	99.22
	Industrial Chemicals	78	0.39	0.03	99.62
	Petroleum Products	48	0.24	0.02	99.86
	Agricultural Chemicals	25	0.13	0.01	99.98
	Other	3	0.02	0.00	100.00
	Electric Lime/Limestone	0	0.00	0.00	100.00
	Farm Products	0	0.00	0.00	100.00
	Crude Petroleum	0	0.00	0.00	100.00
	Forest Products	0	0.00	0.00	100.00
Total		19923	100.00	7.36	
OTHER	Metals	13886	31.58	5.13	31.58
	Electric Coal	6971	15.85	2.57	47.43
	Industrial Chemicals	6162	14.01	2.28	61.44
	Petroleum Products	4381	9.96	1.62	71.41
	Non-Metallic Minerals	3461	7.87	1.28	79.28
	Construction	2602	5.92	0.96	85.20
	Agricultural Chemicals	2064	4.69	0.76	89.89
	Coal and Coke	1799	4.09	0.66	93.98
	Farm Products	1566	3.56	0.58	97.54
	Forest Products	795	1.81	0.29	99.35
	Electric Lime/Limestone	250	0.57	0.09	99.92
	Crude Petroleum	22	0.05	0.01	99.97
	Other	13	0.03	0.00	100.00
Total		43973	100.00	16.24	
TENNESSEE/CUMBERLAND	Construction	12914	41.92	4.77	41.92
	Electric Coal	10485	34.03	3.87	75.95
	Farm Products	1587	5.15	0.59	81.10
	Metals	1514	4.91	0.56	86.01
	Non-Metallic Minerals	1156	3.75	0.43	89.77
	Coal and Coke	1108	3.60	0.41	93.36
	Industrial Chemicals	1008	3.27	0.37	96.63
	Electric Lime/Limestone	757	2.46	0.28	99.09
	Petroleum Products	196	0.64	0.07	99.73
	Forest Products	56	0.18	0.02	99.91
	Agricultural Chemicals	20	0.07	0.01	99.97
	Crude Petroleum	6	0.02	0.00	99.99
	Other	2	0.01	0.00	100.00
Total		30807	100.00	11.38	
UPPER OHIO	Electric Coal	25443	78.47	9.40	78.47
	Coal and Coke	2299	7.09	0.85	85.57
	Construction	1572	4.85	0.58	90.41

	Petroleum Products	976	3.01	0.36	93.43
	Metals	849	2.62	0.31	96.04
	Crude Petroleum	511	1.58	0.19	97.62
	Non-Metallic Minerals	455	1.40	0.17	99.02
	Industrial Chemicals	203	0.62	0.07	99.65
	Farm Products	94	0.29	0.03	99.94
	Other	9	0.03	0.00	99.96
	Agricultural Chemicals	7	0.02	0.00	99.99
	Electric Lime/Limestone	5	0.01	0.00	100.00
	Forest Products	0	0.00	0.00	100.00
Total		32422	100.00	11.98	

In summary, tonnages have increased about million tons since 1985. Most of the growth occurred from 1985 to 1994 with modest and stable growth since the mid-1990s. There are a large number of commodities that were aggregated into major commodity groups. Of these groups, coal movements for electricity plants dominate the ORS, accounting for 47 percent of all commodities. Construction (aggregates) account for about 18 percent, while "default" coal accounts for about 9 percent of tonnages. About 65 percent of flows both originate and terminate within the ORS. Locations along the main stem of the Ohio account for about 55 percent of termination points with the Upper, Middle, and Lower reaches accounting for 14, 27, and 14 percent of the tonnages, respectively. Other major termination reaches include locations outside of the ORS (17%) and locations within the Tennessee/Cumberland reaches (15%). Most origination points are from locations on the Ohio (49%), with significant origins from locations outside the ORS (16%) and the Tennessee/Cumberland (11%). Apart from coal, there are substantial differences across the origin reaches in terms of commodities. But, in most reaches, coal for electricity plants dominates the tonnages originated.

3. FORECASTING APPLICATIONS

In this section, the model and results are presented. First, we provide a short discussion of the theoretical underpinnings of the empirical models that are used to obtain forecasts. Next, there is a description of the time series properties and specific techniques that are used to estimate the forecasting models. Fnally, these techniques are applied to the data on river traffic flows. Appendix A provides a synopsis of the alternative forecasting techniques considered along with the advantages and disadvantages of each approach in forecasting waterway movements. In the particular application of this section, three different time-series models are examined, and the models are applied to the data described in the previous section at three different levels of aggregation. That is, there are nine different forecasting results delineated by three different models and three different levels of aggregation of the data. Recall, that there are nine regions in the data and 13 different commodity/demander groups (hereinafter, commodity group). The three aggregations are as follows: 1. Commodity totals for the entire system (Commodity Aggregates); 2. Commodity total received in each region (Commodity-Destination Aggregates); and 3. Commodity totals shipped between each region (Commodity-Destination-Origin Aggregates).

Time series analysis is conducted on each of the three data sets with each of the three forecasting models, and in each case low, medium and high forecasts are made. The forecasts are made using either an ARMA or ARIMA model, and the particular parameterization is determined using Box-Jenkins methodology.[4] The first model is a declining growth rate model with a linear deterministic trend. The second and third models are both constant growth rate models; one with a deterministic linear trend and the other with a stochastic trend. The former two models are Box-Jenkins type Autoregressive-Moving Average (ARMA) models.[5] The latter is an Autoregressive-Integrated-Moving Average (ARIMA) model. Each of the models is augmented with two additional explanatory variables that represent, in a general form, factors that cause shifts in the demand and supply curves for the commodity under consideration e.g., personal income in the receiving region and average wage levels in the supplying region.[6]

3.1 Theoretical Basis

This subsection develops a simple supply and demand model and uses it to derive the econometric models that are estimated below. This allows the bias and efficiency properties of the models to be assessed, and it provides direction as to the variables that need to be added in the model to improve the precision of the forecasts. However, the primary purpose is to illustrate how theory can be used to motivate the empirical models

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[4] Box-Jenkins techniques are well known and found in most econometrics text books. For an elementary review see Granger (1989) and also Greene (2003).

[5] ARMA is an acronym for Auto-regressive-moving-average, and ARIMA model is an acronym for Auto-Regressive-Integrated-Moving Average. These are generally written as ARIMA(p,i,q) or an ARMA(p,q), where p, i, and q are the orders of the autoregressive, integration, and moving average components. Hence, an ARMA is simply an ARIMA(p, 0, q) process.

[6] More specifically, Samuelson (1952) is the seminal article for trade between regions. Anderson and Wilson (2007) provide an example of how transportation demands may be derived.

presented later in this section. Of course, the simple model presented below can be refined to capture more complicated market behavior, but the intent is to provide the simplest model that can illustrate the connections between theory and estimation.

For each data series on traffic flows used in the estimation of the forecasting models, it is assumed there is a demand curve for the commodity of the form:

$$Q_i^d = D(P_i, X_i^d) \quad (1)$$

In this specification, i is the index over the commodities, so this is the demand curve for commodity i, P_i is the price of commodity i, and X_i^d is a set of exogenous variables that affect the demand for the commodity. Growth in these factors, as shown below, drives growth in demand.

The supply curve follows a similar specification:

$$Q_i^s = S(P_i, X_i^s) \quad (2)$$

Once again, i is the index over the commodities, and X_i^s is a set of exogenous variables that affect the supply of this good.[7]

This system has two equations, two unknowns P_i and Q_i, and the exogenous variables X_i^d and X_i^s. The equilibrium for this model, i.e. the price, P_i, where $Q_i^d = Q_i^s = Q_i$, is defined by the two reduced form equations:

$$Q_i = f(X_i^d, X_i^s) \quad (3)$$

$$P_i = g(X_i^d, X_i^s) \quad (4)$$

Thus, as usual, the reduced-form solution for the endogenous variables, price and quantity, are functions of the exogenous variables in the system.

The next step is to look at a linearized version of the reduced form solution for the quantity of the i^th^ commodity:

$$Q_i = f_0 + f_1 X_i^d + f_2 X_i^s + e_i \quad (5)$$

Now let the demand factor grow according to[8]:

---

[7] Generally, the shift variables in the supply and demand curves can be vectors of exogenous variables, but for purposes of illustration it is easiest to think of them as a single variable.

[8] For example, this variable could be income, population, or some other variable indicating the extent to which market demand trends upward over time.

$$X_i^d = a_0 + a_1 t + \widetilde{X}_i^d \quad (6)$$

Similarly, suppose the supply factor follows:

$$X_i^s = b_0 + b_1 t + \widetilde{X}_i^s \quad (7)$$

In these specifications of the processes determining the evolution of the exogenous variables in the supply and demand curves over time, the first two terms on the right-hand side -- the trend terms involving the constant and t -- capture the long-run growth in the demand and supply factors, and the terms $\widetilde{X}_i^d$ and $\widetilde{X}_i^s$ capture the short-run variation in these factors around the long-run trends.

Substituting these equations back into the solution for quantity in equation (5) gives:

$$Q_i = f_0 + f_1(a_0 + a_1 t + \widetilde{X}_i^d) + f_2(b_0 + b_1 t + \widetilde{X}_i^s)X_i^s + e_i \quad (8)$$

$$Q_i = (f_0 + f_1 a_0 + f_2 b_0) + (f_1 a_1 + f_2 b_1)t + f_1 \widetilde{X}_i^d + f_2 \widetilde{X}_i^s + e_i \quad (9)$$

Rewrite this as:

$$Q_i = g_0 + g_1 t + g_2 \widetilde{X}_i^d + g_3 \widetilde{X}_i^s + e_i \quad (10)$$

This is, essentially, the equation estimated in the empirical application when the trend is assumed to be deterministic.

This equation points to several issues with regard to estimation and forecasting. First, consider estimation of an equation that omits the x values from the model

$$Q_i = g_0 + g_1 t + \widetilde{e}_i. \quad (11)$$

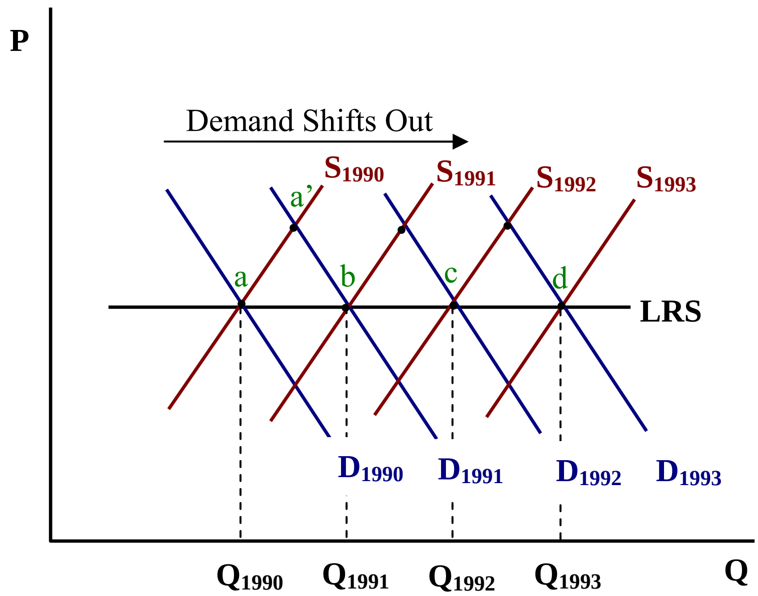
In this equation, $\widetilde{e}_i$ includes the original error plus the demand and supply factors. When this equation is estimated, the constant and trends from the supply and demand factors in the error term will be extracted by the trend terms $g_0 + g_1 t$, and this means the error term will be $g_2 \widetilde{X}_i^d + g_3 \widetilde{X}_i^s + e_i$. Since the error term is uncorrelated with the trend variable on the right-hand side of the equation, and since the trend has been extracted, estimation of equation (11) will be unbiased and consistent, but inefficient. Thus, importantly, omitting explanatory variables from the model does not bias the estimates of the coefficients g_0 and g_1.[9] More generally, then, while we include two explanatory variables to capture shifts in the supply and demand curves, if there are explanatory variables missing from

[9] For example, if the model is y = a + bt + (x+ u), where the term is parentheses is the error term in the estimated model, and x = c + dt + v, then OLS of y on a constant and on t will estimate the trend coefficient as (b+d).

the right-hand side, this affects the efficiency of the estimates, but it does not cause bias or inconsistency in the estimates of the growth rates.[10]

The model described above can also be presented graphically:

Figure 3.1: Demand and Supply Illustration



In this diagram, there is a demand curve with the arguments described above in equation (1), though they are not shown explicitly, and two supply curves, a short-run supply curve indicated by "S", and a long-run supply curve identified as "LRS".

In the diagram, the point labeled "a" represents the initial equilibrium point, which, for purposes of illustration, is assumed to be the outcome in 1990. Thus, point a is the intersection of the demand curves for 1990, the short-run supply curve for the same year, and the long-run supply curve.

Now, suppose that demand is growing at a constant rate over time so that, in the next year, 1991, demand shifts out as shown in the diagram. The market adjusts by first moving along the short-run supply curve (to the extent that the increase in demand was unanticipated), and the market will move to a'. This, in turn, leads to excess profits and an expansion of supply causing the short-run supply curve to shift as shown by the curve labeled 1991, and after the adjustment the market reaches a new equilibrium at point b.[11] As demand grows over time and this process repeats itself and the market moves from a

[10] The limited degrees of freedom due to data availability limit the number of explanatory variables that can be included in the forecasting models.
[11] Short-run fluctuations continually push the economy away from the long-run outcome, so actual data will not, of course, be precisely at points a or b.

to b to c to d, and so on. The econometric models outlined below estimate this trend rate of growth in demand over time.

3.2 Forecasting Procedures and Results

This section presents a discussion of the time series methods used to produce forecasts of river flows. The models are a declining growth rate model, and two constant growth rate models. Whether the growth rate is declining or constant depend upon whether the data are logged or not. The declining growth rate in the first model arises from the use of unlogged data, while the constant growth rate models use logged data.

The declining growth rate model is an ARMA model in levels with a deterministic trend. Estimates from this model imply a constant rate of change (equal to the estimated coefficient on the trend term), and with a growing value of X_t over time, the growth rate will fall asymptotically to zero. This is because the growth rate in will be a fixed change in X_t divided by a growing value of X_t, and this implies the growth rate in X_t, will eventually fall to zero.

The two constant growth rate models use logged data, and the models are differentiated by whether they use levels ($\ln X_t$) or differences ($\Delta \ln X_t = \ln X_t - \ln X_{t-1}$). The levels specification is an ARMA model with a deterministic trend, and the differences specification is an ARIMA model which, when converted back to levels, implies a stochastic trend In the levels specification, the growth rate is estimated directly as the coefficient on the trend term, while in the differences specification the growth rate is the estimated constant

To describe the ARMA and ARIMA models augmented with explanatory variables used to produce the forecasts, it's easiest to begin by discussing the two components of the ARMA and ARIMA models, their autoregressive (AR) and moving average (MA) parts, and then put the two pieces together to form the larger ARMA and ARIMA models. Once the ARMA and ARIMA models are presented, we then discuss the augmentation of the models through the addition of explanatory variables.

ARMA models are commonly described with two parameters p and q, and written as ARMA(p,q), where p is the order of the autoregressive part of the process and q is the order of the moving average part. The value of p is simply the number of lags of the dependent variable in the model (the AR or autoregressive component), while q is the number of lags of the error term that are included (the lagged errors are the MA or moving average component). ARIMA(p,i,q) models can be interpreted as ARMA models where the data have been differenced i times. Thus, the discussion below covers the ARIMA case; just assume the X_t term has been differenced as necessary (e.g. see the example showing how to make Y_t stationary presented below).

A. MA Models

A moving representation for the variable X_t, which can designated as an ARMA(0,q) using the notation above, can be written:

$$X_t = c + u_t + \rho_1 u_{t-1} + \rho_2 u_{t-2} + ...\rho_q u_{t-q} \qquad (12)$$

In this model, the error term is assumed to follow a qth order process.[12]

The variable X_t must be stationary, and this motivates the use of either levels data with an assumed determistic trend, or differenced data (which implies a stochastic trend).[13] . That is, one way to make the data on X_t stationary is to difference the data. Thus, if Y_t is the non-stationary variable, stationarity can generally be achieved by differencing the data once (occasionally two differences are needed to make economic data stationary):

$$X_t = \Delta Y_t \qquad (13)$$

Differencing the data removes the stochastic trend from the data series.[14]

Another means of achieving stationarity is to detrend the data, i.e. to transform the data according to:

$$X_t = Y_t - c_1 - c_2 t \qquad (14)$$

where the $c_1 + c_2 t$ term is the trend that is being removed from Y_t.

B. AR Models

A pth order autoregressive representation of the model i.e. an ARMA(p,0), is:

$$X_t = c + a_1 X_{t-1} + a_2 X_{t-2} + ... + a_p X_{t-p} + u_t \qquad (15)$$

---

[12] As explained below, when the model is a estimated, p and q, the order of the lags, are determined by the Schwartz Information Criterion (SIC). For more on the SIC, see Greene, William H., *Econometric Analysis*, 4th ed., pgs 306 and 717.

[13] The weak form of stationarity says, in essence, that the mean, variance, and autocovariances of the variable are independent of the point in time at which they are measured. The strong form requires all moments to be independent of time. For example, a variable that trends upward/downward is not stationary because the mean of the variable increases/decreases over time.

[14] To explain a stochastic trend, suppose that $x_t = a + x_{t-1} + u_t$. With a little bit of algebra, this can be written as $x_t = x_0 + at + \sum_{j=1}^{t} u_j$, where $x_0 + at$ is the stochastic or random trend component (x_0 is a random variable). To see that differencing removes the trend, note that he difference in x_t is $\Delta x_t = a + u_t$.

Again, the data must be stationary. As before, the trend can be removed be differencing the data if the trend is stochastic, or it can be removed by subtracting off a time trend in the deterministic trend case.

C. ARMA Models

The two models shown in equations (12 and (15) can be combined into an ARMA(p,q) model:

$$X_t = c + a_1 X_{t-1} + ... + a_p X_{t-p} + \rho_1 u_{t-1} + ... + \rho_q u_{t-q} + u_t \quad (16)$$

More explicitly, three versions of this model are estimated. Two of these are unlogged and logged data (levels and log levels) with a trend included. These are the declining growth rate model and the constant growth deterministic trend model. The third model we use is a constant growth model (logged data) with an implied stochastic trend i.e., the data are differenced to achieve stationarity.[15] The stochastic trend version of the models can be denoted as ARIMA(p,1,q) and are written as:

$$\Delta Y_t = c + a_1 \Delta Y_{t-1} + ... + a_p \Delta Y_{t-p} + \rho_1 u_{t-1} + ... + \rho_q u_{t-q} + u_t \quad (17)$$

while the deterministic trend version can be denoted as ARMA(p,q) and written as:

$$Y_t = c_1 + c_2 t + a_1 Y_{t-1} + ... + a_p Y_{t-p} + \rho_1 u_{t-1} + ... + \rho_q u_{t-q} + u_t \quad (18)$$

These represent, generally, the models that are estimated by Box-Jenkins methodology described below.

Finally, as described above, both of these models are augmented be adding shift variables for supply and demand. In the differences model, i.e. the stochastic trend model, the X values are also differenced:

$$\Delta Y_t = c_0 + c_1 \Delta X_i^d + c_2 \Delta X_i^s + a_1 \Delta Y_{t-1} + ... + a_p \Delta Y_{t-p} + \rho_1 u_{t-1} + ... + \rho_q u_{t-q} + u_t \quad (19)$$

In the deterministic trend version, the additional explanatory variables $\widetilde{X}_i^d$ and $\widetilde{X}_i^s$ are detrended as above, i.e. $\widetilde{X}_i^d = X_i^d - (a_0 + a_1 t)$ and $\widetilde{X}_i^s = X_i^s - (b_0 + b_1 t)$:

$$Y_t = c_1 + c_2 t + c_3 \widetilde{X}_i^d + c_4 \widetilde{X}_i^s + a_1 Y_{t-1} + ... + a_p Y_{t-p} + \rho_1 u_{t-1} + ... + \rho_q u_{t-q} + u_t \quad (20)$$

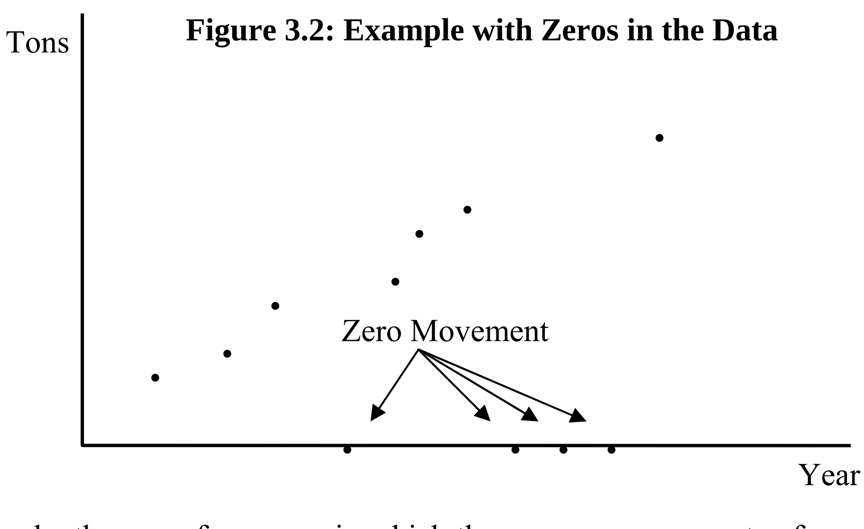
[15] It would also be possible to estimate a model where the unlogged data are differenced which would also yield a declining growth rate, but this specification is rare partly because simple differencing unlogged economic data does not achieve stationarity (because with a constant growth rate, as occurs with most economic time series, the differences increase over time).

These models are estimated by Box-Jenkins,[16] and the resulting models are used to produce forecasts. Again, there are two deterministic trend models estimated, one with the variables in levels (declining growth) and one with the variables in log levels (constant growth). There is also one stochastic trend model, which is specified with the variables in log differences (constant growth).

Before turning to the forecasts, there are two more issues to be discussed. The first is a specification issue, the choice of the parameters p and q for the ARMA(p,q) models. Because of the large number of variables to be forecast - there are hundreds of variables - and because we allow for 18 different models for each variable - from an ARMA(0,0) up to an ARMA(2,2) for both difference (stochasatic trend) and levels (deterministic trend in levels and in logs) specifications - it was necessary to automate this procedure. Examining each case manually would not have been possible in a reasonable amount of time. Thus, for each of the levels and differences specifications, the procedure adopted is to have the statistical program used to generate the forecasts select the variables to be forecast one by one, and then loop over and estimate the nine possible ARMA models. The next step is to look across the nine estimated models where the procedure converges, and select the best fitting model according to the Schwarz Information Criterion (SIC). This is the model used to generate the forecasts.[17]

The second issue is how to handle zeros in the data. Many of the series, particularly in the more disaggregated data, had years for which there was no movement of the commodity on the river at all interspersed with observations where the values were non-zero. For example, a series for tons moved for a hypothetical commodity might look like:

Figure 3.2: Example with Zeros in the Data



In this example, there are four years in which there are no movements of commodities at all, and other years where the movements are present. In addition, in the years where

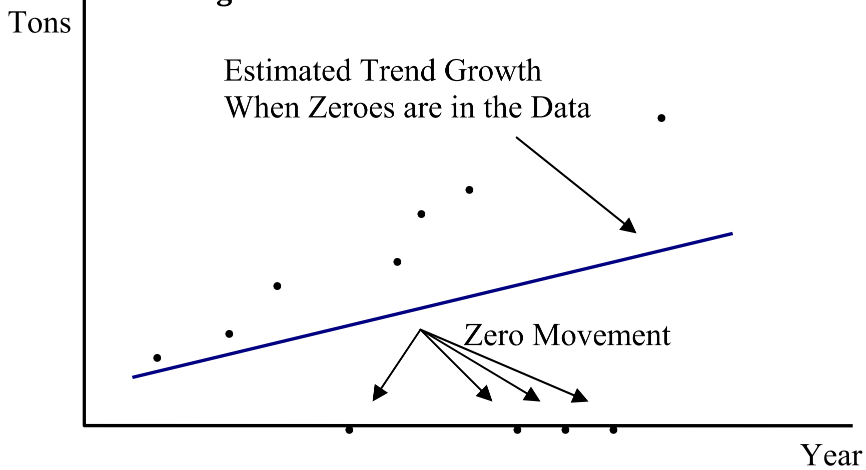
[16] A general description of the Box-Jenkins technique is in Appendix A.

[17] Using the Akaike Information Criterion instead makes little difference. Also, if none of the models converge during the estimation step, which occurs in a few cases, an ARMA(0,0) is selected.

there are movements, the movement reflects growth over and above the amount that moved that last time there was a non-zero observation, i.e. there is an underlying trend rate of growth in the commodity shipments.

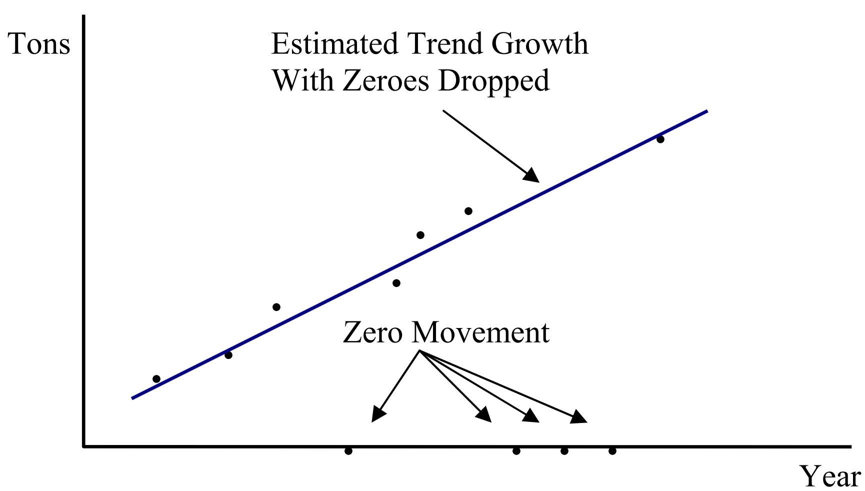
Now, if a trend is fitted to these data without taking account of the zero values, it will understate the true rate of growth:

Figure 3.3: Biased Estimates with Zeros Included



However, if the zeroes are dropped while preserving the distance relationships on the x-axis, then the underlying trend in the growth rate can be estimated without bias:

Figure 3.4: Unbiased Estimates with Zeros Excluded



This is the procedure adopted in the paper. When there are non-zero values in the data, these observations are eliminated, but the data are not collapsed. That is, if the trend values are 8, 9, and 10 for movements in time periods 8, 9, and 10, and the observation in period 9 has a zero value, this value is eliminated leaving the values for periods 8 and 10. In addition, and importantly, the trend values remain at 8 and 10.

3.3 Forecasting Specification

The left-hand side variable in each ARMA or ARIMA model, tons, i.e. the variable to be forecast, has been described in detail above. However, the variables that are included to capture supply and demand shocks have not yet been described.

The first variable used to augment the ARMA model is personal income.[18] This variable is included to capture changes in demand driven by growth in income, the major source of demand growth over time. The second variable is the average wage. This variable is included to pick up shifts in the supply of the product shipped due to changes in input costs as measured by wages, which is by far the largest component of the costs of production. The first variable, the demand component, is taken from the destination, and the second variable is taken from the origin of the commodity flows. That is, it is assumed that the origin is the supplier, and destination is the demander. These two components together fuel the demand for transportation.

Both of these variables are nominal. To obtain real values for each of the two series, they are deflated by the index of personal consumption expenditures minus food and energy.[19] Finally, in the declining growth rate model (tons in levels and a linear deterministic trend), the added right hand side variables are in levels. In the constant growth rate models, (tons in logs and either a deterministic or stochastic trend), the added right hand side variables are in logs.

There are a total of nine sets of results using the three models and three different levels of data aggregation. A complete set of results for each combination are provided in the appendices as follows:[20]

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[18] There are three different levels of aggregation in the data. The choice of personal income and average wages mirror the level of aggregation. Specifically, for the system aggregates, it is the total personal income of the BEA regions comprising the ORS and the non-ORS average wages. For the destination-commodity aggregates, it is the personal income of the regions receiving the commodities shipped and the average wage excluding that region. Finally, for the origin-destination-commodity aggregates, it is the personal income of the receiving region, and the average wage of the originating region. There are a number of different variables available from the Bureau of Economic Analysis. Most of these are highly correlated with each other.

[19] Using the CPI less food and energy rather than the PCE less food and energy makes little difference. Using the total values of the PCE rather than the value stripped of volatile food and energy prices adds noise to the model and makes the underlying trend rate of growth - the goal of the estimation - harder to discern.

[20] Note should be taken that a semi-log specification is used. Since the model is log-linear i.e., of the form $\ln y_t = \alpha_1 + \alpha_2 t + b_1 x_1 + b_2 x_2 + u_t$, some care must be taken in recovering the forecasts for the level of the left-hand side variable, y_t (i.e. the unlogged value). To see this, note that $e^{\ln Y_t} = e^{(\alpha_1 + \alpha_2 t + b_1 x_1 + b_2 x_2 + u_t)} = e^{\alpha_1} e^{\alpha_2 t} e^{\beta_1 x_1} e^{\beta_2 x_2} e^{u_t}$ Take the expected value of this equation, and use the result that $E(e^{u_t}) = e^{\sigma^2/2}$ when the residual is normally distributed to get

	Declining Growth	Constant Growth Deterministic trend	Constant Growth Stochastic Trend
System-Commodity	C	D	E
Destination-Commodity	F	G	H
Origin-Destination Commodity	I	J	K

Before the results are summarized in the next subsection, there are a few final notes. First, the right hand side variables included in the models are either differenced or detrended. This allows the series to be broken up into two estimated components, the trend and deviations from the trend. However, this is only possible within sample, out of sample only the trend component can be estimated, finding deviations from the trend requires that the actual values be known This means that forecasts within sample can be informed by deviations of the right-hand side variables from their long-run trends, but out of sample forecasts must rely solely upon the estimated trend.

Figure 3.4 illustrates. The black line shows the actual data,[21] the blue line shows the in-sample and out of sample forecasts, and the green and red lines show the upper and lower one standard deviation bounds on the estimated trend. The bounds begin at the first year of the out of sample forecasts. In this specific case, the black and blue line correlate quite well, and it is clear that the right hand side variables, i.e. the deviations of the these variables from trend, are helping to explain the in-sample tonnage levels. For this reason, in the appendices the forecasted values include only the trend component and are therefore a straight line.

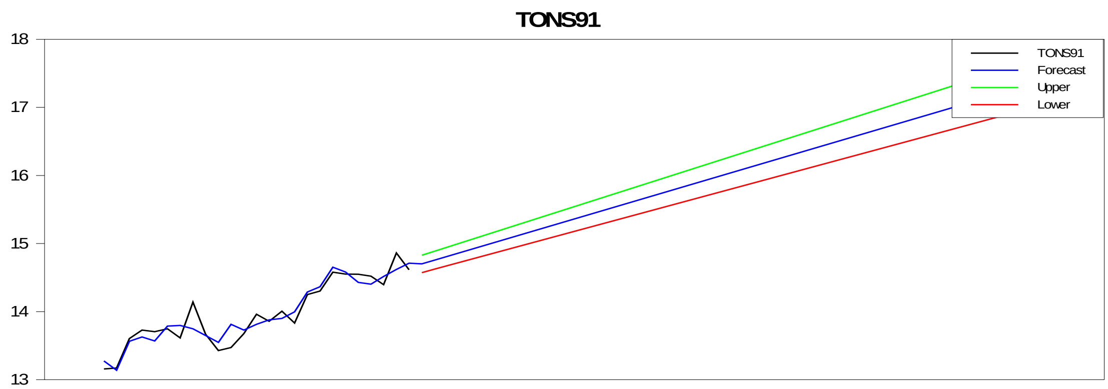
Second, the growth rates can be obtained from the stimated parameters within each model. In the case of the declining growth rate model, the annual change in the medium forecast is the coefficient estimate on the trend. In the case of the constant growth rate models, the medium growth rates listed in the tables is the estimate of the constant for the log differenced model, and the coefficient on the trend term for the model in log levels.

Third, we capture uncertainty in the estimates by presenting high and low forecasts that represent one standard deviation variation in the estimated slope.

$E(e^{\ln Y_t}) = e^{\alpha_1} e^{\alpha_2 t} e^{\beta_1 x_1} e^{\beta_2 x_2} e^{\sigma^2/2}$. To make this operational, $\hat{\sigma}^2$ can be used as an estimate of σ^2 in the procedure used to uncover tonnage forecasts. These will be provided electronically to ACE.

[21] The graphs do not show the observations for years in which the flows were zero.

Figure 3.4: Estimated Growth Rate Illustration



3.4 A Brief Summary of the Estimated Growth Rates

All forecasted values for each time series model and for each market are provided in the appendices. The time series techniques are: 1. Declining Growth-Deterministic Trend (DG-DT); 2. Constant Growth-Deterministic Trend (CG-DT); and 3. Constant Growth-Stochastic Trend (CD-ST). The three data sets are: 1. System Aggregates by Commodity (C); 2. Aggregates by destination reach by commodity (D-C); and 3. Aggregates by origin and destination reach (O-D-C). For the System-Commodity aggregates, there are 13 series and 3 estimation procedures for a total of 39 different forecasts; For the destination reach-commodity aggregates, there are 117 possible flows (9 regions*13 commodities=117 possible flows), but over the time period of available data, flows occur in 109 of the possible markets, and there is enough data (15 or more years of observed flows) in 92 of the possible 117 flows. Given the 3 different time series models, there are 3*92=276 forecasts. Finally, for the origin-destination-commodity aggregates, there are 9 regions and 13 commodities that yield 1053 possible flows to forecast. However, over the entire range of the data set, there are 671 flows that occur, and 333 that have 15 or more years of data. This gives 3*333=999 different forecasts. In total, there are 39+276+999 = 1314 different forecasts.

In this section, the results are first described across estimation procedures. The description is made in terms of weighted averages of growth rates. While there are many alternative weights that could be used, we use the 2006 tonnages.[22] We then describe the results in terms of levels of aggregation, and across commodities, destination reach and origin reach. In so doing, the "best" forecast is chosen in terms of average forecast error. This has the effect of removing the influence of outliers.

[22] Generally, the forecasted values should be used at each point in time. However, the forecasts vary across time series model and through time. Further, a feature of the declining growth model is that the annual change is constant and, as such the growth rate converges to zero. In contrast, in the constant growth rate model, forecasted values (for positive growth) are exponentially growing and, as such, longer periods and "large growth" rates lead to unreasonably large forecasted values. To avoid this issue, the weights are held fixed at 2006 tonnage values.

Table 3.1 contains average growth rates by time series model for the entire system and by various levels of aggregation. Generally, system growth rates are smaller given the same time series model as the level of aggregation increases. Second, the declining growth model tends to give lower growth rates regardless of the level of aggregation. However, it is also clear that there are substantial differences in the system growth rates. These growth rates have a range from -0.128 to 4.688, depending on the time series model and the level of aggregation.

Also included in table 3.1 are estimates by commodity, destination reach, and origin reach. In seven of the thirteen commodity groups, the estimated growth rates are positive *regardless of time series model and data aggregation*, while in other cases they are both positive and negative. It is noteworthy, that in some cases, e.g., Farm Products, the growth rates (given the level of data aggregation) are very comparable in magnitude. However, there are also a number of differences with the level of data aggregation. This is dealt with below. Similar patterns are observed for the destination reach aggregations. Given the time series model, the Big Sandy and Green Rivers are the "high growth" markets. The Monongahela/Allegheny and Other tend to be low growth (or negative) growth reaches. But, as with the commodity aggregations, there are substantial differences across data aggregations, and in some cases, across specifications. Finally, in the case of Origin-Destination-Commodity aggregations, growth rates by source of origin can be made as well. In this case, the declining growth models give lower growth rates than the constant growth rate models *in all cases*. And, in most cases, the constant growth stochastic trend models give higher growth rates than the constant growth deterministic trend model. It is noteworthy, that in all cases, the growth rates are positive. The largest growth rates are for the Tennessee/Cumberland, the Upper Ohio, and the Green and Big Sandy Rivers, while the lowest are for the Monongahela/Allegheny and Lower Ohio.

Generally, estimates across the estimation procedures are positively correlated with correlation coefficients in excess of .55 for the commodity aggregates, .85 for the destination-commodity aggregates, and .4 for the origin-destination-commodity aggregates.[23] This along with casual inspection suggests that within the data set, the results are generally consistent. While generally consistent, there are, however, some considerable differences across the results. And, of course, there is no reason that any of the models should give the same results. In particular, there are three different time series models, and because the models embed different maintained hypotheses about growth rates, not all of which will be consistent with the actual data (e.g. growth rates that are declining are inconsistent with a constant growth rate model) they can generate different results. To distinguish these results and choose the best fitting model, we examine each of the time series models with a simple calculation of average forecast error. The model with the lowest average forecast error was deemed the "best" forecast, and the aggregations conducted above were recalculated only for the "best" forecast. The results are in Appendix L.

[23] On this latter, the correlation coefficients are .7984 (DG-DT, CG-DT), .7068 (CG-DT, CG-ST) and .4038 (DG-DT, CG-ST).

In table L-1 in Appendix L, there are 438 different forecasts formed (13+92+333=438) for which there are three different possible time series models (DG-DT, CG-DT, and CG-ST). The average forecast error associated with each time series model is presented. The "best" in terms of lowest forecast error is shaded. The growth rate, 2006 tonnage and the weighted (share * growth) are also provided. The later is particularly useful in identifying major contributors/detractors from system growth.

Cursory inspection of the forecast error suggests that there is a wide range across time series models. That is, not all models fit the data equally well and, in some cases, it is important to identify the "best" model. In the case of the commodity system aggregates, there are 13 markets. The DG-DT, CG-DT, and CG-ST models dominated in 8, 3, and 2 markets, respectively. In the case of destination-commodity aggregates, there are 92 markets. The DG-DT, CG-DT, and CG-ST models dominated in 40, 50, and 2 markets, respectively. Finally, in the case of the origin-destination-commodity aggregates, there are 333 markets. The DG-DT, CG-DT, and CG-ST models dominated in 111, 144, and 78 markets, respectively.

In each market, the "best" forecast is chosen according to the minimum average forecast error. The growth rate attached to the best along with the 2006 tonnage share in the market is used to estimate the system growth. The commodity aggregates yield a .615 percent growth rate; the destination-commodity aggregates yield a 1.65 percent growth rate; and the origin-destination-commodity aggregate forecasts yield a 3.27 annual growth rate. The weighted growth column provides the contribution of each series to the system total. In the case of Commodity system aggregates, Electric Coal and Construction are the primary contributors to the .615 growth rate. Electric coal accounts for .41 of the .615, while construction accounts for .25 of the .615. In the case of destination reach-commodity aggregates, the primary contributors are electric coal on the Middle and Upper Ohio, contributing .45 and .19 of the total 1.65 system growth rate. Finally, in the case of the Origin-Destination-Commodity aggregates, the top 10 O-D-C triples account for over ½ of the 3.27 system growth rate. Of those, 8 of the 10 are electric coal movements, a finding that reinforces and is, indeed, consistent with the fact that electric coal dominates the river.

Table 3.2 provides estimates by commodity, destination and origin reach. In terms of commodities, there are three different sets of results that can be used. The different estimates are positively correlated, although there are also some differences across the level of data aggregation. In 9 of the 13 markets, the estimated growth rates are uniformly positive. This finding suggests that in these 9 markets, growth is increasing. These include Agricultural Chemicals, Construction, Electric Coal, Electric Lime/Limestone, Farm Products, Forest Products, Industrial Chemicals, Metals, and non-metallic minerals. The Crude Petroleum market is uniformly decreasing, while Default Coal and Coke, Other, and Petroleum Products are mixed. In some cases, the estimates across datasets are very comparable e.g., Farm Products, while in other cases there are marked differences e.g., Forest Products.

The results by destination point to growth to all regions, with growth rates that range from .035 to 15.132 percent per year. With very few exceptions, there is considerable similarity across the data aggregations. The results point to the Big Sandy and the Green River as being markets with substantial growth. The Ohio River (all reaches) has positive growth in excess of 1 percent per year. Finally, the most disaggregated data also allows for growth rates by originating reach. The results point to growth in all areas. The largest growth is for the Green River and the smallest for the Monongahela/Allegheny. The three reaches on the Ohio (Upper, Middle and Lower) have growth rates of 5.047, 2.519, and 1.902, respectively.

Table 3.1—Time Series Model Alternatives									
	Commodity			**Destination-Commodity**			**Origin-Destination-Commodity**		
	DG-DT	**CG-DT**	**CT-ST**	**DG-DT**	**CG-DT**	**CG-ST**	**DG-DT**	**CG-DT**	**CG-ST**
System	0.873	-0.128	1.606	1.034	2.296	2.468	1.132	2.985	4.688
Commodity									
Agricultural Chemicals	0.391	0.415	0.572	0.380	0.891	0.732	0.046	2.795	2.727
Coal and Coke	0.000	-2.971	-1.239	0.373	-1.487	1.463	0.551	-1.468	3.022
Construction	1.375	-5.857	1.833	1.347	3.218	2.405	1.323	2.916	3.396
Crude Petroleum	-1.113	-2.630	2.334	-0.148	-7.993	-2.034	-1.020	-1.143	12.088
Electric Coal	0.878	1.437	1.561	1.121	2.379	2.411	1.141	3.772	6.021
Electric Lime/Limestone	1.997	7.713	6.209	1.389	-1.982	2.999	1.408	3.913	1.977
Farm Products	0.594	0.839	0.960	0.610	0.884	1.494	0.723	0.920	1.348
Forest Products	0.757	0.331	2.733	2.295	11.249	16.621	2.403	8.562	19.080
Industrial Chemicals	0.454	0.526	0.756	0.618	0.863	1.165	0.731	1.487	2.054
Metals	1.760	4.504	6.738	1.693	5.299	5.996	1.663	6.202	5.998
Non-Metallic Minerals	0.927	1.476	1.139	1.459	3.452	3.305	1.489	5.222	5.475
Other	0.000	-4.530	1.819	-0.013	-7.261	-0.807	0.998	0.494	-0.079
Petroleum Products	-0.192	-0.176	-0.350	-0.163	0.461	0.904	1.268	0.635	2.725
Destination Reach									
BIG SANDY				2.097	14.601	15.323	5.273	14.198	10.204
GREEN RIVER				2.223	17.268	15.357	2.306	15.819	26.444
KANAWHA				0.843	3.050	2.398	1.116	4.802	3.130
LOWER OHIO				1.040	2.786	2.970	1.075	2.837	3.927
MIDDLE OHIO				1.344	2.754	3.071	1.444	3.967	7.867
MONONGAHELA/ALLEGHENY				0.098	-1.859	-0.117	0.508	0.628	1.023

OTHER				0.852	0.210	1.564	0.829	-0.436	2.848

Table 3.1-Continued

	Commodity			**Destination-Commodity**			**Origin-Destination-Commodity**		
	DG-DT	CG-DT	CT-ST	DG-DT	CG-DT	CG-ST	DG-DT	CG-DT	CG-ST
TENNESSEE/CUMBERLAND				1.228	1.936	1.193	1.362	4.469	3.480
UPPER OHIO				0.731	1.557	1.721	0.729	2.858	2.548
Origin Reach									
BIG SANDY							1.423	4.119	8.882
GREEN RIVER							1.110	3.828	12.436
KANAWHA							0.699	2.787	3.108
LOWER OHIO							1.050	1.422	3.054
MIDDLE OHIO							0.693	2.397	1.179
MONONGAHELA/ALLEGHENY							0.094	2.411	0.872
OTHER							1.560	3.444	9.046
TENNESSEE/CUMBERLAND							1.584	3.380	4.139
UPPER OHIO							1.517	5.464	6.161

Table 3.2—Forecasted Growth Rates by Data Aggregation

	System	Destination	Origin-Destination
Agricultural Chemicals	0.391	0.928	1.696
Coal and Coke	-2.971	0.024	0.033
Construction	1.375	1.347	1.879
Crude Petroleum	-2.630	-7.333	-1.870
Electric Coal	0.878	1.873	4.403
Electric Lime/Limestone	1.997	1.704	6.193
Farm Products	0.594	0.584	0.611
Forest Products	0.757	8.863	8.225
Industrial Chemicals	0.454	0.880	1.253
Metals	1.760	4.606	5.556
Non-Metallic Minerals	1.476	2.378	3.771
Other	1.819	-0.144	0.882
Petroleum Products	-0.350	0.734	3.415
Destinations			
BIG SANDY		15.132	15.099
GREEN RIVER		2.328	28.447
KANAWHA		2.920	1.160
LOWER OHIO		1.224	2.472
MIDDLE OHIO		2.834	3.630
MONONGAHELA/ALLEGHENY		0.180	1.147
OTHER		0.035	0.399
TENNESSEE/CUMBERLAND		1.341	4.739
UPPER OHIO		1.610	3.266
Origins			
BIG SANDY			4.858
GREEN RIVER			12.428
KANAWHA			2.926
LOWER OHIO			1.902
MIDDLE OHIO			2.519
MONONGAHELA/ALLEGHENY			1.449
OTHER			3.694
TENNESSEE/CUMBERLAND			3.113
UPPER OHIO			5.047

4. SUMMARY

This report documents a summary of ORS traffic and a time series analysis of river movements. To this end, commodities were grouped into 13 different demand groups. The groupings were defined in concert with ACE and reflect commodity and end-use. In particular, 11 commodity groups were defined along with locations that receive primarily coal, coke, lime and limestone for electricity generation.

Waterborne Commerce data are the primary data employed in estimation. The data were provided by ACE in two separate files with different units of record. The early data consisted of four digit commodity and location codes from 1980-1989. The latter data consisted of five digit commodity and dock codes. These data were combined by location code and four digit commodity codes. Due to underreporting, the 1980-4 data were discarded, further due to a commodity reclassification, some of the results are based on 1985-2006 data while others on 1990-2006. There were three levels of aggregation including 13 different commodities and 9 different regions. Both the commodity and the regional aggregations were determined in concert with ACE. These different regions may have different supply and demand characteristics and tonnage movements. Section 2 provides an in depth summary of movements to and from each of the regions.

Section 3 provides a description of the time series techniques used to generate the forecasts. There are nine different sets of forecasts provided in the appendices. These include three different time series models (declining growth-deterministic trend, constant growth-deterministic trend, and constant growth-stochastic trend) that are applied to three different levels of commodity aggregation (commodity-system, destination reach-commodity, and origin reach-destination reach-commodity). In the former, there are 13 different markets forecasted (one for each commodity group), in the second, there are 92 different markets forecasted of 117 possible, and in the last there are 333 markets forecasted out of 1053 total possible markets. Markets are excluded because in some instance there are no flows over the entire time period or because there were fewer than 15 years of data, but in all cases all or almost all traffic is accounted in for in the remaining observations (100%, over 99% and over 97%). In total there are 13+92+333=438 different forecasts formed, and there were three different time series models used on each (438*3=1314). Further, for each forecast formed, each different time series model was specified with Box-Jenkins techniques, whereupon 9 different pairings of autoregressive and moving average representations were compared.

The results were inspected across the different estimation techniques and data. While differences do occur, this is expected given the multiplicity of techniques and data alternatives as well as the sheer number of forecasts made. Nevertheless, the correlations between the growth rates are positive and statistically important at conventional levels.

The forecasts are consistent with an underlying supply and demand model for the product transported, and the estimated model captures supply and demand shifts and growth by including personal income in the receiving region and average wage in the supply region as explanatory variables. There are, of course, a wide range of variables that could have been used instead. Some alternatives were considered e.g., total and sectoral employment, but generally, as is common, the alternatives were either extremely correlated with those used or the alternatives did not have complete data through time.

A summary of growth rates is provided in section 3.4, and all growth rates are provided in the various appendices. System level aggregates yield a growth rate of .615, destination-commodity aggregates yield a growth rate of 1.65, and origin-destination aggregates yield a system growth rate of 3.27. While there are important differences across commodity groups as well as origin and destination regions, the bulk of the growth is fueled by growth in the electricity market. Electricity movements of coal account for nearly one-half of all movements, and fuel much of the growth in the markets.

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APPENDICES

Upper Ohio Navigation Study Pennsylvania
Draft Feasibility Report

Appendix B - Project Economics

Attachment 3

TRAFFIC DEMAND FORECASTS

ATTACHMENT 3. TRAFFIC DEMAND FORECASTS

TABLES

FIGURES

ADDENDA

Executive Summary

The traffic demand forecasts presented herein represent a comprehensive update of the Ohio River System traffic demand forecasts completed in 2003. New forecasts were prepared for all commodity groups under three forecast scenarios. Because of the dominance of utility steam coal on the system and the uncertainties surrounding the environmental regulatory future, greater attention was devoted to the development of the coal traffic forecasts, in particular for utility steam coal.

The traffic demand forecasts for the ORS are generally divided between coal and noncoal commodities. Coal, in this instance, includes all categories of coal and coke, meaning utility steam coal, coking coal, industrial coal, export coal and petroleum coke. Additionally, sorbent materials forecasts, which refers to the lime and limestone used in coal desulfurization, were developed in conjunction with the utility steam coal forecasts, since the usage of sorbent materials is associated with levels of coal consumption. All remaining commodities are categorized as noncoal and are forecast separately.

In order to deal with a broad range of issues affecting electricity generation, particularly the environmental issues, the current forecasting effort makes use of a linear programming approach through the use of the Greenmont Energy Model (GEM). The GEM is a detailed model of the electric utility and coal industries. For every year in the forecast horizon the model determines the least-cost means to produce required generation in a market context and within existing and expected future environmental constraints. In this process, the model determines coal consumption and coal sourcing for every coal-fired power plant in the country. The coal sourcing determined in the modeling process is key to estimating coal flows to waterside electric generating facilities. Other categories of coal consumption, specifically coking, industrial and export coal are forecast separately and future traffic is determined by indexing existing waterborne flows. Sorbent materials flows are forecast based on coal consumption and sourcing at waterside utility plants.

The forecast of the remaining or so-called “noncoal” commodities was generated using statistical time series techniques. For the purposes of this forecasting effort, the annual ORS dock-to-dock traffic data contained in the Waterborne Commerce Statistics (WCSC) was used. Data for the 26-year period 1980-2006 were made available for this analysis. As a part of the analysis, the data were grouped into 13 distinct commodity groupings based on common supply and demand characteristics.

The traffic demand forecasts for the EDM reach as well as Emsworth, Dashields and Montgomery locks are summarized in the following table. It should be noted that the terms High, Base and Low generally describe the rank ordering of the forecasts at the system (ORS) level. At the individual lock level, because of coal switching and interactions that arise in different scenarios, the rank ordering of the forecasts is not necessarily the same as at the system level in any given year. For the Upper Ohio reach, the range in the forecasts for 2030 is between 29.0 million tons in the Base Case scenario and 42.1 million tons in the High Case. By 2070, the range is between 30.3 million tons in the Base Case and 72.4 million in the High Case. Annual growth rates for the 2006-2070 period range between 0.32 and 1.69 percent.

Given the level of commonality of traffic among the Emsworth, Dashields and Montgomery locks, the forecast patterns for the individual locks is largely similar to that of the Upper Ohio reach. It should be noted that historic traffic trends at the Upper Ohio projects are essentially flat, while the forecasts call for some level of mid-term growth (relative to the base year) in every forecast scenario. This is supported, in part, by DOE's outlook for Northern Appalachian coal production.

Traffic Demand Forecasts for the EDM Reach and Emsworth, Dashields and Montgomery Locks, 2006-2070 (Million Tons)

	EDM Reach			Emsworth			Dashields			Montgomery		
	High	Base	Low	High	Base	Low	High	Base	Low	High	Base	Low
Actual												
1980	NA	NA	NA	20.0	20.0	20.0	21.0	21.0	21.0	20.4	20.4	20.4
2006	24.8	24.8	24.8	20.6	20.6	20.6	20.7	20.7	20.7	20.4	20.4	20.4
Projected												
2010	29.4	27.5	27.7	24.4	22.7	22.9	24.9	23.2	23.4	25.8	24.1	24.3
2020	32.1	32.0	34.1	25.6	24.6	26.8	26.3	25.2	27.4	28.1	28.1	30.5
2030	42.1	29.0	38.5	34.9	22.1	30.1	35.6	22.9	30.7	37.9	24.8	34.7
2040	54.8	39.5	36.3	45.2	31.2	27.3	46.0	32.0	28.1	50.2	34.9	32.0
2050	57.8	36.9	33.9	47.5	29.3	23.8	48.4	30.1	24.6	52.7	32.1	29.2
2060	54.7	38.3	32.2	43.3	29.9	22.5	44.4	30.9	23.4	49.3	33.1	27.1
2070	72.4	30.3	31.0	60.7	21.9	21.2	61.8	23.0	22.2	66.6	24.7	25.6
Annual Growth												
1980-06	-	-	-	0.11	0.11	0.11	-0.06	-0.06	-0.06	0.00	0.00	0.00
2006-70	1.69	0.32	0.35	1.70	0.10	0.05	1.72	0.16	0.11	1.86	0.30	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center for Expertise in Inland Navigation.

ATTACHMENT 3. TRAFFIC DEMAND FORECASTS

3.1 INTRODUCTION

This attachment describes the methodologies employed and the results attained in developing the waterway traffic demand forecasts used in the current analysis. Waterway traffic demand forecasts are a necessary input to navigation system modeling. The forecasts, which are developed at the overall system (ORS) level, help guide and justify waterway system investments. They do this first, by assisting in the identification of future congestion points in the system and secondly, by enabling a means of calculating the transportation costs associated with this congestion through system modeling.

The traffic demand forecasts presented here represent a comprehensive update of previous forecasts completed in the spring of 2003. The forecasts were prepared from the perspective of the entire ORS, of which the EDM reach is an important subcomponent. New forecasts were prepared for all commodity groups for three forecast scenarios. Because of the dominance of utility steam coal on the system and the uncertainties surrounding the regulatory future, greater attention was devoted to the development of the coal traffic forecasts, in particular for utility steam coal. The current round of adjustments to the utility coal forecasts was necessitated by existing and likely future regulatory changes affecting the electric utility industry. Environmental issues are acknowledged by industry experts to be the dominant issues expected to affect future coal utilization and sourcing on the part of the electric utilities. In light of this, the alternative forecast scenarios reflect alternative legislative/regulatory approaches to emissions reductions. These scenarios are discussed in subsequent sections of this attachment.

The traffic demand forecasts for the ORS are generally divided between coal and noncoal commodities. Coal, in this instance, includes all categories of coal and coke, meaning utility steam coal, coking coal, industrial coal and export coal. Additionally, sorbent materials forecasts, which refers to the lime and limestone used in coal desulfurization, were developed in conjunction with the utility steam coal forecasts, since the usage of sorbent materials is associated with levels of coal consumption. All remaining commodities are categorized as noncoal and are forecast separately.

The forecasting approaches used to generate the coal and noncoal forecasts are substantially different. The coal forecasts are based on the output of a detailed proprietary linear program, the Greenmont Energy Model (GEM). The GEM, which is discussed in greater detail in subsequent paragraphs, is a detailed model of the electric utility and coal industries that determines, in essence, the least cost combinations of inputs (or the least cost strategies) for meeting given levels of national and regional electricity demands within a set of environmental and other constraints. For coal-fired powerplants, the model determines coal consumption and coal sourcing down to the electric unit level of detail. The noncoal forecasts (which are discussed in greater detail below) were developed from a detailed statistical analysis of the Waterborne Commerce dock-to-dock commodity flows. Twenty-six years of data (1980-2006) were made available for the purpose of this forecasting effort.

The traffic demand forecasts presented herein are unconstrained forecasts, meaning that they were developed without regard to capacity limitations of the waterway. The forecasts are developed at the system level, which of course includes the EDM projects, and represent traffic that could potentially use the waterway at a rate savings. It is left to navigation system modeling to determine what share of this traffic demand actually uses the waterway.

3.2 FOCUS ON COAL

The bulk of the effort in forecasts of traffic demand on the Ohio River System centers on potential coal traffic. Coal traffic typically accounts for more than half of the traffic on the system and government policy and other issues affecting coal usage have a direct effect on coal traffic levels. In 2006, coal and coke traffic on the ORS amounted to some 151 million tons of traffic, which was about 56 percent of total traffic. By way of comparison, coal and coke in the EDM reach amounted to about 18 million tons, which was about 73 percent of total traffic.

The Ohio River Basin contains large portions of the Appalachian coal producing region as well as the Illinois Basin portion of the Eastern Interior producing region. The Appalachian producing region covers much of the eastern part of the ORB, while the Illinois Basin producing region is to the west, in Illinois, Indiana and western Kentucky. As shown in Table 3-1, the eight ORB states have demonstrated reserves totaling about 231 billion tons, which is about 47 percent

TABLE 3-1 – Demonstrated Reserves and Coal Production in the ORB States and the Nation

	Million Tons	
ORB State/ Region	Demonstrated Reserve Base 2007	Coal Production 2007
Alabama	4,141	19.3
Illinois	104,347	32.4
Indiana	9,379	35.0
Kentucky	29,618	115.3
Ohio	23,220	22.6
Pennsylvania	27,228	65.0
Tennessee	766	2.7
West Virginia	32,450	153.5
ORB States	231,149	445.8
U.S. Total	489,395	1,145.5
ORB as % of U.S..	47%	39%

SOURCE: Energy Information Administration of the nation's demonstrated reserves. Both the Appalachian and Illinois Basin coals have a relatively high energy content, especially when compared to the sub-bituminous western coals. The Appalachian coals, especially those in Central Appalachia, are lower in sulfur content than the Illinois Basin coals, although higher in sulfur content than most western coals. Coal production in the ORB states totaled about 446 million tons in 2007, which was about 39 percent of the nation's output. Most of the ORB output in 2007 came from the Appalachian producing region.

ORB coals are used in all of the major coal markets, including the utility and industrial steam coal, coking coal and export coal markets, and the ORS has been an important conduit for accessing each of these markets. The dominant market for ORB coals is the utility steam coal market, which annually accounts for more than 85 percent of ORB coal consumed. Utility steam coal moves via the ORS to utility plants both inside and outside of the ORS, but a large majority of this coal traffic remains within the ORS. Currently, more than 70 coal-fired electric generating facilities are located along the ORS. Over several decades, electric generating facilities have concentrated along the navigable waterways of the ORS, both for the transportation advantage and for a source of water supply.

As environmental regulations have evolved, the ORS has become more important in the delivery of utility steam coal. Coal-fired plants are normally designed to burn the most readily-available coals. Environmental regulations have prompted many utilities to source at least a portion of their coal supplies at greater distances from their plants in order to meet their emissions restrictions in a least-cost fashion, within the technical limitations of their facilities. In this regard, the low-sulfur coals of Central Appalachia were long the most sought-after coal resources in the ORB, and the ORS has been an important conduit for their delivery. In recent years, several ORB utilities, have turned increasingly to western coal as a less polluting energy source. This has resulted in more intensive use of the ORS by some utilities, because western coals have a much lower energy content than eastern coals and substantially more (approximately 30 percent more) is required to produce the same energy output as eastern coals.

3.3 COAL FORECASTING

3.3.1 Utility Steam Coal

3.3.1.1 Introduction

Among the many issues currently facing the electric utility industry, two that stand out are the environmental concerns, especially those associated with pollutant emissions, and the continuing deregulation of the electric utility industry. While both of these issues have a potential bearing on utility coal flows, it is currently acknowledged by industry representatives that the future of environmental regulations will have, by far, the greatest impact.

Increasingly stringent regulation of air emissions continues to be one of the greatest challenges facing the electric power industry. In the 1980s, growing national and international concern over acid rain deposition eventually led to passage of the 1990 amendments to the Clean Air Act.

This legislation was designed primarily to cap sulfur emissions, the largest sources of which are coal-fired electric power plants. Because there are dramatic regional differences in the sulfur content of eastern coal deposits, the difficulty has traditionally been one of reducing sulfur emissions without causing extensive economic and social disruption in the eastern coalfields of Appalachia and the Illinois Basin.

Technological advances in various forms of clean coal technology make it possible to remove sulfur and other pollutants during or after combustion, but at considerable cost to the electric utility. Use of this equipment allows utilities to continue buying coal from local, higher sulfur coal producers, for example, thereby guaranteeing continued employment and production for the region's miners. However, utilities have frequently found that the least costly option for reducing emissions is not to build or install these expensive clean coal devices, but to find sources of less-polluting coal and pay the higher transportation costs associated with getting this more distant coal to their plants. Deposits of such coals are somewhat limited in the east, but are abundant in the western sub-bituminous fields of Wyoming, Montana, and in the hard coal deposits of Colorado and Utah.

The Clean Air Act and its amendments to date have produced increasingly restrictive regulations governing emissions of major pollutants, most notably sulfur dioxide and nitrogen oxide. Phases I and II under the amendments established a blueprint for setting individual plant emission limits. Frequently, the EPA interprets/modifies the requirements in environmental legislation through the issuance of implementing regulations. In 1997, the EPA issued some important implementing regulations known as the National Ambient Air Quality Standards, which placed further restrictions on powerplant emissions than had been planned under Phase II.

The electric utility industry has long complained that it was faced with a multitude of largely uncoordinated environmental regulations and that their ability to plan for the future was impaired. As a result, around 2001, industry began calling for some sort of coordinated multi-emissions approach to emissions regulation. In response, the Bush administration and the congress developed a variety of multi-emissions proposals, the best known of which was the administration's Clear Skies Initiative. None of these proposals was enacted into law, however, in 2005 the EPA developed some additional implementing regulations designed to provide more of a multiple-emissions approach to the emissions reduction problem. Principal among these regulations were the Clean Air Interstate Rule and the Clean Air Mercury Rule, which remained in effect until 2008, when they underwent court challenges that resulted in their being vacated on technical grounds. Given the level of uncertainty in the environmental regulations, the coal traffic forecasts were not developed within the precise framework of any existing regulations. Rather, they were developed assuming a reasonable evolution in the regulations that included, for one scenario, limitations on carbon dioxide emissions. The forecasts were developed for base case, high and low scenarios, as described in subsequent paragraphs.

3.3.1.2 The Clean Air Act .

3.3.1.2.1 The Law Prior to 1990

The evolution of clean air legislation (Table 3-2), particularly as it applies to the use of coal, illustrates a difficult balancing of economic and environmental concerns. The Clean Air Act of

1963 was the first significant piece of legislation that recognized the existence of a national air pollution problem. The Clean Air Act of 1970 established ambient air quality standards for ozone, lead, sulfur dioxide, particulates, nitrogen oxide, and carbon monoxide. Under the 1970

TABLE 3-2 - Summary of Clean Air Act Legislation and Regulations

Year	Legislation/Regulation	New or Modified Source		Existing Sources	
		Attainment	Nonattainment	Attainment	Nonattainment
1963	Clean Air Act	Recognized existence of an air pollution problem			
1970	Clean Air Act	Required EPA to set nationwide ambient air standards for SO2, NOx and six other pollutants. States were required to develop State Implementation Plans describing measures that would be taken to meet standards.			
1971	EPA - New Source Performanc Standards	As of 17 August 1971 emissions no to exceed 1.2 lbs/mm Btu. <=========MUST SCRUB=======>			Must use Reasonably Available Control Technology (RACT)
1977	Amendments to CAA	Best Available Control Technology (BACT) required and emissions were not to exceed 1.2 lbs/mm Btu. <=========MUST SCRUB=======>			
1979	EPA - Revised New Source Performance Standards (RNSPS)	As of 18 Sep 1978, 1.2 lbs/mm Btu limit. For all coals, 90% of sulfur removal required (exception for coals with < 0.6 lbs/mm Btu - 70-90% removal) <=========MUST SCRUB=======>			SWITCH OR SCRUB
1990	Amendments to CAA (CAA of 1990)	Instituted strict emission limits on sulfur dioxide and nitrogen oxides. Established successively stricter SO2 emission levels in 1995 and again in 2000. Created an emissions allowance/credit system for achieving reduced emissions.			
1995	Phase I of CAAA 1990	Phase I - Allowances issued permitting SO2 emissions up to 2.5 lbs/mm Btu as of 1 Jan 1995. Two-year extension granted if clean coal system installed. Applies directly to 110 existing plants <=========MUST SCRUB=======>			
2000	Phase II of CAAA 1990	Phase II - Allowances issued permitting SO2 emissions up to 1.2 lbs/mm Btu as of 1 Jan 2000. Applies to all plants of 25 MW or more. Three-year extension granted if clean coal system installed. Emission cap of 8.9 mm tons of SO2/year. <=========MUST SCRUB=======>			
1998	EPA - National Ambient Air Quality Standards	Regulations affect ground level ozond and 2.5 micron particulate matter; reduces nitrogen oxide emissions to 3.1 million tons by 2004-2005; reduces sulfur dioxide emissions to 4.5 million tons by 2010.			
2005	EPA - Clean Air Interstate Rule	Implements cap and trade programs for 25 states and the District of Columbia to reduce emissions of SO2 and NO x from electric generating units. Annual emission cap for SO2 is 3.67 mm tons by 2010; 2.57 mm tons by 2015; NO x caps are 1.52 mm tons by 2010 and 1.27 mm tons by 2015.			
2005	EPA - Clean Air Mercury Rule	Implements a cap and trade program for mercury emissions from coal-fired electric generating plants. Program covers all 50 states and the District of Columbia. National targets are 38 tons per year beginning in 2010 and 15 tons per year beginning in 2018.			

Act, the states were required to develop state implementation plans (SIPS) that would both estimate the emission reductions required to attain the ambient standards and institute the control programs to achieve the required reductions. In addition, the Environmental Protection Agency (EPA) was required to promulgate New Source Performance Standards (NSPS), which it did in regulations issued in 1971, for new or modified stationary pollution sources.

A more aggressive control program was instituted in the Clean Air Act Amendments of 1977 in response to the country's failure to meet the goals of the 1970 Act. Areas of the country that failed to meet their air quality goals were designated non-attainment areas. Existing power plants in non-attainment areas were required to retrofit with reasonably available emission control technologies (RACT). A new source could be constructed in a non-attainment area only if it would operate at the lowest achievable emission rate, in effect requiring the installation of the best achievable control technology (BACT).

The EPA puts legislation into action through its implementing regulations, and since 1978 utilities have operated under regulations referred to as the Revised New Source Performance Standards (RNSPS). By requiring new or modified coal-fired electric generating plants to use the BACT in achieving a 1.2 lbs./mmBtu limit on sulfur dioxide emissions, this set of regulations in effect required all new or extensively modified coal-fired electric generating stations to be equipped with some form of clean coal technology

3.3.1.2.2 The 1990 Clean Air Act Amendments

The amendments to the Clean Air Act passed in November 1990 represented the culmination of nearly 30 years of legislation aimed at improving air quality. Title IV of the amendments established a blueprint to quickly reduce sulfur dioxide emission levels and the levels of other pollutants, most notably the nitrogen oxides. This is brought about through strict emission limitations on the subject gases accomplished within the context of an emission allowance program (EPA's Acid Rain Program). Annual allowances, each permitting the emission of one ton of sulfur dioxide, were allocated by EPA based on unit size, primary fuel, on-line year, 1985 emission rate and past energy use. The law establishes successively stricter emission levels in two major phases: Phase I, having a target date of 1 January 1995 and Phase II, having a target date of 1 January 2000

By 1 January 1995, the target date under Phase I of the amendments, the highest 110 polluting power plants nationwide were limited to emission of an average 2.5 lbs. of sulfur dioxide per million Btus of energy consumed from coal. Existing units subject to emission limitations received allowances equal to the amount of sulfur dioxide they were permitted to emit under Title IV of the amended act. Several strategies were available for reducing emissions to allowable levels. These included switching to lower sulfur coal or installing clean coal technologies. Those plants that reduced emissions below the allowable level could transfer their extra allowances to other plants.

Any new utility plants remained subject to the RNSPS and were required to hold allowances equal to the amount of their expected annual sulfur dioxide emissions. In practical terms this meant that utilities bringing new plants on-line had to be equipped with some form of clean coal technology and had to have sufficient allowances in-hand to cover expected emissions. The utility could get these allowances by over-complying at other plants in their system or by purchasing allowances from other utilities.

By 1 January 2000, the target date under Phase II of the amendments, affected plants (any plant of 25 megawatt capacity or greater) were required to emit on average less than 1.2 pounds of sulfur dioxide per million Btus of energy input from coal. Additionally, utility plant emissions were capped at 8.9 million tons of sulfur dioxide, a steep reduction from 1985 emissions of 16.1 million tons. Obviously, this represented a substantial tightening of the Phase I requirements with respect to sulfur dioxide emissions.

3.3.1.2.3 The National Ambient Air Quality Standards

Concern with the formation of ground level ozone, which health officials believe to have deleterious health effects, caused EPA to issue additional regulations, aimed especially at nitrogen oxide emissions, under the CAAA in 1998. Under Title IV of the Clean Air Act Amendments, a blueprint was established for setting individual utility plant emission limits designed to bring national sulfur dioxide utility emissions in year 2000 and thereafter (Phase II) to a level 10 million tons below the 1980 emission levels. The corresponding target for nitrogen oxide emissions was 2 million tons below 1980 levels. However, Title I of the CAAA, in addition to establishing the Northeastern U. S. Ozone Transport Commission (OTC), retained an older emission-limiting process that had been part of the original Clean Air Act. This empowered the EPA to develop National Ambient Air Quality Standards (NAAQS) under which each state is required to file State Implementation Plans (SIPs) with site-specific emission limits. Under the authority of Title I of the CAAA, EPA issued standards governing ground-level ozone and 2.5 micron particulate matter in mid-1997, which became effective in 1998.

The 1998 regulations translated into much more stringent sulfur dioxide and nitrogen oxide restrictions than those flowing from the Phase II regulations. By 2010, under NAAQS, nationwide sulfur dioxide emissions were limited to 4.5 million tons, down from an actual 1999 level of 12 million tons. Nitrogen oxide emissions were restricted to 3.1 million tons, compared to the 1999 level of 7.1 million tons.

3.3.1.2.4 Multi-Emissions Proposals

By 2000, the utility industry was faced with as many as 20 uncoordinated and often conflicting environmental regulations. As a result, in 2001, both industry and affected government agencies began calling for some sort of coordinated multi-emissions solution to the regulatory problem. In response to these concerns, the administration and the congress developed a variety of proposals for amendments to the Clean Air Act that would, in effect, consolidate the regulations into a multi-pollutant emissions approach.

A common feature of all of the multi-emissions proposals is that, rather than simply eliminating conflicts that existed under the existing regulatory scheme, they added restrictions that were considerably more stringent. These restrictions included, but were not limited to, severe cuts in already relatively low mercury emissions as well as cuts to sulfur dioxide and nitrogen oxide emissions to levels far below the most stringent previously-proposed restrictions.

The administration's three-pollutant proposal is referred to as the Clear Skies Initiative. Under this proposal, nationwide sulfur dioxide emissions are restricted to 4.5 million tons by 2010 and 3.0 million tons by 2018, compared to actual emissions of 12.0 million tons in 1999. Nitrogen oxide emissions are reduced from an actual level of 7.1 million tons in 1999 to levels of 2.1 million tons in 2008 and 1.7 million tons in 2018. Mercury emissions are restricted to 26 tons in 2010 and 15 tons in 2018, versus actual emissions of 48.6 tons in 1999. Clear Skies, in contrast to other multi-emissions proposals, contains no restrictions on carbon dioxide emissions. The proposal does, however, encourage voluntary reductions in carbon dioxide emissions.

3.3.1.2.5 The Clean Air Interstate and Clean Air Mercury Rules

Inaction by the congress on the Clean Skies Initiative or other multi-pollutant proposals caused the Bush administration in 2005 to turn to EPA implementing regulations to formulate a multi-emissions strategy. The resulting Clean Air Interstate Rule (CAIR) and Clean Air Mercury Rule (CAMR) echo many features of the administration's Clear Skies Initiative.

The Clean Air Interstate Rule caps annual emissions of sulfur dioxide (SO2) and nitrogen oxides (NOx) from electricity generators in the eastern United States. The NOx rules include both annual and seasonal cap and trade programs. The Clean Air Mercury Rule caps emissions of mercury from electricity generators nationwide through a cap-and-trade program.

The Clean Air Interstate Rule affects principally fossil fuel-fired electric generating units with a capacity greater than 25 megawatts. It implements an annual cap-and-trade program for 25 states and the District of Columbia to reduce emissions of SO2 and NOx from electric generating units. It also implements a seasonal cap and trade program for 25 states and the District of Columbia to reduce emissions of NOx from electric generating units during the ozone season. The annual allowance caps for SO2 are 3.67 million tons by 2010 and 2.57 million tons by 2015. For NOx, the annual caps are 1.52 million tons by 2009 and 1.27 million tons by 2015. In 2008, the CAIR was partially vacated by the court because of a legal challenge to the authority of the EPA administrator.

The Clean Air Mercury Rule is aimed principally at coal-fired electric generating units having a capacity of 25 megawatts or greater in each of the 50 states. The program establishes a national annual cap and trade program for mercury emissions. The program is set up in phases, with Phase I beginning in 2010 and Phase II beginning in 2018. The national annual emission allowance caps are 38 tons beginning in 2010 and 15 tons beginning in 2018. In 2008, CAMR was vacated by the court essentially on the grounds that the cap-and-trade system was insufficiently stringent.

3.3.1.3 Other Utility Steam Coal Forecasting Issues

3.3.1.3.1 Utility Industry Deregulation

The issue of deregulation is one that is causing many fundamental adjustments in the electric utility industry. The industry, prompted by federal legislation, is continuing a transition from a vertically integrated and regulated monopoly to an entity in a competitive market where retail customers choose the suppliers of their electricity.

The electric utility industry can be divided conveniently into three segments: generation, transmission, and distribution. In the generation segment, electricity is actually produced through the conversion of energy (fossil fuels, water, sunlight, or nuclear fuels) into electric currents. The transmission arm of the industry can be thought of as an interstate highway system that transports the electricity from the generating plant to the distribution center. The distribution segment then sends the power out to the final end-use customer. Traditionally, all three segments were thought to be a "natural monopoly". This thinking has given way to a consensus among legislators, regulators, industry analysts, and economists that the generation segment is more efficient in a competitive environment, and that only the transmission and distribution segments should remain regulated and noncompetitive.

Deregulation has spawned a variety of actions on the part of electric utility companies. Utility companies are assuming a much more competitive posture vis-a-vis other utility companies. A number of utility company mergers have taken place on the theory that size will prove advantageous in a deregulated environment. Other companies have spun off non-utility subsidiaries. Utility companies are purchasing power plants in areas far-removed from their current service areas, in the attempt to gain a “footprint” in other parts of the country and hopefully reduce the risk associated with operating in a confined geographic area.

Utility industry representatives previously indicated that deregulation in the electric utility industry is an issue that could impact ORS waterway commodity flows, given the natural competitive advantages of waterside coal-fired plants in the Ohio River Basin. As events have unfolded, however, deregulation appears not to have had the degree of favorable impact on waterside coal-fired plants that was anticipated. So while deregulation is an important process for the utility industry, the direct impact, as far as waterway coal flows is concerned, is slight, especially when compared to the demonstrated impact of environmental regulations.

3.3.1.3.2 Global Warming

In December 1997, the U.S. and 158 other nations agreed, as part of the Kyoto Protocol, to binding limits on the emissions of six greenhouse gases, including carbon dioxide. Although signed by the administration at that time, the Kyoto Protocol generated considerable controversy, both because of the exclusion of developing countries from emission limitations, and because of expected serious economic impacts in the U. S. Of particular note was the potential impact of the agreement on the use of coal by electric utilities. The controversy surrounding this agreement was such that Congress at the time prohibited EPA from implementing the agreement through its regulatory functions.

Although it is now acknowledged that the issue of global warming is a valid one, no national-level initiatives have, as yet, been undertaken to address it. In the absence of national-level initiatives, interests at the state and broader regional levels are increasingly taking steps toward the goal of reducing greenhouse gas emissions within their boundaries. An example of this is the Regional Greenhouse Gas Initiative (RGGI). The Regional Greenhouse Gas Initiative is the first mandatory, market-based effort in the United States to reduce greenhouse gas emissions. Ten Northeastern and Mid-Atlantic states, under this agreement, will cap and then reduce CO_2 emissions from the power sector 10 percent by 2018. It is regarded as increasingly likely, given the current administration’s emphasis on environmental issues, that some sort of national initiative to reduce greenhouse gases will eventually emerge, particularly in light of these state and regional efforts.

3.3.1.3.3 Nuclear Power Development/Plant Re-licensing

Nuclear power plants account for about 20 percent of electricity generation nationwide. The last nuclear power plant constructed entered commercial operation in 1996. Concerns such as storage of nuclear waste, expense of development, potential terrorist attacks and especially accidents like Three Mile Island and Chernobyl have substantially inhibited both new plant development and the re-licensing of nuclear plants once their initial operating licenses have expired.

The concerns surrounding nuclear power, however, currently intersect with the issue of global warming. Nuclear power does not produce the carbon dioxide and other greenhouse gases implicated in global warming, as coal-burning plants do. Some public officials and others advocate new development of nuclear power to reduce America's dependence on fossil fuels. Public opposition to nuclear power is apparently diminishing with the realization that global warming may pose the greater danger in this tradeoff.

3.3.1.3.4 Resource Constraints

The issue of resource constraints is one that is becoming increasingly important, especially, but not exclusively, in the Central Appalachian producing region. Remaining resources become increasingly difficult to extract and are located farther away from the navigable waterways. While the affected resources will continue to be available and will be produced, they will not be able to compete on a delivered cost basis in some markets.

Resource availability could be substantially affected by the outcome of the valley fill/mountaintop removal controversy that arose in 1998. This issue arose from a lawsuit that was filed by an environmental group challenging the legality of surface mining practices, specifically in Central Appalachia, where spoil materials originating at mountaintop surface mining sites, as well as other sites, were placed in streambeds. This, and a series of other lawsuits ended with mixed results. The ultimate outcome of this controversy could make it considerably more difficult and expensive to mine coal in Central Appalachia.

3.3.1.3.5 Alternate Fuel Pricing

The demand for coal on the part of the electric utilities is obviously affected by the prices and delivery capabilities of alternate fuels, including oil and especially natural gas. In recent years, environmental regulations have prompted many utilities (and non-utility generators) to turn to natural gas when additions to generating capacity are needed and to convert some coal-fired units to natural gas. Subsequent spikes in natural gas prices and doubts concerning resource availability and delivery capabilities caused many of these plans to be shelved.

A relatively recent development is the increased capability of gas producers to recover gas from shale deposits by means of underground cracking. It is estimated by some industry experts that, as a result of this advance, the nation's total supply of developable natural gas has increased by a minimum of one-third over previous estimates. The long-term impact of this advance on natural gas pricing is yet to be determined, however, it is speculated that the numerous existing and potential future alternative uses for natural gas, particularly for use as vehicle fuel, will result in continued price pressures.

3.3.1.3.6 Technological Advances

Advances in clean coal technologies have been and continue to be crucial to the continued viability of coal as an energy source in electricity generation. Additionally, clean coal technologies determine coal sourcing and the volumes of coal required to provide equivalent energy. In recent years, over 100 clean coal technologies have been under development at any given time, and most of these technologies are add-ons to existing plant structures.

Currently, the best known of the clean coal technologies are integrated gasification combined cycle (IGCC or coal gasification) and carbon sequestration. These two technologies, when combined, result in what is known as the "near zero emissions powerplant". IGCC is a coal gasification process that eliminates many pollutants prior to combustion in the power plant itself. Carbon sequestration is the process whereby carbon dioxide from the combustion process is captured and pumped to spent-out oil or gas wells for permanent storage. Carbon sequestration technology is still under development and a number of problems remain to be overcome. For example, the space requirements for the equipment involved in carbon sequestration is large and not always available. The power requirement of this equipment is estimated to be about 15 percent of the generation of the units served (parasitic power requirements). Adequate storage areas for CO2 must be located and the impacts of sequestering CO2 are not yet fully known.

The development of so-called "smart grid" technologies is gaining traction and could greatly impact the usage of fossil fuels or any other power source. A smart grid delivers electricity from suppliers to consumers using digital technology that concurrently saves energy, reduces costs and increases reliability. This technology, in effect, optimizes the routing of electricity to respond to a very wide range of conditions.

3.3.1.3.7 Renewables Development

Concerns over global warming have intensified the interest in the usage of renewable resources, especially hydropower, wind and solar, in electricity generation to replace the usage of fossil fuels. Efforts have focused on overcoming problems associated with renewables technologies. For example, it is often noted that renewables plants have a relative large immediate physical footprint from which they produce relatively little electricity. Fossil fuel plants and especially nuclear facilities have relatively small immediate physical footprints from which they produce large amounts of electricity. In order to avoid having to transmit electricity long distances, which has its own multitude of difficulties, it is desirable that electric generating facilities be located relatively close to urban areas that they serve. Given the acreage requirements of especially wind and solar plants, it will be difficult to locate adequate acreage in or near areas where electric power is needed.

Another important problem with renewables development is the fact that generation from renewables cannot be scheduled, but must occur when the power source is available. It is agreed at this point that the nature of renewables technologies dictates that backup facilities be available to cover periods when the renewables plants are not producing.

It is expected, also, that future construction plans for many large commercial buildings as well as individual houses will include small on- and off-grid renewable energy applications. This type of development will certainly impact fossil fuel usage, particularly in areas where conditions lend themselves to this type of construction. However, this again will not preclude the need for backup to the individual systems.

3.3.1.4 Forecast Methodology

3.3.1.4.1 Introduction

Coal that moves by barge to electric utilities accounts for nearly half of all traffic on the ORS (128.3 million tons) but only about 40 percent of traffic in the EDM reach (8.3 million tons). This market for coal continues to receive much attention from government regulators, the administration, the congress, and the public. While other commodities and barge-served markets face uncertainty, none matches the dominance of coal or level of uncertainty regarding future use.

Waterway traffic demands for steam coal are a function of three major drivers: electricity demand, coal consumption by electric power plants, and the supply source of the coal consumed by the electric utility.

Future growth in electricity demand is related to expectations for both population and economic growth. Electricity growth per capita and relative to Gross Domestic Product (GDP) growth has tempered in recent years now that nearly all homes have major electric appliances, and devices become ever more energy efficient. In spite of this, industry experts are universal in projecting sustained growth in electricity demands over the foreseeable future.

Although coal is the dominant fuel used to generate electric energy in the United States, the use of coal for electricity generation has been tied to a myriad of pollution problems such as acid rain deposition, ground-level ozone (smog), elevated levels of greenhouse gases (global warming), and unhealthy levels of airborne particulate matter. Federal and state governments have acted to cause electric generating companies to emit fewer pollutants through Clean Air legislation and subsequent amendments, and through increasingly aggressive application of these laws through regulation.

The coal supply sources and the transportation modes used to serve individual plants were previously fairly stable. Utilities generally designed plants to consume local coals – coals produced in the immediate area or region. Transportation alternatives were largely dictated by the location of the plant. Coal production costs and supply constraints are now affecting the original cost equation that dictated coal supply source, but environmental regulations are an even more powerful force. With each change in environmental regulation, the utility re-calculates its choice of coal type (and sometimes fuel) for each plant and balances the cost of buying and transporting coals from longer distances against the cost of retrofitting the plant with emission reduction equipment. When planning new capacity, the utility balances the cost of building and operating coal plants against the cost of building and operating natural gas-fired units.

In order to deal with the range of issues affecting electricity generation, this forecasting effort makes use of a linear programming approach to the problem through the use of the Greenmont Energy Model (GEM). The GEM focuses primarily on the electric utility and coal industries. In essence, this model determines the least-cost means to produce needed future generation in a market context and within existing and expected future environmental constraints. Additional details on the GEM are provided in the following paragraphs.

3.3.1.4.2 The Greenmont Energy Model (GEM)

The Greenmont Energy Model is an optimization model which calculates the unique combination of a large number of parameters that achieves the lowest cost of electricity generation in the U.S. for a given amount of electricity demand. The model uses both Linear Programming (LP) and Mixed Integer Programming (MIP) optimization techniques and thus can be characterized as an LP/MIP optimization model. GEM simultaneously solves 84 time blocks for a single year (six seasons times 14 time zone combinations for time-of-day load distribution). Since all this is done simultaneously, it means that in one single module of computation, optimal co-dependent values are determined for all of the varying parameters including, among others, amount and type of coal choice by unit; level of each unit's dispatch; environmental clean-up decisions between new equipment, fuel switching or allowance purchasing; location, amount and type of new generation capacity; retirement of existing units; amount of economically justified mining capacity expansion for each cost level for each type of coal; fob coal mine prices; wholesale electricity prices; and pollutant allowance prices. The model carries forward results from each previous year so that in a succeeding year the correct amount of (1) generation capacity by type, (2) mining capacity and remaining reserves by type and cost level, and (3) clean-up capacity for each pollutant are available.

The cost minimization process carried out in the GEM model traces impacts down to the electric-generating unit level of detail. Electricity demand zones or areas, together with load curves, are given and connected by way of a transmission network. Power plants supply energy into this network. A power plant is assigned to a particular demand area, based on its location. For power plants not fired by coal or gas, a simplified generation cost and emission rate is applied. For gas-fired plants, the generation cost is taken off a gas supply curve based on elasticity assumptions. A transportation sub-model (GTM) optimizes coal routings.

Coal-fired power plants are modeled at a highly detailed level. Every boiler of every coal-fired power plant in the U.S. is represented separately in the GEM model. Pollution abatement technology also plays a major role in the GEM model. Coal fired power plants can invest or use previously-installed abatement technology capacity to reduce the emission rates for all major pollutants. In addition, they can buy emission allowances from other emitters (if permitted in the scenario setup). The coal-fired power plants also have complete freedom of choice in the quality of coal to use. All coals are available to every coal-fired unit (except for coals that would be technically infeasible to burn in the unit). The delivered cost of coal is determined for each plant by a coal price which is drawn from the marginal point of production on a set of detailed mine cost supply curves and by a transportation cost estimate from the GTM sub-model. Other cost modules of the GEM compute the cost of wheeling of power, the cost of constructing a new plant of a certain type, generation costs and the cost of construction of new mining capacity for each coal type.

In addition to generating power with existing power plant capacity, the model can also build new or extend existing power plants and increase coal mining capacity to satisfy growing energy demand. However, new capacity of either type must meet specific economic criteria, which are inputs to the model, before it can be built. If the economic criteria are not met, then the additional capacity is not built, and energy commodity prices keep rising until the economics favor building new capacity. In the current application of the GEM, additions to coal-fired generating capacity are made at existing, least-cost locations within utility planning areas. These least-cost locations may, in fact, shift from one location to another at any point in the modeling process.

The GEM model operates with a number of key model inputs. These would include (1) electricity demand by generation area and transmission capabilities between generation areas; (2) natural gas prices based on prices at the Henry Hub; (3) coal-specific mine cost curves; (4) transportation prices as computed by the Coal Transportation Costing Module; (5) data for all electric generating facilities in the U.S. and Canada with boiler-level data for the coal-fired plants; (6) capital and operating costs for new generation by plant type; (7) Internal Rate of Return (IRR) criteria for addition of coal mine and electric plant capacity; (8) pollutant emission limits (SO2, NOx, Hg and CO2) by region and multi-pollutant emission allowance trading capabilities; (h) capital and operating cost of cleanup equipment; (9) planned cleanup equipment installations at existing facilities; (10) 104 modeled coal types; (11) 123 modeled generation areas; and (12) specific mine data including capacity, mining costs, reserves and expandability.

The modeling process generates a number of important outputs. These would include (1) projected FOB mine prices and production by specific coal; (2) projected natural gas prices and production volumes; (3) wholesale prices for electricity; (4) electricity generation by coal-fired unit and plant; (5) dispatch curves by generation area from unit-level costs; (6) projected SO2, NOx, Hg, and CO2 allowances; (7) projected new generation by plant type and location; (i) coal sourcing by unit; (j) optimized clean-up equipment installations by unit and year of installation; and (k) generation capacity using each type of clean-up equipment.

3.3.1.4.3 Scenario Development .

3.3.1.4.3.1 Introduction

Though most commodity movements on the Ohio River System serve stable and fairly predictable markets, considerable uncertainty is inherent in projecting commodity flows 50 years into the future. Much of the uncertainty, especially where coal is concerned, is attributable to the behavior and policies of the national and state governments, rather than that of individual consumers. In the ORB this is especially manifest in the application of federal government regulations and policies directed at electric utilities.

It is generally agreed by industry experts that environmental regulations currently overwhelm all other issues relating to the usage of coal by electric utilities. As demonstrated by the vacatur of the Clean Air Interstate and Clean Air Mercury rules, the precise form of future environmental laws and regulations is difficult to discern. For this reason, three alternative forecast scenarios, designated the Base Case, High and Low scenarios were developed based on an analysis of existing regulations and an assessment of reasonable future developments that could affect waterborne coal traffic either positively or negatively.

In the modeling process, the primary drivers of the alternative forecast scenarios include Gross Domestic Product (GDP); sulfur dioxide and nitrogen oxides emissions restrictions; mercury emissions restrictions; carbon dioxide emissions restrictions and the rate of nuclear capacity additions. A higher rate of growth in GDP would normally be associated with higher level of aggregate coal consumption and waterway traffic. For comparison purposes, average GDP for the 40-year period 1970-2009 was 2.8 percent. More stringent pollutant emission restrictions and a higher level of growth in nuclear capacity would normally result in lower aggregate coal consumption and waterborne coal traffic. The alternative forecast scenarios are described in the following paragraphs. Differences in the key variables underlying these scenarios are displayed in Table3-3.

TABLE 3-3 - Key Variables in Development of Forecast Scenarios

Variable	Low Case	Base Case	High Case
Annual GDP Growth	2.0%	2.4%	4.0%
SOx/NOx emissions	Stricter than Clean Air Interstate Rule	Same as Clean Air Interstate Rule	Same as Clean Air Interstate Rule
Mercury emissions	Maximum Available Control Technology	Maximum Available Control Technology	Maximum Available Control Technology
CO2 emissions	Waxman-Markey Bill (R.H. 2454)	Regional Greenhouse Gas Initiative	Regional Greenhouse Gas Initiative
Nuclear additions	2250 mw in 2014 growing to 5500 mw in 2027 and beyond	2200 mw in 2014 growing to 4000 mw in 2032 and beyond	500 mw in 2014 growing to 1500 mw in 2018 and beyond

3.3.1.4.3.2 Base Case Scenario

The Base Case scenario is essentially a momentum scenario that assumes a reasonable evolution of existing environmental regulations. Since the Clean Air Mercury Rule (CAMR) was vacated by the courts, the Base Case Scenario assumes that the CAMR rules are replaced with a Maximum Available Control Technology (MACT) logic in which existing coal-fired units must remove 85 percent of the mercury in feed coal and newly-constructed units must remove 90 percent of the mercury, based on the amount in the feed coal.

The Base Case assumes that the Regional Greenhouse Gas Initiative (RGGI) is in effect, which will limit emissions of greenhouse gases within the boundaries of ten northeastern states. This program, which began in 2009, calls for signatory states to limit power sector carbon dioxide emissions over the first six years of the program to current levels and thereafter to reduce emissions 2.5 percent per year until 2018.

In the modeling process, new nuclear plant construction is permitted to begin in year 2014. A ceiling is placed on new nuclear capacity, beginning at 2200 megawatts in 2014 and increasing to 4000 megawatts by 2032. In the Base Case, coal’s share of total generation diminishes from over 50 percent before 2030 to around 43 percent by 2070, with much of the loss picked up by nuclear-fired generation.

With respect to economic growth, the Base Case Scenario assumes that real national GDP will grow at an average annual rate of 2.4 percent between 2008 and 2070, which is similar to AEO's assumed growth rate through 2030. For more accuracy in forecasting, the GEM uses regionalized GDP, according to the nine census regions.

New plant and new mine construction are triggered in the model by internal rate of return criteria. Other capital equipment items, such as scrubber equipment are evaluated using a discount rate of 10 percent and a discount period of 20 years. Also, the line loss rate for wheeled power is assumed to be 2 percent.

3.3.1.4.3.3 Low Case Scenario

For the Low Case scenario, it was assumed, in light of the vacatur of the Clean Air Interstate Rule (CAIR) by the courts, that stricter limitations would be placed on SO2 and NOx emissions limitations than existed under CAIR. This serves to make coal even less environmentally attractive and also hastens the need for even scrubbed plants to move away from the highest sulfur coals that comprise a substantial portion of ORS traffic. The mercury MACT restrictions used in the Base Case remain the same in the Low Case.

The Low Case Scenario assumes the implementation of strict national-level limitations on emissions of CO2 in accordance with the provisions of the Waxman-Markey bill (H.R. 2454), which was introduced in early 2009. The CO2 limitations then become the most important driver in coal consumption and waterborne coal traffic. It was assumed for this current analysis that the electric generation sector would only bear its proportionate share of the percentage reduction limits stated in the bill, and that no offsets were available from international sources or from activities such as reforestation, etc. The emission limits for electricity generation used in the modeling begin at 2.696 billion tons in 2005 and diminish to 0.458 billion tons by 2070.

Relative to the Base Case, there is an increased ability for nuclear power to grow. New capacity could begin to come on line in 2014, similar to the Base Case. Annual additions to nuclear capacity are capped at 2250 megawatts in 2014, but the cap increases to 5500 by 2027 and remains at that level until the end of the forecast period. It is important to note that both nuclear plants and gas-fired plants are built at a faster rate than in the Base Case, at least in the early years of the forecast horizon. This occurs because both nuclear and gas-fired plants help to lower CO2 emissions.

GDP growth in the Low Case is assumed to be about 2.0 percent per year over the forecast horizon, compared to the Base Case's 2.4 percent. Other features of the Low Case are generally similar to the Base Case.

3.3.1.4.3.4 High Case Scenario

The evolution of the environmental regulations, for the most part, is similar in the High Case to that of the Base Case. The MACT requirement with respect to mercury emissions is the same as the Base Case. The major points of divergence from the Base Case are in the assumptions regarding nuclear plant development and relicensing; natural gas price levels: and the overall levels of economic growth.

Compared to the Base Case, the High Case assumes that the ability of nuclear power to grow will be substantially constrained. Once again, new nuclear capacity could become available beginning in 2014. Nuclear capacity additions are limited to 500 megawatts in 2014 and grow to 1500 megawatts by 2018. Capacity additions never exceed 1500 megawatts per year over the forecast horizon.

In addition to the nuclear power constraints, the High Case assumes higher levels of natural gas prices than the Base Case. This has the effect of making natural gas less attractive and coal more attractive as a fuel for electric power generation. In the High Case scenario, each step of the Henry Hub gas supply curve was raised $6 per million cubic feet over that used in the Base Case.

In the High Case scenario, coal consumption by the electric utilities is driven, as well, by high levels of economic growth. GDP growth in the High Case is assumed to be about 4.0 percent per year over the forecast horizon, compared to the Base Case's 2.4 percent .

3.3.1.4.4 Application of GEM Outputs

The primary outputs from the utility steam coal forecasting effort were plant and unit-level coal consumption and coal sourcing patterns based on 104 national (12 in the ORB) and foreign supply regions for every year in the 64-year forecasting horizon (2006-2070). Separate forecasts were prepared for the Base Case, Low Case and High Case scenarios. The alternative scenarios indicate appropriate shifting among coal supply regions to reflect developments in the forecast scenarios.

In addition to the coal consumption and coal sourcing estimates, the forecasting effort also included a preliminary assessment of origin-to-destination transportation patterns using LTI/Greenmont Energy's transportation module. Because of the preliminary nature of these estimates, USACE undertook a refinement of the estimate of waterborne coal receipts at waterside plants that would be expected to receive coal moving at least in part on the ORS.

To develop the final utility steam coal waterway traffic forecasts, USACE analysts made use of the LTI plant-level coal consumption and coal sourcing forecasts, historic power plant coal consumption data from the CoalDat database, and the Waterborne Commerce dock-to-dock utility steam coal traffic data. The LTI coal consumption forecasts were calibrated to year 2006, so a first step in the traffic forecast development was to compare the LTI plant-level consumption results for 2006 with historic consumption records, as reflected in the CoalDat database. From this comparison, factors were developed to adjust the LTI-generated coal consumption forecasts to actual coal consumption as reflected in the CoaDat dataset. A second factor was then developed for waterside plants, relating total adjusted coal consumption to waterborne coal receipts. The waterborne receipts share was based on the average historic share, 2003-2006. The two factors were used to adjust projected plant-level coal consumption and the levels of waterborne receipts.

The plant-level waterborne coal receipts were allocated back to origin docks within the producing regions identified by LTI based on historic waterside sourcing patterns (2003-2006). A series of lookup tables were developed for waterside plants, for their respective companies and for all of the companies collectively. For the individual plants these tables identified the percentage shares of coal traffic, between 2003 and 2006 collectively, originating at specific docks within the production areas identified by LTI. These percentages were applied to projected waterway traffic for that plant originating within the production area identified by LTI. If a plant had no historic record of receiving waterborne coal from a particular production area, the parent company's lookup table was used for allocation purposes. If the parent company had no historic record of receiving waterborne coal from the identified production area, the lookup table for all companies was used for the allocation.

3.3.2 Sorbent Materials

The term sorbent materials refers to the lime and limestone used for coal desulfurization in scrubber units at coal-fired electric generating facilities. ORS waterborne traffic in sorbent materials totaled about 3.6 million tons in 2006 or about 1 percent of total traffic. Through the EDM reach sorbent materials traffic was only about 18,000 tons or about 0.09 percent of total traffic. The sorbent materials consumption forecast was handled by reference to the alternative consumption forecasts for utility steam coal. Sorbent usage was determined based on coal type, coal volumes and plant dispatch. Existing scrubbers entered into the analysis as well as any announced scrubbers. Aside from these, scrubbers were added to units when they were indicated in the modeling process. Beyond the existing and announced scrubbers, it was assumed that all new scrubbers installed would be wet scrubbers (limestone-based).

Much of the waterborne lime and limestone that enters into coal desulfurization has been shipped rather long distances from quarries/kilns to destination plants. This has occurred despite the fact that suitable limestone resources are actually rather widespread throughout the ORB. It has long been anticipated that the scrubber market would require greatly increased quantities of limestone to enable utility plants to meet their environmental requirements. In actuality, the need for scrubber limestone has developed much more slowly than ever expected, and quarry operators have been reluctant to commit to new resource development. Although no new lime plants are expected to be built over the forecast horizon, it is expected that eventually new limestone resources will be developed to accommodate the scrubber market. For the purposes of the current analysis, it was assumed that current waterside lime and limestone sources would continue to be used, but that by around 2030, new resources would begin to be developed to accommodate the expanding market for scrubber limestone. It was assumed that this limestone would access the inland waterways at key points along the ORS. It was further assumed that if receiving plants are located in the same navigation pool as the newly-developed limestone resources, the plants would receive this material by overland modes.

3.3.3 Coking Coal

ORS coal movements to coking facilities amounted to about 8.7 million tons and accounted for about 6 percent of total coal traffic in 2006. Through the EDM reach, by way of comparison, coking coal totaled 6.6 million tons and comprised around 40 percent of total coal traffic. The Department of Energy forecasts a decline in domestic consumption of coking coal as well as a reduction in domestic coking capacity. This occurs for a variety of reasons. Raw steel production from integrated steel mills is expected to continue to be displaced by production from steel minimills, which require no coke. Increased imports of both coke and semi-finished steel products are expected to occur. The quantity of coke required per ton of pig iron produced is expected to continue to decline as process efficiency improves and innovations such as injection of pulverized steam coal into blast furnaces are increasingly used. Additionally, coking facilities are expected to come under increasing pressure as environmental regulations evolve.

As an initial step in developing the coking coal traffic forecasts, forecasts of domestic metallurgical coal consumption were developed independently and outside the GEM framework, based on forecasts of domestic iron and steel production and other factors. These forecasts then became input to the modeling process. Once these forecasts were developed, they were coordinated with DOE's forecasts of domestic metallurgical coal consumption. LTI's Base Case metallurgical (coking) coal consumption forecast along with industrial and export coal is displayed in Table 3-4. The finished Base Case metallurgical coal consumption forecasts show domestic metallurgical coal consumption diminishing from about 23 million tons in 2006 to about 18 million tons in 2030, an annual rate of decline of about 1 percent. After 2030, the LTI forecast shows metallurgical coal consumption remaining at the 18 million ton level through the end of the forecast period, representing an overall rate of decline of about 0.4 percent. Because domestic metallurgical coal forms a relatively small part of total coal consumption, the High Case forecast was generated using a simplified approach. The High Case forecast simply added 5 million tons to the Base Case for forecast years. The Low Case was the same as the Base Case.

TABLE 3-4 - Base Case Coking, Industrial and Export Coal Consumption Forecasts #9* (Million Tons)**

Year	Coking Coal	Industrial Coal	Export Coal
2006	23	61	50
2010	23	64	71
2015	21	60	45
2020	20	59	34
2025	20	58	35
2030	18	58	35
2050	18	58	35
2070	18	58	35
Annual Growth	-0.4	-0.1	-0.5

SOURCE: Leonardo Technologies (LTI)

The ORS waterway traffic forecasts for metallurgical coal were generated using growth rates from the domestic consumption forecasts for Base Case, High Case and Low Case scenarios. These growth rates were applied to a base year tonnage consisting of a composite of ORS movements to coking facilities for the 2004-2006 period.

3.3.4 Industrial Coal

Industrial steam coal movements totaled about 11.3 million tons and accounted for about 8 percent of total coal traffic in 2006. Similarly, within the EDM reach industrial coal accounted for 1.1 million tons or about 7 percent of total coal traffic. The primary types of industrial facilities receiving ORS coal are cement plants, aluminum plants and other manufacturing facilities. Boiler replacements and increased implementation of cogeneration will support continued usage of coal on the part of industrial users, but overall, largely because of environmental requirements, coal usage by industrial users is expected to diminish. The DOE forecast of industrial coal usage shows industrial usage diminishing by about 0.2 percent per year between 2006 and 2030.

Similar to coking coal, LTI's forecast of industrial coal consumption was developed independently, outside of the GEM, and then used within GEM to assure balance in coal supply and demand in the modeling process. The LTI Base Case estimate of industrial coal consumption reaches a level of about 58 million tons by 2030, which represents an annual reduction of about 0.2 percent. After 2030, the LTI estimate shows industrial coal consumption remaining at the 58 million ton level through the end of the forecast period. Overall, the annual rate of decline in industrial coal consumption is about 0.1 percent (Table 3-4). The High Case was handled in a highly simplified fashion by adding 5 million tons to the Base Case. The Low Case was again, the same as the Base Case.

Waterway traffic forecasts for the ORS were generated using the annual rate of change from LTI's forecast for the Base Case, High Case and Low Case scenarios. These rates of change were applied to a composite of movements to industrial facilities for the period 2004-2006.

3.3.5 Export Coal

Examination of historic data on U.S. exports shows that U.S. export markets have been subject to a measure of volatility. Except for certain specialty markets, especially metallurgical coal markets, the U.S. has been viewed as a swing supplier, or, more accurately, a supplier of last resort in most export markets. U.S. coal exporters have been subject to intense and growing competition from other coal exporting countries, most notably, Venezuela, Columbia and South Africa in European markets, and Australia and Indonesia in Asian markets. Many opportunities for U.S. exporters have arisen because of infrastructure, political, or other problems in other coal producing/exporting countries. In recent years, U.S. exporters have benefited in some measure from the surge in demand in China and India coupled with supply problems in South Africa and Australia.

Like the coking and industrial coal, export coal forecasts were developed outside of the modeling process and then used as input to the GEM. The export forecasts were developed through an independent analysis of existing and potential export markets for steam and metallurgical coal followed by comparison/coordination with DOE results.

After an initial spike in U.S. coal exports attributable to demands in the Far East, the LTI forecast shows export coal reaching a level of about 35 million tons by 2030, representing a rate of decline of about 0.4 percent from 2006. After 2030, coal exports are held constant at the 35 million ton level through the end of the forecast horizon. Overall, exports are shown to decline at a rate of 0.5 percent year over the forecast horizon. The High Case forecast was developed by adding 5 million tons to the Base Case forecasts. The Low Case, again, was the same as the Base Case.

Similar to the U.S. export market, the ORS has experienced considerable volatility in export traffic. The ORS, in fact, has been viewed as a kind of routing of last resort within a supplier of last resort. In 2006, export tonnage originating on the ORS totaled about 1.6 million tons (1 percent of total coal traffic), with only about 133,000 tons of that transiting the EDM reach (about 0.8 percent of total coal traffic). Exporters have typically turned to the ORS when U.S. coastal ports are at or near capacity.

As a first step in the traffic forecasting process, export movements were identified from the Waterborne Commerce data for the period 2004-2006. Once that was accomplished the national rates of growth for export coal traffic were applied to a composite of export coal movements for the 2004-2006 period.

3.3.6 Coke

Coke is typically included in the coal and coke group. A majority of the coke traffic moving on the ORS is petroleum coke rather than coke produced from coal. Coke produced from coal is brittle and deteriorates in transportation, and shippers try to avoid long-distance transport and transloading, where possible. ORS coke traffic totaled about 3.5 million tons in 2006, which was about 2 percent of tonnage in the coal and coke group. In the EDM reach, coke traffic totaled about 138,000 tons or about 1 percent of the total in the coal and coke category. The major recipients of ORS coke movements are industrial and utility plants where they are used in electricity generation. Other manufacturing usages are more limited.

ORS coke movements to utility plants were forecast within the GEM modeling process, discussed previously. Coke movements to coking plants were forecast in a manner similar to coking coal. Movements to all other industrial facilities were forecast in a manner similar to industrial coal.

3.3.7 Coal-to-Liquids

In addition to utility steam coal, industrial coal, coking coal export coal and coke, LTI developed independent forecasts of coal-to-liquids production/consumption. Little, if any, of this production takes place currently, although the technology exists for future development. It is expected that petroleum supply pressures will eventually favor the development of these facilities. It is believed that coal-to-liquids plants would be developed close to coal production sites in order to avoid the problem of having to transport coal long distances to production facilities. Because of the uncertainty surrounding the expected locations of coal-to-liquids plants and the nature of the commodities requiring transport, no traffic associated with coal-to-liquids development was forecast.

3.4 NONCOAL COMMODITY FORECASTING

3.4.1 Introduction

Noncoal commodity traffic refers to all other commodities except coal, coke and the sorbent materials (i.e., lime and limestone) used in coal desulfurization. The forecasts of noncoal commodities was accomplished using statistical time series techniques. For informational purposes, the time series techniques were actually applied to all commodities, but since a separate, more rigorous analysis was conducted for coal, coke and sorbent materials, only the time series analyses conducted for the other commodities were ultimately used.

For the purposes of the time series analyses, the individual five-digit commodities were assigned to one of thirteen groups, the notion being that commodities in a group should share common demand and supply drivers. Ultimately, the commodities were re-grouped into the traditional nine-group classification scheme, specifically coal and coke, petroleum fuels, crude petroleum, aggregates, grains, chemicals, ores and minerals, iron and steel and all other, for reporting purposes. The following paragraphs present a discussion of the individual commodity groups identified as noncoal commodities. This is followed by a discussion of the forecasting methodology.

3.4.2 Petroleum Fuels and Crude Petroleum

Petroleum fuels and crude petroleum totaled 13.0 million tons on the ORS in 2006, or about 5 percent of total traffic. More than 95 percent of this traffic is petroleum fuels; crude petroleum has nearly disappeared from the ORS since the opening of crude oil pipeline links to the Gulf Coast in the early 1970s. Petroleum fuels and crude petroleum traffic transiting the EDM reach totaled only 434,000 tons in 2006 which was about 2 percent of the total.

Currently, only three refineries have direct access to the ORS for shipment and receipt of petroleum products. The largest of these is Marathon’s 226,000 barrel per day refinery at Catlettsburg, Kentucky. The others include Countrymark Cooperative’s 23,000 barrel per day refinery at Mt. Vernon, Indiana and Ergon Energy’s 20,000 barrel per day refinery at Newell, West Virginia. Marathon’s 204,000 barrel per day refinery at Robinson, Illinois has pipeline access to the ORS through Mt. Vernon, Indiana, and Louisville and their 78,000 barrel per day refinery at Canton, Ohio has access to the ORS at Midland, Pennsylvania.

The ORS competes with petroleum product pipelines for the distribution of petroleum products in the ORB. The opening and expansion of important petroleum product pipelines into the ORB from southeastern sources, as well as the east coast, has dampened growth of waterborne petroleum products traffic since the 1970s. The newest pipeline competitor for ORS traffic is the Cardinal Products Pipeline, which was completed in 2003 and connects Marathon’s Catlettsburg, Kentucky, refinery to a distribution terminal in Columbus, one of the Midwest’s fastest growing petroleum products markets.   Some markets served out of Columbus would previously have been served out of waterside terminals on the Ohio River.

Typically, waterborne petroleum fuels traffic on the system originates in the middle Ohio Valley and moves to petroleum product terminals throughout the ORS. From waterside terminals products would typically move to nearby tank farms for local/regional distribution. For terminals along the lower Ohio or the Tennessee or Cumberland rivers or for specialty product movements, traffic sometimes originates along the Gulf Coast.

3.4.3 Aggregates

ORS aggregates traffic is made up primarily of crushed limestone, sand and gravel, and building stone. This group also includes limestone sorbent material used in coal desulfurization, which is linked to utility steam coal for forecasting purposes. This commodity group was the second largest commodity group on the ORS in 2006, accounting for about 44.9 million tons or 17 percent of total traffic.   Within the EDM reach, aggregates totaled 2.4 million tons, which was only about 10 percent of total tonnage.

Limestone deposits are widespread throughout the ORB, with vast reserves underlying the Ohio and Tennessee river basins. The mineral content, as well, is suitable to a wide range of uses, although the availability of material suitable to specialized uses, such as coal desulfurization, is more limited.   Sand and gravel deposits are more limited in their geographic scope than limestones, with most of the better deposits being located in the northern, glaciated portions of the basin.

Sand, gravel and limestone are used principally in the construction industry as aggregate materials. Limestone is also used in cement and lime manufacturing, and as flux material in the steel manufacturing process, among other uses. The use of limestone is as a sorbent material in utility plant coal desulfurization processes is a relatively recent development.

Sand and gravel and crushed limestone are low-priced commodities that ordinarily do not withstand high transportation costs. It is advantageous for sand and gravel and limestone producers to be located as close as possible to their market areas, with truck being the primary mode of delivery.   An important exception to this is what are described as “aggregate poor” areas in the Southeast, which have long relied on the ORB as a supply area for their aggregate needs.   Waterborne sand and gravel traffic on the ORS is frequently short-haul traffic from dredge sites.   Specialized uses of limestone make it capable of absorbing higher transportation costs. Construction limestone on the ORS typically travels relatively short distances, while material with more specialized uses, e.g. coal desulfurization or cement manufacturing can travel farther.

3.4.4 Grains

Grains traffic on the ORS is made up primarily of corn, wheat and soybeans.   In year 2006, grains traffic amounted to about 11.6 million tons which was about four percent of total traffic. Grains traffic was absent from the EDM reach.

Corn, wheat and soybean production in the ORB states for calendar year 2007 is summarized in Table 3-5. Within the ORB, the states of Illinois, Indiana and Ohio are a part of the rich Corn Belt region. A large majority of the farmland in these three states is in crops, whereas in other ORB states, pastureland is much more prevalent. Those three states produced nearly one third of the nation's corn output and an equal share of the nation's soybean output in 2007. Illinois,

TABLE 3-5 - Corn, Wheat and Soybean Production in the ORB States and the U.S., 2007 (Millions of Tons)

State	Corn	% of U.S.	Wheat	% of U.S.	Soybeans	% of U.S.
Alabama	0.6	0.2	0.1	0.2	0.1	0.1
Illinois	63.0	17.7	1.4	2.4	8.4	10.8
Indiana	26.9	7.5	0.6	1.0	6.3	8.2
Kentucky	4.7	1.3	0.3	0.6	0.9	1.1
Ohio	14.7	4.1	1.3	2.2	5.7	7.4
Pennsylvania	3.3	0.9	0.3	0.4	0.5	0.7
Tennessee	2.3	0.7	0.3	0.5	0.6	0.7
West Virginia	0.1	0.0	0.0	0.0	0.0	0.0
ORB States	115.6	32.4	4.3	7.2	24.8	32.0
U.S.	356.7	100.0	59.8	100.0	77.5	100.0

SOURCE: U.S. Department of Agriculture

Indiana and Ohio produce corn and soybeans far in excess of their own needs. Surpluses are shipped to deficit regions and the export market. Wheat output is much less prominent.

The most important usage for ORB corn production is as feed for poultry and livestock. Large volumes of corn for animal feed are shipped from Illinois, Indiana and Ohio to domestic deficit areas. Corn, wheat and soybeans all move in considerable volumes to grain processors in the Midwest and Southeast. Corn is typically processed into sweeteners, oils and animal feed. Wheat is processed into flour and soybeans into soybean meal which is also used in animal feed. A growing market for corn is the production of corn-based ethanol. Large volumes corn and soybeans enter the export market both directly and indirectly, following processing. Roughly half of the wheat raised in the ORB states is typically supplied directly to the export market

Of the 11.6 million tons of grains moving on the ORS in 2006, approximately 81 percent of this traffic was outbound from the ORS; 12 percent was inbound to the system, and about 7 percent was internal to the system. Outbound traffic was destined largely for the export market. Inbound traffic was destined largely for grain processors on the Tennessee River. Internal traffic, which was less than one million tons, was destined for internal processors along the mainstem Ohio.

3.4.5 Chemicals

Chemicals traffic on the ORS is made up primarily of industrial and agricultural chemicals. Chemicals traffic amounted to about 10.5 million tons in 2006, which was nearly 5 percent of total traffic. Chemicals traffic transiting the EDM reach totaled about 824,000 tons or about 3 percent of total traffic.

Industrial chemicals are chemical feedstocks that are used principally in the manufacture of other chemicals. Clusters of industrial chemical plants developed along the ORS over many years, the most important of these being along the Lower Monongahela and Upper Ohio, in the Parkersburg area, in the Kanawha Valley, in the Louisville area, around Calvert City, Kentucky and around Decatur, Alabama. Most of the plants on the ORS, with the exception of the chloralkali plants, are downstream chemical plants that process basic chemicals into intermediate chemical products. As downstream plants, their degree of dependence on waterway transportation varys. Higher value added facilities typically receive inputs in less-than-barge-load quantities, which makes waterway transportation a less viable option. Where waterway transportation is an option, chemical feedstocks for these facilities (and other manufacturing facilities), are typically transported by barge from the chemical complexes on the Gulf Coast or from sources along the ORS.

The agricultural chemicals, for the most part, are the chemical fertilizers. Similar to the industrial chemicals, most of the agricultural chemicals on the ORS originate at refinery complexes on the Gulf Coast. Most of the chemical fertilizers on the ORS move to fertilizer terminals for distribution to local and regional retailers.

3.4.6 Ores and Minerals

Traffic in the ores and minerals group includes commodities such as salt, natural and synthetic gypsum, and bauxite, with lesser amounts of manganese, clay, and other ores and minerals. Ores and minerals traffic in 2006 amounted to 9.0 million tons, which was about 3 percent of total traffic. For the EDM reach, ores and minerals totaled about 977,000 tons, which was 4 percent of total traffic.

Most of the nation’s major salt deposits are located in the Southeast, particularly along the Gulf Coast. Salt has widespread use as road salt in the Ohio River Basin as well as a chemical feedstock at ORS chloralkali plants for the production of chlorine and sodium hydroxide. Salt is distributed by barge and rail to ORS population centers and chemical complexes.

Bauxite, the primary raw material used in aluminum manufacturing, was produced for many decades in central Arkansas. Other operations were located in Alabama and Georgia. With domestic sources of bauxite nearly exhausted, the aluminum producers have turned increasingly to foreign sources of the mineral in recent years. Bauxite, the primary raw material used in aluminum manufacturing, is almost entirely imported at this point, and moves to refiners in Louisiana and Texas for processing into alumina. From there the alumina is typically barged to smelters, five of which are waterside plants on the ORS.

Gypsum, both natural and synthetic, is now used largely in the production of wallboard. Synthetic gypsum is a byproduct of coal desulfurization at utility plants. A growing number of wallboard plants have developed in recent years, including some along the ORS, which rely on supplies of synthetic gypsum from utility plants. The material generally moves by rail or barge to the manufacturing facilities.

3.4.7 Iron and Steel

Commodities in the iron and steel group include iron ore; pig iron; intermediate iron and steel products, including iron and steel ingots and ferroalloys; and iron and steel scrap. Iron and steel traffic on the ORS totaled about 14.6 million tons in 2006, which was about five percent of total traffic. This was more than double the levels of the early 1990s. Iron and steel traffic on the EDM reach totaled approximately one million tons or four percent of total tonnage.

The domestic steel industry, the ORB industry included, has undergone some fairly massive restructuring over the last several decades. The restructuring has been the result of reduced rates of domestic economic growth, substitution of other materials for steel in manufacturing processes; technological changes in steel usage; lower rates of infrastructure development; increasing competition from imports; and environmental regulations. Integrated steel mills, in addition, have faced intense intra-industry competition from the development of numerous mini-mill operations. As a result, many integrated mills have closed in the face of these pressures. On the ORS only four waterside integrated steel mills remain in operation, out of about a dozen that were operating as recently as 1980. New technologies are further reducing the role of integrated steel mills in the industry. For example, direct reduction technology eliminates the need for pellet plants, coke ovens, blast furnaces, and basic oxygen furnaces.

Most of the iron ore and a sizeable portion of the intermediate iron and steel products moving on the ORS were imported in 2006. The iron ore moved from Gulf Coast ports to the remaining integrated mills on the ORS. The intermediate products moved both from the Gulf Coast ports and from ORS mills to steel service centers and to other ORS manufacturing plants. Iron and steel scrap generally originates at urban areas on the ORS and is transported to basin mini-mills.

3.4.8 All Others

The all others category accounted for about 16.2 million tons, or about six percent of total ORS commodity traffic in 2006. Through the EDM reach, the total was about one million tons or four percent of total tonnage. The primary commodities in this group are cement, lime, asphalt, animal feed, oil seeds, lubricating oils and greases, waterway improvement materials, slag, vegetable oils, fabricated metal products, and woodchips. These 11 commodities accounted for about 92 percent of the tonnage in this category. Cement, lime, asphalt and animal feed alone accounted for more than 55 percent of total traffic in the all others category.

The ORB states currently have 24 portland cement plants located within their boundaries, primarily near the population centers, and seven of those are located along the ORS. In addition to the production facilities, numerous terminals along the ORS regularly handle cement. Most of the cement received at waterside facilities moves a short distance by truck to concrete ready mix plants.

Out of the 25 lime plants in the ORB states, only three are located along the ORS. The manufacture of lime is a limestone-intensive process, with two tons of limestone required for every ton of lime produced. Consequently, lime plants are typically located close to their limestone sources. Lime is used in a wide variety of processes, the most important being metallurgical, chemical and coal desulfurization processes. In the ORB, lime is typically transported relatively long distances by rail and barge to manufacturing facilities and utility plants.

Asphalt that moves on the ORS typically originates at the refinery complexes in the Middle Ohio Valley or along the Lower Mississippi/Gulf Coast. Asphalt typically moves long distances in the ORB to asphalt terminals near population centers. Transportation is usually by rail or barge, since asphalt has special transportation requirements, i.e. heated barges or rail cars.

Animal feeds that move on the ORS originate at processing plants along the Ohio River main stem and especially along the Tennessee River. These consist of corn gluten feed and soybean meal and are destined almost entirely for the export market. Processing plants along the ORS typically account for about one-fourth of U.S. animal feeds exports.

3.4.9 Forecasting Methodology

As indicated previously, the forecast of noncoal commodities was generated using statistical time series techniques. In actuality, this forecast was not confined to the noncoal commodities. For informational purposes, the statistical forecast was extended to include coal and coke and the sorbent materials (lime and limestone) used in coal de-sulfurization. This section describes the procedures involved in generating these forecasts in a generalized fashion. Detailed descriptions of the forecast procedures, the models developed and associated diagnostics are provided in Addendum 2.

For the purposes of this forecasting effort, the annual ORS dock-to-dock traffic data contained in the Waterborne Commerce Statistics (WCSC) was used. Commodity traffic is defined as ORS traffic if it uses all or part of the ORS in its routing. In this instance a record in the WCSC data consists of an annual movement of a commodity (five-digit) between an origin dock and a destination dock by way of a particular waterway routing. In any given year, this traffic can total 10,000-12000 individual movements. Initially, the data for calendar years 1990-2006 were made available for the analysis because these data were the most readily accessible and because there were fewer complications related to commodity codes, port-dock codes and other issues. Subsequently, the data set was extended to include calendar years 1980-2006.

The WCSC data were divided into 13 commodity groupings for the purposes of forecasting. These groups are displayed in Table 3-6. In economic analyses, commodity groups should be defined in terms of demand and supply considerations, the notion being that commodities in a group should share common demand and supply drivers. The groups in Table 3-6 appear to follow this principle reasonably well.

Originally, the commodity grouping list contained only 11 groups. To increase the usefulness of the econometric forecasting approach, it was determined that utility steam coal (electric coal) and sorbent materials (electric lime/limestone) should be isolated and shown separately. It is also noteworthy that the commodity groups in Table 3-6 represent summations of the old 4-digit (pre-1990) commodity classifications. Retaining the old 4-digit commodity codes enables the splicing of the pre- and post-1990 databases. Additionally, it facilitates the construction of times series data in project documentation.

TABLE 3-6 - Commodity Groupings Used in Forecasting

	Commodity Group	2006 Mtons	% Share
1	Coal and Coke (default)	23.9	8.8
2	Crude Petroleum	0.7	0.3
3	Petroleum Products	13.6	5.0
4	Agricultural Chemicals	2.6	1.0
5	Industrial Chemicals	4.1	1.5
6	Forest Products	1.0	0.4
7	Non-Metallic Minerals	8.2	3.0
8	Metals	18.4	6.8
9	Farm Products	15.4	5.7
10	Other	0.1	0.0
11	Construction Materials	52.2	19.3
12	Electric Coal (Utility Steam Coal)	127.1	47.0
13	Electric Lime/Limestone (Sorbent Materials)	3.4	1.3
	TOTAL	270.7	100.0

As a part of the current forecasting effort, a number of forecasting techniques were considered and evaluated as to their usefulness. Forecasting techniques can be placed into broad groupings such as single equation versus multiple equation methods and structural versus non-structural approaches. Specific techniques considered included single equation time trend models; local trend models; Box-Jenkins ARIMA (autoregressive moving average) models; vector-autoregressive (VAR) models; error correction models; structural vector-autoregressive (VAR) models; and restricted vector-autoregressive (VAR) models.

Ultimately, for the purposes of the current forecasting exercise, the Box-Jenkins ARIMA models were pursued because these models were considered to produce the best forecasts in preliminary analyses. Three time series models with a Box-Jenkins approach are used. Two of the models forecast a constant growth rate and one forecasts a declining growth rate. The distinction between the constant growth rate and declining growth rate models is that for the constant growth rate models, variables are expressed as logs, while in the declining growth rate models the variables are expressed as actual values. The constant growth rate models are developed with a stochastic trend as well as a deterministic trend. The stochastic trend means essentially that calculations are performed using the logs of the differences between historic observations. The deterministic trend means that the calculations are performed using the log of actual observed values.

In an effort to improve the forecasts, additional explanatory variables were added to the models. A variety of variables were considered, including personal income, total employment, sectoral employment and various price deflators. Ultimately, real personal income and average real wages entered into the forecasting. The data on these variables are from the Bureau of Economic Analysis (BEA) and are collected at the level of the economic area (EA) as defined by BEA.

In the course of this analysis, it was determined that the traffic demand forecasts could potentially be improved by regionalization. To this end, nine geographic regions were defined that represent important shipping and/or receiving regions on the waterway. These include the Monongahela/Allegheny rivers; the Upper, Middle and Lower Ohio; the Kanawha River; the Big Sandy River; the Green River; the Tennessee/Cumberland rivers and all waterways outside of the ORS.

With the regions defined, the econometric analyses were conducted for three different data aggregations. The first of these aggregations was the overall ORS, including the Ohio River main stem and all of its navigable tributaries as a unit. This resulted in 13 separate analyses, corresponding to the 13 commodity groups. In the second instance, the traffic data were aggregated and the analysis conducted over destination regions. The number of potential analyses was expanded to 117 (9 regions and 13 commodity groups). In the final effort, the data were aggregated over origin-destination regions, which resulted in 1053 (9 regions x 9 regions x 13 commodity groups) potential separate analyses.

The needs of project economic analysis required that a selection be made from among the several forecast approaches. The first selection to be made was between the constant growth and declining growth models. A feature of the constant growth models is that, at some point in the 70-year forecast horizon, increasing tonnages begin to increase exponentially, reaching levels that are clearly unreasonable. For the declining growth models, increasing tonnages increase at a decreasing rate until, at some point in the future, the growth rate is equivalent to zero. Declining growth appears to be the more reasonable outcome, and in fact, is the pattern that has prevailed historically on the ORS. For this reason, the declining growth model was selected as the most reasonable forecasting approach.

A second selection was required from among the regional aggregations. For this purpose a distinction was made between commodities that respond more to demands in regional markets and those that are linked more closely to national or international markets. Specifically, the petroleum products, crude petroleum, agricultural chemicals, construction materials, electric coal and electric lime/limestone are considered to be linked closely to regional demand drivers. For this reason, the forecasts based on destination regions were selected for these commodity groups. The other commodity groups are associated, for the most part, with manufacturing activities that reach beyond regional markets to broader national or even international markets. For this reason, the system forecasts for these commodity groups were selected for use, because the system forecasts are considered to be more reflective of future developments in entire industries.

In addition to the Base Case forecast, Low and High Case scenarios were also developed from the time series results. The High Case and Low Case forecasts were developed by reference to the Base Case. Essentially, the High and Low cases represent modifications of the slope of the Base Case forecast. The High and Low cases were developed by adding or deducting one standard error from the Base Case result.

3.5 FORECAST RESULTS

3.5.1 Total Traffic Demand

Total traffic demands for the ORS, the Ohio River main stem and the EDM reach as well as Emsworth, Dashields and Montgomery locks are displayed in Tables 3-7 and 3-8 [1]. Traffic demand is the projected future traffic that could realize a cost savings if navigation system constraints are not considered. In other words, it is the traffic that could be expected to materialize in the absence of navigation system constraints. Figures 3-1 - 3-4 show historical and projected traffic for the Ohio River mainstem and the Upper Ohio projects under each scenario.

TABLE 3-7 - Projected Traffic Demands for the EDM Reach, Ohio River and ORS, 2006-2070 (Million Tons)

	EDM Reach			Ohio River			ORS		
	High	Base Case	Low	High	Base Case	Low	High	Base Case	Low
Actual									
1980	NA	NA	NA	174.9	174.9	174.9	200.5	200.5	200.5
2006	24.8	24.8	24.8	241.5	241.5	241.5	270.7	270.7	270.7
Projected									
2010	29.4	27.5	27.7	259.1	255.6	254.8	286.3	283.6	282.2
2020	32.1	32.0	34.1	319.4	301.8	279.2	351.5	334.4	300.9
2030	42.1	29.0	38.5	346.5	297.9	272.7	378.9	329.9	289.1
2040	54.8	39.5	36.3	400.0	327.5	254.3	436.7	360.2	268.1
2050	57.8	36.9	33.9	430.5	358.1	272.9	470.2	388.7	291.7
2060	54.7	38.3	32.2	434.3	381.1	283.7	479.4	413.3	298.8
2070	72.4	30.3	31.0	432.2	397.9	277.5	485.1	429.2	291.6
Annual Growth									
1990-06	-	-	-	1.25	1.25	1.25	1.16	1.16	1.16
2006-70	1.69	0.32	0.35	0.91	0.78	0.22	0.92	0.72	0.12

SOURCE: COE Waterborne Commerce Statistics; Planning Center for Expertise in Inland Navigation.

The Ohio River mainstem typically accounts for 85-90 percent of the traffic on the Ohio River System. Ohio River traffic trends, accordingly, are generally reflective of the overall system.

[1] It should be noted that the traffic demand forecasts are presented in 10-year increments for convenience. Actual system modeling is done on an annual basis. (CMT 3886780)

TABLE 3-8 - Projected Traffic Demands for the Upper Ohio Projects, 2006-2070 (Million Tons)

	Emsworth			Dashields			Montgomery		
	High	Base Case	Low	High	Base Case	Low	High	Base Case	Low
Actual									
1980	20.0	20.0	20.0	21.0	21.0	21.0	20.4	20.4	20.4
2006	20.6	20.6	20.6	20.7	20.7	20.7	20.4	20.4	20.4
Projected									
2010	24.4	22.7	22.9	24.9	23.2	23.4	25.8	24.1	24.3
2020	25.6	24.6	26.8	26.3	25.2	27.4	28.1	28.1	30.5
2030	34.9	22.1	30.1	35.6	22.9	30.7	37.9	24.8	34.7
2040	45.2	31.2	27.3	46.0	32.0	28.1	50.2	34.9	32.0
2050	47.5	29.3	23.8	48.4	30.1	24.6	52.7	32.1	29.2
2060	43.3	29.9	22.5	44.4	30.9	23.4	49.3	33.1	27.1
2070	60.7	21.9	21.2	61.8	23.0	22.2	66.6	24.7	25.6
Annual Growth									
1980-06	0.11	0.11	0.11	-0.06	-0.06	-0.06	0.00	0.00	0.00
2006-70	1.70	0.10	0.05	1.72	0.16	0.11	1.86	0.30	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center for Expertise in Inland Navigation

FIGURE 3-1

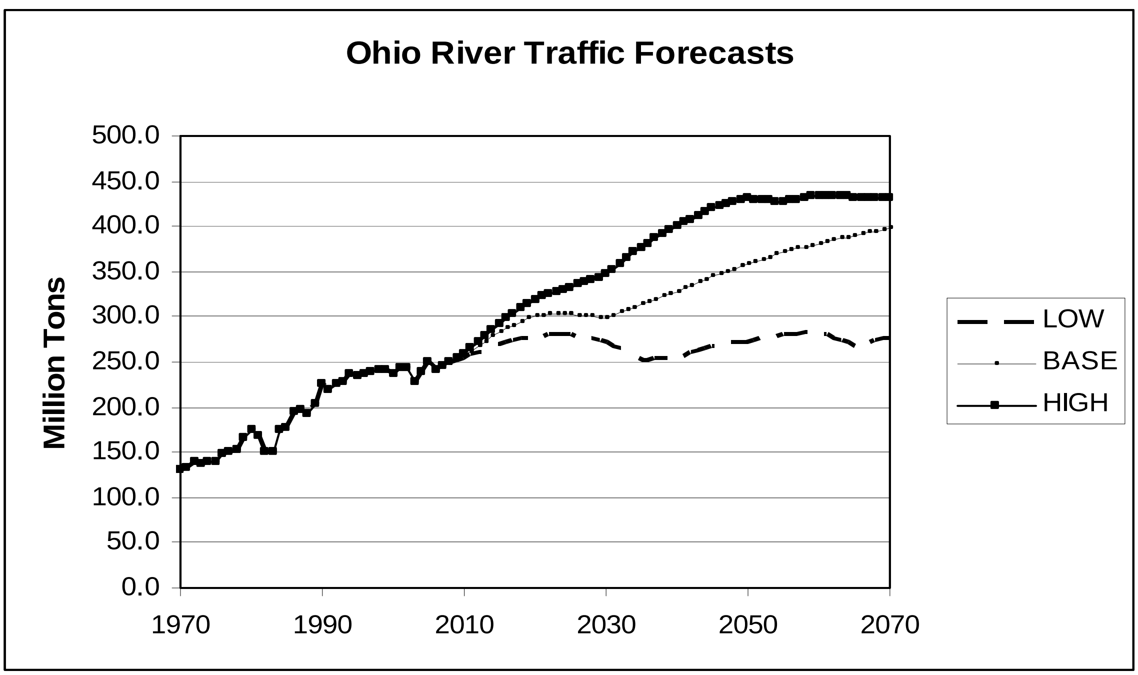


FIGURE 3-2

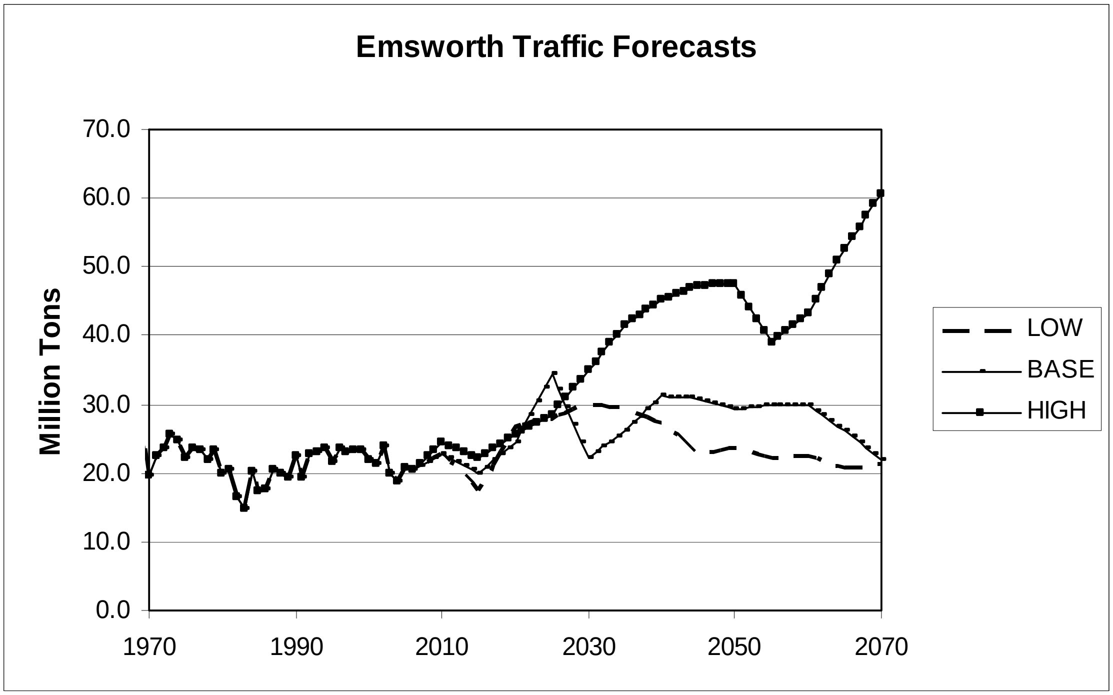


FIGURE 3-3

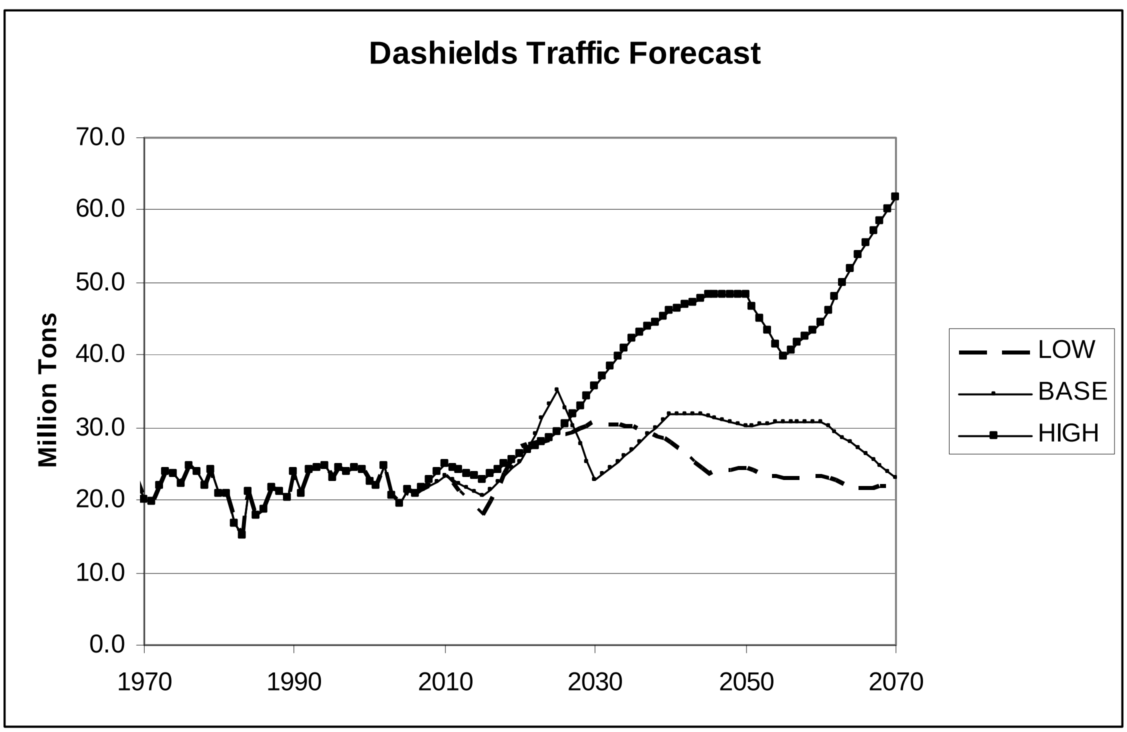
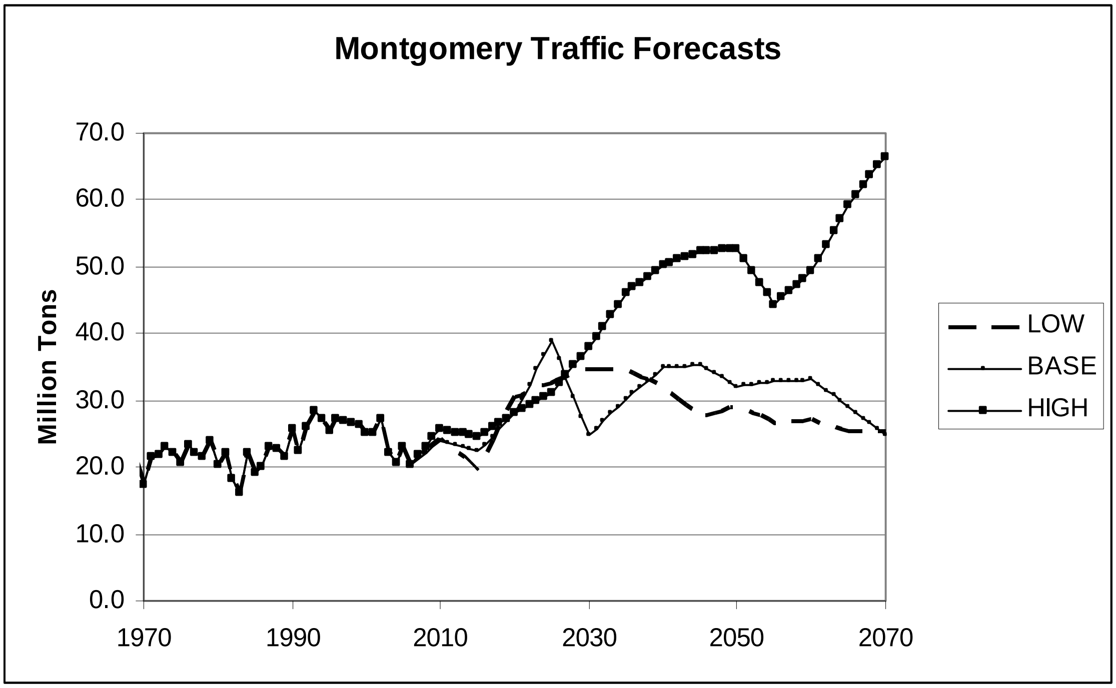


FIGURE 3-4



For the Ohio River, the range in the forecasts for 2030 is between 272.7 million tons in the Low Case and 346.5 million tons in the High Case. By 2070, the range is between 277.5 and 432.2 million tons for these same scenarios. Annual growth rates for the 2006-2070 period range between 0.22 and 0.91 percent, compared to the historical (1980-2006) growth rate of 1.25 percent.

Forecast results for the EDM reach show substantially different patterns from the Ohio River and the overall system. Because of coal switching and interactions that arise in different scenarios, the rank ordering of the forecast scenarios is not necessarily the same as the Ohio River and ORS ordering in any given year. For the EDM reach, the range in the forecasts for 2030 is between 29.0 million tons in the Base Case scenario and 42.1 million tons in the High Case. By 2070, the range is between 30.3 million tons in the Base Case and 72.4 million in the High Case. Annual growth rates for the 2006-2070 period range between 0.32 and 1.69 percent.

Given the level of commonality of traffic among the Emsworth, Dashields and Montgomery locks, the forecast patterns for the individual locks is largely similar to that of the EDM reach. It should be noted that historic traffic trends at the Upper Ohio projects are essentially flat, while the forecasts call for some level of mid-term growth (relative to the base year) in every forecast scenario. This is supported, in part, by DOE's outlook for Northern Appalachian coal production. Since the early 1970s, coal output in the Northern Appalachian producing region has been disadvantaged by the requirements of the Clean Air Act, given that coal from this region is generally in the medium-to-high sulfur range. As scrubbing becomes more and more widespread and as Central Appalachian low sulfur resources continue diminish, DOE forecasts an increase in North Appalachian coal production amounting to about 1.5 percent per year between 2006 and 2030.

3.5.2 Traffic Demands by Commodity Group

Traffic demands by commodity group for the EDM reach along with Emsworth, Dashields and Montgomery locks are displayed in Tables 3-9 and 3-10. Coal continues to be a major

TABLE 3-9 - Projected EDM Reach Traffic by Commodity Group, 2006-2070 (Thousand Tons)

	Actual 2006	2010	2020	2030	2040	2050	2060	2070	Annual Growth 2006-70
High									
Coal & Coke	18173	21417	22959	32330	43822	45532	41222	57650	1.82
Petroleum Fuels	427	375	286	289	291	296	302	308	-0.51
Crude Petroleum	7	6	6	6	6	6	6	6	-0.14
Aggregates	2420	3224	3853	3774	4274	4775	5275	5824	1.38
Grains	0	0	0	0	0	0	0	0	-
Chemicals	898	902	962	1022	1082	1142	1202	1262	0.53
Ores & Minerals	977	1243	1449	1654	1860	2065	2271	2477	1.46
Iron & Steel	1005	1229	1598	1967	2336	2705	3074	3443	1.94
All Other	894	963	970	1070	1147	1242	1359	1466	0.78
Total	24800	29359	32083	42112	54819	57763	54711	72435	1.69
Base Case									
Coal & Coke	18173	20010	23336	19678	29033	25303	25472	16317	-0.17
Petroleum Fuels	427	342	268	259	254	249	244	239	-0.90
Crude Petroleum	7	6	6	6	6	6	6	6	-0.14
Aggregates	2420	2951	3550	3634	4075	4556	5126	5697	1.35
Grains	0	0	0	0	0	0	0	0	-
Chemicals	898	898	944	990	1036	1082	1127	1173	0.42
Ores & Minerals	977	1234	1408	1582	1756	1930	2104	2278	1.33
Iron & Steel	1005	1223	1571	1918	2266	2614	2962	3309	1.88
All Other	894	884	896	959	1026	1114	1213	1322	0.61
Total	24800	27548	31979	29027	39452	36853	38255	30342	0.32
Low									
Coal & Coke	18173	20020	25744	29666	26408	22916	20102	17803	-0.03
Petroleum Fuels	427	275	247	228	210	192	175	162	-1.51
Crude Petroleum	7	6	6	6	6	6	6	6	-0.14
Aggregates	2420	3211	3453	3462	3910	4457	5005	5552	1.31
Grains	0	0	0	0	0	0	0	0	-
Chemicals	898	894	924	955	986	1017	1048	1079	0.29
Ores & Minerals	977	1222	1358	1494	1629	1765	1901	2036	1.15
Iron & Steel	1005	1215	1538	1861	2184	2506	2829	3152	1.80
All Other	894	877	830	860	918	1008	1099	1190	0.45
Total	24800	27720	34100	38532	36250	33868	32165	30980	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center for Expertise in Inland Navigation

component of traffic on the EDM reach as well as on the Ohio River and ORS. Coal traffic in 2006 totaled 18.2 million tons. The 2070 forecast for the Upper Ohio ranges between 57.7 million tons in the High Case and 17.8 million tons in the Low Case. These traffic levels represent annual growth ranges between 1.82 and –0.03 percent relative to 2006. Also over the 2006-2070 timeframe, coal traffic increases as a share of total traffic under the High Case scenario, but diminishes under the Low Case. Under the High Case, coal traffic increases from 73 percent of total traffic in 2006 to about 80 percent, while under the Low Case it diminishes to about 58 percent. The key driver in the High Case is the relatively low level of nuclear development, while in the Low Case it is the carbon dioxide emissions limitations.

The forecast for petroleum fuels on the EDM reach diminishes under every forecast scenario, which is likely reflective of the growing reliance on pipeline distribution throughout the ORB region. The forecast of crude petroleum remains small (>7,000 tons) and essentially flat under

TABLE 3-10 - Projected Emsworth, Dashields and Montgomery Traffic Demand by Commodity Group, 2006-2070 (Thousand Tons)

	Actual	2030			2070			Annual Growth (%), 2006-70		
	2006	High	Base Case	Low	High	Base Case	Low	High	Base	Low
Emsworth:										
Coal & Coke	16,368	29,618	17,178	25,436	53,138	14,748	14,495	1.86	-0.16	-0.19
Petroleum Fuels	205	69	66	63	107	99	90	-1.02	-1.12	-1.27
Crude Petroleum	7	6	6	6	6	6	6	-0.14	-0.14	-0.14
Aggregates	1,308	1,456	1,348	1,210	1,923	1,879	1,829	0.60	0.57	0.53
Grains	0	0	0	0	0	0	0	-	-	-
Chemicals	731	831	805	776	1,026	954	876	0.53	0.42	0.28
Ores & Minerals	486	829	795	754	1,273	1,180	1,067	1.52	1.40	1.24
Iron & Steel	732	1,368	1,334	1,294	2,395	2,302	2,192	1.87	1.81	1.73
All Other	664	688	594	515	859	760	684	0.40	0.21	0.05
Total	20,501	34,865	22,127	30,056	60,726	21,929	21,241	1.71	0.11	0.06
Dashields:										
Coal & Coke	16,368	29,616	17,177	25,435	53,136	14,747	14,493	1.86	-0.16	-0.19
Petroleum Fuels	249	229	206	183	254	202	146	0.03	-0.33	-0.83
Crude Petroleum	7	6	6	6	6	6	6	-0.14	-0.14	-0.14
Aggregates	1,404	1,847	1,734	1,591	2,583	2,525	2,459	0.96	0.92	0.88
Grains	0	0	0	0	0	0	0	-	-	-
Chemicals	744	848	821	792	1,046	973	894	0.53	0.42	0.29
Ores & Minerals	527	925	886	839	1,412	1,306	1,178	1.55	1.43	1.27
Iron & Steel	761	1,435	1,400	1,358	2,512	2,414	2,299	1.88	1.82	1.74
All Other	677	719	622	541	896	790	705	0.44	0.24	0.06
Total	20,738	35,624	22,852	30,745	61,843	22,963	22,181	1.72	0.16	0.11
Montgomery:										
Coal & Coke	15,799	30,848	18,155	28,390	56,142	14,922	16,530	2.00	-0.09	0.07
Petroleum Fuels	332	288	259	228	308	239	162	-0.12	-0.51	-1.12
Crude Petroleum	7	6	6	6	6	6	6	-0.14	-0.14	-0.14
Aggregates	582	1,177	1,114	1,035	1,700	1,661	1,616	1.69	1.65	1.61
Grains	0	0	0	0	0	0	0	-	-	-
Chemicals	898	1,022	990	955	1,262	1,173	1,079	0.53	0.42	0.29
Ores & Minerals	909	1,497	1,432	1,353	2,248	2,070	1,853	1.42	1.29	1.12
Iron & Steel	1,005	1,960	1,911	1,854	3,430	3,297	3,140	1.94	1.87	1.80
All Other	893	1,069	958	859	1,464	1,320	1,188	0.78	0.61	0.45
Total	20,424	37,868	24,825	34,680	66,559	24,688	25,575	1.86	0.30	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center of Expertise in Inland Navigation.

all scenarios. Petroleum fuels traffic in 2006 reached 427,000 tons. The range in the forecasts for 2070 is between 308,000 tons in the High Case Scenario and 162,000 tons in the

Low Case Scenario, representing annual growth rates ranging between -0.51 and -1.51 percent respectively. Petroleum fuels diminishes as a share of total traffic under every scenario. In 2006, petroleum fuels was about 1.7 percent of total traffic. By 2070, petroleum fuels' share of total traffic is 0.4 percent in the High Case and 0.5 percent in the Low Case.

Aggregates traffic forecasts for the Upper Ohio increase under every scenario, reflecting expanding infrastructure investment as well as increased usage of limestone in coal desulfurization. A total of 2.4 million tons of aggregates moved on the EDM reach in 2006. The 2070 forecasts range between 5.8 million tons in the High Case and 5.5 million tons in the Low Case. Annual growth rates are between 1.38 and 1.31 percent, respectively. Aggregates diminishes as a share of total traffic in the High Case, but increases in the Low Case. In 2006, aggregates traffic was about 9.8 percent of total traffic. In 2070, aggregates accounts for between 8.0 (High Case) and 17.9 (Low Case) percent of total traffic.

In the past, grains movements on the EDM reach have been occasional and quite small in volume. Accordingly, no grains traffic is forecast for the EDM reach under any of the forecast scenarios.

Various types of chemicals transit the EDM reach and are frequently destined for eventual use in some segment of the steel and glass industries or as fuel additives. Chemicals tonnage totaled 898,000 tons in 2006. Forecasts for 2070 range between 1.3 million tons in the High Case and 1.1 million in the Low Case. The resulting annual growth is between 0.53 and 0.29 percent for these same scenarios. As of 2006, chemicals traffic made up around 3.6 percent of total traffic through the EDM reach. For 2070, the range is between 1.7 (High Case) and 3.5 (Low Case) percent of total traffic.

Ores and minerals on the EDM reach consists principally of salt, gypsum, clay, bauxite and manganese. In 2006, the group totaled just under 1 million tons. By 2070, the forecasts range between 2.5 million tons in the High Case and 2.0 million tons in the Low Case, representing annual growth rates of 1.46 and 1.15 percent, respectively. In 2006, the ores and minerals traffic comprised about 3.6 percent of total traffic. By 2070, the range in the forecasts shows ores and minerals comprising between 3.4 (High Case) and 6.6 (Low Case) percent of the total.

Traffic in iron and steel in the EDM reach typically consists of iron ore, pig iron, various iron and steel forms, ferroalloys and iron and steel scrap. Totaling just over 1 million tons in 2006, the range in the forecasts for 2070 is between 3.4 million tons in the High Case and 3.1 million tons in the Low Case. The projected annual growth rates range between 1.94 to 1.80 percent under these scenarios. The 2006 EDM reach iron and steel tonnage was about 4.1 percent of the total, while the forecasts show that iron and steel tonnage will range from 4.8 percent in the High Case to 10.2 percent in the Low Case.

On the EDM reach, the all other category consists largely of lubricating oils and greases, asphalt, fabricated metal products, building cement and lime. For 2006, traffic in the all other category totaled 894,000 tons. The forecast for 2070 shows all other traffic ranging from 1.5 million tons in the High Case to 1.2 million tons in the Low Case, with annual growth rates ranging from 0.78 to 0.45 percent. All other traffic on the EDM reach in 2006 was about 3.6 percent of the total, while the 2070 forecasts show all other traffic ranging between 2.0 percent in the High Case and 3.8 percent in the Low Case.

Again, because of the high percentage of shared traffic at EDM, traffic and trends for the individual locks bear many similarities to the EDM reach.

3.6 COMPARISON WITH PREVIOUS FORECASTS

Table 3-11 compares the current forecasts for the Ohio River with the previous forecasts completed in 2003. The traffic range for 2030 under the current forecasts is between 346.5 million tons under the High Case Scenario and 272.7 million tons under the Low Case. In the 2003 forecasts, the range is between 342.2 million tons under Utility-Based High and 286.1 million tons under Clear Skies. The current high forecast is slightly higher than the previous, while the current low forecast is substantially lower (>13 million tons). The traffic range for 2060 under the current forecasts is between 434.3 million tons in the High Case and 283.7 in the Low Case. The 2003 forecasts show a range between 443.2 million tons in the Utility-Based High scenario and 322.3 million tons under Clear Skies. In this instance, the current High Case scenario is nearly nine

TABLE 3-11 Current vs 2003 Traffic Demand Forecasts for the Ohio River, 2006-2060 (Million Tons)

	Current Forecasts			2003 Forecasts				
	High	Base	Low	Utility-Based High	Utility-Based	NAAQS	Clear Skies	Modified Clear Skies
Actual								
2006	241.5	241.5	241.5	241.5	241.5	241.5	241.5	241.5
Projected								
2010	259.1	255.6	254.8	273.3	273.3	267.0	235.1	271.3
2020	319.4	301.8	279.2	306.1	294.9	302.6	273.6	297.4
2030	346.5	297.9	272.7	342.2	323.2	327.8	286.1	320.5
2040	400.0	327.5	254.3	380.0	350.8	355.6	298.9	347.5
2050	430.5	358.1	272.9	403.4	368.0	373.1	310.6	364.6
2060	434.3	381.1	283.7	443.2	394.7	399.8	322.3	390.5
Annual Growth								
2006-30	1.52	0.88	0.51	1.46	1.22	1.28	0.71	1.19
2006-60	1.09	0.85	0.30	1.13	0.91	0.94	0.54	0.89

SOURCE: COE Waterborne Commerce Statistics; Planning Center of Expertise for Inland Navigation

million tons lower than Utility-Based High, while the Low Case scenario is nearly 39 million tons lower than Clear Skies. The annual growth rates in Table 3-11 show traffic under the current High Case scenario growing slightly faster than the 2003 Utility-Based High scenario

(1.52 vs 1.46 percent) over the short term (2006-2030), but slower (1.09 vs 1.13 percent) over the long term (2006-2060). The current Low Case scenario is shown to grow more slowly than the comparable low scenario (Clear Skies) from the 2003 forecasts over both the short term (0.51 vs 0.71 percent) and long term (0.30 vs 0.54 percent).

Addendum 1

to

Attachment 3

Forecast of Coal and Sorbent Materials Traffic Demands for the Ohio River Navigation System

Addendum 2

to

Attachment 3

Time Series Forecasts of Ohio River Traffic

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 4
Transportation Rate Analysis

12 April 2011

Executive Summary

Based on a sample of 1,552 movements, shippers on the Ohio River navigation system are estimated to have saved, on average, more than $13.32 per ton in transportation and handling charges for the movement of 231 million tons of cargo compared to the next-best, all-overland transportation alternative. The savings represent National Economic Development (NED) benefits. They are calculated across eight commodity groups including over 85 separate commodities and range between a high of $50.32 per ton for chemicals and $8.16 per ton for coal. The study was conducted by the Tennessee Valley Authority (TVA) under contract with the Huntington District of the US Army Corps of Engineers. Freight rates for each sample movement were calculated based on the actual water-inclusive routing, as well as for a competing all-land alternative. All computations reflect those rates and fees which were in effect in the third quarter 2007 (FY 08).

Table E-1 below shows a sub-set of our system rate matrix as applied to upper Ohio movements. Over eighty-five percent of upper Ohio traffic is composed of coal and aggregates which explains why the overall upper Ohio NED rate savings is below the Ohio River system. NED savings from waterway transportation are the basis by which the navigation system is valued and the basis by which economic justification for re-investment in the system is derived.

Upper Ohio NED Savings

Group	Commodities	Average Per-Ton* Water Rate	All-Land Rate	NED Saving
1	Coal	$ 18.65	$ 24.03	$ 5.37
2	Petroleum Fuel Products	$ 16.87	$ 54.51	$ 37.64
3	Aggregates	$ 8.46	$ 15.56	$ 7.10
4	Food and Processed Food Products	$ 23.74	$ 52.27	$ 28.53
5	Chemicals	$ 40.48	$ 94.90	$ 54.42
6	Non-Metallic Minerals	$ 33.08	$ 49.47	$ 16.39
7	Ferrous Ores, I&S Products	$ 37.67	$ 69.96	$ 32.29
8	Manufactured Goods	$ 20.52	$ 55.15	$ 34.63
AVERAGE ALL COMMODITIES		**$ 18.88**	**$ 28.75**	**$ 9.87**

* All rates and rate differentials are weighted average.

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ATTACHMENT 4
FY 2008 Transportation Rate Analysis

I. Introduction

The basic economic benefit of a navigation project is the reduction in cost of transporting commodities by water rather than by overland modes and is estimated as the difference in cost for each ton moved. We measure the economic benefit as the "willingness-to-pay for waterway transportation" from the increase in producer and consumer surplus. Practically, it can be measured as the delivered price of the commodity less all associated economic costs, including all of the costs of barge transportation other than those of the navigation project. This benefit cannot exceed the reduction in transportation costs achieved by the project.

Corps navigation studies use transportation rates as a proxy for long-run marginal costs of commodity movements. In competitive markets, rates (prices) correspond to marginal cost, and given market stability, prices will settle at a long-run equilibrium. Section 7a of the Department of Transportation (DOT) Act of 1966 (Public Law 89-670) requires the use of prevailing rates as the best available approximation of long-run marginal costs.

In our economic analyses of potential navigation improvement investments, expected transportation rate savings are adjusted by factors affecting the willingness of users to pay like congestion and project reliability. Specifically, our economic models divert traffic from the waterways in the order of the willingness of users to pay for waterway transportation. Users with the lowest willingness to pay are diverted first. These are the shipments with the lowest rate savings such that an event or change in the system, like higher delays, increases the cost of water routed transportation so that it becomes more costly than the all-overland transportation alternative.

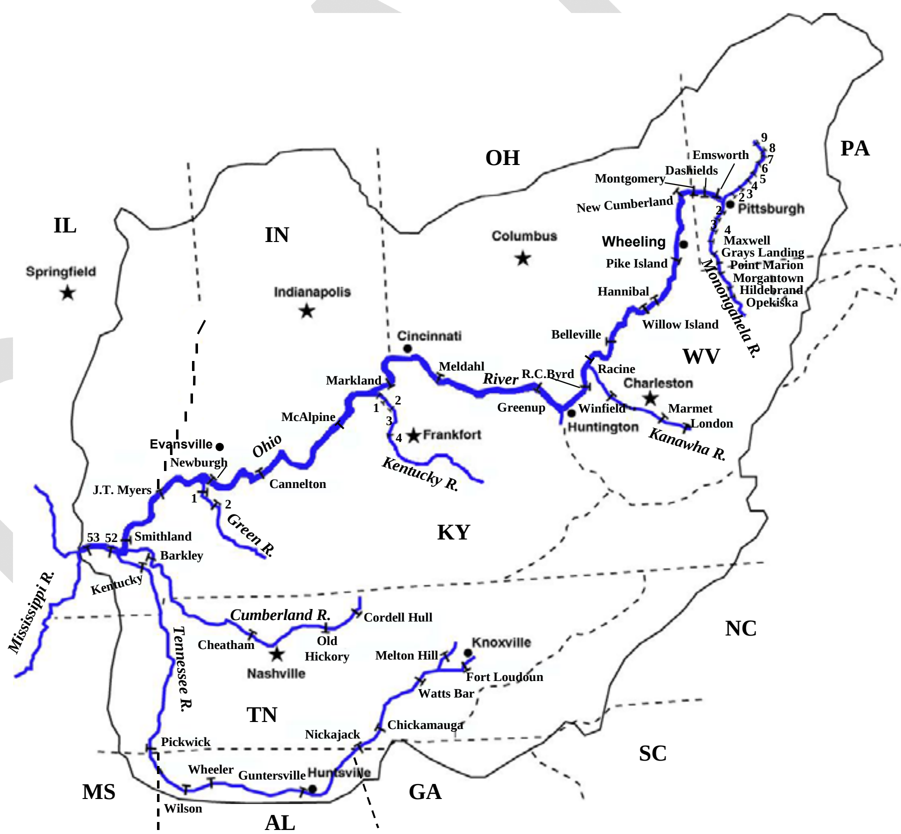
This Corps of Engineers report documents and explains the results of an FY08 study on the transportation cost savings for barge shipments on the Ohio River Navigation System (ORS). The study results in a detailed transportation rate matrix that will be used in conjunction with other navigation and economic data and analytic tools to evaluate specific waterway improvements to meet short-term and long-term navigation needs. The ORS includes the mainstem Ohio River, the Allegheny, Monongahela, Kanawha, Big Sandy, Kentucky, Green, Tennessee and Cumberland rivers as well as other smaller navigable tributaries and backwater embayments.

Transportation rate savings are used in navigation studies as an input to ORNIM (the Ohio River Navigation Investment Model) where they are combined with traffic demands, lock capacity performance and engineering reliability data to estimate the benefits of the existing and modified navigation system. Modified system benefits are compared to system costs to determine the economic feasibility of a modification.

II. The Study

The Tennessee Valley Authority (TVA) conducted this study under contract with the Huntington District of the U.S. Army Corps of Engineers[1]. Study results serve as input to cost-benefit analysis for ORS feasibility studies (Figure 1). Transportation rates and costs were estimated, based on detailed rate studies, for a sample of 2004 ORS barge movements. These were the latest available at the start of the study. The use of older shipment pairs does not adversely affect the analysis since most pairs are stable and new pairs are estimated along with unsampled movements. The barge movements are part of the Waterborne Commerce Statistics Center (WCSC) database. Rate estimating equations were developed from the sample rate and cost information and applied to the un-sampled movements. All rates and costs reflect FY 2008 prices.

Figure 1
Ohio River Navigation System



[1] The proprietary movement level rate data developed by TVA is available for review from the Huntington District.

ER 1105-2-100 (page 3-6 and 3-7) describes the use of the current cost of waterway use and of the alternative movement as ways to estimate benefits associated with waterway improvements. For each sample movement in this study, a calculation of freight rates was made by the existing route traversing the ORS and for a competing land route utilizing an alternate mode of transportation. Computations reflect those charges that were in effect during the third quarter of 2007 (FY 08). Fuel prices used an average to avoid market anomalies.

The results of this study were documented on a movement-by-movement basis, with a separate worksheet for each movement. Spreadsheet information for each movement is also available in the Navigation Planning Center (LRH-NC). Full explanation of TVA's methods of rate research and construction and supporting assumptions are appended at the end of this attachment.

The transportation rate data produced by the TVA in this study were used to develop rate-estimating equations for application to the unsampled ORS movements. The sample rate information and the estimated unsampled rate information were then combined into a transportation rate matrix used in the cost benefit analysis of navigation studies.

III. The Sample

A sample of 1,552 commodity movements, totaling over 231 million tons and 86 percent of system tonnage was selected for transportation rate analysis.[2] The sample was selected based on size and geography. We wanted to measure as much traffic as possible and ensure adequate distribution of tributaries. The movements were grouped into one of eight commodity groups. Table 1 displays the sample and total population number of movements and tonnage. The sample was constructed to maximize the amount of tonnage rated and minimize the amount of tonnage estimated using rate-estimating equations. All movements greater than 100,000 tons were selected for rating. This method assures the direct measurement of the more significant commercial flows on the Ohio River navigation system. Geographic representation was considered when selecting the smaller, less dominant commercial movements. With a little more than 85 percent of system tonnage rated, rate estimating equations were used on the unsampled 15 percent of system tonnage.

[2] The unsampled (roughly) 8,500 movements account for only 14 percent of system tonnage. The un-sampled movements are low-tonnage movements. Application of the rate estimating equations and statistics, developed from high-volume flows, results in higher rate savings for the smaller movements. Given a limited rate budget, the decision was made to rate the most tonnage possible with adequate geographic representation at the expense of overestimating savings for a relatively small amount of system tonnage. Also, the smaller movements tend to be special cargoes or low-volume, high-value (chemicals) with higher rate savings than the population as a whole.

Table 1
Sample Size by Commodity Group
2004 WCSC Data

Commodity Group	Sample		Population	
	Movements	Tonnage	Movements	Tonnage
Coal and Coke	545	140,238,442	1,258	145,256,328
Petroleum Products	157	11,883,127	1,016	17,019,864
Aggregates	343	42,025,987	1,326	48,032,516
Grains	139	8,524,689	1,824	16,556,509
Chemicals	93	5,909,635	1,430	11,499,905
Ores & Minerals	70	5,396,531	539	7,406,300
Iron & Steel	111	10,344,089	1,425	15,288,459
Other	94	7,099,240	620	8,883,722
Total	1,552	231,421,740	9,438	269,943,603

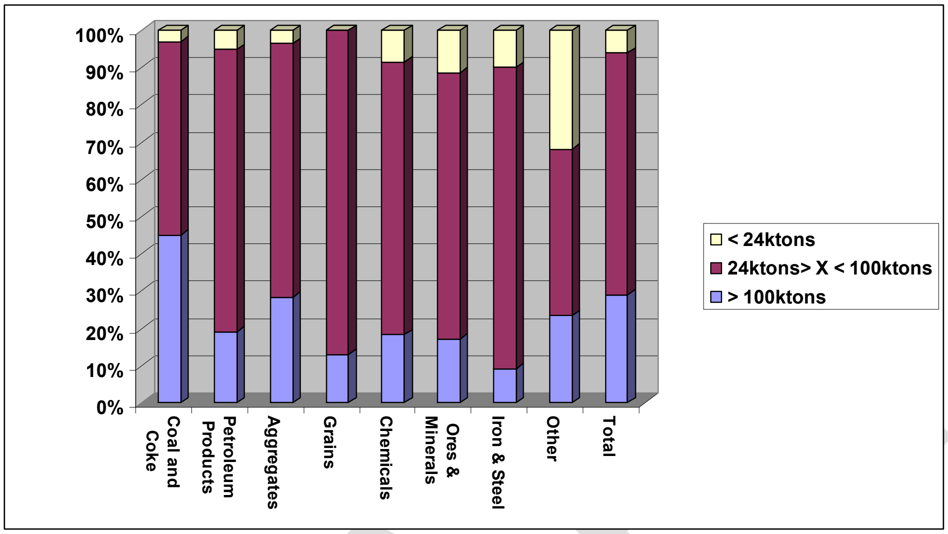
Table 2 describes the sample in terms of percentage of population commodity movements and tonnage. Coal and coke traffic make up over 53 percent of system tonnage and therefore is sampled more heavily than the other commodity groups. Forty-three percent of all the coal and coke traffic movements, representing 97 percent of system coal and coke tonnage are included in the sample.

Table 2
Commodity Group Sample Percentage of Population

Commodity Group	Sample	
	Movements	Tonnage
Coal and Coke	43%	97%
Petroleum Products	15%	70%
Aggregates	26%	87%
Grains	8%	51%
Chemicals	7%	51%
Ores & Minerals	13%	73%
Iron & Steel	8%	68%
Other	15%	80%
Total	16%	86%

Figure 2 shows the commodity group sample composition by movement size. A fully loaded 15-barge tow pushes around 24 to 25 ktons of product. The commodity group sample movements are broken out by size in Figure 2: < 24 ktons, between 24 ktons and 100 ktons, and >100 ktons. All movements larger than 100 ktons were sampled for each commodity group. Coal accounts for 54 percent of system tonnage and over 96 percent of system coal was included in the sample. Overall for the sample, 29 percent of the movements were > 100 ktons and 65 percent were between 24 and 100 ktons.

Figure 2
Commodity Sample Composition by Movement Size



The geographic coverage of coal was also extensive as it covered every navigable tributary in the basin. Table 3 displays the geographic origins of the coal sample movements.

Table 3
Coal Sample River Origins

River of Coal Origin	Number of Movements	Tonnage
Ohio	240	72,702,719
Big Sandy	103	18,089,520
Monongahela	75	15,201,572
Kanawha	74	14,096,660
Tennessee	15	11,474,240
Green	25	4,473,201
Upper Mississippi	9	4,035,814
Lower Mississippi	3	139,716
Total	545	140,238,442

IV. Rate Estimating Equations

For the purpose of transportation rate analysis, a commodity movement is broken into three distinct parts: i) transportation leg(s), ii) transportation line-haul, and iii) accessorial charges. Transportation legs usually involve trucking from origin to the line-haul mode and trucking from the line-haul mode to the ultimate destination. All legs to/from the river dock and to/from the rail head are accounted for in the transportation rate analysis. Transportation line-hauls involve barge transportation for the existing water routing and, depending on the volume shipped, usually rail transportation for the least-cost all-overland alternate routing.[3] Accessorial charges include all loading, trans-loading and unloading charges involved to get the commodity from its ultimate origin to its ultimate destination. The sum of the three parts develops the total rate-estimating equation:

Total Rate = Total Leg Rates + Total Accessorial Charges + Total Line-Haul Rate

a. Negative Sample Rate Savings. In the sample, 80 movements were rated with negative rate savings (the existing water routing rate was greater than the least-cost all-overland alternative). They rate negatively for a variety of reasons: (i) low tonnage (resulting in a high unit cost) (ii) locked into a long-term contract; or (iii) are logistically integrated (i.e. mine-dock-utility) such that they make up for the transportation loss somewhere else in the supply chain. The rate data for these outliers were not used in developing the rate estimating equations. The negative rate savers are summarized in Table 4.

Table 4
Negative Sample Rate Savings

Commodity Gp	Movements	Tonnage		Rate Savings		SPT
Coal and Coke	40	11,434,675	$	(15,040,736)	$	(1.32)
Petroleum Products	3	44,690	$	(369,796)	$	(8.27)
Aggregates	6	311,305	$	(1,035,422)	$	(3.33)
Grains	1	53,146	$	(649,976)	$	(12.23)
Chemicals	5	67,057	$	(2,242,475)	$	(33.44)
Ores & Minerals	3	92,484	$	(2,599,212)	$	(28.10)
Iron & Steel	5	148,203	$	(1,033,534)	$	(6.97)
Other	17	1,948	$	(85,590)	$	(43.94)
Total	80	12,153,508	$	(23,056,741)	$	(1.90)

b. Leg Rates and Accessorial Charges. Transportation leg rates and accessorial charges are estimated from the sample by calculating tonnage weighted averages at the commodity group level. Table 5 shows that, on average, transportation leg rates to and from river docks are greater than the rates to and from rail sidings. In general, within the Ohio River Basin (ORB), it appears that railroads enjoy a cost advantage in terms of access to/from the line-haul mode. This advantage is not apparent with the loading and unloading charges (Table 5). On average, these charges are about the same regardless of routing.

[3] Track related rail capacity is not an issue in the ORB. The rail capacity issue in the ORB is with the short lines and lack of motive power in the short run. This issue is overcome in the rate analysis by assuming engine purchase or leasing as the long-run solution.

Table 5
Transportation Leg Rates and Accessorial Charges

Commodity Group	Existing Water		Least Cost Overland	
	Legs	Accessorial	Legs	Accessorial
Coal and Coke	$ 7.42	$ 3.67	$ 2.48	$ 2.85
Petrol Prods	$ 0.06	$ 2.30	$ 0.33	$ 4.72
Aggregates	$ 0.13	$ 2.36	$ 1.11	$ 2.53
Grains	$ 9.15	$ 5.82	$ 7.10	$ 5.97
Chemicals	$ 0.53	$ 2.06	$ -	$ 4.71
Ores & Minerals	$ 0.43	$ 5.10	$ -	$ 5.31
Iron & Steel	$ 0.81	$ 6.72	$ 0.09	$ 6.16
Others	$ 0.45	$ 3.73	$ -	$ 4.15
Total	**$ 4.81**	**$ 3.57**	**$ 1.97**	**$ 3.32**

c. <u>Overland Line-Haul Mile Estimation</u>. Corps WCSC data contain the barge line-haul distance in miles, for each movement record. Barge line-haul distance is an important parameter for estimating line-haul rates. The rated sample “acquires” overland line-haul mileage information during the rating process. For obvious reasons, WCSC data does not include any least-cost overland line-haul distance data. This information, critical to the estimation of the least-cost overland line-haul rate, is estimated for the unsampled movements using the line-haul mile relationships contained in the rated sample. The statistical relationship between least-cost overland line-haul miles and existing waterway line-haul miles is estimated through simple linear (ordinary least squares) regression.

Land line-haul miles are assumed a function of water line-haul miles. The fitted equation assumes:

Land line-haul miles = y-intercept + B(Water line-haul miles)

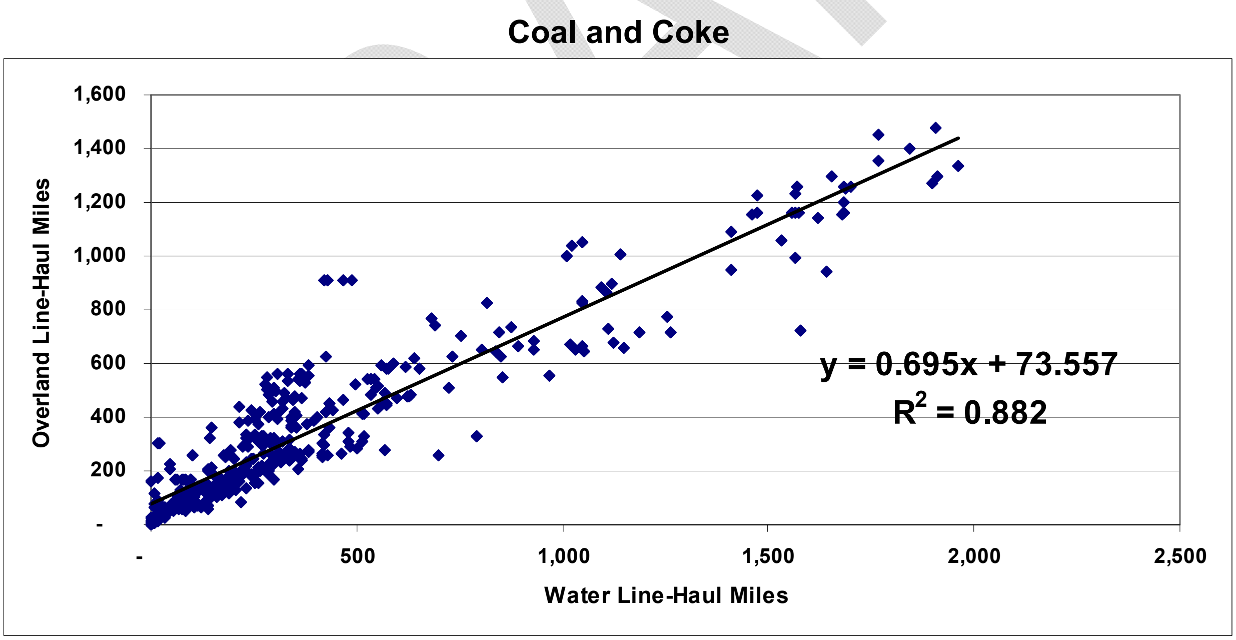
Table 6 displays parameter estimates and goodness-of-fit for the regression equations. Statistically, all the coefficients are significant at least at the 1.0 percent level and they have signs consistent with observation. The simple linear specification is a reasonable approximation for estimating overland line-haul miles. The Total in Table 6 is the regression result for the whole sample of movements.

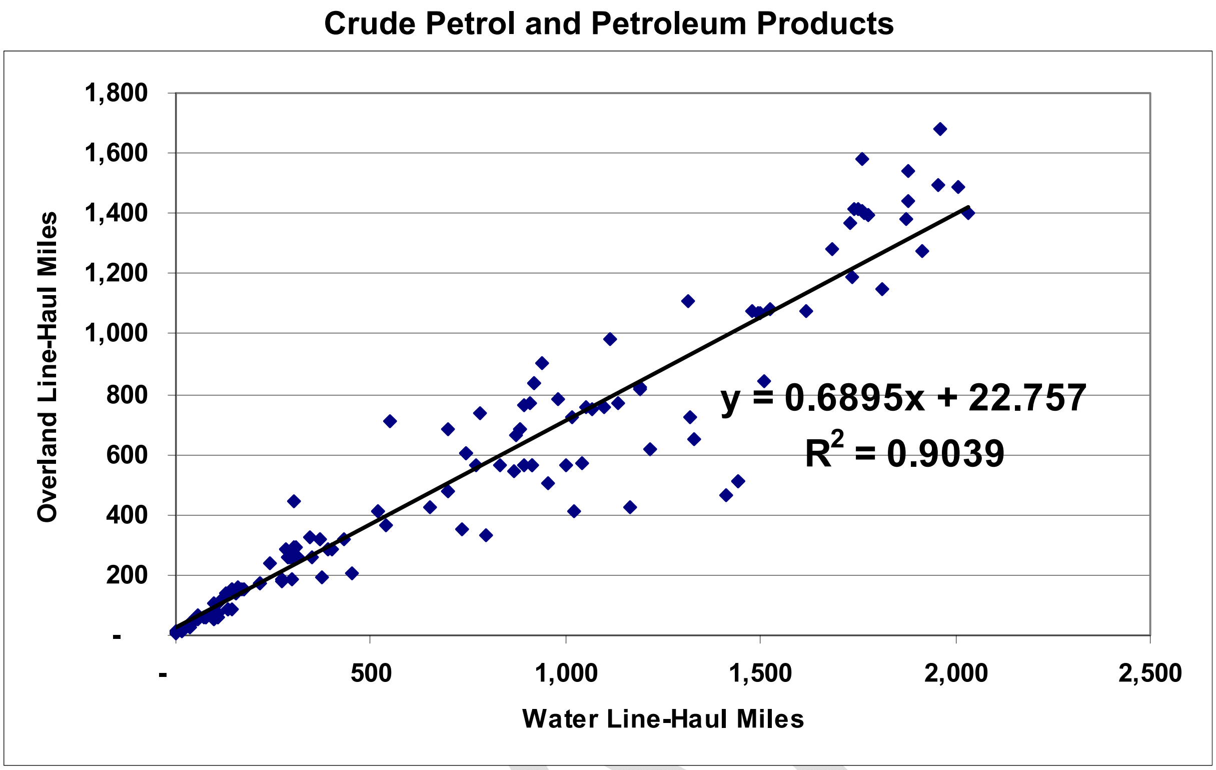
Table 6
OLS Parameter Estimates for Overland Line-haul Miles

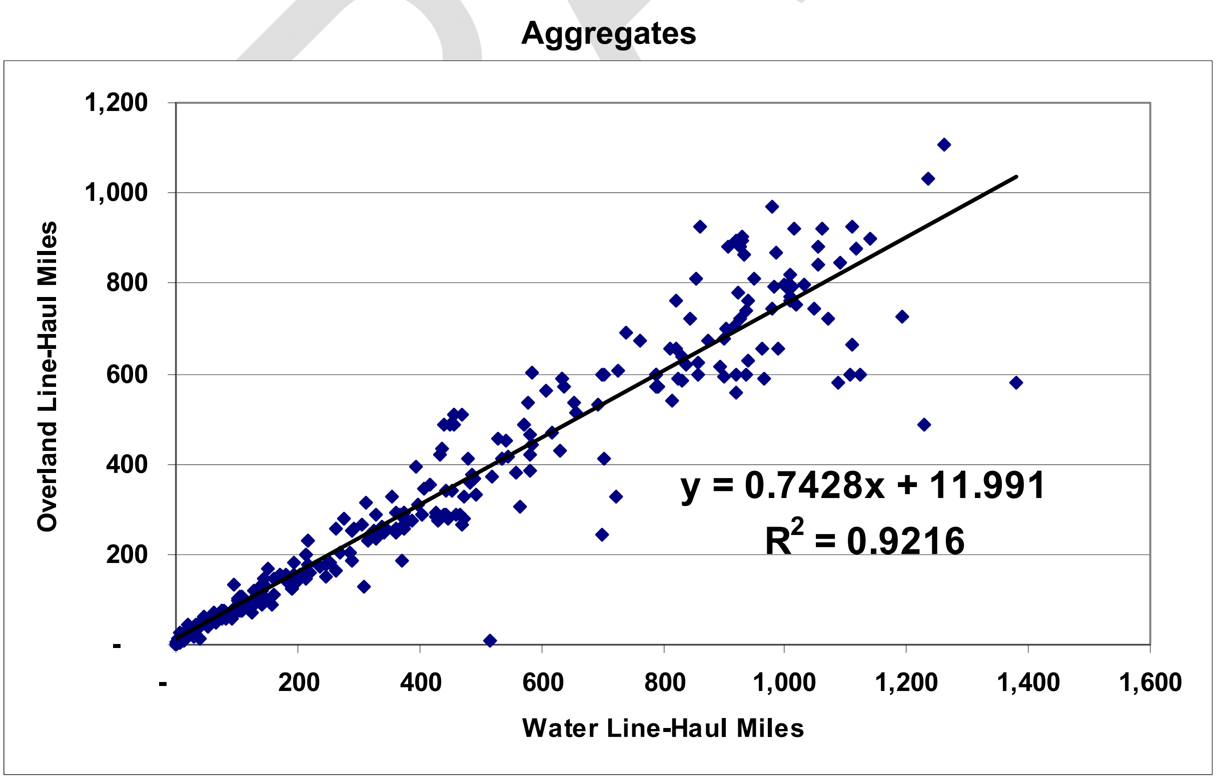
Commodity Group	y-intercept	B-coefficient	R-Square
Coal and Coke	74	0.695	0.880
Petrol Prods	23	0.690	0.900
Aggregates	12	0.743	0.920
Grains	197	0.650	0.560
Chemicals	40	0.770	0.800
Ores & Minerals	14	0.730	0.690
Iron & Steel	(31)	0.683	0.880
Others	51	0.626	0.830
Total	56	0.697	0.880

Graphical representation of the commodity group specific line-haul mile regressions is provided in Figure 3

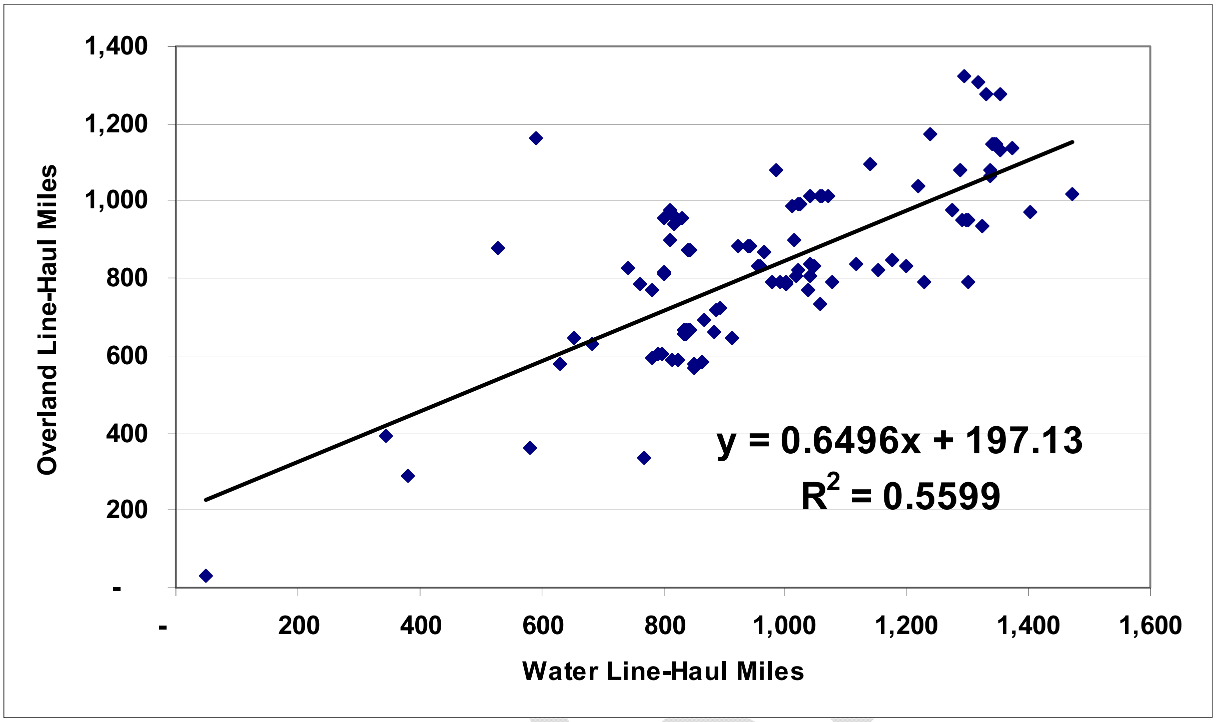
Figure 3
Overland Line-Haul Mile Regression Equations



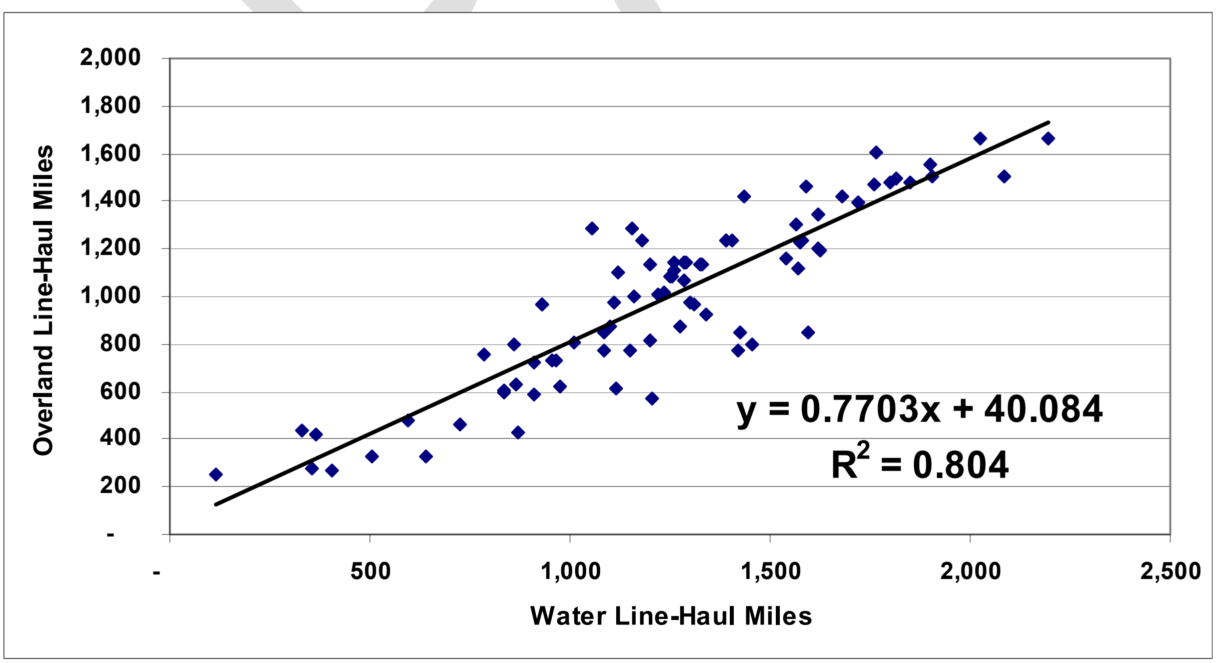

Crude Petrol and Petroleum Products
1,800
1,600
1,400
1,200
1,000
800
600
400
200
-
Overland Line-Haul Miles
-
500
1,000
1,500
2,000
2,500
Water Line-Haul Miles
y = 0.6895x + 22.757
R2 = 0.9039


Aggregates
1,200
1,000
800
600
400
200
-
Overland Line-Haul Miles
-
200
400
600
800
1,000
1,200
1,400
1,600
Water Line-Haul Miles
y = 0.7428x + 11.991
R2 = 0.9216

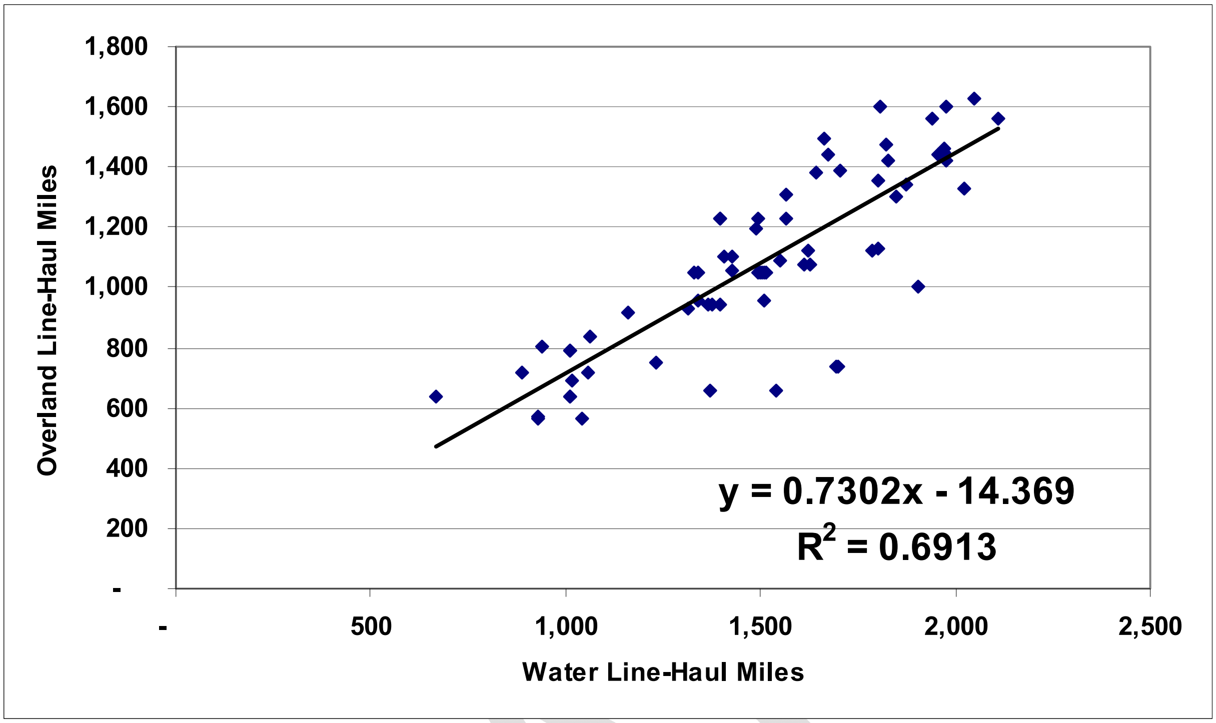
Grains and Grain Products



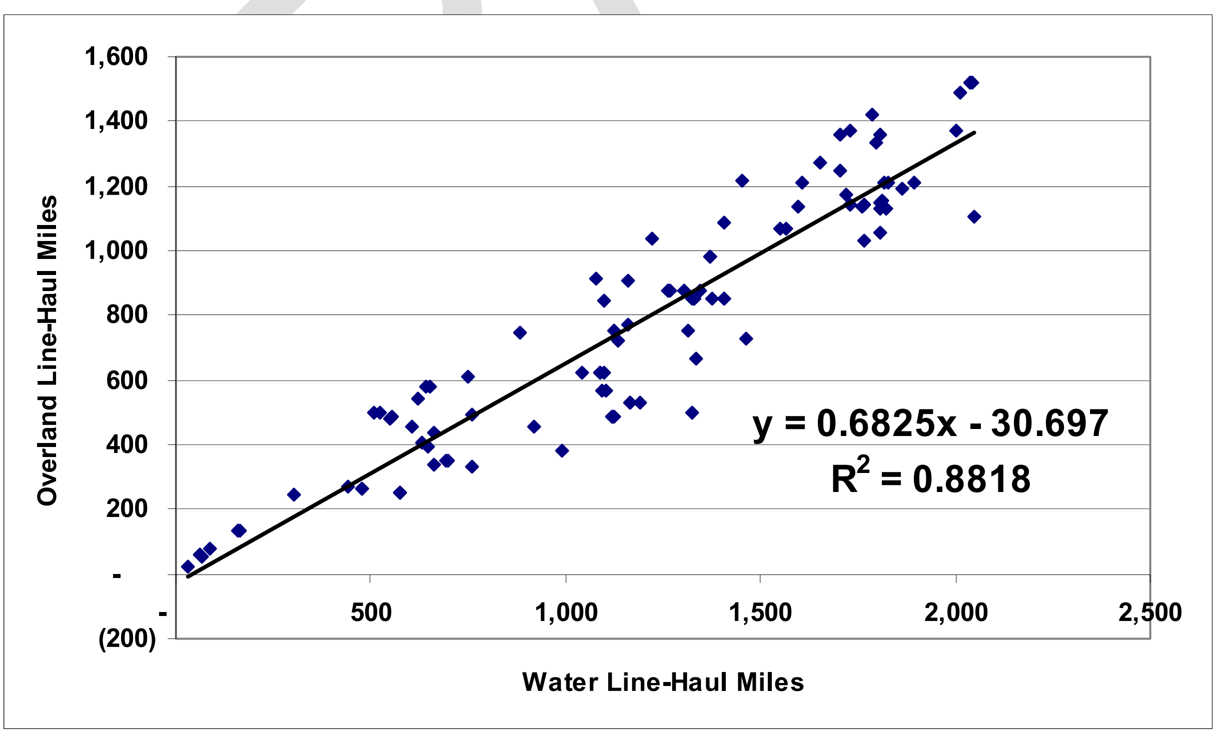
Chemicals

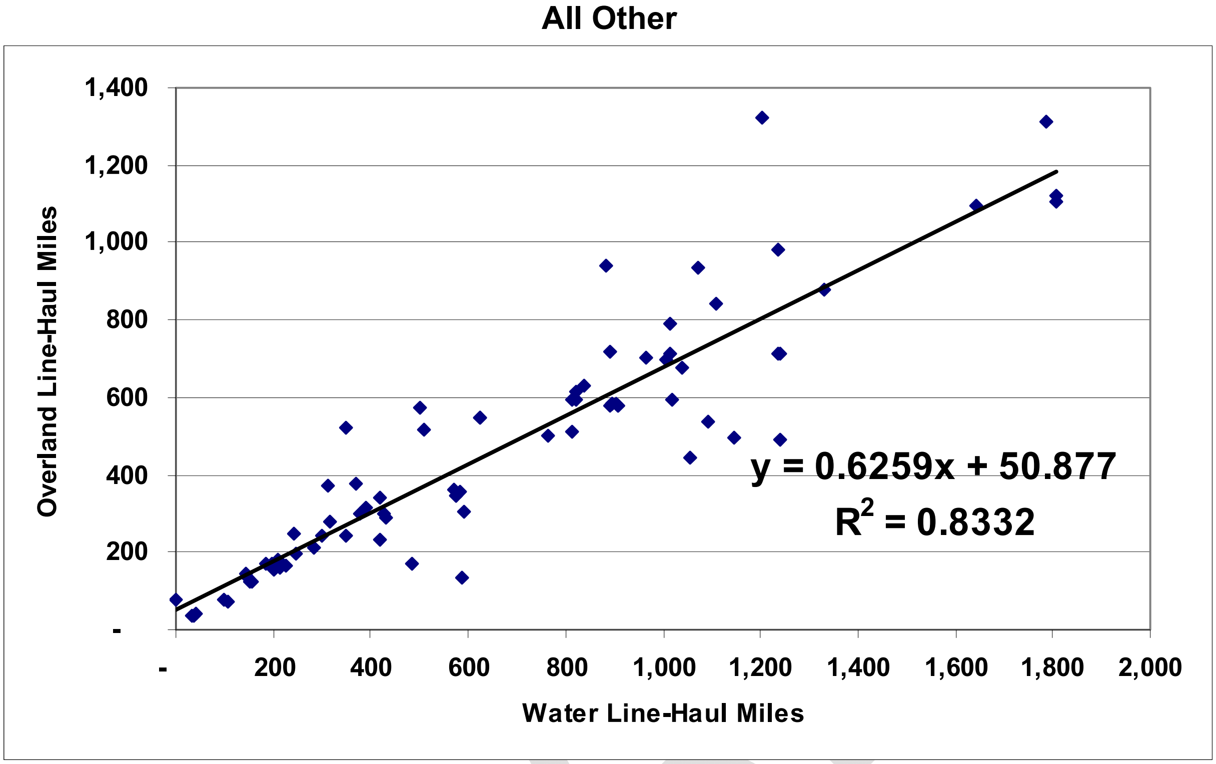


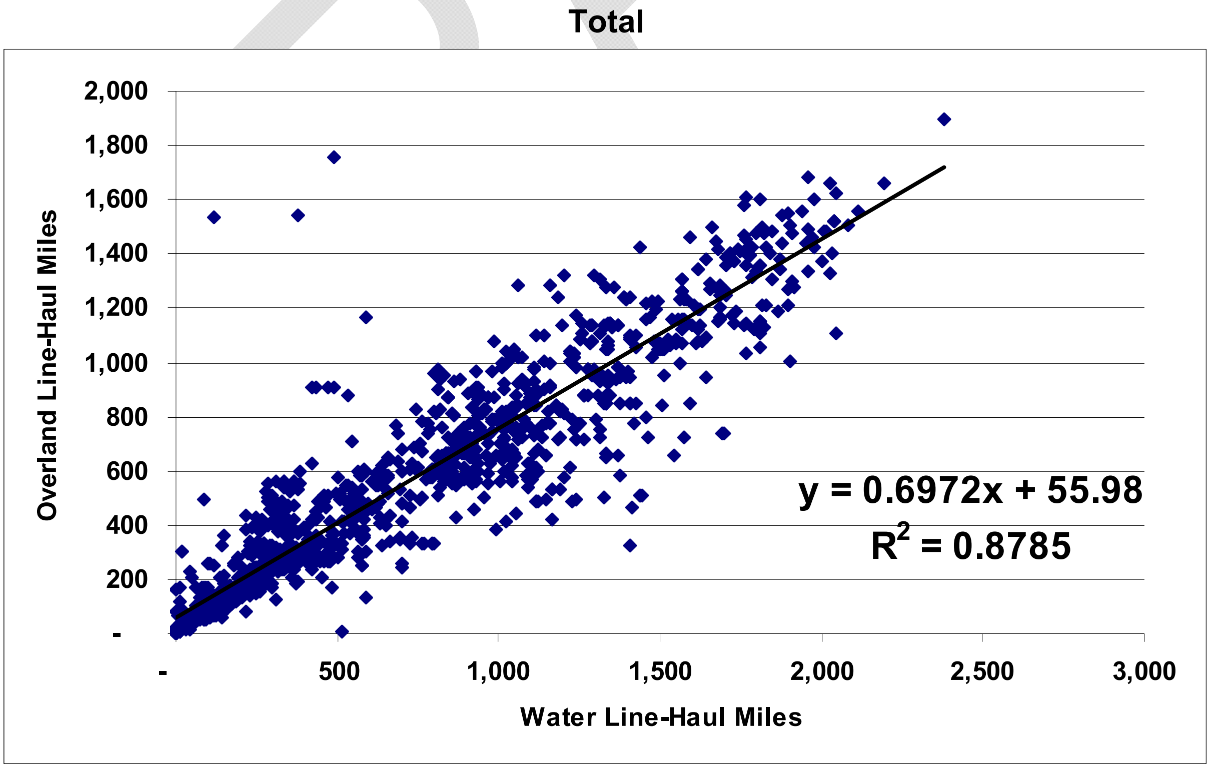
Ores and Minerals



Iron and Steel




All Other
Overland Line-Haul Miles
1,400
1,200
1,000
800
600
400
200
-
-
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Water Line-Haul Miles
y = 0.6259x + 50.877
R2 = 0.8332


Total
Overland Line-Haul Miles
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
-
-
500
1,000
1,500
2,000
2,500
3,000
Water Line-Haul Miles
y = 0.6972x + 55.98
R2 = 0.8785

d. Modal Line-Haul Estimation. Total line-haul rate is assumed a function of freight. Freight is measured as ton-miles. The linear regression model forced the y-intercept through zero (i.e. no freight means no rate). Tables 7 and 8 show the parameter estimates for the barge line-haul rate estimating and rail line-haul rate estimating equations. All betas were statistically significant at 1.0 percent and the functional form:

total rate = y-intercept + B(ton-miles)*

approximated the line-haul production function fairly well. In the long run, it is assumed that all commodities will divert to rail as rail is more competitively priced to barge transportation than is trucking. Figure 4 shows the commodity group line-haul rate-estimating regressions for existing waterway and least-cost overland routings. Again, the Total in Tables 7 and 8 show parameter estimates for the whole sample of movements.

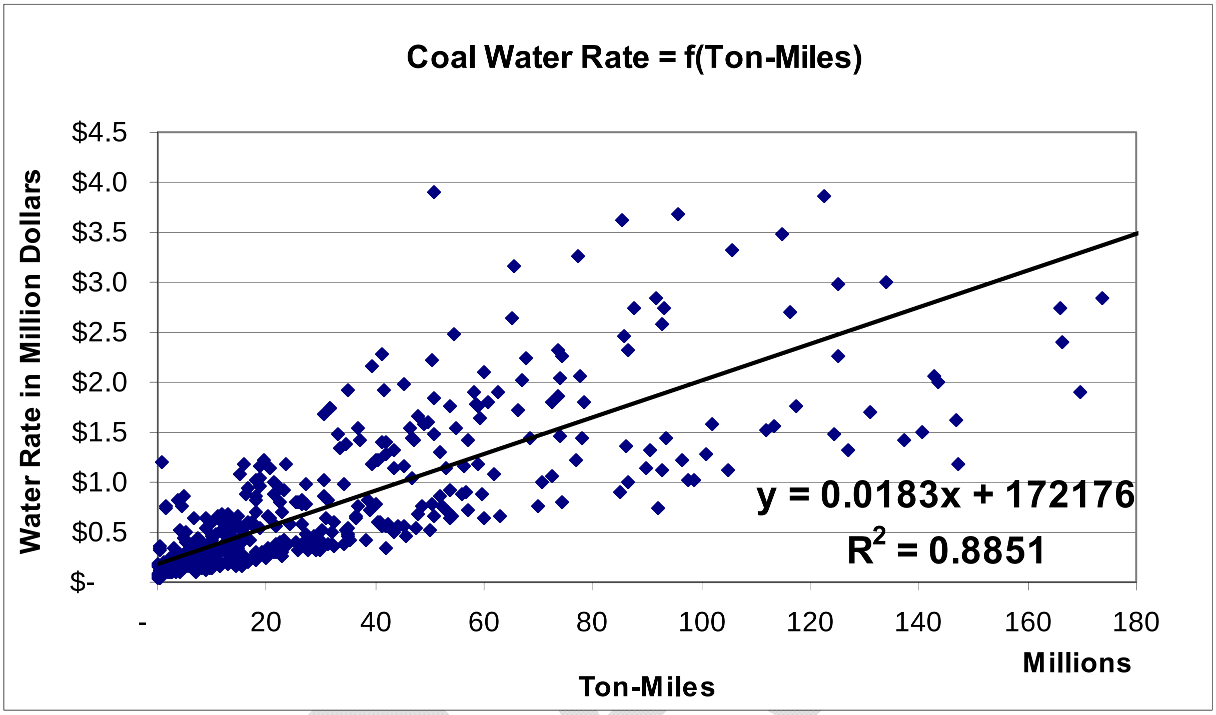
Table 7
Waterway Line-Haul Rate Parameter Estimates

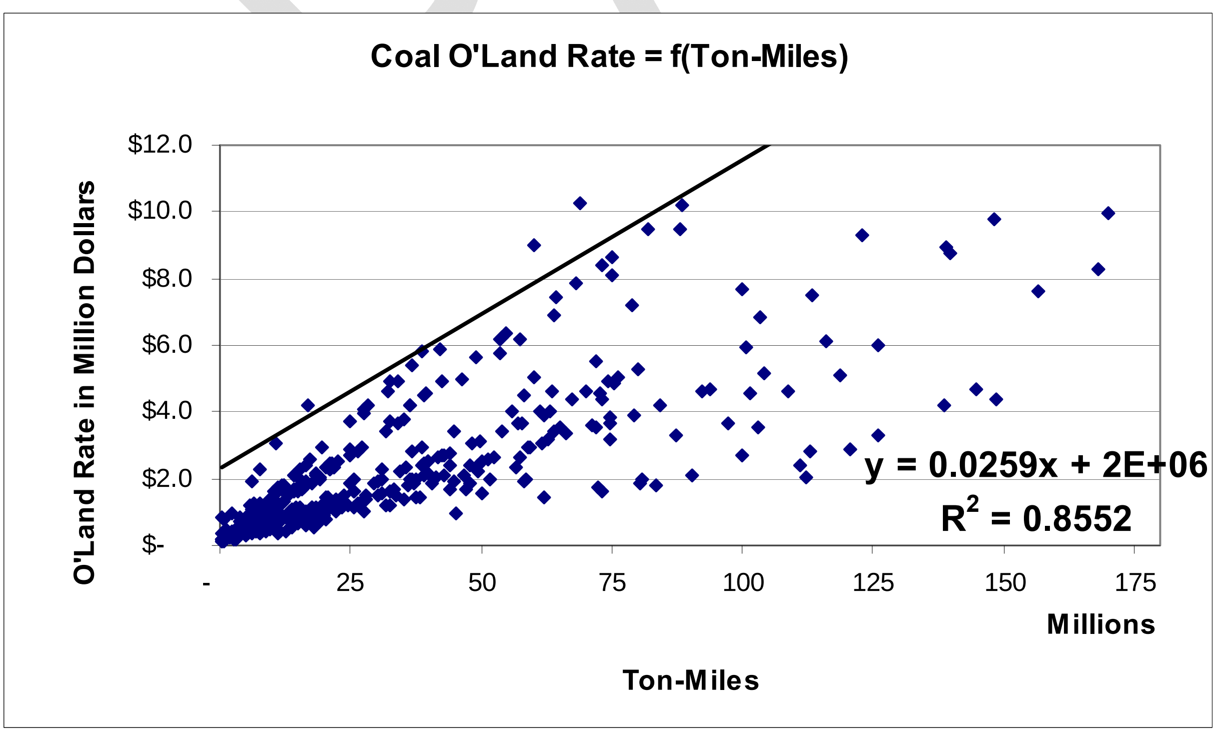
Commodity Group	y-intercept	B-coefficient	R-Square
Coal and Coke	172,176	0.0186	0.89
Petrol Prods	445,321	0.0152	0.64
Aggregates	134,320	0.0152	0.76
Grains	255	0.0121	0.94
Chemicals	125,979	0.0255	0.91
Ores & Minerals	-	0.0161	0.91
Iron & Steel	80,828	0.0128	0.99
Others	144,964	0.0198	0.77
Total	288,426	0.0146	0.89

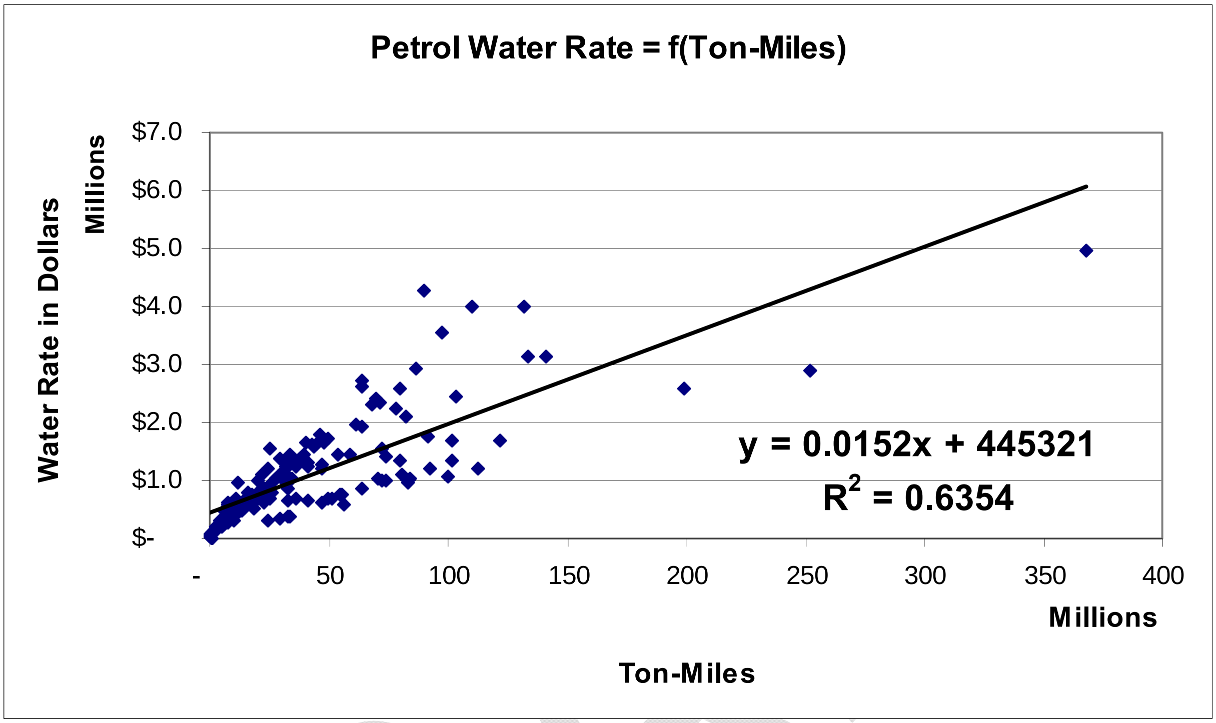
Table 8
Overland Line-Haul Rate Parameter Estimates

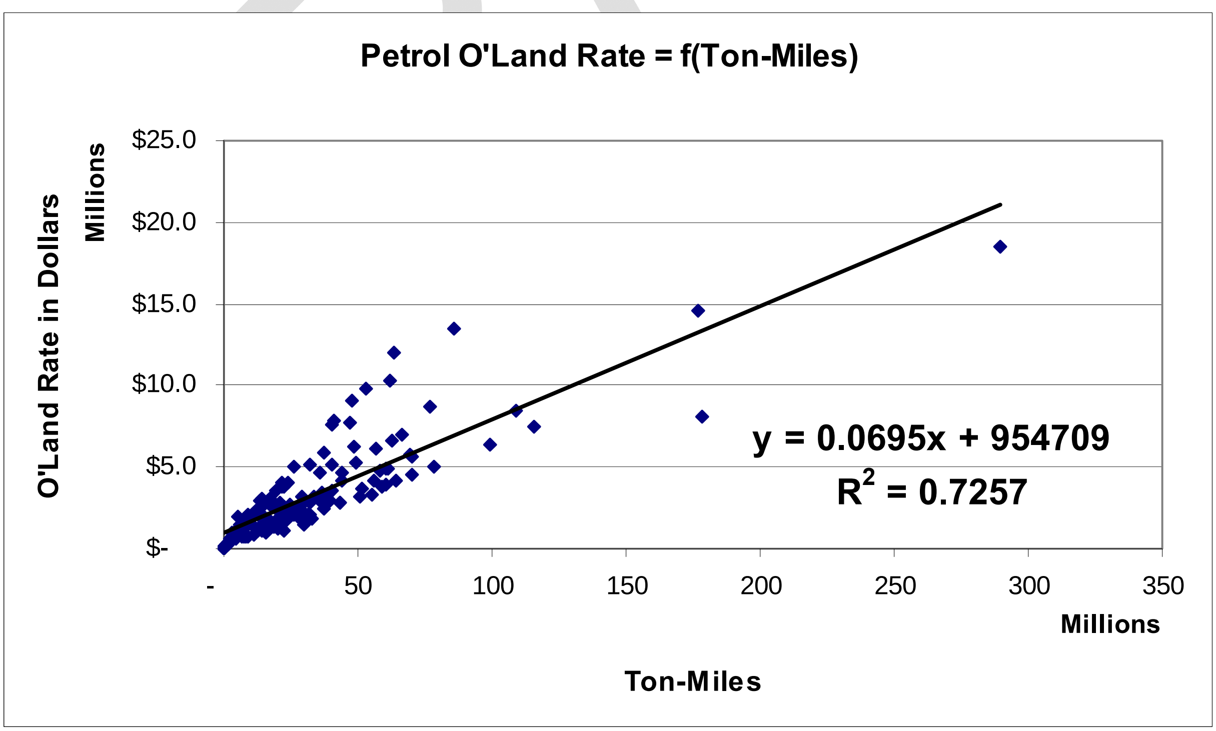
Commodity Group	y-intercept	B-coefficient	R-Square
Coal and Coke	2,349,200	0.0259	0.86
Petrol Prods	954,709	0.0695	0.73
Aggregates	550,074	0.0525	0.54
Grains	-	0.0357	0.95
Chemicals	525,238	0.0765	0.82
Ores & Minerals	-	0.0580	0.90
Iron & Steel	359,926	0.0531	0.94
Others	1,297,356	0.0635	0.72
Total	1,829,329	0.0287	0.80

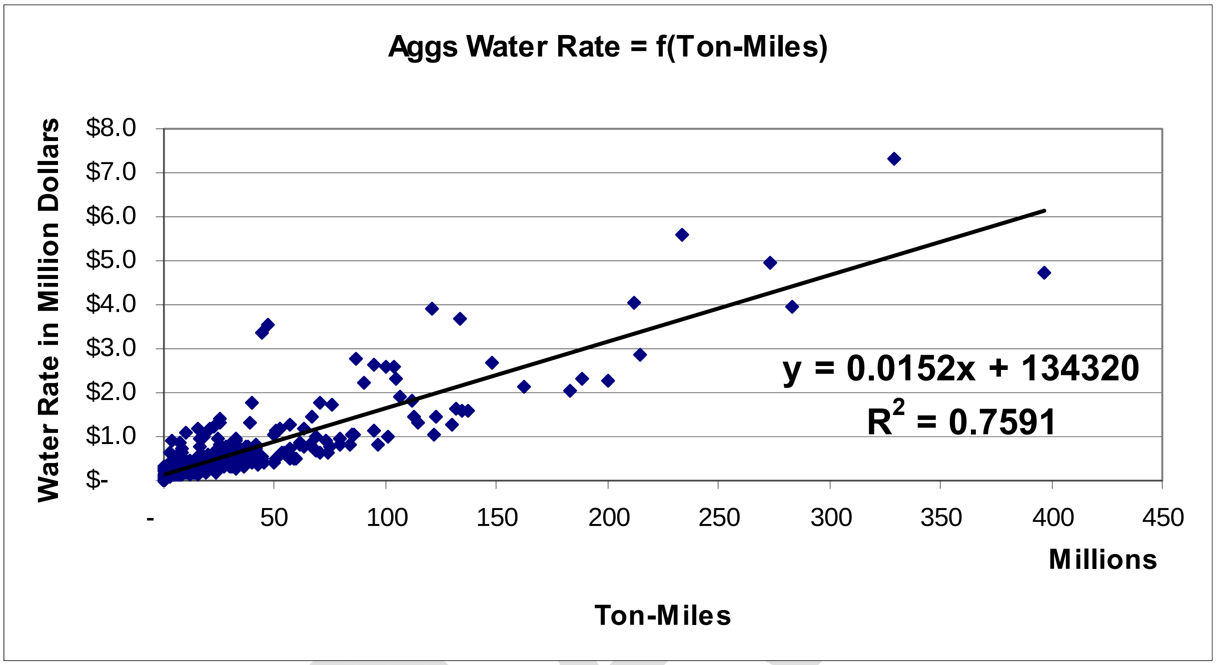
Figure 4
Waterway and Overland Line-Haul Rate Regression Equations

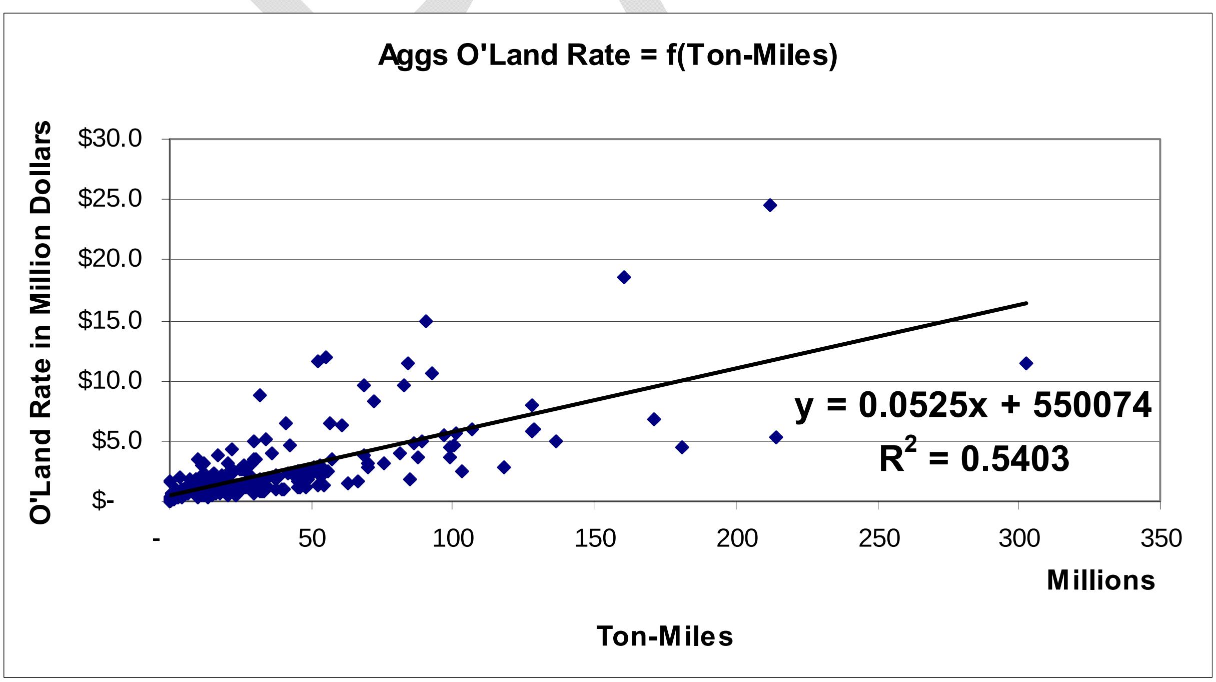


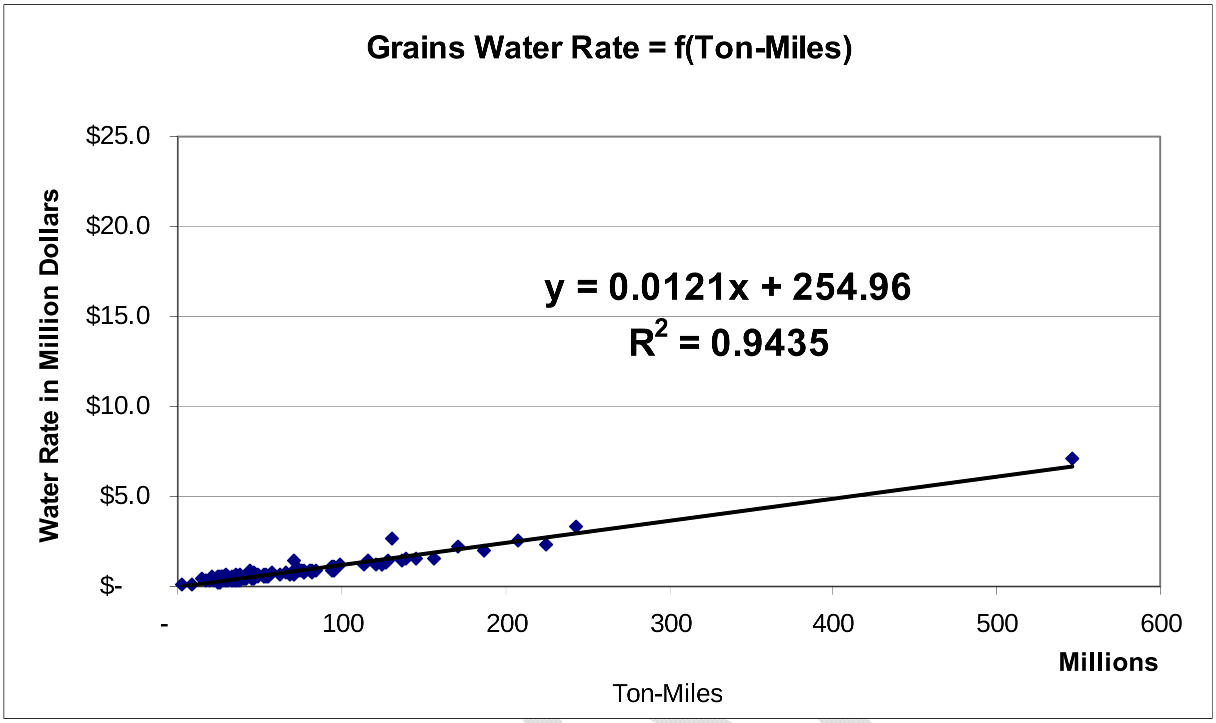


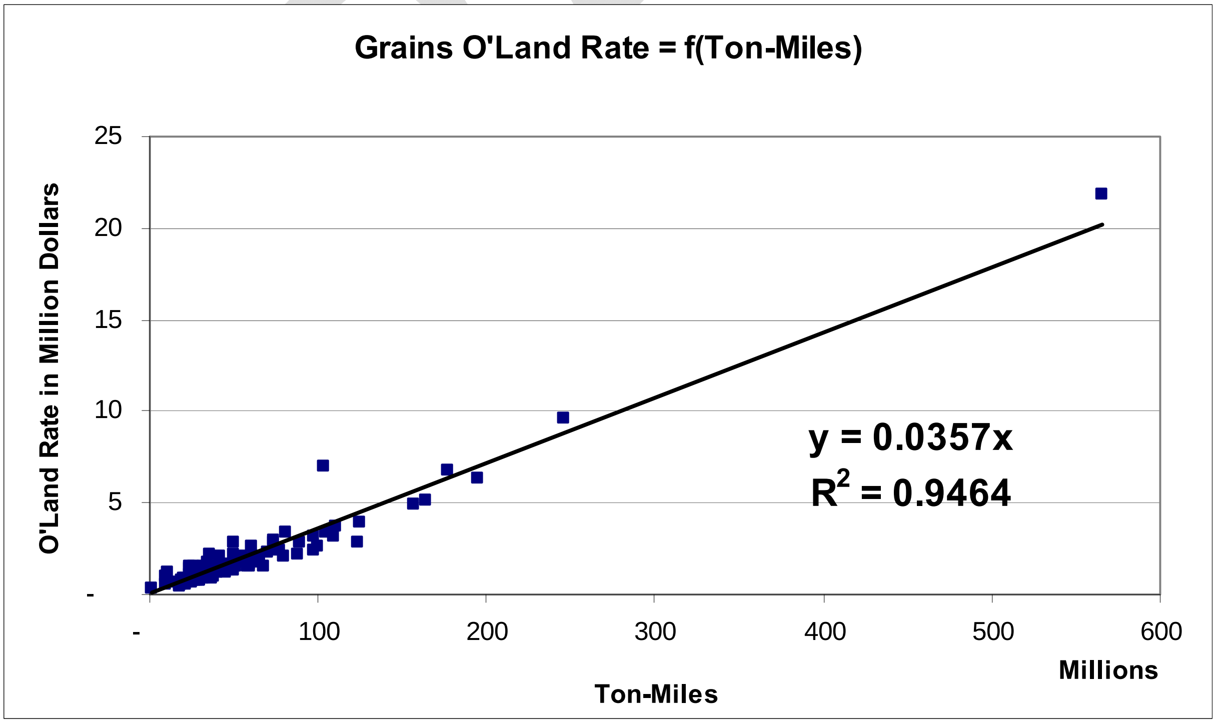

Petrol Water Rate = f(Ton-Miles)
Water Rate in Dollars
Millions
$7.0
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$-
-
50
100
150
200
250
300
350
400
Millions
Ton-Miles
y = 0.0152x + 445321
R2 = 0.6354

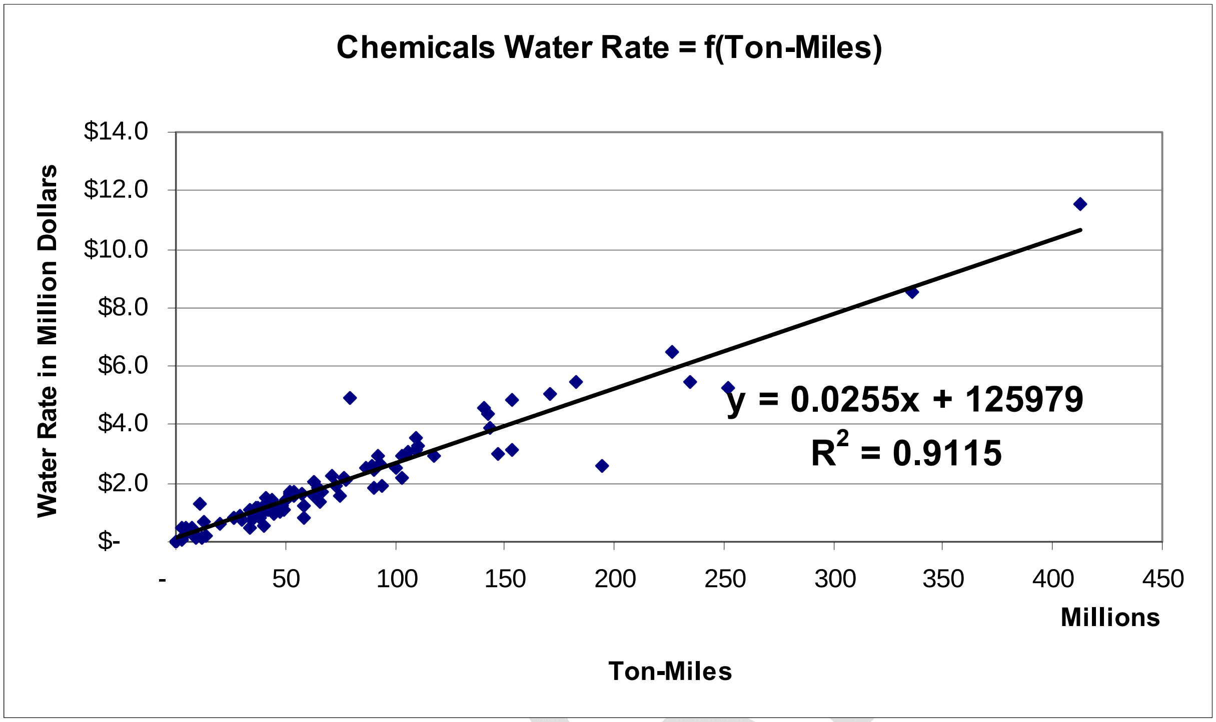

Petrol O'Land Rate = f(Ton-Miles)
O'Land Rate in Dollars
Millions
$25.0
$20.0
$15.0
$10.0
$5.0
$-
-
50
100
150
200
250
300
350
Millions
Ton-Miles
y = 0.0695x + 954709
R2 = 0.7257

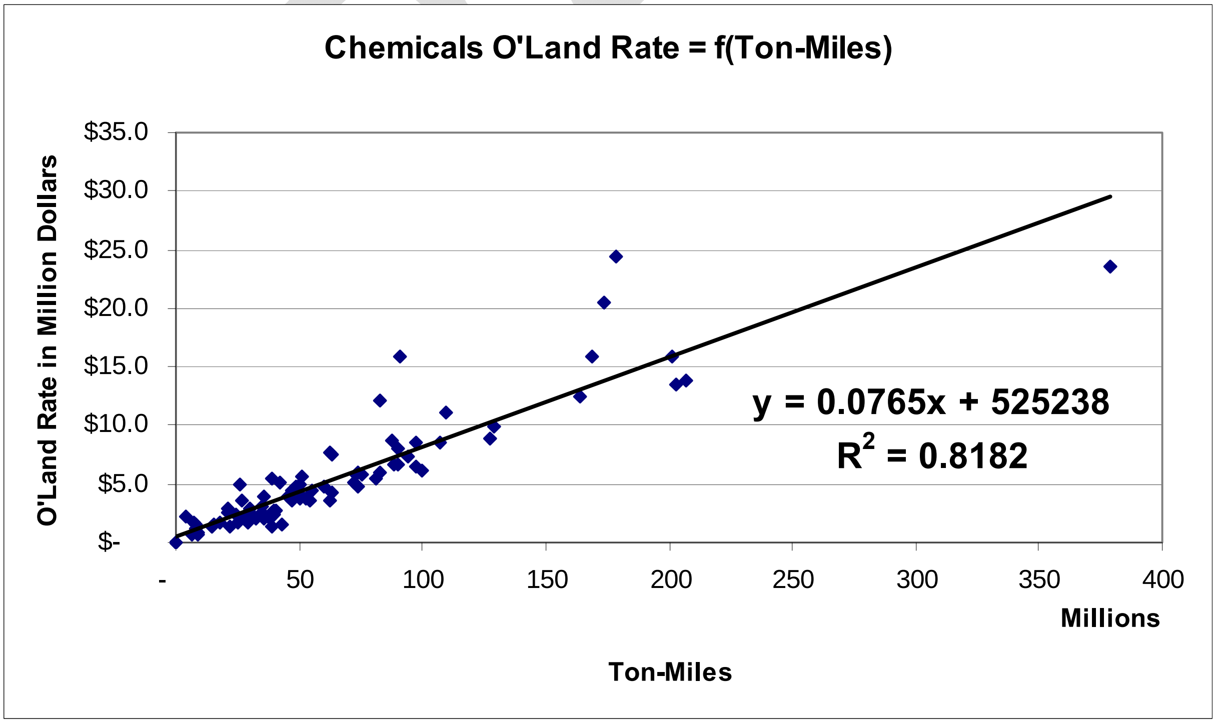

Aggs Water Rate = f(Ton-Miles)
Water Rate in Million Dollars
$8.0
$7.0
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$-
-
50
100
150
200
250
300
350
400
450
Millions
Ton-Miles
y = 0.0152x + 134320
R2 = 0.7591

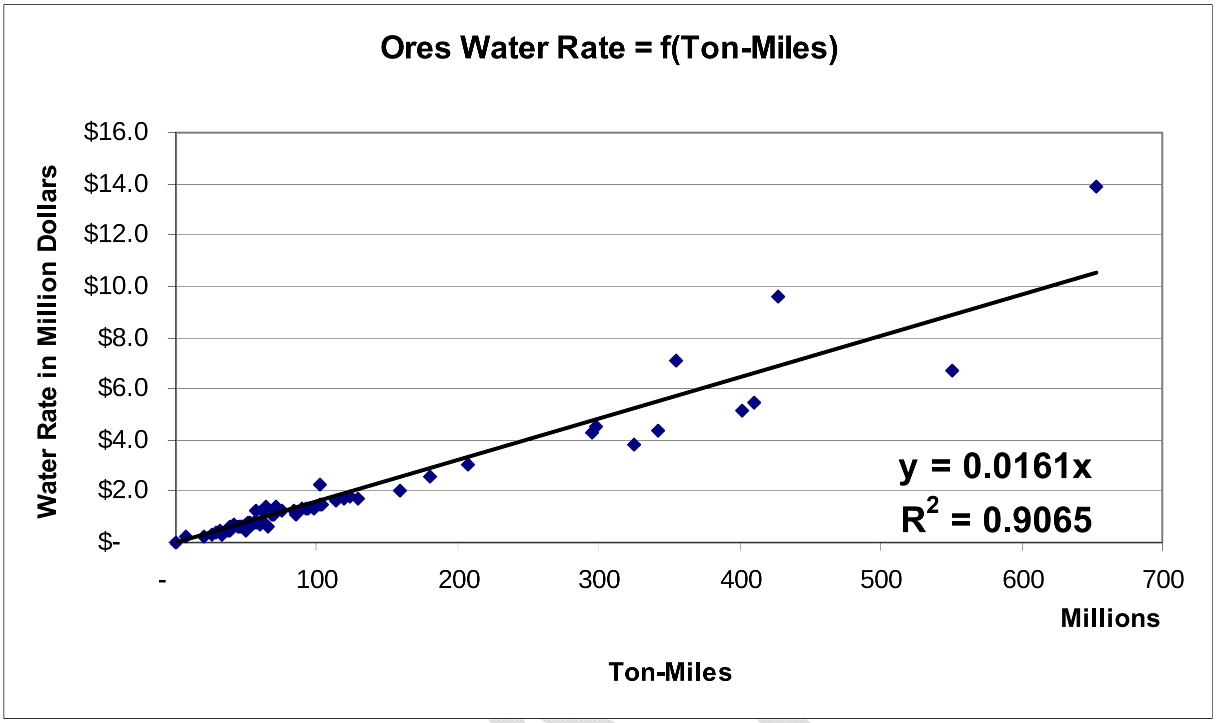

Aggs O'Land Rate = f(Ton-Miles)
O'Land Rate in Million Dollars
$30.0
$25.0
$20.0
$15.0
$10.0
$5.0
$-
-
50
100
150
200
250
300
350
Millions
Ton-Miles
y = 0.0525x + 550074
R2 = 0.5403

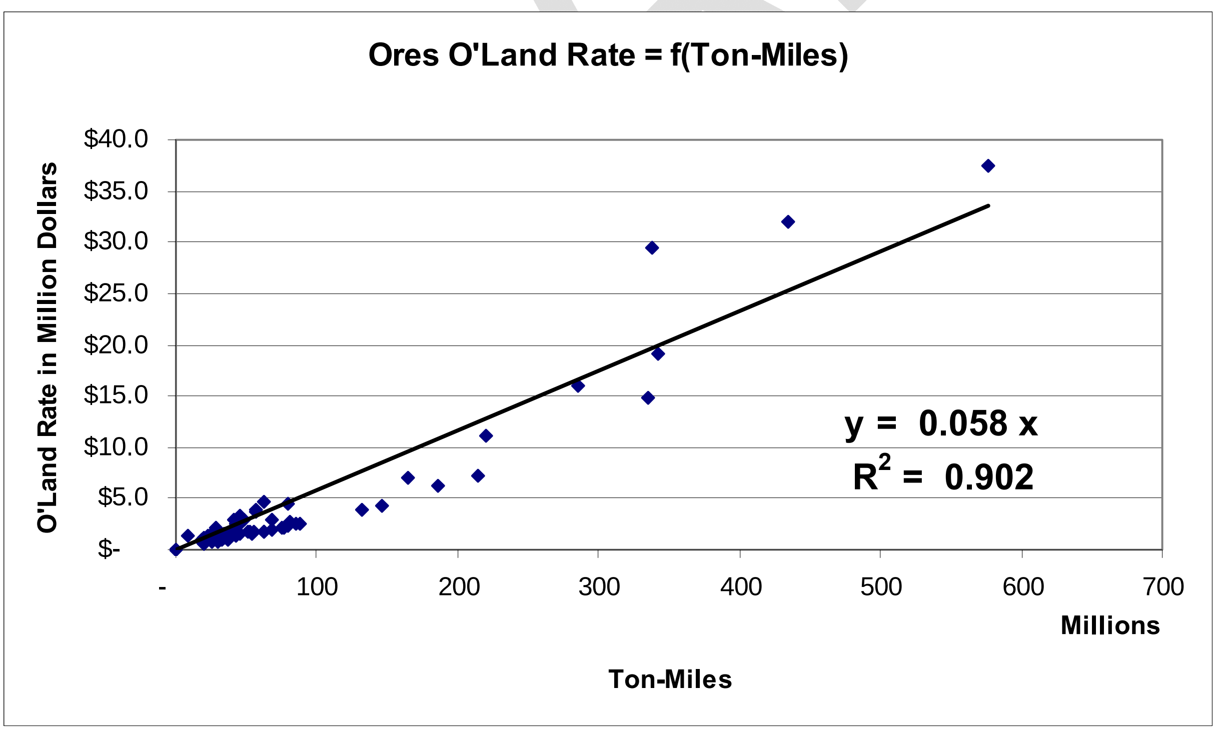

Grains Water Rate = f(Ton-Miles)
$25.0
$20.0
$15.0
$10.0
$5.0
$-
Water Rate in Million Dollars
y = 0.0121x + 254.96
R2 = 0.9435
-
100
200
300
400
500
600
Millions
Ton-Miles

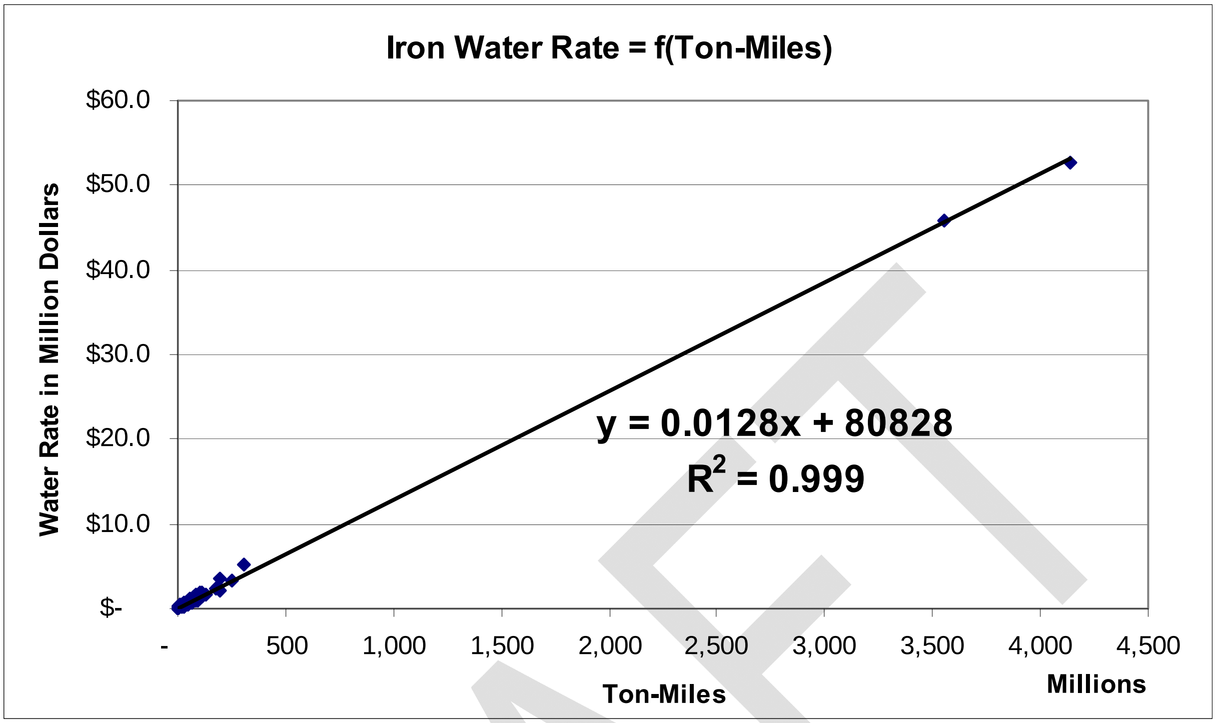

Grains O'Land Rate = f(Ton-Miles)
25
20
15
10
5
-
O'Land Rate in Million Dollars
y = 0.0357x
R2 = 0.9464
-
100
200
300
400
500
600
Millions
Ton-Miles

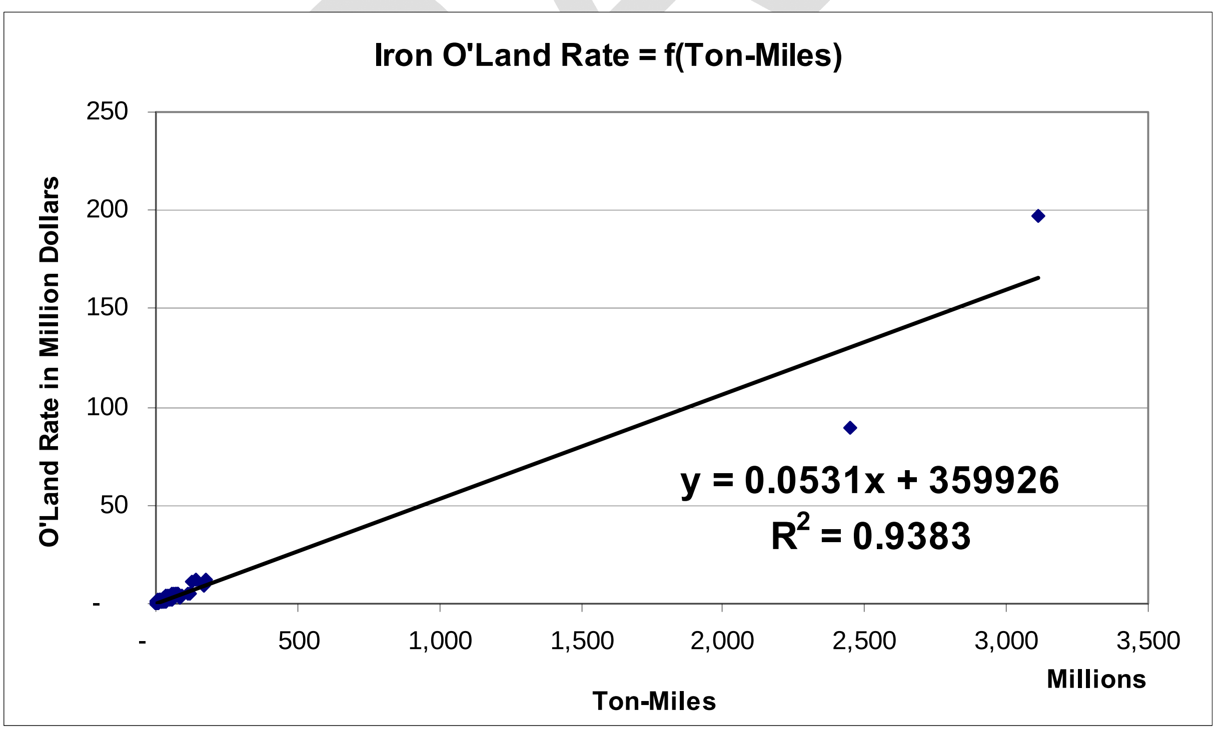

Chemicals Water Rate = f(Ton-Miles)
Water Rate in Million Dollars
$14.0
$12.0
$10.0
$8.0
$6.0
$4.0
$2.0
$-
-
50
100
150
200
250
300
350
400
450
Millions
Ton-Miles
y = 0.0255x + 125979
R2 = 0.9115

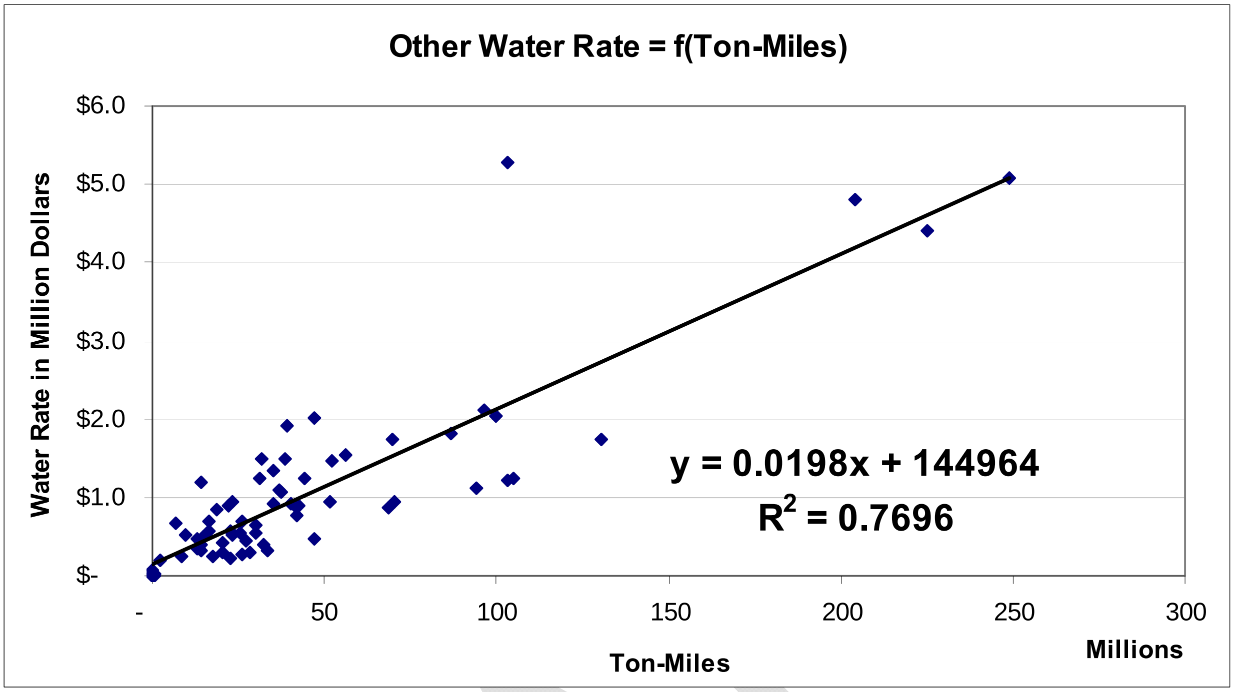

Chemicals O'Land Rate = f(Ton-Miles)
O'Land Rate in Million Dollars
$35.0
$30.0
$25.0
$20.0
$15.0
$10.0
$5.0
$-
-
50
100
150
200
250
300
350
400
Millions
Ton-Miles
y = 0.0765x + 525238
R2 = 0.8182

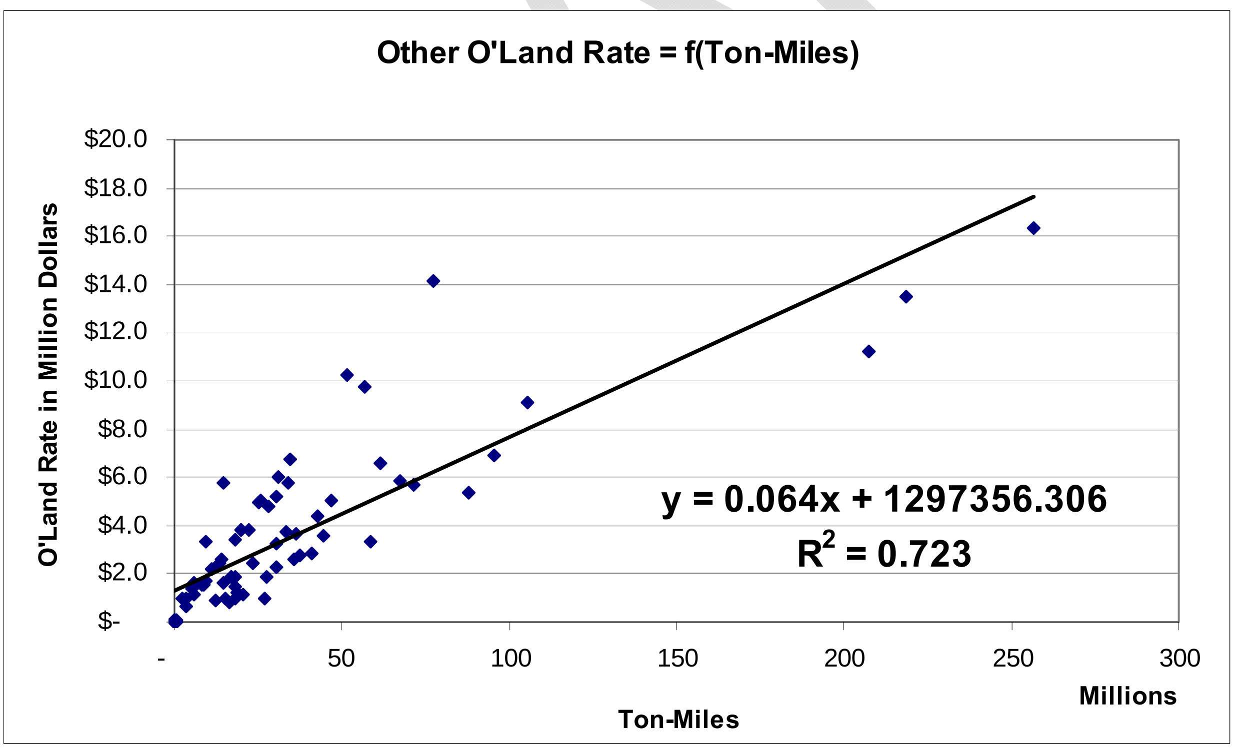

Ores Water Rate = f(Ton-Miles)
Water Rate in Million Dollars
$16.0
$14.0
$12.0
$10.0
$8.0
$6.0
$4.0
$2.0
$-
-
100
200
300
400
500
600
700
Millions
Ton-Miles
y = 0.0161x
R2 = 0.9065

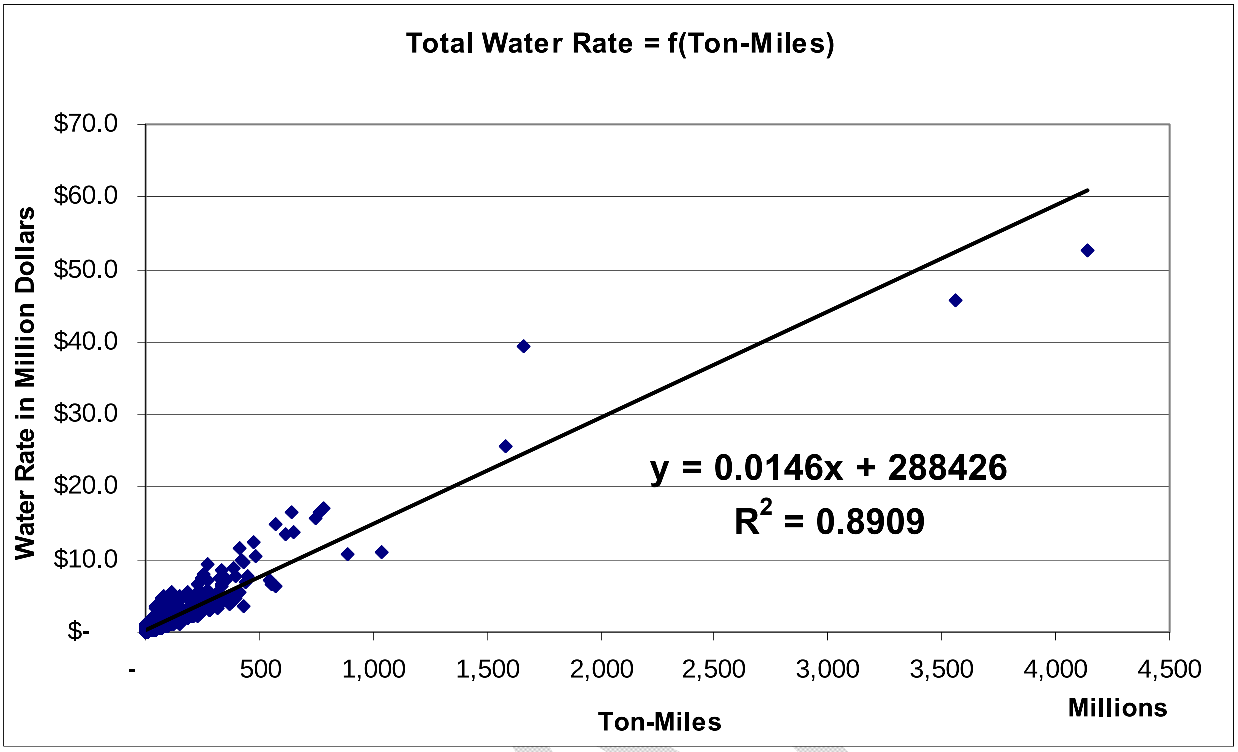

Ores O'Land Rate = f(Ton-Miles)
O'Land Rate in Million Dollars
$40.0
$35.0
$30.0
$25.0
$20.0
$15.0
$10.0
$5.0
$-
-
100
200
300
400
500
600
700
Millions
Ton-Miles
y = 0.058 x
R2 = 0.902

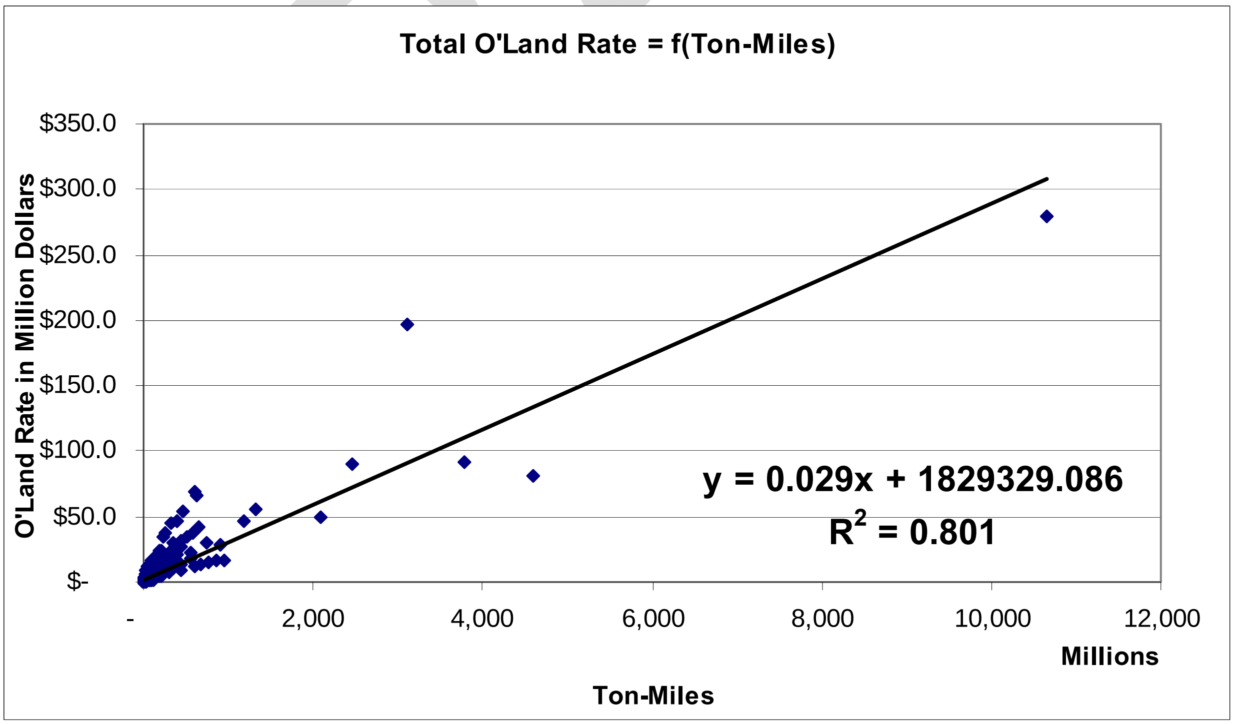

Iron Water Rate = f(Ton-Miles)
Water Rate in Million Dollars
$60.0
$50.0
$40.0
$30.0
$20.0
$10.0
$-
-
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
Ton-Miles
Millions
y = 0.0128x + 80828
R2 = 0.999


Iron O'Land Rate = f(Ton-Miles)
O'Land Rate in Million Dollars
250
200
150
100
50
-
-
500
1,000
1,500
2,000
2,500
3,000
3,500
Ton-Miles
Millions
y = 0.0531x + 359926
R2 = 0.9383


Other Water Rate = f(Ton-Miles)
Water Rate in Million Dollars
$6.0
$5.0
$4.0
$3.0
$2.0
$1.0
$-
-
50
100
150
200
250
300
Millions
Ton-Miles
y = 0.0198x + 144964
R2 = 0.7696


Other O'Land Rate = f(Ton-Miles)
O'Land Rate in Million Dollars
$20.0
$18.0
$16.0
$14.0
$12.0
$10.0
$8.0
$6.0
$4.0
$2.0
$-
-
50
100
150
200
250
300
Millions
Ton-Miles
y = 0.064x + 1297356.306
R2 = 0.723


Total Water Rate = f(Ton-Miles)
Water Rate in Million Dollars
$70.0
$60.0
$50.0
$40.0
$30.0
$20.0
$10.0
$-
-
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
Millions
Ton-Miles
y = 0.0146x + 288426
R^2 = 0.8909


Total O'Land Rate = f(Ton-Miles)
O'Land Rate in Million Dollars
$350.0
$300.0
$250.0
$200.0
$150.0
$100.0
$50.0
$-
-
2,000
4,000
6,000
8,000
10,000
12,000
Millions
Ton-Miles
y = 0.029x + 1829329.086
R^2 = 0.801

V. Application to the Population

The commodity group rate estimating parameters developed from the sample rate data were applied to the unsampled movements according to the following functional form:

$$\text{Rate per Ton} = \left[\frac{\text{line-haul}}{\text{ton}}\right] + \text{legs} + \text{accessorials}$$

(OR)

$$\text{Rate per Ton} = \left[\frac{(\beta(\text{ton-miles}) + b)}{\text{tons}}\right] + \text{legs} + \text{accessorials}$$

More detail on the application of sample rate data to the population of unsampled movements can be found in the Rate and River Closure Response Addendum of the Ohio River Navigation Investment Model (ORNIM) Attachment of the Upper Ohio Navigation Study Economics Appendix.

Table 9 compares the overall transportation rate savings per ton for the sample movements, unsampled movements and the entire population of movements used in the Upper Ohio Navigation Study.

Table 9
Upper Ohio Navigation Study
Transportation Rate Savings
(FY 2008 price level)

Commodity Group	Rate Savings per Ton		
	Sampled	Un-Sampled	Total
Coal and Coke	$ 8.16	$ 12.43	$ 8.41
Petrol Prods	$ 28.75	$ 57.60	$ 36.88
Aggregates	$ 11.25	$ 18.96	$ 12.25
Grains	$ 15.08	$ 15.42	$ 15.31
Chemicals	$ 50.32	$ 63.04	$ 56.95
Ores & Minerals	$ 30.03	$ 35.70	$ 31.57
Iron & Steel	$ 33.77	$ 30.43	$ 32.93
Others	$ 26.12	$ 47.25	$ 31.04
Total	$ 13.32	$ 32.67	$ 16.15

TRANSPORTATION RATE ANALYSIS: OHIO RIVER STSTEM
National Economic Development

Prepared for U.S. Army Corps of Engineers
Huntington District

by

The Tennessee Valley Authority
Water Management Support
Knoxville, Tennessee

July 2008

CONTENTS

ADDENDA

I. Summary

Based on a 1,552 movement survey of barge shipping, users of the Ohio River Navigation System are estimated to have saved, on average, more than $13.32 per ton in transportation and handling charges for the movement of 231 million tons of cargo when available barge costs are compared to the next-best, all-land transportation alternative. These savings are calculated across eight commodity groups including over 85 separate commodities and range between a high $50.32 per ton for chemicals and $8.16 per ton for coal. A full reporting of all rate calculations is provided through individual rate sheets (see Addendum 1) available from the Navigation Planning Center, Huntington.

II. Introduction

This study is conducted by the Tennessee Valley Authority (TVA) under contract with the Huntington District of the U.S. Army Corps of Engineers (Corps) in order to facilitate the calculations of the National Economic Development (NED) benefits attributable to Ohio River navigation. Toward this objective, the study provides a full range of transportation rates and supplemental costs for a sampling of one thousand five hundred fifty two 2004 waterborne commodity movements which, in total or in part, were routed on the Ohio River Navigation System or were inclusive of survey responses conducted by the Pittsburgh District of the Army Corps of Engineers.

Freight rates for each sample movement are calculated based on the actual water-inclusive routing, as well as for a competing all-land alternative. All computations reflect those rates and fees which were in effect in the third quarter 2007. Results are documented on a movement-by-movement basis, including a separate worksheet for each observation. These dis-aggregated data are also integrated into individual spreadsheets for each of the eight commodity groupings. A full description of the study's scope and guidelines, TVA's methods of rate research and construction, and supporting assumptions is provided below.

III. STUDY PARAMETERS

A sample of 1,552 movements was identified for inclusion in this analysis. Dock-to-dock tonnage over included origin destination pairs ranges between 14 tons and ten million tons annually representing individual commodities. Reported rates for both the water movement and the all-land alternative are based on the actual location of shipment origins and destinations.

1. *Water Routings*

Because many of the sample movements have off-river origins and/or destinations, a full accounting of *all* transportation costs for waterborne movements also requires the calculation of railroad and/or motor carrier rates for movement to or from the nearest appropriate port facility. Additionally, all calculations reflect the loading and unloading costs at origin and destination, all transfer costs to or from barge, and any probable storage costs.

2. *Land Routes*

With the exception of over-dimension shipments and intra-pool sand dredging, rail or truck rates are calculated for all movements (See Section VI for a discussion of exceptions.). For over dimension truck and intra-pool dredged materials, the land rate was estimated as compared to a specific modeled rate using identifiable data inputs. Additionally, pipeline or conveyor alternatives are calculated for applicable commodities when both the origin and destination are pipeline or conveyor served. As in the case of the barge-inclusive routings, many all-land routes require the use of more than one transport mode. Therefore, when appropriate, calculations include all requisite transfer charges.

3. *Seasonality and Market Anomalies*

To accurately reflect NED benefits, it is necessary to develop rates which portray the normal market conditions which are anticipated over the project life. For this reason, every attempt was made to purge the data of anomalous or transitory influences. As a part of all shipper surveys and interviews, respondents were directed to ignore temporary market disruptions and provide information reflective of "normal" operating conditions. As a result of the commodity mix represented within the sample, we detected no need to adjust for seasonal fluctuations. Annual contract barge rates with a fuel escalation feature and five year average spot market grain rates provide an annual average barge rate that is comparable to the multi year contract rail rates that remove seasonality. The result is consistent rate treatment for each mode.

In the Ohio River FY 2006 Rate Study, three notable situations have emerged in respect to long-term cost efficiencies for the rail mode of transportation. First, prior rail mergers in 1996 through 2005 time periods have been completed. The result of these mergers is a decrease in the variable cost of the surviving carrier and a decrease in absolute rates to reflect the surviving carriers' historic rate levels. Second, the Class 1 rail carries continue to deploy larger capacity rail cars and to install heavier gauge rail track capacity. Lading weights in excess of 120 tons for coal and grains frequently occur, reducing unit costs by fifteen to twenty percent compared to the traditional 100 ton capacity rail cars. Third, the decline in volume in the export coal market has forced rail carriers to reduce coal pricing to selected export locations to maintain the viability of railroad owned transfer docks and terminals.

IV. Worksheet Explanation

There are individual worksheets for each of the 1,552 movements. Each worksheet consists of 1 - 2 pages and catalogues basic shipment information including:

1) Corps assigned shipment reference number
2) Individual commodity description
3) Commodity group description
4) River origin

5) River origin waterway mile
6) Off-river origin (if applicable)
7) WCSC number
8) Shipment tonnage
9) River destination
10) River destination waterway mile
11) Off-river destination (if applicable)

Section I of the worksheet contains the analysis of the barge-inclusive routing from origin to destination via the Ohio River Navigation System. Section II contains information describing the best available all land alternative. When multiple off river origins were observed, a supplemental page calculating a tonnage weighted average of the transportation rate is shown.

Authorities or sources for all calculations are reported in footnotes to the appropriate worksheet items. All rates and supplemental costs are expressed on a per net ton basis in third quarter 2007 U.S. dollars. When the river port town name and the railroad station name are different, the railroad station name is indicated as an off-river origin or destination with no cost to and/or from the river.

V. Judgments and Assumptions

Based on information collected from shippers, receivers, carriers, river terminal operators, stevedores, federal agencies, and private trade associations, TVA was able to identify probable origins and destinations for the majority of those movements that originated or terminated at off-river locations. In the absence of specific shipper/receiver information, it is assumed that the river origin and destination are the respective originating and terminating points for both river and alternative modes of transportation. In every case, an attempt was made to gather information from all shipping ports. However, in some instances, 2004 logistical data are not available from these ports. In other cases, port representatives declined to provide the requested information.

Specific commodity groups are discussed in more detail later in this section. However, for those movements that originate or terminate at a river port location, it is assumed that rail service could also be utilized by the shipper or receiver if that port is rail served. Exceptions to this assumption are noted on individual worksheets. When the shipper or receiver is served by truck only, a railroad team track or transfer facility at the station nearest the off-river shipper or receiver is used for the land alternative. Only those shippers who ship more than 150,000 tons annually and who are adjacent to rail tracks would be assumed to undertake the significant capital expenditures necessary to acquire direct rail service. Mileage allowances made by carriers to shippers for the use of private equipment are also ignored as are rebates to shippers.

For the long run, in all cases, it is assumed that the alternative modes of transportation would have the physical capacity to accommodate the additional tonnage represented by each commodity movement (This is provided for in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G)). Commodity specific judgments and assumptions include:

Coal (Group 1)

A number of assumptions are made for land haul rates on the movements of coal to utility destinations that are not rail served. Volumes to these utility destinations are, in many cases, substantial, so that long-haul truck transportation cannot be considered a viable option. In the absence of water transportation, receiving utilities would have to carefully evaluate those available options which might insure their ability to continue to receive large volumes of coal. These considerations might include the replacement cost of transfer and handling facilities, the construction cost of switch or main line rail track, the cost of new or improved highway access, the economies of buying or leasing rail equipment, and the possibility of shifting origins to assure adequate coal supply. For their part, we may assume that rail carriers would be willing to construct additional track capacity if volumes are sufficient. However, these construction costs would most likely be passed on to the shipper via higher rates.

To accommodate those instances in which sample barge movements are to non-rail served utilities, we have incorporated the following judgments and assumptions.

> If the receiving utility is not rail served, rates are applied to the nearest railhead, and trucking costs from the railhead to the destination are applied. If the shipping point is not rail served, a motor carrier charge is applied from the mine origin to the nearest railhead. It is assumed that transfer facilities would be available at both origin and destination for transfer between rail and truck.
>
> If the receiving utility is rail served for supplies only, but not coal, the rail car unloading cost of the utility is inflated to accommodate a rail track expansion to the coal stockpile.
>
> In some instances, movements involve a truck haul from multiple origins to a concentration or preparation point for loading to rail. In these instances, where shipments originate at several mines within the same general area, a representative rail origin is selected as the transfer location.

Aggregates (Group 2)

Land haul rates on limestone and sand and gravel reflect the modes necessary to transport the shipments from actual origins to actual destinations. If origins or destinations are not rail served, a trucking charge is applied from the nearest rail station. For those movements where both rail and truck transportation are an option, truck hauls are limited to a distance of 100 miles. This, on occasion results in slightly higher rates. However it was deemed impractical, in the absence of water transportation, to transport large volumes of these commodities for long distances by truck. Limiting factors of truck transport include lower cargo carrying capacity, the inability to round-trip more than three times per day, and the absence of loaded back-haul opportunities.

With regard to waterway improvement materials, we assume that land movements would require a truck haul at the destination for delivery to river bank work locations. These truck movements would likely average five miles each. It should be noted that a significant amount of channel improvement and bank stabilization work is conducted off shore or at locations without highway access, making land transportation impractical.

Grain (Group 4)

The computation of rates for grain is based upon the survey responses of the shippers and receivers and the percentage of waterway freight bureau tariff for the movement of grain (Addendum 3). Specifically, if a country elevator gathers grain then ships it to the river terminal we assume a 20 mile truck haul from the farmer's field to the country elevator. If the grain moves for export, a unit train movement is assumed, and land rates are computed from a unit train capacity elevator to a Gulf port location. For domestic shipments, the computation of rail rates is based on the track capacity of the country elevator or domestic receiver. We assume that the grain shipper would maximize the use of his facilities and utilize gathering rates to reach the track capacity of the receiver.

The rail rating of feed ingredients follows assumptions similar to those used for the rating of grain - namely rates constrained by track capacity. Rail and barge transit programs for meals (soybean, cottonseed, oilseed and fish) were not considered.

VI Methods and Procedures

As a result of pricing flexibility and differential rates allowed by surface transportation deregulation, it is sometimes difficult to determine the exact rate charged by a carrier on shipments moving under contract. Barge rates are a matter of negotiation between shipper and barge line operator, and these rates are not published in tariff form. Each carrier's rates are based on individual costs and specific market conditions, so that these rates will vary considerably between regions, across time, and from one barge line to another.

Contract rates are also common in pipeline, rail and motor carrier transportation and, like barge rates, may be maintained in complete confidentiality. In other cases (particularly grain), tariff rates are still applied. However, there is rarely any dependable means for determining whether a contract rate or a tariff rate should be used to price a particular movement. A further complication is the use of rebates and allowances as an incentive by carriers to shippers to induce higher traffic volumes.

Barge Rates

With the exception of grain and feed ingredients and average trade publication spot market rate quotes, unobservable barge rates are calculated through the application of a computerized barge costing model developed by the Tennessee Valley Authority. The TVA model has been refined to include 2007 fixed and variable cost information obtained directly from the towing industry and from 2006 data published within the Corps' annual *Estimated Towboat and Barge Line-Haul Cost of Operating on the Mississippi River System (This is an update of data and equations using a 2000 report methodology)*. Additionally, 2006 data from the Waterborne Commerce Statistical Center trip reports and 2006 data from the Lock Performance Monitoring System are incorporated into TVA BCM costing parameters.

The TVA model contains three costing modules: a one-way general towing service module, a round-trip dedicated towing service module, and a round-trip general towing service module. The one-way module calculates rates by simulating the use of general towing conditions between origin and destination, including the potential for a loaded return. The dedicated towing service module calculates costs based on a loaded outbound movement and the return movement of empty barges to the origin dock. The round-trip general towing service module is similar to the one-way, except that it provides for the return of empty barges to the point of origin. This module does not calculate costs for towboat standby time during the terminal process but does include barge ownership costs (maintenance, replacement cost, supplies, insurance, and administration) for both the terminal and fleeting functions. It does not require that the empty barges be returned with the use of the same towboat. Depending on the module in use inputs may include towboat class, barge type shipment tonnage, the interchange of barges between two or more carriers, switching or fleeting costs at interchange points or river junctions, and barge ownership costs accruing at origin and destination terminals, fuel taxes, barge investment costs, time contingency factors, return on investment, and applicable interest rates.

Barge rates on dry commodities are calculated with the use of the general towing service round-trip costing module. Inputs, based on information from carriers and the Corps' Performance Monitoring System

(PMS) database were programmed into the module to simulate average towboat size (horsepower) and corresponding tow size (barges) for each segment of the Inland Waterway System. Other inputs include barge types, waterway speeds, horsepower ratios and empty return ratios. These inputs are documented by Addendum 2 for 2006.

An example of a typical shipment cost in this analysis would be a dry bulk commodity (iron ore intermediates or cement clinker) originating on the Mobile River at Mobile, Alabama and terminating on the Ohio River at Cincinnati, Ohio. Based on the modeling process, this shipment would be assumed to move in an four barge tow from Mobile to the Mississippi River at New Orleans, a twenty four barge tow from New Orleans to Cairo, and a fifteen barge tow from Cairo to Cincinnati. At each interchange point, appropriate fleeting charges would be calculated. Empty return (back haul) factors would also be included for each segment of the movement.

With the exception of movements involving Northbound and tributary rivers, barge rates for grain and feed ingredients are estimated on the basis of a percentage of base rates formerly published in Waterway Freight Bureau Tariff 7.[4] For movements with origins in the Ohio River Basin, the five year average percent of base for the Lower Ohio, Mid Ohio, Upper Mississippi, Illinois, and Missouri Rivers is used. For movements on the Tennessee, Gulf Inter Coastal Waterway, an arbitrary charge is added to the New Orleans base rate. Rates for those movements that traversed the Tennessee -Tom Bigbee Waterway are calculated through the use of the TVA general towing service round-trip costing module.[5]

Barge rates for asphalt, heavy fuel oils, and light petroleum products are calculated through the use of the dedicated service round-trip costing module. Twenty hours standby time is allocated at origin and destination for towboat terminal functions. Finally, rates for sodium hydroxide, vegetable oils, lubricating oils, liquid chemicals, and molasses are calculated through the use of the general service round-trip costing

[4] The expression of barge rates for agricultural commodities as a percentage of waterway Freight Bureau Tariff 7 is consistent with industry standards (see Addendum 3).
[5] There is no basis for rates via the Tenn-Tom in the Waterway Freight Bureau Tariff.

module. As a result of comparable barge sizes, these commodities normally move in the same tow with dry commodities.

Barge rates calculated by the use of the TVA model reflect charges that would be assessed in an average annual period of typical demand for waterway service. It should be noted that the model does not explicitly consider market factors such as intra or inter modal competitive influences, favorable back haul conditions created by the traffic patterns of specific shippers, or the supply and demand factors which affect the availability of barge equipment. These and other factors can influence rate levels negotiated by waterway users. The model does, however, calculate rates based on the overall industry's fully allocated fixed and variable cost factors, including a reasonable rate of return on assets. It is TVA's judgment that the rates are representative of the industry and provide a reasonable basis for the calculation of NED benefits.

The spot market hopper barge rates were derived from the River Transport News published by the Criton Corporation of Silver Springs, Maryland. The average spot market rate for the second and third quarters of 2007 was utilized.

Railroad Rates

In 2007, rail shippers received rate relief from the Surface Transportation Board (STB) in the calculation of fuel surcharges. The result of the STB decision was a new calculation method for surcharges based upon mileage with the Class 1 rail carriers adopted the ALK mileage software program to estimate mileage.

To resolve the above analytical issues, TVA developed a rail rate estimating technique using the attributes of rail shipping exhibited in the STB Waybill Sample. This technique was first employed in the Upper Mississippi and Illinois Rivers 2006 Transportation Rates Project for the Army Corps of Engineers.

The TVA rail rate estimating method has six steps. First, TVA field or telephone interviews the dock operator to establish the off river origin and/or destination, the mode and carrier of transport to or from the dock, rail track capacity at the dock, and river dock handling capability. Second, a rail route is constructed from either the off river origin or the dock origin. Third, the STB Waybill Sample for 2006 was sorted by seven digit STCC number (or five digit if insufficient observations) by carrier, by state (or all states if insufficient observations), by single car-multi car-small unit train-large unit train, and by distance (less than 500 miles or greater than 500 miles). Fourth, the average revenue per mile was calculated along with the standard deviation. Fifth, a derived revenue masking factor, an index from 2006 to third quarter 2007 (non fuel 3.5%), and a fuel surcharge (0.28 per mile) were applied. Last, carrier mileage was multiplied by the adjusted revenue per mile, and the result was divided by the average weight per car to produce an estimate of the rail rate per short ton for the land move.

Motor Carrier Rates

Truck rates for off-river movements were obtained from the shipper and dock surveys conducted by TVA for the Army Corps of Engineers. In addition, TVA maintains transportation trade publications that report various regional trucking rates and costs. The truck rate methods TVA uses consist of a rate per loaded mile for moves over 100 miles or a shuttle truck rate per hour for moves under 100 miles. The truckload weight is provided by the individual state highway axel load and bridge formula for truckload and permitted load limits.

Handling Charges

Handling charges between modes of transportation are estimated on the basis of information obtained from shippers, receivers, stevedores, and terminal operators. Handling charges for the transfer of commodities from or to ocean-going vessels are on the basis of information obtained from ocean ports or stevedoring companies. For import or export movements that involved mid-stream transfer operations, handling costs to or from land modes at a competing port with rail access are applied.

Except as noted within individual worksheets, it is assumed that movements of bulk products (for example, grain or fertilizer) would be handled through elevators or storage facilities. It was also assumed that liquid commodities transferred between modes would require tank storage. Additional costs are incurred at both river and inland locations if shipments remain in storage past the free-time period allocated by the facilities involved. Storage charges are usually assessed on a monthly basis.

Loading and Unloading Costs

Because loading and unloading costs are not usually documented by shippers and receivers, they are particularly difficult to obtain.[6] Moreover, these costs can vary considerably across firms. In an attempt to provide the best possible estimates of these costs, we use available shipper and receiver information in combination with data from Corps studies performed by other researchers, as well as previous TVA studies. These data are revised to reflect 2007 conditions then averaged as required. In those cases where varying sources produced disparate estimates, we relied most heavily on shipper and receiver estimates.

Methodological Standards

Two points should be noted regarding the methodological standards applied within this study. First, the standards described above reflect essentially the same processes TVA has applied (or will apply) in developing transportation rates for other recent (or ongoing) Corps studies. Specifically, the outlined methodology was used in the 1996 and 2000 Ohio River Studies and the 1996 and 2006 Upper Mississippi Navigation Feasibility Study and was applied in the Missouri River Master Manual Review process, the Soo Locks Study and Port Allen Cutoff assessment. Thus, inter-project comparison is facilitated by this uniform approach. More importantly, recent methodological improvements enable TVA to produce transportation rate/cost materials which are, simultaneously, more complete and more reliable than the transportation data TVA (or other agency) has produced for similar studies in the past. Each Rate study for each District of the USACOE is integrated into a series of data bases for quick accessibility and data manipulation.

VII SAVINGS TO USERS

Based on the third quarter 2007 cost levels, those users of the Ohio River represented by the 1,552 sampled movements saved, on average, about $13.32 per ton over the best possible land routing. Savings for each of the eight commodity groupings identified for this analysis are summarized in **Table 1** below.[7]

Table 1
Average Rate Savings by Commodity Group

Group	*Commodities*	*Average Per-Ton Water Rate*	*Average Per-Ton All-Land Rate*	*Average Per-Ton NED Saving*
1	Coal	$16.95	$25.12	$8.16
2	Petroleum Fuel Products	$16.67	$45.42	$28.75
3	Aggregates	$7.75	$19.00	$11.25
4	Food and Processed Food Prod.	$26.98	$42.07	$15.08
5	Chemicals	$34.18	$84.50	$50.32
6	Non-Metallic Minerals	$27.65	$57.69	$30.03
7	Ferrous Ores, I&S Products	$25.84	$59.61	$33.77
8	Manufactured Goods	$14.37	$40.49	$26.12
AVERAGE ALL COMMODITIES		$16.64	$29.97	$13.32

During the preparation of this study, we observed that, in some instances, the selection of barge transportation is more costly than the land alternative. There are any number of scenarios which work individually or in combination to explain this phenomenon. First, in some cases, the sample may occasionally captured a transitory use of barge which occurs when pipelines lack capacity or when rail cars are in short supply. That is to say, for some particular shipper/receiver barge is only the mode of choice when other transportation markets are unusually active. Secondly, long term contracts and large capital investments may lead to discontinuities in the relationship between relative rates and modal choice. In many areas barge shippers and receivers are captive to the navigation mode because they lack the industrial footprint to build the infrastructure for a modal change. While this can be a short-run situation, it may, nonetheless help to explain what appears to be perverse behavior. Next, the analysis superimposes 2004

[6] Loading and unloading costs are often considered a part of through-put or production costs.

transport market conditions on set of 2007 modal choice decisions. In the vast majority of cases, this dichotomy is of little import. However, in a few cases, transportation rates may have changed sufficiently, so that in 2007, barge would no longer have been the mode of choice. Finally, regulatory constraints on the new construction of coal and hazardous materials handling facilities may preclude the development of facilities necessary for some shippers to take advantage of changes in the vector of available transportation rates.

Next, a few observations should be made that describe the traffic patterns for the Ohio River FY2006 Rate Study. First, the length of haul has been reduced as shown by the reduction in the average barge and land rates. Second, the empty return ratios on the Ohio River are increasing to levels reflecting greater tow and barge operating inefficiencies from contract and dedicated towing. Third, total traffic sample tons continues to grow resulting in a greater accuracy of the sample to explain the behavior of the population. Fourth, the growth in the import of steel intermediates has provided reduced barge fleet capacity for domestic shipping, leading to elevated barge haul rates. Last, the number of rated commodities has grown reflecting a more diverse usage of the navigation system.

Finally, a discussion needs to be given to clarify the use of a 2004 barge sample for traffic flows, and then the use of the most recent barge and rail operating parameters from 2006 and 2007 for modeling rates. At the start of the rating process, the most recent barge traffic sample is drawn from the Water bourn Commerce Statistical Center. For the Ohio River System this means a sample in excess of 80% of the total tons moving from, to or through the Ohio River and its tributaries.[8] The traffic in the sample is rated using the most current cost and operating parameters for the models (rate outliers for traffic that has ceased moving due to uneconomical conditions are removed). The result is arrayed by commodity group and river reach and

[7] All rates and rate differentials are weighted average.

[8] Traditionally, ORB transportation rate studies have constructed 1,500-some movement samples representing over 80+ percent of system traffic. The 80% refers to the Ohio River System as a whole; the comparable number for the upper Ohio projects is 86%. The percentages are high because we selected a sample to be rated that is weighted towards the high volume movements. The EDM lock study used the current ORB rate data-set but focused the economic analysis on upper Ohio navigation system costs and benefits.

then applied to future forecasted traffic for the planning period (50-60 years). The goal of the rate study is to provide the most current typical rates for future application.

ADDENDUM 1

SAMPLE RATE WORKSHEET

TRANSPORTATION RATE ANALYSIS

Ref No.: 1 (Page 1)

Commodity	Coal		
WCSC Gp.	32100	Tonnage	80,930
River Origin	42004502	Riv. Dest	20055502
Origin Port Code	BIG SANDY RIVER MILE 4	Dest Port Code	LOWER MISS RIVER MILE 55 (PORT OF PL
Origin WW Mile	BS 4	Dest WW Mile	LM 55
Off-River Orig.	Radius 100 Miles	Off-River Dest	East Tampa, FL

WATER ROUTE

	Mode	Miles	Cost	
(1) Loading at origin			1.35	
(2) Charge to transfer point				
(3) Transfer charge				
(4) Charge to river	TRUCK	100	10.80	a/
(5) Handling at river origin			1.35	b/
(6) Line haul charge	BARGE	1567	16.30	c/
(7) Handling at river destination			1.90	
(8) Charge ex river	OCEAN BARGE	658	9.25	d/
(9) Unloading at destination			1.75	
(10) Other				
(11) Total		2325	42.70	

LAND ROUTE

	Mode	Miles	Cost	
(1) Loading at origin			1.35	
(2) Charge to transfer point	TRUCK	100	10.80	a/
(3) Transfer charge			1.50	
(4) Line-haul charge	RAIL	1159	57.92	e/
(5) Transfer charge				
(6) Final leg to destination				
(7) Unloading at destination			1.25	
(8) Other				
(9) Total		1259	72.82	

SUMMARY

	Cost
(1) Water Route	42.70
(2) Land Route	72.82

AUTHORITIES FOR CHARGES AND EXPLANATION OF REFERENCE MARKS

a/ Coal permited truck rate $75 per hour plus fuel surcharge
b/ Supplied by dock
c/ Published spot barge rate average 3rd & 4th quarter 2007
d/ Tow rate $12,000 per day
e/ STB Waybill 2006 indexed to 3rd quarter 2007 plus fuel surcharge CSX multi car

SUPPLEMENTAL DATA

		Ref. No.:	107 (Page 2)
Commodity:	Coal	Tonnage:	3,047,444
River Origin	UPPER MISS RIV	River Dest.:	OHIO RIVER MILE

A. Cost Computation for Land Route Factor from Off-River Origin to Riverport (Section I):

Location	Tonnage	Miles	Truck Rate	Rail Trf Rate	Est Rail Rate	Charges
Colorado-UPRR	457117	1367			25.35	11587915.95 a/
Wyoming-UPRR	2590327	1104			16.42	42533169.34 a/
						0.00
						0.00
						0.00
						$54,121,085.29

Average Rate: $17.76 Average Miles: 1236

B. Cost Computation for Land Route Factor from Riverport to Off-River Destination (Section I):

Location	Tonnage	Miles	Truck Rate	Rail Trf Rate	Est Rail Rate	Charges

Average Rate: $0.00 Average Miles: 0

C. Cost Computation for Through Land Route Factor (Section II):

Location	Tonnage	Miles	Truck Rate	Rail Trf Rate	Est Rail Rate	Charges
Colorado-UP	457117	1583			34.02	15551120.34 b/
Wyoming-UP	2590327	1431			24.34	63048559.18 b/
						0.00
						0.00
						0.00
						$78,599,679.52

Average Rate: $25.79 Average Miles: 1507

AUTHORITIES FOR CHARGES AND EXPLANATION OF REFERENCE MARKS

a/ 2006 STB Waybill indexed to 3rd quarter 2007 plus fuel surcharge
b/ STB Waybill 2006 indexed to 3rd quarter 2007 plus fuel surcharge UP-CSX-CMPA private car large unit train

ADDENDUM 2.

EMPTY RETURN RATIOS, HORSEPOWER AND TOW SIZE BY RIVER SEGMENT

MTY_RET (% EMPTY UP AND DOWN) DATABASE FOR BARGE MODEL 10:15 Monday, June 30, 2008 1

Obs	RIVNUM	RIVER	MTYUP	MTYDOWN
1	1	ALABAMA	0.90	0.90
2	2	ALLEGHENY	0.90	0.90
3	3	A/C/F/	1.00	1.00
4	4	ARKANSAS	0.20	0.20
5	5	ATCHAFALAYA, N	0.97	0.50
6	6	ATCHAFALAYA, S	0.97	0.50
7	7	BIG SANDY	1.00	1.00
8	8	BLACK/OUCHITA	0.90	0.90
9	9	BLACK-WARRIOR	0.27	0.80
10	10	CUMBERLAND	0.97	0.28
11	11	GIW(E) NOLA-MOBILE	0.40	0.40
12	12	GIW(E) MOBILE-ACF JCT	0.40	0.40
13	13	GIW(W) HARVEY LOCK-MORGAN CITY	0.65	0.90
14	14	GIW(W) MORGAN CITY-BROWNSVILLE	0.35	0.35
15	15	GREEN	0.58	0.70
16	16	HOU S/C	0.28	0.42
17	17	IHNC	0.40	0.40
18	18	ILL	0.40	0.27
19	19	KAN	0.58	0.96
20	2	LM 1-98	0.50	0.50
21	21	LM 99-229	0.25	0.50
22	22	LM 230-954	0.25	0.50
23	23	MO LOWR	0.10	0.25
24	24	MO MID	0.10	0.15
25	25	MO UPR	0.10	0.10
26	26	MOB RIV	0.30	0.90
27	27	MOB S/C	0.50	0.50
28	28	MON	0.39	0.81
29	29	MCPA	0.20	0.60
30	30	MRGO	1.00	1.00
31	31	OHIO	0.27	0.28
32	32	OLD	0.90	0.95
33	33	RED	0.85	0.85
34	34	TN LOWER	0.51	0.26
35	35	TN UPPER	0.68	0.35
36	36	TENN-TOM	0.30	0.99
37	37	TOMB	0.30	0.90
38	38	UM 0-185	0.18	0.37

MTY_RET (% EMPTY UP AND DOWN) DATABASE FOR BARGE MODEL 10:15 Monday, June 30, 2008 2

Obs	RIVNUM	RIVER	MTYUP	MTYDOWN
39	39	UM 186-865	0.18	0.37
40	40	YAZOO	0.20	0.97
41	41	OTHER	0.37	0.37
42	42	ALGIERS CANAL	0.90	0.42
43	43	COLUMBIA	0.25	0.70
44	44	SNAKE	0.45	0.55

GEN TOW DATABASE FOR BARGE MODEL 10:22 Monday, June 30, 2008 1

Obs	SEG_NO	RIVER	GTOW_HP	GTOW_CLS	GTOW_SIZ
1	1	ALABAMA	1207	1	2
2	2	ALLEGHENY	1340	1	2
3	3	A/C/F/	900	0.9	1
4	4	ARKANSAS	2947	5	8
5	5	ATCHAFALAYA, NORTH	1412	2	2
6	6	ATCHAFALAYA, SOUTH	1181	1	1
7	7	BIG SANDY	1323	1	4
8	8	BLACK/OUCHITA	1513	2	2
9	9	BLACK-WARRIOR	1888	3	6
10	10	CUMBERLAND	2541	4	8
11	11	GIW(E) NOLA-MOBILE	1286	1	4
12	12	GIW(E) MOBILE-ACF JCT	1267	1	3
13	13	GIW(W) HARVEY LOCK-MORGAN CITY	1147	1	3
14	14	GIW(W) MORGAN CITY-BROWNSVILLE	1363	2	3
15	15	GREEN	1736	3	4
16	16	IHNC (NEW ORLEANS)	1050	1	4
17	17	ILLINOIS	2529	4	7
18	18	KANAWHA	2194	4	6
19	19	LOWER MISS	4750	8	25
20	20	MISS RIV-GULF OUTLET	925	0.9	2
21	21	MISSOURI KAN CITY-SOUTH	1800	3	4
22	22	MISSOURI KAN CITY-OMAHA	1100	1	2
23	23	MISSOURI OMAHA-S CITY	1800	3	2
24	24	MOBILE RIVER	1888	3	5
25	25	MONONGAHELA	1732	3	5
26	26	MOR CITY-PT ALLEN ROUTE	1366	2	4
27	27	OHIO	2682	5	11
28	28	OLD	1513	2	4
29	29	RED	1666	3	4
30	30	TENNESSEE, LOWER	2580	4	10
31	31	TENNESSEE, UPPER	2405	4	6
32	32	TENNESSEE-TOMBIGBEE	3280	6	6
33	33	TOMBIGBEE RIVER	1888	3	6
34	34	UPPER MISS CAIRO-ST LOUIS	4696	8	20
35	35	UPPER MISS ST LOUIS-MPLS	3971	7	10
36	36	YAZOO	2043	3	3
37	37	OTHER	2000	3	2
38	38	ILL RIV ABOVE MI 291(L'PORT)	2529	4	4

GEN TOW DATABASE FOR BARGE MODEL 10:22 Monday, June 30, 2008 2

Obs	SEG_NO	RIVER	GTOW_HP	GTOW_CLS	GTOW_SIZ
39	39	ALGIERS CANAL	1350	2	3
40	40	COLUMBIA	3170	5	3
41	41	SNAKE	3017	5	3

ADDENDUM 3.

PERCENTAGE OF WATERWAY FREIGHT BUREAU TARIFF NO. 7 FOR THE MOVEMENT OF GRAIN

Waterway Segment	*2007 Percent of Tariff*	*2003-2007 Average Percent of Tariff*
Upper Mississippi River	458%	364%
Upper Mississippi River (243-634)	423%	330%
Illinois River	398%	319%
Middle Mississippi River (0-243)	338%	278%
Upper Ohio River	361%	286%
Lower Ohio River	361%	287%
Lower Mississippi River (Memphis)	317%	256%
Lower Mississippi River (NOLA)	424%	344%

Source: Illinois Department of Transportation / U.S. Department of Agriculture

Upper Ohio Navigation Study
ECONOMICS APPENDIX

Attachment 5
Upper Ohio River
External Effects

02 April 2010

Executive Summary

Externalities are effects of existing or proposed projects that are not normally evaluated as standard economic and environmental effects. Externalities evaluated for this study include roadway congestion, fuel usage, accident, air pollution, and employment. The effects were evaluated by experienced agencies and firms: the Tennessee Valley Authority, the University of Tennessee Center for Transportation Research, and Linare Consulting of Pittsburgh.

The effects were categorized into the four accounts used by the Corps in the evaluation of proposed projects: National Economic Development (NED); Regional Economic Development (RED); Environmental Quality (EQ); and Other Social Effects (QSE).

The estimated effects are summarized in Table E-1. Nearly 91 percent of effects of disruptions to the navigation system are in the RED account, where the investigations indicated the potential for significant shifts in coal sourcing from the Mon Basin to Central Appalachia. Overall, the approximate NED losses are in the range of $106 million per year, the RED losses are approximately $1 billion per year, and the OSE are approximately $16 thousand per year.

Table E-1: Effects categorized by Accounts

	NED	RED	EQ	OSE	Total
Increased roadway congestion	$ 1,059				$ 1,059
Increased accidents				$ 104	$ 104
Increased emissions				$ (160)	$ (160)
Others				$ 72	$ 72
Water supply disruptions	$ 105,600	$ 105,600			$ 211,200
Barge transportation disruptions	$ 41	$ 943,200			$ 943,241
Total	$ 106,700	$1,048,800	$ -	$ 16	$ 1,155,516

Note: water supply disruption costs were not categorized clearly as NED or RED; the total was divided by two and assigned equally to NED and RED.

Guidance provided by the Corps' Headquarters office limited NED benefits that could be considered in the economic evaluation to roadway congestion. Roadway congestion effects represented as increased costs per ton attributable to lock closures are listed in Table E-2. These values were input to the Ohio River Navigation Investment Model (ORNIM) where they were included in the calculation of system benefits for different project alternatives.

Table E-2: Roadway Congestion Disbenefits

Year	< 60 days			60 - 180 days		
	Delay	Other	Total	Delay	Other	Total
1	$0.57	$0.01	$0.57	$0.44	($0.27)	$0.16
10	$0.70	($0.08)	$0.61	$0.54	($0.32)	$0.22
20	$0.88	($0.08)	$0.81	$0.68	($0.33)	$0.35
30	$1.21	($0.04)	$1.17	$0.93	($0.31)	$0.62
40	$1.77	$0.02	$1.79	$1.39	($0.29)	$1.10
50	$2.84	$0.08	$2.93	$2.24	($0.25)	$1.99
51	$2.99	$0.09	$3.08	$2.36	($0.25)	$2.11

The year one increase in roadway congestion is $0.57 per ton for a less than 60 day lock closure and $0.16 per ton for a 60 to 180 day closure. The costs increase over time to equal $3.08 and $2.11 per ton respectively in year 51. The roadway congestion costs are approximately 25 percent of the traditional transportation benefits measured as the cost savings of waterway routed shipments compared to the least cost all overland routing.

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Tables

Addenda

Addendum 1 - Social Costs of Barge Cargo Diversions due to Unscheduled Closures at Emsworth, Dashields, and Montgomery Locks; University of Tennessee Center for Transportation Research

Addendum 2 - Transportation Rate Analysis: EDM Regional Economic Development, Tennessee Valley Authority, July 2008

1.0 Introduction

The Federal Government and the Corps of Engineers consider four categories of accounts when assessing the merits of proposed structural and non-structural project alternatives: 1) the national economic development (NED) account; 2) the regional economic development (RED) account; the environmental quality (EQ) account; and 4) the other social effects (OSE) account. NED for inland navigation projects are largely the savings in using the waterway transportation system compared to the least cost all overland system. RED represents a regional gain or loss in employment and income at the expense of some other region of the U.S., such as the relocation of a manufacturing plant from Utah to Ohio to take advantage of a waterway transportation system. EQ refers to ecological, cultural, and aesthetic effects attributable to the proposed project. OSE are the potential effects on social aspects such as community impacts, health and safety, displacement, energy conservation, and others. The studies that were conducted to measure these effects are described in this attachment.

2.0 Studies

Three studies were conducted to estimate the NED, RED, EQ, and OSE of the existing and proposed upper Ohio navigation system alternatives. The studies were performed by the University of Tennessee (UT), the Tennessee Valley Authority (TVA), and Linare Consulting. The reports contain company specific information not for public release but are available to approved personnel, such as those responsible for review. The reports documenting the studies are listed in Table 1 and are maintained on file in the PCXIN.

Table 1: Studies conducted on Subject

	Report	Date	Conducted by	Pages
1	"Transportation Rate Development: Ohio River System, National Economic Development"	July 2008	TVA	13
2	"Transportation Rate Development: Ohio River EDM, Social Costs"	July 2008	TVA	7
3	"Social Costs of Barge Cargo Modal Diversions Due to Unscheduled Closures at Emsworth, Dashields, and Montgomery Locks"	undated but published in July 2008	University of Tennessee Center for Transportation Research	27

4	"Economic and Job Effects of Possible Ohio River Closures: Emsworth, Dashields and Montgomery Projects; Navigation and Water Supply Disruptions"	August 2009	Linare Consulting	28

3.0 Conceptual Basis

The conceptual basis of the accounting system is to consider all positive and negative effects of proposed actions when selecting the recommended alternative. Of particular importance to the Upper Ohio Feasibility Study is the conceptual basis for measuring the NED benefits, specifically the NED benefits external to the navigation system. According to ER 1105-2-100, page E-33, (7) "Determine Future Cost of Alternative Modes": "the without-project condition normally assumes that the alternative modes have sufficient capacity to move traffic at current rates unless there is specific evidence to the contrary". Even if specific evidence exists, prior approval of an evaluation with restricted overland capacity requires prior approval from HQ per page D-13 of the above referenced ER. A request was made to HQ in 2006 for approval to consider overland capacity constraints in the Upper Ohio study but there was no official response. The unofficial response was to follow the guidance provided by HQ in the PGM for the Southwest Arkansas Feasibility Report which stated:

"Externalities should not be used to justify a navigation project. These benefits are an add-on after BCR is greater than 1 for traditional benefits. Roadway delays appear to be the only benefits category that is based on a current standard methodology which is sufficient for district to pursue as part of this study."

Based on this guidance and the expectation that roadway capacity problems could materialize if sufficient traffic was diverted off the waterway, the roadway delays were estimated and included in the NED account. Other externalities, such as reduced fuel usage, were also estimated but included in accounts other than NED.

Table 2: References

	Report	Date	Conducted by
1	AFB PGM (12-13-05), "Red River Navigation Study Southwest Arkansas Draft Feasibility Report and Draft EIS May 2005"	30 January 2006	CECW-PC/MVD
2	ER 1105-2-100		
3	E-mail		

The AFB PGM and the referenced e-mail are available for review on request.

4.0 Methodology

The study was performed as a series of incremental steps designed to focus future investigations in areas that appear important given the completion of the preceding step. The first step was to verify dock information and to update points of contact for each dock. The second step was to select a sample of Upper Ohio movements for detailed transportation analysis in terms of the existing routing and the least cost all overland routing. This was obtained by surveying the points of contact obtained in step 1. The shipping dock owners were also surveyed regarding their expected response to river closures of two different durations – between 0 and 60 days and between 60 and 180 days. If the response indicated that traffic would be diverted to the roadways, then the survey requested the likely route. The routes were then checked against traffic statistics obtained from the appropriate state department of transportation to obtain usage and trip times. The potential traffic diverted off the waterway was then added to the existing volume to recomputed trip times. The difference in total trip times without and with the increment of diverted traffic was computed and multiplied by a travel time cost per hour to obtain the roadway trip cost. The end product was an estimate of roadway congestion attributable to diverted traffic, which is an allowable NED benefit.

Responses to the survey that the firm would temporarily or permanently close if the river was closed was investigated following completion of the preceding step. However variations of the impacts of closure were investigated with regard to employment, the impacts on firms on the possible loss of low cost waterway transportation and the impact of the potential loss of water supplies. Again, the expected losses were obtained by surveying the shippers of commodities moving on the waterway. More details on the studies are provided in the following section.

5.0 Effects of disruptions to navigation system

The Corps study team contracted with the Tennessee Valley Authority (TVA) to estimate the social costs of shipping by land rather than barge as result of an unscheduled closure of either Emsworth, Dashields, or Montgomery Locks (EDM) for time periods of less than 60 days and a of 60-180 days. TVA subcontracted the modeling of the motor carrier social costs to the University of Tennessee, Center for Transportation Research. The additional components of the project were completed by Tennessee Valley Authority, River Operations, River Operations Support Staff, Navigation and Water Supply group. The social cost measurement of the EDM was an added component to the National Economic Development (NED) transportation rates for the Ohio River Navigation System and the Regional (RED) transportation rates for the Upper Ohio River Navigation Study Projects. The NED and RED transportation rates studies are submitted as separate reports.

The Corps provided a sample of 205 movements that passed through one of the EDM locks in 2004 as reported in the Waterborne Commerce Statistical Center (WCSC) trip reports or from a survey conducted by the Pittsburgh District of the United States Corps of Engineers. The 205 movements represented 20.6 million tons of cargo that either moved by barge through one of the named locks.

The UT study was first and focused on the identification of alternative overland routes for existing waterway traffic and how the diversion of traffic off the waterway would increase congestion and pollution on and along side the overland roads and railroads. The alternatives overland routes originated at the origin dock and terminated at the receiving dock of the waterway shipment. The TVA study took the results of the UT study but identified the off river origin and destinations of existing waterway traffic, if they were off river, and modified the routes to be consistent with this information. The TVA team re-estimated the congestion and other effects of diverted traffic based on the true origins and destinations of the shipments. The results of the TVA effort generally resulted in lower congestion and less pollution than the UT study since waterway shipments often include significant overland components. The Linare effort built upon the TVA results by surveying the companies that would be affected by closure of the Upper Ohio River to ascertain the affects upon their mining and manufacturing facilities. The findings were categorized in the NED and RED accounts. The UT, TVA, and Linare reports are maintained on file by the Planning Center of Expertise for Inland Navigation (PCXIN) in the Huntington District.

5.1 Transportation Impacts

TVA developed transportation costs for the existing water routing and for the least cost all overland model for a sample of 1,552 shipments that had an origin or destination in the Ohio River Basin. The work was performed in 2007-2008 and is documented in Addendum x, Transportation Rates. This work requires surveys of shippers to acquire not only waterway rate data but also off river information regarding origins, destinations, and off river modes of travel. Anticipating the need for detailed off river information for use in "externality" studies, TVA was also tasked to survey 205 shipments that pass through the Upper Ohio River system regarding their reaction to project closures of short, medium and long term durations, including what overland routes they would use if they diverted their shipments to overland modes.

The project methodology has nine steps:

1. Identify and profile river terminals and docks
2. Survey each terminal and dock
3. Prepare alternative land routes
4. Validate truck routes

5. Model truck diversion social costs

6. Model rail diversion social costs

7. Model barge diversion social costs

8. Model non specific truck social costs

9. Integrate truck, rail, and barge values

5.1.1 Identification of dock operators

The identification and profiling of the river terminals was obtained from port and dock location codes assigned to the barge operator trip reports by the WCSC. Once the dock is located by mile marker and name, then the location address, mailing address, telephone, and terminal manager are listed on a survey report. Each dock is then telephoned to validate the dock profile information and to also make an appointment to visit the dock for an in person survey.

5.1.2 Survey

After each river terminal in the study was located, TVA personnel visited each dock that was open in the winter of 2006 and in the spring of 2007. The survey response report for each dock by commodity has been included as a pdf on the master cd-rom disc titled "Surveys" and are available for review in the Navigation Planning Center, Huntington. For the less than a 60-day unscheduled closure, the following origin/destination (O/D) observations occurred.

Total O/Ds	205
Dock closed prior to 2007	20
O/Ds shut down with closure	4
O/Ds wait for lock to open	6
Divert to truck	67
Divert to rail	108

In contrast, the 60-180 day unscheduled closure produced many variations to the above responses with a substantially increased shut down with closure response.

Total O/Ds	205

Dock closed prior to 2007	20
O/Ds shut down with closure	51
O/Ds wait for lock to open	0
Divert to truck	51
Divert to rail	54
Divert to barge new origin	29

5.1.3 Identify alternative routes

The next step in computing the social cost of modal diversion is to prepare alternative truck and rail routes for each closure period.

5.1.4 Validate truck routes

The truck routes are a street by street specific route based upon the survey response and field observations. The selected truck routes were augmented by the Map Quest software program to compute highway and street mileage. Each truck route is shown in the survey report in the pdf file titled "Surveys".

The rail routes were determined by survey response with the specific rail routes supplemented by the ALK software, PC Rail, to determine route mileage.

Once the truck routes are established for each modal diversion by origin/destination pair, the University of Tennessee Center for Transportation Research (UTCTR), proceeded to validate the truck routes by traveling each highway and street to ascertain the routes correctness. With the exception of one truck route that had a bridge weight restriction that needed re-routing, it was determined that the modeled truck routes were the truck routes to be used by the shippers and motor carriers for each river terminal.

It should be noted that the truck diversion routes in the Upper Ohio River System could be characterized as a "spider web" as opposed to a single highway "corridor". Thus, the truck routes are spread out and not concentrated.

5.1.5 Model truck diversion social costs

The next step in the social cost analysis required the UTCTR to model highway mode shifting changes in added delay, increased fuel use, increased accidents, increased emissions, and premature pavement damage for the added trucks as well as the impact on resident traffic. The UTCTR report (Appendix 1 to this report) explains their methods and values. The UTCTR truck results are limited to diverted trucks that cause additional delay to the exclusion of diverted trucks that do not cause additional delay.

5.1.6 Model rail diversion social costs

The modeling of the social costs for rail diversions for the two lock closure periods measured the change in emissions for the rail carriers. It needs to be noted that during the shipper field interviews and highway route investigation, the rail social costs associated with delay, track maintenance, and accidents, due to increased rail traffic, were not identified as measurable or they were incorporated in the RED transportation rate analysis (Appendix 2 to this report) as a component of the transportation rate. The specific method to measure the change in emissions by rail was accomplished by computing the change in route miles multiplied by the average number of tons in the closure period for each origin/destination pair that diverted by rail, producing the net incremental ton mile change. The traffic was then divided between coal and non coal moves (coal in unit train and multi car and non coal in multi car and single car service), and the ton miles per gallon of fuel was computed from the Reebie Rail Costing Model from third quarter 2004 (the most current available time period) for the rail carriers in the RED rate study. The change in the number of gallons of fuel used was arrived at by dividing change in the number of ton miles by the number of ton miles per gallon. The change in the number of gallons of fuel with the resulting emission rates were carried over to the integration step. The dollar value per ton, for emissions, was the same value used by UTCTR in their truck externality study:

$372,797 per ton of directly emitted particulate matter
$59,780 per ton ammonia
$8,961 per ton nitrogen oxides
$27,088 per ton sulfur dioxide
$695 per ton VOCs

5.1.7 Model barge diversion social costs

The modeling of the social costs for the reduction in barge usage for the two lock closure periods was measured in a similar manor as the rail diversion measurement. The change in cost from the reduction in fuel use and accidents through the reduced trip length was included in the RED transportation rate analysis as a component of the transportation rate. The specific method to measure the change in emissions by barge was accomplished by computing the change in route miles multiplied times the average number of tons in the closure period for each origin/destination pair that diverted by rail or truck, producing the net ton mile change. Origin/destination pairs that either waited or closed were given a zero value since no diversion occurred. The net ton miles were divided by the ton miles per gallon for towboat operations on the Ohio, Allegheny, and Monongahela Rivers from the 2006 TVA fuel efficiency model. The change in the number of gallons of fuel was carried over to the integration step.

5.1.8 Model non specific truck social costs

The modeling of the non specific truck diversion social costs is a means of capturing all truck modal diversions. During the UTCTR analysis it was determined that many of the truck diversions were on routes where delay could not be measured. A total of 67 origin/destination pairs were identified as diverting to truck; however, only 36 origin/destination pairs had measurable delay. The remaining 31 origin/destination pairs were dropped from the UTCTR analysis. To compensate for removing the 31 origin/destination pairs, the average emission and accident values from the UTCTR report per ton were multiplied by the lock closure period tons for the origin/destination pairs that were excluded. It can be postured that the modal diversion to truck would experience emissions and accidents, but not exhibit measured delay. The use of the average regional emission and accident values in the greater Pittsburgh area, that experienced measurable delay, can be applied to the diversion routes that did not have delay. The dollar value for emissions and accidents was carried to the integration step.

5.1.9 Integrate truck, rail, and barge values

The last step in the methodology was to combine each of the modal diversion values for the base year, and then forecast the values over the 51 years of the study period. Here, the truck diversion externality (emissions, delay, and accidents), the rail diversion (emissions), the truck routes without delay (emissions and accidents) and barge route reductions (emissions) were summed and divided by the number of diverted tons to arrive at the rate per ton of social cost for each lock closure period. The dollar values per ton came from the UTCTR study. This last process has been identified as the integration step.

One key to the forecast of values for the 51 year period is the growth rate for the period. The Huntington District of the COE in its traffic projection has used a 0.0085 simple barge traffic growth rate for the Ohio River Navigation System. For consistency the analysis of social costs used the same barge growth rate. A further assumption was the use of the average outage period of 38 days for the less than 60 day lock closure and 120 days for the 60-180 day lock closure.

Tables 2 and 3 show the UTCTR total truck diversion social costs and the component delay, accident, and emission costs. It is important to note here that UTCTR only accounted for diverted truck traffic that caused delay. Some of the diverted truck traffic diverted in areas with negligible highway or public transit impacts.

Non-delay truck accidents and non-delay truck emissions costs were computed by TVA. To compensate for removing the non-delay truck accidents and emissions, the average emission and accident values from the UTCTR report per ton were multiplied by the lock closure period tons for the 31 origin/destination pairs that were excluded from the UTCTR study.

Tables 2 and 3 also show reduced rail and barge emissions for diversions. The closure of one of the EDM locks, and the resulting modal diversions, changes the number of miles traveled by each mode and the type of service rendered by each mode. The modal diversion from barge to truck results in a gain in truck miles and emissions and a reduction in barge miles and emissions. The modal diversion from barge to rail with unit train service results in a reduction in emissions. This is due mainly to the switch from less efficient small tows to more efficient unit trains. The rail diversions show a lower social cost but a substantial economic rate cost (see Appendix 2 of this report).

Table 3: Social Cost of a 0 to 60 Day Closure

Less Than 60 Days Closure

	Yr1	Yr10	Yr20	Yr30	Yr40	Yr50	Yr51
Base Tons	1,872,118	2,015,335	2,174,465	2,333,595	2,492,725	2,651,855	2,667,768
UTTRC Truck Delay Dollars	$ 1,059,374	$ 1,407,343	$ 1,923,394	$ 2,815,781	$ 4,423,272	$ 7,542,609	$ 7,987,362
UTTRC Truck Accidents Dollars	$ 103,590	$ 130,180	$ 163,657	$ 214,281	$ 291,498	$ 416,019	$ 431,974
UTTRC Truck Emissions Dollars	$ 323,201	$ 113,741	$ 49,953	$ 43,379	$ 60,771	$ 85,441	$ 87,271
UTTRC Truck Delay, Accidents, Emissions - Subtotal	$ 1,486,165	$ 1,651,264	$ 2,137,004	$ 3,073,441	$ 4,775,541	$ 8,044,069	$ 8,506,607
TVA Non Delay Truck Accident, Emissions -Subtotal	$ 72,109	$ 63,516	$ 55,164	$ 47,910	$ 41,609	$ 36,138	$ 35,632
Truck Diverted Social Costs - TOTAL	**$ 1,558,274**	**$ 1,714,780**	**$ 2,192,168**	**$ 3,121,351**	**$ 4,817,150**	**$ 8,080,207**	**$ 8,542,239**
TVA Rail & Barge Emissions Dollars	$ (483,021)	$ (478,000)	$ (432,294)	$ (390,959)	$ (353,576)	$ (319,768)	$ (316,571)
Truck and Rail Diverted Social Cost -TOTAL	**$ 1,075,253**	**$ 1,236,781**	**$ 1,759,873**	**$ 2,730,391**	**$ 4,463,574**	**$ 7,760,438**	**$ 8,225,668**
Per Ton Social Externality Cost	$ 0.57	$ 0.61	$ 0.81	$ 1.17	$ 1.79	$ 2.93	$ 3.08
Per Ton Truck Delay Cost Only	$ 0.57	$ 0.70	$ 0.88	$ 1.21	$ 1.77	$ 2.84	$ 2.99

Table 4: Social Costs of a 60 to 180 Day Closure

60-180 Days Closure

	Yr1	Yr10	Yr20	Yr30	Yr40	Yr50	Yr51
Base Tons	6,744,765	7,260,740	7,834,045	8,407,350	8,980,655	9,553,960	9,611,290
UTTRC Truck Delay Dollars	$ 2,949,206	$ 3,897,827	$ 5,328,816	$ 7,842,713	$ 12,447,693	$ 21,415,211	$ 22,693,644
UTTRC Truck Accidents Dollars	$ 276,211	$ 344,681	$ 432,023	$ 565,968	$ 773,136	$ 1,105,303	$ 1,147,626
UTTRC Truck Emissions Dollars	$ 844,552	$ 294,180	$ 129,793	$ 133,398	$ 158,948	$ 224,240	$ 230,069
UTTRC Truck Delay, Accidents, Emissions - Subtotal	$ 4,069,969	$ 4,536,688	$ 5,890,632	$ 8,542,079	$ 13,379,777	$ 22,744,754	$ 24,071,339
TVA Non Delay Truck Accident, Emissions -Subtotal	$ 235,456	$ 207,397	$ 180,124	$ 156,438	$ 135,866	$ 117,999	$ 116,347
Truck Diverted Social Costs - TOTAL	**$ 4,305,425**	**$ 4,744,085**	**$ 6,070,756**	**$ 8,698,517**	**$ 13,515,643**	**$ 22,862,753**	**$ 24,187,686**
TVA Rail & Barge Emissions Dollars	$ (3,202,528)	$ (3,169,235)	$ (3,331,310)	$ (3,501,673)	$ (3,680,749)	$ (3,868,983)	$ (3,888,328)
Truck and Rail Diverted Social Cost -TOTAL	$ 1,102,897	$ 1,574,850	$ 2,739,446	$ 5,196,843	$ 9,834,893	$ 18,993,770	$ 20,299,358
Per Ton Social Externality Cost	$ 0.16	$ 0.22	$ 0.35	$ 0.62	$ 1.10	$ 1.99	$ 2.11
Per Ton Truck Delay Cost Only	$ 0.44	$ 0.54	$ 0.68	$ 0.93	$ 1.39	$ 2.24	$ 2.36

Guidance provided by the Corps' Headquarters office limited NED benefits that could be considered in the economic evaluation to increased roadway congestion costs. Roadway congestion effects represented as increased costs per ton attributable to lock closures are listed in Table E-2. These values were input to the Ohio River Navigation Investment Model (ORNIM) where they were included in the calculation of system benefits for different project alternatives.

Table 5: Roadway congestion costs per ton

Year	< 60 days			60 - 180 days		
	Delay	Other	Total	Delay	Other	Total
1	$0.57	$0.01	$0.57	$0.44	($0.27)	$0.16
10	$0.70	($0.08)	$0.61	$0.54	($0.32)	$0.22
20	$0.88	($0.08)	$0.81	$0.68	($0.33)	$0.35
30	$1.21	($0.04)	$1.17	$0.93	($0.31)	$0.62
40	$1.77	$0.02	$1.79	$1.39	($0.29)	$1.10
50	$2.84	$0.08	$2.93	$2.24	($0.25)	$1.99
51	$2.99	$0.09	$3.08	$2.36	($0.25)	$2.11

5.2 Employment Impacts

The loss of employment due to an unreliable navigation system was investigated with regard to the separable effects of the loss of barge transportation and the loss of water supplies for industrial use. The investigation built upon the TVA/UT effort in terms of the appropriate points of contact and the general response of the firm to loss of navigation. The study was designed to quantify the potential job losses due to loss of navigation and loss of water supplies and categorize the cost in either the NED account or the RED account. While the costs are considered as NED, they were not included in the NED account when computing the economics of the project alternatives because they are non-traditional benefits and have not been approved for use in this study.

Table 6: Employment Impacts of Project Failure

	RED Effects (1)		NED Effects (2)		OSE Effects (3)
	Jobs	Output per Month	Jobs	Output per Month	
		(Million)		(Million)	
Disruption of Water Supply					
Four Municipal Intakes					Various and substantial
One Commercial Intake					Various and substantial
Three Industrial Intakes	-2,675	-$17.6	Some Portion of 2,675	Some Portion of $17.6 million	

Disruption of Navigation					
Downbound Steam Coal	-1,763	-$32.5	0	$0.0	
Upbound Met Coal	-438	-$14.4	0	$0.0	
Downbound Steel	-769	-$20.3	-131	-$3.4	
Upbound Chemicals	-293	-$11.4	0	$0.0	
Subtotal	-3,263	-$78.6	-131	-$3.4	

Notes: (1) Regional Economic Development Effects (RED) reflect changes in the distribution of regional economic activity -- output of goods and services.

(2) National Economic Development Effects (NED) represent changes in the economic value of the national output of goods and services.

(3) Other Social Effects (OSE) represent effects from other perspectives that cannot be expressed in quantitative and dollar-valued terms.

6.0 Summary

Externalities are effects of existing or proposed projects that are not normally evaluated as standard economic and environmental effects. Externalities evaluated for this study include roadway congestion, fuel usage, accident, air pollution, and employment. The effects were evaluated by experienced agencies and firms: the Tennessee Valley Authority, the University of Tennessee Center for Transportation Research, and Lenare Consulting of Pittsburgh.

The effects were categorized into the four accounts used by the Corps in the evaluation of proposed projects: National Economic Development (NED); Regional Economic Development (RED); Environmental Quality (EQ); and Other Social Effects (QSE).

The estimated effects are summarized in Table E-1. Nearly 91 percent of effects of disruptions to the navigation system are in the RED account, where the investigations indicated the potential for significant shifts in coal sourcing from the Mon Basin to Central Appalachia. Overall, the approximate NED losses are in the range of $106 million per year, the RED losses are approximately $1 billion per year, and the OSE are approximately $16 thousand per year.

Table 7: Effects of Traffic Disruptions by Account

	NED	RED	EQ	OSE	Total
Increased roadway congestion	$ 1,059				$ 1,059
Increased accidents				$ 104	$ 104

Increased emissions				$ (160)	$ (160)
Others				$ 72	$ 72
Water supply disruptions	$ 105,600	$ 105,600			$ 211,200
Barge transportation disruptions	$ 41	$ 943,200			$ 943,241
Total	$ 106,700	$1,048,800	$ -	$ 16	$ 1,155,516
Note: water supply disruption costs were not categorized clearly as NED or RED; the total was divided by two and assigned equally to NED and RED.					

Guidance provided by the Corps' Headquarters office limited NED benefits that could be considered in the economic evaluation to increased roadway congestion costs. Roadway congestion effects represented as increased costs per ton attributable to lock closures are listed in Table E-2. These values were input to the Ohio River Navigation Investment Model (ORNIM) where they were included in the calculation of system benefits for different project alternatives.

Table 8: Roadway Congestion Costs per Ton

	< 60 days			60 - 180 days		
Year	Delay	Other	Total	Delay	Other	Total
1	$0.57	$0.01	$0.57	$0.44	($0.27)	$0.16
10	$0.70	($0.08)	$0.61	$0.54	($0.32)	$0.22
20	$0.88	($0.08)	$0.81	$0.68	($0.33)	$0.35
30	$1.21	($0.04)	$1.17	$0.93	($0.31)	$0.62
40	$1.77	$0.02	$1.79	$1.39	($0.29)	$1.10
50	$2.84	$0.08	$2.93	$2.24	($0.25)	$1.99
51	$2.99	$0.09	$3.08	$2.36	($0.25)	$2.11

The year one increase in roadway congestion is $0.57 per ton for a less than 60 day lock closure and $0.16 per ton for a 60 to 180 day closure. The costs increase over time to equal $3.08 and $2.11 per ton respectively in year 51. The roadway congestion costs are approximately 25 percent of the traditional transportation benefits measured as the cost savings of waterway routed shipments compared to the least cost all overland routing.

Addendum 1

Social Costs of Barge Cargo Modal Diversions Due To Unscheduled Closures at Emsworth, Dashields, and Montgomery Locks

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7.0 Executive Summary

The U.S. Army Corps of Engineers (USACE) expects unplanned closures of the navigation locks at Emsworth, Dashields, and Montgomery (EDM) Dams due to their age and condition. Outages will result in diversion of waterborne cargo to overland transportation, commodities trans-loading to either truck or rail transportation for delivery to their ultimate destination. Coal diverted to rail will reload onto barges for final delivery to steam plants. The Tennessee Valley Authority (TVA) contracted the Center for Transportation Research (CTR) at the University of Tennessee to estimate the social cost of the barge cargo diversions to truck. For purposes of estimation, these outages can have short duration of 60 days or an intermediate duration of 180 days. The study places annual dollar values on costs borne by society for both the short and intermediate duration outages.

The core of the methodology is a model of highway traffic flows in the study area that analytically determines hourly congestion and speeds on the affected roadways. First, congestion and speed are forecast in future years for a base case traffic volume and growth rate. Diverted cargo truck traffic due to lock outage is then introduced into the base traffic flows to estimate the traffic and social cost differentials due to lock closure.

The measured effects on both the existing and introduced vehicle traffic include the changes in fuel consumed, time spent in transit, air pollution emissions, and crashes. Each of the four effects is given dollar values using data obtained from the AASHTO Red Book (*User Benefit Analysis for Highways)* and the Environmental Protection Agency's MOBILE6 and BenMap models. The National Cooperative Highway Research Program (NCHRP) Report 387 contains the essential methods the model uses to calculate highway traffic flow effects.

The period of analysis covers 51 years beginning with the year 2005 and ending with the year 2055. For each of these years, the model estimates baseline highway traffic volumes and speeds for the base scenario without any lock closures. TVA, using information from the shippers in field interviews, developed the origin or destination locations and routes for the commodities barged from or to each river terminal for traffic passing through EDM. For some truck movements, the shippers told the TVA field staffs the routes they would use in the event of lock outages. For the remaining movements, TVA used MapQuest to establish the routes. To verify that the routes were reasonable, CRT staff visited Pittsburgh on November 12 and 13, 2007, driving each route; as a result, one route was altered due to the discovery of a load limited bridge. The Southwestern Pennsylvania Commission (SPC) was also consulted on the reasonableness of the routes.

Imposing linear growth from an initial rate of 1.07 percent (used by the SPC in their study: *Southwestern Pennsylvania Commission, 2035*) for base-case traffic, the social costs-per-ton for the short and intermediate duration truck diversion scenarios are \$3.10 and \$3.45 in the initial year. The diverted cargo is projected to grow at a linearized 1.0 percent per year rate, as estimated by the USACE in their forecast of upper Ohio River barge traffic. The short and intermediate duration constant-dollar costs-per-ton change very little in the early years of the scenario, but rise to $10.92 and $12.90 by the 51st year. As shown in the study, the EPA MOBILE6 model forecasts a drastic decline in mobile source emissions over a very short period of time--a major factor in preventing rising costs in the early years. Increasing traffic counts relative to fixed capacity, however, ultimately result in higher volume to capacity ratios, causing highway transit unit costs to rise.

At a higher linearized annual 1.6 percent rate for vehicles, traffic in the Pittsburgh area would increase by about 80 percent over the 51 year forecast period. This higher level of traffic growth results in higher volume to capacity ratios than in the lower growth scenarios, overwhelming the decline in pollution values at an earlier date. By the 51st year, the diversion social costs-per-ton values rise to $38.47 (short duration) and $46.54 (intermediate duration).

At the very low linearized annual 0.55 percent rate, the social costs-per-ton for truck diversions are essentially flat. The decline in mobile source emissions, coupled with relatively static (relative to the base scenario) volume to capacity ratios results in relatively flat costs-per-ton values throughout the 51 year forecast period. Appendix A contains the total diversion social costs-per-ton for the entire 51 year period. The attached compact disc contains the data for the cost components for each growth scenario.

8.0 Introduction

The upper Ohio River navigation infrastructure is defined as Emsworth, Dashields, and Montgomery (EDM) locks and dams. They are the oldest lock and dam projects on the Ohio River, having been built prior to World War II. Two major problems associated with the upper Ohio projects are deteriorated structural conditions and insufficient auxiliary capacities.

The upper Ohio projects allow producers and consumers to move large quantities of bulk and semi-bulk cargoes into and through the Pittsburgh area at relatively low cost and with minimal effects on land based passenger and freight transportation. Coal and aggregates (stone, sand and gravel) firms are the primary producers, while electric utilities and steel mills are the primary consumers of commodities moving through EDM locks.

Reduced system reliability and limited capacity have led to traffic routings that avoid transiting the upper Ohio projects. This modal diversion by shippers is expected to increase in the future as the projects continue to age and periodic closures become more frequent and of longer duration. The additional diversion to truck transportation will have a variety of adverse impacts affecting both industry and the general public. These impacts would exacerbate existing traffic congestion, crashes, pavement deterioration, and air pollution from vehicular emissions.

Given the condition of these locks, dependable navigation services will require increased outages during which navigation services will not be available. Diversion of barge cargoes to overland transportation is expected, as commodities are trans-loaded to either truck or rail for delivery to the intermediate or final destination. These outages can be either a short duration of 60 days or an intermediate duration of 180 days.

This paper describes the methodology, data, and analytical tools used in this study to calculate these impacts and provides estimates of social costs due to these diversions of commodities from barge to truck transport.

9.0 Methodology

The study begins with the examination of barge movements in 2005 that are expected to divert to truck during future unplanned EDM outages. Having identified the highway route segments for the cargoes and their characteristics, base case highway traffic is projected for 51 years, growth in average daily traffic affecting highway volume/capacity ratios and average vehicle speeds in the manner described in the NCHRP report 387[1].

To obtain traffic impact estimates for the diversions, the new trucks trips are introduced into the base vehicle counts, resulting in increased volume/capacity ratios, decreased highway speeds, and increased hours in transit. The differences in the values of these

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[1] Report 387 is titled *Planning Techniques to Estimate Speeds and Service Volumes for Planning Applications.*

parameters from the base case constitute the basis for the social cost estimates due to EDM lock closures.

Increased travel times, crashes, fuel consumed, and emissions are translated into diversion social costs, or "externalities," using parameter values found in the AASHTO Red Book, *User Benefit Analysis for Highways*[2] and other sources, including the Environmental Protections Agency's MOBIL6.2[3] and BenMap[4] models. Later sections provide more detailed information. The social cost calculations cover 51 years, beginning with the year 2005 and ending with the year 2055.

9.1 Barge To Truck Diversions - Highway Routings

The Tennessee Valley Authority (TVA), using survey information from the shippers in field interviews, determined the origin, destination, and routes for the truck trips from or to each terminal for the potential barge cargo diversions. For some truck movements, the shippers told the TVA field staffs the routes that they would use in the event of lock outage. For the remaining movements, TVA used MapQuest[5] to establish likely routes. To verify that the routes were reasonable, CTR staff visited Pittsburgh on November 12 and 13, 2007 and drove each route. One route was altered as a load limited bridge was discovered in driving the roads[6]. The Southwestern Pennsylvania Commission (SPC) was also consulted as to the reasonableness of the routes.

The CTR collected information on the geometric characteristics of the overland network and traffic control devices. These data were verified and augmented using video logs provided by the Pennsylvania Department of Transportation.

CTR staff divided the affected transportation network into links (discussed below) spanning portions of Allegheny, Beaver and Washington Counties in southwestern Pennsylvania. The analysis includes commodities shipped from Ohio terminals, as it transits the congested links analyzed in the study. The road types used in the study include portions of river and urban arterials (principal and minor), freeways, expressways, bridges, and tunnels. The route segments are portions of US routes 22 and 30 and Pennsylvania routes 28, 51, 60, 65, 68, and 108; Interstate highways 279, 376; and named roads such as Shipping Port Road, Green Garden Road, Mill Street, Kennedy Boulevard, Franklin Street, Braddock Avenue, Carston Street, West End Bridge, McKeesport Bridge and access roads, Fleming Bridge, Neville Road, Fairhaven Run, and Cleaver, Beaver, and Montour Roads.

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[2] American Association of State Highway and Transportation Officials (AASHTO), *User Benefit Analysis for Highways*, August 2003.
[3] Mobile is a software tool developed by the Environmental Protection Agency (EPA) for predicting gram per mile emissions of hydrocarbons, carbon monoxide, oxides of nitrogen, carbon dioxide, and particulate matter and air toxins from cars, trucks, and motorcycles under various conditions.
[4] BenMap is an EPA windows-based computer program that estimates health benefits from improvements in air quality or, conversely, costs from decreased air quality.
[5] Mapquest can be viewed at www.mapquest.com
[6] The Southwest Pennsylvania Commission (SPC) also noted the weight restricted bridge in conversations with them about the routes. Ms. Sara Walfoort of the SPC rode with CTR staff on the majority of the routes.

9.1.1 Pittsburgh Truck Flows

TVA obtained the shipper responses to the lock outages in field interviews and provided the CTR with diversions of commodities to truck transportation under two scenarios of cessation of lockage services at the EDM projects: one scenario is unexpected short duration diversions of 60 days of interruption and the other is intermediate duration diversions of 180 days.

From those field interviews and tabulations from the Waterborne Commerce Statistical Center data base, TVA provided CTR with commodity movements, including tonnages and associated highway routing. From this information, CTR estimated that 4.0 million annual tons of commodities could potentially divert to truck transportation, involving 58 movements between specific origin and destination combinations. Of this traffic, 1.4 million annual tons is coal traffic and 2.6 million annual tons is non-coal traffic. Coal tonnage is treated separately because the shift to trucks represents a short-term event (60 days or less)[7]. The movements involved 37 distinct origin-destination pairs, including six for coal movements. Each tonnage was then converted from annual tons to truck movements by considering the time profile of its movement as follows:

- Daylight (6am – 6pm); 12 hours per day for 6 days per week, or 304 days per year
- Nighttime (6pm- 6am): 12 hours per day for 6 days per week, or 304 days per year
- All Day (6am – 6 am): 24 hours per day for 7 days per week, or 350 days per year

All day movements include coal, pig iron, asphalt, coke, and others where storage facilities were either not available or the nature of the commodity dictated the need for continuous transport. All commodities were converted to truck loads at the following equivalences[8]:

- 23 tons/truck: feed
- 23½ tons/truck: ferrous waste, coal, flat rolled iron and steel, manufactured iron and steel products.
- 24 tons/truck: salt, gypsum, pig iron, stone, fuel, quick lime limestone flux
- 25½ tons/truck: pitch coke or asphalt.

Additionally, deadheading require a doubling of all truck movements. In turn the truck movements were converted, as follows, to hourly volumes for flat rolled iron and steel:

- There are168,034 annual tons of flat rolled iron and steel with the trucks loaded at 23½ tons/truck for shipment in the daylight hours.
- This equates to 168,034 tons/23½ tons/truck or 7,150 loaded trucks/year.
- This equates to 7,150 trucks x 2 or 14,300 truck movements/year

[7] The logic to this scenario is that coal barges already in route to area utilities or those trapped inside the EDM pools will be unloaded, and the coal will be trucked to the plants. In a longer outage, coal will be shipped by rail transportation to terminals above EDM and then trans-loaded to barge and shipped on to the utilities.
[8] These data were obtained by TVA in field interviews.

Assuming a uniform distribution of movement across the day, this represents four truck movements (14,300/ (12 hrs days x 304 days years)) for each of the twelve hours between 6am and 6pm.

The 37 distinctive origin-destination movements were overlaid on a regional roadway map (consisting of 124 links) for the three county Pittsburg area, resulting in 51 critical roadway links warranting further consideration. Also, terminal access/egress routings were studied. Coal movements were always treated separately. Based on the results from the select link assignment, the CTR conducted a three day field reconnaissance to check the routings, obtain physical characteristics of the links, and review terminal access/egress routes. The field review also determined other issues, such as a 13 ton weight limit on a structure along Bradock Avenue which would restrict truck movements between I-376 and the USX Steel-Edger Thompson Plant. The field reconnaissance collected data on:

- Link length
- Number of lanes
- Degree of access control
- Speed limit
- Pavement conditions
- Signalizations
- Special land uses such as schools, hospitals, etc.
- Lateral clearances/passing-no passing sections
- Grades
- Speed restrictions for trucks
- Terrain

GIS files and video logs provided by the Pennsylvania Department of Transportation were used to obtain average daily traffic counts (ADT), functional classification, percent trucks, and other information on roadway characteristics. Ultimately, the links were consolidated to 42 links for analysis. The EXCEL workbook on the accompanying compact disk (Pittmodel input data.xls) contains the data for all links. The availability of the video logs was an excellent tool for validating data collected in the field study.

9.1.2 Traffic Growth

Historical Growth

From the Pennsylvania Department of Transportation's Web page[9], the CTR found 1997 through 2006 annual state level traffic data growth factors for Transportation Planning Groups (TPG) and 2001 through 2006 county level growth factors for Functional Class Groups (FCG).

[9] The web page is www.state.pa.us

The roads of most interest in the study are urban Interstates and arterials. Over the longer time series, 1997-2006, the annual compound growth rates for urban Interstates in the state (TPG 1) averaged 2.5% per year. For this same period, urban principal arterials averaged 1.7% per year. For 2001-2006, state level TPG 1 and TPG 3 groups averaged 3.1% and 1.5% respectively.

The county data presented at the FCG level do not exactly correspond to the TPG designations. Urban Interstates are classed as FCG 1, while the FCG 3 group, which also covers minor arterials and ramps, includes urban principal arterials. Over the available period, he FCG 1 factors are identical to the state values, averaging 3.1% per year. The FCG 3 values are lower than the TPG values, possibly caused by a differing composition of types of roadways. The TPG average is 1.5%, while the FCG average is 1.1%.

In contrast to the fairly high traffic growth rates for Interstates and other arterials, expected area population and employment growth, absent large shifts in productivity, suggest slow growth for the region. Employment is projected to grow at a compound annual growth rate of 0.53% during the period 2005-2035. Population is projected to grow at about the same rate (0.55%). However, during the period when Allegheny, Beaver and Washington Counties were declining in population, Interstate traffic in the state grew at 2.5% per year, and principal arterials were growing at 1.7% per year[10].

Forecast Growth

Are these highway growth rates indicative of future highway growth in the Pittsburgh area? Probably not. The CTR expects inertial pressure for the relatively high historical trip growth rates to carry over into the first few years of the 51-year forecast period. But these rates cannot be sustained on many of the routes on which the diverted traffic will travel because capacity is insufficient to support the growth. Trip growth rates will likely begin to decline then for a variety of reasons, including higher fuel prices, increasing congestion, and public policy initiatives affecting highway usage. Well into the forecast period, traffic growth rates could stagnate and possibly decline.

Given the already heavy traffic on certain links in the Pittsburgh area, traffic growth is a critical factor in the potential for increased congestion in certain key corridors. Traffic forecasting and highway congestion have been studied by the SPC and discussed in their long range plan, *2035 Transportation and Development Plan for Southwestern Pennsylvania*, which was adopted June 28, 2007. In the SPC plan, vehicle trips are expected to expand 30% during the period 2007-2035 which equates to an incremental change (or linearized rate) of 1.07 percent (of the base year value) per year (30% / 28

[10] The forecasts of economic and demographic conditions in Allegheny are presented by Deitrick and Briem (2005).

years). This traffic forecast is for the entire ten-county area in southwestern Pennsylvania which is a composite of urban and rural areas[11].

For simplicity, the CTR analysis uses the SPC linearized rate through the first 28 years of the forecast period, but then extends the linear growth path through the 51 year forecast horizon. This results in a simple 55 percent traffic growth over the entire period in the three counties. The traffic model operates to calculate an initial increase in traffic for each link, and this increment adds to each annual estimate, such that the forecast growth follows the linear path. Thus, trips increase by the same amount in each of the 51 years, and the compound growth rate declines from year to year. This follows the expected pattern of relatively high growth rates in the earlier years of the forecast period and declining growth in the later years.

For the commodities that are trucked or railed in and around the Pittsburgh area, the U.S. Army Corps of Engineers is forecasting river traffic to increase by an increment of 0.85% (of the base year) per year (rounded up to one percent per year). This growth factor is applied in the traffic model to the new trucks resulting from the maintenance outages due to EDM closures[12].

9.2 Rail Transportation Diversion

The rail impacts of the traffic diversion are related to the factors that are a function of the distance traveled in the lock closure scenarios. This is because railroad track construction in the study area is generally below or above grade at most intersections, making freight transportation very safe in the region. This being the case, the TVA study of rail externalities is limited to the impact on fuel consumption and the resulting impact on air pollution. TVA will examine the ton-miles and associated fuel consumption required to move the diverted commodities by rail relative to the fuel consumed in moving these commodities by barge.

9.3 Pittsburgh Traffic Diversion Model

9.3.1 Overview

The Pittsburgh traffic diversion model developed in a Microsoft Excel workbook, tracks hourly traffic volumes on the specified highway links through 51 years for three traffic flow growth scenarios:

A base case with no lock closure and, thus, no additional truck traffic;
An unplanned lock closure extending to 60 days; and
An unplanned lock closure extending to 180 days.

[11] 2035 Transportation and Development Plan for Southwestern Pennsylvania, June 28, 2007, Southwestern Pennsylvania Commission

[12] The USACE has prepared five forecasts for the upper Ohio River. Growth at the three EDM projects is projected to essentially be the equivalent. The growth range is from 1.34 to 0.34. The average of the five forecasts is 0.85% per year.

In scenario 2, the 60-day traffic flows include both new coal and new non-coal truck volumes. The expectation is that coal traffic trapped in the EDM pools due to a lock failure will, of necessity, be trucked to final destinations. In scenario 3, coal traffic is not included in the traffic flow for time periods beyond 60 days, as shippers are likely to shift coal transport to rail as they react to the absence of water transportation. This is a more cost effective alternative of coal shipment and was used in earlier outages of Montgomery Lock by the coal shippers[13]. When rail transportation is used, coal will be shipped to terminals above EDM, transferred to barge transportation, and then moved on to final delivery and unloaded at water docks. The model uses 38 days in scenario 2 and 120 days in scenario 3, as per guidance from the U. S. Army Corps of Engineers (USACE).

The net impact on traffic and social costs of the cargo diversions are the differences between scenarios 2 and 3 and the base case.

The traffic model accepts a variety of user inputs for the scenarios. These include base case traffic growth rates by major road types and new truck growth rates. The values input for the new trucks in this study are those of USACE long term traffic forecasts for the upper Ohio River[14]. Other input parameters available for setting via the user interface are the number of forecast years, number of days per year of new coal plus non-coal trucks, number of days per year of new coal-only trucks, constant dollar fuel price per gallon, value of travel time for auto and for truck, accident cost factors for auto and for truck, and emission cost factors for five pollutants.

Several tables also constitute part of the inputs to the model program: highway link characteristics, base year ADT (total and truck), number of new trucks due to diversion (coal and non-coal by day and night), traffic distribution patterns (by functional class, direction, and hour), grams of pollutants per mile (truck and auto by 5mph speed bin and year), and new truck tonnage matrix by movement and link.

For a 51-year run, the model outputs some 75,000+ values in tables in various worksheets. Traffic tables include:

- vehicle miles traveled (VMT) for auto and truck, by year and 5mph speed bin, base and 2 impact scenarios
- travel hours, VMT, fuel costs, pollutant costs for auto and truck, by link, base and 2 impact scenarios
- average speed by hour and direction by (user selected) link and year, base and 2 impact scenarios
- minimum speed occurring during year by link and year, base and 2 impact scenarios

[13] Montgomery Lock was closed for gate maintenance for 26 days in 2002 during the period June 18-July 31. In the absence of an all-barge alternative, major coal shippers during this period of time developed and tested a strategy for the shipment of coal to their plants via rail with a trans-load to barge for delivery to the water docks.

[14] A variety of forecasts were supplied by the U.S. Army Corps of Engineers, Huntington District via email on February 29, 2008.

- kilogram emissions by year, base and 2 impact scenarios

The model operates in Microsoft Excel, relying on Visual Basic (VB) routines to perform the more complex and extensive calculations. For 51 years, the execution time on a 2Ghz desktop PC is typically from four or five minutes to complete operation.

The model calculates hourly traffic flows, based on specified distribution patterns, for each combination of base or diversion scenario (day and night), vehicle type (automobile or truck), and direction. New trucks, if a diversion scenario is being calculated, add to base traffic volumes, and the percent trucks for the hour and direction changes accordingly. The calculated truck percent enters into the capacity calculation routine affecting average speed. Along with the segment length, the average speed determines travel hours and fuel consumption per mile for autos and for trucks. Total vehicle miles traveled are determined by segment length and traffic volume.

Vehicle miles traveled by 5 mph ranges, by year for auto and for truck, are calculated in a subroutine that performs the necessary volume growth calculations, accumulates the quantities into the required average speed bins, and writes the output in another worksheet.

9.3.2 Highway Traffic Equations

For each scenario, the model distributes ADT by hour and direction for each highway link based on the functional class of the link. Each link's traffic capacity is calculated based on road type, terrain, and the percentage trucks are of total traffic. Capacity decreases as the percentage of trucks rises and speed decreases (and travel time increases) as the volume/ capacity ratio rises.

Capacity in one direction for one lane is given by:

Urban freeway, non-signalized, Sf = 55 mph

c=2300*PHF*Fp/ (1+Pt (Et-1))

Assume PHF=0.9, and Fp=1.0

Rural freeway, non-signalized, Sf = 65 mph

c=2400*PHF*Fp/ (1+Pt (Et-1))

Assume PHF = 0.80, Fp = 1.0

Non-freeway 2-lanes or 1-lane, non-signalized; Sf = 55 mph

c=1700*PHF*Fp*Fg/ (1+Pt (Et-1))

Assume PHF = 0.85, Fp = 1.0

Signalized urban arterials, signal spacing <= 2 miles

c = 1900*PHF*(g/c)/ (1+1.0*Pt)

Assume PHF = 0.90, g/c = 0.45

where PHF = peak hour factor (distribution of traffic in the peak hour)

Fp = adjustment for driver familiarity

Pt = proportion of heavy vehicles

Et = passenger car equivalents (varies by highway type and terrain)

Fg = grade adjustment factor

g/c = duration of green to cycle length

The NCHRP report 387 provides the following speed and travel time equations:

Travel times for each link are determined as follows:

- For roads without signals
  - Posted speed limit > 50 mph

    Sf = 0.88 * Sp + 14

    S = Sf/ (1+0.15 * (v/c) ^4)[15]

    T = 1/S. This is travel time.
  - Posted speed limit <= 50 mph

    Sf = 0.79 * Sp + 12

    S = Sf/ (1 + 0.05(v/c) ^10)
- For roads with signals

  Smb= 0.79* Sp +12

  D= Df * 0.5 * C * (1-.45) ^2

  Sf= L/ (L/Smb + N'*(D/3600))

  S = Sf/ (1+0.05 * (v/c) ^10)

  T=1/S

where

Sp = posted speed limit in miles per hour (mph),

Sf = free flowing speed in mph,

S = average speed in mph,

v=traffic volume by direction by hour,

c=capacity in one direction in vehicles per hour,

T=travel time,

Smb = the mid-block free flowing speed in miles per hour,

[15] This speed equation has its origin in the Bureau of Public Roads. It is used for adjusting speeds for traffic assignment on a road network for the planning of roadways.

Df = degree of coordination between signals (NHCRP Report 387 suggests that Df should equal one when fixed time signals are uncoordinated,

C = cycle length = 120 seconds,

D = delay in seconds per vehicle,

L = length of segment;

N' = the # of signalized intersections in each link.

9.3.3 Social Cost Computations

Once the model finishes calculating the traffic flows, it proceeds to estimate social costs by scenario, diversion social costs, and diversion unit (per ton) social costs. outputs include these tables:

- total social cost by link by year, base and 2 impact scenarios
- diversion social costs per ton by link and year, 2 impact scenarios
- diversion social costs per mile by link, 2 impact scenarios
- social costs, total and four components for auto and truck, by year, base and 2 impact scenarios
- diversion social costs, total and four components for auto and truck, by year, 2 impact scenarios
- diversion social costs per ton by movement and year, 2 impact scenarios

The next section discusses the components of social costs in more detail.

10.0 Social Cost Components

10.1 Congestion Delay

10.1.1 Non-Commercial

Increased travel time resulting from diversion of river traffic on to Pittsburgh highways is a major component of user costs. Economists have studied the value of time and in particular how motorists value their time in traffic delays[16]. The value of time for the motorists depends on the opportunity cost of using their time in some other manner. Revealed preference studies, that is, studies of the value of time based on actual choices, allow values to depend on wage rates, incomes, and other factors[17]. Small and Winston, in a 2005 study, examined the behavior of motorists in Los Angeles who may use express lanes but must first set up a financial account and carry an electronic transponder in order to pay a toll. The authors find that the average valuation in the value of time is quite high, thus

[16] For example, Calfee, J. and C. Winston (1998). "The Value of Automobile Travel Time: Implications for Congestion Policy," Journal of Public Economics, 69, pp. 699-707.

[17] Small, K.A. and C. Winston (1999), "The Demand for Transportation: Models and Applications," in Gomez-Ibanez, W. Tye and C. Winston editors, Essays in Transportation Economics and Policy: A Handbook In Honor of John R. Meyer, Washington, DC: Brookings Institution Press.

suggesting that time is much more valuable than the revealed preference theoretical model might suggest.

The U.S. Army Corps of Engineers has also studied the value of time. David Hill and David Moser laid out guidance for handling this problem in 1991 in the Institute for Water Resources Report, *Value of Time Saved for Use in Corps Planning Studies: A Review of the Literature and Recommendations*. The report focuses on the value of time related to personal vehicle use but gives no guidance on value of time to commercial operators. The report cites a rich array of studies on the subject including the American Association of State Highway Officials (AASHO). Since the Corps report was published, AASHO (now AASHTO, the American Association of State Highway and Transportation Officials) has published further guidance to highway planners. The latest AASHTO report is commonly referred to as the Red Book[18].

The Red Book document suggests that the value of time for personal vehicle use is 50% of the wage rate per person in each vehicle. The CTR follows the suggestion in the Red Book and uses the 50% factor, which seems conservative in view of the findings of Small and Winston. In 2005 the average wage rate per employee per year in Allegheny County was $36 thousand or $17 per hour. The value of time for non-truck traffic is thus $8.50 per hour per person.

The Bureau of Transportation Statistics (BTS) reports that, for all personal vehicle trips in the nation, there are 1.63 persons per vehicle[19]. Vehicle occupancy by type of trip is shown in Table 1. Note that occupancy in work related trips is 1.14 which is the lowest value among the different types of trips. Deitrick and Briem reproduce Census data for Allegheny County and the 6 county remainder of the Pittsburgh MSA[20]. The data show that in Allegheny County 72.1% of the commuters drive alone. In the remainder of the MSA, 83.8% drive alone. These data provide some evidence that, at least for commuters to work, it is appropriate to use the national data to reflect conditions in Pittsburgh area.

Table 9: National Vehicle Occupancy Per Vehicle Mile by Daily Trip Purpose

Trip Purpose	Mean Value
All Person Vehicle Trips	1.63
Work	1.14
Work-related	1.22
Family-Personal	1.81

[18] American Association of State Highway and Transportation Officials (AASHTO), User Benefit Analysis for Highways Manual, August 2003.
[19] Bureau of Transportation Statistics, daily trip file for 2001.
[20] Allegheny County Economic Trends, page 57.

Church-school	1.76
Social-recreational	2.05
Other	2.02

Using BTS's mean value for all trips, the total estimated cost per hour is $13.86 ($8.50 x 1.63)...

The CTR methodology is comfortably compatible with the aforementioned Hill and Moser document. For high time savings over 15 minutes, Hill and Moser suggest $8.33 dollars (1991 dollars) on a per vehicle-occupant basis. For other trips they suggest $9.98 on a per vehicle basis. For reference, the CPI calculator suggests an inflation adjustment from 1991 to 2005 of 1.43. Adjusting work trips for inflation and using the work-related vehicle occupancy rate suggested in the table above, the Hill and Moser work related savings would be ($8.33 x 1.43 x 1.14 = $13.58). The current value of the other trips category is $14.27 ($9.98 x 1.43). One other category suggested by Hill and Moser is social and recreational trips. The current value of time savings for this category is $13.28 ($9.29 x 1.43). Thus, whether suggested parameters come from the Red Book or from inflation adjusted data offered by Hill and Moser, an estimate of cost per hour per vehicle is approximately $14.00.

10.1.2 Commercial Highway Use

The opportunity cost of a commercial truck is equal to the benefit-loaded cost of hiring a new driver plus other operating expenses. The TVA has surveyed commercial highway users and found that the average cost of supplying a semi-tractor trailer driver is $65 per hour including fuel. But since this study groups all commercial vehicles together, the rate of $55 per hour is more reasonable since some of the deliveries would be made in smaller commercial vehicles that are less expensive to operate than the larger trucks[21]. However, the cost of fuel must be netted out. TVA estimates that, of the $55 per hour estimate, $13.10 should be allocated to fuel consumption, leaving $41.90 as the net time value cost per hour.

10.2 Fuel Consumption

A component of this study is calculation of the fuel required by the addition of new trucks into the traffic flow. When new trucks enter into the traffic flow, other traffic experiences additional delays and longer driving times. Thus, these vehicles, trucks and automobiles, consume more fuel per trip. This fuel consumption is an externality. The new trucks also consume fuel as an element of doing business, and this consumption is an NED cost of doing business under normal operating conditions. This cost is included in the estimate of shipper savings, which does not incorporate delays induced by the trucks themselves. The additional fuel consumed by the new trucks, over and above that required to make

[21] The commercial data were supplied by TVA in an email dated March 4, 2008.

deliveries under normal operating conditions, is an externality. The CTR estimates the required fuel consumption for all vehicles in the base case and in the two scenarios, nets out the increase in fuel consumption, and values the cost of the net increase at a real cost of $4.00 per gallon[22].

10.3 Crash Costs

Additional truck traffic on the roads can degrade highway safety, increasing either or both the rate and severity of accidents. Increased rail traffic, however, should not affect the safety of highway transportation because virtually all rail crossing are not at grade.

Calculating accident costs can be very complicated, as accident frequency and accident unit costs must be computed. Total accident unit costs include all costs resulting from fatalities, injuries, and property damage. As discussed in the Red Book, "…accident unit costs are calculated net of insurance costs to avoid double counting that portion of costs that are already covered by insurance."[23] Insurance costs are a cost of doing business and are included in calculations of transportation rates.

The U.S. Department of Transportation provides accident cost data by category of accident for fatal accidents, non-fatal accidents, and property damage and for all accidents[24]. Table 2 presents these data for the year 2000; the values are converted to the initial year values in the EXCEL workbook for use in estimating the accident costs due to the diversions to truck:

Table 10: Motor Vehicle Accident Costs in Cents per Vehicle Mile Traveled (2000 dollars)

Category of Accidents	Passenger Cars	Large Trucks
Fatal Accidents	4.2	5.86
Injury (non-fatal Accidents)	11.16	3.66
Property Damage Only	0.61	0.38
All Accidents	15.97	9.90

In 2000 dollars, the CTR used 15.97 cents per VMT for the accident costs for personal vehicle travel and 9.9 cents per VMT for commercial trucks.

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[22] It is possible that a small amount of double counting will occur as fuel costs for the diverted traffic also appears in the shipper savings calculations. However, this potential effect is felt to be too small to be of any consequence.

[23] Red Book, page 5-23.

[24] U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety Facts 2000*. U. S. Department of Transportation, Federal Highway Administration, *Highway Statistics 2000.*

10.4 Air Quality

10.4.1 Vehicle Emissions

The model calculates air pollution emissions from on-road mobile sources by multiplying VMT (vehicle miles of travel) for the various scenarios; times an emission factor (in grams per vehicle mile). It computes VMT for two vehicle types: heavy-duty diesel vehicles class 8b (HDDV8b) and all other vehicles combined. HDDV8b vehicles are those with GVWR (gross vehicle weight ratings) of more than 65,000 pounds equivalent to 18-wheeled tractor-trailer trucks. All other vehicles combined includes light-duty gasoline fueled automobiles, SUV's, pickup and delivery trucks, and light to moderate weight diesel vehicles (both cars and trucks).

Emission factors were obtained for each calendar year using the USEPA MOBILE6.2 emissions model, which determines emission factors for each pollutant, taking into account the model year, the national average age mix of each vehicle type, the average speed, fuel composition factors, and environmental conditions, such as ambient temperature and humidity. Emission factors calculated for this project are based on a minimum/maximum temperature of 56/80 F (average summer), the default humidity of 75 grains per pound of dry air, a gasoline RVP (Reid vapor pressure) of 7.8 psi (Pennsylvania requires this in most areas of the state) and a diesel sulfur content of 43 ppm until May 2010, and 11 ppm after June 2010 as required by USEPA nationwide. The most important factors are vehicle type, age, and speed. Newer vehicles of all types generally have lower emissions than older vehicles due to USEPA's ever more stringent emission standards for newer vehicles. The MOBILE6.2 model predicts that emission factors for all pollutants will decrease in future years (as they have been since the first emission standards in the 1970's) until about 2030 when all existing emission standards will be fully implemented. In fact, emissions from mobile sources will probably decrease even after 2030, but future emission standards are not currently known, so the model cannot account for these reductions.

HDDV8b vehicles have the highest emission factors for particulate matter (PM) and nitrogen oxide (NOx) emissions compared to other vehicles. Nitrogen oxide emissions from HDDV8b vehicles vary by vehicle speed. For this reason, emission factors were calculated for a range of speeds from 2.5 to 65 mph for different calendar years from 2006 to 2051 and for HDDV8b vehicles only and all other vehicles combined. The mix of all other vehicles combined followed USEPA's default national average values built into the MOBILE6.2 model. The effects of vehicle age, model year, and speed on emissions are all accounted for in the MOBILE6.2 model, so emission rates from on-road mobile sources can be estimated throughout the United States on a consistent basis. The use of the MOBILE6.2 model is recommended by USEPA for calculating emissions from on-road mobile sources for transportation and air quality planning in all US states except California (California uses the CARB EMFAC model, very similar to MOBILE6.2).

For this study, the MOBILE6.2 model was used to calculate emission factors for particulate matter, nitrogen oxides, sulfur dioxide, VOC's (volatile organic compounds), and ammonia. Separate tables of results were prepared for each calendar year. In each table, emission factors for each pollutant, for HDDV8b and all other vehicles combined, were summarized for each speed ranging from 2.5 mph to 65 mph in 5 mph increments. After multiplying emission factors times the VMT for each diversion scenario, total tons/year or pounds/day of emissions were determined for each scenario.

10.4.2 Air Quality Benefits

Whenever USEPA proposes stricter emission standards for pollution sources they conduct a cost/benefit analysis to estimate the costs and benefits of the proposed regulations. The costs are primarily the costs of installing more efficient pollution controls while the benefits are largely health benefits resulting from reduced air pollution concentrations. USEPA has performed many health effects and epidemiological studies that quantify the health benefits of reducing air pollution.

In 2000 USEPA implemented new emission standards for trucks and buses (as well as sulfur limits in diesel fuel) that are expected to reduce emissions by 97 percent from these vehicles. EPA further concluded that diesel exhaust is likely to cause lung cancer in humans and that the new standards would prevent 8,300 premature deaths annually. The new standards are expected to prevent 5,500 cases of chronic bronchitis, 17,600 cases of acute bronchitis in children, 360,000 asthma attacks, and more than 386,000 cases of respiratory symptoms in asthmatic children annually (See EPA Fact Sheet at www.epa.gov/otaq/diesel.htm). The new emissions standards are expected to reduce nitrogen oxide emissions by 2.6 million tons per year and particulate matter emissions by 110,000 tons per year, once fully implemented. In order to estimate the costs and benefits of saving lives, EPA uses $6 million per life saved (8,300 lives per year), resulting in a potential $49.8 billion benefit per year. According to EPA "the benefits of the action outweigh costs by 16 to one".

The methods EPA uses to relate the health effects to the change in ambient air pollution concentrations is beyond the scope of this report, but is based on epidemiological studies of the frequency of health effects in various cities with different air pollution concentrations. EPA developed a model called "BenMAP" (Environmental Benefits Mapping and Analysis Program) to estimate the benefits (dollars per ton of air pollution reduction) expected to result from the implementation of new the emission standards. This model was used by EPA in the RIA (Rule Impact Assessment) for the new truck and bus emission standards to provide "monetized benefit estimates of air quality improvements". BenMAP was run for different areas of the US to determine representative changes in air quality resulting from potential reductions in air pollutants, as well as the health and cost benefit resulting from the emission reductions. The values obtained for a 25% reduction in mobile source emissions (the minimum considered) were $ 372,797 per ton of directly emitted particulate matter, $59,780 per ton of ammonia, $8,961 per ton of nitrogen oxides, $27,088 per ton of sulfur dioxide, and $695 per ton of VOC's. The benefits attributed to ammonia, nitrogen oxides, sulfur dioxide and VOC emission reductions were due to their being precursors to particulate matter formed in the atmosphere after it is emitted, such that reducing these emissions also reduces particulate matter concentrations to which people are exposed. Note that while the cost benefit of reducing a ton of directly emitted particulate matter is much higher than for the other pollutants, nitrogen oxide emission reductions from trucks and buses are much greater than direct PM reductions, making the cost benefit of nitrogen oxide emission reductions comparable to the cost benefit from direct exhaust PM reductions.

For this study, the costs used to estimate each ton of emission reduction from mobile sources are the same values used by USEPA for the cost/benefit analysis in the RIA for the new emission standards for trucks and buses, based on the USEPA BenMAP model results. For each ton/year of emission change predicted by the traffic model, total incremental costs were calculated by multiplying the tons of emission reduction per year times the following cost per annual ton (as determined by USEPA for mobile sources):

- $ 372,797 per ton of directly emitted particulate matter
- $ 59,780 per ton of ammonia
- $ 8,961 per ton of nitrogen oxides
- $ 27,088 per ton of sulfur dioxide, and
- $ 695 per ton of VOC's.

11.0 Diversion Results

11.1 Unit Social Costs

As previously mentioned, the CTR made estimates of diversion social costs per ton for short and intermediate term closures at the EDM projects by year for four types of externalities using a customized computer analytic traffic and cost estimation model. A model run produces forecast values is based on a set of parameter values entered into the model by the user. The traffic growth rate for freeways and arterials is a critical specification. In certain of the highway links, limited capacity in combination with rising demand causes volume to capacity ratios to rise after a few years of simulation, increasing, of course, congestion and lowering operating speeds. The timing of congestion severity is dictated by the choice of the growth rate

Table 3 shows user input data for a run of the Excel workbook model. Here the growth factor is set at 1.07 percent per year (that is, the growth path is linear, so each year's traffic volumes get an increment of 1.07 percent of the initial year's value). This study reports results from runs for three rates; only the freeway and arterial growth rates change in the three runs, all other parameter values remain the same. The growth factor for new trucks is held at the five-scenario forecast average of about 1.0 percent per year, as suggested by the barge traffic forecast for the Upper Ohio River prepared by the Huntington District of the USACE. The base highway traffic forecast comes from the Southwest Pennsylvania Commission's study referenced above, where traffic is forecast to grow 30.0% over the period 2007-2035 , equating to 1.07% per year. The CTR extrapolates this same linear growth through the 51 year study period. High and low growth factors are set at 50% above (1.6% per year) and 50% below (0.55 percent per year) the base factor.

Table 11: Parameter Values Set by the User

Parameters	Values
Linearized annual growth factor for base load traffic freeways and arterials	1.07%
Linearized annual growth factor for new trucks from diversion	1.00%
Minimum speed constraint	0 mph
Price of fuel	$4.00 per gallon
Traffic signal cycle length	120 seconds
Value of travel time per hour-automobiles	$14.00
Value of travel time per hour-trucks	$41.90
Crash cost per VMT-automobiles	$0.001597
Crash cost per VMT-trucks	$0.00099
Emission cost per ton PM2.5	$372,797
Emission cost per ton SO2	$27,088
Emission cost per ton NOx	$8,916
Emission cost per ton NH3	$59,780
Emission cost per ton VOC	$695

By using what the CTR believes are conservative growth rates, an assumption is made that the historically high growth rates will not continue well into the 51 year forecast horizon. Pittsburgh highway capacity is constrained by mountains and rivers and the tunnels and bridges necessary to transit the city. Economists at the University of Pittsburgh, maintain the city is also transiting into a services economy, which will reorient traffic toward the services and away from heavy trucks that are necessary to facilitate manufacturing[25].

The Huntington District Center for Inland Navigation Planning Expertise will use the model's results as input into the Oak Ridge National Laboratory's (ORNL) Ohio River Navigation Investment Model (ORNIM), which can be used to select the optimal timing and set of measures to maximize the net benefits of the river system. The CTR model will interface with ORNIM. providing the social cost per ton of traffic diverted into the

[25] Deitrick and Briem.

Pittsburgh area by year and by the four components of cost: air pollution, crashes, and fuel consumed, and time traveled.

Table 4 shows the diversion constant-dollar total social costs per ton (over all highway links) for selected years for the three growth scenarios. In the initial year, the costs-per-ton for the short and intermediate duration scenarios are $3.10 and $3.45, respectively. Growth in both the short and intermediate duration values change very little by the 10th year of the forecast period, but rise well above the starting year values; for example, in the 1.07% scenario, rising to $10.92 and $12.90, respectively, by the 51st year.

Table 12: Diversion Total Social Costs Per Ton for Selected Years (constant dollars)

Year	Growth Rate %	Short Duration	Intermediate Duration
1	0.55	$3.10	$3.45
10		2.92	3.28
25		3.20	3.61
51		4.30	4.91
1	1.07	$3.10	$3.45
10		3.11	3.50
25		4.09	4.66
51		10.92	12.90
1	1.6	$3.10	$3.45
10		3.34	3.76
25		5.95	6.90
51		38.47	46.54

Table 5 shows slow growth or decline in the total diversion costs per ton early in the forecast period is due to a rather drastic decline in the values of the air pollution component, while base and new traffic growth has not increased to the point to cause longer travel times. As noted, the MOBILE6 model forecasts a drastic decline in mobile source emissions over a very short period of time.

Table 13: Short-term Closure - Diversion Cost Per Ton (constant dollars) by Externality Type

Year	Growth Rate	Travel Hours	Crashes	Fuel	Air Pollution	Total	Percent Travel Hours
1	0.55%	1.46	0.14	1.05	0.44	3.10	47.10%
25		1.76	0.14	1.26	0.03	3.20	55.00%
51		2.63	0.14	1.50	0.03	4.30	61.16%
1	1.07%	1.46	0.14	1.05	0.44	3.10	47.10%
25		2.46	0.14	1.46	0.03	4.09	60.15%
51		8.72	0.14	2.02	0.03	10.92	79.85%
1	1.60%	1.46	0.14	1.05	0.44	3.10	47.10%
25		4.08	0.14	1.705	0.03	5.95	68.57%
51		35.74	0.14	2.56	0.03	38.47	92.90%

At a linearized annual growth factor of 1.6 percent, traffic in the Pittsburgh area would increase by about 80 percent over the 51 year forecast period. This higher level of traffic growth causes the volume to capacity ratios to rise faster than those in the lower growth scenarios, overwhelming the decline in pollution values. By the 51st year, the total cost-per-ton values rise to $38.47 (short duration) and $46.54 (intermediate duration).

At the very low growth factor of 0.55 percent, the total cost-per-ton values are essentially flat throughout the forecast period due to a decline in mobile source emissions, coupled with relatively low estimated volume to capacity ratios.

Appendix A contains the diversion total cost-per-ton values by year for the entire 51 year period for the short and intermediate durations and each growth scenario.

Figures 1 and 2 display diversion total cost-per-ton estimates graphically for the three growth scenarios in the short and intermediate duration scenarios.

Figure 1: Diversion Cost-per-Ton Estimates for Three Growth Scenarios – Short Duration

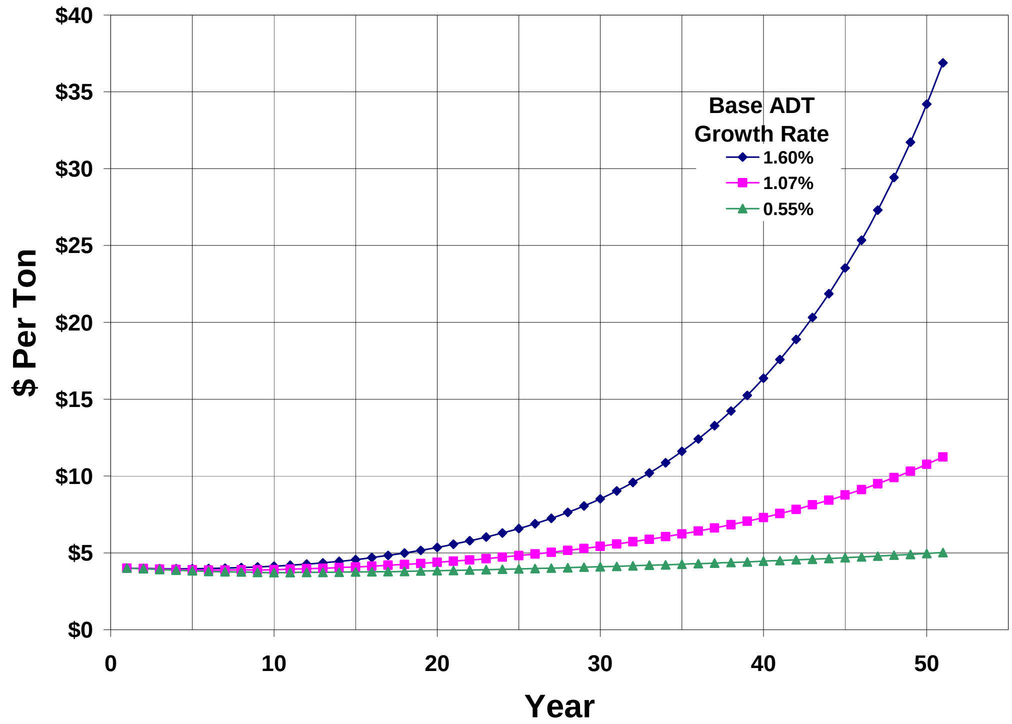
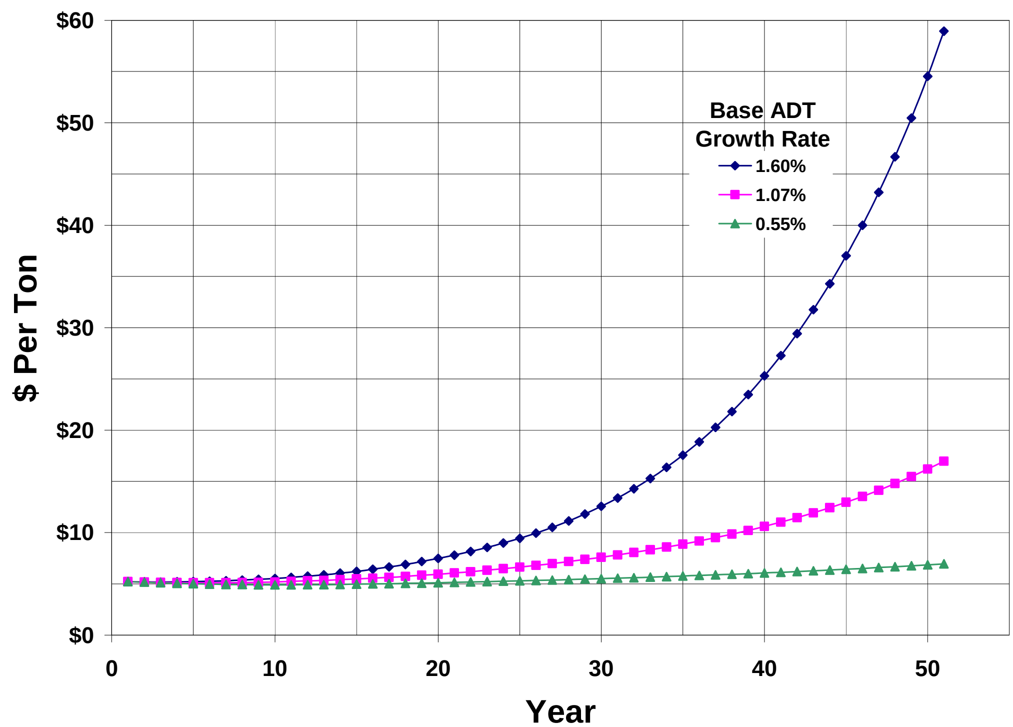


Figure 2: Diversion Cost-per-Ton Estimates for Three Growth Scenarios – Intermediate Duration



The current interpretation of the *Principles and Guidelines*[26] allows the incorporation of travel time impacts into lock construction benefit-cost studies if the benefit-cost ratio for a project is greater than unity. It is thus instructive to examine how the diversion highway travel time estimates are impacted by highway traffic growth. In the starting year, travel time accounts for about 47 percent of total diversion social costs. In the 51st year of the simulation, travel time account for 61.16 percent of total diversion social costs in the 0.55 percent scenario, 79.85 percent of total diversion social costs in the 1.07 percent scenario, and 92.90 percent of total diversion social costs in the 1.60 percent scenario.

Table 14: Percent of Cost-Per-Ton Accounted For by Travel Time

Growth Rate-%	Year 1	Year 25	Year 51
0.55	47.10	55.00	61.16
1.07	47.10	60.15	79.85
1.60	47.10	68.57	92.90

11.2 Critical Links

All 42 highway links identified in the study experience some impact from the diversion of traffic due to EDM closures, both in the short and intermediate duration scenarios. One way to examine these impacts is to sum the impacts by link over the 51 year period and standardize these data by dividing by the one-way distance of the link. The longest link is 13.83 miles while the shortest link is 0.25 miles. Shown in Table 7, the link most heavily impacted by the truck diversion (on a per mile basis) is Carston Street which is a narrow urban arterial road located near the water terminals. Additionally, the Interstate highways coming into or leaving the Pittsburgh City limits, roads in the industrial area along the rivers, and the bridges are heavily impacted by the new trucks.

[26] *The Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, U.S. Water Resources Council, March 10, 1983.

Table 15: Several Major Critical Highway Network Areas

Roadway	From	To
Carston Street	Third Street	Intermediate Point
I-279 to I-376	Fort Pitt tunnel east end	North end of Fort Pitt Bridge to I-376
I-279	Exit 5a	End of Tunnel
Pa 51	McKeesport 51	Fleming Bridge
US 22/US 30/I-279	Pa 22	Exit 41 Greentree
I-279	Exit 4a	Exit 5a to Pa 19
Pa 60	Exit 6	Exit 2 to Montour
Pa 60	Exit 2	Route 22 Moon

12.0 Dock-to-Dock Unit Diversion Social Costs

The traffic-cost model also calculates diversion social costs per ton by dock-to-dock movements. This requires, in addition to the per ton diversion social costs by highway segments the model produces, the base year matrix of new truck flows for movements over the highway segments they each traverse in order to move their loads from dock A to dock B.

The matrix of diversion social costs by year and highway segment, accounting for the growth in base and new truck traffic, is calculated within the model as previously discussed. Mathematically, the derivation of diversion social costs by movements, then, can be accomplished, in principle, by a composition of linear transformations, where:

$T_{mxk,n}$ = matrices of base year tons by movement m and link k; each year n denotes a new matrix where tonnages have grown by the factor specified in the Model's user inputs

tt_n = column vector, m x1, of total tons by movement (Σ [elements of T by row over k]) for year n

S_{kxn} = matrix of highway segment diversion social costs per ton computed by the Model, accounting for the growth in both base and new truck traffic

s_n = column vector of matrix S for year n

M_{mxn} = matrix of diversion social costs per ton by dock-to-dock movement m and year n

m_n = column vector of M for year n.

Diversion social costs per ton by movement and year, then, are computed as:

$m_n = T_n s_n \bullet tt_n^{-1}$, where "•" is the entrywise product and superscript -1 denotes each element in the vector is inverted (1/element),

and, therefore, the m x n movement diversion unit social cost per ton matrix is

$$M = [m_1\ m_2\ m_3\ \ldots\ m_n].$$

For computational purposes, the model reformulates the system of vectors and matrices and performs an equivalent set of operations requiring only one T matrix and one matrix multiplication in the spreadsheet. The dock-to-dock data are provided to TVA for use in estimating total private and diversion social costs related to each set of movements. These data are not included in this report.

13.0 Thoughts on Traffic Growth Rates

As discussed above, traffic growth in the three county study area has averaged about 3.0 percent per year on freeways and about 1.0 percent per year on arterials in recent history. This level of growth cannot continue in the Pittsburgh area, at least in the three county area where the CTR modeled capacity. If traffic continued to grow at these historical rates, Pittsburgh would see gridlock as speeds fall to unacceptably low levels. Natural forces will take care of part of the problem of traffic growth, as the price of fuel continues to rise and longer transit times cause drivers to reconsider some of their trips. The projected further shift from a manufacturing to a services economy will further reduce truck traffic. Telecommuting could also reduce traffic. As in other areas, van and car pooling could be a factor.

Most likely, though, the high growth rates found in the last decade will continue in the early years of the forecast period and then decline for the reasons discussed above. The SPC, who study the region, contend for a linearized growth rate of 1.07 percent through 2035. Even this growth rate in the later years of the forecast period causes average speed problems on Carston Street and around the Fort Pitt Tunnel. Thus, CTR feels that growth rates higher than 1.07 percent per year are less likely to occur in the long run in the Pittsburgh area, and growth rates lower than 1.07 percent are also unlikely, given the inertia of high historical traffic growth in the region.

14.0 Summary and Conclusions

The U.S. Army Corps of Engineers expect that maintenance on the navigation locks at Emsworth, Dashields, and Montgomery Dams will increase due to their age and condition. The result will be diversions of cargo handled at the locks to overland transportation as commodities are trans-loaded to either truck or rail for delivery to their ultimate destination. For purposes of estimation, these outages are specified as short duration of 60 days or intermediate duration of 180 days. This research paper, addressing only transshipment to truck transportation, describes a study wherein annual dollar values are placed on the diversion costs to society for both the short and intermediate duration maintenance outages.

The basic methodology of the study models traffic conditions in the study area and then transforms traffic and congestion impacts into additional fuel consumed, time spent in transit, air pollution, and crashes. Dollar values are placed on each of the four effects using data obtained from the ASSHTO Red Book (*User Benefit Analysis for Highways*) and the Environmental Protection Agency. The study formulates the base case where existing traffic is projected for 51 years and related to existing capacity in the manner described in the NCHRP report 387. The 51 year period begins with the year 2005 and ends with the year 2055. For each of these years, baseline traffic conditions represent the situation without any closure of the locks.

The Tennessee Valley Authority (TVA), using information from the shippers in field interviews, learned the origin or destination locations for the commodities shipped out of or to each terminal. For some truck movements, the shippers told the TVA field staffs the routes that would be used in the event of lock outage. For the remaining movements, MapQuest[27] was used to establish the routes. To verify that the routes were reasonable, the CRT staff visited Pittsburgh on November 12 and 13, 2007 and drove each route. The Southwestern Pennsylvania Commission (SPC) was also consulted as to the reasonableness of the routes. One route was altered as a load limited bridge was discovered in driving the roads

Diversion over all affected highway links, for short and intermediate duration, results in total cost per ton estimates of $3.20 and $3.45 in the starting year. Both the short and intermediate duration values change very little in the early years, but in the 1.07 percent per year scenario the values reach $10.92 and $12.90 respectively by the 51st year. An initial decline in the cost-per-ton values results from a rather drastic decline the values of the air pollution component (as shown in the study, the EPA MOBILE6 model forecasts a drastic decline in mobile source emissions over a very short period of time) and volume/capacity ratios not yet severely impacted early in the forecast period. This cost decline is soon reversed by the impact of congestion on travel time and average speeds.

At a linearized annual growth factor of 1.6 percent, traffic in the Pittsburgh area would increase by about 80 percent over the 51 year forecast period. This higher level of traffic growth causes the volume/capacity ratios to rise significantly faster, overwhelming the decline in pollution values at an earlier date. By the 51st year, the cost-per-ton values rise to $38.47 (short duration) and $46.54 (intermediate duration).

At the low growth factor of 0.55 percent, the cost-per-ton values are essentially flat. The decline in mobile source emissions, coupled with relatively low estimated volume/capacity ratios, results in relative flat cost-per-ton values throughout the 51 year forecast period.

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[27] Mapquest can be viewed at www.mapquest.com

The diversion social costs-per-ton values for the entire 51 year period for each duration and each growth rate are given below.

Truck Diversion Unit Social Costs By Year

	Short Term			Intermediate Term		
Year	0.55%	1.07%	1.60%	0.55%	1.07%	1.60%
1	$3.10	$3.10	$3.10	$3.45	$3.45	$3.45
2	$3.07	$3.08	$3.09	$3.42	$3.44	$3.45
3	$3.03	$3.06	$3.09	$3.38	$3.42	$3.45
4	$3.01	$3.05	$3.10	$3.36	$3.41	$3.47
5	$2.98	$3.05	$3.13	$3.33	$3.41	$3.50
6	$2.96	$3.05	$3.15	$3.31	$3.41	$3.53
7	$2.94	$3.06	$3.19	$3.30	$3.43	$3.58
8	$2.94	$3.08	$3.24	$3.29	$3.45	$3.63
9	$2.93	$3.09	$3.28	$3.28	$3.47	$3.69
10	$2.92	$3.11	$3.34	$3.28	$3.50	$3.76
11	$2.93	$3.15	$3.42	$3.29	$3.54	$3.85
12	$2.94	$3.19	$3.50	$3.30	$3.59	$3.95
13	$2.95	$3.22	$3.59	$3.31	$3.63	$4.06
14	$2.96	$3.27	$3.69	$3.32	$3.68	$4.18
15	$2.98	$3.32	$3.81	$3.34	$3.74	$4.33
16	$2.99	$3.37	$3.95	$3.36	$3.81	$4.49
17	$3.01	$3.43	$4.10	$3.38	$3.88	$4.67
18	$3.03	$3.49	$4.27	$3.41	$3.95	$4.87
19	$3.05	$3.56	$4.45	$3.43	$4.03	$5.08
20	$3.08	$3.63	$4.65	$3.46	$4.12	$5.33
21	$3.10	$3.71	$4.87	$3.49	$4.21	$5.59
22	$3.12	$3.80	$5.11	$3.51	$4.31	$5.87
23	$3.15	$3.89	$5.37	$3.54	$4.42	$6.18
24	$3.17	$3.99	$5.65	$3.57	$4.54	$6.52
25	$3.20	$4.09	$5.95	$3.61	$4.66	$6.90
26	$3.22	$4.21	$6.29	$3.63	$4.79	$7.30
27	$3.25	$4.33	$6.66	$3.67	$4.94	$7.75
28	$3.28	$4.46	$7.07	$3.70	$5.09	$8.24
29	$3.31	$4.59	$7.51	$3.74	$5.25	$8.78
30	$3.34	$4.73	$8.01	$3.77	$5.43	$9.38
31	$3.37	$4.89	$8.55	$3.81	$5.61	$10.04
32	$3.41	$5.05	$9.15	$3.85	$5.80	$10.76
33	$3.44	$5.21	$9.80	$3.89	$6.00	$11.55
34	$3.48	$5.39	$10.52	$3.93	$6.22	$12.42
35	$3.51	$5.58	$11.30	$3.97	$6.45	$13.37
36	$3.55	$5.78	$12.16	$4.02	$6.69	$14.40
37	$3.59	$5.99	$13.09	$4.06	$6.94	$15.54
38	$3.63	$6.22	$14.11	$4.11	$7.22	$16.77
39	$3.67	$6.46	$15.21	$4.16	$7.51	$18.11
40	$3.71	$6.71	$16.41	$4.21	$7.82	$19.57
41	$3.76	$6.99	$17.71	$4.27	$8.15	$21.15
42	$3.80	$7.28	$19.12	$4.32	$8.50	$22.87
43	$3.85	$7.59	$20.65	$4.38	$8.87	$24.74
44	$3.90	$7.92	$22.31	$4.44	$9.27	$26.76
45	$3.96	$8.27	$24.10	$4.50	$9.70	$28.96
46	$4.01	$8.64	$26.05	$4.56	$10.15	$31.34

	Short Term			Intermediate Term		
Year	0.55%	1.07%	1.60%	0.55%	1.07%	1.60%
47	$4.06	$9.04	$28.16	$4.63	$10.64	$33.91
48	$4.12	$9.47	$30.44	$4.70	$11.15	$36.71
49	$4.18	$9.92	$32.91	$4.77	$11.70	$39.73
50	$4.24	$10.40	$35.58	$4.84	$12.28	$43.00
51	$4.30	$10.92	$38.47	$4.91	$12.90	$46.54

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Addendum 2

TRANSPORTATION RATE ANALYSIS:
EDM Regional Economic Development

Prepared for U.S. Army Corps of Engineers
Huntington District

by

The Tennessee Valley Authority
Water Management Support
Knoxville, Tennessee

July 2008

CONTENTS

EXHIBITS

I. Summary

Based on a 205 movement survey of barge shipping, users of the Upper Ohio River Navigation System that passed through either Emsworth, Dashields, or Montgomery Locks are estimated to spend, on average, \$6.28 more per ton in transportation and handling charges for a less than 60 day lock closure for the movement of 1.8 million tons of cargo when available barge costs are compared to the NED, water transportation alternative. Likewise, Upper Ohio River Navigation System users are estimated to spend, on average, \$6.94 more per ton in transportation and handling costs for a 60-180 day lock closure for the movement of 4.6 million, when compared to the NED, water transportation alternative. These savings are calculated across eight commodity groups including over 35 separate commodities and for the less than 60 day lock closure range between a high \$55.40 per ton for chemicals and minus \$11.91 per ton for non metallic minerals. Only those movements with a modal diversion had the RED transportation rate analysis undertaken. A full reporting of all rate calculations is provided through a combination of spreadsheets and worksheets in Volume II.

II. Introduction

This study is conducted by the Tennessee Valley Authority (TVA) under contract with the Huntington District of the U.S. Army Corps of Engineers (Corps) in order to facilitate the calculations of the Regional Economic Development (RED) benefits attributable to Upper Ohio River navigation. The Upper Ohio River Navigation System is defined as the barge traffic that passed through one of the three Upper Ohio River Locks, Emsworth, Dashields, and Montgomery, Toward this objective, the study provides a full range of transportation rates and supplemental costs for a sampling of two hundred five, 2004 waterborne commodity movements which, in total or in part, were routed on the Upper Ohio River Navigation System or were inclusive of survey responses conducted by the Pittsburgh District of the Army Corps of Engineers.

Freight rates for each sample movement are calculated based on the actual water-inclusive NED routing, as well as for a less than 60 day closure and 60-180 day closure alternatives. All computations reflect those rates and fees which were in effect in the third quarter 2007. Results are documented on a movement-by-movement basis, including a separate worksheet for each observation. These dis-aggregated data are also integrated into individual spreadsheets for each of the eight commodity groupings. A full description of the study's scope and guidelines, TVA's methods of rate research and construction, and supporting assumptions is provided below.

III. Study Parameters

A sample of 205 movements was identified for inclusion in this analysis. Reported rates for both the water movement and less than 60 day and 60-180 day closure alternatives are based on the actual location of shipment origins and destinations if a modal diversion would occur.

1. *Water Routings*

Because many of the sample movements have off-river origins and/or destinations, a full accounting of *all* transportation costs for waterborne movements also requires the calculation of railroad and/or motor carrier rates for movement to or from the nearest appropriate port facility. Additionally, all calculations reflect the loading and unloading costs at origin and destination, all transfer costs to or from barge, and any probable storage costs. Finally, though it was rarely a concern, all waterborne routings were constrained to include at least partial use of the Ohio River navigation system.

2. *Land Routes*

With the exception of over-dimension shipments and intra-pool sand dredging, rail or truck rates are calculated for all movements (See Section VI for a discussion of exceptions.). For over dimension truck and intra-pool dredged materials, the land rate was estimated as compared to a specific modeled rate using identifiable data inputs. Additionally, pipeline or conveyor alternatives are calculated for applicable commodities when both the origin and destination are pipeline or conveyor served. As in the case of the barge-inclusive routings, many all-land routes require the use of more than one transport mode. Therefore, when appropriate, calculations include all requisite transfer charges.

3. Less than 60 day and 60-180 Day Lock Closures

Each of the shippers on the Upper Ohio River Navigation System were interviewed to determine their specific modal response to an unscheduled less than 60 day and a 60-180 day lock closure. These 205 O/D interviews found the following for a less than 60 day lock closure; 4 O/D's would shut down, 20 O/D's had already closed to barge shipping, 6 O/D's would wait, 108 O/D's would use rail, and 67 O/D's would use truck.

For the 60-180 day closure, the following interview responses were observed: truck around or truck direct or the use of truck from a new source, 51; closed to barge shipping 20; rail around or rail direct or resource by rail 54; wait for lock to open 0; close dock or plant 51; re-source from new location by barge, pipeline, or unknown mode 29.

For the rail and truck users, an RED transportation rate analysis was performed for each sample movement.

4. Seasonality and Market Anomalies

To accurately reflect RED benefits, it is necessary to develop rates which portray the normal market conditions which are anticipated over the project life. For this reason, every attempt was made to purge the data of anomalous or transitory influences. As a part of all shipper surveys and interviews, respondents were directed to ignore temporary market disruptions and provide information reflective of “normal” operating conditions. As a result of the commodity mix represented within the sample, we detected no need to adjust for seasonal fluctuations. Annual contract barge rates with a fuel escalation feature and five year average spot market grain rates provide an annual average barge rate that is comparable to the multi year contract rail rates that remove seasonality. The result is consistent rate treatment for each mode.

IV. Worksheet Explanation

Volume II contains the individual worksheets for each of the 205 movements. Each worksheet consists of 1 - 3 pages and catalogues basic shipment information including:

1) Corps assigned shipment reference number
2) Individual commodity description
3) Commodity group description
4) River origin
5) River origin waterway mile
6) Off-river origin (if applicable)
7) WCSC number
8) Shipment tonnage
9) River destination
10) River destination waterway mile
11) Off-river destination (if applicable)

Section I of the worksheet contains the analysis of the barge-inclusive routing from origin to destination via the Upper Ohio River Navigation System. Section II contains information describing the best available all land alternative. When multiple off river origins were observed, a supplemental page calculating a tonnage weighted average of the transportation rate is shown. Section III contains the less than 60 day lock closure information, and Section IV contains the 60-120 day lock closure information.

Authorities or sources for all calculations are reported in footnotes to the appropriate worksheet items. All rates and supplemental costs are expressed on a per net ton basis in third quarter 2007 U.S. dollars. When the river port town name and the railroad station name are different, the railroad station name is indicated as an off-river origin or destination with no cost to and/or from the river.

V. Judgments and Assumptions

Based on information collected from shippers, receivers, carriers, river terminal operators, stevedores, federal agencies, and private trade associations, TVA was able to identify probable origins and destinations for the majority of those movements that originated or terminated at off-river locations. In the absence of specific shipper/receiver information, it is assumed that the river origin and destination are the respective originating and terminating points for both river and alternative modes of transportation. In every case, an attempt was made to gather information from all shipping ports. However, in some instances, 2004 logistical data are not available from these ports. In other cases, port representatives declined to provide the requested information.

Specific commodity groups are discussed in more detail later in this section. However, for those movements that originate or terminate at a river port location, it is assumed that rail service could also be utilized by the shipper or receiver if that port is rail served. Exceptions to this assumption are noted on individual worksheets. When the shipper or receiver is served by truck only, a railroad team track or transfer facility at the station nearest the off-river shipper or receiver is used for the land alternative. Only those shippers who ship more than 150,000 tons annually and who are adjacent to rail tracks would be assumed to undertake the significant capital expenditures necessary to acquire direct rail service. Mileage allowances made by carriers to shippers for the use of private equipment are also ignored as are rebates to shippers.

For the long run, in all cases, it is assumed that the alternative modes of transportation would have the physical capacity to accommodate the additional tonnage represented by each commodity movement (This is provided for in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G)). Commodity specific judgments and assumptions include:

Coal (Group 1)

A number of assumptions are made for land haul rates on the movements of coal to utility destinations that are not rail served. Volumes to these utility destinations are, in many cases, substantial, so that long-haul truck transportation cannot be considered a viable option. In the absence of water transportation, receiving utilities would have to carefully evaluate those available options which might insure their ability to continue to receive large volumes of coal. These considerations might include the replacement cost of transfer and handling facilities, the construction cost of switch or main line rail track, the cost of new or improved highway access, the economies of buying or leasing rail equipment, and the possibility of shifting origins to assure adequate coal supply. For their part, we may assume that rail carriers would be willing to construct additional track capacity if volumes are sufficient. However, these construction costs would most likely be passed on to the shipper via higher rates.

To accommodate those instances in which sample barge movements are to non-rail served utilities, we have incorporated the following judgments and assumptions.

> If the receiving utility is not rail served, rates are applied to the nearest railhead, and trucking costs from the railhead to the destination are applied. If the shipping point is not rail served, a motor carrier charge is applied from the mine origin to the nearest railhead. It is assumed that transfer facilities would be available at both origin and destination for transfer between rail and truck. In addition if the receiving utility is not rail served, the option of railing to a barge transfer dock for barge furtherance to the utility was incorporated into the analysis.

> If the receiving utility is rail served for supplies only, but not coal, the rail car unloading cost of the utility is inflated to accommodate a rail track expansion to the coal stockpile for the NED analysis. For the RED analysis only coal receivers

that are directly rail served were considered to switch to the rail mode in the short term.

In some instances, movements involve a truck haul from multiple origins to a concentration or preparation point for loading to rail. In these instances, where shipments originate at several mines within the same general area, a representative rail origin is selected as the transfer location.

Aggregates (Group 2)

Land haul rates on limestone and sand and gravel reflect the modes necessary to transport the shipments from actual origins to actual destinations. If origins or destinations are not rail served, a trucking charge is applied from the nearest rail station. For those movements where both rail and truck transportation are an option, truck hauls are limited to a distance of 100 miles. This, on occasion results in slightly higher rates. However it was deemed impractical, in the absence of water transportation, to transport large volumes of these commodities for long distances by truck. Limiting factors of truck transport include lower cargo carrying capacity, the inability to round-trip more than three times per day, and the absence of loaded back-haul opportunities.

With regard to waterway improvement materials, we assume that land movements would require a truck haul at the destination for delivery to river bank work locations. These truck movements would likely average five miles each. It should be noted that a significant amount of channel improvement and bank stabilization work is conducted off shore or at locations without highway access, making land transportation impractical.

Grain (Group 4)

The computation of rates for grain is based upon the survey responses of the shippers and receivers. Specifically, if a country elevator gathers grain then ships it to the river terminal; we assume a 20 mile truck haul from the farmer's field to the country elevator. If the grain moves for export, a unit train movement is assumed, and land rates are computed from a unit train capacity elevator to a Gulf port location. For domestic shipments, the computation of rail rates is based on the track capacity of the country elevator or domestic receiver. We assume that the grain shipper would maximize the use of his facilities and utilize gathering rates to reach the track capacity of the receiver.

The rail rating of feed ingredients follows assumptions similar to those used for the rating of grain - namely rates constrained by track capacity. Rail and barge transit programs for meals (soybean, cottonseed, oilseed and fish) were not considered.

VI Methods and Procedures

As a result of pricing flexibility and differential rates allowed by surface transportation deregulation, it is sometimes difficult to determine the exact rate charged by a carrier on shipments moving under contract. Barge rates are a matter of negotiation between shipper and barge line operator, and these rates are not published in tariff form. Each carrier's rates are based on individual costs and specific market conditions, so that these rates will vary considerably between regions, across time, and from one barge line to another.

Contract rates are also common in pipeline, rail and motor carrier transportation and, like barge rates, may be maintained in complete confidentiality. In other cases (particularly grain), tariff rates are still applied. However, there is rarely any dependable means for determining whether a contract rate or a tariff rate should be used to price a particular movement. A further complication is the use of rebates and allowances as an incentive by carriers to shippers to induce higher traffic volumes.

Barge Rates

With the exception of grain and feed ingredients and average trade publication spot market rate quotes, unobservable barge rates are calculated through the application of a computerized barge costing model developed by the Tennessee Valley Authority. The TVA model has been refined to include 2007 fixed and variable cost information obtained directly from the towing industry and from 2006 data published within the Corps' annual *Estimated Towboat and Barge Line-Haul Cost of Operating on the Mississippi River System (This is an update of data and equations using a 2000 report methodology)*. Additionally, 2006 data from the Waterborne Commerce Statistical Center trip reports and 2006 data from the Lock Performance Monitoring System are incorporated into TVA BCM costing parameters.

The TVA model contains three costing modules: a one-way general towing service module, a round-trip dedicated towing service module, and a round-trip general towing service module. The one-way module calculates rates by simulating the use of general towing conditions between origin and destination, including the potential for a loaded return. The dedicated towing service module calculates costs based on a loaded outbound movement and the return movement of empty barges to the origin dock. The round-trip general towing service module is similar to the one-way, except that it provides for the return of empty barges to the point of origin. This module does not calculate costs for towboat standby time during the terminal process but does include barge ownership costs (maintenance, replacement cost, supplies, insurance, and administration) for both the terminal and fleeting functions. It does not require that the empty barges be returned with the use of the same towboat. Depending on the module in use inputs may include towboat class, barge type shipment tonnage, the interchange of barges between two or more carriers, switching or fleeting costs at interchange points or river junctions, and barge ownership costs accruing at origin and destination terminals, fuel taxes, barge investment costs, time contingency factors, return on investment, and applicable interest rates.

Barge rates on dry commodities are calculated with the use of the general towing service round-trip costing module. Inputs, based on information from carriers and the Corps' Performance Monitoring System (PMS) database were programmed into the module to simulate average towboat size (horsepower) and corresponding tow size (barges) for each segment of the Inland Waterway System. Other inputs include barge types, waterway speeds, horsepower ratios and empty return ratios. These inputs are documented by Appendix 2 for 2006.

An example of a typical shipment cost in this analysis would be a dry bulk commodity (iron ore intermediates or cement clinker) originating on the Mobile River at Mobile, Alabama and terminating on the Ohio River at Cincinnati, Ohio. Based on the modeling process, this shipment would be assumed to move in an four barge tow from Mobile to the Mississippi River at New Orleans, a twenty four barge tow from New Orleans to Cairo, and a fifteen barge tow from Cairo to Cincinnati. At each interchange point, appropriate fleeting charges would be calculated. Empty return (back haul) factors would also be included for each segment of the movement.

With the exception of movements involving Northbound and tributary rivers, barge rates for grain and feed ingredients are estimated on the basis of a percentage of base rates formerly published in Waterway Freight Bureau Tariff 7.[28] For movements with origins in the Ohio River Basin, the five year average percent of base for the Lower Ohio, Mid Ohio, Upper Mississippi, Illinois, and Missouri Rivers is used (See Appendix 3). For movements on the Tennessee, Gulf Inter Coastal Waterway, an Arbitrary charge is added to the New Orleans base rate. Rates for those movements that traversed the Tennessee -Tombigbee Waterway are calculated through the use of the TVA general towing service round-trip costing module.[29]

Barge rates for asphalt, heavy fuel oils, and light petroleum products are calculated through the use of the dedicated service round-trip costing module. Twenty hours standby time is allocated at origin and destination for towboat terminal functions. Finally, rates for sodium hydroxide, vegetable oils, lubricating oils, liquid chemicals, and molasses are calculated through the use of the general service round-trip costing module. As a result of comparable barge sizes, these commodities normally move in the same tow with dry commodities.

Barge rates calculated by the use of the TVA model reflect charges that would be assessed in an average annual period of typical demand for waterway service. It should be noted that the model does not explicitly consider market factors such as intra or inter modal competitive

[28] The expression of barge rates for agricultural commodities as a percentage of waterway Freight Bureau Tariff 7 is consistent with industry standards.
[29] There is no basis for rates via the Tenn-Tom in the Waterway Freight Bureau Tariff.

influences, favorable back haul conditions created by the traffic patterns of specific shippers, or the supply and demand factors which affect the availability of barge equipment. These and other factors can influence rate levels negotiated by waterway users. The model does, however, calculate rates based on the overall industry's fully allocated fixed and variable cost factors, including a reasonable rate of return on assets. It is TVA's judgment that the rates are representative of the industry and provide a reasonable basis for the calculation of NED benefits.

The spot market hopper barge rates were derived from the River Transport News published by the Criton Corporation of Silver Springs, Maryland. The average spot market rate for the second and third quarters of 2007 was utilized.

Railroad Rates

In 2007, rail shippers received rate relief from the Surface Transportation Board (STB) in the calculation of fuel surcharges. The result of the STB decision was a new calculation method for surcharges based upon mileage with the Class 1 rail carriers adopted the ALK mileage software program to estimate mileage. A further complication in rail rate calculation was the failure of Global Insight, Inc. to correct and update the Reebie Rail Costing Model that they purchased in 2004 when Global Insight acquired Reebie & Associates.

To resolve the above analytical issues, TVA developed a rail rate estimating technique using the attributes of rail shipping exhibited in the STB Waybill Sample. This technique was first employed in the Upper Mississippi and Illinois Rivers 2006 Transportation Rates Project for the Army Corps of Engineers.

The TVA rail rate estimating method has six steps. First, TVA field or telephone interviews the dock operator to establish the off river origin and/or destination, the mode and carrier of transport to or from the dock, rail track capacity at the dock, and river dock handling capability. Second, a rail route is constructed from either the off river origin or the dock origin. Third, the STB Waybill Sample for 2006 was sorted by seven digit STCC number (or five digit if insufficient observations) by carrier, by state (or all states if insufficient observations), by single car-multi car-small unit train-large unit train, and by distance (less than 500 miles or greater than 500 miles). Fourth, the average revenue per mile was calculated along with the standard deviation. Fifth, a derived revenue masking factor, an index from 2006 to third quarter 2007 (non fuel 3.5%), and a fuel surcharge (0.28 per mile) were applied. Last, carrier mileage was multiplied by the adjusted revenue per mile, and the result was divided by the average weight per car to produce an estimate of the rail rate per short ton for the land move.

Motor Carrier Rates

Truck rates for off-river movements were obtained from the shipper and dock surveys conducted by TVA for the Army Corps of Engineers. In addition, TVA maintains transportation trade publications that report various regional trucking rates and costs. The truck rate methods TVA uses consist of a rate per loaded mile for moves over 100 miles or a shuttle truck rate per hour for moves under 100 miles. The truckload weight is provided by the individual state highway axel load and bridge formula for truckload and permitted load limits.

Handling Charges

Handling charges between modes of transportation are estimated on the basis of information obtained from shippers, receivers, stevedores, and terminal operators. Handling charges for the transfer of commodities from or to ocean-going vessels are on the basis of information obtained from ocean ports or stevedoring companies. For import or export movements that involved mid-stream transfer operations, handling costs to or from land modes at a competing port with rail access are applied.

Except as noted within individual worksheets, it is assumed that movements of bulk products (for example, grain or fertilizer) would be handled through elevators or storage facilities. It was also assumed that liquid commodities transferred between modes would require tank storage. Additional costs are incurred at both river and inland locations if shipments remain in storage past the free-time period allocated by the facilities involved. Storage charges are usually assessed on a monthly basis.

Loading and Unloading Costs

Because loading and unloading costs are not usually documented by shippers and receivers, they are particularly difficult to obtain.[30] Moreover, these costs can vary considerably across firms. In an attempt to provide the best possible estimates of these costs, we use available shipper and receiver information in combination with data from Corps studies performed by other researchers, as well as previous TVA studies. These data are revised to reflect 2007 conditions then averaged as required. In those cases where varying sources produced disparate estimates, we relied most heavily on shipper and receiver estimates.

Methodological Standards

Two points should be noted regarding the methodological standards applied within this study. First, the standards described above reflect essentially the same processes TVA has applied (or will apply) in developing transportation rates for other recent (or ongoing) Corps studies. Specifically, the outlined methodology was used in the 1996 and 2000 Ohio River Studies and the 1996 and 2006 Upper Mississippi Navigation Feasibility Study and was applied in the Missouri River Master Manual Review process, the Soo Locks Study and Port Allen Cutoff assessment. Thus, inter-project comparison is facilitated by this uniform approach. More importantly, recent methodological improvements enable TVA to produce transportation rate/cost materials which are, simultaneously, more complete and more reliable than the transportation data TVA (or other agency) has produced for similar studies in the past. Each Rate study for each District of the USACOE is integrated into a series of data bases for quick accessibility and data manipulation.

[30] Loading and unloading costs are often considered a part of through-put or production costs.

VII Savings to Users

Based on the third quarter 2007 cost levels, those users of the EDM section of the Ohio River represented by the 205 sampled movements spent, on average, about $6.28 per ton over the best possible land routing. Savings for each of the eight commodity groupings identified for this analysis are summarized below.[31]

Group	*Commodities*	*Average Per-Ton NED Savings*	*Average Per-Ton RED <60 Day Spending*	*Average Per-Ton RED 60-180 Day Spending*
1	Coal	$5.13	$4.87	$4.96
2	Petroleum Fuel Products	$37.46	$18.73	$18.47
3	Aggregates	$8.40	$2.64	$2.69
4	Food and Processed Food Prod.	$28.53	$15.75	$0.00
5	Chemicals	$54.76	$55.40	$55.40
6	Non-Metallic Minerals	$17.43	-$11.91	-$16.16
7	Ferrous Ores, I&S Products	$32.29	$12.22	$17.04
8	Manufactured Goods	$57.40	$30.39	$33.47
AVERAGE ALL COMMODITIES		$9.59	$6.28	$6.94

During the preparation of this study, we observed that, in some instances, the selection of barge transportation is more costly than the land alternative. There are any number of scenarios which work individually or in combination to explain this phenomenon. First, in some cases, the sample may occasionally capture a transitory use of barge which occurs when pipelines lack capacity or when rail cars are in short supply. That is to say, for some particular shipper/receiver barge is only the mode of choice when other transportation markets are unusually active. Secondly, long term contracts and large capital investments may lead to discontinuities in the relationship between relative rates and modal choice. In many areas barge shippers and receivers are captive to the navigation mode because they lack the industrial footprint to build the

[31] All rates and rate differentials are weighted average.

infrastructure for a modal change. While this can be a short-run situation, it may, nonetheless help to explain what appears to be perverse behavior. Next, the analysis superimposes 2004 transport market conditions on set of 2007 modal choice decisions. In the vast majority of cases, this dichotomy is of little import. However, in a few cases, transportation rates may have changed sufficiently, so that in 2007, barge would no longer have been the mode of choice. Finally, regulatory constraints on the new construction of coal and hazardous materials handling facilities may preclude the development of facilities necessary for some shippers to take advantage of changes in the vector of available transportation rates.

EXHIBIT 1

SAMPLE RATE WORKSHEET

TRANSPORTATION RATE ANALYSIS

Ref No.: 41 (Page 1)

Commodity	Coal		
WCSC Gp.	32100	Tonnage	110,781
River Origin	42007502	Riv. Dest	43231702
Origin Port Code	BIG SANDY RIVER MILE 7	Dest Port Code	ALLEGHENY RIVER MILE 31 (PORT OF PIT
Origin WW Mile	BS 7	Dest WW Mile	ALLEG 31
Off-River Orig.	Radius 75 Miles	Off-River Dest	Radius 15 Miles

WATER ROUTE

	Mode	Miles	Cost	
(1) Loading at origin			1.35	
(2) Charge to transfer point				
(3) Transfer charge				
(4) Charge to river	TRUCK	75	8.88	a/
(5) Handling at river origin			1.45	b/
(6) Line haul charge	BARGE	355	10.60	c/
(7) Handling at river destination			1.50	
(8) Charge ex river	TRUCK	15	5.04	d/
(9) Unloading at destination			0.75	
(10) Other				
(11) Total		445	29.57	

LAND ROUTE

	Mode	Miles	Cost	
(1) Loading at origin			1.35	
(2) Charge to transfer point	TRUCK	80	9.36	a/
(3) Transfer charge			1.45	b/
(4) Line-haul charge	RAIL	406	30.66	e/
(5) Transfer charge			1.50	
(6) Final leg to destination	TRUCK	15	5.04	d/
(7) Unloading at destination			0.75	
(8) Other				
(9) Total		501	50.11	

AUTHORITIES FOR CHARGES AND EXPLANATION OF REFERENCE MARKS

a/ Coal permited truck rate $75 per hour plus fuel surcharge
b/ Supplied by dock
c/ Published spot barge rate average 3rd & 4th quarter 2007
d/ Truck rate $65 per hour plus fuel surcharge
e/ STB Waybill 2006 indexed to 3rd quarter 2007 plus fuel surcharge NS multi car

TRANSPORTATION RATE ANALYSIS

Ref No.: 41 (Page 2)

Commodity	Coal		
WCSC Gp.	32100	Tonnage	110,781
River Origin	42007502	Riv. Dest	43231702
Origin Port Code	BIG SANDY RIVER MILE 7	Dest Port Code	ALLEGHENY RIVER MILE 31 (P
Origin WW Mile	BS 7	Dest WW Mile	ALLEG 31
Off-River Orig.	Radius 75 Miles	Off-River Dest	Radius 15 Miles

ALTERNATE ROUTE (1)

	Mode	Miles	Cost
(1) Loading at origin			1.35
(2) Charge to transfer point			
(3) Transfer charge			
(4) Charge to river	TRUCK	75	8.88 a/
(5) Handing at river origin			1.45 b/
(6) Line haul charge	BARGE	280	8.25 c/
(7) Handling at river destination			1.50
(8) Charge ex river	TRUCK	82	12.88 d/
(9) Unloading at destination			0.75
(10) Other			
(11) Total		437	35.06

ALTERNATE ROUTE (2)

	Mode	Miles	Cost
(1) Loading at origin			e/
(2) Charge to transfer point			
(3) Transfer charge			
(4) Charge to river			
(5) Handing at river origin			
(6) Line haul charge			
(7) Handling at river destination			
(8) Charge ex river			
(9) Unloading at destination			
(10) Other			
(11) Total		0	0.00

SUMMARY

	Cost
(1) Water Route	29.57
(2) Land Route	50.11
(3) Alternate Route (1)	35.06
(4) Alternate Route (2)	0.00

AUTHORITIES FOR CHARGES AND EXPLANATION OF REFERENCE MARKS

a/ Coal permited truck rate $75 per hour plus fuel surcharge
b/ Supplied by dock
c/ Published spot barge rate average 3rd & 4th quarter 2007
d/ Truck rate $65 per hour plus fuel surcharge
e/ Customer re-source; dock would close

SUPPLEMENTAL DATA

		Ref. No.:	41	(Page 3)
Commodity:	Coal	Tonnage:	110,781	
River Origin	BIG SANDY RIVE	River Dest.:	ALLEGHENY RIVE	

B. Cost Computation for Land Route Factor from Riverport to Off-River Destination (Section I):

Location	Tonnage	Miles	Truck Rate	Rail Trf Rate	Est Rail Rate	Charges

Average Rate: $0.00 Average Miles: 0

AUTHORITIES FOR CHARGES AND EXPLANATION OF REFERENCE MARKS

EXHIBIT 2.

EMPTY RETURN RATIOS, HORSEPOWER AND TOW SIZE BY RIVER SEGMENT

MTY_RET (% EMPTY UP AND DOWN) DATABASE FOR BARGE MODEL 10:15 Monday, June 30, 2008 1

Obs	RIVNUM	RIVER	MTYUP	MTYDOWN
1	1	ALABAMA	0.90	0.90
2	2	ALLEGHENY	0.90	0.90
3	3	A/C/F/	1.00	1.00
4	4	ARKANSAS	0.20	0.20
5	5	ATCHAFALAYA, N	0.97	0.50
6	6	ATCHAFALAYA, S	0.97	0.50
7	7	BIG SANDY	1.00	1.00
8	8	BLACK/OUCHITA	0.90	0.90
9	9	BLACK-WARRIOR	0.27	0.80
10	10	CUMBERLAND	0.97	0.28
11	11	GIW(E) NOLA-MOBILE	0.40	0.40
12	12	GIW(E) MOBILE-ACF JCT	0.40	0.40
13	13	GIW(W) HARVEY LOCK-MORGAN CITY	0.65	0.90
14	14	GIW(W) MORGAN CITY-BROWNSVILLE	0.35	0.35
15	15	GREEN	0.58	0.70
16	16	HOU S/C	0.28	0.42
17	17	IHNC	0.40	0.40
18	18	ILL	0.40	0.27
19	19	KAN	0.58	0.96
20	2	LM 1-98	0.50	0.50
21	21	LM 99-229	0.25	0.50
22	22	LM 230-954	0.25	0.50
23	23	MO LOWR	0.10	0.25
24	24	MO MID	0.10	0.15
25	25	MO UPR	0.10	0.10
26	26	MOB RIV	0.30	0.90
27	27	MOB S/C	0.50	0.50
28	28	MON	0.39	0.81
29	29	MCPA	0.20	0.60
30	30	MRGO	1.00	1.00
31	31	OHIO	0.27	0.28
32	32	OLD	0.90	0.95
33	33	RED	0.85	0.85
34	34	TN LOWER	0.51	0.26
35	35	TN UPPER	0.68	0.35
36	36	TENN-TOM	0.30	0.99
37	37	TOMB	0.30	0.90
38	38	UM 0-185	0.18	0.37

MTY_RET (% EMPTY UP AND DOWN) DATABASE FOR BARGE MODEL 10:15 Monday, June 30, 2008 2

Obs	RIVNUM	RIVER	MTYUP	MTYDOWN
39	39	UM 186-865	0.18	0.37
40	40	YAZOO	0.20	0.97
41	41	OTHER	0.37	0.37
42	42	ALGIERS CANAL	0.90	0.42
43	43	COLUMBIA	0.25	0.70
44	44	SNAKE	0.45	0.55

GEN TOW DATABASE FOR BARGE MODEL 10:22 Monday, June 30, 2008 1

Obs	SEG_NO	RIVER	GTOW_HP	GTOW_CLS	GTOW_SIZ
1	1	ALABAMA	1207	1	2
2	2	ALLEGHENY	1340	1	2
3	3	A/C/F/	900	0.9	1
4	4	ARKANSAS	2947	5	8
5	5	ATCHAFALAYA, NORTH	1412	2	2
6	6	ATCHAFALAYA, SOUTH	1181	1	1
7	7	BIG SANDY	1323	1	4
8	8	BLACK/OUCHITA	1513	2	2
9	9	BLACK-WARRIOR	1888	3	6
10	10	CUMBERLAND	2541	4	8
11	11	GIW(E) NOLA-MOBILE	1286	1	4
12	12	GIW(E) MOBILE-ACF JCT	1267	1	3
13	13	GIW(W) HARVEY LOCK-MORGAN CITY	1147	1	3
14	14	GIW(W) MORGAN CITY-BROWNSVILLE	1363	2	3
15	15	GREEN	1736	3	4
16	16	IHNC (NEW ORLEANS)	1050	1	4
17	17	ILLINOIS	2529	4	7
18	18	KANAWHA	2194	4	6
19	19	LOWER MISS	4750	8	25
20	20	MISS RIV-GULF OUTLET	925	0.9	2
21	21	MISSOURI KAN CITY-SOUTH	1800	3	4
22	22	MISSOURI KAN CITY-OMAHA	1100	1	2
23	23	MISSOURI OMAHA-S CITY	1800	3	2
24	24	MOBILE RIVER	1888	3	5
25	25	MONONGAHELA	1732	3	5
26	26	MOR CITY-PT ALLEN ROUTE	1366	2	4
27	27	OHIO	2682	5	11
28	28	OLD	1513	2	4
29	29	RED	1666	3	4
30	30	TENNESSEE, LOWER	2580	4	10
31	31	TENNESSEE, UPPER	2405	4	6
32	32	TENNESSEE-TOMBIGBEE	3280	6	6
33	33	TOMBIGBEE RIVER	1888	3	6
34	34	UPPER MISS CAIRO-ST LOUIS	4696	8	20
35	35	UPPER MISS ST LOUIS-MPLS	3971	7	10
36	36	YAZOO	2043	3	3
37	37	OTHER	2000	3	2
38	38	ILL RIV ABOVE MI 291(L'PORT)	2529	4	4

GEN TOW DATABASE FOR BARGE MODEL 10:22 Monday, June 30, 2008 2

Obs	SEG_NO	RIVER	GTOW_HP	GTOW_CLS	GTOW_SIZ
39	39	ALGIERS CANAL	1350	2	3
40	40	COLUMBIA	3170	5	3
41	41	SNAKE	3017	5	3

EXHIBIT 3.

PERCENTAGE OF WATERWAY FREIGHT BUREAU TARIFF NO. 7 FOR THE MOVEMENT OF GRAIN

Waterway Segment	*2007 Percent of Tariff*	*2003-2007 Average Percent of Tariff*
Upper Mississippi River	458%	364%
Upper Mississippi River (243-634)	423%	330%
Illinois River	398%	319%
Middle Mississippi River (0-243)	338%	278%
Upper Ohio River	361%	286%
Lower Ohio River	361%	287%
Lower Mississippi River (Memphis)	317%	256%
Lower Mississippi River (NOLA)	424%	344%

Source: Illinois Department of Transportation / U.S. Department of Agriculture

Attachment 6: Procedure to update economics to Oct 2013 price level

1.0 General: The evaluation documented in the draft Feasibility Report used costs and benefits expressed at Oct 2009 price levels. The analysis concluded that the national economic development (NED) plan was the construction of new 600’ x 110’ sized locks at Emsworth, Dashields, and Montgomery, and the retention of the existing 600’ x 110’ locks as auxiliaries. Based on consideration of all pertinent criteria, this plan was also selected as the tentatively recommended plan. The costs of the plan were then developed to greater detail using M-CACES procedures with the initial results expressed at October 2010 price levels. The economics of the plan were also updated to October 2010 price levels and provided on a fact sheet attached to the report submitted to the division office in April of 2011. The costs, benefits, and economics of the recommended plan have since been updated to October 2013 price levels with the results attached to this report, which will be submitted to USACE headquarters. The procedure for updating the economics is summarized in this paper and is the same as used in the October 2010 and all subsequent updates.

2.0 Procedure: Construction and related costs are regularly updated to current price levels using indices based on civil works construction cost index systems (CWCCIS) numbers. However, benefits are not indexed since there is no proven method that produces results that can be validated. For this effort the update was accomplished by updating the transportation costs for both the water routed mode of transportation and the least cost all overland mode of transportation. The difference between the updated water routed costs and the all overland routed transportation costs are the updated transportation benefits. These updated benefits, expressed in terms of savings per ton, were used to update the transportation benefits of the recommended Upper Ohio River navigation project. The benefits of the recommended project in terms of reduced maintenance and repair costs were computed in a similar manner but using construction cost indices rather than transportation cost indices as a basis for the update. The updates are discussed in greater detail in the following paragraphs.

3.0 Categories of benefits: The benefits of the recommended project compared to the baseline (“without”) project condition are: 1) reduced transportation costs; and 2) reduced maintenance and repair costs. The categories are listed in Table 1 along with pertinent data used in the updates, which are discussed below.

Table 1: Factors of change from 2009 to 2012

	Category	Basis for update	Oct 2009	Oct 2013	Index
1	Transportation	Change in waterways savings per ton	$13.38	$16.38	1.22
2	Maintenance and repair	Change in total project costs	$1,479,000	$2,143,687	1.45

3.1 Transportation savings: The principle benefit of inland navigation projects and/or improvements is the lower costs of water routed transportation compared to the least cost all overland routed mode of transportation. The costs of both transportation routings along with their accessorial charges were updated to Oct 2013 price levels using BLS based indices. This was accomplished by taking the 1,552 shipments in the sample that was rated in 2010 and updating the components costs of each shipment (loading, etc) by the appropriate BLS based index for both the water-routed shipping alternative and the least cost all-overland shipping alternative. The detailed commodity shipments (such as gasoline) were then aggregated into nine general commodity groupings, such as petroleum products, which include gasoline and other detailed types of commodities. The transportation costs were then weighted by the tonnage of the commodity group in the sample to compute a tonnage weighted savings per ton for the sample. The transportation costs were then reweighted based on current total tonnage (sampled and unsampled) as expressed as the 2008 to 2012 average for each commodity group to compute a tonnage weighted savings per ton for all shipments. The savings per ton were then adjusted downward by 14 percent based on a validation test.

This procedure was used to update the national database of transportation costs for seven different watersheds, including the Ohio River Basin, with the results listed in Table 2. The procedure was documented and underwent a national QA-level of review for an identical update performed in 2012 and found to be adequate. Since the transportation benefits are the product of the savings per ton times the number of tons, and the number of tons was not changed, then updated benefits could be computed by multiplying the updated savings per ton by the number of tons at the project. To simplify matters while achieving the same results, a savings per ton index was computed by dividing the updated ($Oct 13) savings per ton by the savings per ton used in the analysis ($ Oct 2009). The values and resulting index are listed in both Tables 1 and 2; the estimated change in savings per ton from Oct 2009 to Oct 2013 was 22%. The savings per ton index of 1.22 was applied to the transportation costs and savings at Oct 2009 price levels to update the transportation savings to Oct 2013 price levels.

Table 2: Savings per ton - tonnage weighted

	Basin	Original price level	Original	2009 Feasibility Report	SCC-13	% change from 09 to 13
1	Arkansas	Oct-03	$ 10.19		$ 14.23	
2	Columbia-snake	Oct-10	$ 10.36		$ 11.68	
3	GIWW-W	Dec-10	$ 28.94		$ 31.96	
4	Great Lakes	Dec-08	$ 15.84		$ 14.37	
5	Ohio	Oct-10	$ 13.46	$ 13.38	$ 16.38	1.224
6	Red	Oct-00	$ 1.35		$ 2.90	
7	Upper Miss	Oct-06	$ 21.46		$ 27.90	

3.2 Reduced repair and maintenance costs: The benefits of reduced maintenance and repair costs were computed in a similar manner but using construction cost indices rather than transportation cost indices as a basis for the update. Since repairs and maintenance often involve construction or reconstruction, it was assumed that repair and maintenance costs would change at the same rate as the construction costs of the recommended project. Therefore a construction index was computed by dividing the Oct 2013 M-Caces cost by the Oct 2009 venture level costs used in the analysis. The construction index was then applied to the repair and maintenance costs in the "without" condition and for the recommended project to obtain updated repair and maintenance costs. The difference or avoided repair/maintenance are credited as benefits of the recommended plan, provided the costs are lower for the recommended plan. The values and resulting index are listed in Table 1; the change in total project cost from 2009 to 2013 was 45%.

4.0 Application: Transportation costs and maintenance/repair costs are computed for a wide variety of classifications to allow the computed values to be reviewed and verified at the most detailed levels. Transportation costs are computed within the model according to the following: normal water-routed transportation costs; water routed transportation costs given a disruption in lock operations (possibly lower due to less traffic); tow delay costs under the normal and disruption scenarios (typically higher during disruptions); normal overland routed costs; and overland costs when traffic increases due to disruptions on the river (normally higher due to more traffic and increased congestion). Maintenance and repair costs are likewise calculated at more detailed levels which include: maintenance costs during scheduled repairs; repair costs for unscheduled events; normal operation and maintenance costs; and the construction and related costs for constructing/reconstructing the projects. All costs for the different categories of transportation were updated using the transportation index while all categories of repair/maintenance work were updated using the construction index, with the exception of normal O&M costs which were not changed based on feedback from programming people in the Pittsburgh District.

5.0 Results: The economics at October 2009 and 2013 price levels are listed in Table 3 at discount rates in effect at the time (4 1/8% in 2009 and 3 ½% in 2013) and at 7%. Because the increase in costs was greater than the increase in benefits between 2009 and 2013, the economics of the project diminished. For example, the BCR of the recommended project in 2009 at 7% was 1.4 while in 2013 it was 1.2.

Table 3: Economics of Upper Ohio project updated to Oct 2013 price level using report format

	Screening		M-Caces	
	4.125%	7.000%	3.500%	7.000%
Without				
Costs	$ -	$ -	$ -	$ -
Benefits	$ 249.6	$ 312.6	$ 311.7	$ 438.9

Recommended plan				
Costs	$ 64.9	$ 106.1	$ 90.1	$ 182.4
Benefits	$ 433.5	$ 462.2	$ 569.4	$ 650.2
Incremental values				
Costs	$ 64.9	$ 106.1	$ 90.1	$ 182.4
Benefits	$ 183.9	$ 149.6	$ 257.7	$ 211.2
Net benefits	$ 119.0	$ 43.5	$ 167.5	$ 28.8
BCR	2.8	1.4	2.9	1.2

The current economics expressed as a benefit to cost ratio (BCR) is listed in Table 5 along with earlier updates dating back to the completion of the Feasibility Study. The BCRs vary within a fairly narrow range with the variation due to the discount rate used in the economics, the increase in the magnitude of the cost of the project over time, and changes in the benefits (not shown below but discussed previously).

Table 5: BCR changes over time since 2009

	Price Level (Oct)	Cost	Discount rate	BCR	BCR @ 7%	Comment
1	2009	$ 1,479,000,000.00	4.125%	2.8	1.4	Venture level used in study
2	2010	$ 1,923,641,000.00	4.000%	2.4	1.2	M-CACES
3	2012	$ 2,104,736,000.00	4.000%	2.3	1.1	M-CACES
4	2012	$ 2,104,736,000.00	3.750%	2.5	1.1	M-CACES
5	2013	$ 2,143,687,145.65	3.500%	2.9	1.2	M-CACES – certified by Walla Walla

Attachment 7: Economic Update and Analysis

Upper Ohio – Supplementary document to Feasibility Report

19 Feb 2014

Executive Summary

The draft Feasibility Report for the Upper Ohio River Navigation System was completed in 2010 based on data and analysis developed between 2003 and 2009. The passage of time has raised concerns that circumstances may have changed to the extent that the economics contained in the report are no longer valid. The results of investigations regarding this matter are contained in this paper. The conclusion is that the economics in the report remain valid and that a reanalysis of a limited and/or extensive nature is not warranted or necessary.

The major concern is that the benefits may be optimistic given the reduction in traffic that has occurred over the past five years. The traffic, which is primarily coal moving to electric generating plants, has declined due to the development of shale gas fields in the Appalachian basin. Gas is more environmentally friendly than coal, is currently cheaper than coal, and has supplanted coal to a certain extent in the generation of electricity. To determine if the downward trend would continue, the study team reviewed current forecasts by the Department of Energy and a separate set of forecasts developed by a consulting firm that specializes in the electricity market. The findings of both reports were that coal, particularly Northern Appalachian coal, will continue to be a major fuel in the electric generating market. The opinion of the study team is that the forecasts used in the study are still valid and that the benefits in terms of the savings of waterway traffic to shippers are also valid.

Tables

Attachments

1.0 Purpose

The purpose of this paper is to provide updated data and analysis with regard to the data and analysis contained in the Upper Ohio Navigation Feasibility Report. The need for the update is the long period of time that has elapsed between the original data collection and analysis and the current date. The long period was due to the number and length of the reviews and the additional analysis required as a result of the reviews. The updated materials are provided in this supplementary paper rather than revising the Feasibility Report to save time and money as well as to provide an efficient template for possible future updates. This is "Smart Planning" in that it provides the materials that are important and in an efficient and cost effective manner.

2.0 Traffic

Historic traffic in the Feasibility Report extended up to the year 2008; it is currently the year 2014 so four to five additional years (depending on source of data) of historic traffic data are available for display and analysis. In addition, market conditions have changed in the past five years, particularly with regard to energy, i.e., coal and natural gas (from fracking) which may affect future traffic levels and therefore project economics. Recent changes in market conditions are discussed in this update along with their affect on long term traffic trends. The data confirms a recent decline in traffic, but a literature search indicates that the long-term projections are consistent with current DOE and an AE firm's expectations. Therefore a reanalysis does not appear warranted or necessary.

2.1 Historic traffic

Historic and projected traffic are presented in the Feasibility Report in Section 5 of Appendix B: Project Economics. Truncated versions of the table are provided below, with the truncation consisting of listing data at five year rather than one year intervals up through 2005, followed by yearly values through 2012. Current traffic levels are at the low points of the cycle.

2.1.1 Tonnage

Table 1: Historic tonnage at EDM, Ohio River, and Ohio River including tribs (thousands of tons)					
	Emsworth	Dashields	Montgomery	Ohio River Mainstem	Ohio River System
1970	24,076	21,739	19,697	129,585	-
1975	22,094	22,348	20,759	140,058	-
1980	21,202	22,178	21,799	155,907	-
1985	17,246	17,912	19,012	177,484	-
1990	23,068	24,025	25,447	224,747	260,000
1995	23,075	24,551	25,515	234,064	267,600
2000	22,335	23,335	25,974	236,300	274,400
2005	21,178	22,024	23,142	249,212	280,142
2006	21,425	22,032	20,756	241,535	270,700
2007	19,399	20,171	19,310	230,845	260,200
2008	21,273	21,788	20,813	230,812	259,225
2009	15,687	16,477	16,390	207,199	229,539
2010	15,326	16,365	18,237	220,594	245,169
2011	14,888	15,958	17,389	215,077	239,599
2012	16,520	17,897	18,756	-	-

Table 5-3 from the Feasibility Report is listed below followed by the same a table in the same format with 2012 numbers. Tonnage in 2012 is 4 million less than in 2006 with the decrease almost entirely attributable to reduced transportation of coal.

Table 2: "TABLE 5-3 – Historic EDM Reach Traffic by Commodity Group, 1990-2006"

(Thousand Tons)

	1990	1995	2000	2004	2005	2006	Annual % Change
Coal & Coke	17,929	19,276	18,770	16,027	19,321	18,173	0.08
Petroleum Fuels	1,955	1,361	781	396	478	427	-9.1
Crude Petroleum	1	0	0	0	12	7	12.5
Aggregates	3,614	3,124	3,759	2,932	2,515	2,420	-2.5
Grains	10	8	2	0	0	0	-
Chemicals	1,009	1,030	977	796	773	824	-1.3
Ores & Minerals	616	803	988	1,406	1,161	977	2.9
Iron & Steel	844	1,233	1,201	1,254	1,097	1,005	1.1
All Other	1,492	1,373	1,529	1,153	990	967	-2.7
Total	27,469	28,207	28,007	23,964	26,346	24,801	-0.6

SOURCE: COE Waterborne Commerce Statistics

Table 5.3 - Historic EDM Reach Traffic by Commodity Group, 2012 (Tons in Thousands)	
	Ktons
Coal	13,150
Petroleum	1,003
Crude Petroleum	-
Aggregates	3,722
Grains	5
Chemicals	604
Ores/Minerals	827
Iron/Steel	642
Others	762
	20,715
Source: COE Waterborne Commerce Statistics	

The original and updated Tables 5-4 are listed below. The 2012 numbers show the decrease in tonnage through the projects was largely due to less down bound and outbound movements of coal. The down bound coal largely originated on the Monongahela River and was destined for electric generating plants on the mid-Ohio River.

Table 3: "TABLE 5-4 – EDM Reach Traffic by Direction of Movement, 2006 "

(Thousand Tons)

	Inbound	Outbound	Internal	Thru Traffic Upbound	Thru Traffic Downbund	Total
Coal & Coke	1,399	2,558	361	7,060	6,795	18,173
Petroleum Fuels	189	138	0	66	34	427
Crude Petroleum	0	0	0	7	0	7
Aggregates	1,376	318	534	135	56	2,420
Grains	0	0	0	0	0	0
Chemicals	416	10	0	368	30	824
Ores & Minerals	618	1	68	276	14	977
Iron & Steel	172	163	0	196	475	1,005
All Other	460	21	1	392	94	967
Total	4,631	3,210	964	8,499	7,497	24,801
SOURCE: COE Waterborne Commerce Statistics						

Table 5.4 - EDM Reach Traffic by Direction of Movement, 2012 (Tons in Thousands)						
				Thru Traffic		
	Inbound	Outbound	Internal	Upbound	Downbound	Total
Coal	1,321	678		7,199	3952	13,150
Petroleum	525	233	59	92	94	1,003
Crude Petroleum						
Aggregates	1,839	823	426	596	37	3,721
Grains				5		5
Chemicals	235	2		340	28	605
Ores/Minerals	675	4		148		827
Iron/Steel	161	195		126	160	642
Others	551	10		109	91	761
	5,307	1,945	485	8,615	4,362	20,714
Source: COE Waterborne Commerce Statistics						

The original and updated Tables 5-5 are listed below. Compared to 2006 data, the lower 2012 shipments from Charleston and Pittsburgh-New Castle account for most of the decrease in traffic. Most of the coal from the Charleston area is coking coal which decreased due to poor market conditions following the recession that began in 2008 while the Pittsburgh traffic is northern Appalachian coal which declined due the closure of coal-fired electric generating plants.

Table 4: "TABLE 5-5 – EDM Reach, Shipments and Receipts by Economic Area, 2006"

(Tons)

	Shipping/Receiving EA	Shipments	Receipts
11	Atlanta-Sandy Springs-Gainesville, GA-AL	0	39,311
15	Baton Rouge-Pierre Part, LA	332,271	2,167
16	Beaumont-Port Arthur, TX	41,564	0
19	Birmingham-Hoover-Cullman, AL	1,600	15,850
29	Charleston, WV	5,232,986	670,651
32	Chicago-Naperville-Michigan City, IL-IN-WI	9,944	16,982
33	Cincinnati-Middletown-Wilmington, OH-KY-IN	94,898	748,560
34	Clarksburg, WV + Morgantown, WV	1,353,048	942,236
35	Cleveland-Akron-Elyria, OH	131,659	0
40	Columbus-Marion-Chillicothe, OH	2,204,141	944,497
41	Corpus Christi-Kingsville, TX	3,336	0
54	Evansville, IN-KY	4,134	52,371
59	Fort Smith, AR-OK	0	20,561
75	Houston-Baytown-Huntsville, TX	434,451	135,565
76	Huntsville-Decatur, AL	31,437	0
80	Jackson-Yazoo City, MS	20,052	0
82	Jonesboro, AR	77,549	33,630
88	Knoxville-Sevierville-La Follette, TN	1,553	0
90	Lafayette-Acadiana, LA	468,577	0
91	Lake Charles-Jennings, LA	108,638	0
96	Little Rock-North Little Rock-Pine Bluff, AR	3,975	1,620
98	Louisville-Elizabethtown-Scottsburg, KY-IN	130,082	1,224,443
104	McAllen-Edinburg-Pharr, TX	0	69,150
105	Memphis, TN-MS-AR	7,133	33,001
109	Minneapolis-St. Paul-St. Cloud, MN-WI	0	3,187
112	Mobile-Daphne-Fairhope, AL	4,737	0
116	Nashville-Davidson--Murfreesboro--Columbia, TN	2,303	882,696
117	New Orleans-Metairie-Bogalusa, LA	687,462	199,088
122	Paducah, KY-IL	8,045	473,442
126	Peoria-Canton, IL	3,806	14,319
129	Pittsburgh-New Castle, PA	13,360,933	18,008,796
153	Shreveport-Bossier City-Minden, LA	1,244	0
160	St. Louis-St. Charles-Farmington, MO-IL	37,048	183,050
170	Tulsa-Bartlesville, OK	0	81,035
171	Tupelo, MS	2,477	4,875
	TOTALS	24,801,083	24,801,083

SOURCE: COE Waterborne Commerce Statistics

Table 5.5 - EDM Reach, Shipments and Receipts by Economic Area, 2012			
	2012		
	Shipping/Receiving EA	Shipments	Receipts
15	Baton Rouge-Pierre Part, LA	210,485	-
16	Beaumont-Port Arthur, TX	41,756	2,802
29	Charleston, WV	3,612,099	511,748
32	Chicago-Naperville-Michigan City, IL-IN-WI	14,075	-
33	Cincinnati-Middletown-Wilmington, OH-KY-IN	583,327	1,491,745
34	Clarksburg, WV + Morgantown, WV	873,391	1,166,308
35	Cleveland-Akron-Elyria, OH	425,074	213
40	Columbus-Marion-Chillicothe, OH	1,672,046	118,403
54	Evansville, IN-KY	182,239	3,239
60	Fort Wayne-Huntington-Auburn, IN	3,484	-
75	Houston-Baytown-Huntsville, TX	200,518	134,289
76	Huntsville-Decatur, AL	42,384	89,334
80	Jackson-Yazoo City, MS	32,851	-
82	Jonesboro, AR	62,253	22,488
90	Lafayette-Acadiana, LA	259,159	1,666
91	Lake Charles-Jennings, LA	98,214	-
96	Little Rock-North Little Rock-Pine Bluff, AR	1,600	43,229
98	Louisville-Elizabethtown-Scottsburg, KY-IN	506,329	1,101,203
104	McAllen-Edinburg-Pharr, TX	1,636	31,165
109	Minneapolis-St. Paul-St. Cloud, MN-WI	3,014	3,335
112	Mobile-Daphne-Fairhope, AL	9,307	-
117	New Orleans-Metairie-Bogalusa, LA	408,964	500,303
122	Paducah, KY-IL	129,803	62,551
123	Panama City-Lynn Haven, FL	11,038	-
126	Peoria-Canton, IL	4,588	12,132
129	Pittsburgh-New Castle, PA	10,790,848	15,089,135
160	St. Louis-St. Charles-Farmington, MO-IL	534,182	246,896
43	Davenport-Moline-Rock Island, IA-IL	-	2,852
105	Memphis, TN-MS-AR	-	38,160
170	Tulsa-Bartlesville, OK	-	13,854
171	Tupelo, MS	-	27,614
		20,714,664	20,714,664
Source: COE Waterborne Commerce Statistics			

The original and updated Tables 5-6 and 5-7 also show decreased tonnage since 2006, with the decrease primarily due to reduced down bound shipments of coal. This is another way of looking at the data but does not lead to any further insights.

Table 5: "TABLE 5-6 – Upper Ohio Traffic by Direction of Movement, 2006"

(Thousand Tons)

	Emsworth		Dashields		Montgomery		EDM Reach	
	Upbound	Downbound	Upbound	Downbound	Upbound	Downbund	Upbound	Downbound
Coal & Coke	8,929	7,439	8,929	7,439	7,816	7,983	9,187	8,986
Petroleum Fuels	212	48	180	70	255	77	350	77
Crude Petroleum	7	0	7	0	7	0	7	0
Aggregates	667	641	1,221	183	495	86	1,317	1,103
Grains	0	0	0	0	0	0	0	0
Chemicals	622	38	633	38	784	40	784	40
Ores & Minerals	471	15	512	15	894	15	894	83
Iron & Steel	258	475	258	504	368	637	368	637
All Other	644	100	651	100	851	115	853	115
Total	11,809	8,755	12,390	8,348	11,470	8,954	13,759	11,042

SOURCE: COE Waterborne Commerce Statistics

Table 6: "TABLE 5-7 – Upper Ohio Traffic by Direction of Movement, 2006"

(Percent)

	Emsworth		Dashields		Montgomery		EDM Reach	
	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound
Coal & Coke	75.6	85.0	72.1	89.1	68.1	89.2	66.8	81.4
Petroleum Fuels	1.8	0.5	1.4	0.8	2.2	0.9	2.5	0.7
Crude Petroleum	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0
Aggregates	5.6	7.3	9.9	2.2	4.3	1.0	9.6	10.0
Grains	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chemicals	5.3	0.4	5.1	0.4	6.8	0.5	5.7	0.4
Ores & Minerals	4.0	0.2	4.1	0.2	7.8	0.2	6.5	0.8
Iron & Steel	2.2	5.4	2.1	6.0	3.2	7.1	2.7	5.8
All Other	5.4	1.1	5.3	1.2	7.4	1.3	6.2	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

SOURCE: COE Waterborne Commerce Statistics

Table 5.6 - Upper Ohio Traffic by Direction of Movements, 2012 (Tons in Thousands)

	Emsworth		Dashields		Montgomery		EDM Reach	
	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound
Coal	7,846	4487	7,846	4487	7,924	4394	8161	4989
Petroleum	182	116	617	328	617	311	633	370
Crude Petroleum	0	-	0	-	0	-	-	-
Aggregates	1,499	224	2,145	52	1,610	653	2241	1481
Grains	5		5		5	-	5	-
Chemicals	419	30	419	30	574	30	574	30
Ores/Minerals	271	3	271	3	822	4	822	4
Iron/Steel	154	160	154	214	287	354	287	354
Others	472	93	492	102	660	101	660	102
	10,848	5,113	11,949	5,216	12,499	5,847	13,383	7,330
		15,961		17,165		18,346		20,713

Source: COE Waterborne Commerce Statistics

Table 5.7 - Upper Ohio Traffic by Direction of Movement, 2012 (Percent)

	Emsworth		Dashields		Montgomery		EDM Reach	
	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound	Upbound	Downbound
Coal	72.3%	87.8%	65.7%	86.0%	63.4%	75.1%	61.0%	68.1%
Petroleum	1.7%	2.3%	5.2%	6.3%	4.9%	5.3%	4.7%	5.0%
Crude Petroleum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aggregates	13.8%	4.4%	18.0%	1.0%	12.9%	11.2%	16.7%	20.2%
Grains	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Chemicals	3.9%	0.6%	3.5%	0.6%	4.6%	0.5%	4.3%	0.4%
Ores/Minerals	2.5%	0.1%	2.3%	0.1%	6.6%	0.1%	6.1%	0.1%
Iron/Steel	1.4%	3.1%	1.3%	4.1%	2.3%	6.1%	2.1%	4.8%
Others	4.4%	1.8%	4.1%	2.0%	5.3%	1.7%	4.9%	1.4%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: COE Waterborne Commerce Statistics

The original and updated Tables 5-8 which show the commonality of Upper Ohio traffic are listed below. There appears to be little change over time.

Table 7: "TABLE 5-8 – Commonality of 2006 Traffic With Other Selected Projects"

(Percent)

Project	Emsworth traffic thru	Other project traffic thru Emsworth	Dashields traffic thru	Other project traffic thru Dashields	Montgomery traffic thru	Other project traffic thru
Emsworth	100%	100%	97%	97%	85%	85%
Dashields	97%	97%	100%	100%	87%	86%
Montgomery	85%	85%	86%	87%	100%	100%
Allegheny L/D 2	5%	56%	5%	56%	3%	35%
Monongahela L/D 2	86%	92%	83%	89%	75%	80%
Monongahela L/D 4	44%	71%	41%	66%	33%	53%
Gray's Landing	9%	40%	7%	29%	3%	12%
Winfield	8%	8%	7%	8%	8%	8%
Marmet	7%	9%	7%	9%	7%	9%
Byrd	55%	20%	55%	20%	62%	22%
Greenup	38%	11%	38%	11%	44%	13%
McAlpine	18%	7%	19%	7%	23%	8%
Myers	17%	5%	18%	5%	22%	6%
Kentucky/Barkley	7%	3%	7%	3%	7%	4%
L/D 52	11%	2%	11%	2%	15%	3%

SOURCE: COE Waterborne Commerce Statistics

Table 5.8 - Commonality of Traffic With Other Selected Projects, 2012 (Percent)

Project	Emsworth traffic thru	Other Project traffic thru Emsworth	Dashields traffic thru	Other Project traffic thru Dashields	Montgomery traffic thru	Other Project traffic thru Montogmery
Emsworth	100%	100%	97%	97%	85%	85%
Dashields	97%	97%	100%	100%	87%	86%
Montgomery	85%	85%	86%	87%	100%	100%
Allegheny L/D 2	5%	56%	5%	56%	3%	35%
Monongahela L/D 2	86%	92%	83%	89%	75%	80%
Monongahela L/D 4	44%	71%	41%	66%	33%	53%
Gray's Landing	9%	40%	7%	29%	3%	12%
Winfield	8%	8%	7%	8%	8%	8%
Marmet	7%	9%	7%	9%	7%	9%
Byrd	55%	20%	55%	20%	61%	22%
Greenup	38%	11%	38%	11%	43%	13%
McAlpine	18%	7%	19%	7%	23%	8%
Myers	17%	5%	18%	5%	22%	6%
Kentucky	7%	4%	6%	4%	7%	4%
Barkley	0%	2%	0%	2%	0%	3%
L/D 52	13%	2%	12%	2%	17%	4%

Source: COE Waterborne Commerce Statistics

The original and updated Tables 5-9 are listed below and show the monthly distribution of traffic. Monthly traffic is normally distributed nearly equal by month since most of the traffic is coal used by electric power plants to generate electricity which is used throughout the year.

Table 8: "TABLE 5-9 - Monthly Distribution of Traffic Through the Upper Ohio Projects"

(Thousand Tons)

	2007			2008			2009		
	Emsworth	Dashields	Montgomery	Emsworth	Dashields	Montgomery	Emsworth	Dashields	Montgomery
Jan	1,517	1,509	1,436	1,748	1,741	1,753	1,693	1,644	1,560
Feb	1,327	1,335	1,264	1,678	1,658	1,494	1,465	1,494	1,539
Mar	1,480	1,486	1,567	1,696	1,658	1,483	1,263	1,228	1,292
Apr	1,535	1,569	1,569	1,832	1,886	1,736	1,294	1,393	1,212
May	1,714	1,905	1,831	1,925	2,010	1,917	1,398	1,441	1,331
Jun	1,564	1,641	1,588	1,912	1,982	1,897	1,501	1,633	1,512
Jul	1,571	1,678	1,573	1,668	1,709	1,702	989	1,079	1,154
Aug	1,720	1,776	1,647	1,962	2,012	1,957	1,490	1,622	1,579
Sep	1,745	1,858	1,642	1,778	1,802	1,687	1,417	1,571	1,478
Oct	1,849	1,989	1,789	1,697	1,810	1,734	823	1,004	1,107
Nov	1,764	1,813	1,758	1,783	1,866	1,800	1,245	1,317	1,435
Dec	1,614	1,611	1,615	1,594	1,655	1,653	1,110	1,107	1,191

SOURCE: LPMS

Table 5.9 - Monthly Distribution of Traffic Through the Upper Ohio Projects (Thousand Tons)

	2010			2011			2012		
	Emsworth L&D	Dashields L&D	Montgomery L&D	Emsworth L&D	Dashields L&D	Montgomery L&D	Emsworth L&D	Dashields L&D	Montgomery L&D
Jan	987	991	1,236	1,267	1,302	1,471	964	1,107	1,159
Feb	1,225	1,279	1,427	1,116	1,080	1,224	1,261	1,197	1,295
Mar	1,241	1,228	1,461	903	918	1,119	1,215	1,253	1,298
Apr	1,478	1,548	1,543	1,016	1,112	1,226	1,149	1,287	1,290
May	972	1,110	1,399	1,458	1,536	1,542	1,178	1,227	1,293
Jun	1,350	1,511	1,674	1,574	1,727	1,814	1,282	1,363	1,446
Jul	1,475	1,590	1,713	1,492	1,640	1,741	1,356	1,526	1,529
Aug	1,378	1,487	1,628	1,345	1,446	1,660	1,444	1,562	1,675
Sep	1,343	1,492	1,588	1,339	1,515	1,578	1,315	1,441	1,552
Oct	1,427	1,515	1,694	1,249	1,336	1,469	1,704	1,872	1,963
Nov	1,198	1,324	1,476	1,026	1,148	1,269	1,817	2,062	2,190
Dec	1,246	1,284	1,406	1,098	1,193	1,314	1,847	2,003	2,060

Source: LPMS

2.1.2 Fleet

The fleet is the towing equipment described in terms of types of barges, horsepower of towboats, and barges per tow that transit a particular area. The fleet is an important determinant of the capacity of a project to process traffic, particularly when measured in barges or tons. Fleet characteristics for the most recent five years available and for an earlier time period as appeared in the Feasibility Report are listed in the tables below. There does appear to be one especially important change and that is the size of the tows, which appears to have increased. The increase in barges per tow also resulted in an increase in the number of lockage cuts required to process a tow. The data indicated that the number of tows requiring more than one lockage cut increased from about 15 percent (1/1.2) to 33 percent (1/1.5). It is thought that this reflects a decrease in small tow movements of coal off the Mon River to downstream locations of the Ohio and the maintenance of large tow movements of coking coal to the Clairton Coke Plant on the Mon. Like traffic levels, these changes may be cyclical and, in any event, capacity is not a constraint on the Upper Ohio provided that a 600' chamber is available to process traffic.

Table 9: "TABLE 4-3 - 2004-2009 Average Lock Performance Characteristics"

River/Project	No. Tows	Number of Barges Loaded	Empty	Total	Avg. Barges /Tow	Ktons	Avg. Tons /Tow	Avg. Time /Tow (min.) Delay	Process	Total	Comm. Lockages	Avg. Lock Cuts/Tow
Emsworth	3,816	14,076	8,444	22,520	5.9	19,627	5,143	41.84	68.74	110.58	4,764	1.2
Dashields	3,634	14,781	9,156	23,937	6.6	20,361	5,604	30.38	66.19	96.57	4,618	1.3
Montgomery	3,652	13,866	8,147	22,013	6.0	20,112	5,507	40.57	71.03	111.59	4,561	1.2

2008-2012 Average Lock Performance Characteristics

River/Project	No. Tows	No. Barges Loaded	Empty	Total	Avg. Barges/To	Ktons	Avg. Tons/Tow	Avg. Time/Tow (min.) Delay	Process	Total	Comm. Lockages	Avg. Lock Cuts/Tow
Emsworth	3,198	12,039	8,037	20,077	6.28	16,789	5.25	33.45	51.31	84.76	4,826	1.51
Dashields	3,203	12,826	8,729	21,555	6.73	17,724	5.53	41.12	54.23	95.35	4,549	1.42
Montgomery	3,250	12,469	8,276	20,744	6.38	18,353	5.65	31.76	60.89	92.65	4,650	1.43

2.2 Commodity markets

Changes in the energy market over the past decade have been more extensive than originally anticipated by most experts. Increases in the production of natural gas in the U.S. have been significant and have changed the energy market in important ways. One example is that natural gas has increasingly displaced coal as the fuel used to generate electricity. Since coal is the major commodity shipped on the Ohio River and thru the EDM projects, the question arises as to how the changes in energy markets may reduce the economics of proposed alternatives to maintain the projects. The issue is addressed below.

2.2.1 Coal burned by electric generating plants

USEIA forecasts show the burning of coal to produce electricity is expected to decline as a share of the total from 43% in 2011 to 35% in 2040, but the absolute amount that is burned is expected to remain fairly constant and even increase in the latter part of their forecast period.

Table 10: Electricity generation by fuel, 2011, 2025, and 2040

(billion kilowatt hours)

	2011	2025	2040
Coal	1,730.28	1,726.72	1,829.35
Natural gas	1,000.40	1,252.49	1,582.43
Nuclear	790.22	912.37	902.86
Renewables	525.82	660.79	858.23
Total	4,046.72	4,552.36	5,172.88

Source: U.S. Energy Information Agency

2.2.2 Regional shifts in coal production

U.S. coal production is projected by the Department of Energy to decrease through 2020 due to slowing demand, increased gas usage, and increased generation of electricity from "green" sources. Despite the overall decline, production in Northern Appalachia is projected to increase. The down bound coal moving through the Upper Ohio River projects is Northern Appalachian coal, so there is reason to believe that the recent reduction is a temporary aberration.

Table 11: Projected coal production by region

Projected coal production by region (millions of tons)								
	2010	2015	2020	2025	2030	2035	2040	Growth Rate (2011-2040)
Northern Appalachia 1/	129.6	145.4	171.2	174.2	178.8	177.9	182.7	1.1%
Central Appalachia	186.4	138.8	101.0	105.8	102.3	96.9	87.2	-2.6%
Southern Appalachia	20.4	18.1	16.2	14.6	13.9	14.6	13.4	-1.3%
Eastern Interior	109.8	119.5	150.0	152.7	160.5	165.2	169.7	1.2%
Rest of U.S.	638.2	620.1	632.9	666.1	697.3	716.4	714.1	1.8%
Total	1,084.4	1,041.8	1,071.4	1,113.4	1,152.9	1,171.1	1,167.2	0.2%
Source: AEO 2013 "Annual Energy Outlook"								

2.2.3 Other commodities

There is a potential for increased barge shipments of fracking sand and gas pipes into the area to serve the shale gas industry and for the outbound movement by barge of fracking water for disposal in facilities along the Gulf Coast. To date these shipments have been limited but the logistics are still being worked out. The potential is high for significant increases in barge traffic of these commodities.

2.3 Future traffic

Projections are the estimates of experts based on known facts and trends and are thus no assurance of future traffic levels since new and unexpected developments typically can intrude and change trends and negate the validity of current assumptions. While the projections of experts infer that traffic through the Upper Ohio, particularly coal, will likely be constant or growing, they could be off and traffic could continue to decrease. Given the uncertainly, the PCXIN contracted with an energy industry expert to review and update the commodity projections used in the Feasibility Report. The expert was Leonardo Technologies Incorporated (LTI) which is unknown to most of the general public but well known, utilized, and respected in the energy-analysis business. LTI performed a study for the PCXIN to project waterborne coal traffic, and their findings were consistent with the DOE 2013 projections and the projections used in the Feasibility Study (2009). Therefore it was not considered necessary to reevaluate the economics of the Upper Ohio Study using updated traffic forecasts since the LTI update confirmed the 2009 projections. A summary of the LTI work is provided below. A detailed table of historic and projected traffic at EDM is provided as Attachment 1.

The updated coal forecasts by Leonardo Technologies (LTI2012) noted the “development and application of massive hydraulic fracturing, horizontal drilling, and advanced seismic visualization technologies”.[1] Shale gas has changed the landscape of the regional economies of southeastern Pennsylvania, eastern Ohio and West Virginia. Rapid production increases and falling prices have reassured markets (most notably steel, glass, chemical, and electric utilities) damaged by natural gas shortfalls in the late 1970s and four decades of price volatility. The most immediate impact has been on electric utilities’ consumption of coal, further pressured by the likelihood of carbon emission regulations.

Reaction from the electric utility industry, the predominant shipper on the Upper Ohio has been quick. Coal-fired electric generating units not equipped with scrubber (flue-gas desulfurization units) have been retired, resulting in mine closures and/or reduced production of low-sulfur coals in southern West Virginia and in the Powder River Basin. Ohio Valley proximate coals with equivalent or higher Btu content and higher sulfur content have replaced these more expensive, low sulfur “compliance coals” that could meet emission requirements without the need for expensive scrubbers (often costing as much as the original generating unit). These new realities are not reflected in the Feasibility forecasts, but are driving the more recent LTI2012-based waterway traffic forecasts referred to above.

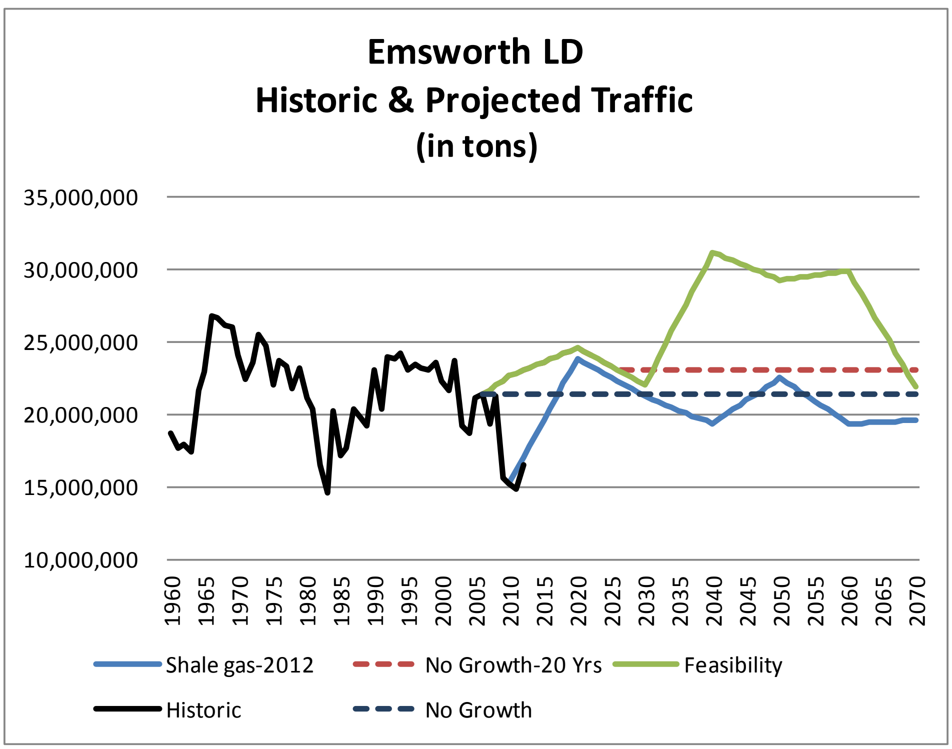
In the graph below (Emsworth is used in subsequent discussions as its trends are representative of both Dashields and Montgomery), these forecasts are shown alongside historic traffic and compared with the most-likely Feasibility forecasts, the Feasibility No Growth traffic scenario, and the Feasibility No Growth After 20 Years scenario. Economic downturns are apparent in historic trends. The most recent occurring immediately after the reference year for the Feasibility forecasts, the recession of 2008/2009. Both the Feasibility and LTI shale gas 2012 forecasts rely on economic outlooks that suggest an eventual return to more typical traffic levels (the upturn in 2012 traffic offers a hint of this possibility), though the Feasibility forecasts indicate that by 2040 traffic will be greater than at any time in the past 50 years (traffic reached 26.9 million tons in 1966 and is forecast to reach 31.2 in 2040). While the most-likely Feasibility forecasts are significantly higher beyond 2030, they are within 5% of one another during 2025-2030 (how many years beyond 2030 are they close?), the years that have the greatest impact on economic analyses due to discounting (Base year is now 2025, so can we say that traffic before then which differs somewhat between the two estimates doesn’t impact the analysis?). Using LTI2012-based forecasts can be expected to result in a benefit-cost ratio that lies somewhat below, but close to the No Growth After 20 Years scenario.

Table 12: Historic and projected traffic at Emsworth L&D

	Actual	LTI2012	Feasibility
1990	23,068,000		

[1] *Forecast of Utility Steam Coal Consumption, Sourcing and Transportation for the Great Lakes and Ohio River Basin Regions, Shale Gas Scenario,* prepared by Leonardo Technologies for the USACE Planning Center of Expertise for Inland Navigation (PCXIN), March 27, 2012.

1995	23,075,000		
2000	22,232,000		
2008	21,273,003		22,062,584
2009	15,698,750		22,381,292
2010	15,325,612	15,325,612	22,700,000
2011	14,888,472	16,180,405	22,890,000
2012	16,536,494	17,035,199	23,080,000
2013		17,889,992	23,270,000
2014		18,744,785	23,460,000
2015		19,599,579	23,650,000
2016		20,454,372	23,840,000
2017		21,309,165	24,030,000
2020		23,873,545	24,600,000
2025		22,563,487	23,350,000
2030		21,253,429	22,100,000
2040	-	19,390,338	31,200,000



As seen in the table below, the 20-Year Limited Growth (No Growth After 20 Years) BCR is 2.4 and the No Growth is 1.5. This suggests that using the LTI2012-based waterway traffic would result in a BCR of not less than 2.0.

Upper Ohio System - EDM	New 600' Lock and FAF Old (LMA 7) No Growth	20-Year Limited Growth	Mid Forecast
Incremental Benefits over the WOPC (MM$)	96.2	153.7	183.8
Incremental Costs over the WOPC (MM$)	64.9	64.9	64.9
Incremental Net Benefit (MM$)	31.3	88.8	118.9
Incremental BCR	1.5	2.4	2.8

Shale gas development could also result in significant upward pressure on regional waterway traffic demands from other sectors, especially steel and chemicals. A report prepared by the Tioga Group in May 2013 noted the industry's logistics chain is still evolving, but saw the likelihood of steel pipe, cement, sand, and wastewater moving by barge (sand is already observed moving by barge). Tioga also recognized the likelihood of what they termed induced industrial development of ethane plants, ethane cracking plants, steel mills, chemical and plastics plants, and fertilizer plants. Shale gas has shifted the competitive advantage in these industries and sectors toward the US. The Gulf Coast will reap significant benefits, but it is likely that plants will be sited in the upper Ohio Basin for gas processing and steel production.[2] These developments are not reflected in the LTI2012-based forecasts. Of course, this kind of industrial expansion also suggests increased demand for electricity that the shale gas and coal industries will need to accommodate.

During a period of rapid technological advance, gaining higher levels of comfort and confidence in traffic projections will require more frequent assessments than current funding allows. Absent this and given available information and analyses, it appears that a BCR between 2.0 and 2.5 is reasonable.

3.0 Construction schedule

The project schedule was driven by technical factors that assume that funding will be available when needed, which is the standard assumption underlying all Corps analyses. While this assumption may not be as reasonable as it was in the past, it remains a basic and important assumption that allows the analysis to develop the timing and type of solutions required to solve the nation's inland waterway need. We are not aware of any written guidance or other types of publications that allow or require deviation from this tenet.

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[2] *Shale Gas Outlook for Great Lakes and Ohio River Basin States: Production, Production Facilities, Products, and Methods of Delivery,* prepared by CDM Smith and the Tioga Group for the USACE Planning Center of Expertise for Inland Navigation, May 15, 2013.

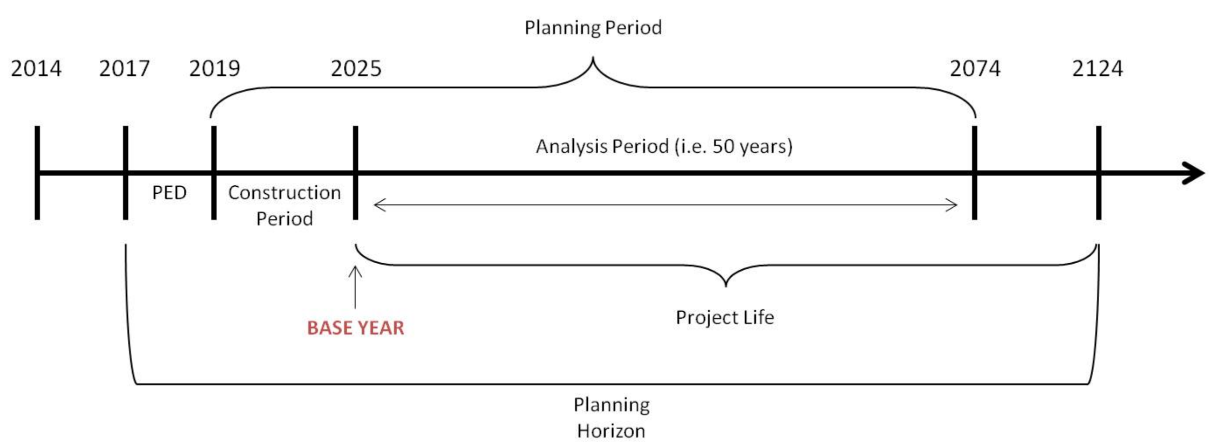
The technical factors that drive the project schedule are the project reliability and the traffic numbers. The key tenets related to these factors are: 1) the lower the reliability of the projects, then the more immediate is the need for work; and 2) the higher the level of traffic, then the more immediate is the time for work. The timing of "pro-active" work is computed by comparing the costs of pro-active repairs to the potential "risk-weighted" adverse impacts of failure (repair costs and increased transportation costs) in different years starting with the current year. A simple example is provided below in Table 13 to illustrate the computations. The optimum time to complete pro-active construction is the end of year six since the disruptive costs of failure exceed the planned pro-active construction costs in year seven.

Table 13: Example of timing analysis

Simple example of computations to determine optimum timing for construction								
Year	Prob of failure in given year	Repair costs	Increased transportation costs	Expected repair costs	Expected increased transportation costs	Total expected costs	Pro-active work	BCR
1	0.1	10.0	5.0	1.0	0.5	1.5	10.0	0.2
2	0.2	10.0	5.0	2.0	1.0	3.0	10.0	0.3
3	0.3	10.0	5.0	3.0	1.5	4.5	10.0	0.5
4	0.4	10.0	5.0	4.0	2.0	6.0	10.0	0.6
5	0.5	10.0	5.0	5.0	2.5	7.5	10.0	0.8
6	0.6	10.0	5.0	6.0	3.0	9.0	10.0	0.9
7	0.7	10.0	5.0	7.0	3.5	10.5	10.0	1.1
8	0.8	10.0	5.0	8.0	4.0	12.0	10.0	1.2
9	0.9	10.0	5.0	9.0	4.5	13.5	10.0	1.4
10	1.0	10.0	5.0	10.0	5.0	15.0	10.0	1.5

The key finding of the engineering/economic analyses of the 2006 Ohio River System Study and the Upper Ohio Feasibility study were that the optimal timing for construction of new main chambers is ASAP at all three sites, which was 2020 when the draft feasibility report was prepared. That required PED to begin in 2012, which obviously is no longer possible. The dates will be therefore adjusted based to reflect a more realistic "asap" schedule and that would allow PED to begin in fy 2017 and construction to be complete by the end of fy 2024 such that the base year for the economic evaluation is 2025. (Figure 3.2 from econ appendix with current dates).

FIGURE 3.2 – Planning Period



While the median reliability values were used in the analysis, there are low and high estimates of which the median is the mid-point. An extract from the Expert Elicitation Report that illustrates the range of numbers is provided below. The implication is that the "optimum year" for the completion of work from the analysis is in fact an approximation, and that the year could be somewhat sooner or later, depending on the deviation of the low and high estimates from the median. It was not considered feasible or necessary to model all of these possibilities or to use distributions other than point estimates of the reliability factors since the additional modeling effort would greatly increase the time and cost of the effort, with little expected differences in the results. In conclusion it is believed that some adjustments in the construction schedule and base year can be made and still be consistent with the reliability values per point in time estimated by the engineering panel of experts.

Table 14: Extract of probabilities from Expert Elicitation Report

	Description of Component & Issues		Expert Elicitation Question 1		Response	ISSUE 1
	Monolith Stem Failure		First	Median	Second	Median
Landwall Monoliths	Condition: The stem is a thin-wall section (5' thick) which is sensitive to tension cracks. Reinforcement in the form of epoxy-coated bars was provided during the major rehab. However, embedment lengths are deficient by today's design standards. Please answer the following questions. Frame your response in the form of a percentage					
Year 2005	1. What is the probability p(2005) of the monolith developing a horizontal or diagonal crack that would permit the monolith stem to move?					
		1	20		20	
		2	15		15	
		3	20		20	
		4	20		15	
		5	20		20	
		Low		15		15
		Median		20		20
		High		20		20
Year 2030	1. What is the probability p(2030) of the monolith developing a horizontal or diagonal crack that would permit the monolith stem to move?					
		1	40		45	
		2	30		35	
		3	50		50	
		4	50		60	
		5	80		50	
		Low		30		35
		Median		50		50
		High		80		60
	1. What is the probability p(2060) of the monolith					

4.0 Economics

The project economics are presented below at different price levels, discount rates, base years, and projected traffic levels. The range is fairly narrow except for the discount rate, particularly when the OMB rate of 7% is used rather than the current rate, which is 3.5% in FY 2014. Roughly speaking, using a discount rate of 7% rather than 3.5% doubles the economic cost of the project (interest plus capital) which would reduce the benefit to cost ratio (BCR) by half (i.e., from 3.0 to 1.5). Corps authorization decisions are based on the economics of the recommended project at the current rate (3.5%) with the 7% used as a common denominator in funding decisions that allows a comparison with other projects whose economics may have been based on different discount rates. A table in this format will be included in the Feasibility Report with updated values included as line 6 and so on. The table will be included in Attachment 6 to the Economics Appendix with an example provided as Attachment 2.

Table 15: BCR changes over time since 2009

	Price Level (Oct)	Cost	Discount rate	BCR	BCR @ 7%	Comment
1	2009	$ 1,479,000,000.00	4.125%	2.8	1.4	Venture level used in study
2	2010	$ 1,923,641,000.00	4.000%	2.4	1.2	M-CACES
3	2012	$ 2,104,736,000.00	4.000%	2.3	1.1	M-CACES
4	2012	$ 2,104,736,000.00	3.750%	2.5	1.1	M-CACES
5	2013	$ 2,143,687,145.65	3.500%	2.9	1.2	M-CACES – certified by Walla Walla

5.0 Summary

The principle points concluded from this paper deal with the issue of whether to recompute the benefits to reflect recent low traffic levels A review of recent traffic levels through 2012 and expectations for future traffic based on coal usage in electric generating plants and sources for the coal shows that current traffic levels are lower in the most recent five years than in the preceding five years, but that expectations for the sourcing of coal by electric generating plants is favorable in terms of EDM (Northern Appalachian) coal. Other observations/facts are that the conclusions and recommendations of the study are most sensitive to the reliability assessments, and that traffic is a secondary factor with less impact on the recommendation. Moreover, a BCR of 2.9 means that the incremental benefits are three times the costs, which again suggests a relative insensitivity of the recommendations to current traffic levels. While a case could be made that the economics should be recomputed based solely on the recent low traffic levels, the totality of the evidence leads the PDT to conclude that a recomputation is neither necessary nor warranted given the time and money required.

Attachments 1: Historic and projected traffic

Year	Emsworth					Dashields			Montgomery		
	Historic	Shale gas-2012	No Growth	No Growth-20 Yrs	Feasibility	Historic	Shale gas-2012	Feasibility	Historic	Shale gas-2012	Feasibility
1960	18,744,350					18,569,280			15,855,700		
1961	17,663,400					17,396,690			15,865,900		
1962	17,908,000					17,702,000			16,699,000		
1963	17,426,000					18,468,000			16,732,000		
1964	21,679,000					21,548,000			18,862,000		
1965	22,927,000					22,314,000			19,407,000		
1966	26,845,000					24,349,000			21,354,000		
1967	26,700,000					23,720,000			21,285,000		
1968	26,117,000					23,507,000			22,665,000		
1969	26,067,000					22,984,000			21,322,000		
1970	24,076,000					21,739,000			19,697,000		
1971	22,460,000					19,729,000			21,549,000		
1972	23,671,000					21,917,000			21,742,000		
1973	25,590,000					23,923,000			22,915,000		
1974	24,707,000					23,683,000			22,111,000		
1975	22,094,000					22,348,000			20,759,000		
1976	23,724,000					24,624,000			23,356,000		
1977	23,378,000					23,987,000			22,264,000		
1978	21,785,000					22,031,000			21,559,000		
1979	23,212,000					24,082,000			23,818,000		
1980	21,202,000					22,178,000			21,799,000		
1981	20,376,000					20,940,000			22,280,000		
1982	16,542,000					16,829,000			18,153,000		
1983	14,666,000					15,001,000			16,017,000		
1984	20,268,000					21,207,000			22,233,000		
1985	17,246,000					17,912,000			19,012,000		

Year	Emsworth					Dashields			Montgomery		
	Historic	Shale gas-2012	No Growth	No Growth-20 Yrs	Feasibility	Historic	Shale gas-2012	Feasibility	Historic	Shale gas-2012	Feasibility
1986	17,649,000					18,623,000			20,099,000		
1987	20,449,000					21,742,000			22,967,000		
1988	19,812,000					21,071,000			22,762,000		
1989	19,274,000					20,271,000			21,451,000		
1990	23,068,000					24,025,000			25,447,000		
1991	20,420,000					21,712,000			22,996,000		
1992	23,931,000					24,659,000			26,402,000		
1993	23,901,000					24,961,000			28,510,000		
1994	24,272,000					25,602,000			27,313,000		
1995	23,075,000					24,551,000			25,515,000		
1996	23,424,000					24,765,000			27,132,000		
1997	23,201,000					24,452,000			26,480,000		
1998	23,153,000					24,563,000			26,866,000		
1999	23,552,000					24,513,000			26,545,000		
2000	22,332,000					23,232,000			25,968,000		
2001	21,736,000					22,840,000			25,555,000		
2002	23,687,086					24,515,998			26,709,182		
2003	19,209,287					20,011,747			21,084,201		
2004	18,790,529					19,678,550			20,259,884		
2005	21,178,251					22,024,127			23,141,529		
2006	21,425,168		21,425,168	21,425,168	21,425,168	22,031,523		22,031,523	20,755,743		20,755,743
2007	19,399,305		21,425,168	21,743,876	21,743,876	20,170,881		22,323,642	19,310,192		21,591,807
2008	21,273,003		21,425,168	22,062,584	22,062,584	21,788,444		22,615,762	20,813,374		22,427,872
2009	15,698,750		21,425,168	22,381,292	22,381,292	16,470,633		22,907,881	16,389,991		23,263,936
2010	15,325,612	15,325,612	21,425,168	22,700,000	22,700,000	16,364,952	16,364,952	23,200,000	18,251,508	18,251,508	24,100,000
2011	14,888,472	16,180,405	21,425,168	22,890,000	22,890,000	15,958,070	17,183,487	23,400,000	17,433,457	19,270,133	24,500,000
2012	16,536,494	17,035,199	21,425,168	23,080,000	23,080,000	17,906,030	18,002,021	23,600,000	18,755,879	20,288,757	24,900,000
2013		17,889,992	21,425,168	23,270,000	23,270,000		18,820,556	23,800,000		21,307,382	25,300,000

Year	Emsworth					Dashields			Montgomery		
	Historic	Shale gas-2012	No Growth	No Growth-20 Yrs	Feasibility	Historic	Shale gas-2012	Feasibility	Historic	Shale gas-2012	Feasibility
2014		18,744,785	21,425,168	23,460,000	23,460,000		19,639,090	24,000,000		22,326,006	25,700,000
2015		19,599,579	21,425,168	23,650,000	23,650,000		20,457,625	24,200,000		23,344,631	26,100,000
2016		20,454,372	21,425,168	23,840,000	23,840,000		21,276,160	24,400,000		24,363,256	26,500,000
2017		21,309,165	21,425,168	24,030,000	24,030,000		22,094,694	24,600,000		25,381,880	26,900,000
2018		22,163,958	21,425,168	24,220,000	24,220,000		22,913,229	24,800,000		26,400,505	27,300,000
2019		23,018,752	21,425,168	24,410,000	24,410,000		23,731,763	25,000,000		27,419,129	27,700,000
2020		23,873,545	21,425,168	24,600,000	24,600,000		24,550,298	25,200,000		28,437,754	28,100,000
2021		23,611,533	21,425,168	24,350,000	24,350,000		24,291,127	24,970,000		28,247,700	27,770,000
2022		23,349,522	21,425,168	24,100,000	24,100,000		24,031,955	24,740,000		28,057,646	27,440,000
2023		23,087,510	21,425,168	23,850,000	23,850,000		23,772,784	24,510,000		27,867,592	27,110,000
2024		22,825,499	21,425,168	23,600,000	23,600,000		23,513,612	24,280,000		27,677,538	26,780,000
2025		22,563,487	21,425,168	23,350,000	23,350,000		23,254,441	24,050,000		27,487,485	26,450,000
2026		22,301,475	21,425,168	23,100,000	23,100,000		22,995,270	23,820,000		27,297,431	26,120,000
2027		22,039,464	21,425,168	23,100,000	22,850,000		22,736,098	23,590,000		27,107,377	25,790,000
2028		21,777,452	21,425,168	23,100,000	22,600,000		22,476,927	23,360,000		26,917,323	25,460,000
2029		21,515,441	21,425,168	23,100,000	22,350,000		22,217,755	23,130,000		26,727,269	25,130,000
2030		21,253,429	21,425,168	23,100,000	22,100,000		21,958,584	22,900,000		26,537,215	24,800,000
2031		21,067,120	21,425,168	23,100,000	23,010,000		21,775,115	23,810,000		26,323,309	25,810,000
2032		20,880,811	21,425,168	23,100,000	23,920,000		21,591,646	24,720,000		26,109,403	26,820,000
2033		20,694,502	21,425,168	23,100,000	24,830,000		21,408,177	25,630,000		25,895,497	27,830,000
2034		20,508,193	21,425,168	23,100,000	25,740,000		21,224,708	26,540,000		25,681,591	28,840,000
2035		20,321,884	21,425,168	23,100,000	26,650,000		21,041,240	27,450,000		25,467,685	29,850,000
2036		20,135,574	21,425,168	23,100,000	27,560,000		20,857,771	28,360,000		25,253,779	30,860,000
2037		19,949,265	21,425,168	23,100,000	28,470,000		20,674,302	29,270,000		25,039,873	31,870,000
2038		19,762,956	21,425,168	23,100,000	29,380,000		20,490,833	30,180,000		24,825,967	32,880,000
2039		19,576,647	21,425,168	23,100,000	30,290,000		20,307,364	31,090,000		24,612,061	33,890,000
2040		19,390,338	21,425,168	23,100,000	31,200,000		20,123,895	32,000,000		24,398,155	34,900,000
2041		19,708,369	21,425,168	23,100,000	31,010,000		20,444,742	31,810,000		24,764,374	34,620,000
2042		20,026,400	21,425,168	23,100,000	30,820,000		20,765,589	31,620,000		25,130,593	34,340,000

Year	Emsworth					Dashields			Montgomery		
	Historic	Shale gas-2012	No Growth	No Growth-20 Yrs	Feasibility	Historic	Shale gas-2012	Feasibility	Historic	Shale gas-2012	Feasibility
2043		20,344,431	21,425,168	23,100,000	30,630,000		21,086,437	31,430,000		25,496,813	34,060,000
2044		20,662,462	21,425,168	23,100,000	30,440,000		21,407,284	31,240,000		25,863,032	33,780,000
2045		20,980,494	21,425,168	23,100,000	30,250,000		21,728,131	31,050,000		26,229,251	33,500,000
2046		21,298,525	21,425,168	23,100,000	30,060,000		22,048,978	30,860,000		26,595,470	33,220,000
2047		21,616,556	21,425,168	23,100,000	29,870,000		22,369,825	30,670,000		26,961,689	32,940,000
2048		21,934,587	21,425,168	23,100,000	29,680,000		22,690,673	30,480,000		27,327,909	32,660,000
2049		22,252,618	21,425,168	23,100,000	29,490,000		23,011,520	30,290,000		27,694,128	32,380,000
2050		22,570,649	21,425,168	23,100,000	29,300,000		23,332,367	30,100,000		28,060,347	32,100,000
2051		22,252,078	21,425,168	23,100,000	29,360,000		23,016,559	30,180,000		27,708,431	32,200,000
2052		21,933,506	21,425,168	23,100,000	29,420,000		22,700,751	30,260,000		27,356,516	32,300,000
2053		21,614,935	21,425,168	23,100,000	29,480,000		22,384,944	30,340,000		27,004,600	32,400,000
2054		21,296,363	21,425,168	23,100,000	29,540,000		22,069,136	30,420,000		26,652,684	32,500,000
2055		20,977,792	21,425,168	23,100,000	29,600,000		21,753,328	30,500,000		26,300,769	32,600,000
2056		20,659,220	21,425,168	23,100,000	29,660,000		21,437,520	30,580,000		25,948,853	32,700,000
2057		20,340,649	21,425,168	23,100,000	29,720,000		21,121,712	30,660,000		25,596,937	32,800,000
2058		20,022,077	21,425,168	23,100,000	29,780,000		20,805,905	30,740,000		25,245,021	32,900,000
2059		19,703,506	21,425,168	23,100,000	29,840,000		20,490,097	30,820,000		24,893,106	33,000,000
2060		19,384,934	21,425,168	23,100,000	29,900,000		20,174,289	30,900,000		24,541,190	33,100,000
2061		19,408,658	21,425,168	23,100,000	29,100,000		20,200,777	30,110,000		24,568,046	32,260,000
2062		19,432,382	21,425,168	23,100,000	28,300,000		20,227,265	29,320,000		24,594,901	31,420,000
2063		19,456,106	21,425,168	23,100,000	27,500,000		20,253,752	28,530,000		24,621,757	30,580,000
2064		19,479,830	21,425,168	23,100,000	26,700,000		20,280,240	27,740,000		24,648,612	29,740,000
2065		19,503,555	21,425,168	23,100,000	25,900,000		20,306,728	26,950,000		24,675,468	28,900,000
2066		19,527,279	21,425,168	23,100,000	25,100,000		20,333,216	26,160,000		24,702,324	28,060,000
2067		19,551,003	21,425,168	23,100,000	24,300,000		20,359,704	25,370,000		24,729,179	27,220,000
2068		19,574,727	21,425,168	23,100,000	23,500,000		20,386,191	24,580,000		24,756,035	26,380,000
2069		19,598,451	21,425,168	23,100,000	22,700,000		20,412,679	23,790,000		24,782,890	25,540,000
2070		19,622,175	21,425,168	23,100,000	21,900,000		20,439,167	23,000,000		24,809,746	24,700,000

Attachment 2 "Attachment 6: Procedure to update economics to Oct 2013 price level"

1.0 General: The evaluation documented in the draft Feasibility Report used costs and benefits expressed at Oct 2009 price levels. The analysis concluded that the national economic development (NED) plan was the construction of new 600' x 110' sized locks at Emsworth, Dashields, and Montgomery, and the retention of the existing 600' x 110' locks as auxiliaries. Based on consideration of all pertinent criteria, this plan was also selected as the tentatively recommended plan. The costs of the plan were then developed to greater detail using M-CACES procedures with the initial results expressed at October 2010 price levels. The economics of the plan were also updated to October 2010 price levels and provided on a fact sheet attached to the report submitted to the division office in April of 2011. The costs, benefits, and economics of the recommended plan have since been updated to October 2013 price levels with the results attached to this report, which will be submitted to USACE headquarters. The procedure for updating the economics is summarized in this paper and is the same as used in the October 2010 and all subsequent updates.

2.0 Procedure: Construction and related costs are regularly updated to current price levels using indices based on civil works construction cost index systems (CWCCIS) numbers. However, benefits are not indexed since there is no proven method that produces results that can be validated. For this effort the update was accomplished by updating the transportation costs for both the water routed mode of transportation and the least cost all overland mode of transportation. The difference between the updated water routed costs and the all overland routed transportation costs are the updated transportation benefits. These updated benefits, expressed in terms of savings per ton, were used to update the transportation benefits of the recommended Upper Ohio River navigation project. The benefits of the recommended project in terms of reduced maintenance and repair costs were computed in a similar manner but using construction cost indices rather than transportation cost indices as a basis for the update. The updates are discussed in greater detail in the following paragraphs.

3.0 Categories of benefits: The benefits of the recommended project compared to the baseline ("without") project condition are: 1) reduced transportation costs; and 2) reduced maintenance and repair costs. The categories are listed in Table 1 along with pertinent data used in the updates, which are discussed below.

Table 1: Factors of change from 2009 to 2012

	Category	Basis for update	Oct 2009	Oct 2013	Index
1	Transportation	Change in waterways savings per ton	$13.38	$16.38	1.22
2	Maintenance and repair	Change in total project costs	$1,479,000	$2,143,687	1.45

3.1 Transportation savings: The principle benefit of inland navigation projects and/or improvements is the lower costs of water routed transportation compared to the least cost all overland routed mode of transportation. The costs of both transportation routings along with their accessorial charges were updated to October 2013 price levels using BLS based indices. This was accomplished by taking the 1,552 shipments in the sample that was rated in 2010 and updating the components costs of each shipment (e.g., loading) by the appropriate BLS based index for both the water-routed shipping alternative and the least cost all-overland shipping alternative. The detailed commodity shipments (such as gasoline) were then aggregated into nine general commodity groupings, such as petroleum products, which include gasoline and other detailed types of commodities. The transportation costs were then weighted by the tonnage of the commodity group in the sample to compute a tonnage weighted savings per ton for the sample. The transportation costs were then reweighted based on current total tonnage (sampled and unsampled) as expressed as the 2008 to 2012 average for each commodity group to compute a tonnage weighted savings per ton for all shipments. The savings per ton were then adjusted downward by 14 percent based on a validation test.

This procedure was used to update the national database of transportation costs for seven different watersheds, including the Ohio River Basin, with the results listed in Table 2. The procedure was documented and underwent a national QA-level of review for an identical update performed in 2012 and found to be adequate. Since the transportation benefits are the product of the savings per ton times the number of tons, and the number of tons was not changed, then updated benefits could be computed by multiplying the updated savings per ton by the number of tons at the project. To simplify matters while achieving the same results, a savings per ton index was computed by dividing the updated ($Oct 13) savings per ton by the savings per ton used in the analysis ($ Oct 2009). The values and resulting index are listed in both Tables 1 and 2; the estimated change in savings per ton from Oct 2009 to Oct 2013 was 22%. The savings per ton index of 1.22 was applied to the transportation costs and savings at Oct 2009 price levels to update the transportation savings to Oct 2013 price levels.

Table 2: Savings per ton - tonnage weighted

	Basin	Original price level	Original	2009 Feasibility Report	SCC-13	% change from 09 to 13
1	Arkansas	Oct-03	$10.19		$14.23	
2	Columbia-snake	Oct-10	$10.36		$11.68	
3	GIWW-W	Dec-10	$28.94		$31.96	
4	Great Lakes	Dec-08	$15.84		$14.37	
5	Ohio	Oct-10	$13.46	$13.38	$16.38	1.224
6	Red	Oct-00	$1.35		$2.90	
7	Upper Miss	Oct-06	$21.46		$27.90	

3.2 Reduced repair and maintenance costs: The benefits of reduced maintenance and repair costs were computed in a similar manner but using construction cost indices rather than transportation cost indices as a basis for the update. Since repairs and maintenance often involve construction or reconstruction, it was assumed that repair and maintenance costs would change at the same rate as the construction costs of the recommended project. Therefore a construction index was computed by dividing the Oct 2013 M-CACES cost by the Oct 2009 venture level costs used in the analysis. The construction index was then applied to the repair and maintenance costs in the “without” condition and for the recommended project to obtain updated repair and maintenance costs. The difference or avoided repair/maintenance was credited as benefits of the recommended plan, provided the costs are lower for the recommended plan. The values and resulting index are listed in Table 1; the change in total project cost from 2009 to 2013 was 45%.

4.0 Application: Transportation costs and maintenance/repair costs are computed for a wide variety of classifications to allow the computed values to be reviewed and verified at the most detailed levels. Transportation costs are computed within the model according to the following: normal water-routed transportation costs; water routed transportation costs given a disruption in lock operations (possibly lower due to less traffic); tow delay costs under the normal and disruption scenarios (typically higher during disruptions); normal overland routed costs; and overland costs when traffic increases due to disruptions on the river (normally higher due to more traffic and increased congestion). Maintenance and repair costs are likewise calculated at more detailed levels which include: maintenance costs during scheduled repairs; repair costs for unscheduled events; normal operation and maintenance costs; and the construction and related costs for constructing/reconstructing the projects. All costs for the different categories of transportation were updated using the transportation index while all categories of repair/maintenance work were updated using the construction index, with the exception of normal O&M costs which were not changed based on feedback from programming people in the Pittsburgh District.

5.0 Results: The economics at October 2009 and 2013 price levels are listed in Table 3 at discount rates in effect at the time (4 1/8% in 2009 and 3 ½% in 2013) and at 7%. Because the increase in costs was greater than the increase in benefits between 2009 and 2013, the economics of the project diminished. For example, the BCR of the recommended project in 2009 at 7% was 1.4 while in 2013 it was 1.2.

Table 3: Economics of Upper Ohio project updated to Oct 2013 price level using report format

	Screening		M-Caces	
	4.125%	7.000%	3.500%	7.000%
Without				
Costs	$-	$-	$-	$-
Benefits	$249.6	$312.6	$311.7	$438.9
Recommended plan				
Costs	$64.9	$106.1	$90.1	$182.4
Benefits	$433.5	$462.2	$569.4	$650.2
Incremental values				
Costs	$64.9	$106.1	$90.1	$182.4
Benefits	$183.9	$149.6	$257.7	$211.2
Net benefits	$119.0	$43.5	$167.5	$28.8
BCR	2.8	1.4	2.9	1.2

The current economics expressed as a benefit to cost ratio (BCR) is listed in Table 5 along with earlier updates dating back to the completion of the Feasibility Study. The BCRs vary within a fairly narrow range with the variation due to the discount rate used in the economics, the increase in the magnitude of the cost of the project over time, and changes in the benefits (not shown below but discussed previously).

Table 5: BCR changes over time since 2009

	Price Level	Cost	Discount rate	BCR	BCR @ 7%	Comment
1	2009	$ 1,479,000,000.00	4.125%	2.8	1.4	Venture level used in study
2	2010	$ 1,923,641,000.00	4.000%	2.4	1.2	M-CACES
3	2012	$ 2,104,736,000.00	4.000%	2.3	1.1	M-CACES
4	2012	$ 2,104,736,000.00	3.750%	2.5	1.1	M-CACES
5	2013	$ 2,143,687,145.65	3.500%	2.9	1.2	M-CACES – certified by Walla Walla

Attachment 8: IEPR – revised economic tables; coal sourcing; economic updates; and equilibrium traffic

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1.0 Revised economic tables

The economics appendix (Appendix B) contained several tables that had values that logically should have been itemized for additional clarification. The tables always started with a line item described as "Waterway Transportation Surplus", but this line item differed between the tables with no detailed explanation of the underlying value. The explanation and revised tables are provided below.

1.1 Definition of "Waterway Transportation Surplus"

Page 96 of the Economic Appendix defines "waterway transportation surplus" as the consumer surplus (savings) realized by shippers under the normal operation of the waterway. Normal operation includes scheduled and random minor maintenance but does not include unscheduled closures.

The values in the tables differ because the normal operations, specifically the scheduled repairs and maintenance, can vary between scenario plans. Only the unscheduled event waterway transportation surplus reduction was itemized to highlight their impacts, however, in hindsight not itemizing the scheduled event waterway transportation surplus reduction can cause confusion. Between reactive and advanced maintenance, unscheduled repairs (which tend to be longer duration) are traded off against scheduled repairs.

The tables have been revised to start with the "base" waterway transportation surplus which excludes reductions due to scheduled closures as well as unscheduled closures. Additional line items have been added to the table to show the diminution of the "base" surplus due to schedule closure impacts, unscheduled closure impacts, and unscheduled closure diversion and externality costs.

1.2 Revised economic tables

The revised economic tables with the "waterway transportation surplus" listing are provided below.

MAIN: TABLE 4-16 Revised

ECON APP: TABLE 7-4 Revised

EDM Reactive Maintenance - EDM

Mid Forecasts, Average Annual Costs and Benefits

(2012-2068, 4.125%, base year 2018, Million FY09 $)

Upper Ohio System - EDM	Average Annual
Reactive maintenance Benefits	
Base Waterway Transportation Surplus (full operations)	$475.0
Reduced Surplus from Scheduled Closures	-$23.6
Land transportation costs Incurred from Unscheduled diversions	-$134.6
Reduced Surplus from Unscheduled Closures	-$65.1
Externality Costs Incurred	-$2.1
Total System Benefits	$249.6
Reactive maintenance Costs	
Scheduled Lock Improvements	$0.0
Scheduled Lock Maintenance	$8.4
Unscheduled Lock Repair	$22.2
Normal O&M	$8.0
Random Minor	$0.8
Total System Costs	$39.5
Net Benefits	$210.1
BCR	6.3

MAIN: TABLE 4-29 Revised

ECON APP: TABLE 9-2 Revised

Advanced Maintenance - EDM

Mid Forecasts, Average Annual Costs and Benefits

(2012-2068, 4.125%, base year 2018, Million FY09 $)

Upper Ohio System - EDM	Average Annual
Advanced maintenance Benefits	
Base Waterway Transportation Surplus (full operations)	$475.0
Reduced Surplus from Scheduled Closures	-$87.0
Land transportation costs Incurred from Unscheduled diversions	-$17.5
Reduced Surplus from Unscheduled Closures	-$6.0
Externality Costs Incurred	-$0.2
Total System Benefits	$364.3
Advanced maintenance Costs	
Scheduled Lock Improvements	$57.1
Scheduled Lock Maintenance	$7.8
Unscheduled Lock Repair	$3.8
Normal O&M	$8.0
Random Minor	$0.8
Total System Costs	$77.5
Net Benefits	$286.9
BCR	4.7
Incremental Benefits	$114.8
Incremental Costs	$38.0
Incremental Net Benefits	$76.8
BCR (Incremental)	3.0

MAIN: TABLE 4-32 Revised
ECON APP: TABLE 9-4 Revised
New 600', 800', or 1200' Locks at EDM
Mid Forecasts, Average Annual Costs and Benefits
(2012-2068, 4.125%, base year 2018, Million FY09 $)

Upper Ohio System - EDM	New Lock (Average Annuals)		
	600' (LMA 7)	800' (LMA 8)	1200' (LMA 9)
New Lock Benefits			
Base Waterway Transportation Surplus (full operations)	$475.0	$475.0	$475.0
Reduced Surplus from Scheduled Closures	-$0.7	-$0.6	-$0.6
Land transportation costs Incurred from Unscheduled diversions	-$33.2	-$38.0	-$47.7
Reduced Surplus from Unscheduled Closures	-$6.8	-$7.0	-$8.3
Externality Costs Incurred	-$0.9	-$1.0	-$1.3
Total System Benefits	$433.5	$428.4	$417.0
New Lock Costs			
Scheduled Lock Improvements	$72.2	$84.0	$100.1
Scheduled Lock Maintenance	$4.7	$4.5	$4.2
Unscheduled Lock Repair	$18.8	$18.8	$18.8
Normal O&M	$8.0	$ 8.0	$ 8.0
Random Minor	$0.6	$0.6	$0.6
Total System Costs	$104.3	$115.9	$131.6
Net Benefits	$329.1	$312.4	$ 285.4
BCR	4.2	3.7	3.2
Incremental Benefits	$183.9	$178.8	$ 167.5
Incremental Costs	$64.9	$76.5	$92.1
Incremental Net Benefits	$119.0	$102.3	$75.3
BCR (Incremental)	2.8	2.3	1.8

MAIN: TABLE 4-35 Revised

ECON APP: TABLE 9-6 Revised

Dual 600' Locks at EDM (LMA 1)

Mid Forecasts, Average Annual Costs and Benefits

(2012-2068, 4.125%, base year 2018, Million FY09 $)

Upper Ohio System - EDM	Average Annual Dual 600' Locks (LMA 1)
New dual 600' Lock Benefits	
Base Waterway Transportation Surplus (full operations)	475.0
Reduced Surplus from Scheduled Closures	-0.7
Land transportation costs Incurred from Unscheduled diversions	-33.2
Reduced Surplus from Unscheduled Closures	-6.4
Externality Costs Incurred	-0.9
Total System Benefits	434.0
New dual 600' Lock Costs	
Scheduled Lock Improvements	92.8
Scheduled Lock Maintenance	1.2
Unscheduled Lock Repair	7.3
Normal O&M	8.0
Random Minor	0.4
Total System Costs	109.8
Net Benefits	324.2
BCR	4.0
Incremental Benefits	184.4
Incremental Costs	70.3
Incremental Net Benefits	114.1
BCR (Incremental)	2.6

1.3 Original economic tables

The original economic tables that appear in Appendix B and the Main Report of the Feasibility Study are provided below for comparison. All "waterway transportation surplus" rows have been substituted with the "base waterway transportation surplus" of $475.0 million. For example, in Table 4-16 (Appendix B Table 7-4) the difference of $23.6 million between the "waterway transportation surplus" of $451.4 is itemized under "Reduced surplus from scheduled closures" in the revised Table 4-16 shown in section 1.2. In some cases there were minor rounding differences that result in minor differences in the numbers.

MAIN RPT: TABLE 4-16

ECON APP: TABLE 7-4

EDM Reactive Maintenance - EDM

Mid Forecasts, Average Annual Costs and Benefits

(2012-2068, 4.125%, base year 2018, Million FY09 $)

Upper Ohio System - EDM	Average Annual
Reactive maintenance Benefits	
Waterway Transportation Surplus	$451.4
Transportation Losses from Unscheduled Closures	-$199.7
Externality Costs Incurred	-$2.1
Total System Benefits	$249.6
Reactive maintenance Costs	
Scheduled Lock Improvements	$0.0
Scheduled Lock Maintenance	$8.4
Unscheduled Lock Repair	$22.2
Normal O&M	$8.0
Random Minor	$0.8
Total System Costs	$39.5
Net Benefits	$210.1
BCR	6.3

MAIN: TABLE 4-29

ECON APP: TABLE 9-2

Advanced Maintenance - EDM

Mid Forecasts, Average Annual Costs and Benefits

(2012-2068, 4.125%, base year 2018, Million FY09 $)

Upper Ohio System - EDM	Advanced Maintenance EDM, System Economics Mid0Forecast	
Advanced maintenance Benefits		
Waterway Transportation Surplus	$	388.0
Transportation Losses from Unscheduled Closures	$	(23.5)
Externality Costs Incurred	$	(0.2)
Total System Benefits	$	364.3
Advanced maintenance Costs		
Scheduled Lock Improvements	$	57.1
Scheduled Lock Maintenance	$	7.8
Unscheduled Lock Repair	$	3.8
Normal O&M	$	8.0
Random Minor	$	0.8
Total System Costs	$	77.5
Net Benefits	$	286.9
BCR		4.7
Incremental Benefits	$	114.8
Incremental Costs	$	38.0
Incremental Net Benefits	$	76.8
BCR (Incremental)		3.0

Main: TABLE 4-32
ECON APP: TABLE 9-4
New 600', 800', or 1200' Locks at EDM
Mid Forecasts, Average Annual Costs and Benefits
(2012-2068, 4.125%, base year 2018, Million FY09 $)

	New Lock		
Upper Ohio System - EDM	**600' (LMA 7)**	**800' (LMA 8)**	**1200' (LMA 9)**
New Lock with FAF Benefits			
Waterway Transportation Surplus	$ 474.3	$ 474.4	$ 474.4
Transportation Losses from Unscheduled Closures	$ (40.0)	$ (45.0)	$ (56.0)
Externality Costs Incurred	$ (0.9)	$ (1.0)	$ (1.3)
Total System Benefits	$ 433.5	$ 428.4	$ 417.0
New Lock with FAF Costs			
Scheduled Lock Improvements	$ 72.2	$ 84.0	$ 100.1
Scheduled Lock Maintenance	$ 4.7	$ 4.5	$ 4.2
Unscheduled Lock Repair	$ 18.8	$ 18.8	$ 18.8
Normal O&M	$ 8.0	$ 8.0	$ 8.0
Random Minor	$ 0.6	$ 0.6	$ 0.6
Total System Costs	$ 104.3	$ 115.9	$ 131.6
Net Benefits	$ 329.1	$ 312.4	$ 285.4
BCR	4.2	3.7	3.2
Incremental Benefits	$ 183.9	$ 178.8	$ 167.5
Incremental Costs	$ 64.9	$ 76.5	$ 92.1
Incremental Net Benefits	$ 119.0	$ 102.3	$ 75.3
BCR (Incremental)	2.8	2.3	1.8

MAIN: TABLE 4-35
ECON APP: TABLE 9-6
Dual 600' Locks at EDM (LMA 1)
Mid Forecasts, Average Annual Costs and Benefits
(2012-2068, 4.125%, base year 2018, Million FY09 $)

Upper Ohio System - EDM	Dual 600' Locks (LMA 1)	
New Lock with FAF Benefits		
Waterway Transportation Surplus	$	474.3
Reduced Surplus from Unscheduled Closures	$	(39.5)
Externality Costs Incurred	$	(0.9)
Total System Benefits	$	434.0
New Lock with FAF Costs		
Scheduled Lock Improvements	$	92.8
Scheduled Lock Maintenance	$	1.2
Unscheduled Lock Repair	$	7.3
Normal O&M	$	8.0
Random Minor	$	0.4
Total System Costs	$	109.8
Net Benefits	$	324.2
BCR		4.0
Incremental Benefits	$	184.4
Incremental Costs	$	70.3
Incremental Net Benefits	$	114.1
BCR (Incremental)		2.6

2.0 River origin of coal traffic

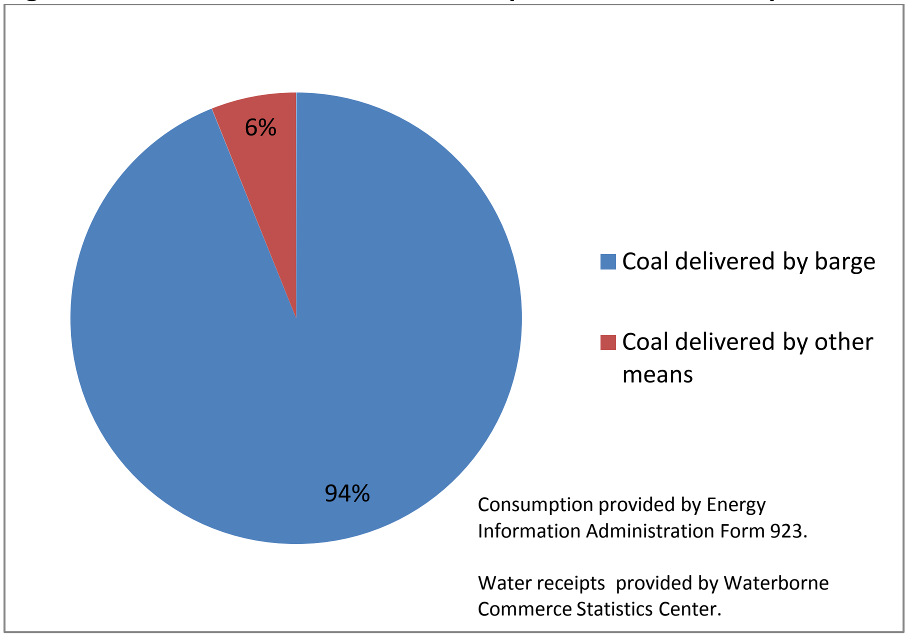
2.1 Forecasted Coal Apportionment and Routing

Steam coal is a major part of the traffic on the Ohio River, accounting for approximately 60 percent of total tonnage. It is equally important on the Upper Ohio River, where downbound coal – moving from Northern Appalachian mines in the Monongahela River basin to coal-fired electric generating plants on the Ohio River – accounts for approximately 37 percent of all Upper Ohio river coal traffic. Because of its high importance, the Corps contracted Leonardo Technologies Inc. (LTI), a firm with expertise and modeling capabilities that allowed it to forecast coal consumption at the plant level. LTI's model, the Greenmont Energy Model (GEM), was used for the forecasts because of its ability to find the least cost solution for expected electricity demands. GEM optimizes fuel selection, plant selection, estimates coal consumption, and selects the coal source; all while taking into account emission control investments and their timing at the plant level. By making adjustments at the unit/plant level from historical sources, based upon the lowest cost for meeting environmental and generation targets, LTI's GEM model changed coal sourcing in significant ways. Central Appalachia lost production to the Powder River Basin (PRB) and Interior and Northern Appalachian (NAPP) coal fields as plants with flue-gas desulfurization units (FGD units or scrubbers) were favored over plants that burned lower emission coals without this technology.

The LTI forecasts were developed in the 2006-2008 time period and were used in the Upper Ohio Navigation study. The end-product of the LTI forecasting effort were annual coal consumption estimates at the plant level, and the mining regions that serve them; the forecasts do not include the specific modal choices (rail, barge, etc.) for moving the coal from the mining origin to the power plant destination. This was done by Corps analysts using a pro-rating procedure as described below.

The first step was to calculate the percentage of total coal consumption that would be delivered by water to each plant. The range is 0% for plants that receive no coal via the waterway to 100% for plants that receive all their coal by waterway. Coal consumption for each plant was obtained from the Department of Energy's (DOE) analytic section. Waterway receipts were obtained from the Corps Waterborne Commerce Statistics database, which are data provided annually by shippers specifying the origin dock, destination dock, and commodity type of shipments. Total consumption was then compared to the dock-level coal receipts for each plant to develop historic percentages of waterborne receipts of coal. These percentages were applied to the forecasted coal consumption by plant to estimate future water coal tonnage. An example calculation for plants that utilized EMD coal in 2012 is given in **Figure 1**.

Figure 1: 2012 EDM Coal Plants – Consumption vs. Water Receipts



Once the forecasted amount of water delivered coal had been calculated for each plant, the next step was to identify the specific origin docks that would likely ship the projected tonnage so a route could be determined. By examining historic waterborne coal flows, a series of lookup tables were developed for origins docks that matched LTI's forecasted mining regions. This was done at the individual plant level, for their respective operating companies, and for all of the companies collectively. These routing changes, based on the LTI forecast, altered the forecasted tonnage at each lock and dam project.

The first step in the routing process was to determine if a plant had historic record of shipment of coal from the region specified by LTI. If a match was found, then the same origin dock(s) were used for the forecasted shipment. If more than one dock from that region was used, then the forecasted tonnage was distributed among those docks in proportion to their historic usage. For example, suppose LTI forecasted Plant XYZ to burn 1.5 million tons of Powder River Basin coal in 2020. As seen in the table below, ABC Shipping historically provided 100% of that plants shipment of PRB Coal. This dock would be used in the forecast to source the 1.5 million tons.

	Year	Plant	Coal Region	Origin Dock	Percent Share	Tons
Plant Lookup	2005	Plant XYZ	PRB	ABC Shipping	100%	250,000
				↓	↓	
Plant Forecast	2020	Plant XYZ	PRB	ABC Shipping	100%	1,500,000

If such a historic origin dock was not found for the plant, as was typically the case, then the search was broadened to the origin docks in use by the operating company in the LTI specified coal region. The same process outlined at the plant level was used, only using the company lookup table. Using the example above, the 1.5 million tons would be distributed as shown below if the lookup failed at the plant level.

	Year	Plant	Company	Coal Region	Origin Dock	Percent Share	Tons
Plant Lookup	2005	Plant XYZ	Energy 1	NAPP	ABC Shipping	100%	1,000,000
Company Lookup	2005		Energy 1	PRB	T1 Terminal	50%	5,000,000
	2005		Energy 1	PRB	Ace Coal	50%	5,000,000
Plant Forecast	2020	Plant XYZ	Energy 1	PRB	T1 Terminal	50%	750,000
	2020	Plant XYZ	Energy 1	PRB	Ace Coal	50%	750,000

If neither of these criteria were met, then the coal shipment was allocated based on the likely origin docks in use among all the operating companies that use the Ohio River System for that particular region. Using the same 1.5 million tons, an example is provided below.

	Year	Plant	Company	Coal Region	Origin Dock	Percent Share	Tons
Plant Lookup	2005	Plant XYZ	Energy 1	NAPP	ABC Shipping	100%	1,000,000
Company Lookup	2005		Energy 1	ILB	T1 Terminal	50%	5,000,000
	2005		Energy 1	NAPP	ABC Shipping	50%	5,000,000
All Companies Lookup	2005			PRB	Cook	50%	14,000,000
	2005			PRB	Cora	30%	8,400,000
	2005			PRB	Calvert City	20%	5,600,000
Plant Forecast	2020	Plant XYZ	Energy 1	PRB	Cook	50%	750,000
	2020	Plant XYZ	Energy 1	PRB	Cora	30%	450,000
	2020	Plant XYZ	Energy 1	PRB	Calvert City	20%	300,000

These are simplified examples, since LTI may have forecasted a plant to burn coal from a combination of regions, and plants might have historically drawn coal from a variety of docks within that region. Additional complications exist for origin docks that receive significant amounts of coal from more than one coal region, and often blend. In those particular cases, the docks are assigned more than one coal region type, based on the company's procurement strategy. In summary, this process allowed the waterborne origin and destination pairs to be created based on the coal production regions forecasted by LTI.

Once the forecasted origin and destination pairs had been created, the final step was to run them through a lock flagging program. This identified the lock(s) expected to be used for each movement along the waterborne leg of transportation, and provided the subsequent tonnages for each project, including EDM.

2.2 Powder River Basin coal shipments

Most of the steam coal shipments are multimodal shipments since the origin mines are usually off-river. For Powder River Basin (PRB) coals moving from the western interior of the country into the Ohio River Basin, the coal is first loaded onto unit trains, which haul coal to river terminals on the Mississippi, lower Ohio, and lower Tennessee Rivers. It is then transferred at these locations – often after being blended – to barge for ultimate delivery to Ohio River power plants. This multimodal movement allows shippers to avoid onerous rail exchange fees when cars are transferred from one carrier to the next. In fact, the Cook Terminal at Metropolis, Illinois is the largest coal terminal in the Ohio River System and handles PRB coal exclusively. In the case of the PRB origin coals, the existing water route that TVA rated was a complete origin-to-destination multimodal movement of rail to barge. The alternate rate that is compared to the existing route's rate is an all rail movement direct from the mine to the power plant. TVA rated a sampling of historic movements. These rates calculated for the sample movements are used to estimate transportation rates and rate savings for unsampled movements, including any projected new movements. Statistical relationships are established between waterway miles and alternate route overland miles from the sampled rates. This relationship is used in estimating linehaul rates for unsampled movements where the known variable (recorded in the Waterborne Commerce Statistics) is waterway miles.

2.3 Modal shifts due to lock closures

Diversion to rail during lock closures was based upon a survey of carriers and shippers to elicit their responses to short-term closures of lock chambers. It was determined by TVA that rail was more likely to be used and caused less disruption to surface transportation users in the Pittsburgh area in the event of main chamber closures at Upper Ohio locks. Trucks served as linkages to rail terminals and rail lines for shippers not served by rail; with this multimodal approach surface highway congestion is limited. PRB coal moving by rail would be unaffected. PRB coal moving by barge into the Upper Ohio could be offloaded and transferred to rail during a closure or move by direct rail, but PRB penetration in the Upper Ohio by barge is limited and the availability of the railcars, locomotives, and crews needed to make additional cycles during anything less than a 6 month closure would be problematic.

3.0 Economic updates

3.1 Issue

The Upper Ohio Feasibility study was a multi-year study that involved extensive data development in the areas of traffic forecasts and transportation rates, among other things. The development of the forecasts and rates are extensive efforts in themselves that took approximately 3 years and 2 years respectively. Thus the historic data is already 2 to 3 years out of date by the time the forecasts/rates are complete. Of equal if not greater importance is that the economic/market environments that were the basis for the forecasts are also out of date. Add to this a year to format and input the forecasts and rates into economic models and a minimum of two years for reviews, then the data and environments are six years out of date before the report is ready for consideration by the Corps Civil Works Review Board (CWRB) for approval and possible authorization for construction by Congress. The age of the data and the age of information that was the basis for the analysis are a concern for reviewers who are responsible for determining if the recommendations in the report are valid at the time they do their review. This is a conundrum and an issue in the processing of the Upper Ohio report.

3.2 Status of Corps' inland navigation construction program

The time for the Corps to construct a major project has increased from years to decades over the past 25 years or so. The principle reasons are the high cost of many of the projects and the lack of construction funds from both the federal and non-federal cost sharing partners. At the current time there is only one inland navigation project under continuous construction – the Olmsted locks and dam project - which has been under construction for nearly 25 years, with another 10 years until it is completed. There are at least a dozen projects that are "authorized" for construction that receive little or no funds, or that receive funds intermittently depending on construction activities at Olmsted. The problem of funding was partially addressed by recent legislation (WRDA 2014) which reduced the non-federal share of the Olmsted project so money would be available for the other "authorized" projects. This will alleviate but not solve the problem of construction costs that exceed available funds. According to a Corps construction schedule, most of the "authorized" projects will not begin construction for several decades from today. Moreover, because of constantly changing economic conditions, the projects on the construction list are re-evaluated and re-prioritized every five years or so. The intent is to add the Upper Ohio projects to the list because of their severe structural deficiencies and allow the process to determine if and when to fund construction.

A total of 27 projects were recommended in the Inland Marine Transportation System (IMTS) Capital Investment Strategy (Table 4-9 below), of which eleven were construction and sixteen were rehabilitation. Rehabilitation projects were included on the list even though they can be funded without new "authorization" because the funds for both construction and rehabilitation come from the same Construction General (CG) account.

Table 4-9. The Recommended Program: Projects Included in the 20-Year Funding Horizon

Funding Option	Projects Included in the Funding Level
New Construction	Olmsted L/D Construction
	Lower Monongahela LD 2, 3, and 4
	Chickamauga Lock
	Kentucky Lock Addition
	Upper Mississippi LD 25
	GIWW High Island to Brazos River
	LaGrange ILL WW
	Inner Harbor Navigation Canal Lock
	Greenup Locks and Dam
	Upper Mississippi-LD 22
	Upper Mississippi LD 24
Major Rehabilitation	Emsworth Locks and Dam OHR
	Markland Locks and Dam OHR
	Lockport Lock and Dam ILL WW
	Upper Mississippi LD 25 (Scour Repairs)
	Lower Monumental Lock and Dam
	ILL WW Thomas O'Brien Lock and Dam
	Greenup Dam
	John T. Myers Dam
	Meldahl Locks and Dam
	Montgomery Dam Safety
	Upper Mississippi-Mel Price
	No. 2 Lock Bank Slope Rehab R
	Willow Island Locks and Dam
	Marmet Locks and Dam Rehab
	Joe Hardin Lock
	Upper Mississippi LD 22

3.3 Prioritization of construction of "authorized" projects

The prioritization of construction of "authorized" inland navigation projects is set by a group consisting of industry and government personnel. Industry is represented by the Inland Waterways User Board (IWUB) and is part of the decision-making group because they pay for half of the construction through a fuel tax on their river towing operations. The federal government pays for the other half. The group ranks the projects based on the risk of failure, traffic levels, whether the project had an auxiliary chamber and the transportation savings of barge over rail/truck. The initial priority list for the construction projects is listed below, with start and completion dates assuming current funding per year ($170 million) and increased funding ($320 million).

Table 4-10. Illustrative Program-Level Comparison of Project Construction Schedules

Project	Unconstrained		Current at $170M		Recommended at $320M	
	Start FY	Finish FY	Start FY	Finish FY	Start FY	Finish FY
Olmsted	Ongoing	2018	Ongoing	2019	Ongoing	2019
Lower Mon	Ongoing	2021	Ongoing [1]	2023	Ongoing	2023
Chickamauga	Ongoing	2014	2023 [1]	2026	Ongoing	2015
Kentucky Lock	Ongoing	2016	2024[1]	2029	Ongoing	2019
Inner Harbor	2011	2018	2027	2039	2021	2028
Greenup Locks	2011	2016	2044	2049	2022	2027
Upper Mississippi LD 25	2011	2022	2037	2045	2011	2018
LaGrange	2011	2023	2045	2053	2017	2025
GIWW High Island to Brazos River	2013	2015	2043	2045	2013	2015

1. Ongoing projects would be interrupted or severely limited in funding at the $170 million funding levels and resumed in the fiscal years indicated

3.4 Economic update plan for Upper Ohio project

Authorization of a project does not guarantee construction funds, nor does it guarantee that its position on the priority list will not change. Because of the long period between authorization, start of construction, and completion of construction, the Corps requires economic updates at regular intervals. The current intervals as specified in the "DRAFT FINAL METHODOLOGY FOR CONDUCTING ECONOMIC UPDATES, JANUARY 2011" are three years for projects that are authorized but have not received construction funds, and five years for projects that are authorized and have received construction funds. If the Upper Ohio project is authorized for new construction then the economics would have to be updated within three years. Portions of the draft methodology for conducting economic updates are attached.

Economic updates are production tasks listed in the Project Management Plan (PMP), which is updated following authorization to include the task, schedule, and costs necessary for completion of construction of the authorized project. Typically funds are requested through the budgetary process to update the PMP and initiate detailed design work. In the case of the Upper Ohio, the initial request will include funds for an economic update. Experience has shown that budget requests do not guarantee the approval of funds, which means that the work cannot be performed regardless of the specified cycle. This also means that no substantial work is performed on the project prior to the economic update due to the lack of appropriated funds.

3.5 Conclusion

Funding major construction projects like the Upper Ohio is a lengthy process that is constantly reconsidered in terms of needs and return on investments. Reconsideration is based on economic updates that are required every three or five years depending on whether construction funds have actually been expended on the project, following authorization of construction by Congress. In order to meet the commitments make by the study team to reviewers, the economic update will be included in the initial budgetary request for funds so that it can be performed as soon as possible. The project manager of the Upper Ohio project has committed to this action.

DRAFT FINAL

METHODOLOGY FOR CONDUCTING ECONOMIC UPDATES

JANUARY 2011

Attachment 8-1: ECONOMIC UPDATE METHODOLOGY

1. References:

EC 11-2-199 for the FY2012 Civil Works Program Development
ER 1105-2-100 Planning Guidance Notebook
EC 1165-2-209 CIVIL WORKS REVIEW POLICY
ER 1110-2-1302 CIVIL WORKS COST ENGINEERING

2. Program Development Criteria. Updated Benefit to Cost Ratios (BCR's) are required in support of funding requests for all projects in the Preconstruction Engineering and Design (Investigations Account) or Construction phases. The BCR will be calculated based on the benefits in the latest approved official document, such as Feasibility Report, Chief of Engineers Report, Limited or General Reevaluation Report (LRR or GRR), Engineering Documentation Report (EDR), or other report. In accordance with the current guidance, the updating of economic benefit estimated should be made in coordination with the annual update of project cost estimates. To support of the annual Program Development process, an update of economic benefits and costs should be undertaken in those situations where the Project Delivery Team (PDT) determines changes in project scope and cost warrant a reassessment (ER 1105-2-100 Appendix G).The time frame for economic updates is described below for new start and continuing construction projects.

a. New Construction Projects. For any project or element proposed as new construction, the fiscal year date of approval of the latest economic analysis must not precede the fiscal year of the MSC program submission by more than 3 years. For example, for any new construction project or element in your FY2013 (PY) initial submission, the approval date of the document containing the most recent economic analysis can be no earlier than 1 October 2007 (CCY-4) - the first day of FY2008 (PY-5).

b. Continuing Construction Projects. Continuing construction data from the P2 data base will be used in developing the President's PY Budget. For continuing construction projects, the fiscal year date of approval of the latest economic analysis must not precede the fiscal year of the MSC program submission by more than **5 years**. For example, for any continuing construction project recommended in your June submission, the price level of the economic analysis can be no earlier than 1 October 2005 (**CCY-6)** - the first day of FY 2006 (**PY-7)**. This point in time precedes the start of the fiscal year in which you are making your submission by **5 years**. If the fiscal year of the price level is more than **5 years** ago, you must perform an economic update to show that the calculated BCR and the remaining benefits remaining costs ratio (RBRCR) are current and consistent with this guidance.

3. Economic Update Process. In accordance with the Budget Development Process EC 11-2-199 (for FY 12), the economic update will involve no major new analysis. The purpose of the economic update (Levels 1-3 in Table 1 below) is to support the budget development process and not to reevaluate authorization. It will be limited to reviewing and updating previous assumptions and limited surveying, sampling, and application of other techniques to affirm or develop a reasonable revised estimate of project benefits. Economic updates should be performed in accordance with the update plan in the feasibility or post authorization change report and/or the Project Management Plan. MSCs will approve all economic updates except Level 4. Table 1 describes the four Levels in more detail.

All economic analysis will be conducted using the 7% discount rate and the current year discount rate. BCR's will be calculated using total project cost and total benefits. Costs that have accrued will be discounted back to the price level of the benefits last approved report and this cost will be added to the remaining cost, also in the price year of the last approved report, provided by Engineering as per their guidance. Interest during construction will only be calculated based on remaining construction costs and a schedule to complete that assumes adequate funding.

Table 1

Description of Economic Update Levels

Update Level	**Scope***	**Anticipated Cost and Time****
Level 1 – Reaffirmation (Qualitative analysis affirms that all previous benefits are still valid)	- Qualitative re-verification of key benefit assumptions - Current Cost Estimates - Minimal effort to verify no new Engineering is needed (e.g. H&H) - Discount Costs back to price level of the last approved report - Show BCR and RBRCR - No new plan formulation - No new NEPA	$15K - $50K and One Month Plus
Level 2 – Benefit Update (Some quantitative analysis is needed for benefits, but no major changes)	- Use sampling to update key data in benefits data and assumptions - Re-run economic benefit model - Minimal effort to verify no new Engineering is needed (e.g. H&H) - Current cost estimates - Show BCR and RBRCR at current price levels	$50K-$100K and Two Months Plus

	-No new Plan Formulation - No New NEPA	
Level 3 –Economic Reevaluation (Conditions, Economics, and Engineering have changed so significantly that full reanalysis is warranted)	- Collect all new Economic and Engineering Data - Fully Update Benefits - Obtain Current Cost Estimates - Show BCR and RBRCR at current price levels -No new Plan Formulation - No new NEPA	$100K - $200K and 6 Months Plus
Level 4 – General Reevaluation (Scope is beyond an economic update.)	- Full reanalysis with new Plan Formulation - Follow ER 1105-2-100	Over $200K and 1-year Plus
***Generic scope. Actual process will vary by business line (see attachments 3-6).**		
****These costs are simply estimates for economics and necessary support. These costs do not include funds for updating Total Project Cost estimates. Cost ranges may be exceeded depending on the level of Engineering detail required to support the economic analysis.**		

4. Roles and Responsibilities. The economic update process will require careful coordination between multiple disciplines. The key project delivery team members in the process are project management, economics, and engineering, although this may expand depending on the complexity of the analysis. Each member has specific roles and responsibilities that critical for success.

District Project Management:

- Responsible for providing necessary funding.
- Responsible for complying with all policy and NEPA requirements.
- Responsible for ensuring appropriate level of update is conducted.

District Economics:

- Responsible for providing scope and cost of economic update.
- Responsible for ensuring appropriate level of update is conducted.
- Responsible for all economic documentation to support effort.

District Engineering and Construction:

- Responsible for providing current project cost estimates per EC 1110-2-1302.

- Responsible for providing the appropriate level of engineering support including scope and cost estimate.

MSC Planning and Policy

- Responsible for review and approval (see Table 2 below).

5. Model Certification. There may be cases where economic models used in the last approved report pre-date the current model review and approval requirements in EC 1105-2-407. If the benefits in the last approved report were based on an unapproved/uncertified model and the economic update is a Level 1 or 2, then no new model review and certification requirements will be necessary. If the benefits in the last approved report were based on an unapproved/uncertified model and the economic update would warrant Level 3 or 4 analyses, then EC 1105-2-407 does apply and all review and certification requirements must be followed.

6. Review and Approval Requirements. Review of the economic updates will vary by level of complexity. Each of the levels requires District Quality Control (DQC) and MSC review. Level 4 is subject to all of the review requirements established in EC 1165-2-209. Table 2 outlines the review requirements for each level. A district approval sheet (see attachment 2) must be signed by responsible PDT members.

Table 2

Review and Approval Requirements

Update Level	**DQ**C	**ATR**	**MSC**	**HQ**
Level 1 - Reaffirmation	YES	Done by Another District in MSC	Approves	NA
Level 2 – Benefit Update	YES	Done by Another District in MSC	Approves	NA
Level 3 – Economic Reevaluation	YES	Done by Another District in MSC	Approves	NA
Level 4 - GRR	YES	EC 1165-2-209	Review	Approves

ATTACHMENT 1 – REPORT REQUIREMENTS

1. LEVEL 1 – Reaffirmation Report

- Clearly document authority;
- Clearly document scope has not changed since last approved report (i.e. still within Chief's discretionary authority);
- Clearly document all of key economic (benefit) assumptions;
- Clearly document, through qualitative analysis, that key assumptions have not change since last approved report;
- Clearly document that Engineering does not need updating (e.g. H&H) – *if there is go to at least Level 3*;
- Display benefits at price level of last approved report;
- Display updated costs;
- Discount costs back to price level of last approved report;
- Display BCR and RBRCR for both current discount rate and 7-percent discount rate;
- Recalculate 902 Limit and display all of the required tables and fact sheets in Appendix G of ER 1105-2-100;
- Signed District Approval Sheet (see attachment 2).

2. LEVEL 2 – Benefit Update Report

- Clearly document authority;
- Clearly document scope has not changed since last approved report (i.e. still within Chief's discretionary authority);
- Clearly document all of key economic (benefit) assumptions;
- Clearly document, changes in economic assumptions
    - Use sampling to update economic data
    - Re-run economic model to update benefits to current price level;
- Clearly document that Engineering does not need updating (e.g. H&H) – *if there is go to at least Level 3*;
- Display benefits at current price levels;
- Display updated costs;
- Display BCR and RBRCR for both current discount rate and 7-percent discount rate;
- Recalculate 902 Limit and display all of the required tables and fact sheets in Appendix G of ER 1105-2-100;
- Signed District Approval Sheet (see attachment 2).

3. LEVEL 3 – Economic Reevaluation Report (ERR)

- Clearly document authority;
- Clearly document scope has not changed since last approved report (i.e. still within Chief's discretionary authority);
- Clearly document all of key economic (benefit) assumptions;

- Collect all necessary economic and Engineering data for full reassessment of benefits;
- Re-run economic model using updated economic and Engineering data;
- Display benefits at current price levels;
- Display updated costs;
- Display BCR and RBRCR for both current discount rate and 7-percent discount rate;
- Recalculate 902 Limit and display all of the required tables and fact sheets in Appendix G of ER 1105-2-100;
- Signed District (see attachment 2).

4. LEVEL 4 – General Reevaluation Report (GRR)

    - Follow ER 1105-2-100

ATTACHMENT 2 – EXAMPLE OF DISTRICT APPROVAL SHEET

I submit and certify that all of the requirements for this (**insert Level**) analysis have been fulfilled and the report is in compliance to support budgetary development. The benefits have been calculated and documented as warranted for this analysis, all of the costs are current per ER 1110-2-1302 and the remaining work is in compliance with Section 902 of the Water Resources Development Act of 1986, if applicable, and all of the review requirements required for this (**insert Level**) analysis have been met and documented.

____ Project Manager

____ District Economist

____ District Planning Chief

____District Engineering Chief

____ Deputy District Engineer for Project Management

ATTACHMENT 3 - FLOOD RISK MANAGEMENT REQUIREMENTS

ATTACHMENT 4 – DEEP DRAFT NAVIGATION REQUIREMENTS

ATTACHMENT 5 – COASTAL STORM RISK MANAGEMENT REQUIREMENTS

ATTACHMENT 6 – INLAND NAVIGATION REQUIREMENTS

The Planning Center of Expertise for Inland Navigation (PCXIN) and its virtual resources will be responsible for production and agency technical review for all inland navigation economic updates to ensure consistency and accuracy in the computations. The level of detail for economic updates may fall within three tiers depending on comparison of changes in conditions between the time of the last approved document and current conditions (Tier 4 is beyond the scope of an economic update). The PCXIN will determine the appropriate level of detail and update methodology. Factors that will be considered in determining level of detail include but are not limited to the following:

- Number of years since last official document, lack of available data, approved modeling or current methodology (risk-based for example)
- Methodology and level of detail of previous report
- Changes in traffic at the project under consideration
- Commodity movements: changes in type or composition of commodities moved through the project
- Changes in the project performance or reliability
- Risk of exceeding 902 limit
- Percent of project complete

Level 1 - Minimum effort if there is no evidence to suggest significant changes in the benefits of the project. For navigation projects, the most significant and obvious change would be an increase or decrease in traffic. If there is no marked change in traffic, then the level 1 effort is warranted. For example, if current annual traffic does not significantly deviate from the projected annual taking into account normal variations due to business cycles and weather, then a level 1 update is suggested. The economics will be evaluated based on the benefits in the latest approved document and current cost estimates prepared in compliance with ER 1110-2-1302. The economic update will be restricted to a cursory re-evaluation of the approved project and of the categories of benefits used in the approved report. Once the benefits have been validated, they will be compared to the current cost estimate deflated to the benefits' price level.

Level 2 - Unlike Level 1, this effort will present updated benefits at current price levels. Level 2 is triggered when there are moderate changes to the factors above, but the majority of the assumptions for benefits are still applicable. For example, there is a new commodity movement but the vast majority of the movements in the last approved report are still viable. Level2 effort would update the benefits by evaluating the assumptions and using current levels of traffic and transportation costs. It is not a recalculation of benefits but an updating of benefits based on available data.

Level 3 - Major effort triggered by significant differences in projected and actual traffic. This economic update is limited to re-evaluation of the recommended plan, no reformulation will be conducted.

- **Traffic.** The most recent five year traffic volumes at the project and/or system will be averaged and substituted for the forecasted volume of traffic in the current year. The forecasted growth rate from the current year from the approved report will be applied to the current traffic to yield new traffic forecasts.

- **Capacity.** The updated traffic forecasts will be compared to the estimated capacity of the project to determine if waterway transit times would differ from those in the authorized report. If current traffic is plus or minus 10% of the current year's forecasted traffic, then delay reduction benefits will have to be recomputed for updating purposes. The delay reduction benefits is the WOPC to WPC difference in an average tow delay multiplied by the hourly tow cost for each tow transiting the project The last approved report WOPC and WPC streams of equilibrium tonnage, average tow delays, number of tows, and hourly tow cost. The tonnages and delays would be adjusted to current levels, along with an updated hourly tow cost. The adjusted cash flows will be amortized to compute average annual benefits.

- **Transportation rate savings.** Transportation costs are developed for the existing and least cost all overland transportation mode during the study with the difference represent the transportation benefit of the recommended project (aka barge transportation surplus willingness-to-pay) benefits of the waterway system. Transportation rates at current price levels and IWR hourly operating costs will be used to update the benefits price level.

- **Other project benefits.** Other project benefits vary with the project and the time of the study and could include flood damage reduction, recreation, and ecosystem enhancement, maintenance of the system, water supply benefits and possibly other items. Other project benefits will be updated with the method depending on the importance of the category to total project benefits. For example, for relatively small recreation benefits the update could consist of the application of current day values to recreational usage. Moderate effort that would include a re-computation of benefits based on current traffic and related data.

Level 4 - If there is some indication that the scope of the project has significantly changed, costs are approaching the 902 limit or reformulation may be required, then a General evaluation report (GRR) should be conducted following (See appendix G of ER 1105-2-100).

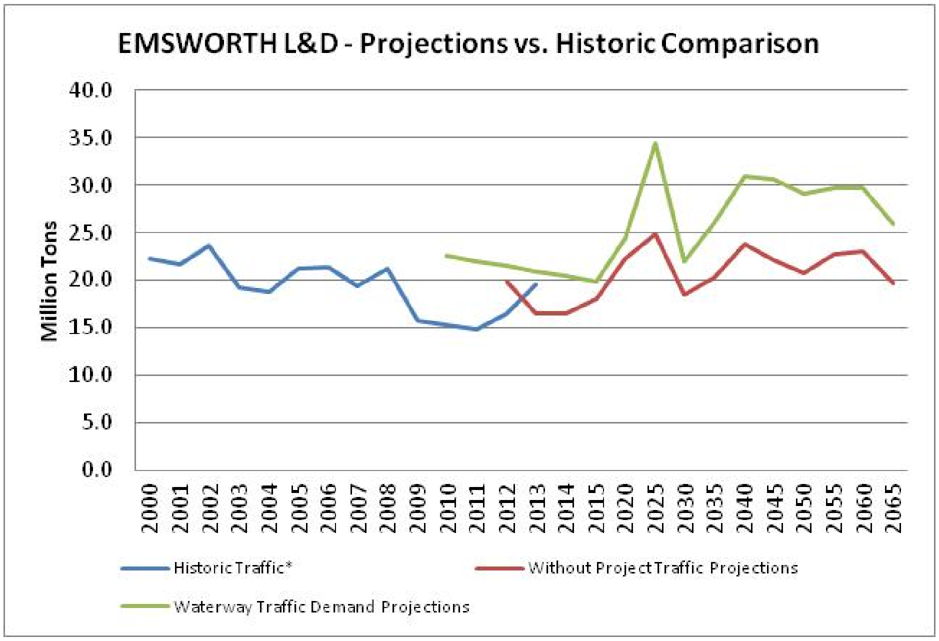
4.0 Equilibrium System Traffic vs. Traffic Demands

A common misconception is that the Corps waterway traffic demand forecasts and waterway traffic forecasts are one and the same: this is not the case. Traffic demand forecasts represent the estimated potential traffic that would move on an unconstrained waterway system while forecasted waterway traffic is the traffic that would move given constraints. The demand forecasts and constraints are input to the system model, (the Navigation Investment Model, or NIM) while forecasted traffic is an output. NIM defines the Ohio River navigation system by not only the number of locks and length of waterway reaches, but also by the performance of the locks – their availability for service, and the cost of waterway transportation resources (equipment and fuel). To the extent that traffic levels increase (congestion occurs) and /or locks are closed, delays occur and the price of waterway transit increases. As waterway transportation costs increase, the willingness-to-pay for barge transportation for some tonnages is exceeded. As a result traffic demands are not fully accommodated. In short, demands are greater than projected traffic.

The "misconception" problem is part of the explanation for an apparent inconsistency between the traffic listed in Table 5-9 and Figure 9-4. In addition to interpreting demands as forecasted traffic, the data in the table and figure are shown at different intervals: one at 10 year intervals and one at 5 year intervals. This inconsistency was corrected in a revised table, Table 5-9, which is included in this document with the data displayed at 5 years intervals to be consistent with the figure.

4.1 Regional coal supply area production forecasts

The 5-year demands were isolated and the Upper Ohio River demands (NAPP – LTI2009) actually peak in the year 2025 (as shown in the graph below).

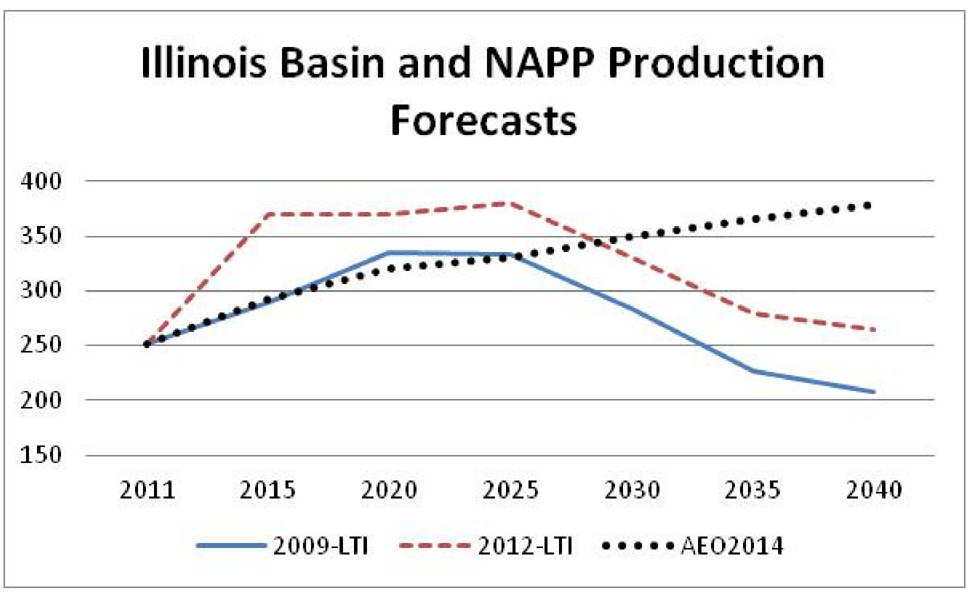


As noted in Appendix B, Attachment 3, Addendum 1 (Forecast of Coal and Sorbent Materials Traffic Demands for the Ohio River Navigation System) "… in the later years, a shift away from the highest sulfur coals is reflected in the projected Base Case coal production totals for the Illinois Basin and for Northern Appalachia, both of which rise strongly due to new scrubbers until the early 2020's and then begin losing tonnage." Though an unusual pattern, it is persistent in the more current AEO and LTI forecasts. In fact, the point of departure between LTI and AEO forecasts is that LTI projects a decline in coal production from these two regions starting in 2020 for LTI2009 and 2025 for LTI2012, while AEO projects continued increases from both regions throughout the forecast period. NAPP forecasts from LTI2009 rise more rapidly before falling below AEO2014, while AEO forecasts for Illinois Basin coals rise more rapidly and sustain this growth to nearly double the levels forecast in LTI2009. As the AEO for 2014 states, "From 2016 to 2030, coal production gradually increases as growing electricity demand and rising natural gas prices spur the use of coal for power generation. After 2030, when existing coal units reach maximum utilization rates and virtually no new capacity is built, coal production stabilizes." It goes on to note, "…strong production growth in the Interior region contrasts with generally stagnant production in Appalachia and the West. Interior coal production reaches new highs as scrubbers installed at existing coal-fired generating units allow them to burn the region's higher-sulfur coals with lower delivered costs."

Mid-Range Coal Production Forecasts from LTI 2009 and LTI 2012 and Reference Case AEO2014
(in millions of tons)

	CAPP			NAPP			Illinois Basin		
	2009-LTI	2012-LTI	AEO2014	2009-LTI	2012-LTI	AEO2014	2009-LTI	2012-LTI	AEO2014
2011	185	185	185	133	133	133	119	119	119
2015	240	140	114	170	205	132	120	165	160
2020	200	140	103	195	175	143	140	195	177
2025	175	137	98	205	175	144	128	205	187
2030	200	150	93	175	150	144	108	180	205
2035	180	175	90	155	130	148	72	150	218
2040	135	160	80	130	120	150	78	145	228

Appalachian coals include CAPP, NAPP, and the relatively small Southern Appalachian fields. CAPP coals are high quality, low sulfur coals – some compliance quality. The CAPP coals of southern West Virginia and eastern Kentucky face high production costs and AEO sees these coals returning to their pre-1990 metallurgical markets. CAPP coal moving through the Upper Ohio is in fact destined for coking facilities. These higher Btu coals will share the same utility coal market as Interior coals (dominated by the Illinois Basin coals of Illinois, Indiana, and western Kentucky). The NAPP coals are more similar to Interior coals in that power plants with scrubbers find these low delivered-price, higher sulfur coals attractive. This attractiveness is reflected in both LTI and AEO forecasts. LTI2009 tracks AEO2014 combined NAPP and Illinois Basin forecasts until 2025, when AEO projections continue to rise and LTI2009 projections for this combined region falls.



Forecasts presented at this fairly disaggregated level are still at a much higher level of aggregation than the microscopic level at which traffic projections are needed. Three traffic levels were prepared: high, medium, and low. The medium forecast represented what was believed to be the most likely regulatory environment. High and low traffic forecasts were governed by commodities other than utility coal – only one forecast was developed for coal. This resulted in some unexpected outcomes at 10 locks on the Ohio and four on the Monongahela, where medium traffic for this subsection was higher than the high traffic scenario for the system as a whole. Traffic demand projections are made at the system level. That is, the region is looked at as a whole in making movement level projections, as opposed to focusing solely on the locks being studied to the exclusion of all others. So while system traffic (traffic moving through any one of the 56 Ohio River System locks or their pools) behaves well, individual locks may not line up as neatly. In the case of locks dominated by coal (greater than 75% of traffic), the high projections of non-utility coals were not able to overcome coal growth, causing the medium scenario to exceed the high scenario.

4.2 Individual project and sub-system traffic

Finally, it has been noted that Upper Ohio traffic is greater than the traffic at any one lock. This is because all the traffic is not “thru” traffic in that some traffic transits one or two of the locks and stops at a dock within the pool, avoiding lockage through one or two of the projects. A movement that passes through all three locks is counted once. A movement that passes through one, but not the others is counted as traffic for that lock and for the system, but not traffic for the other two locks. As a result, Upper Ohio traffic is greater than any one locks traffic, but less than the total traffic counts of the three locks if added together.

MAIN: TABLE 4-6 Revised

ECON APP: TABLE 5-9 Revised

Projected Traffic Demands for the EDM Reach, Ohio River, and ORS, 2006-2070

	EDM Reach[1/]			Ohio River			ORS		
	High	Base Case	Low	High	Base Case	Low	High	Base Case	Low
Actual									
1980	NA	NA	NA	174.9	174.9	174.9	200.5	200.5	200.5
2006	24.8	24.8	24.8	241.5	241.5	241.5	270.7	270.7	270.7
Projected									
2010	28.8	27.0	27.2	259.1	255.6	254.8	286.3	283.6	282.2
2015	27.8	25.4	22.4	293.1	283.3	270.5	323.3	315.2	292.1
2020	31.5	31.4	33.5	319.4	301.8	279.2	351.5	334.4	300.9
2025	34.6	42.2	35.7	332.7	302.7	281.6	366.6	335.7	300.6
2030	41.4	28.3	37.8	346.5	297.9	272.7	378.9	329.9	289.1
2035	49.7	33.7	37.9	376.8	314.0	252.8	411.5	348.6	267.2
2040	54.0	38.6	35.4	400.0	327.5	254.3	436.7	360.2	268.0
2045	56.2	39.1	31.1	419.7	344.9	268.6	463.0	377.3	288.9
2050	56.9	35.9	32.9	430.5	358.1	272.9	470.2	388.7	291.7
2055	48.7	36.8	30.5	427.2	371.3	280.5	470.2	403.2	296.5
2060	53.7	37.2	31.1	434.3	381.1	283.7	479.4	413.3	298.8
2065	63.8	33.5	29.4	432.1	389.5	268.2	478.8	420.9	282.3
2070	71.3	29.2	29.8	432.2	397.9	277.5	485.1	429.2	291.6
Annual Growth									
1990-06	-	-	-						
2006-70	1.70	0.10	0.05	1.72	0.16	0.11	1.86	0.30	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center of Expertise for Inland Navigation

[1/] EMD Reach demands do not include non-lock movements (intra-pool).

MAIN RPT: TABLE 4-6

ECON APP: TABLE 5-9

Projected Traffic Demands for the EDM Reach, Ohio River, and ORS, 2006-2070

	EDM Reach			Ohio River			ORS		
	High	Base Case	Low	High	Base Case	Low	High	Base Case	Low
Actual									
1980	NA	NA	NA	174.9	174.9	174.9	200.5	200.5	200.5
2006	24.8	24.8	24.8	241.5	241.5	241.5	270.7	270.7	270.7
Projected									
2010	29.4	27.5	27.7	259.1	255.6	254.8	286.3	283.6	282.2
2020	32.1	32.0	34.1	319.4	301.8	279.2	351.5	334.4	300.9
2030	42.1	29.0	38.5	346.5	297.9	272.7	378.9	329.9	289.1
2040	54.8	39.5	36.3	400.0	313.9	254.3	436.7	360.2	268.1
2050	57.8	36.9	33.9	430.5	342.9	272.9	470.2	388.7	291.7
2060	54.7	38.3	32.2	434.3	364.2	283.7	479.4	413.3	298.8
2070	72.4	30.3	31.0	432.2	379.4	277.5	485.1	429.2	291.6
Annual Growth									
1990-06	-	-	-						
2006-70	1.70	0.10	0.05	1.72	0.16	0.11	1.86	0.30	0.35

SOURCE: COE Waterborne Commerce Statistics; Planning Center of Expertise for Inland Navigation

Attachment 9

Supplemental Report

Revisions to Upper Ohio Navigation Study Economics due to changes in closure times between failure and repairs of walls in "Without" project condition

Prepared by
Planning Center of Expertise for Inland Navigation
and Risk Informed Economics Division
USACE, Huntington District

Prepared for
USACE, Pittsburgh District

8 April 2016

EXECUTIVE SUMMARY

The *Upper Ohio Navigation Study, Pennsylvania, Final Feasibility Report and Integrated Environmental Impact Statement,* October 2014, formulated, evaluated, and recommended lock improvements at three project sites: Emsworth, Dashields, and Montgomery (EDM). The final feasibility draft report was submitted for Independent External Peer Review (IEPR) and all but one comment was ”concur” between the Project Delivery Team (PDT) and IEPR Team. The only “non-concur” comment was related to the assumption by the PDT that in the event of a catastrophic failure of lock walls at any of the three project sites, preconstruction activities could be accomplished in 12 months. The IEPR panel contended that this duration was unrealistically short. The Civil Works Review Board found merit in the IEPR comment and in May of 2015 directed Pittsburgh District and the Upper Ohio Project Delivery Team (PDT) to review their assumptions regarding preconstruction activity durations. Construction durations were not included in this reassessment (for example, the time to reconstruct the middle wall or land wall at any of these projects would remain at 24 or 30 months, respectively).

A Pittsburgh District team was assembled to re-examine the amount of time that would be required to obtain funds to begin construction of a failed wall after a “catastrophic” failure of a wall at EDM. The team recommended a pre-construction duration of 53 months for the middle wall, land, and guide walls (compared to 12 months used in the Feasibility Study). The team also recommended 85 months for preconstruction activities for a wall failure that would impact only the river chamber in the WOPC (i.e. involving the river and/or guard wall). The use of the recommended durations was approved by Headquarters.

The focus on this supplemental report is an update of economic results and comparison with the results documented in the CWRB report. The report summarizes both the project economics presented in the October 2014 feasibility report submitted to the CWRB (CWRB report) and the revised economics using adjusted closure durations. All other plan formulation rationale is the same as for the CWRB report, i.e. Reactive Maintenance or Fix as Fails is selected as the operations and maintenance strategy and the same lock sizes are deemed appropriate for With Project assessments.

The Without Project condition is a Fix-as-Fails or Reactive Maintenance (RM) policy that replaces major components as they fail. The current evaluation (2015-2016) used longer durations for the downtime following failure. The longer durations result in greater transportation losses from unscheduled closures and higher externality costs associated with higher levels of waterway traffic diverted to overland routes. The changed Without Project condition results in higher net benefits and BCRs.

The economics were recalculated according to a three-step process: first, the economics were recomputed in the system model (NIM) using the venture-level costs and the longer durations; second, the economics were adjusted in an excel workbook for the change between the venture level costs (Oct 09) and the certified M-CACES costs (Oct 14); and third the BCRs were updated in the excel workbook using the recommended deflation of costs procedure rather than the alternative update of benefits and costs procedure.. The economics were computed at four discount rates: the FY 11 rate of 4.125% used in the original study; the FY 14 rate of 3.5% used in report submitted to the CWRB, the current FY 16 rate of 3.125%, and the OMB preferred rate of 7.0%. In sum, the BCRs decrease as the discount rate increases, the BCRs decrease as the costs increase (at a rate higher than inflation), and the BCRs did not change with the update procedure. A full accounting of the original and updated values is given in section 6 of this paper. Table ES-1 is a summary table showing the values in the report submitted to the CWRB and the updated values from this evaluation that were used to replace the CWRB report values in a revised (2016) feasibility report.

Table ES-1: Certified costs at Oct 14 dollars (millions); report submitted to CWRB; updated average annual equivalent values				
Short durations used in CWRB report				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 226.1	$ 220.1	$ 210.3	$ 171.1
Incremental costs over WOPC	$ 82.0	$ 89.2	$ 101.8	$ 166.4
Incremental net benefits	$ 144.1	$ 130.9	$ 108.5	$ 4.7
BCR	2.8	2.5	2.1	1.0
Long durations developed and evaluated in response to IEPR and CWRB comments				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 355.7	$ 346.6	$ 332.1	$ 276.3
Incremental costs over WOPC	$ 83.2	$ 90.5	$ 103.1	$ 168.2
Incremental net benefits	$ 272.5	$ 256.1	$ 229.0	$ 108.1
BCR	4.3	3.8	3.2	1.6

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Contents

Tables

Update of Economics in Response to Reviews by IEPR Panel and CWRB

1. Background

The *Upper Ohio Navigation Study, Pennsylvania, Final Feasibility Report and Integrated Environmental Impact Statement*, October 2014 formulated, evaluated, and recommended lock improvements at three project sites: Emsworth, Dashields, and Montgomery. These three sites, referred to as EDM or the Upper Ohio, were treated as a system. The final feasibility draft report was submitted for Independent External Peer Review (IEPR), beginning with the 7 April 2014 kickoff meeting. The only "non-concur" comment was related to the assumption by the Project Delivery Team (PDT) that in the event of a catastrophic failure of lock walls at any of the three project sites, preconstruction activities could be accomplished in 12 months. The IEPR panel contended that this duration was unrealistically short, while the PDT maintained that emergency funding would be forthcoming at a capability level. The final feasibility report submitted to USACE Headquarters retained the PDT assumption. The Civil Works Review Board (CWRB) unanimously approved moving forward with the Feasibility Study for State and Agency review on 21 October 2014 meeting with this one non-concur comment; however, subsequent to this the CWRB found merit in the IEPR comment and in May of 2015 directed Pittsburgh District and the Upper Ohio Project Delivery Team (PDT) to review their assumptions regarding preconstruction activity durations. Construction durations were not included in this reassessment (for example, the time to reconstruct the middle wall or land wall at any of these projects would remain at 24 or 30 months, respectively). The preconstruction duration is important because it directly translates into time that the river is closed to navigation. This, in turn, affects the economics of the tentatively recommended project.

A Pittsburgh District team was assembled to re-examine the amount of time that would be required to obtain funds to begin construction of a failed wall after a "catastrophic" failure of a wall at EDM. A catastrophic failure was loosely defined as costing more than $20 million in repair costs which is the general limit of capability for Operations and Maintenance funding. Typically, a catastrophic failure would require total wall reconstruction which would cost more than $20 million and thus require additional means and more time to obtain funds from other than the O&M account. The team developed durations to complete each activity under three fund-acquisition scenarios. These scenarios were called Critical, Urgent and Normal, in order of decreasing sense of urgency in the budgeting process, which would be reflected in increasing durations of the activities and therefore greater time required to receive funding. The team recommended that the most appropriate scenario to apply to a main chamber or project closure scenario for the Upper Ohio with no loss of life potential is Urgent. The Urgent scenario's pre-construction duration is 53 months for the middle wall, land, and guide walls (compared to 12 months used in the Feasibility Study submitted to the Civil Works Review Board henceforth referred to as the CWRB report). The team also recommended the Normal scenario of 85 months for preconstruction activities for a wall failure that would impact only the river chamber in the WOPC (i.e. involving only the river and/or guard wall) as the economic impacts would be less. The alternatives considered and the recommendations of this team are detailed in a memorandum for the USACE Chief of Civil Works Planning and Policy signed off and transmitted through the LRD Chief of Planning and Policy on 27 July 2015, subject "Upper Ohio Navigation Study (UONS); Without Project Condition Failure Duration Analysis; Recommended Duration." Time-line graphs of the alternative closure duration scenarios are given in Attachment 1 to this paper. **Figure 1** below identifies the location of the subject project features at Emsworth Locks and Dams. In this figure the larger chamber adjacent to the esplanade is the main or land chamber and the smaller chamber is the auxiliary or river chamber.

Figure 1: Lock Component Nomenclature.

2. Purpose

This purpose of this paper is provide the economics given longer duration times between failures and repairs. In addition the paper will provide adjusted economics using the HQ recommended BCR update procedure rather than the update procedure used in the CWRB report. This paper will provide an explanation of changes in the BCR from the 2009 draft report, the CWRB report, and this current effort.

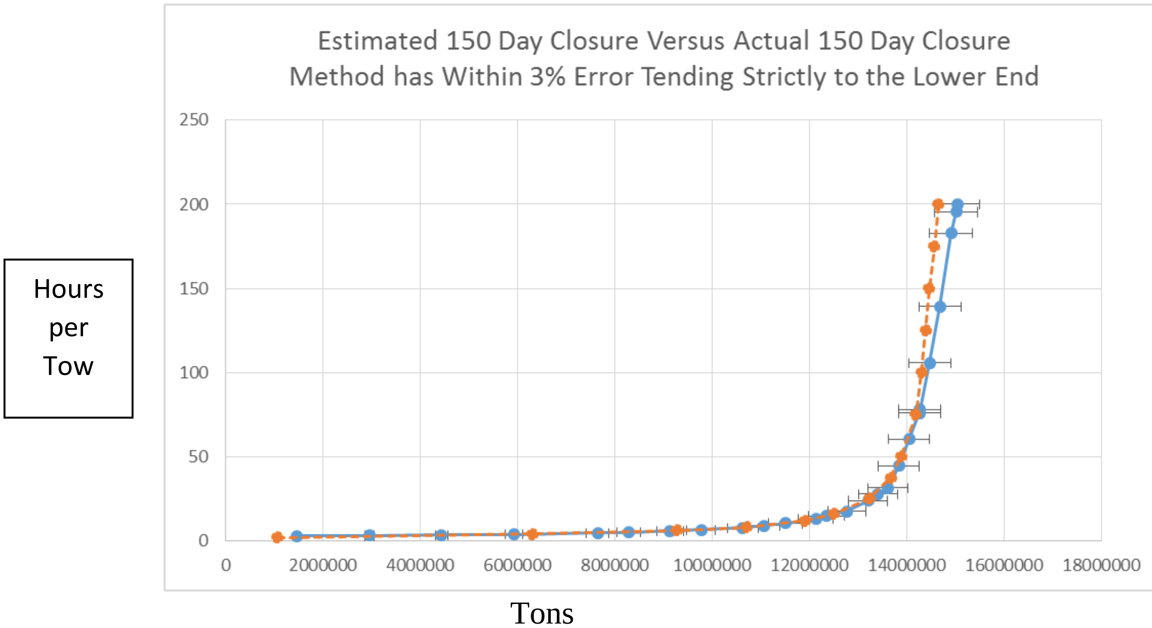
Details on the assumptions, inputs, modeling, and navigation system performance were provided in the CWRB report. The Navigation Investment Model (NIM) was used in this current evaluation and the CWRB report with the only difference being the length of time of chamber downtime between a failure and reconstruction. The closure durations used in this update were approved by HQUSACE in October 2015 and are shown as time-line figures in Attachment 1. All other plan formulation rationale is the same as for the CWRB report, i.e. Reactive Maintenance or Fix as Fails is selected as the operations and maintenance strategy and the same lock sizes are deemed appropriate for With Project assessments. No other model parameters or inputs of the CWRB report evaluation have been adjusted; however, additional lock transit curves were required. This was necessitated by the closure durations that had not been modeled for the CWRB report. The derivation of these new curves is presented in Section 3 below.

3. Additional Transit Curves

Longer replacement durations for failed walls were introduced as part of this supplemental report. These longer durations did not always match-up with closure/lock availability tonnage-transit curves modeled as part of the feasibility report. At a project, the performance of the lock can be represented with a series of curves, referred to as a family of curves, under a range of percent availability characterizations. Each curve represents a series of simulated average tow transit times for a specific lock availability percentage, and the respective tonnage throughput corresponding with each of those times. For example, normal operations would be represented by a tonnage transit curve that reflects 100% availability for service, while a lock that is closed to traffic for 180 days would have a tonnage transit curve that reflects 50% unavailability. While many closure duration-specific curves were available from the CWRB report evaluation, there were closure durations required for this supplement that were not available. Rather than generate additional curves through simulation, a statistical technique was used to generate the needed curves.

First, there was a straight line interpolation between data points on the existing family of closure curves in order to get new data points to compare the tonnage values of the separate curves at the same transit time value. Then the data points were used to create a family of curves, closure versus tonnage, at each of these cross sectional transit time data points. These new curves allowed us to see the decaying trend, which was slightly different for each closure duration's curve. Each decay curve, at each cross sectional point, was straight line interpolated to gather the closure data point we needed. For example, if you have a 50 day closure curve and a 100 day closure curve that at 15 hours of delay move 80 and 60 million tons, respectively, the tons moved at 15 hours delay for the 75 day closure is 70 million tons. These values were then compiled into a data set and plotted as a closure curve. In the cases where the missing curve fell between existing curves, this method worked quite nicely with less than 5% conservative error (see **Figure 2).** The method was lacking in accuracy when attempting to project larger closure values from smaller ones, however, due to the fact that the larger closure values played a more significant role in shaping the curve than the smaller values.

Figure 2: Estimating Traffic-Transit Time Relationships from Existing Curves



4. Project Economics

4.1. Without Project Condition

The Without Project condition is a Fix-as-Fails or Reactive Maintenance (RM) policy that replaces major components as they fail. As discussed above, the revised cost-benefit analysis uses longer periods of time to recover from the failure of the wall components in describing the Without Project condition and assessing its economic performance. As can be seen in **Table 1**, the longer durations result in greater transportation losses from unscheduled closures and higher externality costs associated with higher levels of waterway traffic diverted to overland routes. No repair\replacement costs were changed, but note that the RM alternative's unscheduled lock repair costs are actually less with the revised durations. This phenomenon repeats throughout subsequent analyses of other alternatives whenever failures of existing lock walls are a possibility. Longer repair times mean that costs are spread-out over a longer period of time and are pushed further out in time, meaning discounted values are less in the revised results than they were in the shorter duration outages of the CWRB report. In the end, though, the RM scenario's longer duration replacement activity degrades benefits severely, while costs are only slightly lower. Net benefits drop from $210.2 million to $105.3 million and the Benefit-Cost-Ratio

(BCR) drops from 6.3 to 3.8 between the CWRB and the revised results of this supplemental report.

Table 1: Reactive Maintenance – EDM, Mid Forecast
($ Oct 09 millions; 4.125 percent; average annual equivalent values)

	Mid - Forecasts	
	CWRB report	Revised
Reactive Maintenance Benefits		
Water Transportation Surplus	$ 451.4	$ 451.4
Transportation Losses from Unscheduled Closures	$-199.7	$ -305.1
Externality Costs Incurred	$ -2.1	$ -3.6
Total System Benefits	**$ 249.6**	**$ 142.7**
Reactive Maintenance Costs		
Scheduled Lock Improvements	$ 0.0	$ 0.0
Scheduled Lock Maintenance	$ 8.4	$ 8.4
Unscheduled Lock Repair	$ 22.2	$ 20.2
Normal O&M	$ 8.0	$ 8.0
Random Minor	$ 0.8	$ 0.8
Total System Costs	**$ 39.4**	**$ 37.4**
Net Benefits	**$210.2**	**$105.3**
BCR	**6.3**	**3.8**

See Table 7-4, page 97 UONS Economics Appendix

*Note: Two benefit categories have been redefined from those in the analogous tables in the 2014 Feasibility Report, therefore the 2014 values differ. "Water Transportation Surplus" above equals "Base Waterway Transportation Surplus (full operations)" + "Reduced Surplus from Scheduled Closures" in the 2014 Report, and "Transportation Losses from Unscheduled Closures" above equals "Land transportation costs Incurred from Unscheduled diversions" + "Reduced Surplus from Unscheduled Closures" in the 2014 Report.

4.2. With Project Condition

Five alternatives remained in the final screening: Advanced Maintenance (AMA), new 110'x600' locks and a FAF auxiliary 600' at each of the three project sites (LMA 7), new 110'x800' locks and a FAF auxiliary 600' at each of the three project sites (LMA 8), new 110'x1200' locks and a FAF auxiliary 600' at each of the three project sites (LMA 9), and two new 110'x600' chambers (one chamber's start is deferred) at each of the three project sites. The economic performance of each investment alternative is discussed in the following subsections. The original planning period for each was from 2012 to 2068, with an on-line date of 2018. The schedule has since been slipped by six years.

4.2.1. Advanced Maintenance (AMA)

The AMA alternative provides benefits incremental to the RM alternative. In the AMA, scheduled closures to replace components prior to failure have reduced the Water Transportation Surplus relative to the RM alternative; however, by replacing components ahead of failure where economically justified, Transportation Losses from Unscheduled Closures are greatly diminished in the AMA and this benefit overwhelms the differences between Water Transportation Surplus values in the RM and AMA alternatives (see **Table 2**).

Table 2: Advanced Maintenance (AMA) – EDM, Mid Forecast
($ Oct 09 millions; 4.125 percent; average annual equivalent values)

	Mid - Forecasts	
	CWRB Report	Revised
Advanced Maintenance Benefits		
Water Transportation Surplus	$388.0	$388.0
Transportation Losses from Unscheduled Closures	$ -23.5	$ -34.4
Externality Costs Incurred	$ -0.2	$ -0.2
Total System Benefits	**$364.3**	**$353.4**
Advanced Maintenance Costs		
Scheduled Lock Improvements	$ 57.1	$ 57.1
Scheduled Lock Maintenance	$ 7.8	$ 7.8
Unscheduled Lock Repair	$ 3.8	$ 3.1
Normal O&M	$ 8.0	$ 8.0
Random Minor	$ 0.8	$ 0.8
Total System Costs	**$ 77.5**	**$ 76.8**
Incremental Benefits	**$114.8**	**$210.6**
Incremental Costs	**$ 38.0**	**$ 39.4**
Incremental Net Benefits	**$ 76.8**	**$171.3**
BCR (Incremental)	**3.0**	**5.4**

*Note: Two benefit categories have been redefined from those in the analogous tables in the 2014 Feasibility Report, therefore the 2014 values differ. "Water Transportation Surplus" above equals "Base Waterway Transportation Surplus (full operations)" + "Reduced Surplus from Scheduled Closures" in the 2014 Report, and "Transportation Losses from Unscheduled Closures" above equals "Land transportation costs Incurred from Unscheduled diversions" + "Reduced Surplus from Unscheduled Closures" in the 2014 Report.

Though revised benefits for the AMA alternative are slightly lower than CWRB report benefits, the RM transportation losses increase so dramatically between the CWRB and the revised model runs that incremental benefits relative to the RM alternative are much greater in the revised model results. This relates directly to the fact that longer duration unscheduled outages in the RM alternative impose much higher transportation losses. Incremental costs changed very little between the CWRB and revised model results.

4.2.2. New Lock Chambers at EDM and Reactive Maintenance

All new lock construction footprints include a portion of the existing river chambers and extend riverward of the existing river walls, leaving the existing 600' main chamber in-place to handle waterway traffic during construction. This strategy increases the risk of a total river closure on the upper Ohio River during construction. Component reliability analysis indicates possible failure to occur at the existing 600' chambers during construction. New 600' (LMA 7), 800' (LMA 8), and 1200' (LMA 9) riverward lock chambers at EDM were modeled with the existing 600' land chambers maintained in a reactive maintenance (RM) mode during and after construction. The twin 600' LMA 1 was also modeled with the existing 600' chamber maintained during construction of the first chamber only. It was assumed that if the existing 600' chamber failed during construction, project re-openings would occur in an expedited fashion, while failures after construction would impact the land chamber, resulting in the longer duration schedule for replacement. The results are shown in **Table 3** below.

Table 3: New Twin 600' (LMA 1), 600' (LMA 7), 800' (LMA 8), or 1200' (LMA 9) Locks at EDM, Mid Forecast, Average Annual Costs and Benefits (2012-2068, 4.125%; $ Oct 09 millions; average annual equivalent values)

	Twin 600' (LMA 1)		600' (LMA 7)		800' (LMA 8)		1200' (LMA 9)	
	CWRB Report	Revised	CWRB Report	Revised	CWRB Report	Revised	CWRB Report	Revised
New Lock with RM Benefits								
Water Transportation Surplus	$474.3	$474.3	$474.3	$474.3	$474.4	$474.4	$474.4	$474.4
Transport Losses from Unsched Closures	$-39.6	$-39.6	$-40.0	$-40.2	$-45.0	$-45.1	$-56.0	$-56.1
Externality Costs Incurred	$-0.9	$-0.9	$-0.9	$-0.9	$-1.0	$-1.0	$-1.3	$-1.3
Total System Benefits	**$433.9**	**$433.9**	**$433.4**	**$433.2**	**$428.4**	**$428.3**	**$417.1**	**$416.9**
New Lock with RM Costs								
Scheduled Lock Improvements	$92.8	$92.8	$72.2	$72.2	$84.0	$84.0	$100.1	$100.1
Scheduled Lock Maintenance	$1.2	$1.2	$4.7	$4.7	$4.5	$4.5	$4.2	$4.2
Unscheduled Lock Repair	$7.3	$6.9	$18.8	$17.6	$18.8	$17.6	$18.8	$17.7
Normal O&M	$8.0	$8.0	$8.0	$8.0	$8.0	$8.0	$8.0	$8.0
Random Minor	$0.4	$0.4	$0.6	$0.6	$0.6	$0.6	$0.6	$0.6
Total System Costs	**$109.8**	**$109.3**	**$104.3**	**$103.2**	**$115.9**	**$114.8**	**$131.7**	**$130.5**
Incremental Benefits	**$184.4**	**$291.1**	**$183.8**	**$290.4**	**$178.8**	**$285.5**	**$167.5**	**$274.2**
Incremental Costs	**$70.3**	**$71.9**	**$64.9**	**$65.7**	**$76.5**	**$77.3**	**$92.3**	**$93.1**
Incremental Net Benefits	**$114.1**	**$219.3**	**$118.9**	**$224.7**	**$102.3**	**$208.2**	**$75.4**	**$181.2**
BCR (Incremental)	**2.6**	**4.1**	**2.8**	**4.4**	**2.3**	**3.7**	**1.8**	**2.9**

*Note: Two benefit categories have been redefined from those in the analogous tables in the 2014 Feasibility Report, therefore the 2014 values differ. "Water Transportation Surplus" above equals "Base Waterway Transportation Surplus (full operations)" + "Reduced Surplus from Scheduled Closures" in the 2014 Report, and "Transportation Losses from Unscheduled Closures" above equals "Land transportation costs Incurred from Unscheduled diversions" + "Reduced Surplus from Unscheduled Closures" in the 2014 Report.

NED plan benefits are derived from a more efficient transportation system because of improved reliability and increased capacity. Capacity increases are the result of fewer closures at the new chambers and the fact that the existing 360’ auxiliary chamber will be replaced by a larger lock that can potentially process large tows in fewer cuts, which should lower the average processing times for large tows that are having to be processed in multiple cuts currently. Again, because the NED plan continues to maintain the existing 600’ chamber, the dis-savings associated with the river closures from future scheduled de-waterings of the old chamber are largely avoided. It is important to note that though new lock construction at EDM buys down risk and lowers future unscheduled lock repair and scheduled maintenance costs relative to reactive maintenance, the "…with-project alternatives show lower transportation savings during construction of the new lock. This is due to intermittent river closures when the existing 600’ chamber closes for repair during construction of the new chamber." (see p111, CWRB report Economics Appendix). This also in large part explains the relatively high Transportation Losses from Unscheduled Closures for the four new lock alternatives displayed in **Table 3** above. It is also the reason that revised model results with their longer closure repair durations have slightly higher Transportation Losses from Unscheduled Closures than those for the CWRB report model runs.

Incremental net benefits and the BCR are greatest for LMA 7 in both the CWRB report and revised cost benefit analyses under the Base Case traffic scenario. When comparing between the two reports, the revised results show increased incremental net benefit owing to With Project avoidance of the longer closure disruptions in the revised RM alternative.

5. Sensitivity Analysis

In light of the uncertainty surrounding future market and navigation conditions, analyses were conducted for the purpose of testing the economic viability of the NED plan given changes in key economic variables, namely traffic forecasts and interest rates. Traffic forecast tests included high, low, limiting the growth of traffic to the initial 20 years in the forecast period, and having no growth beyond the base (2007) level. The sensitivity of results to different interest rates was also tested. Specifically, results were tested against the current OMB interest rate of 7.0 percent, the 4.125 percent applicable interest rate used in the CWRB report, and the current interest rate of 3.125 percent. The results of these sensitivity analyses in the CWRB report and these same sensitivities using the longer closure durations of this supplemental report are presented in this section.

5.1. High and Low Alternative Forecasts

Table 4 lists the incremental annual net benefits for each investment plan evaluated under the low, mid, and high case scenarios. Among the five with project plans shown, model results for both the CWRB report and this supplemental report indicate that the optimum investment plan is the installation of a new 600’ lock chamber with reactive maintenance of the existing 600’ lock (LMA 7) under the Low and Mid Case traffic scenarios. Under the High Case traffic forecast scenario, the optimum investment plan is for installation of two new 600’ locks at each facility, with the second locks beginning construction eight years after the beginning of construction on the first locks (LMA 1). Incremental benefits increase substantially between the CWRB report and the supplemental report's revised economics regardless of traffic scenario.

Table 4: Incremental Annual Net Benefits by Plan and Traffic and Duration Scenario 2012-2068, 4.125%, $ Oct 09 millions; average annual equivalent values

Plan Description	Low Case		Mid Case		High Case	
	CWRB report	Revised	CWRB report	Revised	CWRB report	Revised
Advance Maintenance (AMA)	$66.0	$151.9	$76.6	$171.3	$101.4	$219.7
Twin 600' Chambers (LMA 1)	$88.3	$180.8	$113.8	$219.3	**$181.0**	**$299.8**
600' Chamber (LMA 7)	**$93.4**	**$186.4**	**$118.9**	**$224.7**	$178.9	$295.9
800' Chamber (LMA 8)	$77.0	$170.2	$102.3	$208.2	$169.3	$288.1
1200' Chamber (LMA 9)	$51.1	$144.3	$75.2	$181.2	$143.9	$263.1

See Table 10-1 page 121 of UONS Economics Appendix

5.2. No Growth and 20-Year Limited Growth

In addition to the high, mid-level and low growth scenarios, two additional forecast scenarios were analyzed for the tentatively recommended plan (LMA 7) – a no growth in traffic demands beyond the base level and a limitation on growth of traffic demand to the first 20 years of the period of analysis. **Table 5** shows the results for the no growth and twenty year limited growth in traffic demand with the mid-forecast scenario using both the CWRB report and the revised results. Comparing No Growth traffic case with No Growth after 20 Years and the Mid Case demonstrates the effect of traffic levels on incremental benefits, and by extension, on net incremental benefits. The higher the traffic, the greater the benefits. Comparison between CWRB report and the revised results demonstrates the effect of longer replacement durations on incremental benefits and net incremental benefits. The revised, longer outage durations yield higher incremental net benefits. When comparing the original CWRB report and the revised results, net incremental benefits in the No Growth case increase by $72.4 million and increase by $93.8 million in the No Growth after 20-Years case.

Table 5: LMA 7 - Comparison of Results with No Growth and 20-Year Limited Growth Traffic Demands
($ Oct 09 millions; 4.125 percent; average annual equivalent values)

Plan Description	No Growth		20-year Limited Growth		Mid Forecast	
	CWRB report	Revised	CWRB report	Revised	CWRB report	Revised
Incremental Benefits over WOPC	$96.2	$169.4	$153.7	$248.3	$183.8	$290.4

Incremental Costs over WOPC	$64.9	$65.7	$64.9	$65.7	$64.9	$65.7
Incremental Net Benefit	$31.3	$ 103.7	$88.8	$182.6	$118.9	$224.7
Incremental BCR	1.5	2.6	2.4	3.8	2.8	4.4

5.3. Alternative Discount Rate

The draft Feasibility Report dated 2012 used the FY 11 discount rate of 4.125% to identify the NED plan while the CWRB report used the FY 14 discount rate of 3.5%. In addition both reports calculated the economics using the OMB preferred rate of 7 %. The current FY16 discount rate is 3.125%.For this supplemental report, these four discount rates were used to calculate the economics of the tentatively recommended plan. The incremental net benefits decreases as the discount rate increases, but for all rates the economics are positive (see **Table 6**).

Table 6: Economic summaries of short and long durations with varied discount rates ($ Oct 09 millions; average annual equivalent values)

	3.125%		3.500%		4.125%		7.000%	
Cost = $1.48 billion	CWRB report	Revised	CWRB report	Revised	CWRB report	Revised	CWRB report	Revised
Incremental benefits over WOPC	$197.8	$311.1	$192.5	$303.1	$183.9	$290.4	$149.6	$241.7
Incremental costs over WOPC	$52.3	$53.0	$56.9	$57.7	$64.9	$65.7	$106.1	$107.2
Incremental net benefits	$145.5	$258.1	$135.6	$245.5	$ 119.0	$224.7	$43.5	$134.4
BCR	3.8	5.9	3.4	5.3	2.8	4.4	1.4	2.3

6. Economics updated from Oct 2009 to Oct 2014

6.1. Background

The original evaluation of the projects and the identification of the best future course of action regarding the operation and maintenance was performed in the 2009 to 2010 time period. The benefits and costs used in the evaluation were at an October 2009 price level and the discount rate used in the computation was the FY11 rate of 4.125%. The costs were venture level for all potential projects; the costs for the recommended project were then developed at the M-CACES level and certified at an October 2014 price level for inclusion in the report submitted to the Civil Works Review Board (CWRB report) in 2014. The benefits of the recommended plan were updated by updating rail and barge costs from 2009 to 2014 and computing the difference to get benefits (savings per ton) at the 2014 price level. The discount rate used in the computation was the FY14 rate of 3.5%.

The economics for the long durations were computed using the 2009 data used in the original analysis since updated costs for all the alternatives and updated benefits could not be obtained in a timely and cost-effective manner. This approach was approved by HQ. The economics were then updated to 2014 price levels using the same approach as in the CWRB report. However given the time lapse between the original analysis in 2009-2010 and the current time (Apr 2016) the method used to update benefits was questioned by current reviewers since the approach was considered valid for short but not mid-term adjustments. In response the update was also performed using a second method which is also the officially recommended method; i.e. deflating costs back to the price level of the benefits or to Oct 2009. Both methods used the current FY16 discount rate of 3.125%.

The venture level costs in October 2009 dollars and the certified M-CACES cost estimate in $October 2014 dollars are listed in **Table 7**. Estimated costs increased 57 percent from 2009 to 2014 compared to an inflation rate of about 13 percent.

Table 7: Total Project Cost for Recommended Plan – Venture Level and M-CACES ($thousands)

Cost level	Venture	M-CACES Certified
Price level	$Oct 2009	$Oct 2014
Total project cost	$1,479,000	$2,320,082

6.2 Steps to update economics for long durations

The economics for longer duration closures were updated according to a three-step process, as described below.

6.2.1 Step 1 – compute economics using 2009 data and long duration

Step 1 consisted of replacing the short durations between failure and reconstruction with the long durations, with no other changes. The results with both the short and long durations are shown in Table 8. The economic results improved; for example the BCR at 7% increased from 1.4 with the short durations to 2.3 with the long durations.

Table 8: Screening level costs at Oct 09 dollars (millions) for NED alternative; average annual equivalent values				
Short used in original evaluation				
Cost = $1.48 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 197.8	$ 192.5	$ 183.9	$ 149.6
Incremental costs over WOPC	$ 52.3	$ 56.9	$ 64.9	$ 106.1
Incremental net benefits	$ 145.5	$ 135.6	$ 119.0	$ 43.5
BCR	3.8	3.4	2.8	1.4
Long evaluated in response to IEPR and CWRB comments				
Cost = $1.48 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 311.1	$ 303.1	$ 290.4	$ 241.7
Incremental costs over WOPC	$ 53.0	$ 57.7	$ 65.7	$ 107.2
Incremental net benefits	$ 258.1	$ 245.5	$ 224.7	$ 134.4
BCR	5.9	5.3	4.4	2.3

6.2.2 Step 2 – update economics to Oct 2014 price level

Step 2 consisted of updating the economics to account for the more detailed and up-to-date cost estimate at Oct 14 price levels rather than the venture level estimates at Oct 09 price levels used in the original analysis. The results for both the short and long durations are listed in Table 9. Linking to the previous table and the report submitted to the CWRB, the increase in cost reduced the BCR from 1.4 to 1.0 at 7% for the economics using the short durations. Substituting the long for the short durations but with the Oct 14 costs increases the BCR from 1.0 to 1.6 at the 7% discount rate.

Table 9: Certified costs at Oct 14 dollars (millions) for NED alternative; average annual equivalent values				
Short used in original evaluation				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 226.1	$ 220.1	$ 210.3	$ 171.1
Incremental costs over WOPC	$ 82.0	$ 89.2	$ 101.8	$ 166.4
Incremental net benefits	$ 144.1	$ 130.9	$ 108.5	$ 4.7
BCR	2.8	2.5	2.1	1.0
Long evaluated in response to IEPR and CWRB comments				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 355.7	$ 346.6	$ 332.1	$ 276.3
Incremental costs over WOPC	$ 83.2	$ 90.5	$ 103.1	$ 168.2
Incremental net benefits	$ 272.5	$ 256.1	$ 229.0	$ 108.1

BCR	4.3	3.8	3.2	1.6

6.2.3 Step 3 – update economics by deflating costs to Oct 09 price level

The method recommended by HQ to update the economics due to a change in costs is to deflate the costs back to the year of the benefit values using the Civil Works Construction Cost Index composite index. The indices for 2009 and 2014 are listed in Table 10, along with the deflator factor which was computed by dividing the 2009 index by the 2014 index. The deflator factor is 87.4%.

Table 10: CWCCIS indices	
Fiscal Year	Composite index
2009	703.00
2014	804.05
deflator	0.8743237
Source: USACE EM 1110-2-1304 from 30 September 2015	

Table 11 lists the results of the update using the deflation method. The incremental benefits are the 2009 values listed above in Table 8. For example the incremental benefits at 7% for the long duration closure are $241.7 million in Tables 8 and 11. The incremental costs are the October 2014 costs listed in Table 9 multiplied by the deflation factor of 87.4%. For example the incremental cost at 7% in Table 9 is $168.2 million which, when multiplied by 87.4%, gives the $147.1 million listed in Table 11. While the incremental net benefits are lower since they are Oct 2009 price level rather than the October 2014 price level in Table 9, the BCRs are the same.

Table 11: Certified costs at Oct 14 dollars (millions) for NED alternative; average annual equivalent values				
Short used in original evaluation				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 197.8	$ 192.5	$ 183.9	$ 149.6
Incremental costs over WOPC	$ 71.7	$ 78.0	$ 89.0	$ 145.5
Incremental net benefits	$ 126.1	$ 114.5	$ 94.9	$ 4.1
BCR	2.8	2.5	2.1	1.0
Long evaluated in response to IEPR and CWRB comments				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 311.1	$ 303.1	$ 290.4	$ 241.7
Incremental costs over WOPC	$ 72.7	$ 79.1	$ 90.1	$ 147.1
Incremental net benefits	$ 238.4	$ 224.0	$ 200.3	$ 94.6
BCR	4.3	3.8	3.2	1.6

7.0 Conclusion

The use of longer durations between failure and repairs improves the economic results of the recommended plan since the recommended plan avoids many of the longer disruptions that would otherwise occur in the absence of planned reconstruction. At 7% the enhanced economics are evidenced by the BCR, which increases from 1.0 to 1.6 regardless of whether the update or deflation procedure is used. Therefore the benefit update values were selected for use to represent the economics of the project since the values are more current (2014 rather than 2009) and at a level consistent with the comparable numbers in the CWRB report. The economic values in the CWRB report and the values that will replace them in the revised report are listed in Table 12.

Table 12: Certified costs at Oct 14 dollars (millions); report submitted to CWRB; updated average annual equivalent values

Short duration in CWRB report				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 226.1	$ 220.1	$ 210.3	$ 171.1
Incremental costs over WOPC	$ 82.0	$ 89.2	$ 101.8	$ 166.4
Incremental net benefits	$ 144.1	$ 130.9	$ 108.5	$ 4.7
BCR	2.8	2.5	2.1	1.0
Long duration to replace short duration				
Cost = $2.32 billion	3.125%	3.500%	4.125%	7.000%
Incremental benefits over WOPC	$ 355.7	$ 346.6	$ 332.1	$ 276.3
Incremental costs over WOPC	$ 83.2	$ 90.5	$ 103.1	$ 168.2
Incremental net benefits	$ 272.5	$ 256.1	$ 229.0	$ 108.1
BCR	4.3	3.8	3.2	1.6

Attachment 1: Construction Schedule

Figure 1-1: Normal

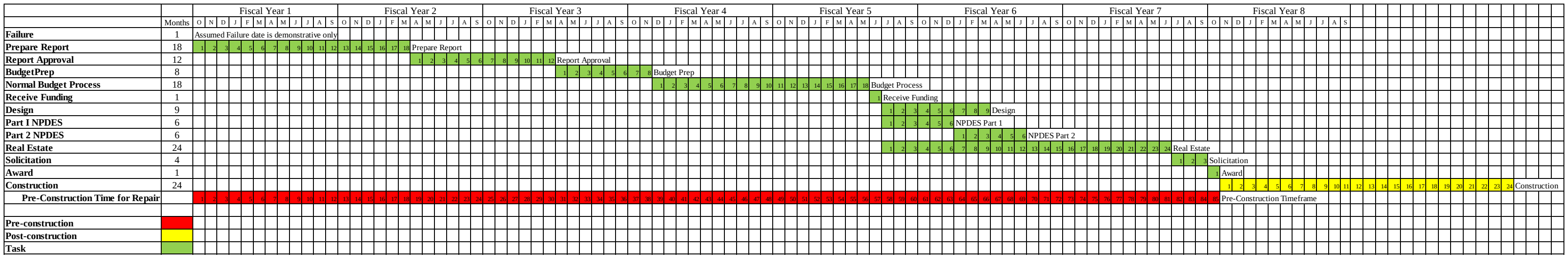


Figure 1-2: Urgent

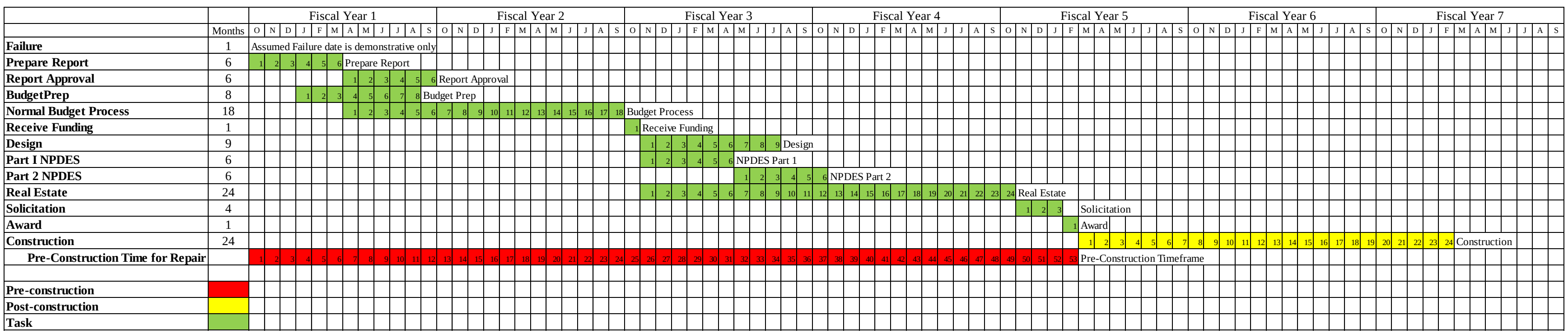


Figure 1-3: Critical

		Fiscal Year 1												Fiscal Year 2												Fiscal Year 3												Fiscal Year 4												Fiscal Year 5												Fiscal Year 6											
	Months	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Failure	1	Assumed Failure date is demonstrative only																																																																							
Prepare Report	6		1	2	3	4	5	6	Prepare Report																																																																
Report Approval	4						1	2	3	4	Report Approval																																																																
BudgetPrep	8								1	2	3	4	5	6	7	8	Budget Prep																																																										
Normal Budget Process	12												1	2	3	4	5	6	7	8	9	10	11	12	Budget Process																																																
Receive Funding	6																				1	2	3	4	5	6	Receive Funding																																														
Design	9																						1	2	3	4	5	6	7	8	9	Design																																									
Part I NPDES	6																						1	2	3	4	5	6	NPDES Part 1																																												
Part 2 NPDES	6																												1	2	3	4	5	6	NPDES Part 2																																						
Real Estate	18																						1	2	3	4	5	6	7	8	9	10	11	12	Real Estate																																						
Solicitation	3																																		1	2	3	Solicitation																																				
Award	1																																				1	Award																																				
Construction	24																																					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Construction											
Pre-Construction Time for Repair		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	Pre-Construction Timeframe																																				
Pre-construction																																																																											
Post-construction																																																																											
Task																																																																											

Figure 1-4: Feasibility Report

		Fiscal Year 1												Fiscal Year 2												Fiscal Year 3												Fiscal Year 4											
	Months	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Failure	1	Assumed Failure date is demonstrative only																																															
Prepare Report	12	1	2	3	4	5	6	7	8	9	10	11	12	Prepare Report																																			
Report Approval	10			1	2	3	4	5	6	7	8	9	10	Report Approval																																			
BudgetPrep	9				1	2	3	4	5	6	7	8	9	Budget Prep																																			
Normal Budget Process	12	1	2	3	4	5	6	7	8	9	10	11	12	Budget Process																																			
Receive Funding	11		1	2	3	4	5	6	7	8	9	10	11	Receive Funding																																			
Design	9				1	2	3	4	5	6	7	8	9	Design																																			
Part I NPDES	9				1	2	3	4	5	6	7	8	9	NPDES Part 1																																			
Part 2 NPDES	9				1	2	3	4	5	6	7	8	9	NPDES Part 2																																			
Real Estate	9				1	2	3	4	5	6	7	8	9	Real Estate																																			
Solicitation	3										1	2	3	Solicitation																																			
Award	1												1	Award																																			
Construction	24													1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Construction											
Pre-Construction Time for Repair		1	2	3	4	5	6	7	8	9	10	11	12	Pre-Construction Timeframe																																			
Pre-construction																																																	
Post-construction																																																	
Task																																																	