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Ohio River Mainstem Systems Study (ORMSS)

Interim Feasibility Report:

J.T. Myers and Greenup Locks Improvements

INDIANA, KENTUCKY and OHIO

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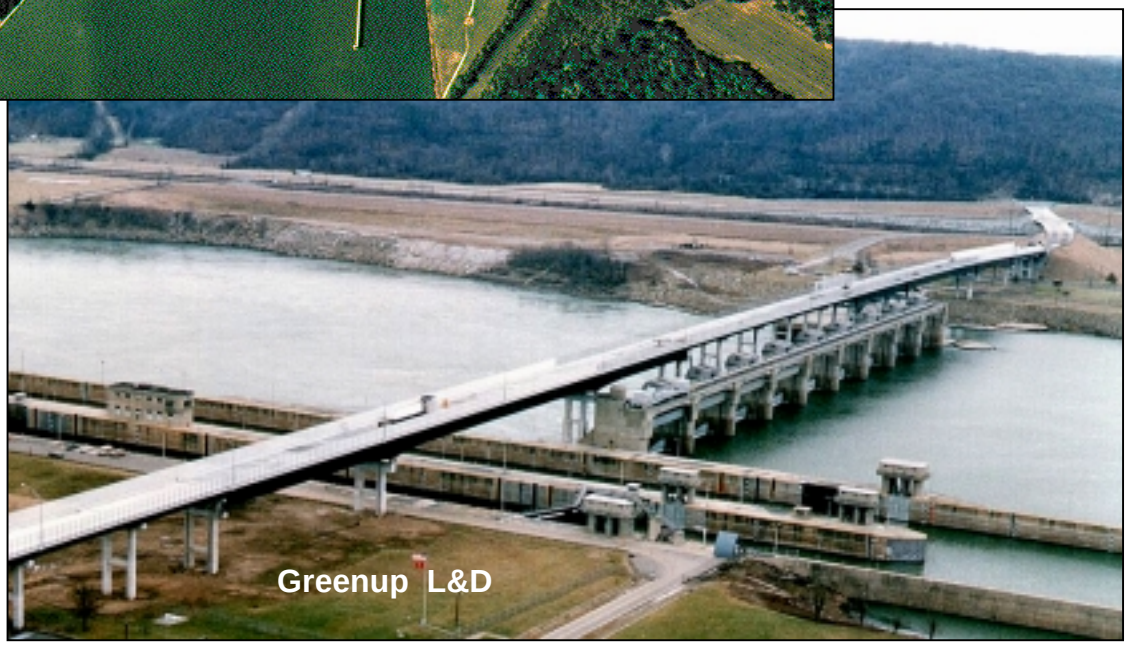

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DEPARTMENT OF THE ARMY
U.S. ARMY ENGINEER DISTRICT, LOUISVILLE
CORPS OF ENGINEERS
P.O. BOX 59
LOUISVILLE, KENTUCKY 40201-0059

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ATTACHMENT 1. CAPACITY ANALYSIS

ATTACHMENT 2. LIFE CYCLE LOCK MODEL (LCLM)

ATTACHMENT 3. ORS TRAFFIC DEMAND FORECASTS

ATTACHMENT 4. CALCULATION OF BENEFITS AND COSTS

ATTACHMENT 5. TRANSPORTATION RATES

ATTACHMENT 6. EMPLOYMENT AND INCOME IMPACTS FROM CONSTRUCTION

Overall Report Structure

Document Code	Title
MR	Main Report and EIS
ERD	Environmental Reference Data
EC	**Economics Appendix**
RE	Real Estate Appendix
GE	General Engineering Reference Data
ED-1	J.T.Myers Engineering Site Appendix
ED-2	Greenup Engineering Site Appendix

THIS DOCUMENT

SECTION 1

INTRODUCTION

1.1 PURPOSE

This document supports the Main Report to the Ohio River Main Stem System (ORMSS) Study, Interim Feasibility report. The interim report comes two years ahead of the scheduled completion of the ORMSS Final Feasibility report. Preliminary analysis of problems and needs along the entire main stem indicated two sites present immediate investment opportunities, and detailed analyses and recommendations should be advanced. The ORMSS interim feasibility report accomplishes that by considering an array of plans for improving navigation on the Ohio River main stem at two sites: J.T. Myers and Greenup locks and dams.

The purpose of this appendix is to explain the rationale and analytic procedures used to estimate the system impacts and National Economic Development (NED) benefits of each of these plans. The economic rationale for selecting J.T. Myers and Greenup locks and dams for advancement will also be discussed.

1.2 NEED FOR SYSTEMS ANALYSIS

Interdependence of traffic flows among the many individual elements of the system is a major problem in the economic evaluation of a lock-and-dam project. A change in the performance capabilities of one lock or channel segment can affect the efficiencies of other components of the system. For example, the additional traffic allowed to move because of improvements at J.T. Myers or Greenup locks and dams may increase delays at other projects in the system and thereby reduce the benefits for improvement. Similarly, other system projects can restrict traffic flows on the main stem Ohio and prevent the materialization of the expected benefits of proposed navigation improvements.

For this reason the evaluation methodology employed in this study measures the performance of the total navigation system. By evaluating the economic performance of the system for each plan of improvement, the marginal system benefits attributable to each plan can be measured. The plans that yield net system benefits can then be determined and compared.

The complex interrelationships and voluminous data dictate the use of computer modeling techniques. The Corps of Engineers, with the aid of various private economic and systems analysis consultants, has developed several transportation, economic, and statistical models and techniques to meet the needs of the analysis of a complex nationwide or regional transportation system. In general these techniques have been designed to help Corps planners achieve two goals: 1) to operate and maintain the inland waterway network as efficiently as possible, and 2) to select the best size, location, and timing of inland navigation waterway improvements.

The series of economic models employed in determining system benefits require four main classes of data as inputs, describing: 1)the navigation system, 2) the equipment used on that system (towboats and barges for example), 3) the origins and destinations, and tonnages of commodities shipped, and 4) the costs of moving these commodities by barge and by overland modes of transportation.

The most important components of the navigation system description are the tonnage-transit curves for each lock being modeled. These curves describe the relationship between traffic levels and the time it takes a tow to transit a given lock. The transit curves are used in the Tow Cost\Equilibrium model (TC\EQ) to estimate movement specific transit time and cost, the most variable component of total waterway transportation costs. Tracking the change in transit costs at different traffic levels and under different system assumptions (lock dimensions, number of locks, lock operating policies, and vessel fleets) allows the analyst to measure changes in waterway system benefits over time.

1.3 FRAMEWORK OF ECONOMIC CONCEPTS

1.3.1 Background

Water resource agencies came to a "*mutual understanding*" regarding the guidelines for estimating waterway benefits in the 1950s. 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, 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*."

Corps analysts apply this guidance by estimating transportation savings for each unique waterside origin, destination, and commodity movement in the system. Each movement's savings are estimated as the difference between the least costly alternate mode (usually rail or truck) and the existing water routing. Using this method, annual waterway system benefits are equal to the product of traffic moving on the waterway and the transportation savings for each ton of that traffic. In 1995 for example, 260 million tons of traffic moved on the ORS at an average transportation rate savings of $9.00 per ton, making system benefits an estimated $2.3

billion. Projecting future system benefits necessarily involves being able to project future traffic levels and transportation rate savings for each movement. Projecting rate savings necessitates consideration of factors which can degrade project performance, namely: 1) traffic congestion; and 2) lock reliability.

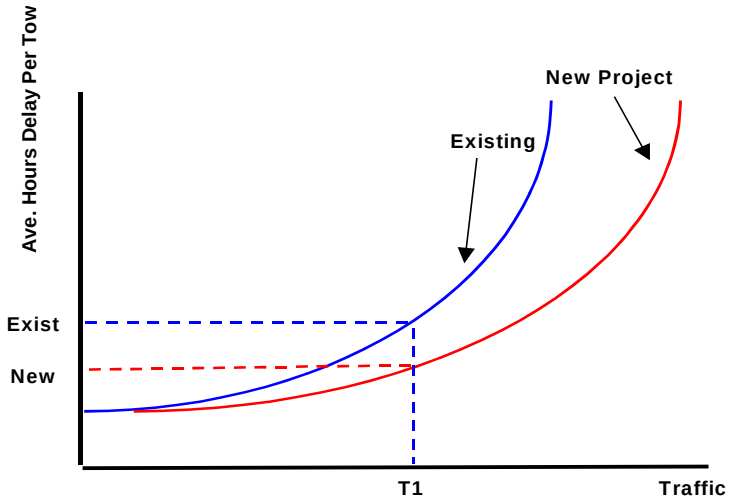
System savings have generally grown over time. Traffic growth has averaged around 3.0 percent annually since 1950, suggesting benefits must be increasing. However, this very growth can cause average rate savings to decline. At locks too small to efficiently handle higher traffic volumes, congestion leads to degradation in service (reflected in higher transit times), which erodes rate savings. Traffic-related service degradation has been the primary focus of lock improvement studies over the years, but reduced performance can be traced to causes other than increasing traffic volumes.

Aging projects and heavy usage can cause serious reliability concerns. In response to these concerns, the Corps pursues aggressive maintenance policies designed to avoid failures of major lock components and the lengthy lock closures they involve. In the ORS, closures of the large main chambers lasting more than a couple of days are especially serious as this causes traffic to be processed in the smaller, less-efficient auxiliary chamber. During main chamber closures, the typically-sized Ohio River tow capable of transiting a main chamber in one, 60 minute operation, must move through the small, auxiliary lock chamber in two operations lasting about 150 minutes. In this situation where the smaller auxiliary chamber carries the whole of the project's traffic, project performance is severely degraded. Service disruptions of this type result in longer transit times, higher waterway transportation costs, and lower transportation rate savings per ton for those shippers relying on the affected lock.

1.3.2 Analysis Framework

Economic analysis of service degradation by the Corps of Engineers focuses on the evaluation of alternative measures: 1) to increase capacity, thereby reducing delay costs; or 2) to replace or rehabilitate aging structures, thereby reducing the probability of structural failure and its consequences. For example, one way to address service degradation is by constructing a larger auxiliary lock chamber at the project. Traffic-delay curves can be used to represent the effect of this solution to degraded service. **Figure 1-1** below illustrates typical traffic-delay relationships. The availability of an auxiliary lock chamber with the same dimensions as the main chamber shifts the curve to the right. These large lock chambers can process the same amount of traffic at lower levels of delay than can the existing lock configuration of one large and one small chamber. The question becomes whether the improvement is economically justified. In other words, are the net benefits (system transportation benefits minus costs) of the improvement alternative greater than the net benefits of the system most likely to exist in the absence of the improvement alternative?

FIGURE 1-1
Traffic-Delay Curves, Existing and New Project



The established framework for answering these questions is described in the Principles and Guidelines--the latest regulatory successor to the Green Book. Identifying two future scenarios, or conditions is central to this framework. The future condition at the project (and in the system) without a new construction investment is referred to as the Without Project Condition (WOPC), and the future condition with new construction investment is referred to as the With Project Condition (WPC). Economic analyses of these competing future conditions seek to estimate the 50-year stream of benefits and costs associated with each respective future. Estimating the contributions to National Economic Development (NED benefits) is accomplished by comparison of both respective futures to yield the incremental benefits or dis-benefits of the WPC.

1.3.3 Transportation Cost Savings

NED benefits are increases in the net value of the national output of goods and services and 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 are also realized from regional and national growth, and from a diversity in transportation modes.

Nevertheless, the primary benefit for Federal investment in commercially navigable waterways is the collective transportation cost savings for barge shipment over the least-costly alternative routing. The benefit, generally referred to as movements rate savings, also accounts for any differences in transportation costs arising from loading, unloading, transloading, demurrage, and other activities involved in the point-to-point transportation of goods. Estimating

waterway investment benefits requires an analysis of: 1)waterway transportation demands and 2)transportation costs for the waterway routing and the least-costly alternative routing.

1.3.4 Supply and Demand

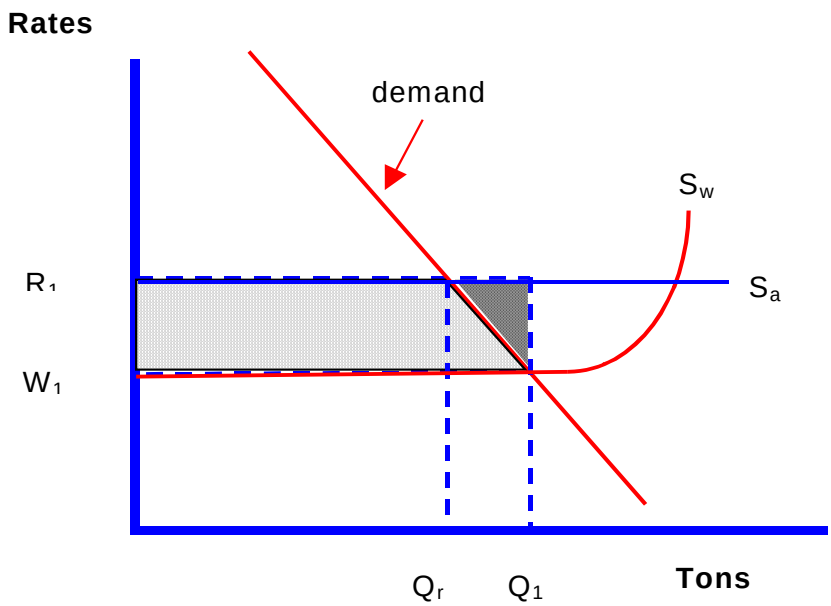
The economic analysis of the waterways can be addressed within a supply and demand framework: demand representing the willingness-to-pay for waterway services and supply representing the cost of the service. Most commodities moved on the Ohio River system are inputs to an intermediate or final product; therefore, transportation demands are derived from the demand for final products, like electricity. Two supply curves are conceptually relevant, the supply curve representing the marginal cost of waterway services and that for the alternate mode. Supply constraints on the alternate mode are assumed away, while supply constraints on the existing waterway rate are assumed to be caused only by traffic congestion and the delay-costs this congestion imposes upon the system. This assumption is generally reasonable; however, where this simplifying assumption appears unreasonable, they can be addressed directly.

1.3.4.1 Movement-Level Supply and Demand

At the individual movement level, a given consumer in region y has some level of demand for transporting commodity n from region x. The slope and location of this demand curve is determined by an array of factors --commodity supply prices, rail rates, barge rates, commodity input requirements, alternative supply region prices, and so on. Maximum willingness-to-pay for waterway transportation of the commodity is not readily observable; however, it is most closely approximated by the most costly transportation mode or least cost re-sourcing option available to the consumer.

The slope of the transportation demand curve is likely negative, though it is possible, especially in the near term, that demands are quite inelastic. For example, electric utility boilers are usually designed to burn a specific type of coal (in terms of a number of characteristics like energy, moisture, ash, water, and sulfur content) identified in specific coal seams and mines prior to coal-fired boiler construction. In fact, prices (rates) are generally quoted for an entire annual movement in multi-year contracts. In the example in Figure 4, the willingness-to-pay for rail (R_1) is below that of the transportation demand curve, indicating consumer surplus associated with both rail and barge up to tonnage level Q_r. The waterway rate (W_1) is below that for rail, indicating an additional increment of consumer surplus made possible by waterway transportation. The lightly shaded area in **Figure 1-2** represents waterway benefits. In this example, transportation demands are fairly elastic, so that the tons between Q_r and Q_1 have decreasing marginal rate savings.

FIGURE 1-2
Individual Movement Demand for Transportation Services



The more inelastic the demand curve, the smaller the range of marginal tons that exhibit declining marginal rate savings. Regardless, consumers/shippers in region y will continue to move commodity n from region x by the waterway up to that point where marginal rate savings equals the marginal cost of waterway transportation (Q_l). Transportation rate surveys are used to estimate the benefit of these existing waterway movements. The estimated benefit of the individual waterway move is the sum of both shaded areas in **Figure 1-2**. This method of estimating benefits may slightly overstate benefits (dark shaded area), especially in the long-term (beyond 30-40 years) as the transportation demand curve becomes more elastic. Nevertheless, this overstatement is likely relatively small, and benefits from project improvements are heavily discounted beyond 30 years, thus contributing very little to the present value of system benefits.

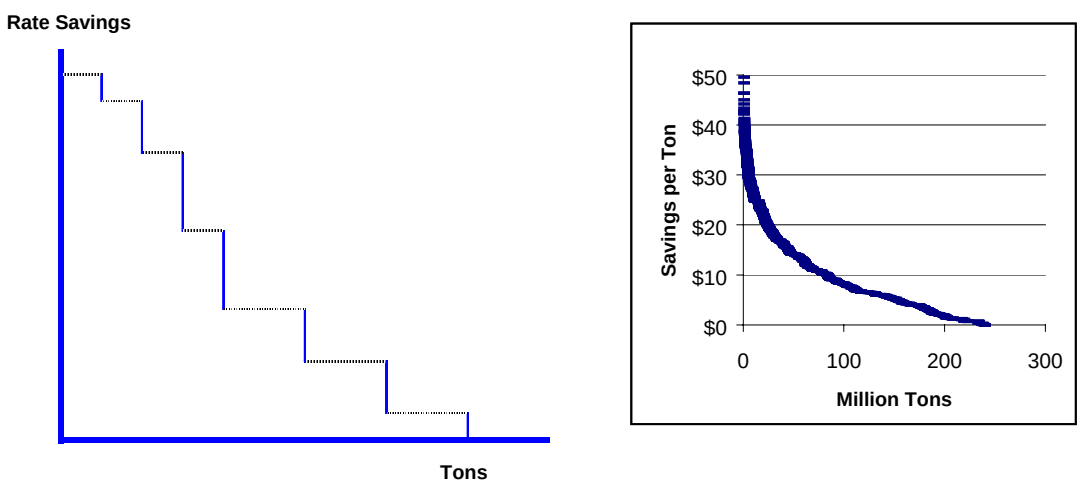
In practical terms, collecting the information necessary to estimate willingness-to-pay along individual demand curves is problematic. Individual moves, movements from the ultimate off-river origins and destinations, are not available in Waterborne Commerce Statistics Center data, only waterside origin and destination movements are reported. Furthermore, these individual movements are discrete by nature, often dependent on the productive capacity of a given mine or quarry, making the potential for the further divisibility suggested by declining marginal rate savings limited (suggesting very inelastic demands at this level). Nevertheless, willingness-to-pay information for individual ultimate origin and destination movements, like those conceptually discussed above, is constructed (see **Section 7.3.4**, Transportation Rate Analysis). Movements at the ultimate origin and destination level probably number from 50,000 to 90,000—far too many to effectively model. The problem is made manageable by gathering ultimate origin and destination rate data for each waterside movement and reporting its transportation rate data as weighted averages based upon ultimate-origin tons. Each reported rate

savings, then, represents individual moves with higher and lower savings. Ranking these 9,000 unique waterside origin and destination movements by rate savings (the marginal willingness-to-pay as measure by the differential between the existing water route and least cost alternate route) yields the waterway system demand curve described below (see **Section 7. Benefit Estimation Procedures** for a discussion of how this framework is applied in the system modeling)..

1.3.4.2 System-Level Supply and Demand

The industry or system-demand curve is an aggregation of the individual movement demand curves. This aggregate demand curve plots the rate savings, or willingness-to-pay, associated with each movement in the system. The result is a discrete curve comprising numerous individual demands. In **Figure 1-3**, the left graph shows an aggregation of seven individual movement demands, the graph on the right is an actual aggregation of 14,000 plus ORS movements ranked by their respective rate savings. A relatively few movements enjoy a high rate savings (consumer surplus) and are, therefore, these shippers are willing-to-pay a high price for waterway service, while the remaining shippers would only willingly pay successively lower prices. The mapping of these individual movement demands yields an empirically-estimated system demand curve. This demand curve also represents the system-level marginal rate savings (MRS) or marginal benefit curve.

FIGURE 1- 3
System Demand or Marginal Benefit Curve

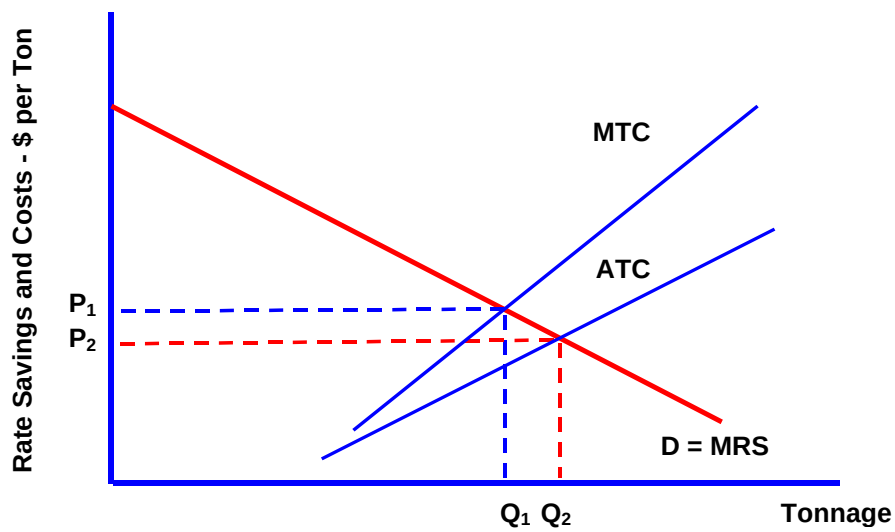


The demand or marginal rate savings (MRS) curve represents, for different levels of traffic, shippers' marginal willingness-to-pay for the use of the waterway. The shippers' marginal willingness-to-pay is measured as the difference in transportation costs via the waterway routing and the routing via the least-cost alternative transportation mode. If the alternative mode offers lower transportation costs (negative rate savings for the waterway routing), then the alternate routing will be used. If the costs via the waterway and alternative routings are equal (zero rate savings), then the shipper is indifferent as to the routing used. If the costs via the alternative routing are higher (positive waterway rate savings), the waterway routing will be used with the

incentive (or willingness-to-pay) for using the waterway increasing as the savings for using the waterway increases. As in **Figure 1-3**, the demand (MRS) curve depicted in **Figure 1-4** summarizes the system tonnage for prospective waterway movements at different levels of waterway rate savings plotted against waterway tonnage.

The supply curves represent, for every level of traffic, the cost of shipping commodities via the water routing. Two cost curves are depicted in **Figure 1-4** --- 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. The costs shown 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. Together with the demand curve, the cost curves provide a graphic representation of the water transportation market.

FIGURE 1-4
Conceptual Model for Waterway Economic Analysis

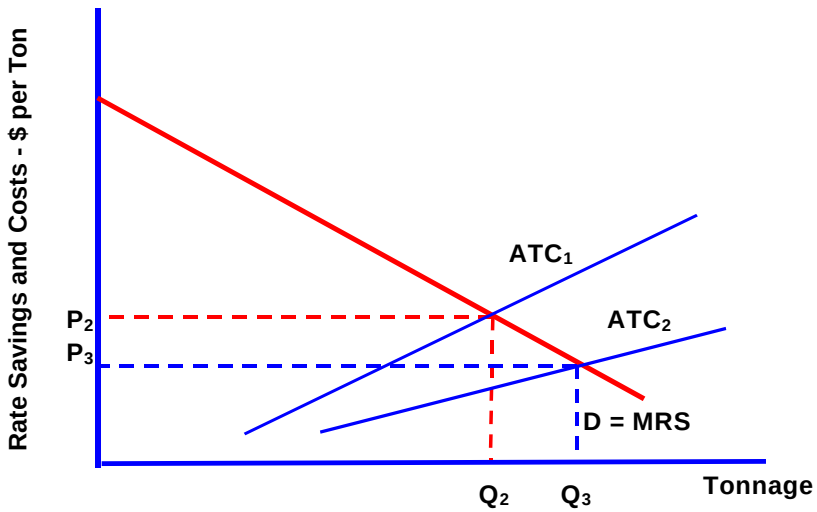


The two system traffic levels represented in **Figure 1-4** are important in the benefit evaluation process. Tonnage level Q_1 represents the economically optimal level of waterway use. At this traffic level, the last increment of tonnage added to the system exhibits just enough marginal rate savings to offset marginal towing costs (including induced delays). Traffic movements beyond Q_1 result in added towing costs (MTC) that exceed the marginal rate savings. Point Q_1 is the traffic level at which maximum system rate savings are attained. Tonnage level Q_2 represents the equilibrium level of traffic that would result in the absence of any institutional restrictions on waterway use, such as a congestion fee. Shippers will not restrict output to point Q_1, but will continue to expand output to the level at which average towing costs

equal 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. 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.

Now, consider the impact of a system change (such as the installation of a larger lock chamber at one or more projects) on the level of system traffic and shipping costs. **Figure 1-5** illustrates the effect of the change and the measurement of resulting benefits.

FIGURE 1-5
System Benefits for Lock Improvement



The equilibrium level of traffic increases from Q_2 to Q_3, with the reduction in shipping costs due to the improvement. The demand curve in this example is assumed to remain the same. The benefits for system change can be broken into two components: (1) the cost savings on the pre-improvement level of traffic, $Q_2 \times (P_2-P_3)$; and (2) the benefits to the new traffic that can move, $1/2\ [(Q_3-Q_2) \times (P_2-P_3)]$. These two benefits correspond to the cost reduction and the shift-of-mode benefit categories described in Principles and Guidelines.

1.4 RISK AND UNCERTAINTY

Corps of Engineer guidelines as presented in Principles and Guidelines have long recognized that uncertainty is inherent in all phases of the analysis of project investments and, for that reason, requires tests of analytical results against a variety of assumptions, particularly with regard to waterway traffic demands. These tests are presented in this appendix.

The analyses presented below also provide more 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 transportation rates. 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 improvement need--traffic demand projections and lock performance. In the case of traffic demand projections, alternative scenarios based upon competing sets of assumptions are presented and analyzed. 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 (see **Attachment 1**). Lock availability and performance is further described through the use of hazard analyses (see the Engineering Appendix M), which is the key input into the Monte Carlo-type simulations which calculate expected future adverse impacts associated with a lock's structural reliability (see **Attachment 2** for a detailed description).

1.5 REPORT ORGANIZATION

The remainder of this report is organized into the following major topical sections. Section 2 describes the resources and economy of the six-state study area. Section 3 highlights the industries dependent upon the waterways. Section 4 describes the navigation system that was analyzed to determine the extent and magnitude of impacts resulting from the improvement of J.T. Myers and Greenup locks and dams. Section 5 analyzes the vessel fleet and the performance characteristics of these two projects. Section 6 discusses the historic and projected traffic demands. Section 7 describes the benefit evaluation procedures, including the computer models used, major model inputs, and the results of model calibration. Section 8 identifies and evaluates alternative without project futures for the Ohio River main stem. Sections 9 through 12 are in both Part A, J.T. Myers Locks and Dam Economic Evaluation, and in Part B, Greenup Locks and Dam Economic Evaluation. Section 9 identifies the without project condition for the subject lock, Section 10 identifies and with project alternatives, Section 11 evaluates the final with project plans, and Section 12 contains the required sensitivity analyses. Section 13 presents the results of the timing analysis of Ohio River main stem investments.

Section 2

RESOURCES AND ECONOMY

2.1 GENERAL

The regional area served by the Ohio River navigation system is a rectangular-shaped area roughly bounded on the east by the Allegheny Mountains, on the west by the Mississippi River, on the north by the Great Lakes, and on the south by the Tennessee River. The Ohio River bisects the study area in an northeast to southwest direction. The eastern portion of the study area is characterized as generally mountainous, giving way to eroded uplands with vast reserves of coal. The western area is characterized as generally rolling terrain, which gives way to the eastern prairie lands of Illinois. **Figure 2.1** illustrates the navigable rivers of the Ohio River Basin (ORB).

The population of the ORB states and waterside economic areas (BEAs) is 55 million, or 21 percent of the national total. Although the population is distributed throughout the area, there are six major population centers in the region: Indianapolis, Columbus, Nashville, Pittsburgh, Cincinnati and Louisville, the last four of which are located on navigable Ohio River Basin waterways. These and smaller riverside cities, like Charleston and Huntington, WV; Evansville, IN; and Knoxville, TN, are indicative of the population concentration in the basin's river valleys. **Table 2-1** shows trends in population, employment and earnings between the basin and the country from 1978 to 1993.

Extensive coal deposits, abundant limestone reserves, fertile soils, abundant water supplies, and extensive woodlands are the area's principal resources. These resources, along with less extensive deposits of crude oil, natural gas, glass sands, clays, and minerals such as salt, zinc and copper, supported initial settlement of the area and the development of its first industries—coal mining, farming, chemical manufacture, meat packing, glass making, pottery, petroleum refining, and steel manufacturing. Some of these are still major industries in the region, most notably the steel, chemical, and coal mining industries.

Though diversified, the economy of the basin is not geographically of one character. In the ORB's major cities the economy is robust and diversified, depending upon services and technology, and much less on manufacturing. The smaller cities still rely heavily upon manufacturing (especially steel, automobile and aluminum production), while the hinterlands are still heavily dependant upon extractive industries (especially coal mining) and farming. The regional sectors of highest importance to waterway traffic are coal mining and their primary customer, electric utilities; stone quarrying and construction; farming; and manufacturing.

FIGURE 2-1
Ohio River Basin

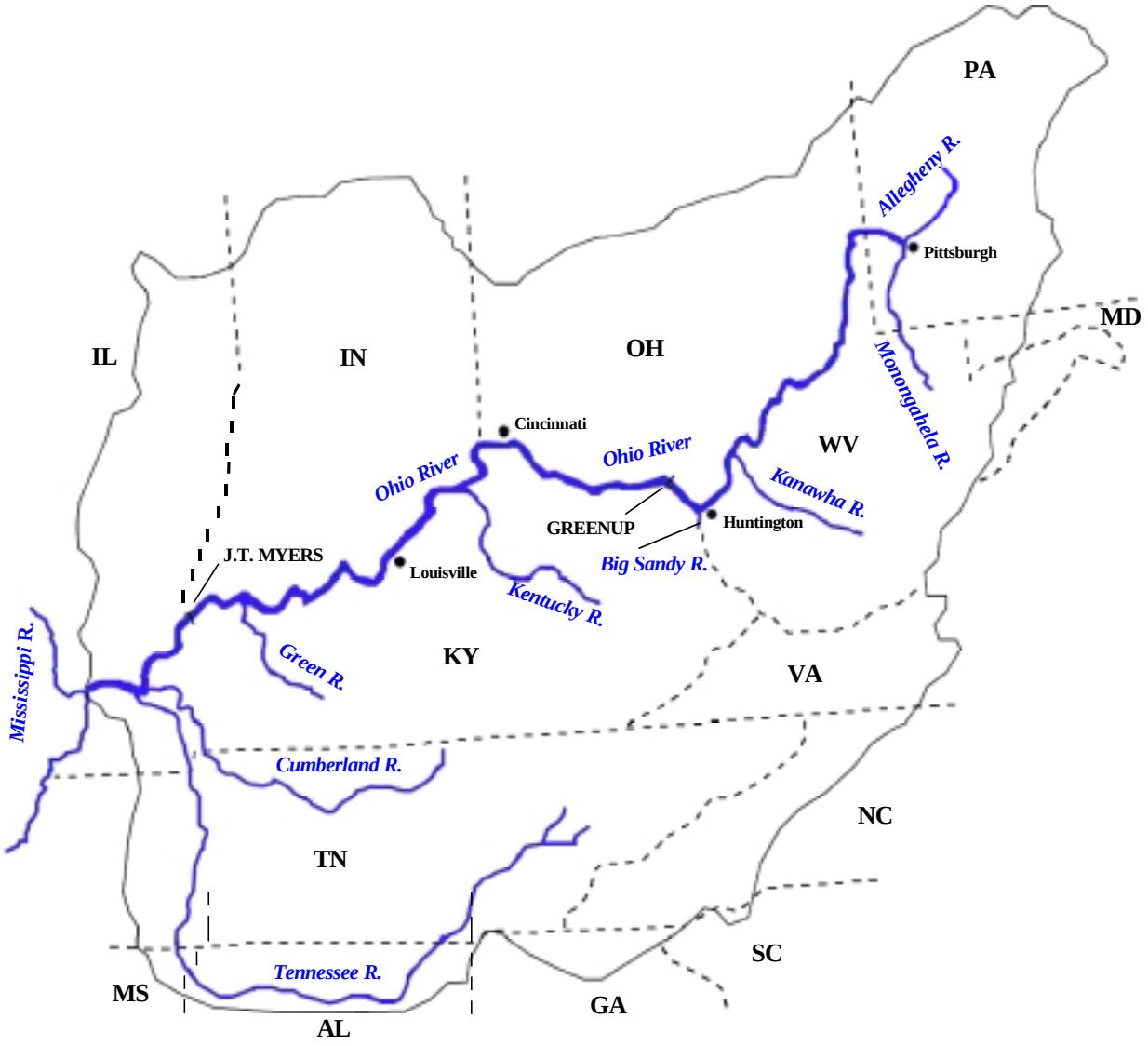


TABLE 2-1
Population, Employment and Earnings for Waterside ORB States and BEAs Compared to the United States

BEA City Name	Population (thousands) 1978	Population (thousands) 1993	Avg. Ann. % Change 1978-93	Employment (thousands) 1978	Employment (thousands) 1993	Avg. Ann. % Change 1978-93	Earnings (thousands) 1978	Earnings (thousands) 1993	Avg. Ann. % Change 1978-93
Chattanooga, TN-GA	601	655	0.58%	295	355	1.23%	5,547	6,586	1.15%
Knoxville, TN	774	884	0.89%	359	485	2.30%	6,529	9,021	2.18%
Lexington, KY-TN-V	1,739	1,782	0.16%	690	835	1.28%	13,441	13,977	0.26%
Charleston, WV-KY	1,281	1,210	-0.38%	516	530	0.17%	11,094	9,901	-0.76%
Cincinnati-Hamilton, OH	1,895	2,076	0.61%	892	1,129	1.58%	19,053	23,397	1.38%
Columbus, OH	1,954	2,186	0.75%	928	1,214	1.81%	18,562	23,931	1.71%
Wheeling, WV-OH	397	344	-0.95%	171	150	-0.85%	3,958	2,788	-2.30%
Pittsburgh, PA-WV	3,240	3,024	-0.46%	1,432	1,510	0.35%	33,311	32,672	-0.13%
Cleveland-Akron, OH	4,738	4,624	-0.16%	2,294	2,450	0.44%	53,206	51,721	-0.19%
Evansville-Henderson, IN	823	836	0.10%	404	456	0.81%	7,973	8,081	0.09%
Louisville, KY-IN	1,280	1,328	0.25%	630	753	1.19%	12,397	14,377	0.99%
Nashville, TN-KY	1,762	2,115	1.22%	894	1,244	2.32%	15,137	23,203	2.89%
Paducah, KY-IL	207	217	0.32%	97	112	1.02%	1,756	1,926	0.62%
Memphis, TN-AR-MS	1,616	1,733	0.47%	783	952	1.31%	13,871	18,135	1.80%
Huntsville, AL-TN	815	925	0.85%	373	503	2.02%	6,988	9,756	2.25%
Tupelo, MS-AL-TN	560	590	0.35%	259	300	0.98%	3,772	4,604	0.34%
St. Louis, MO-IL	3,308	3,454	0.29%	1,595	1,870	1.07%	33,411	38,192	0.90%
Total	26,989	27,983	0.24%	12,610	14,848	1.09%	260,004	292,268	0.76%
BEAs % of U.S	12.15%	10.86%		11.50%	10.56%		11.33%	9.68%	
United States	222,098	257,783	1.00%	109,608	140,612	1.67%	2,294,526	3,018,388	1.84%
Eight ORB States									
Alabama	3,856	4,181	0.54%	1,714	2,142	1.50%	31,293	40,041	1.66%
Illinois	11,438	11,686	0.14%	5,745	6,483	0.81%	135,257	151,432	0.76%
Indiana	5,469	5,706	0.28%	2,670	3,200	1.21%	56,323	62,436	0.69%
Kentucky	3,636	3,794	0.28%	1,644	2,003	1.33%	30,983	3,556	0.92%
Ohio	10,827	11,061	0.14%	5,203	5,977	0.93%	115,146	123,085	0.45%
Pennsylvania	11,893	12,030	0.08%	5,563	6,285	0.82%	121,484	137,323	0.82%
Tennessee	4,531	5,094	0.78%	2,227	2,916	1.81%	39,945	55,476	2.21%
West Virginia	1,931	1,818	-0.40%	781	802	0.18%	16,250	14,501	-0.76%
Total	53,581	55,370	0.22%	25,546	29,809	1.03%	546,681	587,849	0.84%
Percent of U.S.	24.12%	21.48%		23.31%	21.20%		23.83%	20.54%	

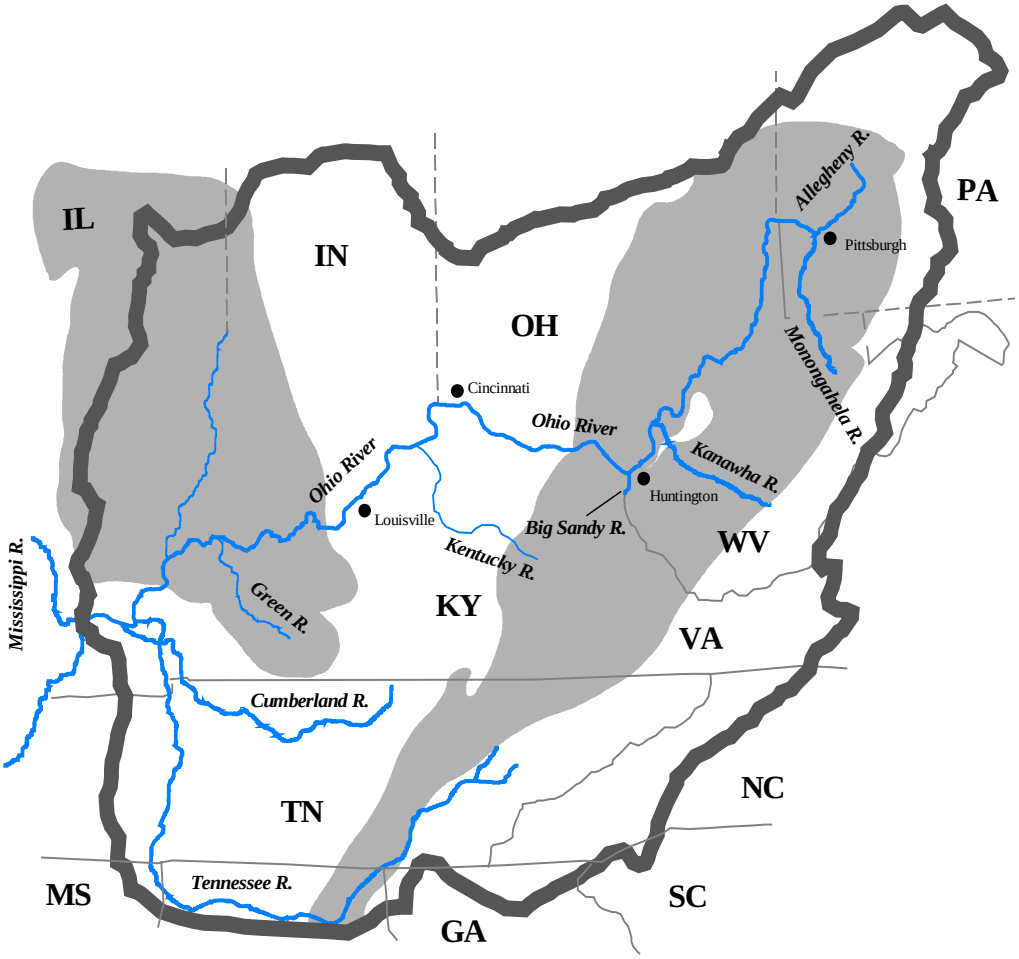
2.2 RESOURCES

2.2.1 Coal

Coal reserves are extensive in the basin, and the availability of low-cost coal is largely responsible for the establishment and growth of manufacturing in the area. Coal was key to the development of the steel industry, which dominated the economy of the Pittsburgh area for over a century, and to electric generating industry, whose low cost made the area attractive for a wide range of industries.

Coal is found in abundance in the basin (**Figure 2.2**), but with the major seams located in the eastern section. The western reserves within the basin are not only less abundant, but have characteristics that are significantly different, reflecting the different geologic forces that created the coal. Bordering the river down to Huntington, the coal is generally high energy and low to medium in sulfur content. The seams extending southward from Pennsylvania's Allegheny River valley through eastern Ohio, West Virginia, Virginia, eastern Kentucky and on into Tennessee are referred to as the Appalachian coalfields. The seams in Illinois, Indiana and western Kentucky are referred to as the Illinois Basin, a subset of the larger Interior coalfields. Both Appalachian and Illinois Basin deposits are bituminous coals of relatively high energy content, especially when compared with the sub-bituminous coals of Wyoming's Powder River Basin (PRB). The Appalachian coals are generally lower in sulfur content than the Illinois Basin coals, though higher in sulfur content than the PRB coals. Sulfur is an undesirable element in a particular grade of coal's makeup.

FIGURE 2-2
Ohio River Basin Coal Reserves



Ohio River Basin coal producers account for nearly one-half of national coal production. Nearly three-quarters or the basin production is from the Appalachian field (see **Table 2-2**). Though most of the coal produced in the basin is consumed in the basin, coals from the northern Appalachian fields are especially valuable as metallurgical coals used in the steel-making process throughout the United States and the world. High quality (low sulfur and high-energy content) coals from these same fields are used to generate electricity throughout the Eastern and Midwestern United States, and in Canada, Asia and Europe.

TABLE 2-2
Coal Production within Ohio River Basin Area, 1998

Coal Field	Tons (Millions)	Percent of US
Appalachian Field	389	35%
Interior Field	139	12%
Basin Total	528	47%
U.S. Total	1,118	

Despite over a century of mining, the area still contains large reserves of coal that are sufficient to meet the nation's needs for several centuries to come. As shown in **Table 2-3,** over one-quarter of the nation's coal reserves, and over 90 percent of its highest energy reserves lie in the Ohio River Basin. At current rates of production, the basin's reserves are sufficient to continue producing coal within the basin for the next 400 years.

2.2.2 Soils

The western basin farms of Ohio, Indiana, and Illinois rest upon the eastern extremity of the nation's most fertile soils, equaled in the world only by the pampas of Argentina and the Ukraine's chernozem grasslands. Agriculture in these states, and to a lesser extent in western Kentucky, revolves around the cultivation of corn, soybeans and wheat, in that order. In 1996 these first three states accounted for 26 percent of the nation's corn production and 32 percent of soybean production. They represent 3.7 percent of the land area of the U.S. but 11.1 percent of the cropland and 16.8 percent of the value of farm products (**Table 2-4**). Barge movements account for 9.4 percent of nationwide shipments of farm products but 19.9 percent of the movements out of Illinois/Indiana/Ohio. In 1996 nearly 15 million tons of farm products were barged on the Ohio River system.

TABLE 2-3
Coal Reserves

Description	Major Coal Field	Demonstrated Reserves 1/ (mmtons)	% of Major Coal Field	% of US
Alabama	Appalachian	4,546.6	4.2%	0.9%
Eastern Kentucky	Appalachian	12,086.2	11.2%	2.4%
Ohio	Appalachian	23,663.9	21.9%	4.7%
Pennsylvania	Appalachian	21,426.6	19.8%	4.2%
Tennessee	Appalachian	815.7	0.8%	0.2%
Virginia	Appalachian	2,202.0	2.0%	0.4%
West Virginia	Appalachian	35,397.1	32.7%	7.0%
		100,138.1	**92.6%**	**19.7%**
Illinois	Interior	105,068.9	65.8%	20.7%
Indiana	Interior	9,916.5	6.2%	2.0%
Western Kentucky	Interior	19,954.4	12.5%	3.9%
		134,939.8	**84.5%**	**26.6%**
Appalachia		**108,088.8**		
Interior		**159,611.4**		
West		**240,039.5**		
US		**507,739.6**		

1/ Demonstrated coal reserves include beds of bituminous and anthracite coals 28 inches or more thick and subbituminous coal 60 inches or more thick at depths up to 1000 feet. Also included are lignite seams 60 inches or more thick that can be surfaced mined.

TABLE 2-4
Cropland and Value of Production
(Millions of acres and Millions of dollars)

Area	Land Area	Cropland	Value of Production
IL, IN, OH	84.7	50.9	23,974
Rest of ORB	128.4	28.4	7,843
U.S.	2,263.2	460.0	142,442
IL, IN, OH			
as % of U.S.	3.7	11.1	16.8

2.2.3 Water Supply

Among the nation's streams, the Ohio River is second only to the lower Mississippi in terms of the volume of flow. Streams flowing out of the Appalachian Mountains and the Allegheny plateau, the Monongahela, Allegheny, Kanawha, Cumberland and Tennessee rivers, contribute the greatest flow to the Ohio, but its vast watershed is also drained by major streams like the Muskingum, Scioto, Little Miami, Kentucky, Green and 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 navigable tributaries.

2.2.4 Woodlands

Forty-three percent of the basin is classified as forestland according to the Department of Agriculture. This compares to 29 percent for the nation as a whole (**Table 2-5**). Most of the basin's forested land is confined to the Appalachian Mountains or its western foothills and upland areas, though sizeable tracts of forestland can be found in southeastern Ohio and southern Illinois. While hardwoods, especially oaks, prevail, there are sizeable stands of cultivated southern pine in the Tennessee Valley in particular. Higher-grade hardwoods are harvested for domestic and foreign manufacture of furniture, while the lower grades going for lumber, railroad timbers, packing material, and more recently, paper manufacture. The pines are used extensively for the manufacture of paper and cardboard, primarily in the Tennessee Valley or along the Gulf Coast.

TABLE 2-5
Land Use
(Millions of Acres)

Land Use	U.S.	%	Basin	%
Forest Land	648.0	29%	91.4	43%
Other	1615.2	71%	121.7	57%
Total	2263.2	100%	213.1	100%

2.3 ECONOMY

The economy of the basin is diversified, but more oriented towards coal mining and manufacturing than the U.S. as a whole. Focusing on coal mining, 62,840, or 77 percent, of the nationwide total number of coal mining jobs, are in the basin states (**Table 2-6**).

TABLE 2-6
Employment by Sector - 1998
(Percentages)

Sector	Ohio Basin	U.S.
Farming	2.1	2.6
Manufacturing	18.3	14.5
Mining (Coal)	0.2	0.001
Other	79.4	82.9
Total Number	27,367,400	129,204,000

2.4 CONCLUSIONS

The basin is rich in natural resources and served by a transportation system that has allowed for extensive economic development. In summary, the principal resources are fertile soils, extensive forests, abundant water supplies, and large deposits of coal. The area is served by all modes of transportation, but with the unique regional advantage of the Ohio River, which bisects the basin. As a result, the area has a robust and diversified economy.

SECTION 3

WATERWAY DEPENDENT INDUSTRIES

3.1 GENERAL

Waterway dependent industries are those industries that realize some advantage for locating alongside a navigable waterway system. The two major advantages are the availability of a large and reliable supply of water for use in the industrial process, and the availability of an efficient and reliable waterway transportation system for the movement of goods into or out-of the facility. The transportation advantage is the advantage of interest to this study, since locks and dam projects are sized and constructed to facilitate waterway transportation. Other location factors, including taxes, labor force, terrain, and rail and road access are also important, but are beyond the scope of this study.

The degree of reliance on waterway transportation differs among industries. Moreover, in some cases the dependency is direct, while in others it is indirect. For example, a new electric furnace steel mill may not use the river at all for transportation, but it may have located in the area because of the availability of low-cost electricity from a nearby generating plant that receives coal by barge. Major industrial users of the waterways are shown in **Table 3-1**.

TABLE 3-1
Major Users of Waterway Transportation and Dependency

1. High Dependence
1) Coal Mining
2) Electric Generating
3) Coke Production
4) Steel Production
5) Petrol-Chemicals
6) Construction
7) Other Lower Profile Industries
2. Low Dependence
1) Agriculture
2) Wood Products

The major users of the waterway are the coal industry and the electric generating industry (see **Table 3-2**). While it is likely that both industries would have developed even without a navigable transportation system, it is unlikely that they would have grown to the extent that they have. The reason is that waterway transportation provides a cost-advantage over other modes, which allows coal produced in the area to be competitively priced in a geographically wider

market than it would be otherwise. As far back as a hundred years ago, coal produced in the Monongahela River Basin was shipped down-river as far as Oklahoma. In contrast, no coal was delivered overland to these markets. The same is true of the electric generating industry; because of the low transportation cost of waterway shipments, and the multiple sources of coal available via waterway transportation, electric generating costs in the basin are among the lowest in the nation.[1] Electricity produced in the basin can be economically exported to high-cost production areas. Again, the size of the market and the amount of electricity generated would be less without the transportation cost savings provided by the waterway system.

TABLE 3-2
ORS Waterway Commodity Traffic, 1997

Commodity		Tons (Millions)
Coal	Total	158.4
	Steam Coal	119.7
	Metalurgical Coal	11.6
	all else	27.1
Crude Petroleum	Total	7.3
Petroleum Products	Total	9.9
Chemicals	Total	9.9
	Fertilizers	2.4
	all else	7.5
Aggregates	Total	47.9
	Sand & Gravel	0.2
	Limestone	0.6
	all else	43.3
Grains	Total	15.0
Ores & Minerals	Total	6.2
Iron & Steel	Total	9.6
	Steel Scrap	1.8
	all else	7.8
Others	Total	6.5
	Wood Products	1.1
	all else	5.4
Grand Total		271.5

Low-cost electricity also attracts energy-intensive industry to the region. Foremost among these are the aluminum and the steel industries, particularly the new electric furnace plants that recycle scrap into steel. The principal input of both industries is electricity, and therefore, the availability of low-cost electricity is a major consideration in location decisions.

The basic (traditional) steel industry is similar to the electric generating industry in its relation to coal and secondary processors. First, coal is the basic fuel of the industry, although the coal is pre-processed at coke plants where impurities and other undesirable characteristics are removed. The coke is then transported to raw steel producing plants where it is burned to

[1] According to the U.S. Department of Energy, Energy Information Administration, average revenue per kilowatthour is 5.9 cents for the eight Ohio River Basin states and 6.8 cents for the entire United States. Only six states have lower average revenues than the mean average revenue for the basin states.

produce the heat to separate iron from other materials. The iron is transformed into steel, which is itself transformed into ingots, slabs, or other shapes for shipment to plants where it is used in the construction of appliances, automobiles, and other final consumer products. The availability of coal, and the efficiency of transporting it by barge to Pittsburgh, were major determinants in the early development of the steel industry in the Pittsburgh area.

While coal and coal/electricity-dependent industries are the major waterway dependent industries, there are important non-coal related industries as well. The largest of these, from a tonnage standpoint, is the aggregates industry, which produces limestone, sand, and gravel. Sand and gravel moves by barge from waterside quarries and dredge sites to riverside yards and ready-mix plants, and in some cases, directly to construction sites, minimizing the movement of trucks through congested areas. Waterside limestone quarries and mines supply these same construction industry users and the cement, lime, and electric utility industries as well. Two other major regional industries, although not as important from a national standpoint, are the oil and chemical industries. In the case of the chemical industry, raw feedstock materials generally come from petrol-chemical complexes located along the Gulf Coast. Barge-sized allotments are the most economical and safest way to supply Ohio Basin facilities producing specialized chemical products. Petroleum refiners depend on the waterways to ship final product to major urban areas located on the river.

Agriculture is an enterprise that uses the waterway transportation system extensively to link to domestic and overseas markets and to diversify its marketing options. For logistical reasons, grain shippers often prefer barge to alternative modes because barges not only provide transportation, but also can serve as relatively low-cost floating warehouses. The waterway system serves as the primary conduit for Midwestern grains and other agricultural products to reach growing domestic and overseas markets. From a national perspective, access to the export market, especially via the Mississippi River, is the waterways principal effect on agriculture. In the Ohio Basin the waterway's role is divided between connecting upper Midwestern farmers with Southeastern grain processors and poultry producers, and connecting lower Ohio Basin farmers with the Mississippi River and the Gulf Coast.

Wood-related activities include timber harvesting for export, lumber and the processing of wood for pulp and paper mills. While a limited amount of hardwood export occurs, most forest products move in the form of pulpwood or wood chips for eventual paper product manufacture. Paper and paper product manufacturers additionally support the manufacture and delivery of salt, which is used to make chlorine and caustic soda—direct inputs to paper and paper product manufacture. Chlor-alkali plants manufacture the critical chlorine and caustic soda inputs, and rely on waterborne shipments of salt, primarily from salt mines along the Gulf Coast. Chlor-alkali plants are often located close by paper plants, allowing chlorine shipments by pipeline, minimizing any transportation risks.

There are a number of other waterway dependent industries along the waterway as well that depend on the waterway more for water supply and as an optional transportation mode, and for an occasional barge shipment, rather than for continuous/high volume shipments. These types of plants include mineral processing plants such as zinc and nickel plants. Other facilities are highly dependent on the waterway transportation system, but may ship modest quantities on the system. These facilities would include the intermodal ports that provide a wide variety of shipping options to a wide variety of industries and cargoes in order to survive.

3.2 HIGH-LEVEL DEPENDENCE

3.2.1 Coal Mining

The markets for coal are electric generating plants, coke plants, other industrial plants such as cement, and export. The electric generating industry dwarfs the other sectors, consuming 911 million tons a year or 87 percent of the one billion tons of coal produced in the U.S. every year. The Ohio River Basin is an important production region and proximity to waterways infers an advantage. A listing of the largest mines located in counties along the Ohio, Monongahela, Green, Kanawha, and Big Sandy rivers is provided in **Table 3-3**, along with production in 1996. Over ten percent of national production came from these large ORB mines in 1998.

TABLE 3-3
Major ORB Waterside Coal Mines, 1996

State	County	Company	Mine	Tons
IL	Gallatin	Coal Miners, Inc.	Eagle Valley Mine	1,323,718
		State Total		**1,323,718**
IN	Warrick	Peabody Coal Co.	Lynnville Surf & Prep Plant	3,404,172
IN	Warrick	Peabody Coal Co.	Squaw Creek & Prep Plant	1,388,485
		State Total		**4,792,657**
KY	Union	Peabody Coal Co.	Camp No. 1	2,886,784
KY	Union	Peabody Coal Co.	Camp No. 11	3,122,868
KY	Union	Island Creek Coal Co.	Ohio #11 Undrgrd Mine	1,351,521
		State Total		**7,361,173**
OH	Belmont	Ohio Valley Coal Co.	Powhatan No. 6 & Prep Plant	4,741,214
OH	Meigs	Southern Ohio Coal Co.	Meigs 31 & Prep Plant (Ms-293)	3,006,877
OH	Meigs	Southern Ohio Coal Co.	Meigs No. 2 (Ms-294)	2,943,735
OH	Monroe	Quarto Mining Co.	Powhatan #4 Mine & Prep	3,382,895
		State Total		**14,074,721**
PA	Greene	Consolidation Coal Co.	Bailey No. 1 Mine	7,469,255
PA	Greene	Cyprus Cumberland Resources	Cumberland Mine & Prep Plant	5,327,908
PA	Greene	Consolidation Coal Co.	Dilworth Mine (NWV Region)	3,632,018
PA	Greene	Enlow Fork Mining Co.	Enlow Fork Mine	8,723,644
PA	Greene	Cyprus Emerald Resources Corp.	Emerald No. 1 Mine & Prep	3,230,625
PA	Greene	New Warrick Mining Co.	Warwick #3 Undrgrd & Prep Plant	1,052,603
PA	Somerset	PBS Coal, Inc.	PBS No.1 Suface Mine	1,374,945
PA	Washington	Maple Creek Mining, Inc.	Maple Creek	2,224,909
PA	Washington	MonView Mining, Inc.	Mathies Mine & Prep Plant	1,078,293
PA	Washington	Eighty Four Mining Co.	Mine No. 84	3,026,551
		State Total		**37,140,751**
WV	Barbour	Phillipi Development, Inc.	Sentinel Mi 1583/2587	1,351,147
WV	Brooke	Windsor Coal Co.	Windsor Mine & Prep Plant	1,438,196
WV	Harrison	Consolidation Coal Co.	Robinson Run #95 D-4786 & Prep	4,216,327
WV	Marion	Consolidation Coal Co.	Loveridge #22 D-403 & Prep	3,073,835
WV	Marshall	McElroy Coal Co.	McElroy Mi 5443	4,305,682
WV	Marshall	Consolidation Coal Co.	Shoemaker Mi 4791	4,415,744
WV	Monongalia	Consolidation Coal Co.	Blacksville No.2 Mine & Prep	3,459,798
WV	Monongalia	Eastern Associated Coal Corp.	Federal No.2 & Prep	4,580,428
WV	Monongalia	Consolidation Coal Co.	Humphrey No.7 D-415 & Prep	3,245,745
WV	Monongalia	Patriot Mining Co., Inc.	Osage & Bethel	1,026,224
WV	Fayette	Cyprus Kanawha Corp.	Armstrong Creek	1,792,658
WV	Kanawha	Cannelton Industries, Inc.	Stockton Mine	2,154,700
WV	Kanawha	Dunn Coal & Dock	No.1	2,137,559
WV	Wayne	Pen Coal Corp.	Kiah Creek Surface Mine	1,174,701
WV	Wayne	Rockspring Development Co.	Camp Creek Mine	1,480,700
		State Total		**39,853,444**
		Grand Total		**104,546,464**

3.2.2 Electric Generation

The electric generating industry is one of the little noticed, but key industries, in the nation's economy. Its importance is little appreciated until we are without power, and find ourselves groping in the dark for candles and throwing out food from our refrigerators.

The electricity industry is an important consumer, as well as a key producer, in the economy. The industry consumes about 87 percent of the over 1 billion tons of coal produced in the country. Of this amount, about 14 percent or nearly 120 million tons moves on the Ohio River system to waterside power plants. The tonnage accounts for about 1 of every 2 tons shipped on the system. **Figure 3-3** shows the location of the coal-fired power plants along the river system and **Table 3-5** shows the capacity and coal-burn of each plant.

3.2.3 Coke Production

Coal is pre-processed in coke plants to remove impurities and other undesirable characteristics 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 to steel. A listing of the waterside coke plants in the basin is provided in **Table 3-4**. The number of coke plants within the basin and the country as a whole has declined significantly over the past 20 years, such that the remaining plants are the survivors and generally considered to be internationally competitive. The coke plant at Clairton is the largest in the country; its output goes to USX steel plants throughout the country.

TABLE 3-4
Waterside Coke Plants

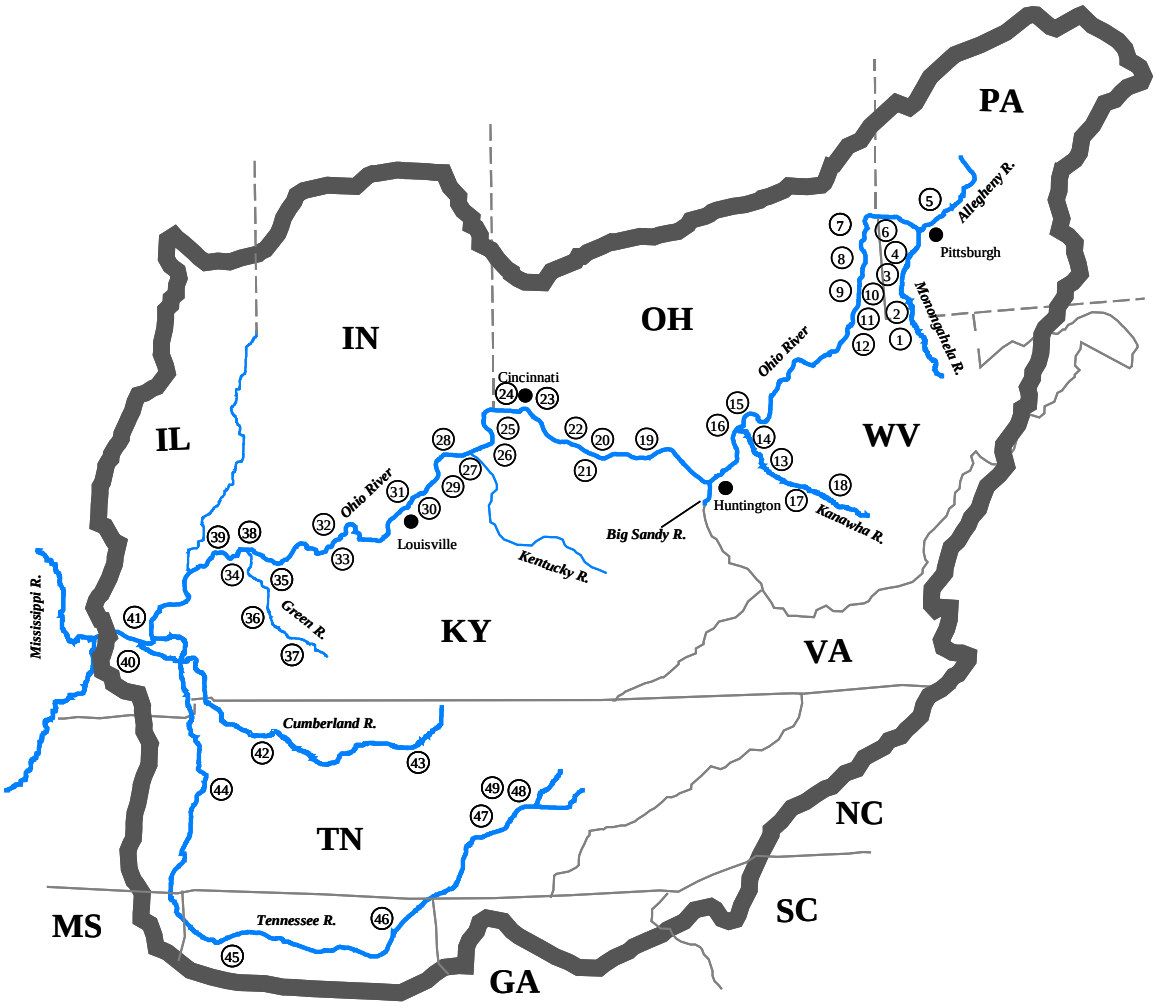
Name	Milepoint	River	State
AK Steel	320.0	Ohio	KY
New Boston Coke Corp.	351.0	Ohio	OH
Koppers Industries	38.0	Monongahela	PA
Shenango, Inc.	8.0	Ohio	PA
USX Clairton	20.1	Monongahela	PA
Wheeling-Pittsburgh Steel	69.0	Ohio	WV

TABLE 3-5
Waterside Electric Generating Plants

Name	Milepoint*	River	State	Electricity Generation (MWh)	Coal Consumption (Ktons)
Amos	39.7	Kanawha	WV	15,332,459	5,891.27
Beckjord	452.9	Ohio	OH	5,996,393	2,581.65
Brown	0.0	Ohio	IN	2,463,116	1,148.86
Bull Run	47.6	Clinch	TN	5,005,472	1,781.99
Burger	102.3	Ohio	OH	2,083,114	852.97
Cardinal	76.2	Ohio	OH	9,318,453	3,751.46
Cheswick	15.4	Allegheny	PA	3,075,764	1,231.58
Clifty Crk	559.6	Ohio	IN	9,731,944	4,909.20
Colbert	245.3	Tennessee	AL	7,700,791	3,224.20
Coleman	728.5	Ohio	KY	3,028,554	1,408.85
Cumberland	103.4	Cumberland	TN	16,172,326	6,867.29
East Bend	511.0	Ohio	KY	3,911,592	1,614.75
Elrama	25.1	Monongahela	PA	2,557,114	1,171.99
Fort Martin	92.0	Monongahela	WV	5,338,113	2,037.71
Gallagher	610.1	Ohio	IN	2,655,158	1,158.53
Gallatin	244.1	Cumberland	TN	6,587,951	2,574.40
Gavin	258.5	Ohio	WV	16,861,183	7,367.77
Ghent	535.8	Ohio	KY	11,916,391	4,995.45
Green River	81.5	Green	KY	708,250	354.78
Hatfield	79.0	Monongahela	PA	9,028,465	3,439.43
Johnsonville	99.6	Tennessee	TN	7,653,279	3,687.73
Joppa	952.3	Ohio	IL	7,873,723	4,833.63
Kammer	111.1	Ohio	WV	4,529,114	1,786.55
Kanawha Rv	78.3	Kanawha	WV	1,920,846	763.62
Killen	390.6	Ohio	OH	4,274,313	1,750.61
Kingston	2.6	Clinch	TN	9,782,767	3,851.90
Kyger Creek	259.6	Ohio	OH	7,739,685	2,924.82
Mansfield	33.1	Ohio	PA	14,556,736	5,944.03
Miami Fort	490.1	Ohio	OH	7,474,143	3,049.96
Mill Crk	626.5	Ohio	KY	8,765,110	3,995.44
Mitchell	112.3	Ohio	WV	8,296,523	3,213.29
Mitchell	29.5	Monongahela	PA	788,777	338.73
Mountaineer	243.4	Ohio	WV	7,363,098	2,756.07
Paradise	99.5	Green	KY	14,335,401	6,117.32
Pleasants	160.5	Ohio	WV	8,232,933	3,454.05
Reid	41.2	Green	KY	85,973	45.20
Rockport	744.7	Ohio	IN	16,790,788	10,100.27
Sammis	52.9	Ohio	OH	13,858,788	5,800.34
Shawnee	946.0	Ohio	KY	7,923,517	3,572.54
Sporn	241.6	Ohio	WV	5,900,556	2,343.48
Spurlock	414.1	Ohio	KY	5,453,418	2,177.98
Stuart	404.5	Ohio	OH	13,860,448	5,770.66
Tanners Crk	494.0	Ohio	IN	4,936,598	1,939.41
Trimble	0.0	Ohio	KY	3,016,348	1,419.80
Warrick	774.0	Ohio	IN	1,149,274	538.57
Watts Bar	529.1	Tennessee	TN	-2,756	0.00
Widows Crk	407.3	Tennessee	AL	8,766,790	3,985.68
Wilson	74.0	Green	KY	3,045,944	1,380.21
Zimmer	0.0	Ohio	OH	10,266,343	4,042.93

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

FIGURE 3-1
Coal-Fired Power Plants along the ORS



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		

3.2.4 Steel Production

Steel is used in construction, automotive assembly, and appliances. Regionally, steel production has declined precipitously since the early 1980s, when most of the old integrated plants in the Pittsburgh area were closed and demolished. The construction or expansion of electric arc furnaces has led to a resurgence of steel production in the 1990s. This growth was accompanied by continuing expansion of the automobile industry in the Ohio River Basin. A list of the major waterside steel plants in the basin is provided in **Table 3-6**.

TABLE 3-6
Major Waterside Steel Plants

Name	Milepoint	River	State	Type	Capacity (mmtons)
AK Steel	320.0	Ohio	KY	BOF	2
Kentucky Electric	n/a	Ohio	KY	Electric	n/a
Gallatin Steel	536.0	Ohio	KY	Electric	1.0
Newport Steel	2.0	Licking	KY	Electric	0.7
Steel of West Virginia	307.0	Ohio	WV	Electric	0.3
Weirton Steel	63.0	Ohio	WV	BOF	3.0
Wheeling	69.0	Ohio	WV	BOF	2.4
USX	11.0	Monongahela	PA	BOF	2.9

3.2.5 Petrol-Chemicals

The heaviest concentration of chemical companies is on the Kanawha River and on the Ohio River between Marietta and Portsmouth, Ohio. One medium-sized refinery, located in Ashland, Kentucky, is located on this same stretch of river. Other petrol-chemical facilities (**Table 3-7**) ranging from plants to tank farms are located throughout the basin.

TABLE 3-7
Waterside Petro-Chemical Facilities

Name	Milepoint	River	State	Type
Amoco Chemicals Corp.	299	Tennessee	AL	Petro
Aristech Chemical Co.	337	Ohio	OH	Chem
Ashland Petroleum Co.	317	Ohio	WV	Petro
Ashland Petroleum Co. Midland	35	Ohio	PA	Petro
B.F. Goodrich Co.	17	Tennessee	KY	Chem
Chevron Chemical Co.	177	Ohio	OH	Chem
Dow Corning	541	Ohio	KY	Chem
Dupont	68	Kanawha	WV	Chem
Koppers Industries, Inc.	70	Ohio	WV	Chem
Monsanto Co.	302	Tennessee	AL	Chem
Nova Chemicals, Inc.	30	Ohio	PA	Chem
PPG Industries, Inc.	120	Ohio	WV	Chem
Quaker State Oil	47	Ohio	WV	Petro
Union Carbide Corp.	55	Kanawha	WV	Chem

3.2.6 Construction

Construction is the largest consumer of raw materials of any industry in the country. The principal raw materials are stone, sand and gravel, steel, and wood products. Most waterborne construction material is crushed stone, sand and gravel used in making concrete. Typically, barges move the aggregate from quarry or dredge site to ready mix plants or stone yards located in or near urban areas. This waterway leg affords these shippers the advantage of bypassing populated areas with these large bulk flows, while still getting product where they need it. Trucks are generally used to transport product to the work site, though some large construction projects receive aggregate by barge directly.

3.2.7 Other Lower Profile Industries

The list of industries and facilities dependent on the waterway system is extensive, and only the major ones are listed above. Some of the "lower profile" industries are highly dependent on the waterways, but involve lower volumes due to the nature of the business and/or the value of the product.

3.2.7.1 Steel Recycling

The steel scrap business involves the acquisition of junked autos, appliances, industrial trimmings, and other items, and processing these items into prime scrap. Processing involves the removal of non-steel components from the junked items. The prime scrap is then sold to steel plants which either blend the scrap with iron to produce steel, or which make steel entirely from melting scrap in an electric furnace. The scrap is sold to both domestic and foreign companies. The U.S. steel industry consumed over 70 million tons of scrap in producing over 100 million tons in 1996. Because of the low value and broad and dispersed sources of scrap, many scrap companies choose to locate along the river system. Prime scrap is generally railed to domestic mills and barged to New Orleans for foreign mills. Shipments of scrap on the Ohio River system totaled 1.8 million tons in 1997.

3.2.7.2 Synthetic Fuel Production

Decades of mining have resulted in millions of tons of waste materials that are aesthetically and environmentally detrimental. Efforts are underway to economically cleanup up these piles of wastes. One effort involves the conversion of part of the wastes into useful products, such as synthetic fuels. The synthetic fuels, referred to as briquettes, are reusable by either the utility industry or the steel industry, depending on the grade of the briquettes. Again, the businesses prefer a waterside site since the wastes come from multiple origins, which are often on or near the water.

3.2.7.3 Gypsum Recycling

Synthetic gypsum, which is a byproduct of flue gas desulfurization, a process that removes SO_2 from coal-fired emissions, is used to produce wallboards for construction industry.

Again, the businesses prefer a waterside site since the wastes come from multiple origins, which are often on or near the water.

3.2.7.4 Aluminum and Zinc Production

The principal minerals refined at basin plants are aluminum bauxite and zinc oxide. The Ohio River Basin is home to the second largest concentration of aluminum plants in the U.S. Aluminum plants are located in the region because of low-cost electricity afforded by the region's coal and hydroelectric power plants. While most zinc used in the U.S. is imported, zinc ores are processed in the basin because of localized deposits on the Tennessee River. The ore is barged to refiners on the Cumberland, McClellan-Kerr-Arkansas, and Ohio rivers.

3.2.7.5 Cement and Lime Production

Rich, vast deposits of limestone supply more than just crushed stone for heavy construction. These deposits also support cement and lime production, which is centered in the southern and western portion of the basin. Numerous cement kilns in Ohio, Indiana, Kentucky, Illinois, Missouri, Tennessee and Alabama receive limestone and ship cement by barge. Six limekilns located in Kentucky, Missouri and Tennessee rely upon waterborne limestone, and in turn ship lime to the region's steel makers, paper plants and electric utilities.

3.3 LOWER LEVEL DEPENDENCE

Farming is dependent on waterway transportation to the extent that waterway transportation allows farm products to be competitive in distant markets. This, in turn, affects the farmer's selection of what to grow since the market for high valued products expands with distance. The most distant markets are overseas, while closer markets are generally food-processing plants. A listing of facilities used to load or unload barges of farm products is provided in **Table 3-8**.

TABLE 3-8
Waterside Facilities for Farm Products

Name	Milepoint	River	State
A.E. Staley	592	Tennessee	TN
Aurora Terminal Co., Inc.	496	Ohio	IN
Bunge Corp.	980	Ohio	IL
Cargill, Inc.	793	Ohio	IN
Cargill, Inc.	479	Ohio	OH
Consolidated Grain & Barge	597	Ohio	IN
Consolidated Grain & Barge	475	Ohio	OH
Continental Grain Co.	831	Ohio	IN
Garnac Grain Co.	780	Ohio	IN
Hopkinsville Elevator Co.	123	Cumberland	TN
Indiana Port Commission	831	Ohio	IN
Livingston Point River Terminal	4	Tennessee	KY
Owensboro Grain Co.	756	Ohio	KY
Peavey Co.	805	Ohio	KY
Wabash Elevator Co.	843	Ohio	KY

Paper and wood product production are major activities in the southern part of the basin, particularly along the Tennessee River. Shipments of products to and from these plants are of significant local importance, although minor in terms of overall Ohio River System tonnage.

3.4 CONCLUSION

All industries in the Ohio River Basin are to some degree dependent on the existence of an efficient and reliable navigation system. This includes industries that may never have shipped via barge and have no plans for doing so. In fact, some of the most highly dependent industries on waterway transportation do not ship on the rivers, but depend on the cost-savings that it provides to their suppliers, making them both more competitive. The waterway transportation system allows for lower transportation costs, and therefore lower delivered costs of basic raw materials, most importantly coal, stone, ores, chemicals and stone, to secondary producers of goods such as electricity, coke, specialty chemicals, and construction materials. In turn, these industries generally spawn tertiary producers of items like steel coils and slabs, aluminum, and paper products, which are then used in factories that produce final consumer goods such as automobiles, appliances, utensils, packaging, and food products.

Section 6, Historic and Projected Traffic, of this appendix documents the steady growth of waterway traffic over the past 60 years, indisputable evidence of basin shipper's dependence on the ORS. With the exception of export demands for coal and grain, the preponderance of commodities shipped on the waterway are relatively unaffected by changes in waterway prices. Both raw material production facilities and the downstream production facilities they supply represent major capital investments. More importantly for this study, these investments represent a long-term commitment to the waterway, a commitment likely unwavering over 20 – 30 year horizons. There are a number of reasons for this. Alternative development sites are extremely limited for quarries, power plants, steel mills, coal mines, chemical plants, petroleum refineries, and paper mills. Some of these facilities are legacies of job-rich economic development now considered undesirable in many areas of the country. And in many instances production is geographically circumscribed, as is the case with stone, wood products and coal. Consuming plants may also require specifications unique to a particular Ohio River Basin resource. This is particularly true with respect to the requirements of some utility plants for certain grades of coal for their boilers and chemical properties of limestone for their flue-gas de-sulfurization units. Finally, transportation options are often extremely limited. Large machines and fabrications, like electricity generators, often can move no other way than by water, and high volume bulk commodity shipments can be moved in a less disruptive fashion past major urban concentrations than through them. Limited alternatives for locating new plants, substituting product from other areas, and arranging alternative transportation act to make long run demands for waterway service in the Ohio Valley relatively stable.

SECTION 4

OHIO RIVER NAVIGATION SYSTEM

4.1 INTRODUCTION

The Ohio River navigation system (ORS) is a major portion of the nation's inland navigation system, providing for commercial navigation in the eastern one-third of the country. The ORS consists of more than 2,600 miles of commercially navigable waterways. It includes the Ohio River and the navigable portions of the Allegheny, Monongahela, Kanawha, Big Sandy, Green, Tennessee, Cumberland and Kentucky rivers (see **Figure 4-1**). The Ohio River serves as a collector of system traffic for distribution to points within and outside the Ohio basin while the tributary streams serve major mining areas and industrial concentrations within the Basin. Through interconnections with the Mississippi River and its tributaries, ORS traffic has access to midwestern states and deep-draft ports on the Great Lakes and Gulf Coast.

The study area includes the mainstem Ohio River, which extends from the junction of the Allegheny and Monongahela rivers at Pittsburgh, Pennsylvania, to near Cairo, Illinois where the Ohio joins the Mississippi River. This area includes 981 miles of commercially navigable channel and a total drainage area of 204,000 square miles. Year-round navigation is provided by a system of 20 locks and dams and annual maintenance dredging. The drainage area encompasses all or portions of fourteen states, including Alabama, Georgia, Kentucky, Indiana, Illinois, Maryland, Mississippi, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. The navigable tributary streams to the Ohio River are not part of this interim report.

4.2 HISTORY OF DEVELOPMENT

Federal involvement in improving the Ohio River for commercial navigation began in 1824, when Congress directed the Corps to find a method of removing sandbars and snags. In 1906, the Rivers and Harbors Board recommended construction of 54 locks and dams providing a nine-foot channel the entire length of the Ohio River. This plan, which called for 600-foot long lock chambers, was completed by the Corps between 1910 and 1929.

Once canalization was completed, the waterway spurred economic growth and assisted the rapid nationwide mobilization during World War II. Sustained post-war expansion of the national economy increased the use of all types of commodities carried on the river. This rapid growth in traffic exceeded the government's ability to increase lock capacity and by the 1950s serious delay problems had become obvious. The original 600-foot lock chambers built during the days of steamboats and small wooden barges were obsolete and could not handle modern tows (flotillas of bigger, steel barges pushed by diesel powered boats) in a single lockage.

FIGURE 4-1
Ohio River Navigation System, J.T. Myers and Greenup Locks and Dams Highlighted

4.3 RECENT LOCKS AND DAM IMPROVEMENTS

Diesel towboats and the new, larger barges brought increased efficiency to the movement of the energy, construction, and food products demanded by a world newly re-constructed following WW II. These efficiencies, however, could not be fully realized because the Ohio River navigation system remained a system designed to accommodate the transportation technology of the previous century. Lock chambers were small, typically a main chamber 600 by 110 feet and an auxiliary of 360 by 56 feet, and because wicket dams were low-lift structures, the projects were relatively close together. As a result, plans were formulated in the 1950s to modernize the navigation system. The plans developed called for the replacement of earlier low-lift structures with fewer high-lift locks. The modernized structures provide higher-lift dams with longer pool-reaches between projects, and larger lock dimensions. The modernization program envisioned 19 modern high-lift projects and began in 1954 with construction of Greenup Locks and Dam with a 30-foot lift, a 1200 by 110-foot main chamber, and a 600 by 110-foot auxiliary chamber. The specifications for the existing mainstem lock and dam projects are listed in **Table 4-1**.

The modernization program continues today with improvement of Robert C. Byrd Locks and Dam (formerly Gallipolis) located just upstream of Huntington, West Virginia; Olmsted Locks and Dam on the lower Ohio River; and McAlpine Locks and Dam located near Louisville, Kentucky. In January 1993, the new Robert C. Byrd Locks, measuring 1200 by 110 feet and 600 by 110 feet, became operational -- replacing the small and outdated locks at Gallipolis; major rehabilitation of the dam is ongoing and scheduled to be competed in September 2000. The new Olmsted Lock and Dam project at river mile 964.4 is currently under construction. The project, which will provide a modern structure to replace old Locks and Dam 52 and Locks and Dam 53, consists of twin 1200 by 110-foot locks and a new dam with submersible gates to allow tow passage over the dam during higher flow conditions. Construction was initiated in 1993 and is scheduled to be completed in the year 2008. With completion of Olmsted, the Ohio River mainstem will be reduced from 20 to 19 projects. The Water Resources Development Act of 1990 authorized improvement of McAlpine Locks and Dam at river mile 606.8. The project, which is currently under construction, will replace the old 600' Auxiliary Lock to a new 1200-foot chamber -- providing this site with twin 1200 by 110-foot locks.

TABLE 4-1
Ohio River Lock Specifications

Lock & Dam	River Mile	Year Operational			Year Rehabilitated			Chamber Sizes		
Project Name	(downstream of Pittsburgh)	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	
N. Cumberland	54.4	1956	1959	1961				1200x110	600x110	
Pike Island	84.2	1963	1963	1965				1200x110	600x110	
Hannibal	126.4	1972	1972	1975				1200x110	600x110	
Willow Island	162.4	1972	1972	1973				1200x110	600x110	
Belleville	203.9	1968	1968	1969				1200x110	600x110	
Racine	237.5	1967	1967	1970				1200x110	600x110	
R.C. Byrd	279.2	1993	1993	1937			2000+	1200x110	600x110	
Greenup	341.0	1959	1959	1962				1200x110	600x110	
Meldahl	436.2	1962	1962	1964				1200x110	600x110	
Markland	531.5	1959	1959	1964				1200x110	600x110	
McAlpine	606.8	1961	1921	1964		1965		1200x110	600x110	a
Cannelton	720.7	1971	1971	1971				1200x110	600x110	
Newburgh	776.1	1975	1975	1975				1200x110	600x110	
J.T. Myers	846.0	1975	1975	1975				1200x110	600x110	
Smithland	918.5	1979	1979	1979				1200x110	1200x110	
L&D No. 52	938.9	1969	1928	1929	1983	1983	1984	1200x110	600x110	*
L&D No. 53	962.6	1980	1929	1929	1983	1982	1984	1200x110	600x110	*

Notes:

a McAlpine Auxiliary is under construction. Will be replaced by a 1200'x110' by year 2002.

* Olmsted L&D (now under construction near L&D53), will replace both L&D 52 and 53.
Olmsted L&D will have 2 identical chambers, both of size 1200'x110' with completion by 2008.

4.4 CURRENT STATE OF THE WATERWAY

The mainstem Ohio River is currently a large canalized river consisting of 20 pools formed by 20 lock and dam structures. There will be 19 pools and 19 locks and dam structures after completion of Olmsted L&D in 2008, which replaces L&Ds 52 and 53. The current profile of the Ohio River mainstem is described in **Figure 4-2**.

The current geometry of the river, as improved by the higher pool levels of the modernized dam system, generally provides for safe navigation of commercial tows as long as they are no more than 1200 feet long and 108 feet wide. A typical large jumbo-hopper-barge tow consists of fifteen 195 by 35-foot barges, plus a towboat of varying dimensions, resulting in a tow of about 1170 feet by 105 feet. Occasionally, tows on the lowermost reaches of the Ohio, below Smithland L&D, operate in a double-wide configuration of 30 barges (5 long and 6 wide), typical of the larger tows on the lower Mississippi River. During winter months, these usually wide tows can navigate over the navigable wickets of Dams 52 and 53 (and after 2008 the wickets at the new Olmsted Dam). Such tows cannot navigate these reaches during the dryer months, when they must use the locks at L&D 52 and 53.

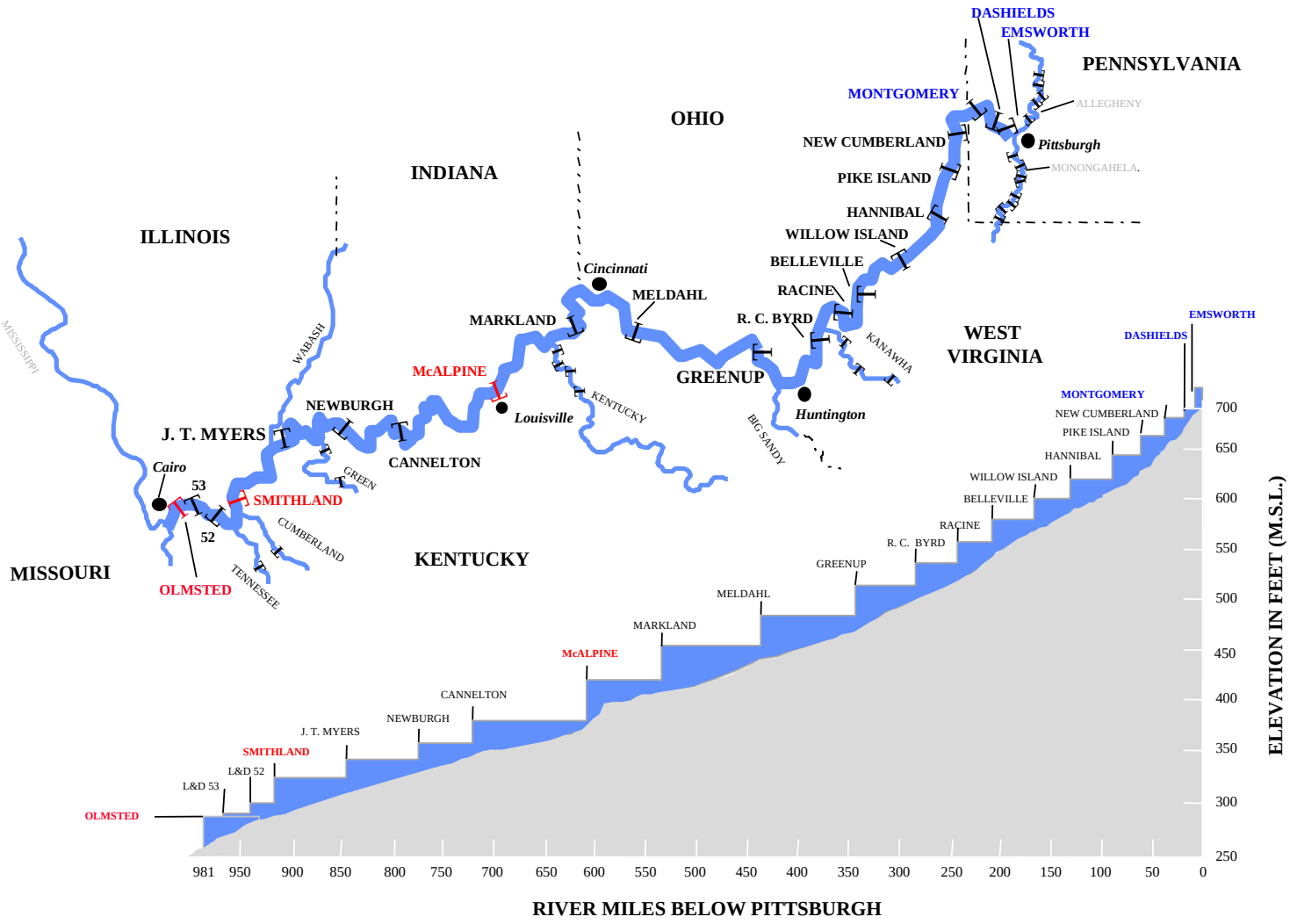
In terms of age and operating characteristics, the locks and dam facilities may be classified into 3 broad groups:

- The 60+ year old upper three structures (Emsworth, Dashshields, and Montgomery L&Ds) just downstream of Pittsburgh PA. These 3 locks each have one 600 by 110-foot main chamber and a 380 by 56-foot auxiliary chamber. Fifteen-barge tows must double cut to negotiate the main chambers, and must break apart up to 15 times to negotiate the small auxiliary chambers. The condition of these old structures, together with the inefficiently-small lock sizes, are major concerns – although lower traffic levels on the upper Ohio have pushed these problems into a lower priority strata compared with Greenup and J.T.Myers Locks (the focus of this Interim Report).

- The 13 modernized lock and dam structures constructed between 1954 and 1979 plus R. C. Byrd L&D (completed in 1993) include all the contiguous locks from New Cumberland downstream to J.T.Myers, a distance of 791.6 miles. Each of these newer locks has a 1200 by 110-foot main lock chamber and a 600 by 110-foot auxiliary chamber. The 1200-foot main chamber allows 15-barge tows to lock through in a single operation, while smaller vessels usually use the auxiliary chambers. These newer locks and dams are spaced about 60 miles apart. They replaced a series of about 40 old lower-lift structures built around the turn of the century.

- Locks which have dual, side-by-side 1200 by 110-foot locks include Smithland L&D (placed in operation in 1980), and Olmsted and McAlpine L&Ds, now under construction.

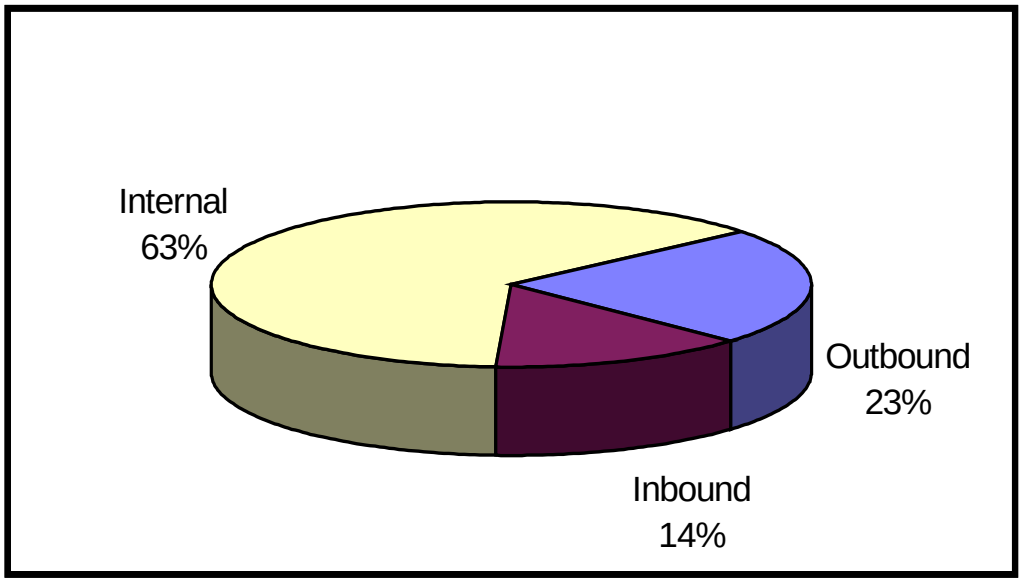
FIGURE 4-2
Ohio River Mainstem Plan and Profile



4.5 TONNAGE GROWTH AND COMMODITY MIX

The ORB states, parts of which area drained by the Ohio River and its tributaries, are home to over 55 million people. Pittsburgh, Cincinnati, Columbus, Indianapolis, Louisville, and Nashville are the region's largest cities. Waterborne commerce is made possible in the basin by a series of 60 lock and dam projects spread throughout the Ohio River and its 12 navigable tributaries (see **Figure 4-1** above). In recent years, barges on the ORS have carried approximately 260-270 million tons of bulk commodities. These commodities are the products of coal mines, petroleum refineries, stone quarries, cement plants, and farms and the raw material for construction companies, steel mills, electric utilities, paper plants, aluminum manufacturers, and chemical companies; the foundation of the region's economy. As can be seen in **Figure 4-3** below, most of this traffic (63 percent) is internal to the ORS.

FIGURE 4-3
Internal, Outbound and Inbound
Ohio River System Traffic



Basin river transportation revolves around the movement of coal and other bulk commodities, traffic most efficiently carried by water. The ORS extends this efficiency deep into the interior of the North American continent. The availability of this form of transportation, along with the availability of rich deposits of coal (approximately 70 billion tons of demonstrated reserves), have made Pittsburgh, Pennsylvania and Huntington, West Virginia, the second and fourth largest coal ports, respectively, in the United States. Most of the basin's coal moves to domestic markets -- primarily to the electric utility industry. Over the last 30 years, much of the region's electricity generating capacity has moved away from small streams and large cities to the more rural areas offered by the Ohio River and its system of navigable rivers. Dependable supplies of cooling water and access to low-cost transportation are the primary attractions. In fact, electric utility companies account for nearly half of system traffic.

The main artery of the Ohio River System is the mainstem Ohio. Eighty nine percent of system traffic moves on the Ohio River (see **Table 4-2**). Growth on the Ohio River has proceeded at a faster pace than the system as a whole, reflecting the relatively recent development of the mainstem as compared with some of the tributary streams like the Monongahela River. While in the last seven years growth on the mainstem Ohio has slowed from its rapid 1940-1990 pace, it continues to set new records for traffic, reaching a peak of 241.3 million tons in 1997.

TABLE 4-2
Historic Ohio River System and Mainstem Ohio Traffic (In mmtons)

Year	Mainstem	% of Total	ORS Total
1940	29.5	58%	51.2
1950	48.6	74%	66.1
1960	79.5	75%	105.3
1970	129.6	79%	163.9
1980	155.9	87%	179.3
1990	225.7	88%	257.8
1996	239.0	89%	267.2
1997	241.3	89%	271.5
Average Annual Percent Growth			
1940-1990	4.2%	NA	3.3%
1990-1997	1.0%	NA	0.7%

Like the system, Ohio River mainstem traffic is dominated by coal transportation (see **Table 4-3**). Of all commodities, coal has grown by the greatest amount over the last 10 years, but other commodities have grown at faster rates. Aggregates, ores and minerals, and iron and steel products all grew at average annual rates in excess of 4.0 percent annually. Petroleum products and chemicals (accounting for less than 10 percent of total Ohio River mainstem traffic) showed traffic declines.

TABLE 4-3
Historic Ohio River Mainstem Traffic by Commodity

Year	Coal	Petro	Aggregates	Grain	Chemicals	Ores	Iron	Other	Total
1965	46.6	20.5	14.2	2.6	6.0	7.6	3.4	2.3	103.2
1970	59.0	25.3	17.2	3.6	10.6	3.9	4.4	5.5	129.5
1975	73.3	19.6	16.5	4.1	9.1	3.5	3.9	10.1	140.1
1980	86.1	18.3	21.2	6.7	11.5	3.2	4.1	9.6	160.7
1981	94.1	15.2	18.6	8.4	10.8	3.9	4.1	9.4	164.5
1982	87.9	13.3	14.1	11.7	9.1	2.3	2.6	9.7	150.7
1983	85.4	12.7	15.3	9.8	10.7	2.2	3.4	10.9	150.4
1984	102.2	13.5	16.4	9.1	13.1	3.1	5.0	12.4	174.8
1985	98.2	12.5	20.9	11.7	12.7	3.5	5.0	13.4	177.9
1986	112.5	13.4	24.4	10.0	12.2	3.0	5.7	14.8	196.0
1987	114.7	14.0	28.0	12.6	12.4	2.7	5.9	8.2	198.5
1988	110.9	13.8	27.3	11.5	13.1	3.1	6.0	9.1	194.8
1989	115.8	14.1	29.0	14.3	11.6	3.2	6.5	9.3	203.7
1990	135.1	14.4	30.4	13.2	9.3	5.5	6.5	11.2	225.6
1991	131.6	13.9	27.0	10.2	9.7	5.7	6.2	14.8	219.1
1992	135.3	13.3	28.1	11.3	10.1	5.5	5.8	18.1	227.5
1993	130.1	13.4	29.9	14.0	10.5	5.8	7.3	17.5	228.5
1994	134.8	14.2	32.6	12.0	10.6	6.5	9.6	17.8	238.1
1995	130.3	13.6	33.4	12.0	10.7	6.7	10.1	19.0	235.8
1996	134.8	13.3	37.4	10.7	9.9	7.5	9.7	15.7	239.0
1997	135.1	12.9	40.2	10.9	10.1	6.8	9.5	15.8	241.3
Avg.Ann. Growth Rate **(65-97)**	**3.38%**	**-1.44%**	**3.31%**	**4.58%**	**1.64%**	**-0.35%**	**3.26%**	**6.21%**	**2.69%**
Recent AA Growth Rate **(87-97)**	**1.65%**	**-0.81%**	**3.68%**	**-1.4%**	**-2.03%**	**9.68%**	**4.88%**	**6.78%**	**1.97%**

Source: WCSC Data

SECTION 5

VESSEL FLEET AND LOCK UTILIZATION

5.1 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 Ohio River fleet consists largely of jumbo barges, 15 of these barges comprising a typical tow. This section describes the existing characteristics of barges and tows using J.T. Myers and Greenup locks and their performance in processing commercial traffic. Detailed discussions of the vessel fleet and lock utilization are presented in **Attachment 1** of this economics appendix.

5.2 VESSEL FLEET

5.2.1 Background

When Greenup and Myers locks were built in 1959 and 1975, respectively, the standard barge on the Ohio River was 175' long and 26' wide. Over the years, this barge type gave way to larger 195'–200' long and 35' wide jumbo barges. Today, super and giant sized jumbo barges measuring 245'-260' long and 35'-52' wide are becoming more prevalent on the lower Ohio River, though jumbo barges remain the most numerous.

Table 5-1 describes barge types used on the ORS and summarizes 1998 traffic by barge type and direction at Myers and Greenup. The larger super and giant jumbo hoppers are more prevalent at Myers than at Greenup. The majority of traffic is upbound at Myers and downbound at Greenup. These characteristics are reflective of the shippers and markets served by these two locks and their relative geographic position to productive and consumptive regions, as described in the following paragraphs.

TABLE 5-1
1998 Kilotons by Barge Type and Direction

Barge Type	Dimension	Myers		Greenup	
		Upbound	Downbound	Upbound	Downbound
Hoppers					
Irregular	135'x27'	101	30	21	16
Regular	175'x26'	8	4	54	64
Stumbo	195'x26'	-	-	192	698
Jumbo	195'x35'	23,622	21,158	14,061	40,222
Covered Jumbo	195'x35'	8,138	5,967	4,524	417
Super Jumbo	245'x35'	-	1,395	-	279
Giant Jumbo	260'x52'	-	2,020	-	4
Tankers					
Jumbo	195'x35'	1,484	531	798	446
147'	147'x52'	902	93	397	576
175'	175'x54'	1,844	247	1,238	476
264'	264'x52'	2,335	211	619	254
290'	290'x54'	3,479	586	1,681	3,591
Total		41,913	32,242	23,585	47,043

Source: COE LPMS data.

5.2.2 Traffic Statistics

Commodity traffic flow at a project is largely determined by its geographic location and the commodity mix influences barge type and tow configuration. Above Greenup Locks is a heavy concentration of shipments from the port of Huntington and the Big Sandy and Kanawha rivers. Below Greenup is Cincinnati, a large consumptive area. The ports of Evansville and Mt. Vernon lie above Myers and the Mississippi, Cumberland and Tennessee rivers are below. Traffic through the Myers and Greenup facilities commonly move to/from areas as distant as Brownsville and Pensacola on the Gulf Intracoastal Waterway, and Minneapolis on the upper Mississippi. However, most of the traffic at both facilities moves to docks on the Ohio River. **Table 5-2** shows 1998 commodity traffic by direction at both projects. Downbound coal originating on the Big Sandy and Kanawha rivers dominates Greenup traffic while that of Myers is more evenly distributed.

Historic data on the number of tons, barges (empty and loaded) and tows transiting Greenup and Myers locks are listed in **Table 5-3**. Both projects average around 17 or 18 tows per day. Greenup handles more barges but fewer loaded barges than Greenup.

The percentage of empty barges indicates the level of backhaul opportunities. This statistic is important 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 backhauls with barges moving loaded in one direction and empty in the opposite direction. **Table 5-3** shows a lower percentage of empty barges at Myers. Again, most traffic through Greenup originates in the Greenup and Byrd pools, a region dominated by the production of coal. Myers serves regions that are both production and consumption oriented, like the Gulf Coast and the Tennessee Valley, so that greater opportunities exist for loaded backhauls. Backhauling imported ore and steel products during the latter 1990s reduced the percentage of empty barges at Myers.

TABLE 5-2
1998 Commodity Traffic by Direction
(Ktons)

	J.T. Myers		Greenup	
Commodity	**Upbound**	**Downbound**	**Upbound**	**Downbound**
Coal	15,421	22,254	3,783	39,363
Petrol	3,521	670	874	4,055
Aggregates	1,964	174	6,204	194
Grains	553	4,649	139	32
Chemicals	6,747	831	3,707	629
Ores	4,289	174	2,247	176
Iron	4,940	1,678	3,035	1,228
Other	4,480	1,810	3,596	1,366
Total	41,915	32,240	23,585	47,043

Source: COE LPMS Data.

TABLE 5-3
Tons, Barges, % Empty and Tows since 1992

	1992	1993	1994	1995	1996	1997	1998
Greenup							
Tons(000s)	61,130	61,339	68,695	67,573	67,262	69,891	70,635
Barges	65,026	64,529	70,180	69,385	68,550	74,266	71,639
% Empty	39%	38%	36%	37%	37%	39%	37%
Tows	5,930	5,793	6,437	6,313	6,415	6,730	6,640
Myers							
Tons(000s)	77,552	80,457	85,718	82,108	77,603	76,218	74,151
Barges	81,494	82,417	83,111	78,249	72,843	71,143	67,835
% Empty	39%	37%	34%	34%	34%	34%	32%
Tows	7,231	6,845	7,070	6,870	6,592	6,339	6,039

Source: COE LPMS Data.

5.2.3 Barge Types

The predominant barge type at Myers and Greenup is the jumbo hopper. While the fleet consists largely of jumbo barges, other types also move through these locks (**Table 5-4**). Myers handles more covered jumbos than Greenup moving fertilizers into and grains out of the Evansville and Cincinnati areas. The super and giant hoppers are more prevalent on the lower Ohio. More long distance movements of coal, coke, slag and grain where these larger hoppers are more economic transit Myers. **Table 5-5** shows the relative usage of all barge types and their average loadings at Myers and Greenup. The overall average barge loading is greater at Myers than at Greenup due to the existence of more loaded giant hoppers.

TABLE 5-4
Description of Barge Types

Barge Type	Dimension	Capacity (Ktons)	Typical Commodities
Hoppers			
Irregular	135'x27'	867	Aggregates
Regular	175'x26'	1,069	Coal, Aggregates
Stumbo	195'x26'	1,121	Coal
Jumbo	195'x35'	1,669	Coal, Aggregates, Ores & Iron
Covered Jumbo	195'x35'	1,764	Grains, Chemicals
Super Jumbo	245'x35'	2,106	Coal, Aggregates
Giant Jumbo	260'x52'	3,329	Coal, Grains, Aggregates & Coke
Tankers			
Jumbo	195'x35'	1,454	Petroleum Products & Chemicals
147'	147'x52'	1,711	Petroleum Products & Chemicals
175'	175'x54'	2,317	Petroleum Products & Chemicals
264'	264'x50'	2,820	Petroleum Products & Chemicals
290'	290'x54'	3,295	Petroleum Products & Chemicals

Source: COE LPMS Data.

Table 5-6 shows the percentage of empty barges at bot projects by barge type and direction. The directional flow of commerce is again evident with 15 percent of Greenup downbound barges and 8 percent of Myers upbound barges being empty. **Table 5-6** also indicates the greater prevalence of empty barges at Greenup than at Myers.

TABLE 5-5

Barge Distributions and Average Barge Loadings
Loaded Barges Only, 1998

Barge Type	Myers		Greenup	
	Loaded Barges	Avg. Loading	Loaded Barges	Avg. Loading
Hoppers				
Irregular	206	636	26	1,423
Regular	17	706	90	1,311
Stumbo	-		455	1,956
Jumbo	30,815	1,453	37,141	1,462
Covered Jumbo	8,563	1,647	3,054	1,618
Super Jumbo	642	2,173	123	2,268
Giant Jumbo	691	2,923	4	1,000
Tankers				
Jumbo	1,664	1,211	1,020	1,220
147'	441	2,256	217	4,484
175'	873	2,395	738	2,322
264'	710	3,586	233	3,747
290'	1,251	3,249	2,129	2,476
Overall	45,873	1,616	45,230	1,562

Source: COE LPMS Data.

TABLE 5-6
Percent Empty by Type and Direction, 1998

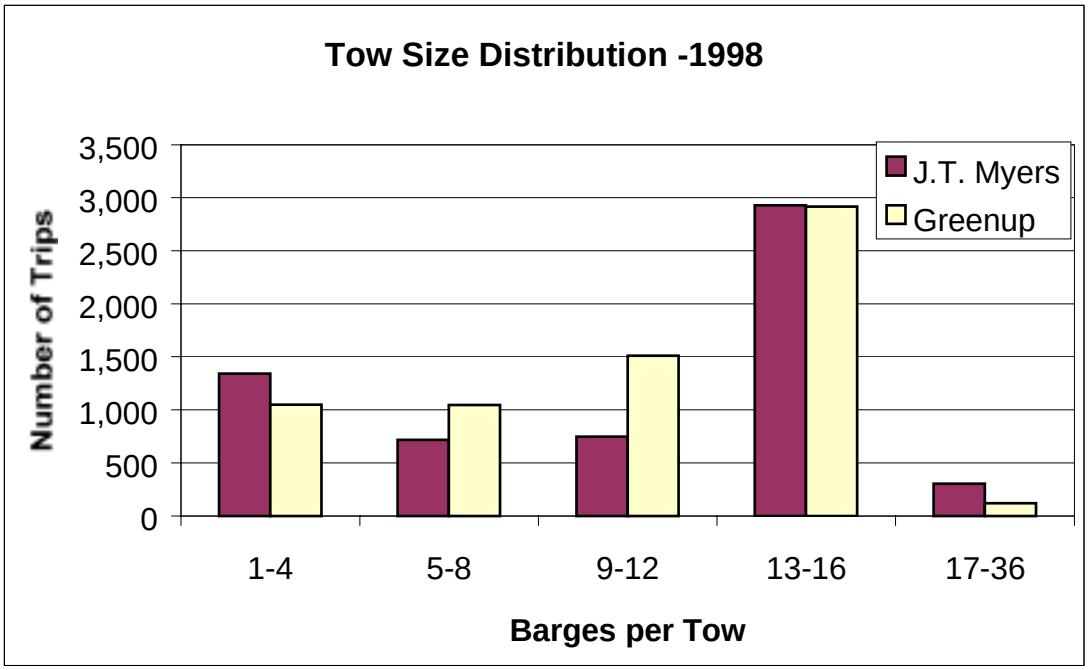
Barge Type	Myers		Greenup	
	Upbound	Downbound	Upbound	Downbound
Hoppers				
Irregular	8%	38%	43%	80%
Regular		37%	40%	26%
Stumbo		100%	67%	7%
Jumbo	3%	38%	65%	9%
Covered Jumbo	15%	29%	21%	72%
Super Jumbo		1%		3%
Giant Jumbo	98%	3%	100%	33%
Tankers				
Jumbo	13%	68%	21%	66%
147'	2%	97%	55%	50%
175'	4%	88%	5%	56%
264'	4%	80%	9%	30%
290'	10%	85%	74%	20%
All Barge Types	8%	40%	59%	15%

Source: COE LPMS Data.

5.2.4 Tow Characteristics

Figure 5-1 displays the commonality of tow configurations at Myers and Greenup locks. Tankers tend to move in 2 barge tows. They typically move petroleum products, chemicals and asphalt. Four-barge tows are normally sand-flats (irregulars). Jumbos tend to move in 12 or 15 barge tows. For both projects, a 15-barge tow is the typical tow size. Ohio River tows take advantage of 1200-foot lock chambers. The main chambers at both Myers and Greenup can accommodate up to 17 jumbo barges, 12 super jumbo barges, or 8 giant jumbo barges in a single lockage. **Table 5-7** shows tow size distributions by barge type.

FIGURE 5-1



Source: COE LPMS Data.

TABLE 5-7
Tow Size Distribution, 1998

Barge Type	Barges per Tow	J.T. Myers Number	J.T. Myers Percent	Greenup Number	Greenup Percent
Irregular	**1-4**	**9**	**45%**	**23**	**96%**
	5-8	2	10%	1	4%
	9-12	-	0%	-	0%
	13-16	2	10%	-	0%
	17-36	7	35%	-	0%
Regular	1-4	3	75%	5	31%
	5-8	-	0%	4	25%
	9-12	-	0%	4	25%
	13-16	-	0%	1	6%
	17-36	1	25%	2	13%
Stumbo	1-4	-	0%	2	4%
	5-8	1	100%	4	8%
	9-12	-	0%	12	24%
	13-16	-	0%	7	14%
	17-36	-	0%	24	49%
Jumbo	1-4	229	7%	269	6%
	5-8	256	8%	414	9%
	9-12	370	11%	1,268	27%
	13-16	**2,386**	**70%**	**2,645**	**57%**
	17-36	162	5%	80	2%
Covered Jumbo	1-4	64	8%	34	8%
	5-8	65	8%	54	13%
	9-12	111	14%	92	23%
	13-16	**405**	**52%**	**213**	**52%**
	17-36	132	17%	13	3%
Super Jumbo	1-4	1	2%	-	0%
	5-8	2	4%	-	0%
	9-12	3	7%	4	40%
	13-16	40	87%	6	60%
	17-36	-	0%	-	0%
Giant Jumbo	1-4	40	20%	9	90%
	5-8	**156**	**77%**	-	0%
	9-12	6	3%	1	10%
	13-16	-	0%	-	0%

Source: COE LPMS Data.

TABLE 5-7 (cont'd)
Tow Size Distribution, 1998

Barge Type	Barges per Tow	J.T. Myers Number	J.T. Myers Percent	Greenup Number	Greenup Percent
Jumbo Tanker	1-4	97	27%	83	30%
	5-8	64	17%	**97**	**35%**
	9-12	**129**	**35%**	61	22%
	13-16	75	20%	36	13%
	17-36	1	0%	1	0%
147 Tanker	1-4	50	43%	67	60%
	5-8	16	14%	37	33%
	9-12	51	44%	8	7%
	13-16	-	0%	-	0%
	17-36	-	0%	-	0%
175 Tanker	1-4	28	21%	46	31%
	5-8	36	26%	67	46%
	9-12	53	39%	26	18%
	13-16	19	14%	8	5%
	17-36	-	0%	-	0%
264 Tanker	**1-4**	**193**	**79%**	**55**	**76%**
	5-8	31	13%	15	21%
	9-12	17	7%	2	3%
	13-16	2	1%	-	0%
	17-36	-	0%	-	0%
290 Tanker	**1-4**	**630**	**87%**	**455**	**54%**
	5-8	90	12%	353	42%
	9-12	6	1%	32	4%
	13-16	-	0%	-	0%
	17-36	-	0%	-	0%
Total		6,039		6,640	

Source: COE LPMS Data.

Average tow sizes are shown in **Table 5-8**. The average tow size at both projects is around 11 barges. Myers, however, averages heavier tows due to accommodating heavier and more giant jumbo hoppers and relatively fewer empty barges.

TABLE 5-8
Average Tow Sizes

	1992	1993	1994	1995	1996	1997	1998
Greenup							
Barges/Tow	11.0	11.1	11.0	11.0	10.7	11.0	10.8
Tons/Tow	10,309	10,588	10,672	10,704	10,485	10,385	10,639
Tons/Barge	1,538	1,545	1,539	1,549	1,554	1,533	1,560
Myers							
Barges/Tow	11.3	12.0	11.1	11.4	11.1	11.2	11.2
Tons/Tow	10,725	11,754	12,124	11,952	11,772	12,024	12,277
Tons/Barge	1,554	1,557	1,574	1,586	1,620	1,628	1,613

Source: COE LPMS Data.

5.3 LOCK OPERATIONS

5.3.1 Towing Operations

During normal operations, the main chamber at Myers and Greenup is used predominantly by large tows and the auxiliary chamber is used by single cut tows of less than 600' in length, recreational traffic, and other smaller vessels like lightboats. The maximum number of cuts allowed at Myers and Greenup is a single cut through the main chamber and a double cut through the auxiliary chamber. This equates to a 17 jumbo barge tow as the largest size tow that can pass through the main chamber in one lockage. Double cuts are allowed in the auxiliary chamber during periods of closure of the main chamber. **Table 5-9** shows chamber utilization by vessel type for 1998.

TABLE 5-9

Usage by Chamber, 1998

Project	Main Chamber			
	Tows	Light Boats	Rec Boats	Other
Myers	5,575	41	145	19
Greenup	5,820	73	36	10
	Auxiliary Chamber			
	Tows	Light Boats	Rec Boats	Other
Myers	464	308	2,605	64
Greenup	820	316	1,015	30
	Both Chambers			
	Tows	Light Boats	Rec Boats	Other
Myers	6,039	349	2,750	83
Greenup	6,640	389	1,051	40

Source: COE LPMS Data.

5.3.2 Lock Operating Hours

Both 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.

5.3.3 Lockage Policy

Tows are normally locked through on a first-come/first-serve basis. Typically tows under 600' use the auxiliary chamber and tows greater than 600' use the main chamber. Nearly all of the tows at Myers and Greenup require one-cut. However, during periods when the main chamber is closed for maintenance/repair, the 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.

5.4 LOCK TRANSIT TIMES

5.4.1 General

The time required for a tow to transit a lock has two components: processing time and delay time. Processing time is the amount of time a lock is obligated to serve a particular tow. Delay time is the time a tow may have to wait to be served. Average processing and delay times for Greenup and Myers since 1992 are provided in **Table 5-10**. At both projects more variability is seen in average delay time compared to average processing time. Heavier use of the auxiliary chamber at Myers during main chamber closure accounts for the increase in processing time since 1992 as single cut tows at the main chamber require two cuts at the auxiliary. Higher than normal delays at Greenup in 1994 and 1998 and at Myers in 1994 and 1995 are attributable to closure of the main or auxiliary chambers for maintenance.

5.4.2 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. For example, a 15-jumbo barge tow (approximately 1140' in length) is processed in one lockage operation through a 1200' main chamber and two lockage operations to process through a smaller 600' auxiliary chamber. 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 (see **Table 5-10**) 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 in 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.

TABLE 5-10
Average Lock Transit Times
(Minutes per Tow)

	1992	1993	1994	1995	1996	1997	1998
Greenup							
Process	48.6	50.4	52.5	51.7	50.9	50.6	53.2
Delay	35.8	41.4	96.6	45.0	44.5	52.7	141.9
Total	84.4	91.8	149.1	96.7	95.4	103.3	195.1
Myers							
Process	42.9	47.6	50.9	50.2	47.8	48.9	51.2
Delay	43.6	44.5	62.5	63.8	43.7	40.1	43.3
Total	86.5	92.1	113.4	114.0	91.5	89.0	94.5

Source: COE LPMS Data.

5.4.3 Delay Time

Delays are recorded in the Lock Performance Monitoring System (LPMS) whenever a tow reaches a given 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. Delays are a problem at Myers and Greenup when the main chamber is closed for maintenance because at current traffic levels tows arrive faster than they can be processed with the smaller auxiliary chamber.

Greenup experienced higher than normal average delay in1994 and 1998 due to main chamber maintenance closures of 1.5 and 4 weeks, respectively. Historic chamber outages at Myers due to maintenance/repair include 2 weeks for the auxiliary chamber in 1996 and 2 weeks for the main chamber in both 1994 and 1995.

5.5 VESSEL FLEET, LOCK PROCESSING TIME AND 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, 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 is discussed briefly in **Section 7.3.5.2** Capacity Analysis and in detail in **Attachment 1** Capacity Analysis. This definition of capacity is a useful descriptive measure but does not attempt to measure economic capacity. Despite sharing identical physical dimensions, Myers and Greenup locks can be expected to have different

capacities based upon significant differences in vessel fleets and processing times (see **Table 5-11**). Given this definition of capacity, Myers has an estimated capacity of 174.2 million tons and Greenup is estimated at 158.0 million tons. The difference in capacity estimates can be attributed to Myers having heavier barge loadings, larger tows, fewer empty barges (more backhaul opportunity) and lower lock processing times.

TABLE 5-11
Comparative Capacity, Myers and Greenup

	Myers	Greenup	% Difference Myers vs. Greenup
Tons/Tow[1] (ktons)	12,024	10,385	14%
Processing Time[1] (minutes)	89.0	103.0	-16%
Capacity[2] (mmtons)	174.2	158.0	9%

[1/] 1997 LPMS

[2/] Capacity estimates are discussed in **Attachment 1** to this appendix

SECTION 6

HISTORIC and PROJECTED TRAFFIC

6.1 GENERAL

This section discusses historic, existing and projected future traffic on the ORS, the Ohio River mainstem, and at the Greenup and Myers facilities. The historic factors that contributed to the growth of waterborne traffic are discussed. The methodology used in projecting future traffic demands is documented and projection results are summarized.

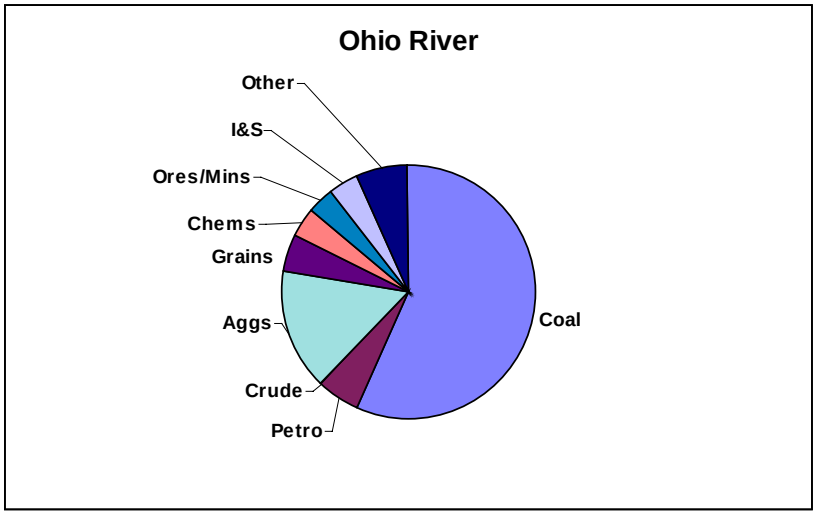
6.2 EXISTING TRAFFIC

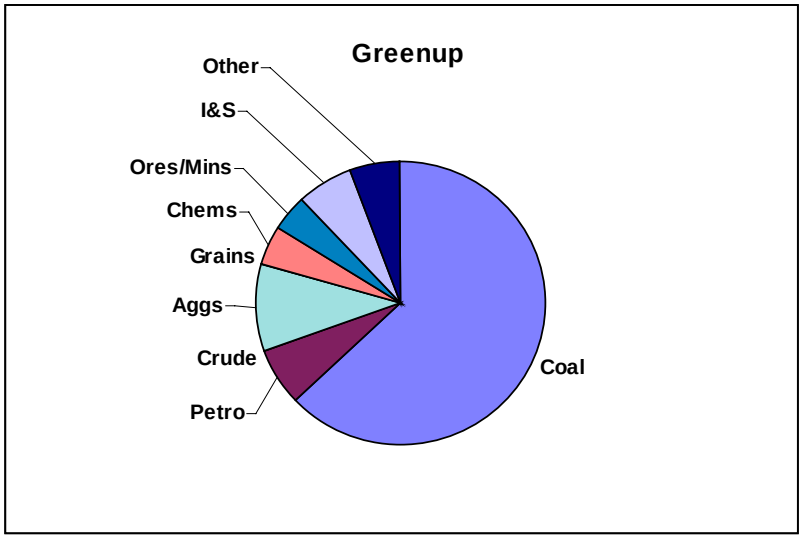
The mainstem Ohio River handled about 239 million tons of traffic in 1996, representing about 89 percent of the traffic on the Ohio River System. The Greenup and Myers facilities handled about 70.8 and 78.9 million tons, respectively, representing 30 and 33 percent of the mainstem total. **Table 6-1** shows 1996 traffic by commodity group for the Greenup and Myers locks, the Ohio River mainstem, and the Ohio River System, in total. The commodity traffic distributions for the mainstem and the individual locks are presented in **Figure 6-1**.

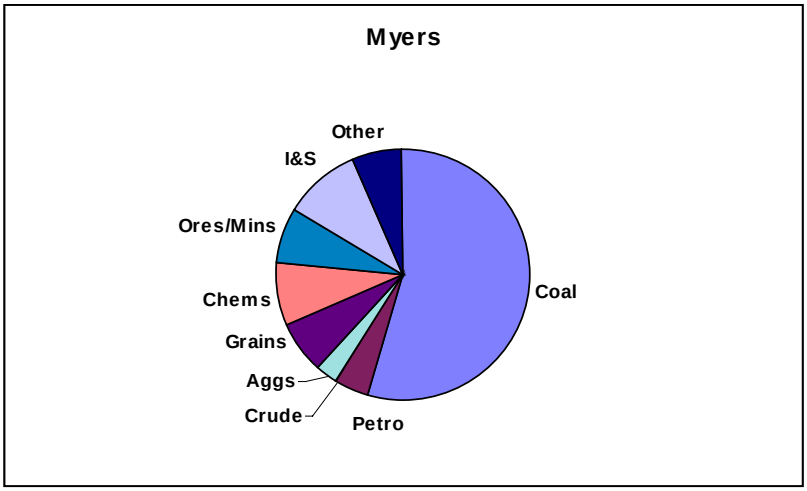
TABLE 6-1
Commodity Traffic at Greenup, Myers, the Ohio River and the ORS, 1996
(Millions of Tons)

Commodity	Greenup	Myers	Ohio River	ORS
Coal	44.4	42.8	134.8	157.2
Petroleum Fuels	4.7	3.5	13.0	13.0
Crude Petroleum	-	-	0.2	0.2
Aggregates	7.0	2.2	37.4	42.1
Grains	-	5.3	10.7	11.0
Chemicals	3.3	6.5	9.9	10.0
Ores & Minerals	2.8	5.8	7.5	7.6
Iron & steel	4.6	7.8	9.7	9.8
All Others	3.9	5.0	15.7	16.3
Total	70.8	78.9	239.0	267.2

Figure 6-1. Commodity Traffic Distributions, 1996







The leading commodity group on the Ohio River mainstem in 1996 was coal and coke, accounting for about 56 percent of total traffic. A large majority (more than 80 percent) of this traffic was utility coal. Aggregates was next in importance (16 percent) followed by all other, comprising mainly animal feeds, lime, asphalt, cement, and waterway improvements material (7 percent); petroleum fuels (5 percent); and grains (5 percent). Collectively, these commodity groups accounted for about 89 percent of total Ohio River mainstem tonnage. The remaining tonnage was made up of chemicals (4 percent); iron and steel (4 percent); ores and minerals (3 percent); and crude petroleum (less than 1 percent).

A comparison of the 1996 commodity distributions in **Figure 6-1** points out the similarities and differences between the lock-level distributions and the Ohio River. The most important similarity among the commodity distributions is the share of coal traffic, ranging between 54 and 63 percent. The comparison shows that Greenup is somewhat more reliant than Myers and the Ohio River on coal and petroleum fuels traffic and less reliant than both on grain traffic. Myers is more reliant than both Greenup and the Ohio River on grains, chemicals, ores and minerals, and iron and steel traffic. Both Greenup and Myers handle a much smaller share of aggregates than the Ohio River as a whole.

6.3 HISTORIC TRAFFIC DEVELOPMENT

6.3.1 Historic Growth Factors

Since the end of the Second World War, fairly continual industrial expansion in the Ohio River Basin has produced significant increases in commodity traffic on the Ohio River mainstem. Dramatic increases occurred in the immediate post-war period as the navigation system accommodated the transportation needs of expanding basin industries, particularly the primary metals industry in the Wheeling and Pittsburgh areas.

Between 1950 and 1965, traffic on the Ohio River mainstem doubled. Over the next 25 years, 1965-1990, traffic on the mainstem doubled once again. Most of this traffic growth was driven by massive investments in waterside coal-fired electric generating facilities that were expanding to accommodate the needs of an expanding economic base. Electric utilities were locating new plants along the Ohio River and expanding their existing waterside facilities to take advantage of the river as a source of water supply and for low-cost waterway transportation of coal. Since 1990, with slower growth in coal traffic, mainstem traffic growth has been driven by rapid increases in aggregates and iron and steel traffic.

6.3.2 Total Traffic

Ohio River mainstem traffic for the period 1940-1997 is presented in **Table 6-2**. In 1940, mainstem traffic accounted for about 58 percent of traffic on the ORS, but by the 1990s, mainstem traffic made up around 89 percent of system traffic. Over the 57-year period, Ohio River mainstem traffic increased at an annual rate of about 3.8 percent, compared to a growth rate of about 3 percent for the ORS. During the 1990s, the growth in mainstem traffic slowed

substantially relative to the historic trend. Between 1990 and 1997, traffic on the mainstem grew at an annual rate of about 1 percent, or just slightly higher than the ORS growth rate of 0.7 percent.

TABLE 6-2

Historic Ohio River System and Mainstem Traffic
1940-1997

	Ohio River System (Mtons)		
Year	Ohio Mainstem	% of ORS	ORS Total
1940	29.5	58%	51.2
1950	48.6	74%	66.1
1960	79.5	75%	105.3
1970	129.6	79%	163.9
1980	174.9	87%	200.5
1990	225.7	88%	257.8
1995	235.8	89%	263.5
1996	239.0	89%	267.2
1997	241.3	89%	271.5
Annual Growth:			
-1940-97	3.8%		3.0%
-1990-97	1.0%		0.7%

Source: Waterborne Commerce Statistics

Table 6-3 shows total commodity traffic at Ohio River mainstem projects for the period 1970-1997. The highest growth rates for the 27-year period occurred at projects in the middle Ohio Valley, while projects along the upper Ohio had the lowest. The highest rate of commodity traffic growth occurred at the Greenup facility (3.5 percent). The growth rate for the Myers facility, 2.9 percent, was the highest among the lower river projects. Lock-level commodity traffic growth has been hampered in the 1990s by a substantial drop-off in export coal and grain traffic, as well as a reduction in the usage of Illinois Basin coal by electric utilities. The projects most severely affected by this are those on the lower river, including the Myers facility.

TABLE 6-3

Historic Traffic at Ohio River Projects and on the Ohio River System
(Million Tons)

Project	1970	1980	1990	1995	1996	1997	Annual % Growth 1970-97
Emsworth	19.6	20.0	21.8	21.6	23.5	23.0	0.6
Dashields	20.2	21.0	23.2	22.8	24.5	23.9	0.6
Montgomery	17.4	20.4	25.0	25.2	27.3	26.8	1.6
New Cumberland	19.2	23.2	30.4	36.5	37.4	36.1	2.4
Pike Island	19.8	26.4	36.0	43.9	45.3	42.3	2.8
Hannibal	22.4	30.4	36.3	47.9	48.8	46.4	2.7
Willow Island	25.6	31.6	34.5	45.6	46.3	43.5	2.0
Belleville	26.1	32.6	37.0	48.4	49.7	47.0	2.2
Racine	27.0	34.0	38.2	49.0	50.6	47.9	2.1
Byrd	28.9	37.4	42.3	60.3	61.9	58.0	2.6
Greenup	**28.7**	**34.8**	**56.2**	**71.0**	**70.8**	**73.3**	**3.5**
Meldahl	28.5	34.6	55.2	65.0	64.0	64.5	3.1
Markland	29.4	37.8	53.6	58.8	55.4	55.5	2.4
McAlpine	33.0	41.5	58.4	60.0	54.5	52.8	1.8
Cannelton	38.1	43.2	62.4	60.5	56.3	55.3	1.4
Newburgh	32.8	43.9	74.3	73.5	69.2	65.1	2.6
Myers	**34.8**	**50.3**	**83.6**	**85.0**	**78.9**	**75.8**	**2.9**
Smithland	39.1	58.5	91.2	89.9	85.0	82.9	2.8
L/D 52	45.9	63.0	101.4	98.2	93.8	92.1	2.6
L/D 53	43.3	53.6	87.8	87.9	86.2	84.8	2.5
Ohio River	129.5	160.7	228.0	235.8	239.0	241.3	2.3
Ohio River System	163.1	200.5	260.3	263.5	267.2	271.5	1.9

Source: Waterborne Commerce Statistics.

6.3.3 Commodity Group Trends

6.3.3.1 General

Ohio River traffic by commodity group for selected years between 1970 and 1997 is shown in **Table 6-4**. On the mainstem, each of the major commodity groups increased in tonnage between 1970 and 1997, with the exceptions of petroleum and chemicals. The highest annual growth rates occurred in shipments of grains, aggregates, all other, and coal. A rather steep drop in petroleum products traffic came about as a result of the completions of several

petroleum products pipelines in the 1970s. Since 1990, the mainstem has witnessed slight decreases in coal, petroleum, and grains traffic, and substantial increases in aggregates, iron and steel, and ores and minerals traffic.

TABLE 6-4

Historic Ohio River Mainstem Traffic by Commodity Group, 1970-1997
(Million Tons)

							Annual % Growth	
Commodity	1970	1980	1990	1995	1996	1997	1970-97	1990-97
Coal	59.0	86.1	136.7	130.3	134.8	135.1	3.1	-0.2
Petroleum Fuels	15.5	17.7	13.4	13.4	13.0	12.7	-0.7	-0.8
Crude Petroleum	7.1	0.6	0.5	0.2	0.2	0.2	-12.0	-11.1
Aggregates	17.2	21.2	28.7	33.4	37.4	40.2	3.2	4.9
Grains	3.6	6.7	10.3	12.0	10.7	10.9	4.2	0.9
Chemicals	10.6	11.5	9.3	10.7	9.9	10.1	-0.2	1.2
Ores & Minerals	3.9	3.2	5.5	6.7	7.5	6.8	2.1	3.0
Iron & Steel	4.4	4.1	6.5	10.1	9.7	9.5	2.9	5.5
Others	5.5	9.6	17.0	19.0	15.7	15.8	4.0	-1.1
Mainstem	126.8	160.7	228.0	235.8	239.0	241.2	2.4	0.8
ORS	163.1	200.5	260.3	263.5	267.2	271.5	1.9	0.6

Source: Waterborne Commerce Statistics

Table 6-5 displays traffic by commodity group for Greenup and Myers. Similar to the Ohio mainstem, the Greenup facility experienced traffic increases in each commodity group except for petroleum and chemicals over the 1970-1997 period. The facility had its most substantial annual growth in ores and minerals, coal, and aggregates. Between 1990 and 1997, total traffic at the Greenup facility grew somewhat faster than during the 1970-1997 period (3.9 vs. 3.5 percent). Once again, the highest growth rates occurred in the aggregates, coal, and ores and minerals groups.

At the Myers facility, every commodity group experienced growth between 1970 and 1997, with the exception of petroleum. The highest growth rates occurred in shipment of aggregates, ores and minerals, grains and coal. From 1990 to 1997, commodity traffic at the Myers locks diminished at an annual rate of about 1.4 percent, driven by decreases in shipments of coal, grains, and petroleum.

TABLE 6-5

Historic Commodity Traffic by Commodity Group at Greenup and Myers, 1970-1997 (Million Tons)

Project/ Commodity	1970	1980	1990	1995	1996	1997	Annual % Growth 1970-97	Annual % Growth 1990-97
Greenup:								
Coal	5.5	17.0	34.0	44.7	44.4	48.5	8.4%	5.2%
Petro Fuels	5.9	6.0	4.4	4.7	4.7	4.5	-1.0%	0.1%
Crude Petro.	5.8	0.1	0.0	0.0	0.0	0.0	-22.0%	-20.2%
Aggregates	1.0	1.8	4.3	6.5	7.0	7.0	7.5%	7.3%
Grains	-	-	-	-	-	-	-	-
Chemicals	4.0	3.6	3.4	3.6	3.3	3.2	-0.9%	-1.1%
Ores & Min.	0.2	1.1	1.9	2.3	2.8	2.3	9.6%	2.8%
Iron & steel	3.4	2.6	3.9	5.5	4.6	3.6	0.3%	-1.1%
All Others	2.9	2.7	4.2	3.8	3.9	4.1	1.3%	-0.2%
Total	28.7	34.9	56.2	71.0	70.8	73.3	3.5%	3.9%
J. T. Myers:								
Coal	13.3	24.9	52.3	46.4	42.8	41.6	4.3%	-3.2%
Petro Fuels	8.7	6.5	4.3	3.8	3.5	3.6	-3.2%	-2.4%
Crude Petro.	-	0.3	0.1	-	-	-	-	-
Aggregates	0.1	0.1	1.1	1.7	2.2	2.0	11.7%	8.5%
Grains	0.6	3.7	5.5	7.1	5.3	4.9	8.0%	-1.9%
Chemicals	4.8	7.2	6.4	7.0	6.5	6.5	1.1%	0.1%
Ores & Min.	0.3	1.9	4.0	5.1	5.8	5.3	11.2%	3.9%
Iron & steel	3.3	2.6	5.4	8.2	7.8	7.1	2.9%	4.0%
All Others	3.7	3.1	4.4	5.7	5.0	4.9	1.0%	1.6%
Total	34.8	50.3	83.6	84.9	78.9	75.8	2.9%	-1.4%

Source: Waterborne Commerce Statistics

6.3.3.2 Coal and Coke

Table 6-4 shows mainstem traffic in coal and coke increasing at a rate of about 3.1 percent per year between 1970 and 1997, reaching a level of 135.1 million tons. The growth in coal and coke traffic was influenced by a number of factors. During the 1970s and 1980s, utilities were continuing to expand coal-fired electric generating capacity along the Ohio River. The oil embargo of the mid-1970s and efforts at oil conservation increased interest in coal as an energy source. In the early 1980s, changes in the steel industry brought about greatly reduced requirements for coke (and therefore coking coal) in steel-making processes. Passage of the Clean Air Act amendments (particularly the 1990 amendments) increased interest in low sulfur

coal from mines in the western U.S. and Central Appalachian, resulting in higher levels of waterborne coal traffic. Also, coal export traffic from the ORS increased rapidly from the mid-1980s until the mid-1990s, at which time, an economic downturn in Asia and competition in foreign markets caused ORS coal exports to diminish. Between 1990 and 1997, largely as a result of decreasing coal exports, Ohio River coal and coke traffic diminished at an annual rate of about 0.2 percent.

As demonstrated in **Table 6-5**, coal and coke through the Greenup facility grew at an annual rate of 8.3 percent between 1970 and 1997, reaching a level of about 47.3 million tons. Between 1990 and 1997, coal and coke traffic growth through Greenup slowed to about 5.2 percent a year. Since 1990, a steep drop in export coal traffic has hurt Greenup tonnage. This drop has been more than offset, however, by increased shipments of Central Appalachia low sulfur coal to utilities in the Middle Ohio Valley, a result of implementation of the Clean Air Act Amendments of 1990.

Coal and coke traffic through the Myers locks increased at a rate of 4.3 percent per annum between 1970 and 1997. In 1997, the facility handled about 41.6 million tons of coal and coke. Between 1990 and 1997, coal traffic at the locks diminished at a rate of 3.2 percent per year. Although the Clean Air Act Amendments resulted in an increase in low-sulfur Western and Central Appalachian coals moving through the facility, this increase was insufficient to offset a steep drop high sulfur Illinois Basin coal and export coal traffic.

6.3.3.3 Petroleum Fuels

Table 6-4 shows that petroleum fuels traffic on the Ohio River mainstem diminished at a rate of 0.7 percent annually between 1970 and 1997, reaching a level of 12.7 million tons. A rather steep drop in petroleum fuels traffic in the 1980s came about as a result of large-scale conservation measures; the recession in the early 1980s; a concentration of refinery capacity in the Gulf Coast area; a shift toward pipeline petroleum product deliveries to the ORB area; and the closure of several water-oriented ORB refineries.

In 1997, the Greenup and Myers locks handled 4.5 and 3.6 million tons of petroleum fuels, respectively. Similar to the mainstem, petroleum fuels traffic at Myers diminished between 1970 and 1997, while petroleum fuels at Greenup increased slightly. The rate of decline at Myers was 2.6 percent per annum, compared to a decline of 0.5 percent for the mainstem itself, and an increase of 0.1 percent at Greenup. Greenup's location near the Marathon-Ashland refinery at Catlettsburg, Kentucky tends to support petroleum fuels traffic at that facility.

6.3.3.4 Crude Petroleum

Annual traffic in crude petroleum on the Ohio River increased fivefold between 1940 and 1970, and thereafter dropped to insignificant levels of less than 1 million tons per year. This near total elimination of crude petroleum from the commodity mix resulted from the completion of crude petroleum pipelines linking the Ohio River Basin to the Gulf Coast area. Remaining crude oil traffic has totaled only around 200,000 tons and is normally internal traffic to the Ohio River System. A small amount of crude petroleum currently moves through the Myers facility, while the Greenup is currently handling none.

6.3.3.5 Aggregates

The rate of growth in Ohio River aggregates traffic over the 1970-1997 period exceeded that of every other commodity except grains. During the 27-year span, aggregates traffic grew at an annual rate of 3.2 percent, reaching a level of 40.2 million tons. Construction aggregates, which includes sand, gravel and crushed rock, are consumed throughout the ORB, with concentrations at population centers, major construction projects, and at lime and cement plants. Construction aggregates traffic is normally fairly localized and increases with the level of economic and demographic development. The fastest growing market for limestone has been for use in coal desulfurization at electric power plants. Continued rapid growth in this market is expected as utilities seek to comply with the mandates of environmental legislation.

Aggregates traffic at the Greenup and Myers locks totaled 7.0 and 2.0 million tons, respectively, in 1997. This represented annual growth of 7.5 and 11.7 percent per year since 1970, which was considerably higher than the mainstem's annual growth rate of 3.4 percent. Rates of growth between 1990 and 1997 diminished at the two facilities to 7.3 and 8.5 percent.

6.3.3.6 Grains

Traffic in grains on the Ohio River increased at an annual rate of 4.2 percent between 1970 and 1997. Grains traffic in 1997 totaled 10.9 million tons. Between 1990 and 1997, mainstem traffic growth slowed to about 0.9 percent per annum. Much of the increase in Ohio River grains traffic since 1970 is explained by outbound shipments, the vast majority of which has been destined for export markets. The slow growth in traffic in the 1990s is similarly explained by downturns in export markets.

Mainstem grains traffic is confined largely to the river reaches below Cincinnati. Grains traffic at the Greenup locks is virtually non-existent. At the Myers locks, grains totaled about 4.9 million tons in 1997, representing annual growth of about 8.0 percent from 1970. This was substantially higher than the mainstem growth rate of 4.2 percent over the same time period. Over the 1990-1997 time period, traffic at the Myers facility diminished at a rate of 1.9 percent, compared to growth of 0.9 percent per annum on the mainstem.

6.3.3.7 Chemicals

Chemicals traffic on the mainstem, comprising industrial chemicals and chemical fertilizers, decreased at a rate of about 0.2 percent between 1970 and 1997. It should be noted that one commodity, alumina, accounting for about 1.5 million tons annually, was re-classified from a chemicals grouping to an ores and minerals grouping in 1990, thus accounting for a substantial portion of the seeming decline in chemicals traffic. Between 1990 and 1997, mainstem chemicals traffic increased at a rate of 1.2 percent per year. Chemicals traffic on the Ohio is primarily inbound, with the bulk of the traffic originating at petrochemical complexes on the Gulf Coast.

Chemicals traffic at the Greenup locks totaled 3.2 million tons in 1997, while Myers handled about 6.5 million tons. Nearly one quarter of the chemicals traffic at Myers is agricultural chemicals traffic, compared to less than 10 percent at Greenup. Chemicals traffic at

Greenup decreased at a rate of 0.9 percent per year from 1970 to 1997, while chemicals traffic at Myers increased at a rate of 1.1 percent. Between 1990 and 1997, chemicals traffic at Greenup decreased at a rate of 1.1 percent per year versus an increase of 0.1 percent at Myers.

6.3.3.8 Ores and Minerals

Mainstem ores and minerals traffic, dominated by bauxite, salt, clay and manganese ore, grew at an annual rate of about 2.1 percent between 1970 and 1997, reaching 6.8 million tons. The reclassification of alumina from a chemical to an ore accounted for a substantial incremental increase in ores and minerals traffic in 1990 and subsequent years.

At the Greenup and Myers locks, ores and minerals traffic totaled 2.3 and 5.3 million tons, respectively, in 1997. Lock traffic in the ores and minerals group grew at rates of 9.6 and 11.2 percent between 1970 and 1997, compared to the mainstem growth rate of 2.1 percent.

6.3.3.9 Iron and Steel

Traffic in iron and steel on the Ohio mainstem reflects the changes that have taken place in the steel industry over the last two decades. Iron ore traffic has diminished as a number of integrated steel mills have closed. Traffic in iron and steel scrap has increased as steel mini-mills have opened for operation. More intermediate steel products are moving on the system as steel processors have taken over some of the functions formerly carried out by integrated producers. Between 1970 and 1997, iron and steel traffic (including iron ore) on the mainstem has increased at an annual rate of 2.9 percent reaching 9.5 million tons.

Iron and steel traffic totaled 3.6 and 7.1 million tons at Greenup and Myers, respectively, in 1997. The annual growth rate for iron and steel traffic at Greenup from 1970 to 1997 was about 0.3 percent. At Myers, iron and steel traffic grew at an annual rate of 2.9 percent, which was equivalent to the mainstem growth rate.

6.3.3.10 All Others

Mainstem traffic in the all others category, made up in large part of commodities like lime, asphalt, cement, and processed products from grains, totaled about 13 million tons in 1997. This represented annual growth of 3.2 percent from 1970. Growth in lime traffic has come about as a result of greatly increased use of lime in coal desulfurization processes.

For the Greenup and Myers facilities, traffic in the all others category totaled 4.7 and 5.2 million tons, respectively, in 1997. Between 1970 and 1997, traffic in all others grew at an annual rates of about 1.8 and 1.3 percent, which were substantially lower than the mainstem growth rate of 3.2 percent.

6.4 SHIPPING PATTERNS

6.4.1 Lock Traffic Patterns

The 1996 directional distributions of traffic at the Greenup and Myers locks are presented in **Table 6-6**. It is apparent from **Table 6-6** that a large majority (69 percent) of the traffic at Greenup is downbound traffic, while traffic at the Myers facility is about evenly distributed between upbound and downbound. Data for previous years show more of a downbound orientation for the Myers facility, but the drop-off in export coal and grains in recent years has evened out commodity traffic at the facility.

A large majority (84 percent) of the downbound coal at Greenup is traffic bound for utility plants in the middle Ohio Valley or for export. The remaining downbound tonnage is made up largely of petroleum fuels, iron and steel, and all other. Upbound traffic at Greenup is more evenly distributed among the commodity groups. The largest share of upbound traffic is aggregates, which accounts for 31 percent of the total. The other important groups are iron and steel, all other, chemicals, ores and minerals, and coal.

Similar to Greenup, the bulk (71 percent) of the downbound traffic at Myers is coal bound for the utility plants on the Tennessee and Cumberland rivers, the export market, and for other utility markets in the Southeast. Other important downbound traffic is grains, made up largely of export-oriented traffic; iron and steel; and all others. Western coals moving to Ohio Valley utility plants (34 percent) dominate upbound traffic at Myers. Chemicals, ores and minerals (like salt and alumina), and iron and steel moving from Gulf coast ports to upper and middle Ohio Valley destinations make up the bulk of the remaining upbound traffic.

TABLE 6-6
Historic Traffic by Commodity Group and by Direction
at Greenup and Myers, Selected Years
(Million Tons)

Project/	1980			1990			1996		
Commodity	Upbound	Downbound	Total	Upbound	Downbound	Total	Upbound	Downbound	Total
Greenup:									
Coal	3.1	13.8	17.0	1.1	32.9	34.0	3.2	41.2	44.4
Petro Fuels	2.5	3.6	6.0	0.7	3.7	4.4	0.4	4.3	4.7
Crude Petro.	-	0.1	0.1	-	-	-	-	0.0	-
Aggregates	1.8	-	1.8	4.3	0.0	4.3	7.0	-	7.0
Grains	-	-	-	-	0.0	-	-	-	-
Chemicals	2.9	0.7	3.6	2.7	0.7	3.4	2.8	0.5	3.3
Ores & Min.	1.0	0.1	1.1	1.8	0.1	1.9	2.7	0.1	2.8
Iron & steel	0.8	1.8	2.6	2.4	1.5	3.9	3.2	1.4	4.6
All Others	1.7	1.0	2.7	2.9	1.3	4.2	2.6	1.3	3.9
Total	13.8	21.1	34.9	15.9	40.2	56.1	21.9	48.8	70.7
J. T. Myers:									
Coal	3.8	21.1	24.9	11.3	41.0	52.3	14.5	28.4	42.9
Petro Fuels	3.8	2.7	6.5	3.7	0.6	4.3	3.0	0.5	3.5
Crude Petro.	0.3	0.1	0.3	-	-	-	-	0.0	-
Aggregates	-	-	0.1	1.1	-	1.1	2.2	-	2.2
Grains	0.1	3.6	3.7	0.2	5.3	5.5	0.3	5.0	5.3
Chemicals	6.5	0.7	7.2	5.7	0.7	6.4	5.9	0.6	6.5
Ores & Min.	1.8	0.1	1.9	4.0	0.1	4.1	5.4	0.4	5.8
Iron & steel	0.9	1.7	2.6	3.3	2.1	5.4	5.2	2.6	7.8
All Others	1.6	1.5	3.1	2.3	2.1	4.4	2.9	2.1	5.0
Total	18.8	31.5	50.3	31.6	51.9	83.5	39.4	39.6	79.0

6.4.2 Commonality of Traffic

Table 6-7 shows the commonality of Greenup and Myers traffic with other selected locks on the ORS in 1996. Downbound coal, originating primarily on the Kanawha and Big Sandy rivers, dominates traffic at the Greenup facility. For that reason, the Greenup Locks have much more traffic in common with locks on the middle and lower Ohio River than with projects on the upper river. Although the commonality of traffic generally diminishes with distance from the Greenup facility, 35 percent of Greenup traffic, largely export coal, also passed through Lock 52, on the lower Ohio in 1996. The impact of Greenup is disproportionately high at locks on the upper Ohio, the Monongahela, the Kanawha, and at some locks on the Tennessee and Cumberland rivers, owing to the smaller sizes of locks in these locations and their lower traffic levels. For example, only 10 percent of Greenup traffic moves through Emsworth, while 30 percent of Emsworth traffic moves through Greenup. By way of comparison, 35 percent of Greenup traffic moves through Lock 52, and 27 percent of Lock 52's traffic moves through Greenup.

TABLE 6-7

Commonality of Greenup and Myers Traffic with Other Selected Projects -- 1996 (in percent)

Project	Greenup Traffic Thru	Other Project Traffic Thru Greenup	Myers Traffic Thru	Other Project Traffic Thru Myers
L/D 2 -- Mon	7	26	4	18
Emsworth	10	30	6	20
Dashields	10	30	6	21
Montgomery	13	35	8	23
New Cumberland	17	32	11	22
Pike Island	20	32	13	23
Winfield	19	58	8	27
Byrd	61	69	28	35
Greenup	100	100	40	45
Meldahl	85	94	41	51
McAlpine	53	69	57	82
Newburgh	45	46	77	88
Myers	45	40	100	100
Smithland	43	36	98	91
Kentucky/Barkley	7	13	15	31
L/D 52	35	27	82	69

Source: Waterborne Commerce Statistics

In contrast to the situation at Greenup, the 1996 commodity traffic at Myers is more evenly divided between upbound and downbound, although much of the upbound traffic apparently terminates in the Myers pool. About 82 percent of Myers traffic also moves through Lock 52. This traffic consists in large part of downbound grain and coal for the export market and upbound western coal. Similar to Greenup, the impact of Myers on the upper Ohio, Monongahela, Kanawha, Tennessee, and Cumberland River locks is substantial, owing again to the small sizes of these locks and the relatively small tonnage handled. While only 8 percent of Myers traffic, for example, also moved through Winfield, that traffic comprised 27 percent of the Winfield total in 1996.

6.4.3 Commodity Distribution Patterns

Greenup and Myers traffic was examined in terms of commodity movements between Bureau of Economic Analysis (BEA) economic areas. BEA areas are economic regions defined by the Bureau of Economic Analysis, U. S. Department of Commerce. BEA areas consist of a major city or Metropolitan Statistical Area (MSA) that serves as a center for economic activity and outlying areas, defined as groups of counties, that are economically connected to the center. The Bureau of Economic Analysis re-defined the nation's BEA areas in 1995 to more accurately reflect economic relationships as they currently exist. The BEA area definitions used in the current discussion are the definitions used prior to the most recent update.

The 1996 shipping and receiving BEA areas for the Greenup and Myers facilities are shown in **Table 6-8**. Traffic through the Greenup and Myers facilities commonly move to/from areas as distant as Brownsville and Pensacola on the Gulf Intracoastal Waterway, and Minneapolis, on the Upper Mississippi. A small amount of 1996 Myers traffic in 1996 moved to the Atlantic Coast to the Norfolk BEA area. The largest volumes of traffic at both facilities, however, move to/from BEAs along the Ohio River.

For the Greenup locks, by far the largest shipping BEA area in 1996 was the Huntington BEA area, accounting for more of one third of shipments. Other major shipping BEA areas in 1996 included the Charleston (14 percent), Wheeling (10 percent), Pittsburgh (6 percent), Cincinnati (6 percent), Baton Rouge (5 percent), and Louisville (4 percent) BEA areas. The largest volume recipient BEA area for Greenup traffic in 1996 was the Cincinnati BEA area (37 percent). Other important recipient BEA areas were the New Orleans (10 percent), Pittsburgh (9 percent), Charleston (7 percent), Wheeling (5 percent), Huntington (5 percent), and Louisville (4 percent) BEA areas.

In 1996, the Evansville BEA area was both the largest shipping and receiving area for Myers traffic. The Evansville BEA area accounted for about one-fifth of both commodity shipments and receipts through the Myers facility. The other important shipping BEA areas were the Paducah (15 percent), Huntington (11 percent), Baton Rouge (9 percent), and New Orleans (8 percent) BEA areas. Other major recipient BEA areas included the New Orleans (18 percent), Nashville (8 percent), Louisville (7 percent), and Pittsburgh (6 percent) BEA areas.

TABLE 6-8

Greenup and Myers Traffic
Shipments and Receipts by BEA Area, 1996
(Thousands of Tons)

		Greenup		Myers	
BEA		Shipments	Receipts	Shipments	Receipts
16	Pittsburgh, PA	4,140	6,325	2,209	4,581
23	Norfolk, VA	-	-	0	1
46	Pensacola, FL	-	1	-	3,339
47	Mobile FL	44	336	105	347
49	Birmingham, AL	515	787	582	790
50	Huntsville, AL	92	1,350	133	1,643
51	Chattanooga, TN	19	1,058	20	1,642
53	Knoxville, TN	1	78	7	87
54	Nashville, TN	5	796	13	6,567
55	Memphis, TN	286	453	837	1,278
56	Paducah, KY	1,706	1,138	12,125	1,614
57	Louisville, KY	3,052	3,012	1,222	5,392
59	Huntington, WV	26,357	3,244	8,537	1,171
60	Charleston, WV	9,648	4,753	4,855	1,908
61	Morgantown, WV	248	96	186	96
62	Parkersburg, WV	233	2,732	222	1,874
63	Wheeling, WV	7,118	3,433	1,800	3,124
64	Youngstown, OH	78	728	76	708
66	Columbus, OH	1,925	977	577	657
67	Cincinnati, OH	4,137	26,422	2,890	4,811
80	Evansville, IN	85	1,152	17,134	15,090
83	Chicago, IL	465	1,385	709	1,654
86	Quincy, IL	15	38	35	45
87	Peoria, IL	25	25	56	294
91	La Crosse, WI	-	26	31	32
96	Minneapolis, MN	91	285	310	303
98	Dubuque, IA	-	126	28	389
99	Davenport, IA	14	545	48	828
105	Kansas City, MO	-	-	-	1
106	Columbia, MO	-	-	2	-
107	St. Louis, MO	753	1,314	3,955	1,612
110	Fort Smith, AR	1	1	6	9
111	Little Rock, AR	77	82	115	90
112	Jackson, MS	60	52	144	66
113	New Orleans, LA	2,841	7,037	6,616	14,904
114	Baton Rouge, LA	3,709	162	6,985	701
115	Lafayette, LA	1,037	15	2,318	15
116	Lake Charles, LA	81	8	324	8
117	Shreveport, LA	-	11	-	11
118	Monroe, LA	5	88	5	91
121	Beaumont, TX	244	53	335	60
122	Houston, TX	1,512	511	2,557	743
130	Corpus Christi, TX	170	7	599	7
131	Brownsville, TX	4	86	13	118
138	Tulsa, OK	26	92	220	240
Totals		70,821	70,821	78,941	78,941

Source: Waterborne Commerce Statistics; 1978 BEA definitions.

6.5 TRAFFIC FORECASTS

6.5.1 Introduction

This section presents the most probable future waterway traffic for the Ohio River mainstem. These traffic projections, which capture the effects of implementation of Phase II of the Clean Air Act Amendments and deregulation in the electric utility industry, were selected from a set of alternative futures. The development of these alternative futures and selection of the most probable future are discussed in detail in **Attachment 3** to this Economics Appendix.

6.5.2 Methodology

The ORS traffic demand forecasts presented here represent a substantial update of the previous forecasts prepared in December 1995. The updating of these forecasts focused on utility and export coal. After examining traffic projection performance for all remaining commodities, the decision was made to continue using the December 1995 data set for these non-coal commodities (see Attachment 3, Section 3.5.1).

A similar forecasting framework for developing waterway traffic demand forecasts is used for all commodities. Individual origin-destination-commodity movements are examined and adjusted to represent base-level expectations for both the pattern and volume of commodity flow. This is done through surveys and analysis of historic waterborne patterns. Then, because projections of future waterway flows are demand-based, the industry and market that each dock serves is identified. Prospects for these industries and markets are then analyzed by means of shipper surveys and examination of relevant industry forecasts. Information and data on industry and market prospects are developed at the company level for all commodities moving to electric generating stations (utility coal, and lime and limestone used in coal desulfurization) and at a more global industry or market level for all other commodities. Using the survey information and the applicable forecasts, future waterway traffic demands are generated on a movement by movement basis.

6.5.3 Results

6.5.3.1 Total Traffic Demand

Table 6-9 shows projected traffic demands for the ORS and the Ohio River mainstem, as well as the Greenup and Myers facilities. The system forecast shows traffic increasing from a

level of 267.2 million tons in 1996 to 539.3 million tons by year 2060. Between 1996 and 2010, the forecast shows traffic increasing at an annual rate of 2.1 percent. Over the short term, the higher utility coal numbers in the forecast are accounted for, in large part, by shifts in coal sources necessitated by existing and pending environmental legislation. Over the long term, between 1996 and 2060, the growth rate diminishes, with traffic increasing at a rate of 1.1 percent.

Table 6-9 shows mainstem traffic increasing from a level of 239 million tons in 1996 to 473.1 million tons in 2060. Over the short term, 1996-2010, mainstem traffic grows at a rate of about 1.9 percent per annum, compared to the system growth rate of 2.1 percent.

TABLE 6-9
Actual and Projected Traffic for Greenup and Myers, the Ohio River and the ORS, 1990-2060
(Millions of Tons)

Year	Greenup	Myers	Ohio River	ORS
Actual:				
1990	56.0	83.6	225.6	257.8
1996	70.8	78.9	239.0	267.2
Projected:				
2010	90.5	99.7	312.5	355.9
2020	101.7	109.2	341.4	388.7
2030	113.0	117.8	370.4	422.3
2040	127.9	129.3	405.9	463.2
2050	143.0	141.1	440.8	502.8
2060	157.4	153.5	473.1	539.3
Annual Growth				
1996-2060	1.3%	1.0%	1.1%	1.1%

Traffic growth on tributary streams, like the Tennessee, Kanawha, and Cumberland rivers more than compensates for the mainstem growth rate. Over the longer term (1996-2060), mainstem traffic grows at a rate of 1.1 percent per annum, which is virtually identical to the growth rate for the ORS.

The forecast for Greenup shows traffic at the facility increasing from a 1996 level of 70.8 millions to 157.4 million tons by 2060. Myers traffic increases from 78.9 to 153.5 million tons over the same time period. Over the short term, 1996-2010, traffic at Greenup and Myers grows at annual rates of 1.8 and 1.7 percent respectively, which are slower than the mainstem growth rate of 1.9 percent. For the longer term (1996-2060), the Greenup growth rate (1.3 percent) exceeds the mainstem rate of 1.1 percent, while the Myers rate (1.0 percent) is slightly lower.

6.5.3.2 Commodity Mix of Projected Traffic Demand

Projected traffic demands by commodity group for the mainstem over the 64-year forecast period are displayed in **Table 6-10**. The highest rate of annual growth (1.9 percent) is shown for crude petroleum, although total projected tonnages are extremely limited and are confined to movements from Ohio Valley producing areas to regional refineries. Aside from crude, the highest growth rates are expected to occur in the all others category (1.3 percent); coal and coke (1.3 percent); grains (1.3 percent); chemicals (0.8 percent); and aggregates (0.5 percent). Somewhat slower growth is forecast for petroleum fuels (0.4 percent), iron and steel (0.4 percent), and ores and minerals (0.2 percent). Little change is forecast in the commodity mix of projected traffic demand, except that coal is projected to increase from 56 percent to about 65 percent of mainstem traffic.

TABLE 6-10
Projected Ohio River Mainstem Traffic by Commodity Group, 1996-2060
(Million Tons)

Commodity	1996	2010	2020	2030	2040	2050	2060	Annual % Growth 1996-60
Coal	134.8	188.5	209.8	231.5	258.5	284.1	306.4	1.3
Petro Fuels	13.0	15.6	16.1	16.3	16.4	16.6	16.7	0.4
Crude Petro	0.2	0.6	0.7	0.7	0.7	0.8	0.8	1.9
Aggregates	37.4	37.9	39.8	42.3	45.4	48.8	52.5	0.5
Grains	10.7	16.4	18.2	19.6	21.0	22.6	24.3	1.3
Chemicals	9.9	12.4	13.2	13.8	14.5	15.2	15.9	0.7
Ores & Mins	7.5	6.7	7.0	7.4	7.7	8.1	8.5	0.2
Iron & Steel	9.7	10.4	10.6	11.0	11.4	11.8	12.2	0.4
Others	15.7	24.0	26.0	28.0	30.4	33.0	35.9	1.3
Ohio River	239.0	312.5	341.4	370.4	405.9	440.8	473.1	1.1
ORS	267.2	355.9	388.7	422.3	463.2	502.8	539.3	1.1

Source: Waterborne Commerce Statistics and LRD Navigation Planning Center

The projected traffic demands by commodity group for Greenup and Myers are shown in **Table 6-11**. At the Greenup facility, the highest annual rates of growth occur in coal and coke (1.5 percent); all others (1.4 percent); chemicals (0.8 percent); aggregates (0.8 percent); and iron and steel (0.7 percent). Traffic in petroleum fuels grows at an annual rate of less than 1 percent, while ores and minerals traffic diminishes at a rate of 0.2 percent. Trace amounts of crude petroleum and grains continue to move through the project. Coal and coke traffic increases as a share of total traffic from 63 percent in 1996 to 74 percent in 2060.

For Myers, the fastest annual growth occurs in grains (1.5 percent), followed by coal and coke (1.2 percent); all other (1.0 percent); chemicals (0.8 percent); petroleum fuels (0.7 percent); iron and steel (0.5 percent); and ores and minerals (0.1 percent). Similar to Greenup, small quantities of locally-produced crude petroleum will continue to move through the facility. Coal and coke traffic is shown to increase from 54 to 61 percent of total traffic between 1996 and 2060.

TABLE 6-11
Projected Future Commodity Traffic by Commodity Group
at Greenup and Myers, 1996-2060
(Million Tons)

Project/ Commodity	1996	2010	2020	2030	2040	2050	2060	Annual % Growth 1996-2060
Greenup:								
Coal	44.4	60.9	70.5	80.0	92.7	105.1	116.7	1.5
Petro	4.7	4.7	4.9	5.0	5.0	5.1	5.1	0.1
Crude Petro.	-	-	-	-	0.1	0.1	0.1	-
Aggregates	7.0	6.2	6.8	7.5	8.6	9.9	11.3	0.8
Grains	-	-	-	-	-	-	-	-
Chemicals	3.3	4.2	4.5	4.8	5.0	5.2	5.5	0.8
Ores & Min.	2.8	2.1	2.1	2.2	2.3	2.4	2.5	-0.2
Iron & steel	4.6	5.9	6.1	6.3	6.5	6.8	7.0	0.7
All Others	3.9	6.3	6.7	7.2	7.8	8.5	9.2	1.4
Total	70.8	90.5	101.6	112.9	127.9	142.9	157.4	1.3
J. T. Myers:								
Coal	42.8	54.2	60.8	66.9	75.7	84.7	94.0	1.2
Petro	3.5	5.1	5.3	5.3	5.4	5.4	5.5	0.7
Crude Petro.	0.0	0.1	0.1	0.1	0.1	0.1	0.1	-
Aggregates	2.2	2.5	2.5	2.6	2.8	2.9	3.0	0.5
Grains	5.3	9.1	10.3	11.1	12.0	13.0	14.1	1.5
Chemicals	6.5	8.4	8.8	9.3	9.7	10.1	10.6	0.8
Ores & Min.	5.8	4.9	5.1	5.4	5.6	5.9	6.2	0.1
Iron & steel	7.8	9.1	9.2	9.5	9.8	10.2	10.5	0.5
All Others	5.0	6.5	7.1	7.6	8.2	8.8	9.5	1.0
Total	78.9	99.7	109.2	117.8	129.3	141.1	153.5	1.0

6.5.3.3 Future Shipping Patterns

Both the Myers and Greenup facilities show substantial increases in the downbound orientation of traffic between 1996 and 2060. At Greenup downbound traffic increases from 69 to 80 percent of total traffic, while at Myers the downbound share increases from 50 to 62 percent. At Greenup, the increase in downbound traffic is coal and coke destined for utility plants in the middle Ohio Valley and for export. At Myers, the increase in downbound traffic is explained largely by increases in utility and export coal and grains.

The 2050 shipping and receiving BEA areas for the Greenup and Myers facilities are shown in **Table 6-12**. Similar to the situation in 1996, the largest shipping BEA area for Greenup traffic in 2050 is expected to be the Huntington BEA area, accounting for around 37 percent of total shipments. Other major shipping BEA areas in 2050 will include the Charleston (19 percent), Wheeling (13 percent), Pittsburgh (5 percent), Cincinnati (5 percent), St. Louis (5 percent), and New Orleans (3 percent) BEA areas.

The largest volume recipient BEA area for Greenup traffic in 2050 is expected to be the Cincinnati BEA area (36 percent). By 2050, the other important recipient BEA areas are expected to be New Orleans (23 percent), Pittsburgh (6 percent), Louisville (5 percent), Wheeling (4 percent), and Parkersburg (3 percent).

For the Myers facility, the largest shipping BEA in year 2050 is expected to be the Huntington BEA area (20 percent). The other high-volume BEA areas are Paducah (15 percent), Evansville (14 percent), Charleston (10 percent), St. Louis (7 percent), and New Orleans (6 percent). On the receipts side, the highest-volume BEA area is New Orleans (39 percent), Evansville (16 percent), Louisville (7 percent), and Cincinnati (5 percent).

TABLE 6-12
Greenup and Myers Traffic
Shipments and Receipts by BEA Area, 2050
(Thousands of Tons)

	BEA	Greenup Shipments	Greenup Receipts	Myers Shipments	Myers Receipts
16	Pittsburgh, PA	7,679	8,070	5,162	5,584
23	Norfolk, VA	-	-	-	1
46	Pensacola, FL	10	3,824	10	4,580
47	Mobile FL	110	761	424	958
49	Birmingham, AL	10	1,852	11	1,856
50	Huntsville, AL	26	1,710	152	2,501
51	Chattanooga, TN	44	1,070	70	1,115
53	Knoxville, TN	7	23	7	23
54	Nashville, TN	44	1,684	80	4,390
55	Memphis, TN	401	508	663	1,112
56	Paducah, KY	2,383	846	21,546	2,563
57	Louisville, KY	3,653	6,729	2,751	10,260
59	Huntington, WV	53,591	4,418	28,221	1,662
60	Charleston, WV	27,098	4,554	14,018	1,742
61	Morgantown, WV	538	445	536	78
62	Parkersburg, WV	221	4,755	90	2,768
63	Wheeling, WV	18,723	5,207	1,615	3,920
64	Youngstown, OH	138	986	136	919
66	Columbus, OH	413	644	1,716	592
67	Cincinnati, OH	7,743	51,898	7,557	7,381
80	Evansville, IN	112	3,841	19,480	22,667
83	Chicago, IL	797	914	972	1,788
85	Springfield, IL	-	7	10	9
86	Quincy, IL	24	45	76	82
87	Peoria, IL	53	10	224	30
91	La Crosse, WI	21	37	79	121
96	Minneapolis, MN	119	260	336	474
98	Dubuque, IA	4	33	31	280
99	Davenport, IA	30	668	116	1,461
103	Sioux City, IA	-	11	-	11
105	Kansas City, MO	1	-	37	-
107	St. Louis, MO	7,344	1,045	9,493	1,435
110	Fort Smith, AR	-	11	-	62
111	Little Rock, AR	143	27	157	32
112	Jackson, MS	64	128	177	170
113	New Orleans, LA	4,049	33,537	8,776	54,492
114	Baton Rouge, LA	3,956	542	8,557	1,674
115	Lafayette, LA	632	-	1,650	-
116	Lake Charles, LA	130	-	252	3
117	Shreveport, LA	-	24	-	24
118	Monroe, LA	21	138	21	142
121	Beaumont, TX	769	48	964	259
122	Houston, TX	1,703	1,020	3,466	1,159
130	Corpus Christi, TX	93	194	1,060	198
131	Brownsville, TX	2	180	4	237
138	Tulsa, OK	56	253	445	334
Totals		142,954	142,954	141,148	141,148

Source: Waterborne Commerce Statistics; 1978 BEA definitions.

SECTION 7

BENEFIT ESTIMATION PROCEDURES

7.1 INTRODUCTION

Cost-benefit analysis is used to identify the investment alternative with the greatest net benefit (benefits minus costs) -- the NED plan. As the analysis technique implies, half of the analysis is the cost estimates themselves (for both the without project condition and the various with project condition alternatives), and the other half of the analysis is the benefit estimation. Corps' project designers provide both without project condition (WOPC) and with project condition (WPC) costs.

Benefits estimates are a product of the system benefit analysis, which is conducted within the supply and demand framework discussed in **Section 1, Introduction**. The Tow Cost/Equilibrium (TC/EQ) is the system model used to keep track of all the traffic interactions and to estimate the NED benefits and navigation impacts for each of the project improvement alternatives being evaluated for the J.T. Myers and Greenup locks and dams. While this model has undergone extensive modification and refinement over the past 20 plus years, it is in essence the same model as that used in a number of past feasibility studies, including, including the Gallipolis, Monongahela Locks and Dams 7 and 8, Locks and Dams 52 and 53, and Winfield Locks and Dams.

7.2 SYSTEM MODEL

7.2.1 General

Given a particular system configuration and traffic level, the TC\EQ has two essential functions: 1)estimating waterway transportation costs at the movement level and 2)finding that combination of movements with positive rate savings that maximize system tonnage. Movements are represented by the annual tonnage of a commodity moving between a unique origin and destination pair. The model begins by estimating waterway transportation costs at the movement level. It recognizes that each system movement has a per ton base rate savings as established by the transportation rate analysis. Referring to **Figure 1-2** in **Section 1.3.4.1**, this rate savings is the difference between the waterway rate and the least cost alternate route. Each movement's total rate savings, or total benefit, is represented by the product of total tons times

the base rate savings. At higher levels of traffic demand, the demand curve shifts out to the right. This shift may push the intersection of waterway supply (the S_w curve in the figure) and demand beyond the supply curve's horizontal reach and into the upward sweeping portion of this cost curve. If this is the case, quantity moved increases, but the waterway rate at which it moves also increases. The TC\EQ estimates the amount of that cost increase -- the amount by which base rate savings per ton decrease, by calculating the increase in movement trip time caused by the increased system congestion. The increase in the movement's cost is then found by multiplying the increase in trip time (hours) by the hourly shipping costs. Dividing this cost increase by the movement's tonnage yields the cost per ton increase in the movement which is then added to the base waterway rate. The rate savings for the movement is lowered as the waterway rate increases and the alternate overland rate remains constant. The movement's new total waterway benefit becomes the product of this higher traffic and the lower rate savings.

While the model operates at the movement level, results are reported and analyzed at the system level. As can easily be seen, the combination of other movements in the system influence the trip time experienced by an individual movement, thus influencing the shape of the individual movement cost curve. The TC\EQ must search for that combination of movements with positive rate savings that will maximize system tonnage. Any movements with negative rate savings are assumed to leave the system for the least cost alternate mode.

Determination of the equilibrium combination of movements is accomplished through an iterative process. Initially, base year transit times are assumed at all modeled projects and all demands are sorted from highest to lowest base rate saving. As the highest rate saver is added to the system, the remaining demands are re-sorted from highest to lowest rate savings based on the new project transit times generated by the movement(s) in the system. Movements are added until only negative rate savers are left in the demand list. This could potentially be the equilibrium mix of movements, however, the rate savings of the movements in the system are not re-checked as additional movements are added, thus some of them could have become negative rate savers. The TC/EQ model theorizes that this solution mix could be equilibrium and that the project transit times are at equilibrium levels. All movements are then removed from the system and placed back in the demand list. Assuming this new mix of project transit times, all demands are again sorted from highest to lowest rate savings and the process is repeated. If this second equilibrium mix of movements is identical to the theorized equilibrium mix of movements -- the equilibrium is found. If the mix is different, the new mix of movements is theorized as the equilibrium and the process repeated.

Once the model has found that equilibrium tonnage, the new rate savings and total benefits for each movement that stays on the system is calculated and summed across the entire system. As will be discussed later, in addition to system benefits, the model reports system delay costs. These costs represent the potential benefits to be gained by implementing system performance improvements, like helper boat programs, wall extensions, additional lock chambers, larger lock chambers and so on. Referring again to **Figure 1-2**, these improvements generally act to shift each movements the S_w curve out to the right. From the system perspective, these improvements also generally shift the system supply curve to the right, as shown in **Figure 1-5** in **Section 1.3.4.2**. The remainder of this section discusses the system model, its inputs, data sources and outputs.

7.2.2 Model Description

The TC/EQ is an analytically based fleet sizing and costing model. Its basic function is to compute the barge line-haul costs for port-to-port traffic movements on a given waterway system with defined towing and operating characteristics. The model then uses the changes in barge line-haul costs for each movement over time, along with externally developed estimates of existing waterway rate savings, to compute equilibrium traffic flows and the resulting system transportation benefits. The TC/EQ solution is presented at both macro and micro levels of detail, which provides the user with great flexibility in choice of analytic characteristics for the entire system, sub-regions of the system, for specific ports, locks and reaches, and for all the traffic between selected port pairs. The effects of a system improvement are easily evaluated by specifying an alternative set of input parameters to reflect the improvement and resolving the model. This gives the analyst the capability to compute the incremental system benefits (transportation cost savings) for virtually any type of system modification and also to trace and describe the system impacts at a very disaggregated level of detail.

The TC/EQ makes its waterway shipment cost calculations by using a set of inter-linked computer programs and detailed data that describe: (1) the waterway system being evaluated; (2) the equipment characteristics and costs used for shipping; and (3) the port-to-port commodity flow demands. Using these inputs, the model calculates the resources required for each port-to-port commodity-barge type movement and the associated shipping costs. The tow size, the resulting number of trips, and the shipping time and cost for each movement is determined on a least-cost basis using a port-to-port algorithm. This algorithm determines the most cost-effective tow size for each movement by cycling through the time and costs for all possible shipping plans and allowable tow sizes. For each port-to-port commodity-barge type movement, the algorithm calculates the round-trip time from shipping port to receiving port. These times are translated into costs of transport by applying the equipment operating costs per unit time. The major time and cost elements considered by the model include: (1) time loading/unloading barges; (2) time waiting for access to docks; (3) time loaded barges wait for a towboat; (4) time making/breaking tows; and (5) tow trip time (including linehaul, lockage and delay time).

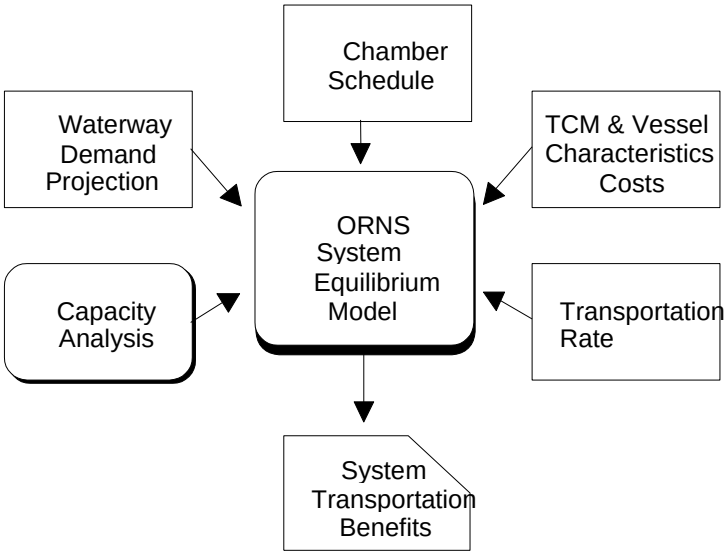
In addition to the five activity cost categories shown above, the model also displays the costs by source (e.g. towboat costs, barge costs, cargo inventory costs, user fees, etc.). The effects of imposing various user charge mechanisms for recovery of Federal operation and maintenance, and construction costs can thus be conveniently evaluated by the model.

Using the characteristic shipping costs for each port-to-port commodity-barge type movement, along with additional input data on each movement's waterway rate savings, the model determines which movements would likely divert to an alternate mode. The model assumes that movements will divert off the waterway system when towing costs increase to the point that it becomes cheaper to move via the least cost all-overland route. Finally the model identifies the quantity that equilibrates the system, the inferred point where the system demand and system cost curves intersect (see **Section 1, Introduction**).

7.3 INPUTS, DATA SOURCES AND OUTPUTS

Figure 7-1 shows the key inputs to the TC/EQ model. Model input data can be generalized in terms of two major components: 1) the network description (ports, constraint points, equipment descriptions and costs, etc.); and 2) the traffic demands (describing flows by tonnage level, commodity type, and barge type). The components of the network description include descriptions and definitions of: (a) the waterway system being analyzed; (b) vessel equipment descriptions; (c) project capacity; and d) the project's reliability. The components of the traffic demands include: (e) waterway traffic demands by commodity; origin-destination area and barge type; and (f) the base-year transportation rate savings for each of the origin-destination commodity movements. These inputs and data sources are briefly discussed in the following paragraphs.

FIGURE 7-1
TC/EQ System Analysis Model Flow Chart



7.3.1 System Analyzed

The system analyzed is described in a network file used by both the model. The system description encompasses model-input data that mathematically defines the physical waterway system in a network fashion using node-link representations. The network nodes consist of ports, fleeting points and waterway junctions. Nodes, therefore, represent either final or intermediate shipping and receiving points for vessel traffic. The navigation projects might also be considered as nodes, although they are considered as a special class of constraint nodes. The links are simply those waterway segments that connect the nodes. Links can be further subdivided into a number of individual sectors having special or distinguishing characteristics. In this node-link network description method, the models are flexible in modeling different systems and/or varying levels of detail.

The ORS is the system analyzed for Ohio River Basin projects. This system includes more than 2,600 miles of commercially navigable channels and as previously mentioned, contains 60 navigation projects. The inland waterway segments outside the Ohio River system are included in the model's network description, but are not modeled at the same level of detail as ORS components. These external segments are included in the model solely to account for the total origin-to-destination routing of ORS traffic that interchanges with these external segments.

Required input data for each waterway link includes its length, minimum and average depth, average current velocity, and maximum tow size. The information on channel depth and current velocity is used to compute tow speeds and barge loading. This, along with the length, is used to determine miles traveled and total tow transit time on each link. The initial information on current velocity and channel depth was collected in 1975-76 as part of the Corps INSA data-development program. These data have been reviewed and adjusted as necessary for individual studies. The maximum tow size for each link is determined by detailed examination of COE Lock Performance Monitoring System (LPMS) data and is updated yearly.

Port nodes are used in the model to represent the generalized loading and unloading points for waterborne commodities. One hundred and seventy-six ports are currently defined in the ORS TC\EQ. This aggregation of the thousands of individual docks in the ORS represents a compromise between the need to keep the analysis in manageable proportions and at the same time retain a high level of detail for origins and destinations of commodities. Required input data for each port includes barge pickup and drop-off time, barge loading and unloading time for each of three major handling classes, delay per tow to access loading and unloading facilities by handling class, and the time that loaded barges spend awaiting tow. The three handling classes represent broad commodity classifications and include (1) dry granular bulk (coal, grains, etc.); (2) dry large bulk and packaged cargo (iron and steel, etc.); and (3) liquid cargo. As each waterway movement is shipped from the origin port to the destination port, the above time factors are considered by the model in calculating the towing costs. Port times are averages based on a telephone surveys of Ohio River dock operators.

Defined re-fleeting areas in the system network description allow for major changes in tow size, particularly for shipments between waterways having different channel dimensions and lock sizes. Most of the re-fleeting areas are therefore placed near the mouth of tributary streams to capture the up-fleeting and down-fleeting of tows as they enter and leave the smaller tributary streams. A lesser number of re-fleeting points were designated on the open-river segments in order to reflect the re-fleeting that occurs due to significant variations in lock size.

7.3.2 Vessel Equipment and Costs

Vessel data provide pertinent physical and operating-cost information on the vessel equipment (e.g. towboats and barges) used by the TC/EQ model modules in computing shipping costs. Based on a highly detailed analysis of the COE LPMS and Waterborne Commerce Statistics (WCSC) data bases, twelve barge classes and eight towboat classes are modeled in ORS studies. This was verified in the latest model calibration completed in 1998. Draft documentation of the calibration process is available in the Navigation Center. These classes serve as a range of types, sizes, costs, shipping characteristics and hauling capacities of equipment used in the inland waterway system.

The capacity for each barge class represents a reasonable approximation of the maximum loading capability for all barges in that class. Actually, maximum loadings are seldom observed on the system due to minimum depth, equipment, and/or other restrictions. The model, therefore, uses these loadings as an upper limit. Computations for actual loadings for each movement are based on the minimum channel depth encountered along the shipping route.

The eight towboat classes were established on the basis horsepower-frequency distribution for tows locked on the Ohio River system. The towboat class definitions are midpoints of the rated horsepower ranges defined by the vessel operating cost estimates supplied by the Corps' Institute for Water Resources. In addition to the rated engine horsepower, information also is presented on the nominal horsepower for each towboat class. The nominal horsepower, which is somewhat less than the rated horsepower of the engines, reflects the estimated horsepower actually delivered to the props. The nominal horsepower is used in computing tow speeds and fuel consumption. The towing capacity (maximum tow size) for each towboat class was determined by analyzing the towboat horsepower-tow size relationships for tows moving on the ORS. These data, along with data provided in the WCSC Transportation Series 4 report are used to develop the towboat dimensions and drafts for each class. The operating fuel consumption rate for each class is based on an estimate of gallon per horsepower per day. Discussions with carriers indicate that fuel consumption while maneuvering was 50 to 67 percent of the consumption rate while operating in a line-haul situation. The average of these quotations, or 58 percent, was used to estimate the rate of fuel consumption during maneuvering operations. The TC\EQ uses this lower consumption rate when tows are in non-line-haul operations (e.g. port activities and lockage maneuvering).

The towboat and barge operating costs are obtained from data collected by the Institute for Water Resources and published in EC 1105-5-144. The towboat operating costs presented do not include fuel costs. The TC/EQ calculates fuel costs and fuel tax separately based on the consumption rates, the price per gallon, and the time involved in shipment.

7.3.3 Waterway Traffic Demands

7.3.3.1 Commodity Shipment List

The commodity shipment list is the main driving force of the model. Most model processing is directed toward determining the towing costs for each movement and how much of the projected shipment demand could move on the waterway at a savings. The information required for each movement includes 1) origin port, 2)destination port, 3)commodity group, 4)annual tonnage, 5)barge type, 6)cargo handling class, 7)commodity value, and 8)a dedication factor. Each traffic projection scenario has its own unique shipment list.

For purposes of systems analysis, the individual commodities that move on the ORS were aggregated into eight major commodity groups:

1) coal and coke
2) petroleum fuels (including crude)
3) aggregates
4) grains
5) chemicals and related products
6) ores and minerals
7) iron and steel
8) all others

These groups are exactly the same as those used for the traffic projection studies – with on minor exception. Since crude petroleum is shipped on the ORS in such minor quantities, it was included in the petroleum fuels group rather than being treated as a separate commodity group.

The information in base-year tonnage flows by origin and destination port for each commodity group was developed using the detailed point-to-point shipping records reported under the COE Waterborne Commerce Statistic program. These data were analyzed and adjusted as necessary to reflect unreported and misreported movements on the Ohio River system. The data were aggregated to yield base year port-to-port tonnage flows for each of the eight major commodity groups. The shipment lists for all future years were developed in the same manner using the projected origin-to-destination traffic demands on the ORS (see **Section 6, Historic and Projected Traffic** for a description of the traffic projection methodology). In developing the base-year and future-year shipment lists, all intra-pool traffic was excluded since these movements would not be impacted by future increases in lock congestion.

The barge type for each movement was determined through detailed analysis of Waterborne Commerce Statistics database. This database provides point-to-point barge trips on an annual basis as well as corresponding loading and draft information. By analyzing the loadings for all reported trips of each unique barge, it was possible to classify each barge into one of the eleven major barge classes being used in the analysis. This classification was then used to compute and assign the tonnage for each port-to-port commodity movement in the shipment list being carried in each of the eleven barge classes.

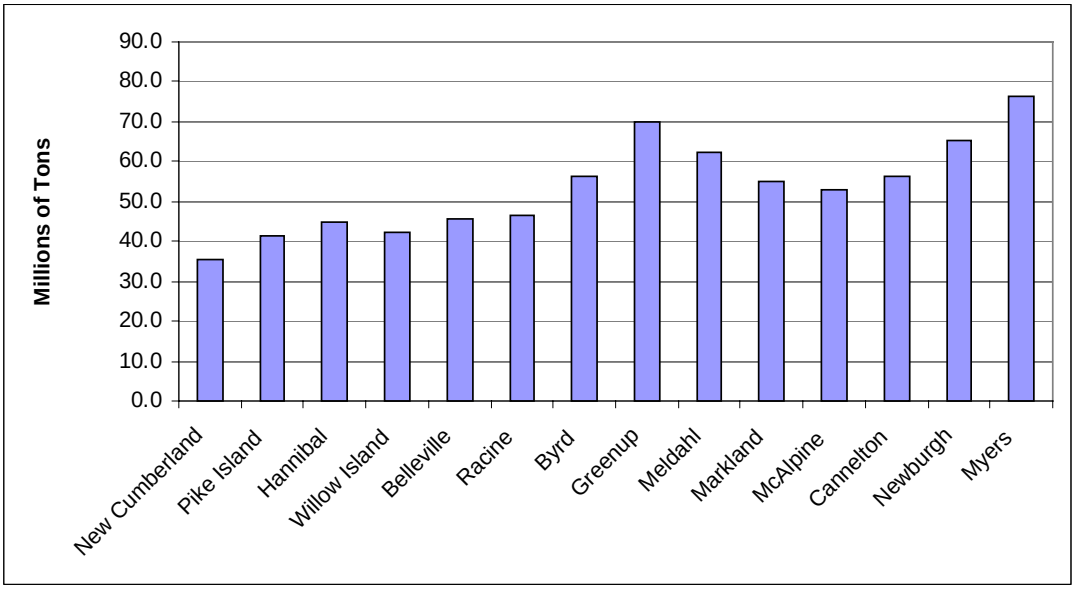
The cargo handling class for each commodity group defines the barge loading and unloading time in port. These are the same classes that were discussed earlier in connection with the model ports and include 1)dry granular bulk, 2)dry large-bulk and manufactured products, and 3)liquid cargo.

The dollar value of each major commodity group is used to compute the inventory holding cost of each movement during shipment. The commodity values were developed using data published in various industry and trade journals and the U.S. Department of Commerce publications. In computing the inventory holding cost, the model applies a cost of 12 percent per year, which is computed on the value per ton of each commodity per day. The inventory costs range from mills to cents per day depending upon the value of the commodity, representing a minor portion of the total cost of transportation by waterway.

7.3.3.2 Waterway Traffic Projections

Total traffic on the Ohio River doubled between 1968 and 1996, when it reached 239 million tons. This growth has not been spread evenly across the river. Greenup and Byrd locks, with an average annual growth of 4.1 percent between 1987 and 1997, were the fastest growing locks. Much of this rapid growth is attributable to electric utilities' reaction to the latest round of Clean Air Act Amendments (CAAA). This surge in traffic leaves Greenup second in total traffic to Myers among the projects with small 600' auxiliary chambers (see **Figure 7-2**).

FIGURE 7-2
Traffic at Ohio River Mainstem Projects with 600' Auxiliaries, 1997



Four traffic projection scenarios have been completed. These projections take into account CAAA effects, initial reactions to electric utility de-regulation initiatives caused by the Energy Policy Act of 1992, a reduced future dependence on nuclear power, and enactment of some form of carbon emission regulation, respectively. Three of these scenarios indicate steady growth at both Myers and Greenup locks. The fourth, the Carbon Limit scenario, indicates traffic would decline between 2010 and 2030, before recovering on the basis of traffic growth in the noncoal commodities. A summary of these projections is presented in **Table 7-1** below. Both **Section 6** and **Attachment 3** of this report contain more complete discussions of traffic projections.

TABLE 7-1
Summary of Waterway Traffic Demand Projections

Project/Scenario	1996	2010	2030	2060	Annual % Growth 1996-2060
Greenup					
- CAAA	70.9	86.3	107.6	149.4	1.17
- Deregulation	70.9	91.1	113.7	158.4	1.26
- Nuclear Limits	70.9	91.4	115.4	160.9	1.29
- Carbon Limits	70.9	79.1	73.6	81.6	0.22
Myers					
- CAAA	78.9	97.3	115.0	149.0	1.00
- Deregulation	78.9	100.5	118.5	154.3	1.05
- Nuclear Limits	78.9	100.6	118.9	154.9	1.06
- Carbon Limits	78.9	89.6	87.0	95.7	0.30
Ohio River System					
- CAAA	266.6	334.1	393.5	498.4	0.98
- Deregulation	266.6	356.0	422.2	539.4	1.11
- Nuclear Limits	266.6	356.9	427.4	547.2	1.13
- Carbon Limits	266.6	320.5	301.8	333.8	0.35

7.3.4 Transportation Rate Analysis

In 1997, transportation rates and costs were estimated, based on a detailed rate study using a sample of 1990 ORS barge movements. This statistically derived sample accounted for over 164 million tons or more than 60 percent of total ORS tonnage. Assuming the rate charged is a function of freight transported (in ton-miles), a sample size of 1,619 movements provided a 95 percent level of confidence that the sample mean ton-mile was within 5 percent of the population mean ton-mile. The sample was also checked for adequate geographic coverage to assure it being representative. Transportation rate specialists at the Tennessee Valley Authority (TVA) measured transportation rates and supplemental costs for the sample of commodity movements using a combination of shipper surveys, costing models, and Waybill data.

The Navigation Center then developed probabilistic inputs and regression equations from the sample rate data to use in estimating rates for the unsampled, population movements. At a commodity group level of aggregation, rail and barge line-haul rates were assumed a function of ton-miles. Simple univariate linear regression yielded statistically significant line-haul rate estimating equations. Also at the commodity group level, sample data for loading/unloading charges and transportation leg(s) rates to/from the modal line-haul were fit to selected statistical distributions. The regression equations and statistical distributions were used to estimate transportation cost savings for the unsampled movements. A basin-wide transportation rate matrix was constructed using the rated sample movements and the estimated unsampled movements. Complete documentation of this study can be found in the LRD Navigation Center.

For purposes of the benefit analysis in the ORMSS, the basin-wide rate matrix was updated to a 1999 price level. To accomplish this, the sample of waterborne commerce movements rated in 1997 was re-rated in 1999 and indices were developed to apply to the entire matrix. The most important goal of indexing is to capture any changes in rate structure that are likely to remain in the long-run (over a project's life of 50 years). The rate analysts from TVA

made every attempt to purge the data of anomalous or transitory influences and develop rates that portray normal market conditions. A full description of TVA's methods of research and rate construction, and supporting assumptions can be found in the LRD Navigation Center.

7.3.4.1 The 1997 Rated Sample

For rate analysis, a commodity movement is broken into three distinct parts: 1) legs to/from the ultimate origin/destination, 2) modal line-haul, and 3) accessorial (loading/unloading/transloading) charges. The overall transportation rate for any sample movement is the sum of these three components. **Table 7-2** summarizes the rated sample at the commodity group level. The component rates/charges are expressed in per to averages by tonnage weighting the sample movements. The overall rate is the sum of the sample tonnage weighted averages of the three components to a movement. In this study, average savings per ton were estimated at $8.46. Waterway savings are driven by the lower line-haul rate.

TABLE 7-2
1997 Sample Summary Statistics

		Water Rate per Ton			Land Rate per Ton		
	SPT	Barge LH	Accessorial	Legs	Rail LH	Accessorial	Legs
Coal	7.50	3.35	3.52	3.67	13.46	3.09	1.51
Petrol Products	7.94	5.76	1.52	0.07	13.38	2.26	0.12
Aggregates	7.70	2.78	2.27	1.52	8.02	3.39	2.50
Grain	7.95	6.68	4.16	2.03	14.09	3.83	0.85
Chemicals	21.27	13.37	2.65	0.63	40.81	2.99	0.57
Ores & Minerals	26.46	8.12	3.78	0.90	32.33	4.51	0.66
Iron & Steel	16.67	7.70	5.23	4.33	23.33	5.68	1.90
All Other	10.97	4.72	3.51	0.64	13.57	3.80	1.48
All Commodities	**$8.46**	**$3.79**	**$3.30**	**$3.01**	**$13.69**	**$3.20**	**$1.54**

7.3.4.2 The 1999 Sample Update

The same commodity movements rated in 1997 were re-rated in FY 1999. **Table 7-3** shows the 1999 sample rate statistics. Overall, the tonnage weighted savings per ton for the sample has reduced slightly. This is because, in the FY99 update, two notable situations have emerged with respect to long-term cost efficiencies of rail transportation. First, the mergers of 1996, 1997, and 1998 have been completed. The result of these mergers has been the decrease in variable cost of the surviving carrier and the decrease in the rate structure, percent of variable cost, to reflect the surviving carrier's historic commodity rate levels. Second, the rail mode is gaining long-run efficiency through the continued deployment of larger, lighter rail cars and the installation of heavier track capacity. More detail on these important changes is provided in **Attachment 1**.

TABLE 7-3
1999 Sample Summary Statistics

		Water Rate per Ton			Land Rate per Ton		
	SPT	Barge LH	Accessorial	Legs	Rail LH	Accessorial	Legs
Coal	7.20	3.34	3.53	3.68	13.24	3.09	1.52
Petrol Products	7.93	5.55	1.52	0.07	12.59	2.31	0.12
Aggregates	6.98	2.79	2.34	1.46	7.68	3.48	2.40
Grain	5.66	6.65	4.23	1.97	13.76	3.90	0.85
Chemicals	27.98	13.28	2.66	0.65	40.99	2.99	0.58
Ores & Minerals	22.64	8.45	3.78	0.88	30.59	4.51	0.66
Iron & Steel	13.01	7.86	5.42	4.17	23.18	5.67	1.88
All Other	9.44	4.86	3.46	0.64	13.12	3.80	1.48
All Commodities	**$7.96**	**$3.78**	**$3.31**	**$3.00**	**$13.38**	**$3.22**	**$1.54**

7.3.5 Lock Performance Analyses

7.3.5.1 Introduction

Performance, as discussed in this report, has two aspects: 1) the ability to pass traffic under normal circumstances and 2) the structural reliability of the project. Performance under historically based or normal circumstances is described through the analysis of a detailed, project-specific database (LPMS) and projected to future project conditions with a discrete event simulator (the WAM). Results of the analysis are most commonly summarized as an annual capacity or a traffic-transit time curve. These descriptions are unique to the project and the lock configuration modeled.

Reliability estimates are similar in that they are unique to the project, and also to future lock maintenance investments. Reliability descriptions are dependent upon detailed engineering inspections and analyses. These analyses, once solely base upon engineering judgment, are becoming increasingly more sophisticated and empirically based. Nevertheless, the critical information required for the economic analysis remains - likelihood of unsatisfactory performance, timing of occurrence, and consequence of unsatisfactory performance. The answers to these questions are contained in the chamber cost and closure matrices for each project.

This section briefly discusses both the reliability and capacity-related performance aspects of the study.

7.3.5.2 Capacity Analysis

7.3.5.2.1 General. The location of each lock and dam project to be considered as a constraint node in the TC\EQ model must be described in the system network. Required input data for each project include the project's physical tonnage capacity and a tonnage-transit (including delay and processing times) function. These values are used by the model to calculate the amount of project transit time incurred by each tow in moving from its origin port to destination port.

Capacities for the 60 projects considered in ORS analyses are computed using the WAM. The WAM is a stochastic simulation model used to estimate the transit times (processing and delays) associated with the processing of vessels through the project, taking into account the variability in inter-arrival times, approach times, chamber entry times, chamber fill/spill times, and exit times. Vessel inter-arrival times and the various components of lockage times are selected randomly by the WAM from distributions derived from historic tow-arrival and lock-processing time distributions found in LPMS data. A detailed discussion of the WAM and the capacity analysis is presented in **Attachment 1, Capacity Analysis**.

The WAM consists of three basic units: model configuration; simulation; and statistics compilation. Model configuration defines the system analyzed in terms of the network description, the barges and towboats to be used in the simulation, the shipment list and a list of downtime events. The simulation module processes the input data and moves the shipments from origin to destination through the system elements. Throughout the simulation, statistics are compiled concerning delays, queue lengths, average processing times, and other variables.

The primary item of interest from any single WAM run is the delay for a given traffic level. By making a series of runs over a wide range of traffic levels, enough observations can be obtained to develop tonnage-transit relationships for each set of conditions. Capacity is then identified as the traffic level at which an increase in tow arrivals results in a large increase in average delay, with very little or no measurable increase in tonnage accommodated.[1]

The model requires three input data files to perform the simulation. These consist of: 1) a network description file containing equipment and cargo characteristics along with the configuration of the waterway network being analyzed; 2) a shipment list containing arrival patterns for tows and recreation craft; and 3) a downtime file containing the frequency and duration of chamber downtime events. Each of these data files is briefly discussed in the following paragraphs.

7.3.5.2.2 WAM Network Description. The network description includes the location, size and operating characteristics of all the relevant components of the system being simulated. This organization allows the WAM to be used as a system simulator, containing several navigation projects, but primarily it is used as a single project simulation.

The most important part of the WAM network, both in terms of the volume of data and its significance in determining capacities and tonnage-transit relationships, is the lock data. These records define the number of lock chambers at the project and their dimensions, the time required for lockage, and the lockage policy. Lock input includes a series of option switches that allow analysis of multi-vessel, open pass, and set-over lockages; recreation vessel traffic; and ready-to-serve restrictions. The lockage times are extracted from LPMS data for each of the components of processing time, identified as Start of Lockage, Chamber Entry Time, Chambering Time, and End of Lockage.

7.3.5.2.3 WAM Shipment List. The shipment list is a stream of shipment demands which is input to the model during execution. Produced by a generator program, the shipment

[1] As used in this study, capacity refers to that level of traffic where the tonnage-delay curve reaches its vertical asymptote. This is a useful measure that approximates the level of tonnage at which average delay increases infinitely. It does not attempt to measure economic or physical capacity.

list drives the simulation in that it contains the arrival times of the vessels at the project and the type of vessel (commercial or recreational). If the vessel is commercial the commodity type, tonnage, barge and towboat type, and the number of barges is also included. Important fleet assumptions and operating procedures are also built into the shipment list generation. These include tow configuration distributions, towboat and recreational vessel arrival patterns.

7.3.5.2.4 WAM Downtime List. One of the critical inputs into the WAM model is chamber downtime. The WAM has the ability to model downtimes as an integral part of the modeling process. It includes the time a chamber is down due to maintenance, hardware malfunction or weather. The LPMS data contain historical records of random minor downtime events and major maintenance closures are determined through reliability analyses.

7.3.5.2.5 Simulation Module. The simulation module is the operational heart of the model. It processes the input data (e.g. lockage distribution components, shipment list and downtime file), produces playback reports (e.g. number of tows locked, number and type of lockage, and delay times), initializes the waterway system, processes each shipment from origin to destination, records statistics for the generation of performance output reports and creates files for post-processing by other programs. Additional simulations are performed, and a capacity/delay curve is developed.

7.3.5.3 Assessment of Project Reliability

7.3.5.3.1 General. In the last twenty years, major model modifications have revolved around efforts to better represent the performance of the system's projects. Queuing theory and mathematical representations used in early system models have given way to discrete event simulations of project performance. New data bases were put in-place by the Corps to collect the detailed timing data required for lock capacity simulations, and considerable efforts went into developing a credible vessel fleet data base. Simulations of this type yield capacity at locks either in terms of an annual throughput capability or a tonnage-transit relationship, given the number and dimensions of chambers, the vessel fleet configuration, the lock's availability profile, and the lock operating policy in use.

Not surprisingly, lock availability greatly affects the entire system's performance. Some availability variables -- relatively short duration events like accidents, weather, and high water -- can readily be incorporated into the lock capacity simulation using probabilities based upon historic data. Relatively longer closure events, closures associated with a lock's structural reliability, are rare events, and for this reason the frequency and duration are difficult to predict. In the absence of historic data, structural analyses and performance standards have been combined with engineering judgment to predict closure events. These closure projections, along with their associated repair cost and duration of chamber closure, are reported in chamber-specific cost and closure matrices (see the **Engineering Appendix** for the complete matrix or **Attachment 4** for the cost schedules). The economic consequences of these closures have been estimated by accounting for the cost of repairs and increased towing industry transit costs. These closure-induced delay costs also erode the benefits of the system.

Recent refinements in the simulation modeling have centered on more accurately representing tow operator behavior during service disruptions. Tonnage-transit simulations are now made at each lock site for a series of closure durations. This is done by adding closure days to the lock downtime file. Annual simulations are made with 3 days of reliability-related loss of

lock availability, 5 days of loss, 15 days of loss, and so on for each project site. Tonnage-transit curve selected by the TC\EQ model module for any given year corresponds to the days of closure scheduled for that year.

Closure event timing and duration are still specified externally to the models. The development of this important information is discussed in the next two subsections.

7.3.5.3.2 Methodology. Closure event timing and duration are described in the cost and closure matrices (see the Engineering Appendix). A cost and closure matrix has been developed for each future project condition alternative, by lock chamber and by year for the next 60 years, for each of the 19 authorized Ohio River mainstem projects. Cells in the matrix indicate the nature of any major maintenance event, the cost of repair or replacement, and the length of any associated chamber closure. Past economic analyses have relied on similar matrices, the information in the matrices being founded upon historical records, condition studies and engineering judgment.

Cost and closure matrices continue to be a key input into the economic analysis, but the information in the matrix is more closely aligned to the results of engineering reliability models. Initial assessments contained in the matrices for all 19 sites were based upon judgment. At the Myers and Greenup sites, these judgments have since been adjusted on the basis of reliability model results and their economic consequences. The economic consequences include both the physical repair cost and navigation industry costs incurred during lock closures for repair. Expected economic costs are estimated with the Life Cycle Lock Model (LCLM) under two alternative conditions -- either fix as the component fails or for scheduling a planned component replacement (individually or as part of a major rehabilitation). The least cost alternative for a given component is reflected in the matrix. If a scheduled component replacement is least cost, the best year for replacement, duration of closure, and repair cost is entered into the matrix for use in system modeling. If fix-as-fail is the least cost alternative, the stream of failure-related costs for these components is included in the matrix and directly deducted from system benefits.

7.3.5.3.3 Engineering Reliability and the LCLM. Major rehabilitation guidance issued by the Corps' Operations and Readiness division was the primary instrument for implementing more stringent analytical requirements in assessing major rehabilitation investments (U.S. Army Corps of Engineers 1995). Because major rehabilitation work is a prominent feature of most without-project conditions, this guidance has affected the analytical framework for new construction analyses.

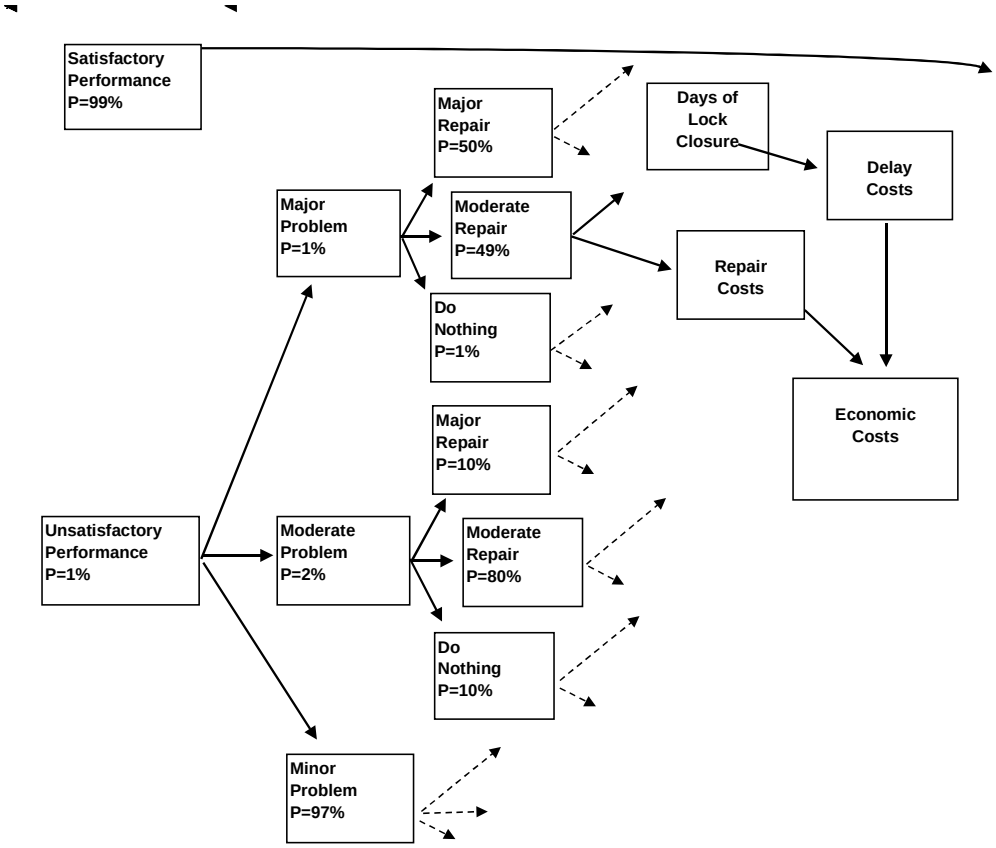
Major rehabilitation investments often involve the replacement of a number of worn or aging major components (usually lock gates, walls, culverts, valves, electrical systems, hydraulic systems, and other critical features). The Major Rehabilitation guidance requires economic justification of any major component replacement, with this justification evaluating replacement against a condition where the component is allowed to fail before it is fixed -- the base condition. Central to this analysis is the ability to both predict when any given component can be expected to fail and to identify the consequences of a failure. Current standards-based approaches to structural reliability assessments are able to identify a component in failure mode, but are not designed to predict when a component is likely to fail.

As a result engineering reliability analyses are moving away from standards-based descriptions of component reliability to probability-based descriptions, especially for major

components. Hazard functions are estimated which describe the probability of unsatisfactory performance (PUP) for each major component. Estimating these hazard functions requires the development of data bases on component performance over time and at different levels of utilization. This methodology allows for differing levels of unsatisfactory performance, each with an associated consequence in terms of repair costs and amount of time the lock chamber is closed for component replacement or repair. The final products of the engineering analysis are reliability forecasts, converted into probabilities of failure, and event trees depicting the possible events following failure (**Figure 7-3**).

The LCLM is a Monte-Carlo type simulation model developed by the ORMSS Economics Team to account for the economic costs associated with reliability analyses. The central inputs to this model are the probabilities of failure and the possible events following failure (as developed by the Engineering team) and presented in an event tree, and the cost incurred by industry because of failure (as developed by the Economics team). Each event tree is specific to and bounded by a particular maintenance policy, a particular component, and a particular lock. Thousands of iterations are made through the event tree in a Monte Carlo simulation of the component's performance, yielding a distribution of expected days of closure and expected repair costs due to unsatisfactory performance. Simulations are made for each component and for each year in the 50-year life of a project. If a component is replaced, PUPs are reset to a new or like-new value. Expected closure days are linked to the EQ model which uses hourly tow costs and tonnage-transit relations to estimate expected closure costs associated with unsatisfactory performance.

FIGURE 7-3
Component Reliability Event Tree



7.3.6 Model Output

The TC\EQ provides detailed data on the port-to-port shipping times, shipping costs, and equipment characteristics for each individual origin-destination/commodity/barge-type movement. **Table 7-4** provides a listing of the available output reports.

7.3.7 Model Calibration and Verification

The TC\EQ is a predictive model, requiring calibration tests to show the model's ability to replicate known shipper behavior and system operating characteristics before attempts are made to forecast future behavior and system operating characteristics. Key variables that describe the characteristics of the towing fleet and the corresponding indicators of system performance should be replicated or approximated in order for the TC\EQ to be considered fully calibrated.

Calibration actually involves fine tuning the static components of the model's shipment list and network description. Since certain model inputs affect output in a more general fashion than others, calibration was carried out in an orderly, systematic fashion. The effort to match the TC\EQ output with the target values required a number of calibration runs, the first of which involved reproducing barge loadings throughout the system. This was accomplished by

adjusting the minimum channel depths along selected river segments, thus reducing allowable barge drafts and lowering average barge loadings past that particular stretch. Calibration of average barge loadings and barge counts is really one in the same. Obtaining correct average loading allows the model to select the correct number of barges required to move the given tonnage flows. Next, tow counts and tow sizes were calibrated by adjusting the towboat efficiencies of the towboat classes considered by the model. In effect, this can be used to restrict the model's selection of certain towboat types on certain river segments, thereby capturing equipment scarcity, channel restrictions and other variables not considered separately by the model. Last, tow speeds were calibrated since all the previous calibration steps affect the average tow speeds. Minor adjustment to the tow speed coefficients was needed to obtain reasonable results. Although no goodness of fit statistical computations were conducted, visual observations indicated that the model output closely matched the targets. Results of the calibration efforts are maintained in LRHNC (*1996 TCM Calibration)*, January 1998).

TABLE 7-4
Tow Cost Model Output Reports

1. Annual Towboat Utilization and Costs Report
   - o Number required by class
   - o Percentage of time in use
   - o Costs per towboat
   - o Total costs by class
   - o Ton-miles by class
   - o Mills per ton-mile
   - o Fuel used by class
   - o Time distribution by function

2. Annual Barge Utilization and Costs Report
   - o Number required by class
   - o Percentage of time in use
   - o Costs per barge
   - o Total cost by class
   - o Ton-miles by class
   - o Mills per ton-mile
   - o Number required by season
   - o Time distribution by function

3. Tow Size Distribution Report
   - o Distribution by towboat class
   - o Distribution by towboat class

4. Annual Lock Utilization Report
   - o Tonnage
   - o Number of lockages
   - o Number of tows and barges
   - o Percent empty barges
   - o Average lockage time
   - o Average delay time

5. User Charge Summary Report
   - o Government Expenditures
     - - Maintenance, Rehabilitation
     - - Project implementation
   - o Industry operating costs
     - - Base cost (excluding user charges)
     - - Costs due to fees
     - - Base cost by river segment
     - - Costs due to fees by river

6. Segment Fee Analysis
   - o Fee (mills/ton-mile)
   - o Kiloton-miles
   - o Total (product of two preceding values)

7. Detailed System Traffic Reports
   - o Origin port - Destination Port
   - o Commodity Group – Annual tonnage
   - o Annual ton-miles
   - o Total rate savings and total towing costs

8. Lock Costs Report
   - o Tonnage
   - o Cost by function
     - - Lockage
     - - Lock delay
   - o Cost by source
     - - Boat costs
     - - Barge costs
     - - Cargo costs
     - - Total costs

9. Annual Port Util.Report
   - o Kilotons shipped
   - o Kilotons received
   - o # of barges loaded
   - o # of barges unloaded
   - o # of barges fleeted
   - o # of tows served
   - o Average wait for dock

10. Port Costs Summary Report
    - o Summary of industry costs at each port

11. Segment Cost Summary Rep
    - o Summary of industry costs on each segment
      - - Total costs
      - - Costs per t-mile

12. Tow Operating Charac
    - o # of barges by class
      - - Loaded, Empty
    - o Tow and barge loads.
    - o Avg. Tow Speeds
    - o # of towbts by class

13. Fuel Tax Analysis Report
    - o Tax
    - o Gallons of fuel used
    - o Revenue

SECTION 8

MAINSTEM OHIO RIVER WITHOUT PROJECT FUTURE

8.1 INTRODUCTION

This section of the report develops and presents the most likely future Without-Project condition for the Ohio River Mainstem – the entire system of channels, pools, and lock and dam structures that provide year-round, 9-foot deep commercial navigation on the Ohio River. While the primary goal was to identify the most likely Without-Project condition, this process also served to identify any possible near term needs. As a result of this analysis, two projects were advanced for immediate treatment—J.T. Myers and Greenup Locks and Dams. Specific features of the most likely Without-Project condition (WOPC) for these two locks is presented in Sections A9 and B9 of this Appendix.

The Without-Project condition is that future condition deemed most likely to exist in the absence of any proposed project(s) or any change in existing law or public policy. It is selected from a set of possible alternative Without-Project futures. Identification of the most likely future Without-Project condition is extremely important because it is used as the baseline for measuring incremental benefits, costs and other effects of alternative plans of improvement (the With-Project condition). Formulation of the WOPC begins with the existing locks, their current performance and their structural condition. Any reasonably expected and economically justified nonstructural practices within the Corps of Engineers' discretion are to be assumed implemented at the appropriate time. Both operational alternatives (the use of helper boats and revised lockage policies) and maintenance alternatives are examined for their ability to improve project performance, insuring the best use of the existing facilities in the Without-Project future.

The mainstem Ohio River is a system of 20 locks that create a series of navigation pools over the 981-mile length of the Ohio River. Today's system will be reduced to 19 locks upon completion of under-construction Olmsted Locks and Dam and the removal of Locks and Dams 52 and 53. Specifically, the ORMSS study evaluates the major maintenance, major rehabilitation, and new construction investment needs for these 19 navigation locks and dams. As navigation traffic grows on the Ohio River, several lock structures will experience increasing delays. These delays will be particularly severe during times of lock chamber maintenance, especially when the Main chamber at any one of these facilities must be closed for routine or emergency repairs or accidents. Other locks may become increasingly unreliable due to age and

cycles of use. Therefore, assessing the structural reliability of these structures is an important component of this Without-Project evaluation. These assessments suggested that some locks might need more immediate, near term attention than other locks. Of course, a complete evaluation of near term needs at specific locks are influenced not only by the structural condition analyses completed by the Engineering team, but also by expected levels of traffic demand, and Auxiliary lock capacity.

8.2 EXISTING CONDITION

This subsection describes the existing condition of the mainstem Ohio and serves as a starting-off point for identifying the most likely WOPC. Lock capacity and reliability, traffic, and traffic delays are discussed for all mainstem sites. More detailed discussions of the WOPC pertaining to J.T. Myers and Greenup Locks and Dams are presented in Sections A9 and B9, respectively. Ultimately, any lock's performance capabilities are limited by two factors: 1) physical lock capacity, and 2) structural reliability. The former is influenced by chamber dimensions, hydraulic conditions, vessel fleet characteristics, weather conditions, and even accident frequencies, while the latter is affected by a given project's structural condition and intensity of maintenance efforts. This capability to process traffic placed in juxtaposition with traffic demands tests a lock's performance. Transit time and its most volatile component, lock delay, readily measure lock performance. The following discusses both the capabilities and performance of Ohio River locks.

8.2.1 Capacity Considerations

Lock performance capability is largely determined by lock chamber dimensions, approach conditions, and service availability. The three uppermost locks, Emsworth, Dashields, and Montgomery (EDM), have a Main chamber measuring 110' x 600' and an Auxiliary lock measuring 56' x 360'. They are the lowest capacity locks on the Ohio River (see **Table 8-1**). 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. Smithland, with the greatest capacity on the river, has twin 110'x1200' chambers. Once authorized construction is completed, both McAlpine and the new Olmsted Locks and Dam (replacing Locks and Dams 52 and 53) will also have twin 1200' chambers. In the Without-Project analysis, these authorized projects and associated capacities are assumed to be in-place. All other locks on the mainstem Ohio have a 110' x 1200' Main chamber and a 110' x 600' Auxiliary chamber (a configuration commonly referred to as a 1200' and a 600'). These project configurations form the basis for subsequent evaluations of competing Without-Project alternatives.

Two non-structural alternatives are already components of the existing system: 1) helper-boats during Main chamber closures and 2) re-scheduling of shipments during long duration, scheduled Main chamber closures. The use of helper-boats, through an industry self-help program, effectively maximizes the capacity of the small 56'x 360' auxiliaries on the upper Ohio

and the 110'x 600' auxiliaries elsewhere.[1] These practices, along with limiting tow sizes to five cuts during Main chamber closures on the upper Ohio, are reflected in lock capacities reported in **Table 8-1**. Re-scheduling during closures re-distributes tows on either side of the closures. Annual throughput, or capacity, is unaffected, but average delay per tow is lower than it would be otherwise.

TABLE 8-1
Ohio River Mainstem Locks
Annual Capacity Estimates
(millions of tons)

Project	Operation of:		
	Main Only	Auxiliary Only	Both
Emsworth	31.5	15.0	40.4
Dashields	37.1	16.5	43.8
Montgomery	37.6	15.7	41.7
New Cumberland	85.4	41.0	119.5
Pike Island	104.0	51.8	147.3
Hannibal	114.4	63.4	169.7
Willow Island	118.2	59.1	159.8
Belleville	118.1	59.3	159.3
Racine	127.7	62.8	181.9
R.C. Byrd	98.6	59.4	148.5
Greenup	111.5	60.0	158.0
Meldahl	105.6	56.9	145.7
Markland	106.1	62.7	155.4
New McAlpine 1/	119.8	123.0	225.5
Cannelton	125.6	61.8	164.1
Newburgh	139.0	65.0	183.0
J.T. Myers	136.7	66.7	174.2
Smithland	128.3	129.0	246.7
Olmsted 1/	NA	NA	275.0

1/ Currently under construction.

8.2.2 Project Reliability

Lock performance is also affected by the availability of the lock for service. Availability is reduced due to random events most often related to accidents and adverse weather or flow conditions – and from maintenance-related closures. The latter events are more likely to be lengthy closures that dramatically affect lock performance than are the random closure events. Age and level of use can act as a rough proxy for major maintenance needs. By the year 2008,

[1] The self-help program at Emsworth, Dashields and Montgomery also includes a restriction on tow sizes to 5 barges-per-tow.

the first year a project might be brought on-line, Emsworth will be 91 years old, Dashields 83, and Montgomery 76 years old.[2] The next oldest locks will be nearing the end of their original 50 year design-life: New Cumberland and McAlpine (49 years old), Greenup and Meldahl (48 years old), and Markland (47 years old). Of this group, Greenup will be handling the greatest level of traffic.

Of course, age alone does not predict structural condition. Engineering reliability assessments of the mainstem locks provide a truer picture of need. Assessments based upon condition surveys, historic component performance, and engineering judgment were completed for all mainstem sites not currently under construction. In addition, full scale engineering reliability and subsequent economic analyses were completed for all the major lock components at the J.T. Myers and Greenup sites. Therefore, both J.T. Myers and Greenup have the reliability analyses embedded into the overall economic analysis. All other sites are based upon condition assessments and engineering judgment. This type of analysis indicates likelihood of component failure based upon factor determinants such as age, usage, loads, existing condition of the component, rate of corrosion, and so on. Reliability analyses will be completed at the upper Ohio sites in the next interim report. All remaining sites will be completed as part of the final ORMSS report.

TABLE 8-2
Major Components Indicated for Replacement, by Lock, Main Chamber Only

Component	Emsworth	Dashields	Montgomery	New Cumberland	Pike Island	Hannibal	Willow Is.	Belleville	Racine	R.C. Byrd	Greenup	Meldahl	Markland	McAlpine	Cannelton	Newburgh	J.T. Myers	Smithland	Olmsted
Miter Gates	none	none	none	R	R	R	R	R	R	none	R	R	R	R	R	none	none	R	none
Lockwalls	R	none	none	none	none	R	none	none	none	none	none	none	none	none	none	none	none	none	none
Guardwalls	R	R	R	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
MG Monoliths	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
MG Sills	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none	none
RT Culvert Valve	none	none	none	R	R	R	R	R	R	R	none	R	R	R	R	R	R	R	none
Hydraulic System	none	none	none	R	R	R	R	R	R	R	none	R	R	R	R	R	R	R	none
MG Machinery	none	none	none	R	R	R	R	R	R	R	none	R	R	R	R	R	none	R	none
CV Machinery	none	none	none	R	R	R	R	R	R	R	none	R	R	R	R	R	R	R	none
Electrical Systems	none	none	none	R	R	R	R	R	R	R	none	R	R	R	R	R	none	R	none

HF -- horizontally framed CV -- culvert valve

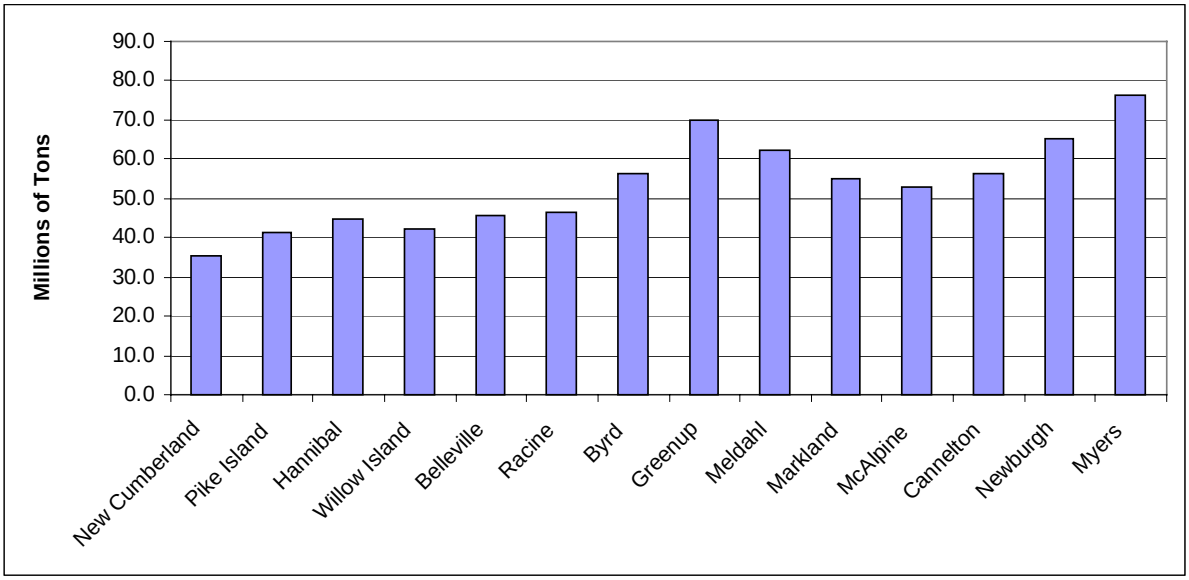
MG -- miter gate R -- Replace or rehabilitate

[2] Emsworth, Dashields and Montgomery were all rehabilitated in the 1980s. These rehabilitations included installations of new miter gates, culvert valves, associated machinery, and re-facing some of the lock concrete structures. Nevertheless, there are still serious concerns regarding the structural integrity and stability of the concrete structures at these three sites. This is a continuing focus of engineering assessments for the Final Report.

8.2.3 Traffic Delays

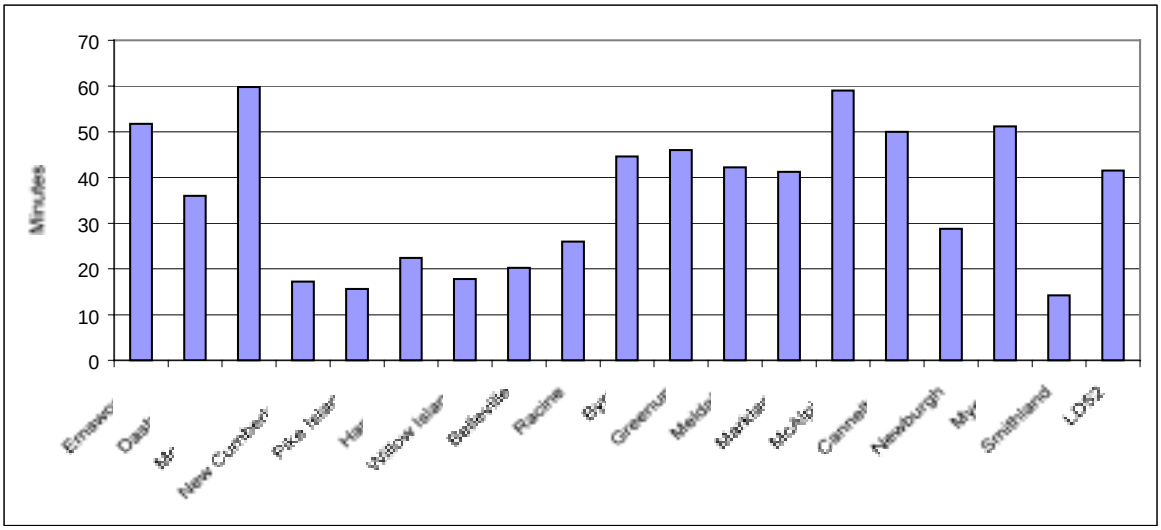
Total traffic on the Ohio River doubled between 1968 and 1996, when it reached 239 million tons. This growth has not been spread evenly along the river. Greenup and Byrd locks, with an average annual growth of 4.1 percent between 1987 and 1997, were the fastest growing locks. Much of this rapid growth is attributable to electric utilities' reaction to the latest round of Clean Air Act Amendments (CAAA). This surge in traffic leaves Greenup second in total traffic to Myers among the projects with small 600' Auxiliary chambers (see **Figure 8-1**).

FIGURE 8-1
Traffic at Ohio River Mainstem Projects with 600' Auxiliaries, 1997



Delays are a function of a project's capacity and reliability, and of the traffic demands placed on the project. Delays during normal traffic operations typically range from less than ten to not more than 75 minutes at all mainstem locks, though delays can be expected to increase as traffic grows over time (see **Figure 8-2**). Excessive levels of delay do occur when the Main chamber is closed at any of these locks. Delays are most severe at the high traffic locks below R.C. Byrd Locks and Dams. A 44-day closure of the Main chamber at Myers in 1989 caused upwards of eight-days delay per tow; a 20-day closure at Greenup in 1998 caused tows to be delayed over a day on average, though some tows waited as long as three days. This is not surprising given that the physical capacity of the small Auxiliary chamber at Greenup is estimated at 48 million tons, an annual ability overwhelmed by annual demands in 1997 that reached 70 million tons. These delays dramatically increase tow transit times and, therefore, tow transit costs. All significant Main chamber closures in recent years have been associated with maintaining project reliability.

FIGURE 8-2
Ohio River Mainstem, Average Lock Delays per Tow, 1993 – 1997



8.3 PRELIMINARY EVALUATION OF NONSTRUCTURAL ALTERNATIVES

Because maintenance and its effect on the satisfactory performance of the Mainstem's aging locks is a key concern, considerable effort was devoted to identifying the least-cost maintenance alternative. Of course, least-cost encompasses both repair costs and navigation industry disruption costs. Therefore, efficient operation of the existing structures is an important consideration. This is especially true during those times when the Main chamber is closed for maintenance, funneling traffic through the much smaller Auxiliary chambers. Both maintenance alternatives and operational alternatives are described below.

8.3.1 Maintenance Alternatives

Condition evaluations indicate that a number of Ohio River mainstem projects will require the repair and/or replacement of major lock components over the next 50 years. These requirements were summarized above in **Table 8-2**. This section describes two alternative scenarios for maintaining, repairing and replacing mainstem locks and their components – the Baseline scenario and the Most Likely Maintenance and Major Rehabilitation (M&MR) scenario.

The Corps of Engineers currently pursues a proactive maintenance policy, scheduling the repair and replacement of these components in order to minimize the adverse industry effects associated with lock outages (a policy reflected in the M&MR scenario discussed in section 8.3.1.2 below). Current policy allows these component replacements to be bundled into major rehabilitation when economically justified. Alternatively, the Corps could pursue a more

reactive maintenance policy (a policy reflected in the Baseline scenario discussed in 8.3.1.1 below). Rather than maintaining components and sub-components through scheduled, periodic repair, these items are simply repaired or replaced when they perform unsatisfactorily.

The performance of these two competing policies is numerically described in cost and closure matrices for each mainstem Ohio lock project, by chamber and by year. Closure matrices contain the yearly replacement costs and days a given chamber is out of service in order to complete the required work. In this interim report, these schedules and costs are based upon engineering judgment and supporting condition studies at all sites, with the exception of J.T. Myers and Greenup locks and dam. Matrices at these sites were initially based upon engineering judgment, which has since been verified with engineering reliability analysis. Eventually, all sites' cost and closure matrices will be developed in the same manner.

8.3.1.1 Baseline

The Baseline Scenario is a reactive, fix-as-fail maintenance strategy. Normal operation and maintenance is performed, along with cyclical major maintenance for inspection, repair and adjustment of components and their sub-component features. No major rehabilitation occurs, though individual components are replaced at their expected failure date.

8.3.1.2 Most Likely Maintenance & Major Rehab

As with the baseline scenario, normal operations and maintenance practices continue along with major maintenance to periodically inspect and repair sub-components and major components. With regard to component replacement, this maintenance scenario mimics current maintenance practices. Components are scheduled for replacement as required and are bundled into major rehabilitation when economically justified.

Past studies have relied upon condition studies and engineering judgment as formed by condition surveys, experience, and engineering standards to determine if and when a major lock component needed to be replaced. While this method continues to be relied upon in this interim report for most sites, reliability-based economic modeling is used to verify engineering judgement at J.T. Myers and Greenup (see **Section 7.3.5.3.3** for a discussion of reliability-based economic modeling using the LCLM). For those components where failure is indicated, the Life Cycle Lock Model (LCLM) is used in conjunction with engineering reliability results to determine if scheduled replacement (indicated by a date in time in the table below) or fix-as-fail (indicated with FAF) is the most economical strategy. As can be seen in **Table 8-3** below, fix-as-fail is the best choice for most components where reliability is a concern. Again, these results have been incorporated into the cost and closure matrices for the M&MR scenario. More detailed discussion of this modeling is presented in the **Engineering Appendix** and in **Attachment 2** to this appendix.

TABLE 8-3
Summary of Reliability-Based Component Replacement Needs
J.T. Myers and Greenup

Major Component	J.T. Myers		Greenup	
	Main	Auxiliary	Main	Auxiliary
Miter Gates	FAF	---	2004	2030
Lockwalls	---	---	---	---
Guardwalls	---	---	---	---
MG Monoliths	---	---	---	---
MG Sills	---	---	---	---
RT Culvert Valves	2030	2030	FAF	FAF
Hydraulic System	2020	2030	FAF	FAF
MG Machinery	FAF	FAF	FAF	FAF
CV Machinery	2030	2030	FAF	FAF
Electrical Systems	FAF	2030	FAF	2030

MG--miter gates RT--reverse tainter
CV--culvert valves

8.3.2 Operational Alternatives

A number of nonstructural operational measures designed to improve lock efficiency were considered; however, these measures are already in use at the Ohio River mainstem projects. Closures of the Main chambers in the Without-Project condition cause traffic demands to overwhelm the small Auxiliary chambers at the high traffic, lower Ohio locks and at the upper Ohio locks. During normal operations project capacity is sufficient to handle traffic efficiently at all mainstem projects throughout the 50-year planning horizon. Additionally, towing companies and their customers reschedule traffic to other times of the year or to other modes during Main chamber closures. The effect of this is captured in future traffic-delay relationships, but the additional costs involved have yet to be satisfactorily quantified. For that reason, current estimates of the Without-Project condition costs may be underestimated. No assessment of alternative Without-Project plans is required, as all reasonable operational measures are already in effect and are incorporated in both the Baseline and M&MR scenarios.

8.4 SYSTEM-WIDE WITHOUT-PROJECT CONDITION

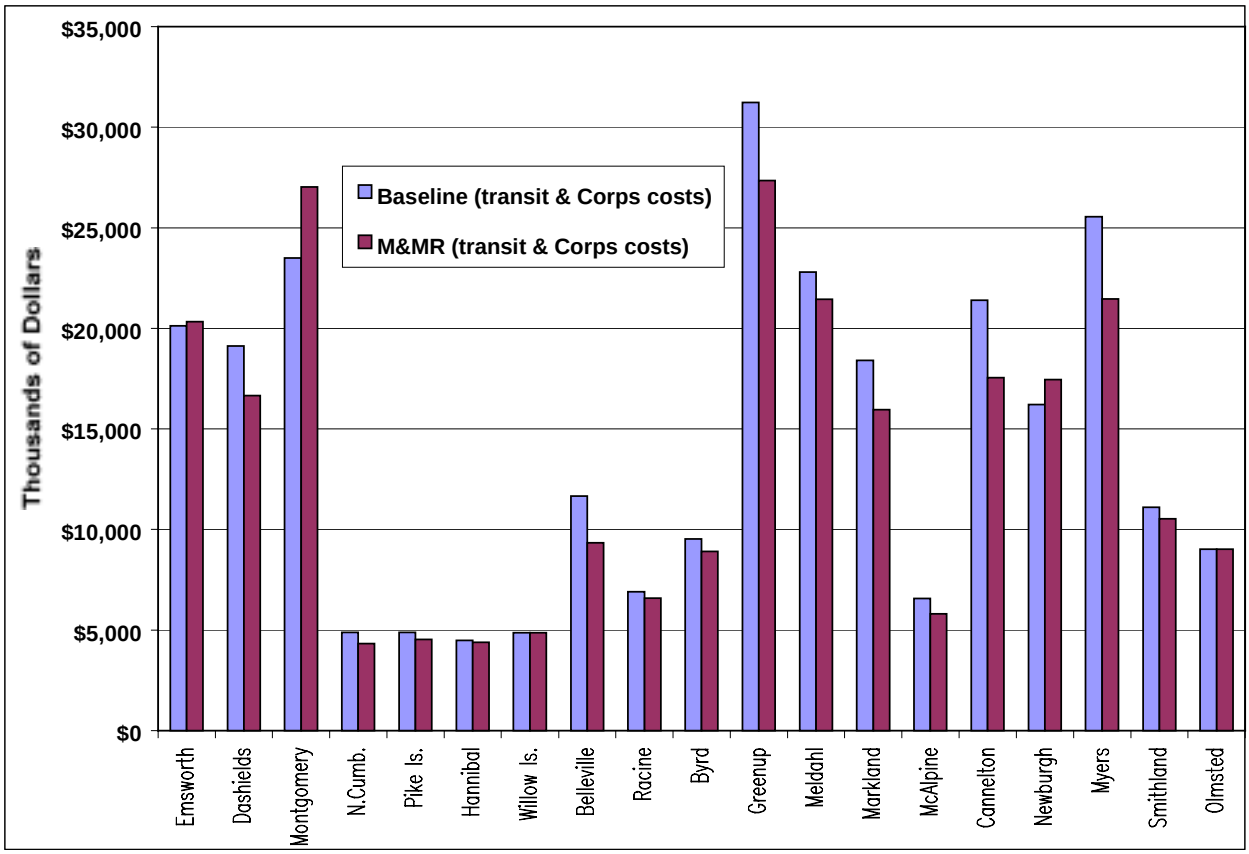
Table 8-4 compares the relative effectiveness of the two WOPC alternatives from an economic standpoint. On a system-wide basis, the M&MR scenario, despite having higher average annual costs, provides the highest net benefits.

TABLE 8-4
Comparison of Maintenance Scenarios
(2000 – 2060, Discounted to 2008 @ 6.875%)

Without Project Alternative	First Cost	Average Annual Values ('000 $)		
		Cost	Benefit	Net Benefit
Baseline	$ 4,919,459	$ 65,598	$ 2,639,311	$ 2,573,713
M&MR	$ 4,776,018	$ 72,321	$ 2,690,257	$ 2,617,936

These two WOPC alternatives were also compared on a project-by-project basis. Again, the M&MR proved to be the best WOPC alternative at all but three sites (see **Figure 8-3**). The M&MR scenario is selected as the most likely WOPC future for the mainstem Ohio River and is used as a system backdrop when evaluating any project-specific improvement alternative.

FIGURE 8-3
Comparison of Maintenance Cost Scenarios, by Project
(2000–2060, discounted to 2000 @ 6.875%)



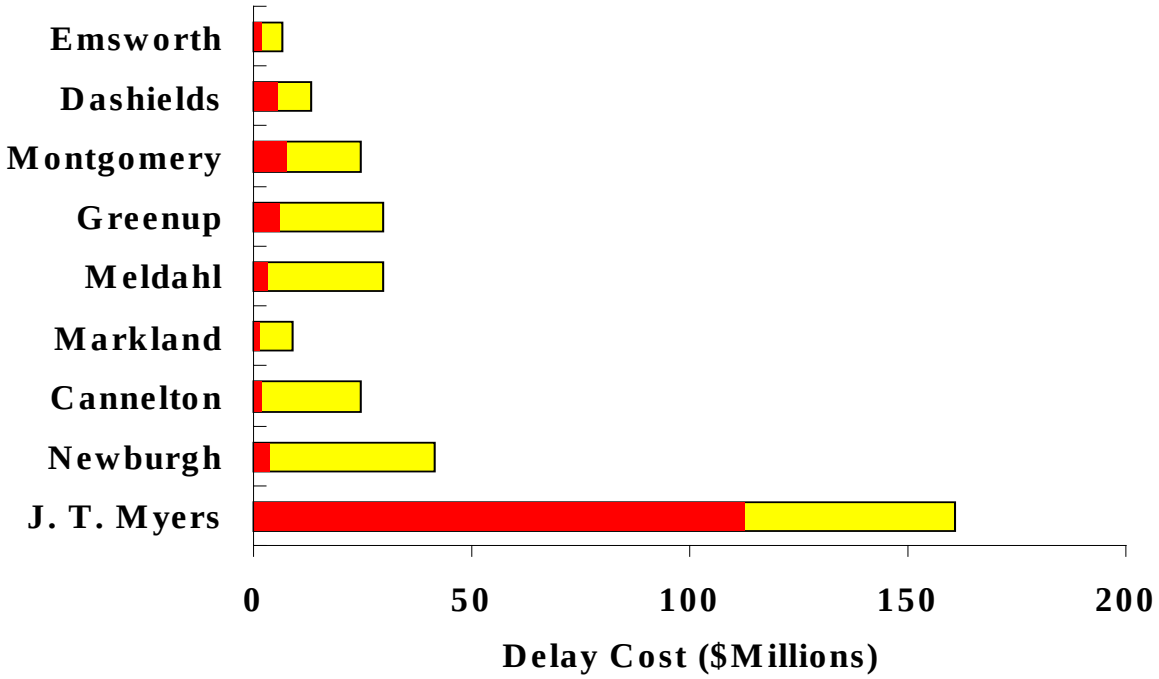
8.5 INTERIM SYSTEM NEEDS

As is apparent in the discussion above, developing a most likely Without-Project condition (WOPC) for the entire mainstem Ohio River requires the systemic assessment of condition, capacity and demand. Because analytical tools and databases were just being developed, condition assessment and associated engineering reliability modeling required the greatest effort and exhibited the greatest evolution over the course of the study. Not surprisingly, then, the process of developing this system's current and most likely WOPC future acted to focus study efforts on refining the assessment of needs. Refinements proceeded through three steps: 1)very preliminary, venture-level assessments based upon condition surveys and engineering judgement, 2)concept-level assessments based upon engineering judgement and initial engineering reliability modeling, and 3)feasibility-level assessments based upon final engineering reliability modeling. Design and cost estimates for structural improvements proceeded along a similar path of refinement. Three distinct phases of the economic assessment accomplished these refinements and led to the conclusion that J.T. Myers and Greenup locks and dams needed immediate attention. Each of these three phases is discussed below.

8.5.1 Preliminary Reliability Assessments (Early 1997)

In the first phase of the system analysis, structural condition surveys at each mainstem site assisted engineers in identifying problem components and sites. Engineering judgement based upon these assessments supported preliminary, venture-level descriptions of lock reliability. These descriptions estimated when a major lock component would need to be replaced, how much it would cost, and how many days, if any, a lock chamber would need to be closed in order to effect repairs. Cyclical maintenance needs, a level of maintenance necessary to ensure good working condition for major components and sub-components, were also described in a similar fashion. These preliminary assessments were inputs to early system economic model runs used in evaluating alternative WOPC futures. These runs indicated that projects with Auxiliary chambers too small to handle traffic during closures of the Main chamber would experience high future transit costs (the sum of costs incurred while waiting and while processing through a lock). System economic model runs for the WOPC completed in early 1997 showed very high transit costs at J.T. Myers and somewhat lower transit costs at, in order of magnitude, Newburgh, Greenup, Meldahl, Montgomery, Cannelton, Dashields, Markland, and Emsworth locks and dams (see **Figure 8-4**).

FIGURE 8-4
Average Annual Delay Costs at Selected Ohio River Mainstem Sites



Note: Heavy shading represents delays during normal operation, light shading Represents delays during closures.

8.5.2 Preliminary With Project Cost Estimates (Late 1997)

The second phase of the analysis focused on improving the performance of the WOPC, incorporating the cost of proposed system improvements, and developing concept-level reliability descriptions. Very preliminary, venture-level designs and costs for structural solutions at all nine sites were used to identify those sites that offered the highest benefits after accounting for the cost of the improvement—the net incremental benefits. This analysis concluded in December 1997 and indicated that the highest net benefits accrued from improving J.T. Myers, Newburgh, Greenup, and Meldahl locks and dams (see **Table 8-5**). However, even as these results were being presented, better reliability information became available that indicated Greenup Locks and Dam might have more serious structural problems than originally thought. This led to the next phase of the system analysis.

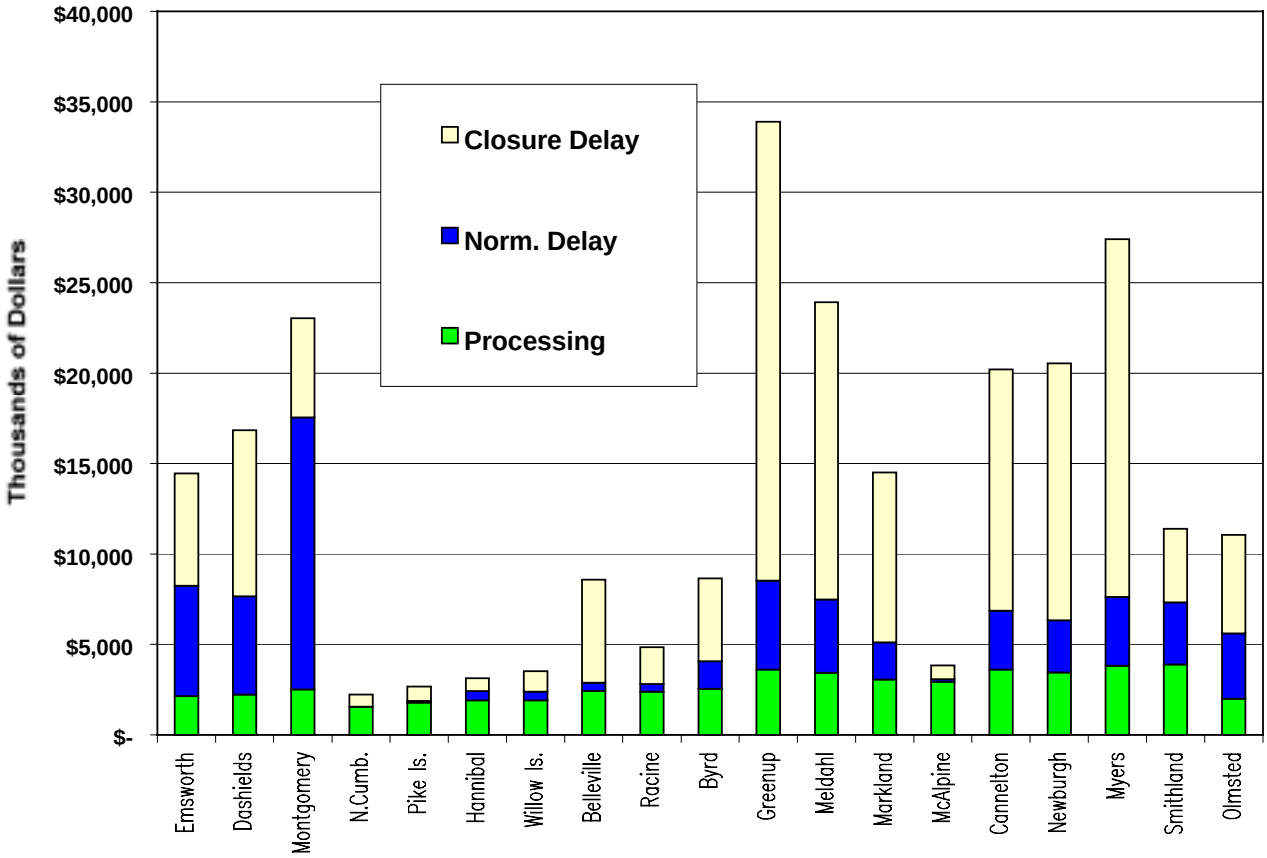
TABLE 8-5
December 1997 Concept-level Improvement Plans
Incremental Net Benefits of Concept Plan Implementation
(millions of October 1997 dollars, 7 1/8% discount rate, base year 2008

Plan	Incremental Net Benefits
Without Project	---
Plan 2b_1 Myers only	29,030
Plan 2b_2 plus Newburgh	19,351
Plan 2b_3 plus Greenup	14,145
Plan 2b_4 plus Emsworth	1,849
Plan 2b_5 plus Cannelton	10,101
Plan 2b_6 plus Meldahl	13,502
Plan 2b_7 plus Markland	5,782
Plan 2b_8 plus Montgomery	4,508
Plan 2b_9 plus Dashields	3,829
Plan 2b all nine	---

8.5.3 Feasibility-level Assessment (for Early-Action Sites)

The third phase turned study attention to refining the reliability descriptions and cost estimates at J.T. Myers and at Greenup. These two inputs became the focus because of J.T. Myers' extremely high transit costs and Greenup's pressing reliability needs. This phase used feasibility-level designs, cost estimates, and reliability estimates, and fully explored non-structural alternatives to identify the most likely WOPC on the mainstem Ohio (see **Section 8.4**, above). **Figure 8-5** shows that despite implementation of aggressive nonstructural measures, excessive lock transit costs were still projected for several sites, though these transit costs were not as high as those estimated in earlier phases. The largest portion of transit costs on the lower river relates to delay costs experienced during closures of the Main chamber, whether for random minor events (like accidents), cyclical maintenance, or scheduled component replacement. This too proved to be a problem on the upper river at Emsworth, Dashields and Montgomery, along with delays during normal operations. Given the combination of Main chamber closures, Auxiliary chamber capacity shortfalls, and traffic demands, transit costs were projected to be highest at Greenup and J.T. Myers – results consistent with earlier analyses

Figure 8-5
Average Annual Transit Costs by Site (2010-2060)



As a result of the findings of the system analyses, J.T. Myers and Greenup locks and dams were advanced in this interim study. Discussions that follow in **Part A** and **Part B** examine alternative Without-Project and With Project futures for J.T. Myers and Greenup, respectively. **Sections A9** and **B9** focus on developing and presenting the most likely Without-Project future condition for J.T. Myers and Greenup locks and dam, respectively. **Sections A10** and **B10** will identify and evaluate With Project alternatives capable of addressing the problems and needs suggested by this mainstem system analysis. **Sections A11** and **B11** describe the performance of the final plan. Finally, **Sections A12** and **B12** test the sensitivity of project benefits to key input data and verify the optimum timing of the proposed investments. That timing analysis verifies the prudence of advancing the recommended improvements for J.T. Myers and Greenup in an interim report. When examined individually, J.T. Myers is optimally timed for improvement in the 2008 to 2010 timeframe and Greenup in 2008; however, this analysis needs to be taken one step further. The final test is whether net benefits are maximized by replacing both J.T. Myers and Greenup in 2008 or Greenup in 2008 and J.T. Myers in 2010. As can be seen in **Table 8-6** below, net system benefits are maximized when both projects are improved in 2008.

TABLE 8-6
Optimum Timing for Improvements at J.T. Myers and Greenup
Incremental Benefits and Costs of the Improvement
(millions of October 1999 dollars, 6 7/8% discount rate, base year 2008)

	On Line Date in:	
	2008 1/	2008/2010 2/
Costs	21.0	19.5
Benefits	45.3	42.8
Net Benefits	24.3	23.4
BCR	2.2	2.2

1/ Complete both Myers and Greenup by year 2008.
2/ Complete Greenup by 2008, and Myers by 2010.

SECTION A-9

J.T. MYERS WITHOUT-PROJECT CONDITION

A-9.1 GENERAL

Federal guidelines for water resource planning studies require that study reports explicitly quantify and describe the conditions that are considered most likely to exist in the study area over the period of analysis in the absence of the proposed project or any change in existing law or public policy. This condition is called the without-project condition. On inland navigation studies such as this, where a Federal project currently exists, the existing project can be included as an element of the without-project condition if it is economically justified. If major rehabilitation of the existing locks and dam is necessary for continued operation of the project, then it will be included in the without-project condition. The guidelines also require that all reasonably expected nonstructural practices for improving project efficiency, within the discretion of the operating agency, be included in the without-project condition.

Section 8, Mainstem Ohio River Without-project Condition, described this system's existing condition and went on to develop the most likely without-project condition for the entire length of the river. The focus of that discussion was the expected performance capabilities of each project, specifically their physical capacity and structural reliability. Capacity constraints, as evidenced by traffic delays during normal operations, were not evident, but major component replacement needs were shown to be acute at a number of sites. This was a particular concern because it was noted that component replacement work causes main chamber closures, which at sites with small 600' auxiliaries had historically caused delays to be as great as average of 100 hours per tow. Nonstructural alternatives were evaluated for their ability to minimize both the cost of replacing components and the cost of tow delays on a system-wide basis. The best combination of nonstructural measures was included in the Ohio River mainstem system most likely without-project condition.

Finally, **Section 8** evaluated the performance of this system-wide without-project condition. It showed that despite instituting aggressive nonstructural measures, excessive lock transit costs were still projected to occur at a number of sites. Given the combination of main chamber closures and traffic demands, transit costs were projected to be highest at J.T. Myers and Greenup and somewhat less severe at six other mainstem sites. For that reason, J.T. Myers

and Greenup were advanced in this interim report. The discussion that follows focuses specifically on J.T. Myers and the development and performance of its most likely without-project condition.

A-9.2 EXISTING PROJECT AND THE WITHOUT-PROJECT CONDITION

A-9.2.1 Description

J.T. Myers Locks and Dam has been in operation for nearly 25 years. Even though it has never undergone a major rehabilitation, the structure is in fairly good condition and should continue to provide navigation service over the period of analysis with proper operation and maintenance and a moderate amount of major maintenance work. The costs for rehabilitation of the locks and dam have been included in the without-project condition and are summarized below. A discussion of the structural features and engineering considerations along with a detailed schedule and cost estimate for the maintenance and rehabilitation work are presented in the General Engineering appendix. A schedule of major chamber maintenance work and associated costs is provided in **Attachment 4** to this Economics Appendix.

J.T. Myers Locks and Dam has a 110'X1200' main chamber and a smaller, 110'X600' auxiliary chamber. The main chamber alone has sufficient capacity to handle current traffic levels, but the auxiliary by itself does not. Therefore, when the main chamber is closed for whatever reason, significant delays occur at the project. In order to minimize delays, aggressive measures are implemented during main chamber closures, including a self-help program of extracting and repositioning barges during multi-lockage operations. Additionally, the Corps and industry work together to schedule closures within the year so as to minimize the costs for each. This pre-planning allows industry to re-schedule shipments around the closure period to the greatest practical extent.

A-9.2.2 Major Maintenance Requirements

A-9.2.2.1 Introduction

The Most Likely Maintenance and Major Rehabilitation (M&MR) scenario was selected as part of the system wide most likely without-project condition future in **Section 8**. This scenario was compared with a Fix-as-Fail maintenance scenario. The M&MR demonstrated the highest net benefits of the two scenarios. The following discusses the engineering and economic assessments for each of J.T. Myers' individual components, and summarizes the findings that supported the selection of the M&MR as part of the without-project condition.

A-9.2.2.2 Major Maintenance

A-9.2.2.2.1 Structural Reliability Assessment. The Engineering Reliability analysis is discussed in detail in the General Engineering Appendix. Hazard values and consequences were developed for each component, the consequences being chamber closure duration, if any, and cost of repairs. This information is presented in the form of an event tree for each component at each chamber. **Table A-9-1** summarizes the Engineering Reliability results for J.T. Myers by lock chamber. Of the ten major components, six will need to be replaced in the main chamber and five in the auxiliary chamber. These replacements can be made either as the component fails or as part of a planned replacement.

TABLE A-9-1
J.T. Myers Locks and Dam
Major Components Indicated for Replacement, by Chamber

Component	Chamber	
	Main	Auxiliary
Miter Gates	Replace	---
Lockwalls	---	---
Guardwalls	---	---
MG Monoliths	---	---
MG Sills	---	---
RT Culvert Valves	Replace	Replace
Hydraulic System	Replace	Replace
MG Machinery	Replace	Replace
CV Machinery	Replace	Replace
Electrical Systems	Replace	Replace

MG--miter gates RT--reverse tainter
CV--culvert valves

A-9.2.2.2.2 Economic Evaluation. The Life Cycle Lock Model (LCLM) was used in this evaluation (see **Attachment 2, Life Cycle Lock Model** for a more detailed discussion of this model). Reliability analysis provides hazard values (probabilities of unsatisfactory performance), and associated consequencesof unsatisfactory performance. Consequences are in the form of repair costs (if any) and chamber closures (if any). These hazard values and consequences, along with a lookup table of industry delay costs by year and duration of closure, are the key inputs into the LCLM. The LCLM is a Monte Carlo type simulation model that accumulates economic costs (repair costs and industry costs) for a 50 year project life cycle in each iteration. Two repair schemes are evaluated: 1) fix-as-fail (FAF) and 2) planned replacement. Planned replacement refers to replacement of a major component in a specific year, so that LCLM runs are made for a series of replacement dates, so that the best year can be selected.

The result of successive iterations is a distribution of expected economic costs for a specific component at a specific lock chamber under either the FAF (fix-as-fail) or planned replacement. These costs can also be expressed as an expected life cycle present value cost for that component. **Table A-9-2** above compares expected present value costs under the two major maintenance alternatives at J.T. Myers. Only the culvert valves in the main chamber were found to require near-term planned replacement. All remaining replacements occur in 2020 and beyond. Planned replacements have the lowest expected costs for culvert valves and hydraulic systems in the main chamber and culvert valves, hydraulic systems, and electrical systems in the auxiliary chamber. The lowest cost alternative for the other components was FAF.

TABLE A-9-2
Summary of Component Replacement Needs at J.T. Myers
Present Value of Expected Life Cycle Costs
(thousands of $1999, 6-7/8% discount rate, base year 2008)

	Major Component					
	Miter Gates	Culvert Valves	Hydraulic System	MG Machinery	CV Machinery	Electrical Systems
Main Chamber						
Fix-as-Fail	45.0	274.7	4,169.5	45.2	64.7	904.5
Planned Replacement in:						
2000	---	433.1	6,760.1	2,128.8	361.7	2,128.8
2010	---	249.3	4,546.1	1,549.0	196.7	1,664.2
2020	---	190.7	3,640.5	1,150.1	120.5	1,398.5
2030	854.3	172.9	2,778.8	823.9	79.7	1,209.9
Auxiliary Chamber						
Fix-as-Fail	---	435.5	95.2	1.5	2.4	99.6
Planned Replacement in:						
2000	---	333.6	282.8	408.8	231.2	408.8
2010	---	197.0	159.7	215.6	124.5	227.2
2020	---	130.7	102.6	122.4	75.7	145.4
2030	---	92.3	70.4	63.4	39.8	98.0

MG – Miter Gate
CV – Culvert Valve

The M&MR policy is a combination of the FAF and planned replacement of components. The replacement pursued is determined by what is economically justified by chamber and by component. When replacements are temporally proximate, they are bundled with the replacement of other components (like valves and culvert valve machinery). If this bundling reaches a specified dollar threshold, it is referred to as a major rehabilitation. The results of this analysis are incorporated into cost and closure matrices, which in turn are used as inputs into the system economic model. The M&MR cost and closure matrix for J.T. Myers is summarized in **Table A-9-3** below, the cost portion of the matrix is displayed in **Attachment 4**. The matrix shows the schedule and costs for all major maintenance work, including major component replacement.

TABLE A-9-3
Schedule of Major Maintenance Activities at J.T. Myers
(millions of $1999)

	Main Chamber			Auxiliary Chamber		
Year	Maint. Description	Days Closed	Repair Costs	Maint. Description	Days Closed	Repair Costs
2003	-	-	$ -	Maint. Dewater	45	$ 1,868
2004	-	-	$ -	MG Paint	45	$ 2,100
2006	Maint. Dewater/Appr. Wall	60	$ 2,490	-	-	$ -
2007	MG Repair and Paint	60	$ 2,100	-	-	$ -
2019	-	-	$ -	Maint Dewater	45	$ 1,868
2020	Hydr. System	65	$ 2,215	-	10	$ 200
2021	Maint Dewater	45	$ 1,868	-	-	$ -
2030	Culvert Valves	5	$ 2,900	Hydr & Elec. System	60	$ 3,642
2031	Inspection	15	$ 525	Culvert Valve	60	$ 1,400
2033	-	-	$ -	Maint. Dewater	45	$ 1,868
2034	-			Mgate Paint	45	$ 2,100
2035	Mgate Paint	45	$ 2,100	-	-	$ -
2036	Maint. Dewater	45	$ 1,868	-	-	$ -
2051	Maint. Dewater	45	$ 1,868	-		

Notes:

1/ MG -- miter gate

2/ Maint. Dewater -- chamber is drained so that routine repairs and inspection can be performed upc features normally under water.

3/ Where components are named, a replacement has been scheduled.

A-9.2.2.2.3 Maintenance Requirements. The normal operation and maintenance (O&M) costs for continuing the existing project are estimated at $3.15 million annually (refer to **Table A-9-4**). These costs provide for staffing the project, routine operation and maintenance activities, and dredging in the lock approach. Component replacements and cyclical maintenance cost $1.24 million on an average annual basis, and random minor repairs are projected to cost another $0.15 million. A $27.5 million dam rehabilitation is scheduled for the years 2050 – 2053, with an average annual cost of $0.10 million. Total average annual operation and maintenance costs are $5.08 million.

A-9.2.3 Operational Alternatives

Nonstructural traffic management measures, within the current purview of the Corps of Engineers and offering opportunities for more effective use of the existing J.T. Myers project are considered as candidate elements for inclusion in the without-project condition. Best practice lockage policies and helper boats (i.e. self-help) are especially effective during high congestion situations at locks where double-cut tow operations are necessary – situations typical of a main chamber closure at J.T. Myers. The average annual economic cost of this operation is estimated to be $0.13 million. Six-up / six-down policies and helper boat operations are both employed as standard practice during main chamber closures. As a result, both of these non-structural

measures are assumed to continue into any without-project future condition. A form of traffic scheduling is also practiced during closures of the main chamber.

As mentioned earlier, the Corps and industry work together to plan and schedule maintenance closures so as to minimize the costs for each. This pre-planning allows industry to re-schedule shipments around the closure period to the greatest practical extent. Tow arrivals are observed to diminish once delays and tows in queue reach a certain level. This acts to reduce the average amount of time each tow sits in queue, reducing delay costs for the tow operators; however, chamber capacity is not increased. Discussions with shippers and towing companies indicate that while lock proximate delays and delay costs are reduced, shippers and/or producers are faced with cost increases elsewhere. Stockpiles and inventories are increased, production is re-dispatched to less efficient plants, short-term productive capacity is added or short-term alternative transportation procured. The capacity of the production and distribution system has not been increased through this re-scheduling; increased costs have merely been re-distributed throughout the system. It is assumed that shippers and carriers have made economically rational decisions in re-distributing these costs; therefore, re-scheduling as currently practiced is retained as part of the future without-project condition. Government-directed scheduling is not currently within the authority of the Corps of Engineers and was not considered as a possible component of the most likely without-project condition.

A-9.2.4 Navigation Benefits and Conclusion

For traffic using J.T. Myers, the transportation cost savings (benefits) over the period of analysis are estimated at $1,558.3 million annually, far in excess of the $5.08 million in average annual project costs for major maintenance, operations, and routine maintenance, and implementation of a helper boat program. Given this and the fact that no other nonstructural measures to improve lock efficiency were identified, the existing condition described in the preceding paragraphs is selected as the most likely without-project future condition at J.T. Myers Locks and Dam.

A-9.3 ECONOMICS OF WITHOUT-PROJECT CONDITION

The annual benefits, annual costs and net benefits for continuing the existing J.T. Myers project are presented in **Table A-9-4**. Total average annual benefits (Myers traffic only) are estimated at $1,558.3 million. Total average annual operations and maintenance costs (including helper boats) are $5.08 million. Industry delay costs incurred during unplanned component replacements are estimated at $1.80 million on an average annual basis. These two costs total to $6.88 million. Comparing total annual benefits and annual costs yields net annual benefits for the without-project condition of $1,551.4 million.

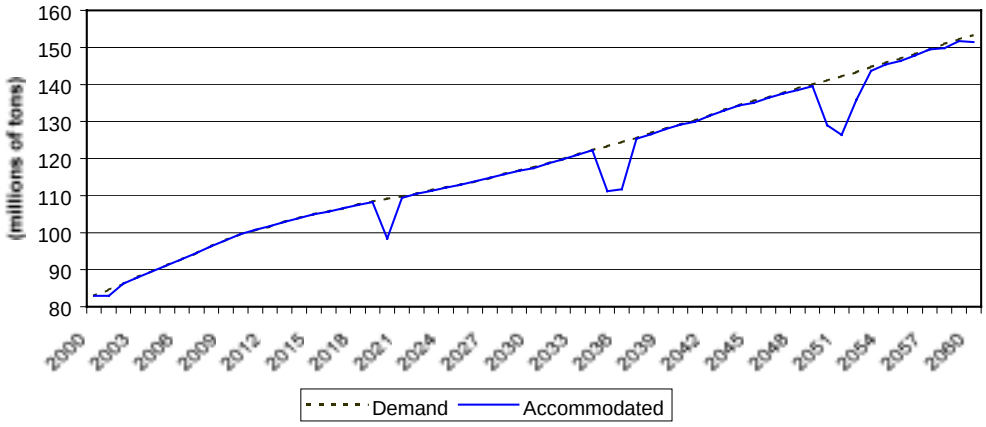
TABLE A-9-4
J.T. Myers Locks and Dam
Annual Benefits, Costs and Net Benefits
(millions of $1999, 6-7/8% discount rate, base year 2008)

Item	Amount
Annual Benefits 1/	$ 1,558.30
Annual Costs	
Normal O&M	$ 3.15
Dam Rehabilitation ($27.5 over years 2050-53)	$ 0.10
Dredging	$ 0.27
Main Chamber	
Component Replacement ($4.9 over 2020 & 2030)	$ 0.11
Cyclical Maintenance ($16.5 in various years)	$ 0.58
Random Minor ($1.5 in various years)	$ 0.13
Auxiliary Chamber	
Component Replacement ($5.0 over 2030-31)	$ 0.08
Cyclical Maintenance ($13.8 in various years)	$ 0.52
Random Minor ($0.8 in various years)	$ 0.02
Helper Boats	$ 0.13
subtotal	**$ 5.08**
Transportation Impacts	$ 1.80
Total Annual Costs	**$ 6.88**
Net Annual Benefits	**$ 1,551.42**

1/ Only those transportation benefits realized by traffic using J.T. Myers Locks and Dam

Traffic demands are generally accommodated the period of analysis, excepting during those times when the main chamber is closed. During closures, traffic demands and traffic accommodated can be seen to diverge in **Figure A-9-1** below. During normal operations, traffic is diverted to alternate modes in very small amounts and only during the last 15 years of the analysis period. Main chamber closures tend to have their greatest effect on waterway operating costs, rather than causing large diversions of demand to other transportation modes.

FIGURE A-9-1
J.T. Myers Without Project Condition Performance



SECTION A-10

IDENTIFICATION OF ALTERNATIVE IMPROVEMENT PLANS

A-10.1 GENERAL

This section discusses the development and screening of alternative plans for addressing the problems and needs at J.T. Myers Locks and Dam. Alternatives were formulated in a two-stage process. In the initial screening a broad range of alternatives was considered in order to identify potential measures that would make future locking conditions at J.T. Myers more efficient, particularly during main chamber closures. Options considered to have practical application and reasonable development costs were carried forward for a more detailed evaluation based upon development costs, navigation benefits, effectiveness and workability. Costs and designs were developed more fully for these alternatives. Screening at this stage produced the set of final plans for detailed engineering and design and identification of the NED plan.

A-10.2 ALTERNATIVES CONSIDERED

The initial screening retained some alternatives and eliminated others based on navigation conditions and other qualitative criteria. Large-scale capital investments, small-scale capital investments, and non-structural improvements were considered. The results of the Large-scale capital investment screening are summarized as follows:

- A new project with a 1200’ main and 600’ auxiliary would provide a more structurally reliable project, but only partially meet the needs. Any closures of the main chamber would continue to impose heavy delay costs on industry and congestion associated with future traffic growth would still be a problem in later years. Additionally, the cost of an entirely new project was judged excessive and the environmental impacts would be quite large. Therefore, this alternative was not carried forward to the intermediate level.

- A new project with twin 1200' chambers would meet the needs from all standpoints: 1) structural reliability, 2) ability to efficiently handle traffic during closures of the main chamber, and 3) ability to efficiently handle future, high volumes of traffic in the later years of the project. Nevertheless, this alternative was not carried forward to the intermediate level because of its excessive costs and major environmental impacts.

- A new 1200' chamber at the existing project results in a project with twin 1200' chambers and a backup 600' chamber (which would be used during closures of one of the 1200' chambers). This configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. Landward, riverward and mid-dam sites were considered. The riverward and mid-dam sites had excessive monetary and environmental costs and were not carried forward. The landward site was carried forward into the intermediate level screening of alternatives.

- Both a 200' and a 400' extension of the existing auxiliary chamber were considered. These extensions would result in projects with a 1200' main chamber and either an 800' auxiliary or a 1000' auxiliary, respectively. Neither alternative would efficiently process traffic during closures of the main chamber. In 1998, 65% of the tows arriving at J.T. Myers would have to double-cut in a 1000' chamber, and 75% would have to double-cut in an 800' chamber, resulting in a continuation of serious delays and industry costs during main chamber closures. Furthermore, these extensions are not practicable from an engineering standpoint. Culverts are located in the middle wall monoliths where the gate recesses would have to be placed. The affected middle wall monoliths would have to be taken out and rebuilt to accommodate the gate recesses. This would probably close the entire river in this vicinity for a year or more. Extending the auxiliary chamber by anything less than 600' would have major effects on waterway traffic. Therefore, these plans were not carried forward to the intermediate level.

- A 600' extension of the existing auxiliary chamber results in a project with twin 1200' chambers. The twin 1200' configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. Future major maintenance will still be required for major components at the existing project to keep the project operating efficiently. This alternative is carried forward into the next level screening.

The results of the screening of three Small-scale capital investments are summarized as follows:

- Currently, two emergency mooring cells are located upstream of the project. While there is industry and public interest in installation of mooring buoys or cells downstream of the project, this small-scale improvement does nothing to reduce approach times and increase efficiency of the project. While these are not carried

forward into the intermediate economic screening, there remains the potential for buoys or cells to provide significant environmental benefits. This shall be addressed in the environmental appendix.

- Guardwall and middle wall extensions on the upper end of the existing project have the potential to greatly reduce interference between tows concurrently using the main and auxiliary. This interference reduction has the potential to reduce lock delays when traffic reaches the level where both chambers are highly utilized. Nevertheless, wall extensions are not expected to be able provide the capacity expansion needed to handle future traffic volumes during the later years of the project, nor will they reduce delays when the main chamber is closed for maintenance (when interference between chambers is not a problem). Wall extensions do not meet current and future needs, so were not carried into the intermediate level screening.

- A Miter Gate Quick Changeout System (MGQCS) would be used to shorten closure durations for any kind of maintenance or accident requiring gate removal. This alternative requires a towboat equipped with a heavy-duty crane (already under construction), a specially equipped barge, gates modified for lifting by crane, an on-site set of additional gates, and an assembly / storage / staging area for these gates. Investment in this equipment allows maintenance closures involving the chamber gates to be significantly shortened, easing the closure-related delay costs experienced by industry. This alternative is carried forward into the next level screening because of its low cost relative to lock chamber extensions, or additions, and because of its obvious benefits.

In addition to the structural measures evaluated for improving the economic efficiency of the existing J.T. Myers project, non-structural alternatives were considered. Two of these, best practice lockage policies and helper-boats (i.e. self help), are especially effective during high congestion situations at locks where double-cut tow operations are necessary – situations typical of a main chamber closure at J.T. Myers. Six-up / six-down policies and helperboat operations are both employed as standard practice during main chamber closures. As a result, these non-structural measures are part of the without-project condition, along with traffic scheduling as currently practiced by Ohio River System carriers and shippers. Two other non-structural alternatives were also considered. These alternatives are summarized below.

- Locks nearing their practical capacity limits can benefit from a traffic-scheduling program that assigns tow arrival times. The goal of such a scheduling program is to reduce delays and their associated costs. However, there are some critical limitations to scheduling. Shipments must still occur, forcing shippers to either re-route these moves to a more expensive transportation mode, re-dispatch their production to less efficient plants, or re-schedule these shipments for another time. Re-scheduling shipments is more costly as well (re-scheduling is practiced at J.T. Myers and was described in **Section A-9** of this appendix as a feature of the without project condition). The shipper may have to pay higher, short-term costs for waterway

service, and stockpiles will either have to be built-up or drawn-down prematurely at an additional cost to the shipper, which in turn may involve additional handling costs. In short, the capacity of the production and distribution system is not increased through a scheduling program during main chamber closures; increased costs are merely re-distributed throughout the production and distribution system. Scheduling does not address the need for additional auxiliary chamber capacity and is unable to alleviate the adverse economic impacts of closure. Any scheduling program or re-scheduling of traffic beyond that based upon the economically rational practices of shippers and carriers is discarded as a with project alternative.

- A congestion lockage fee would be used to influence waterway shippers with very marginal savings to shift their traffic to an alternate overland mode, thereby reducing the amount of lock congestion for the remaining shipments. Thus it serves as a device for rationing lock use to those movements with the highest marginal savings. The result would be an increase in total rate savings net of delay costs for shippers that continue to use the waterway. The lockage fee alternative would reduce queues and, therefore, delay costs at the lock. This alternative is carried forward into the next level screening.

Summarizing, the 600' auxiliary lock extension plan, the Miter Gate Quick Changeout System (MGQCS), and congestion fees are carried forward into the next and final level of screening.

A-10.3 ALTERNATIVES EVALUATED

One non-structural alternative (congestion fees), one small capital investment alternative (MGQCS), and two structural alternative (a 600' extension of the existing auxiliary and a third 1200' lock) are retained for evaluation after the initial screening. The results of the benefit cost analysis are summarized in **Table A-10-1**. The performance of each plan is addressed in detail in the sections below.

TABLE A-10-1
J.T. Myers Locks and Dam
Annual Costs and Benefits for Intermediate Alternatives
(millions of October 1999 dollars, 6 7/8% discount rate, base year 2008)

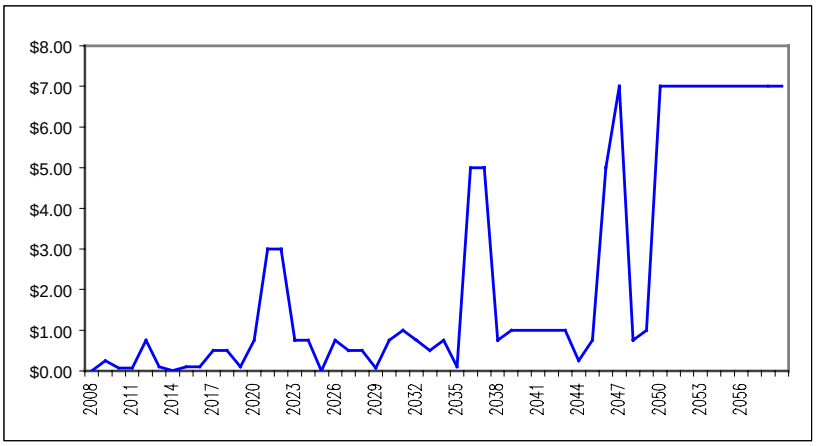
Alternative	First Cost	Incremental Average Annual			BCR
		Costs	Benefits	Net Benefit	
Congestion Fee	1.0	1.0	6.0	5.0	6.0
Gate Change-out System	14.2	0.6	2.1	1.5	3.5
600' Lock Extension	166.0	10.0	18.8	8.8	1.9
Third 1200' Lock	290.0	19.9	24.5	4.7	1.2

A-10.3.1 Congestion Fees

A range of congestion fees was evaluated for each year of J.T. Myers' 50-year project life. Results of the analysis indicated that no one fee level was best, rather each year had a best fee. The best fee was selected as the fee that generated the largest benefit, which consists of the system transportation savings plus fee revenues collected at J.T. Myers. The fee selected is directly related to the closures at Myers, as well as the traffic level and cost characteristics of the movements that transit the project. Higher fees are needed to divert higher levels of traffic.

System benefits presented in **Table A-10-1** above are based upon the best mix of fees throughout the project's life. **Figure A-10-1** shows how this mix changes through time. In a situation where daily traffic levels have nearly reached capacity, congestion fees have been successful in moving marginal movements off the waterway at an advantage to the entire system. While congestion fees do offer positive net benefits, implementing a fee program is impractical from an administrative standpoint. Analysts would need to periodically (once every 5 years or so) reanalyze projected traffic flows and identify each shipper's range of alternative routes, modes, or practices and their related costs. Assembling these other industry costs, those industry costs beyond traffic delay costs, proved intractable during this study and is not expected to become any more manageable over time. Given the paucity of reliable data, results from the analysis likely overstate the effectiveness of the fee program and make the results unreliable. An additional concern with the fee plan is that it does not entirely address the planning objective of efficiently passing traffic at J.T. Myers during lock closures. While fees help in reducing delays, significant delays are still experienced during these closures. This plan is eliminated from further consideration due to serious problems associated with implementing a fee program and its inability to fully address the needs at J.T. Myers.

FIGURE A-10-1
Sequence of Optimum Congestion Fees
(fee in dollars per ton)



A-10.3.2 Miter Gate Quick Changeout System

A Miter Gate Quick Changeout System (MGQCS) would be used to shorten closure durations for any kind of maintenance or accident requiring gate removal. Operations and Engineering personnel estimated that a closure for gate maintenance could be reduced from 45 days to 15 days at J.T. Myers once the system is fully implemented. As discussed above, this alternative requires a barge mounted heavy-duty crane (already under construction), gates modified for lifting by crane, an on-site set of additional gates, and an assembly / storage / staging area for these gates. Investment in this equipment allows maintenance closures involving the chamber gates to be significantly shortened, easing the closure-related delay costs experienced by industry. This plan partially meets study objectives by reducing delays through the shortening of closure durations, but fails to fully address delays related to lock closures. It too is eliminated from further evaluation. While eliminated as a stand-alone plan, because of its beneficial aspects it was subsequently included as part of the 600' auxiliary extension plan.

A-10.3.3 Auxiliary Lock Extension

A 600' extension of the existing auxiliary chamber results in a project with twin 1200' chambers. The twin 1200' configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. Four design variations of this plan have been developed in the Engineering Appendix. These design variations center upon engineering considerations involving implementation of the filling and emptying system and have been designated as Plans 1, 2, 3, and 4. Selection of the best design will be accomplished in the PED phase of this study. In this, the feasibility phase of the study, the 600' extension plan designated in the Engineering Appendix as Plan 3 is used to best represent the costs and desired performance of a 600' lock extension plan. The extension plan includes the MGQCS.

A-10.3.4 Third 1200-Foot Lock

A new 1200' lock landward of the existing auxiliary chamber was carried forward into this screening. This plan, referred to as Plan 5 in the Engineering Appendix, results in a three-lock configuration – twin 1200' chambers and a single 600' chamber. The twin 1200' chambers would be used to process commercial traffic, while the 600' chamber would process single commercial and recreational vessels. The primary benefit of this configuration over the twin 1200' configuration offered by the 600' Lock Extension Plan

is the availability of the additional capacity a 600' chamber offers anytime one of the 1200' chambers is closed for any reason. This plan meets the planning objectives and can be implemented, but has relatively low incremental net benefits and is not carried forward as a final alternative plan.

A-10.4 FINAL ALTERNATIVE

The 600' Auxiliary Lock Extension is the only alternative that can be implemented and fully meet the planning objectives. This plan has the greatest net benefits of any alternative considered and is the National Economic Development (NED) plan.

SECTION A-11

ECONOMIC ANALYSIS OF FINAL PLAN

A-11.1 GENERAL

This section summarizes all of the pertinent benefit and cost data and presents the derivation of average annual benefits and costs for the final alternative at J.T. Myers Locks and Dam. The evaluation process focuses on the effects of traffic delays associated with maintenance closures of the Main lock and the analysis of benefits and costs for the final plan. The performance of the final plan is examined in terms of projected traffic demands, accommodated system traffic, and total rate savings. It is estimated that the year 2008 would be the earliest probable date the plan could be completed and made operational. Though the project life is from 2008 to 2058, the period under analysis extends from 2000 – 2058 in order to capture construction impacts and variations in lock closure schedules between the without and With Project alternatives. It is primarily during Main chamber closures that traffic demands cannot be completely accommodated.

All economic values are expressed in October 1999 dollars. Previous sections detailing the economic screening of alternatives used October 1999 dollars and a discount rate of 6 7/8%. Subsequent to this screening, the discount rate was lowered to 6 5/8%. This current rate is used in the economic analysis of the final plan presented in this section and in the sensitivity analyses presented in Section A-12.

A-11.2 PERFORMANCE OF FINAL PLAN

A-11.2.1 Waterway Traffic

Future waterway traffic demands are projected at the dock level for each movement in the Ohio River System (ORS). These unconstrained demands are presented for each lock in the system in **Attachment 3**. Demands for J.T. Myers are also presented in **Table A-11-1**, along with the portion of these demands economically accommodated by the without condition project and by the final plan. Movements with waterway transportation route costs that are greater than the least cost alternate are not accommodated and are assumed to divert to the least cost alternate route. Under normal operating conditions, both the without condition and the final plan accommodate nearly all of the future traffic demands. It is primarily during Main chamber closures that traffic demands cannot be accommodated.

TABLE A-11-1
J.T. Myers Locks and Dam
Traffic Accommodated by Final Plan

Year	Demand Tonnage	Accommodated Tonnage 1/ Without Project Condition	Accommodated Tonnage 1/ 600' Extension Plan
2000	83.0	83.0	83.0
2010	99.6	99.6	99.6
2020	109.1	98.4	109.0
2030	117.7	117.4	117.4
2040	129.2	129.1	129.1
2050	141.0	128.9	128.9
2060	153.4	151.1	151.3

1/ Fluctuations in accommodated traffic levels (e.g. 2050) caused by closure at Newburgh.

Projected system waterway traffic demands are presented in **Table A-11-2**. Again, nearly all waterway demands are accommodated by both the Without-Project condition and the final alternative plan.

TABLE A-11-2
Ohio River System
Traffic Accommodated by Final Plan

Year	Demand Tonnage	Accommodated Tonnage 1/ Without Project Condition	Accommodated Tonnage 1/ 600' Extension Plan
2000	275.7	275.6	275.6
2010	324.4	324.2	324.2
2020	354.4	343.2	353.8
2030	385.1	381.7	381.7
2040	422.7	419.2	419.2
2050	459.5	442.5	442.5
2060	493.2	465.1	465.1

1/ Closures assumed.

A-11.3 FIRST COSTS

Costs for the final lock extension plan are summarized in **Table A-11-3**, in the feature code of accounts format, which includes contingencies. The final plan includes extension of the Auxiliary lock to 1200 feet, rehabilitation of the Main lock and the navigation dam (also part of the without condition), and implementation of the miter gate quick changeout system.

TABLE A-11-3
J.T. Myers Locks and Dam, Summary of Project Costs for Final Plan 1/
(millions of October 1999 dollars)

Item	First Cost
Near Term Project Costs	
New Lock Construction	
Lands and Damages	-
Relocations	-
Locks	128.9
Fish & Wildlife	4.6
Buildings, Grounds, & Utilities	9.8
Planning, Engineering & Design	19.8
Construction Management	9.9
Subtotal New Lock Construction	173.0
Miter Gate Quick Changeout	8.7
Subtotal Near Term Project Costs	181.7
Longer Term Project Costs	
Component Replacements	10.0
Dam Rehabilitation	27.5
Subtotal Long Term Costs	37.5
TOTAL PROJECT COSTS	219.2

1/ Project costs shown in this table are all first costs expressed in October 1999 dollars, regardless of when the expenditure occurs. Numbers may not add due to rounding.

A-11.4 INVESTMENT AND ANNUAL COSTS

Investment costs are the sum of construction expenditures and the accrued interest (interest during construction or IDC) on those expenditures up to the time the new lock extension

is operational and the project begins producing benefits. Investment costs also include any major maintenance expenditures made during the economic life of the project. Such expenditures include component replacements, rehabilitations and installation of the MGQCO system under the With Project plan. For these post online costs, the opposite of IDC is applied and the costs are discounted to the online date before amortizing. The earliest time that a lock extension project is estimated to be operational is 2008, thus 2008 serves as the base year for amortization. Investment costs for the final plan are displayed in **Table A-11-4** below.

TABLE A-11-4
J.T. Myers Locks and Dam
Summary of Investment and Average Annual Costs for the Final Plan
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Item	Without Project Condition	Final Plan (600' Extension)
INVESTMENT COSTS		
New Construction	-	173.0
Dam Rehabilitation	27.5	27.5
Component Replacement	10.0	10.0
Miter Gate Quick Changeout (2008-2016)	-	8.7
subtotal	**37.5**	**219.2**
IDC (new construction)	-	5.7
Discounting of post 2008 work	(33.2)	(37.8)
Total Investment Costs 1/	**4.3**	**187.2**
AVERAGE ANNUAL COSTS		
Capital Costs	0.3	12.9
O&M Cost		
Normal O&M	3.1	3.1
Helper boats	0.1	0.0
Cyclical Maintenance	1.2	0.9
Dredging	0.3	0.3
Transportation Cost Impacts	1.8	-
TOTAL AVERAGE ANNUAL COSTS 2/	6.8	17.1
INCREMENTAL AVERAGE ANNUAL COSTS	--NA--	10.3

1/ Total investment costs include the project costs (see Table A-11-3) plus interest during construction charges.
2/ Total annual costs are the average annual discounted values of total investment costs (capital costs), O&M costs, and transportation impacts incurred throughout the life of the project.

The total annual costs for the Without-Project condition and the final plan are the summation of the annualized capital costs and other annual costs. Normal O&M costs cover day to day operating expenses and are expected to remain the same with or without the final plan, as are cyclical maintenance costs. Cyclical maintenance includes repair fleet charges for periodic

dewaterings and inspections (not included under normal O&M). Both categories of estimated O&M costs are based on actual cost experience at J.T. Myers, as well as other locks and dam projects on the Ohio River. Dredging costs for upstream and downstream approaches are also expected to be the same between the alternative conditions.

Annual costs differ between the Without and With condition in three areas, the most significant being capital costs. Capital costs are the same between the two conditions, excepting for the construction of the lock extension and full implementation of the MGQCS in the With Project condition. The other two differences relate to helper boat costs and transportation impacts. In the without condition, a self-help program using two helper boats is assumed to be in operation during Main chamber closures. Self-help is effective when only a 600' Auxiliary chamber is available, because the helper boats are there to assist double cutting through the smaller chamber. Often this cost is assumed by industry through a self-help policy, nevertheless, it represents an economic cost. Transportation impacts refer to the industry costs incurred during closures for replacement of components replaced through a fix-as-fail policy. Again, the application of fix-as-fail versus planned replacement was determined on the basis of economic efficiency using engineering reliability analysis and the LCLM. The costs associated with fix-as-fail components are identified as Transportation Impacts in the table above.

Interest charges on the investment costs and amortization were computed using an interest rate of 6 5/8% and an economic life of 50 years (2008-2057). However, it should be noted that all cost and benefit streams from 2000 to 2057 were considered in order to capture pre-online differences, such as transportation impacts of construction and delayed maintenance. **Attachment 4** displays these calculations.

A-11.5 AVERAGE ANNUAL BENEFITS

The navigation benefits for the final plan represent the increase in total system rate savings over the Without-Project condition. A summary of the annual system benefits for the Without-Project condition and for each of the final plan, along with the incremental system benefits, is presented in **Table A-11-5.** The greatest share of the incremental average annual benefits, $15.7 million, is the result of traffic delay reductions. The remaining $3.2 million in benefits are shift-of-mode benefits. Shift-of-mode benefits represent the reduction in transportation costs for those movements that were diverted to the alternate mode during closure events. The 600' Auxiliary lock extension allows these movements to return to the waterway at a transportation cost savings.

TABLE A-11-5
J.T. Myers Locks and Dam
Annual Benefits for Final Plan
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Plan	System Benefits	Incremental Benefits
Without Condition	4,578.8	---
600' Extension	4,597.7	18.9

A-11.6 SUMMARY OF ANNUAL BENEFITS AND COSTS

Table A-11-6 presents the incremental average annual benefits and costs of the final plan. The 600' Lock Extension plan, the NED plan, offers $18.9 million in benefits over the without condition, while costing an additional $10.3 million.

TABLE A-11-6
J.T. Myers Locks and Dam
Annual Costs and Benefits for Final Plan
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Item	600' Extension
Incremental Annual Benefits	$ 18.9
Incremental Annual Costs	$ 10.3
Net Annual Benefits	$ 8.6
Benefit Cost Ratio	1.8

Construction activities associated with modernization of J.T. Myers entails considerable employment of skilled and unskilled labor resources from numerous construction-related professions. Wage compensations would be substantial for constructing the 600' Auxiliary Lock extension. Labor drawn from counties with substantial and persistent unemployment relative to the U.S. as a whole is accountable as a project benefit and is included in NED benefit estimates for the recommended plan (see **Attachment 6** for a full discussion of construction-related NED and Regional Economic Development benefits). For J.T. Myers, these NED employment benefits amount to $0.05 million on an average annual basis and raise the net incremental annual benefits to $8.65 million (see **Table A-11-7**).

TABLE A-11-7
J.T. Myers Locks and Dam
Annual Costs and Benefits for Final Plan, Including Employment Benefits
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Incremental Annual Benefits		
Transportation Savings	$	18.9
Construction Impacts	$	0.1
Total Benefits	**$**	**19.0**
Incremental Annual Costs	**$**	**10.3**
Net Annual Benefits	**$**	**8.7**
Benefit Cost Ratio	**1.8**	

SECTION A-12

SENSITIVITY ANALYSIS

A-12.1 GENERAL

The final plan for improving the existing Federal project at J.T. Myers Locks and Dam has been evaluated using what was judged to be the most probable future navigation conditions both with and without the alternative. In defining these conditions, certain key assumptions and predictions were made regarding the future. Since future conditions cannot be predicted with certainty, several tests were performed to describe the sensitivity of the plan selection to changes in key formulation variables. This section of the report identifies the key areas of uncertainty and describes the sensitivity of plan selection to alternative forecasts of the future.

A-12.2 ALTERNATIVE TRAFFIC PROJECTIONS

One of the major factors affecting the need for improvements at J.T. Myers and also one of the major areas of uncertainty, is the forecast of future traffic demands. Traffic demands at J.T. Myers are projected to grow at a modest rate of 1.1 percent a year between 1996 and 2060. Other growth rates, either higher or lower, are possible. To show the sensitivity of the project to alternative traffic demand forecasts, net benefits for the final alternative were re-evaluated using a no growth after 20 years projection set, the most likely set, and a high traffic projection set (see **Table A-12-1**). The most likely projection set is the De-regulation scenario presented in **Section 6.** The high traffic projections are represented by the upper bound of the 95% confidence level traffic developed in **Attachment 3**. The no growth after 20 years is required by regulation, and it corresponds closely to the Carbon Limits scenario, which was also presented in **Attachment 3**. This sensitivity test shows that the net benefits are sensitive to the level of future traffic demands. As shown in **Table A-12-1**, net benefits are about 18 percent lower under the low projections and approximately 178 percent higher under the high projections. The results show the improvement to be feasible under all three projection sets.

TABLE A-12-1
Sensitivity of Net Annual Incremental Benefits to Alternative Traffic Demand Projections
(millions of October1999 dollars, 6 5/8% discount rate, base year 2008)

Plan	Incremental Annual		
	Benefits	Costs	Net Benefits
No Growth After 20 Years	17.2	10.3	6.9
Most Probable	18.9	10.3	8.6
High Projection	34.6	10.3	24.2

A-12.3 OPTIMUM REPLACEMENT TIMING

In formulating the recommended plan for modernizing the existing J.T. Myers project, it was assumed that the 600' Lock Extension would be completed and made available for use by the year 2008. This date was selected because it was estimated to be the earliest probable date by which the project could be completed. The purpose of this test is to define the optimum replacement timing for the selected plan, or the completion date that would produce the maximum net annual benefits. Optimum replacement timing was evaluated by re-computing the average annual benefits and costs under completion dates between 2008 and 2020. The results of this evaluation, which are presented in **Table A-12-2**, demonstrate that the optimum completion time for the lock extension is in the 2008 to 2010 timeframe. Deferral beyond this period results in a decline in net incremental benefits.

TABLE A-12-2
Sensitivity of Net Annual Benefits to Alternative Project Completion Dates
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

	Incremental Annual		
	Benefits	Costs	Net Benefits
2008	18.9	10.3	8.6
2010	18.7	10.1	8.6
2012	16.4	9.4	7.1
2015	14.0	7.8	6.2
2020	13.2	5.8	7.4

SECTION B-9

GREENUP WITHOUT-PROJECT CONDITION

B-9.1 GENERAL

Federal guidelines for water resource planning studies require that study reports explicitly quantify and describe the conditions that are considered most likely to exist in the study area over the period of analysis in the absence of the proposed project or any change in existing law or public policy. This condition is called the without-project condition. On inland navigation studies such as this, where a Federal project currently exists, the existing project can be included as an element of the without-project condition if it is economically justified. If major rehabilitation of the existing locks and dam is necessary for continued operation of the project, then it will be included in the without-project condition. The guidelines also require that all reasonably expected nonstructural practices for improving project efficiency, within the discretion of the operating agency, be included in the without-project condition.

Section 8, Mainstem Ohio River Without-project Condition, described this system's existing condition and went on to develop the most likely without-project condition for the entire length of the river. The focus of that discussion was the expected performance capabilities of each project, specifically their physical capacity and structural reliability. Capacity constraints, as evidenced by traffic delays during normal operations, were not evident, but major component replacement needs were shown to be acute at a number of sites. This was a particular concern because it was noted that component replacement work causes main chamber closures, which at sites with small 600' auxiliaries had historically caused delays to be as great as average of 100 hours per tow. Nonstructural alternatives were evaluated for their ability to minimize both the cost of replacing components and the cost of tow delays on a system-wide basis. The best combination of nonstructural measures was included in the Ohio River mainstem system most likely without-project condition.

Finally, **Section 8** evaluated the performance of this system-wide without-project condition. It showed that despite instituting aggressive nonstructural measures, excessive lock transit costs were still projected to occur at a number of sites. Given the combination of main chamber closures and traffic demands, transit costs were projected to be highest at J.T. Myers and Greenup and somewhat less severe at six other mainstem sites. For that reason, J.T. Myers and Greenup were advanced in this interim report. The discussion that follows focuses

specifically on Greenup and the development and performance its most likely without-project condition.

B-9.2 EXISTING PROJECT AND THE WITHOUT-PROJECT CONDITION

B-9.2.1 Description

Greenup Locks and Dam has been in operation for nearly 25 years. Even though it has never undergone a major rehabilitation, the structure is in fairly good condition and should continue to provide navigation service over the period of analysis with proper operation and maintenance and a moderate amount of major maintenance work. The costs for rehabilitation of the locks and dam have been included in the without-project condition and are summarized below. A discussion of the structural features and engineering considerations along with a detailed schedule and cost estimate for the maintenance and rehabilitation work are presented in the General Engineering appendix. A schedule of major chamber maintenance work and associated costs is provided in **Attachment 4** to this Economics Appendix.

Greenup Locks and Dam has a 110'X1200' main chamber and a smaller, 110'X600' auxiliary chamber. The main chamber alone has sufficient capacity to handle current traffic levels, but the auxiliary by itself does not. Therefore, when the main chamber is closed for whatever reason, significant delays occur at the project. In order to minimize delays, aggressive measures are implemented during main chamber closures, including a self-help program of extracting and repositioning barges during multi-lockage operations. Additionally, the Corps and industry work together to schedule closures within the year so as to minimize the costs for each. This pre-planning allows industry to re-schedule shipments around the closure period to the greatest practical extent.

B-9.2.2 Major Maintenance Requirements

B-9.2.2.1 Introduction

The Most Likely Maintenance and Major Rehabilitation (M&MR) scenario was selected as part of the system wide most likely without-project condition future in **Section 8**. This scenario was compared with a Fix-as-Fail maintenance scenario. The M&MR demonstrated the highest net benefits of the two scenarios. The following discusses the engineering and economic assessments for each of Greenup's individual components, and summarizes the findings that supported the selection of the M&MR as part of the without-project condition.

B-9.2.2.2 Major Maintenance

B-9.2.2.2.1 Structural Reliability Assessment. The Engineering Reliability analysis is discussed in detail in the General Engineering Appendix. Hazard values and consequences were developed for each component, the consequences being chamber closure duration, if any, and cost of repairs. This information is presented in the form of an event tree for each component at

each chamber. **Table B-9-1** summarizes the Engineering Reliability results for Greenup by lock chamber. Of the ten major components, six will need to be replaced in the main chamber and five in the auxiliary chamber.

TABLE B-9-1
Greenup Locks and Dam
Major Components Indicated for Replacement, by Chamber

Component	Chamber	
	Main	Auxiliary
Miter Gates	Replace	Replace
Lockwalls	---	---
Guardwalls	---	---
MG Monoliths	---	---
MG Sills	---	---
RT Culvert Valves	Replace	---
Hydraulic System	Replace	Replace
MG Machinery	Replace	Replace
CV Machinery	Replace	Replace
Electrical Systems	Replace	Replace

MG--miter gates RT--reverse tainter
CV--culvert valves

B-9.2.2.2.2 Economic Evaluation. The Life Cycle Lock Model (LCLM) was used in this evaluation (see **Attachment 2, Life Cycle Lock Model** for a more detailed discussion of this model). Reliability analysis provides hazard values (probabilities of unsatisfactory performance), cost and closure consequences, and industry delay costs by year and duration of closure are the key inputs. The LCLM is a Monte Carlo type simulation model that accumulates economic costs (repair costs and industry costs) for a 50 year project life cycle in each iteration.

The result of successive iterations is a distribution of expected economic costs for a specific component at a specific lock chamber under either the FAF (fix-as-fail) or planned replacement. These costs can also be expressed as an expected life cycle present value cost for that component. **Table B-9-2** above compares expected present value costs under the two major maintenance alternatives at Greenup. Only the miter gates in the main chamber were found to require near-term planned replacement. All remaining planned replacements occur in 2030. Planned replacements have the lowest expected costs for culvert valves and hydraulic systems in the main chamber and miter gates and electrical systems in the auxiliary chamber. The lowest cost alternative for the other components was FAF.

TABLE B-9-2
Summary of Component Replacement Needs at Greenup
Present Value of Expected Life Cycle Costs
(thousands of $1999, 6-7/8% discount rate, base year 2008)

	Major Component					
	Miter Gates	Culvert Valves	Hydraulic System	MG Machinery	CV Machinery	Electrical Systems
Main Chamber						
Fix-as-Fail	8,718.7	26.9	625.8	26.6	35.7	903.2
Planned Replacement in:						
2000	1,375.8	439.7	4,172.6	1,127.9	369.9	1,127.9
2002	1,332.4	---	---	---		---
2003	1,323.0	---	---	---		---
2004	1,317.6	---	---	---		---
2005	1,332.2	---	---	---		---
2010	2,084.4	227.1	4,250.7	1,073.1	197.6	1,229.2
2020	---	121.2	3,146.5	805.7	113.4	1,130.1
2030	---	64.6	2,246.8	580.8	71.5	1,048.4
Auxiliary Chamber						
Fix-as-Fail	269.3	---	38.3	1.7	3.0	227.6
Planned Replacement in:						
2000	645.0	---	247.8	397.1	219.5	397.1
2010	338.8	---	139.6	206.7	115.7	258.1
2020	172.1	---	91.6	107.2	61.0	207.3
2030	94.0	---	70.3	58.5	35.4	194.9

MG –Miter Gate
CV – Culvert Valve

The M&MR policy is a combination of the FAF and planned replacement of components. The replacement pursued is determined by what is economically justified by chamber and by component. When replacements are temporally proximate, they are bundled with the replacement of other components (like valves and culvert valve machinery). If this bundling reaches a specified dollar threshold, it is referred to as a major rehabilitation. The results of this analysis are incorporated into cost and closure matrices, which in turn are used as inputs into the system economic model. The M&MR cost and closure matrix for Greenup is summarized in **Table B-9-3** below, the cost portion of the matrix is displayed in **Attachment 4**. The matrix shows the schedule and costs for all major maintenance work, including major component replacement and major rehabilitations.

TABLE B-9-3
Schedule of Major Maintenance Activities at Greenup
(millions of $1999)

	Main Chamber			Auxiliary Chamber		
Year	Maint. Description	Days Closed	Repair Costs	Maint. Description	Days Closed	Repair Costs
2003	MGate-S	25	$ 525	MGate-U	45	$ 1,238
2004	SMR (MG, EG)	90	$ 12,975	-	-	$ -
2005	SMR (MG Only)	60	$ 6,150	SMR (EG)	93	$ 6,475
2007	CValve-Q	-	$ 990	CValve-R	45	$ 945
2010	-	3	$ 60	MGate-V	45	$ 1,238
2016	MGate-U	55	$ 1,448	-	10	$ 210
2021	MGate-V	45	$ 1,238	-	-	$ -
2023	-	-	$ -	MGate-U	45	$ 1,238
2027	-	10	$ 210	CValve-R	50	$ 1,050
2030	MGate-U	55	$ 1,448	SMR (MG, Elec)	60	$ 9,475
2031	CValve-P	-	$ 990	SMR (MG Only)	70	$ 6,150
2036	MGate-V	45	$ 1,238	-	-	$ -
2046	MGate-U	48	$ 1,298	-	10	$ 210
2047	CValve-P	-	$ 990	CValve-R	45	$ 945
2048	CValve-Q	10	$ 1,200	MGate-U	45	$ 1,238
2051	MGate-V	45	$ 1,238	-	-	$ -
2052	-	-	$ -	MGate-V	45	$ 1,238

Notes:

1/ MG -- miter gate, EG -- emergency gate

2/ SMR -- component replacements bundled into a major rehabilitation, components in parentheses)

3/ Where components are named, a replacement has been scheduled.

B-9.2.2.2.3 Maintenance Requirements. The normal operation and maintenance (O&M) costs for continuing the existing project are estimated at $3.59 million annually (refer to **Table B-9-4**). These costs provide for staffing the project, routine operation and maintenance activities, and dredging in the lock approach. Cyclical maintenance cost $0.77 million on an average annual basis, and random minor repairs are projected to cost another $0.25 million. The main chamber undergoes a major rehabilitation in 2004-2005 that costs $19.1 million. The auxiliary chamber undergoes a major rehabilitation in 2005 and again in 2030-2031 at a total first cost of $22.1 million, or an average annual cost of $0.76 million. A $24.8 million dam rehabilitation is scheduled for the years 2043 – 2045, with an average annual cost of $0.15 million. Total average annual cost are $7.52 million, which includes capital costs of $2.5 million and operation and maintenance costs of $4.98 million.

B-9.2.3 Operational Alternatives

Nonstructural traffic management measures, within the current purview of the Corps of Engineers and offering opportunities for more effective use of the existing Greenup project are considered as candidate elements for inclusion in the without-project condition. Best practice

lockage policies and helper boats (i.e. self-help) are especially effective during high congestion situations at locks where double-cut tow operations are necessary – situations typical of a main chamber closure at Greenup. The average annual cost of this operation is estimated to be $0.15 million. Six-up / six-down policies and helper boat operations are both employed as standard practice during main chamber closures. As a result, both of these non-structural measures are assumed to continue into any without-project future condition. A form of traffic scheduling is also practiced during closures of the main chamber.

As mentioned earlier, the Corps and industry work together to plan and schedule maintenance closures so as to minimize the costs for each. This pre-planning allows industry to re-schedule shipments around the closure period to the greatest practical extent. Tow arrivals are observed to diminish once delays and tows in queue reach a certain level. This acts to reduce the average amount of time each tow sits in queue, reducing delay costs for the tow operators; however, chamber capacity is not increased. Discussions with shippers and towing companies indicate that while lock proximate delays and delay costs are reduced, shippers and/or producers are faced with cost increases elsewhere. Stockpiles and inventories are increased, production is re-dispatched to less efficient plants, short-term productive capacity is added or short-term alternative transportation procured. The capacity of the production and distribution system has not been increased through this re-scheduling; increased costs have merely been re-distributed throughout the system. It is assumed that shippers and carriers have made economically rational decisions in re-distributing these costs; therefore, re-scheduling as currently practiced is retained as part of the future without-project condition. Government-directed scheduling is not currently within the authority of the Corps of Engineers and was not considered as a possible component of the most likely without-project condition.

B-9.2.4 Navigation Benefits and Conclusion

For the traffic using Greenup, the transportation cost savings (benefits) over the period of analysis are estimated at $1,352.4 million annually, far in excess of the $7.5 million in average annual project costs for major maintenance, operations, and routine maintenance, and implementation of a helper boat program. Given this and the fact that no other nonstructural measures to improve lock efficiency were identified, the existing condition described in the preceding paragraphs is selected as the most likely without-project future condition at Greenup Locks and Dam.

B-9.3 ECONOMICS OF WITHOUT-PROJECT CONDITION

The annual benefits, annual costs, and net benefits (Greenup traffic only) for continuing the existing Greenup project are presented in **Table B-9-4**. Total average annual benefits are estimated at $1,352.4 million. Total average annual operations and maintenance costs are $7.5 million. Industry delay costs incurred during unplanned component replacements are estimated at $1.51 million on an average annual basis. These two costs total to $9.03 million. Comparing

total annual benefits and annual costs yields net annual benefits for the without-project condition of $1,343.4 million.

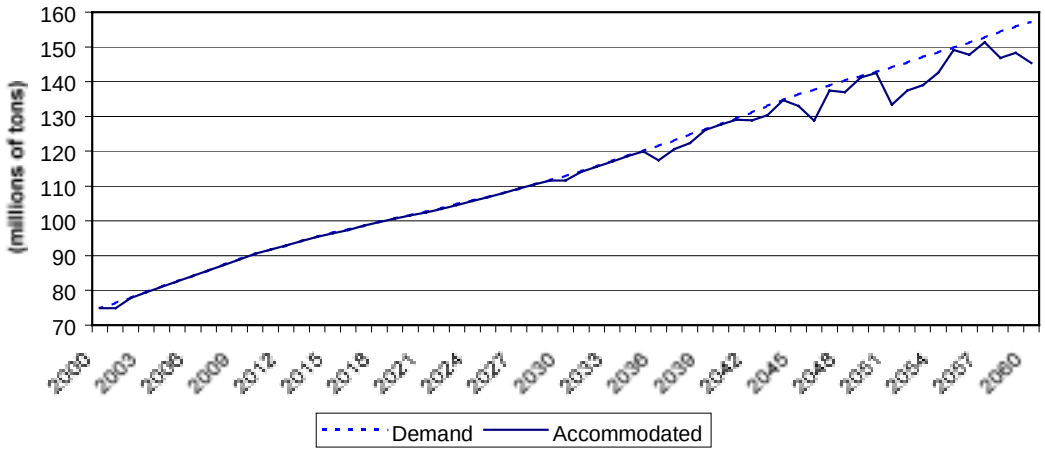
TABLE B-9-4
Greenup Locks and Dam
Annual Benefits, Costs and Net Benefits
(millions of $1999, 6-7/8% discount rate, base year 2008)

Item	Amount
Annual Benefits 1/	$ 1,352.40
Annual Costs	
Normal O&M	$ 3.59
Dam Rehabilitation ($24.8 over years 2043-45)	$ 0.15
Dredging	$ 0.23
Main Chamber	
Rehabilitation ($23.3 over years 2004-5)	$ 1.63
Cyclical Maintenance ($16.9 in various years)	$ 0.43
Random Minor ($2.8 in various years)	$ 0.18
Auxiliary Chamber	
Rehabilitation ($26.2 over 2005 & 30-31)	$ 0.76
Cyclical Maintenance ($10.0 in various years)	$ 0.34
Random Minor ($2.2 in various years)	$ 0.07
Helper Boats	$ 0.15
subtotal	**$ 7.52**
Transportation Impacts	$ 1.51
Total Annual Costs	**$ 9.03**
Net Annual Benefits	**$ 1,343.37**

1/ Only those transportation benefits realized by traffic using Greenup Locks and Dam.

Traffic demands are generally accommodated the period of analysis, excepting during those times when the main chamber is closed. During closures, traffic demands and traffic accommodated can be seen to diverge in **Figure B-9-1** below. During normal operations, traffic is diverted to alternate modes in very small amounts and only during the last 25 years of the analysis period. Main chamber closures tend to have their greatest effect on waterway operating costs, rather than causing large diversions of demand to other transportation modes.

FIGURE B-9-1
Greenup Without Project Condition Performance



SECTION B-10

IDENTIFICATION OF ALTERNATIVE IMPROVEMENT PLANS

B-10.1 GENERAL

This section discusses the development and screening of alternative plans for addressing the problems and needs at Greenup Locks and Dam. Alternatives were formulated in a two-stage process. In the initial screening a broad range of alternatives were considered in order to identify potential measures that would make future locking conditions at Greenup more efficient, particularly during closures of the main chamber. Options considered to have practical application and reasonable development costs were carried forward for a more detailed evaluation based upon development costs, navigation benefits, effectiveness and workability. Screening at this stage produced the final plan for detailed engineering and design and identification of the NED plan.

B-10.2 ALTERNATIVES CONSIDERED

The initial screening retained some alternatives and eliminated others based on navigation conditions and other qualitative criteria. Large-scale capital investments, small-scale capital investments, and non-structural improvements were considered. The results of the Large-scale capital investment screening are summarized as follows:

- A new project with a 1200' main and 600' auxiliary would provide a more structurally reliable project, but only partially meet the needs. Any closures of the main chamber would continue to impose heavy delay costs on industry and congestion associated with future traffic growth would still be a problem in later years. Additionally, the cost of an entirely new project was judged excessive and the environmental impacts would be quite large. Therefore, this alternative was not carried forward to the intermediate level.

- A new project with twin 1200' chambers would meet the needs from all standpoints: 1) structural reliability, 2) ability to efficiently handle traffic during closures of the main chamber, and 3) ability to efficiently handle future, high volumes of traffic in

the later years of the project. Nevertheless, this alternative was not carried forward to the intermediate level because of its excessive costs and major environmental impacts.

- A new 1200' chamber at the existing project results in a project with twin 1200' chambers and a backup 600' chamber (which would be used during closures of one of the 1200' chambers). This configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. The Greenup landward site, unlike Myers' landward site, has to contend with existing bridge piers. All three of the new 1200' chamber alternatives would have excessive monetary and environmental costs and were not carried forward.

- Both a 200' and a 400' extension of the existing auxiliary chamber were considered. These extensions would result in projects with a 1200' main chamber and either an 800' auxiliary or a 1000' auxiliary, respectively. Neither alternative would efficiently process traffic during closures of the main chamber. In 1998, 65% of the tows arriving at Greenup would have to double-cut in a 1000' chamber, and 75% would have to double-cut in an 800' chamber, resulting in a continuation of serious delays and industry costs during main chamber closures. Furthermore, these extensions are not practicable from an engineering standpoint. Culverts are located in the middle wall monoliths where the gate recesses would have to be placed. The affected middle wall monoliths would have to be taken out and rebuilt to accommodate the gate recesses. This would probably close the entire river in this vicinity for a year or more. Extending the auxiliary chamber by anything less than 600' would have major effects on waterway traffic. Therefore, these plans were not carried forward to the intermediate level.

- A 600' extension of the existing auxiliary chamber results in a project with twin 1200' chambers. The twin 1200' configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. Future major maintenance will still be required for major components at the existing project to keep the project operating efficiently. This alternative is carried forward into the next level screening.

The results of the screening of three Small-scale capital investments are summarized as follows:

- Currently, two emergency mooring cells are located upstream of the project. While there is industry and public interest in installation of mooring buoys or cells downstream of the project, this small-scale improvement does nothing to reduce approach times and increase efficiency of the project. While these are not carried forward into the intermediate economic screening, there remains the potential for buoys or cells to provide significant environmental benefits. This shall be addressed in the environmental appendix.

- Guardwall and middle wall extensions on the upper end of the existing project have the potential to greatly reduce interference between tows concurrently using the main and auxiliary. This interference reduction has the potential to reduce lock delays when traffic reaches the level where both chambers are highly utilized. Nevertheless, wall extensions are not expected to be able provide the capacity expansion needed to handle future traffic volumes during the later years of the project, nor will they reduce delays when the main chamber is closed for maintenance (when interference between chambers is not a problem). Wall extensions do not meet current and future needs, so were not carried into the intermediate level screening.

- A Miter Gate Quick Changeout System (MGQCS) would be used to shorten closure durations for any kind of maintenance or accident requiring gate removal. This alternative requires a towboat equipped with a heavy-duty crane (already under construction), a specially equipped barge, gates modified for lifting by crane, an on-site set of additional gates, and an assembly / storage / staging area for these gates. Investment in this equipment allows maintenance closures involving the chamber gates to be significantly shortened, easing the closure-related delay costs experienced by industry. This alternative is carried forward into the next level screening because of its low cost relative to lock chamber extensions, or additions, and because of its obvious benefits.

In addition to the structural measures evaluated for improving the economic efficiency of the existing Greenup project, non-structural alternatives were considered. Two of these, best practice lockage policies and helper-boats (i.e. self help), are especially effective during high congestion situations at locks where double-cut tow operations are necessary – situations typical of a main chamber closure at Greenup. Six-up / six-down policies and helperboat operations are both employed as standard practice during main chamber closures. As a result, these non-structural measures are part of the without-project condition, along with traffic scheduling as currently practiced by Ohio River System carriers and shippers. Two other non-structural alternatives were also considered. These alternatives are summarized below.

- Locks nearing their practical capacity limits can benefit from a traffic-scheduling program that assigns tow arrival times. The goal of such a scheduling program is to reduce delays and their associated costs. However, there are some critical limitations to scheduling. Shipments must still occur, forcing shippers to either re-route these moves to a more expensive transportation mode, re-dispatch their production to less efficient plants, or re-schedule these shipments for another time. Re-scheduling shipments is more costly as well (re-scheduling is practiced at Greenup and was described in **Section B-9** of this appendix as a feature of the without project condition). The shipper may have to pay higher, short-term costs for waterway service, and stockpiles will either have to be built-up or drawn-down prematurely at an additional cost to the shipper, which in turn may involve additional handling costs. In short, the capacity of the production and distribution system is not increased through a scheduling program during main chamber closures; increased costs are merely re-distributed throughout the production and distribution system. Scheduling

does not address the need for additional auxiliary chamber capacity and is unable to alleviate the adverse economic impacts of closure. Any scheduling program or re-scheduling of traffic beyond that based upon the economically rational practices of shippers and carriers is discarded as a with project alternative.

- A congestion lockage fee would be used to influence waterway shippers with very marginal savings to shift their traffic to an alternate overland mode, thereby reducing the amount of lock congestion for the remaining shipments. Thus it serves as a device for rationing lock use to those movements with the highest marginal savings. The result would be an increase in total rate savings net of delay costs for shippers that continue to use the waterway. The lockage fee alternative would reduce queues and, therefore, delay costs at the lock. This alternative is carried forward into the next level screening.

Summarizing, the 600' auxiliary lock extension plan, the Miter Gate Quick Changeout System (MGQCS), and congestion fees are carried forward into the next and final level of screening.

B-10.3 ALTERNATIVES EVALUATED

One non-structural alternative (congestion fees), one small capital investment alternative (MGQCS), and one structural alternative (a 600' extension of the existing auxiliary) are retained for evaluation after the initial screening. The results of the benefit cost analysis are summarized in **Table B-10-1**. The performance of each plan is addressed in detail in the sections below.

TABLE B-10-1
Greenup Locks and Dam
Annual Costs and Benefits for Intermediate Alternatives
(millions of October 1999 dollars, 6 7/8% discount rate, base year 2008)

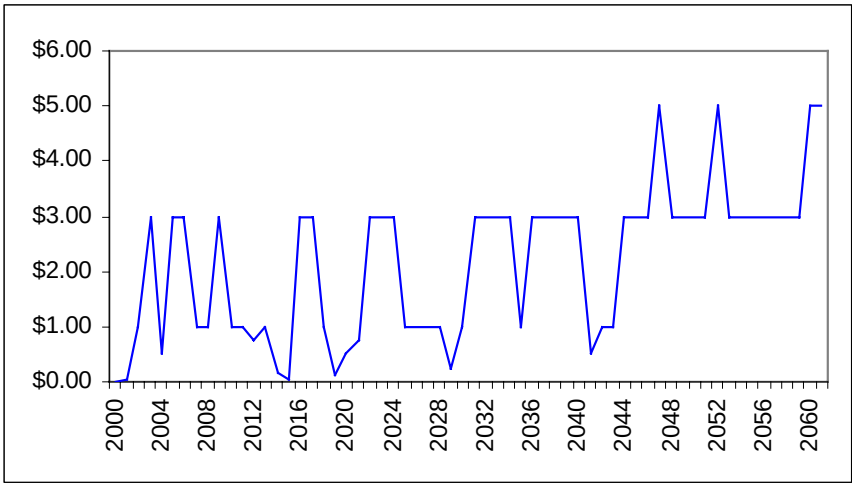
Alternative	First Cost	Incremental Average Annual			BCR
		Costs	Benefits	Net Benefit	
Congestion Fee	1.0	1.0	6.7	5.7	6.7
Gate Change-out System	7.1	0.5	8.6	8.0	16.4
600' Lock Extension	168.0	10.3	24.6	14.3	2.4

B-10.3.1 Congestion Fees

A range of congestion fees was evaluated for each year of Greenup's 50-year project life. Results of the analysis indicated that no one fee level was best, rather each year had a best fee. The best fee was selected as the fee that generated the largest benefit, which consists of the system transportation savings plus fee revenues collected at Greenup. The fee selected is directly related to the closures at Myers, as well as the traffic level and cost characteristics of the movements that transit the project. Higher fees are needed to divert higher levels of traffic.

System benefits presented in **Table B-10-1** above are based upon the best mix of fees throughout the project's life. **Figure B-10-1** shows how this mix changes through time. In a situation where daily traffic levels have nearly reached capacity, congestion fees have been successful in moving marginal movements off the waterway at an advantage to the entire system. While congestion fees do offer positive net benefits, implementing a fee program is impractical from an administrative standpoint. Analysts would need to periodically (once every 5 years or so) reanalyze projected traffic flows and identify each shipper's range of alternative routes, modes, or practices and their related costs. Assembling these other industry costs, those industry costs beyond traffic delay costs, proved intractable during this study and is not expected to become any more manageable over time. Given the paucity of reliable data, results from the analysis likely overstate the effectiveness of the fee program and make the results unreliable. An additional concern with the fee plan is that it does not entirely address the planning objective of efficiently passing traffic at Greenup during lock closures. While fees help in reducing delays, significant delays are still experienced during these closures. This plan is eliminated from further consideration due to serious problems associated with implementing a fee program and its inability to fully address the needs at Greenup.

FIGURE B-10-1
Sequence of Optimum Congestion Fees
(fees in dollars per ton)



B-10.3.2 Miter Gate Quick Changeout System

A Miter Gate Quick Changeout System (MGQCS) would be used to shorten closure durations for any kind of maintenance or accident requiring gate removal. Operations and Engineering personnel estimated that a closure for gate maintenance could be reduced from 45 days to 15 days at Greenup once the system is fully implemented. As discussed above, this alternative requires a barge mounted heavy-duty crane (already under construction), gates modified for lifting by crane, an on-site set of additional gates, and an assembly / storage / staging area for these gates. Investment in this equipment allows maintenance closures involving the chamber gates to be significantly shortened, easing the closure-related delay costs experienced by industry. This plan partially meets study objectives by reducing delays through the shortening of closure durations, but fails to fully address delays related to lock closures. It too is eliminated from further evaluation. While eliminated as a stand-alone plan, because of its beneficial aspects it was subsequently included as part of the 600' auxiliary extension plan.

B-10.3.3 Auxiliary Lock Extension

A 600' extension of the existing auxiliary chamber results in a project with twin 1200' chambers. The twin 1200' configuration has the ability to efficiently process traffic during closures of either 1200' chamber, as well as handle future, higher volumes of traffic during the later years of the project. Four design variations of this plan have been developed in the Engineering Appendix. These design variations center upon engineering considerations involving implementation of the filling and emptying system and have been designated as Plans 1, 2, 3, and 4. Selection of the best design will be accomplished in the PED phase of this study. In this, the feasibility phase of the study, the 600' extension plan designated in the Engineering Appendix as Plan 3 is used to best represent the costs and desired performance of a 600' lock extension plan. The extension plan includes the MGQCS.

B-10.4 FINAL ALTERNATIVE

The 600' Auxiliary Lock Extension is the only alternative that can be implemented and fully meet the planning objectives. This plan has the greatest net benefits of any alternative considered and is the National Economic Development (NED) plan.

SECTION B-11

ECONOMIC ANALYSIS OF FINAL PLAN

B-11.1 GENERAL

This section summarizes all of the pertinent benefit and cost data and presents the derivation of average annual benefits and costs for the final alternative at Greenup Locks and Dam. The evaluation process focuses on the effects of traffic delays associated with maintenance closures of the Main lock and the analysis of benefits and costs for the final plan. The performance of the final plan is examined in terms of projected traffic demands, accommodated system traffic, and total rate savings. It is estimated that the year 2008 would be the earliest probable date the plan could be completed and made operational. Though the project life is from 2008 to 2058, the period under analysis extends from 2000 – 2058 in order to capture construction impacts and variations in lock closure schedules between the Without- and With-Project alternatives. It is primarily during Main chamber closures that traffic demands cannot be completely accommodated.

All economic values are expressed in October 1999 dollars. Previous sections detailing the economic screening of alternatives used October 1999 dollars and a discount rate of 6 7/8%. Subsequent to this screening, the discount rate was lowered to 6 5/8%. This current rate is used in the economic analysis of the final plan presented in this section and in the sensitivity analyses presented in **Section B-12**.

B-11.2 PERFORMANCE OF FINAL PLAN

B-11.2.1 Waterway Traffic

Future waterway traffic demands are projected at the dock level for each movement in the Ohio River System (ORS). These unconstrained demands are presented for each lock in the system in **Attachment 3**. Demands for Greenup are also presented in **Table B-11-1**, along with the portion of these demands economically accommodated by the without condition project and by the final plan. Movements with waterway transportation route costs that are greater than the least cost alternate are not accommodated and are assumed to divert to the least cost alternate route. Under normal operating conditions, both the without condition and the final plan accommodate nearly all of the future traffic demands. It is primarily during Main chamber closures that traffic demands cannot be accommodated.

TABLE B-11-1
Greenup Locks and Dam
Traffic Accommodated by Final Plan

Year	Demand Tonnage	Accommodated Tonnage 1/ Without Project Condition	Accommodated Tonnage 1/ 600' Extension Plan
2000	74.9	74.8	74.8
2010	90.5	90.4	90.4
2020	101.6	101.6	101.6
2030	112.9	111.7	112.8
2040	127.8	127.7	127.7
2050	142.8	142.4	142.4
2060	157.3	147.8	150.6

1/ Closures assumed.

Projected system waterway traffic demands are presented in **Table B-11-2**. Again, nearly all waterway demands are accommodated by both the Without-Project condition and the final alternative plan.

TABLE B-11-2
Ohio River System
Traffic Accommodated by Final Plan

Year	Demand Tonnage	Accommodated Tonnage 1/ Without Project Condition	Accommodated Tonnage 1/ 600' Extension Plan
2000	275.7	275.6	275.6
2010	324.4	324.2	324.2
2020	354.4	343.2	343.2
2030	385.1	381.7	382.9
2040	422.7	419.2	419.2
2050	459.5	442.5	442.5
2060	493.2	465.1	472.1

1/ Closures assumed.

B-11.3 FIRST COSTS

Costs for the final plan are summarized in **Table B-11-3**, in the feature code of accounts format, which includes contingencies. The final plan includes extension of the Auxiliary lock to 1200 feet, rehabilitation of the Main lock and the navigation dam (also part of the without condition), and implementation of the miter gate quick changeout system.

TABLE B-11-3
Greenup Locks and Dam, Costs for Final Plan 1/
(millions of October 1999 dollars)

Item	First Cost
Near Term Project Costs	
New Lock Construction (2006-07)	
Lands and Damages	-
Relocations	0.6
Locks	135.2
Fish & Wildlife	3.6
Buildings, Grounds, & Utilities	0.8
Planning, Engineering & Design	18.8
Construction Management	9.4
Subtotal New Lock Construction	**168.4**
Miter Gate Quick Changeout (2008-16)	7.1
Subtotal 600' Extension Plan	**175.5**
Main Chamber Rehabilitation (2008-09)	19.1
Subtotal Near Term Costs	**194.6**
Longer Term Project Costs	
Auxiliary Lock Rehabilitation (2030-31)	21.9
Dam Rehabilitation (2043-45)	24.8
Subtotal Long Term Costs	46.7
TOTAL PROJECT COSTS	**241.3**

1/ Project costs shown in this table are all first costs expressed in October 1999 dollars, regardless of when the expenditure occurs.

B-11.4 INVESTMENT AND ANNUAL COSTS

Investment costs are the sum of construction expenditures and the accrued interest (interest during construction or IDC) on those expenditures up to the time the new lock extension is operational and the project begins producing benefits. Investment costs also include any major maintenance expenditures made during the economic life of the project. Such expenditures include component replacements, rehabilitations and installation of the MGQCO system under the With Project plan. For these post online costs, the opposite of IDC is applied and the costs are discounted to the online date before amortizing. The earliest time that a lock extension project is estimated to be operational is 2008, thus 2008 serves as the base year for amortization. Investment costs for the final plan are displayed in **Table B-11-4** below.

TABLE B-11-4
Greenup Locks and Dam
Summary of Investment and Annual Costs for Final Plan
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Item	Without Project Condition	Final Plan (600' Extension)
INVESTMENT COSTS		
New Construction	-	168.4
Main Chamber Rehabilitation	19.1	19.1
Auxiliary Chamber Rehabilitation	22.1	21.9
Dam Rehabilitation	24.8	24.8
Miter Gate Quick Changeout (2008-2016)	-	7.1
subtotal	**66.0**	**241.3**
IDC (new construction)	-	5.8
Discounting of post 2008 work	(30.1)	(36.6)
Total Investment Costs 1/	**35.9**	**210.5**
AVERAGE ANNUAL COSTS		
Capital Costs	2.5	14.5
O&M Cost		
Normal O&M	3.6	3.5
Helper boats	0.1	0.0
Cyclical Maintenance	1.0	1.1
Dredging	0.2	0.2
Transportation Cost Impacts	1.5	-
TOTAL AVERAGE ANNUAL COSTS 2/	8.9	19.4
INCREMENTAL AVERAGE ANNUAL COSTS	--NA--	10.5

1/ Total investment costs include the project costs (see Table B-11-3) plus interest during construction charges.

2/ Total annual costs are the average annual discounted values of total investment costs (capital costs), O&M costs, and transportation impacts incurred throughout the life of the project.

The total annual costs for the Without-Project condition and the final plan are the summation of the annualized capital costs and other annual costs. Normal O&M costs cover day to day operating expenses and are expected to remain the same with or without the final plan, as are cyclical maintenance costs. Cyclical maintenance includes repair fleet charges for periodic dewaterings and inspections (not included under normal O&M). Both categories of estimated O&M costs are based on actual cost experience at Greenup, as well as other locks and dam projects on the Ohio River. Dredging costs for upstream and downstream approaches are also expected to be the same between the alternative conditions.

Annual costs differ between the without and with condition in three areas, the most significant being capital costs. Capital costs are the same between the two conditions, excepting

for the construction of the lock extension and full implementation of the MGQCS in the With Project condition. The other two differences relate to helper boat costs and transportation impacts. In the without condition, a self-help program using two helper boats is assumed to be in operation during Main chamber closures. Self-help is effective when only a 600' Auxiliary chamber is available, because the helper boats are there to assist double cutting through the smaller chamber. Often this cost is assumed by industry through a self-help policy, nevertheless, it represents an economic cost. Transportation impacts refer to the industry costs incurred during closures for replacement of components replaced through a fix-as-fail policy. Again, the application of fix-as-fail versus planned replacement was determined on the basis of economic efficiency using engineering reliability analysis and the LCLM. The costs associated with fix-as-fail components are identified as Transportation Impacts in the table above.

Interest charges on the investment costs and amortization were computed using an interest rate of 6 5/8% and an economic life of 50 years (2008-2057). However, it should be noted that all cost and benefit streams from 2000 to 2057 were considered in order to capture pre-online differences, such as transportation impacts of construction and delayed maintenance. **Attachment 4** displays these calculations.

B-11.5 AVERAGE ANNUAL BENEFITS

The navigational benefits for the final plan represent the increase in total system rate savings over the Without-Project condition. A summary of the annual system benefits for the Without-Project condition and for the final plan, along with the incremental system benefits, is presented in **Table B-11-5.** The greatest share of the incremental average annual benefits, $25.2 million, is the result of traffic delay reductions. The remaining $0.8 million in benefits are shift-of-mode benefits. Shift-of-mode benefits represent the reduction in transportation costs for those movements that were diverted to the alternate mode during closure events. The 600' Auxiliary lock extension allows these movements to return to the waterway at a transportation cost savings.

TABLE B-11-5
Greenup Locks and Dam
Annual Benefits for Final Plan
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Plan	System Benefits	Incremental Benefits
Without Condition	4,578.8	---
600' Extension Plan	4,604.8	26.0

B-11.6 SUMMARY OF ANNUAL BENEFITS AND COSTS

Table B-11-6 presents the incremental average annual benefits and costs of the final plan. The 600' Lock Extension plan, the NED plan, offers $26.0 million in benefits over the without condition, while costing an additional $10.5 million.

TABLE B-11-6
Greenup Locks and Dam
Annual Costs and Benefits for Final Plan
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Item	600' Extension
Incremental Annual Benefits	$ 26.0
Incremental Annual Costs	$ 10.5
Net Annual Benefits	$ 15.5
Benefit Cost Ratio	2.5

Construction activities associated with modernization of Greenup entails considerable employment of skilled and unskilled labor resources from numerous construction-related professions. Wage compensations would be substantial for constructing the 600' Auxiliary Lock extension. Labor drawn from counties with substantial and persistent unemployment relative to the U.S. as a whole is accountable as a project benefit and is included in NED benefit estimates for the recommended plan (see **Attachment 6** for a full discussion of construction-related NED and Regional Economic Development benefits). For Greenup, these NED employment benefits amount to $0.5 million on an average annual basis and raise the net incremental annual benefits to $26.5 million (see **Table B-11-7**).

TABLE B-11-7
Greenup Locks and Dam
Annual Costs and Benefits for Final Plan, Including Employment Benefits
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Incremental Annual Benefits	
Transportation Savings	$ 26.0
Construction Impacts	$ 0.5
Total Benefits	$ 26.5
Incremental Annual Costs	$ 10.5
Net Annual Benefits	$ 16.0
Benefit Cost Ratio	2.5

SECTION B-12

SENSITIVITY ANALYSIS

B-12.1 GENERAL

The final plan for improving the existing Federal project at Greenup Locks and Dam has been evaluated using what was judged to be the most probable future navigation conditions, both with and without the alternative. In defining these conditions, certain key assumptions and predictions were made regarding the future. Since future conditions cannot be predicted with certainty, several tests were performed to describe the sensitivity of the plan selection to changes in key formulation variables. This section of the report identifies the key areas of uncertainty and describes the sensitivity of plan selection to alternative forecasts of the future.

B-12.2 ALTERNATIVE TRAFFIC PROJECTIONS

One of the major factors affecting the need for improvements at Greenup and also one of the major areas of uncertainty, is the forecast of future traffic demands. Traffic demands at Greenup are projected to grow at a modest rate of 1.1 percent a year between 1996 and 2060. Other growth rates, either higher or lower, are possible. To show the sensitivity of the project to alternative traffic demand forecasts, net benefits for the final alternative were re-evaluated using a no growth after 20 years projection set, the most likely set, and a high traffic projection set (see **Table B-12-1**). The most likely projection set is the De-regulation scenario presented in **Section 6.** The high traffic projections are represented by the upper bound of the 95% confidence level traffic developed in **Attachment 3**. The no growth after 20 years is required by regulation, and it corresponds closely to the Carbon Limits scenario, which was also presented in **Attachment 3**. This sensitivity test shows that the net benefits are sensitive to the level of future traffic demands. As shown in **Table B-12-1**, net benefits are about 46 percent lower under the low projections and approximately 113 percent higher under the high projections. The results show the improvement to be feasible under all three projection sets.

TABLE B-12-1
Sensitivity of Net Annual Incremental Benefits to Alternative Traffic Demand Projections
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

Plan	Incremental Annual		
	Benefits	Costs	Net Benefits
No Growth After 20 Years	18.5	10.5	8.2
Most Probable	26.0	10.5	15.5
High Projection	43.9	10.5	33.6

B-12.3 OPTIMUM REPLACEMENT TIMING

In formulating the recommended plan for modernizing the existing Greenup project, it was assumed that the 600' Lock Extension would be completed and made available for use by the year 2008. This date was selected because it was estimated to be the earliest probable date by which the project could be completed. The purpose of this test is to define the optimum replacement timing for the selected plan, or the completion date that would produce the maximum net annual benefits. Optimum replacement timing was evaluated by re-computing the average annual benefits and costs under completion dates between 2008 and 2020. The results of this evaluation, which are presented in **Table B-12-2**, demonstrate that 2008 is the optimum completion time for the lock extension. Deferral beyond this year results in a decline in net incremental benefits.

TABLE B-12-2
Sensitivity of Net Annual Benefits to Alternative Project Completion Dates
(millions of October 1999 dollars, 6 5/8% discount rate, base year 2008)

	Incremental Annual		
	Benefits	Costs	Net Benefits
2008	26.0	10.5	15.5
2010	24.1	12.6	11.5
2012	21.7	11.1	10.6
2015	14.1	9.3	4.8
2020	9.0	8.4	0.6

* Numbers may not add due to rounding.

ATTACHMENT1

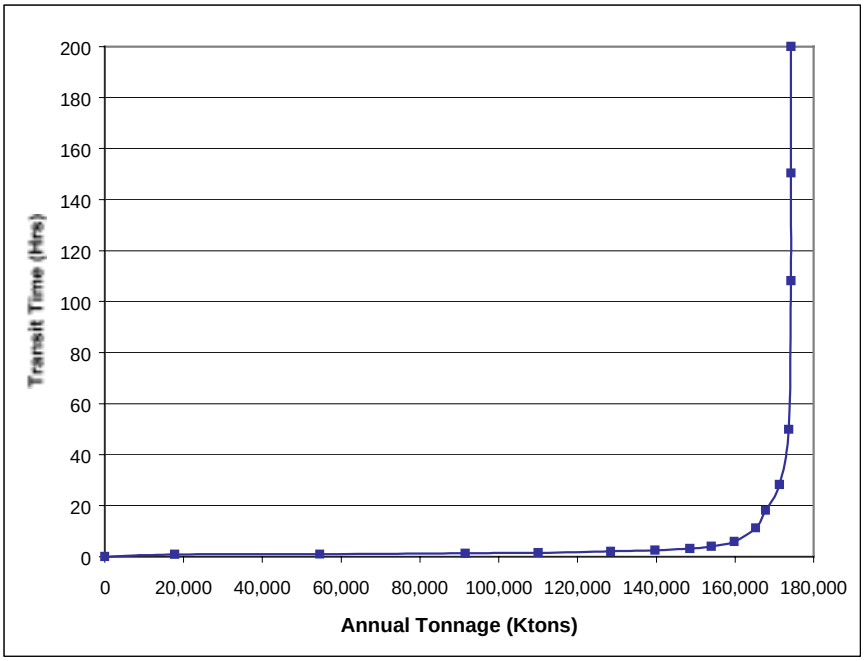
CAPACITY ANALYSIS

1.1 INTRODUCTION

J.T. Myers Locks and Dam and Greenup Locks and Dam are the subjects of an interim report to the Ohio River Main Stem System (ORMSS) study. This capacity analysis is an attachment to that interim report. Tonnage-transit time characteristics were developed for every lock on the Ohio River as part of the ORMSS study. This attachment documents the data sources, assumptions, analytical methods, and the results of the analysis. Since J.T. Myers and Greenup are the primary subjects of the interim report, this attachment addresses those two locks in greater detail than the other locks on the Ohio River.

The Waterways Analysis Model is the analytical tool used in this analysis. Tonnage-transit time curves are developed so that transit time can be estimated for any desired tonnage level. Capacity as determined in this study is defined as the level of tonnage where the tonnage-transit time curve reaches its vertical asymptote and average tow transit time increases without bound. A sample tonnage-transit time curve is shown in **Figure 1**.

Figure 1.
Sample Tonnage-Transit Time Curve



1.2 STUDY BACKGROUND

The ORMSS study is a comprehensive investigation into the future performance and funding requirements for all lock and dam projects on the Ohio River. The study investigates system project needs for the years 2000-2060. During that time, it is assumed there are 19 project sites on the Ohio River. The upper six projects are under the jurisdiction of the Pittsburgh District, Huntington District manages the middle six, and the lower seven are under the control of the Louisville District. Thirteen of the nineteen projects have a main chamber 110' wide by 1200' long, and an auxiliary chamber 110' wide by 600' long. Emsworth, Dashields, and Montgomery on the upper river have a main chamber 110' wide by 600' long and an auxiliary chamber 56' wide by 360' long. Smithland on the lower river has twin 110' wide and 1200' long chambers. Two locks are currently under construction. Olmsted will replace Lock and Dam 52 and Lock and Dam 53. It will have twin 110' wide by 1200' long chambers and a movable dam that provides a navigable pass 60 percent of the year. McAlpine will have twin 110' wide by 1200' long chambers.

1.3 DESCRIPTION OF MODELING PROCESS

1.3.1 Overview

Tonnage-transit time curves were developed using the Waterway Analysis Model (WAM). The WAM is a discrete event 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 has been used in navigation studies on the Ohio River and tributaries since the mid 1980's.

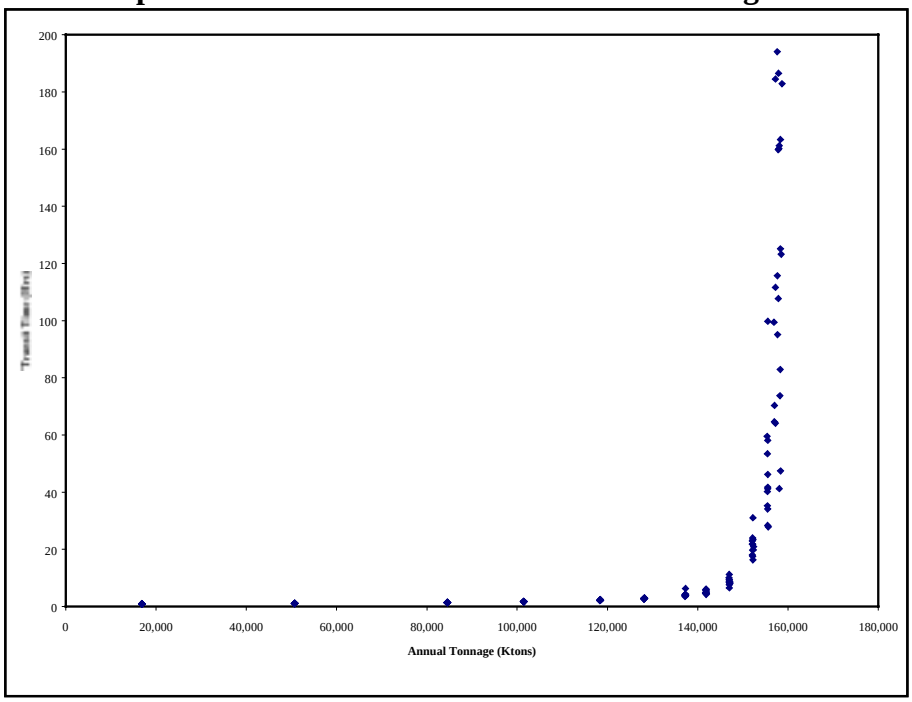
The primary items of interest from any single WAM run is the transit time and the tonnage processed. Transit time is defined as the sum of the delay and processing time. Delay is the period of time between a vessel's arrival at a lock and when it actually starts locking. Delay time can be zero if a vessel does not have to wait to start locking. Processing time is the period of time between the start of lockage and end of lockage. A vessel cannot have a zero processing time.

A WAM "run" consists of a warm-up period followed a statistics gathering period. The warm-up period has a duration of 30 simulated days. It's main purpose is to get queues built up to where they should be before statistics are gathered. The statistics gathering period has a duration of 365 days simulated time. It is the statistics gathered during this period that are referred to in this attachment.

Tonnage-transit time curves are developed by making many WAM runs. Because the WAM is a simulation model, its output is an "estimate". Tonnage and average transit time will

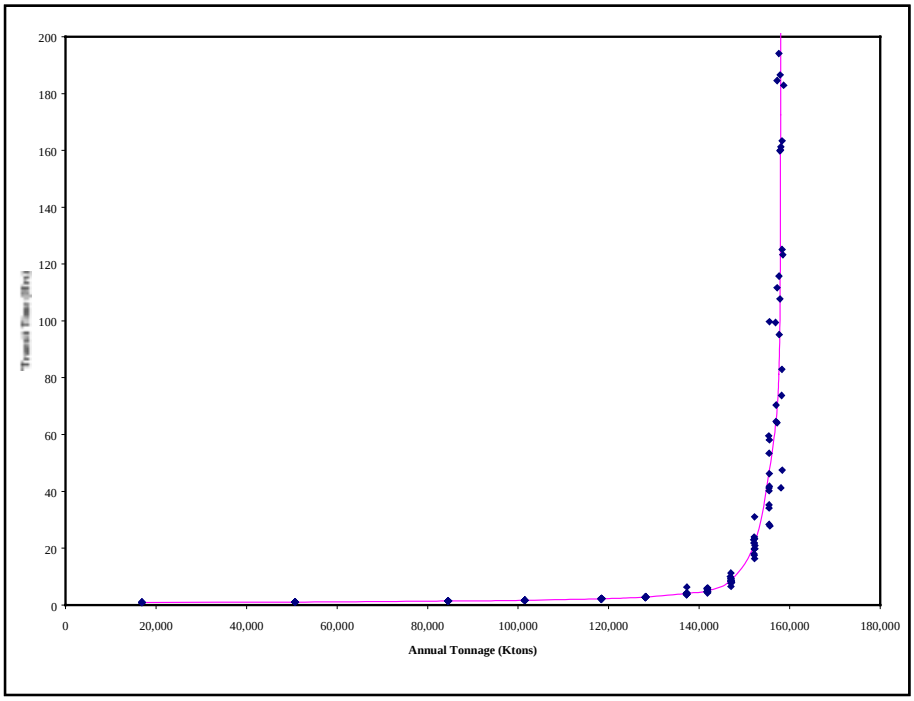
vary between runs. At low tonnage levels, these variations are small. As tonnage increases, transit time variation becomes larger. An example of how tonnage and transit time varies for different traffic levels is shown in **Figure 2.**

Figure 2.
Example of How Transit Time Varies With Tonnage Level



Tonnage-transit time curves were developed for Myers, Greenup, Montgomery, Dashields, and Emsworth based on 12 runs per tonnage level for 16 different tonnage levels. The 12 runs per tonnage level were then averaged to develop a curve with 16 points. **Figure 3** shows an example curve developed from 12 runs at 16 tonnage levels.

Figure 3
Transit Time Curve and Individual Runs



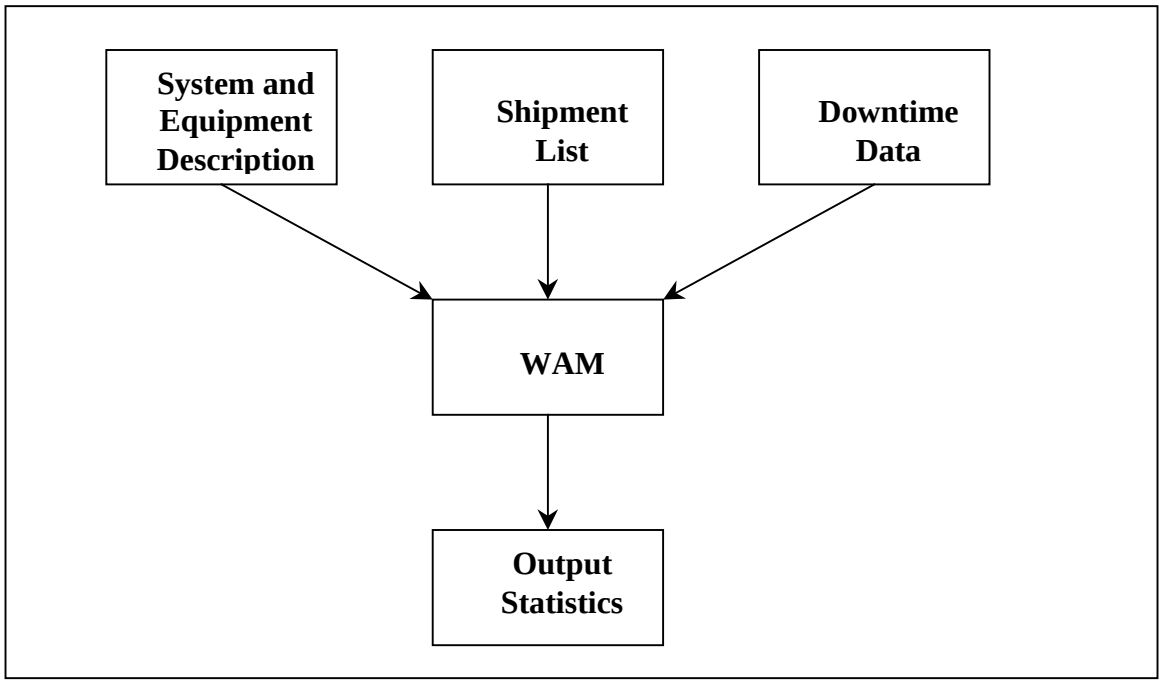
Tonnage-transit time curves for the other locks on the system were developed using fewer runs per tonnage level. The number of runs per tonnage level varied from a low of 6 at very low traffic levels to a high of 12 at higher traffic levels.

Periodically, a WAM run will produce a transit time that appears grossly incorrect when compared to other runs at that tonnage level. Such a run is known as an "outlier". Outliers occur when an extreme value is generated from a processing time distribution. For example, it is extremely unlikely that a number is generated that is, say, 10 standard deviations from the mean. However, given the fact that thousands of random numbers are generated in each run, and almost two hundred runs are made to create one curve, it becomes reasonably possible that a number will be generated that is 10 standard deviations from the mean. Outliers are considered anomalies and are discarded from the statistics set. About 90 percent of the curves generated during this analysis did not have an outlier. In all of the cases where an outlier appeared, only one appeared per curve.

1.3.2 A Closer Look

Figure 4 provides a schematic diagram of the WAM process. The model requires three major types of input data, the description and characteristics of the waterway system and the towboats, barges and commodities that will be using the system, a list of cargo shipments using the system, and a description of the frequency and duration of downtime events.

Figure 4
The WAM Process



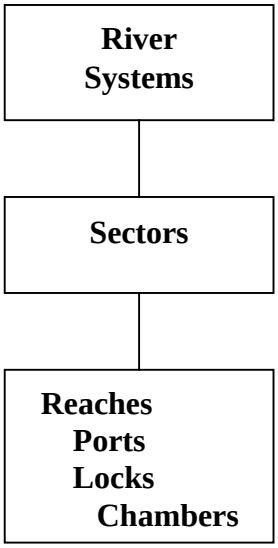
1.3.2.1 System and Equipment Description

<u>1.3.2.1.1 System Description</u>. The system description includes the location, size and operating characteristics of all relevant components of the system. The waterway network used in this analysis is represented in the WAM by a hierarchy of elements shown in **Figure 5**.

Ports and locks are called nodes and represent points on the river system. A reach is an unrestricted section of the waterway between two nodes. Ports and locks have zero length, reaches have non-zero lengths.

Sectors and river systems serve to organize these lower-level elements into convenient units for processing and analysis. A sector is an unbranched section of the network which contains one or more reaches, ports or locks, and typically extends from one river junction to another junction or to a system endpoint. This organization allows the WAM to be used as a system simulator or as a single lock (sector) simulator. For this particular study, the WAM was used as a single lock simulator.

Figure 5
System Hierarchy of Elements



The most important part of the system network is the lock being simulated. It is the locks that are the focus of this investment study. Therefore, a great deal of time and effort goes into defining the locks as thoroughly and accurately as possible. Items that must be defined include the number of chambers and their dimensions, the processing times of each chamber, and the way interference occurs between chambers when they are used concurrently. The number and dimensions of the chambers is easily defined. Section 4, Development of Input Data, provides detailed descriptions of how processing times and interference characteristics are developed.

1.3.2.1.2 Equipment Description. The WAM allows towboats and barges to be classified based on several attributes. For the purposes of this analysis, the most important attributes assigned are the length and width and capacity. These attributes are used by WAM to determine the number of cuts needed to process a vessel, and the tonnage served by that vessel. The WAM determines the number of cuts by comparing the lock chamber size with the number and size of the towboat and barges in a shipment. **Tables 1** and **2** show the towboat and barge classifications used in this analysis. Note that barge capacity is taken directly from data reported in Waterborne Commerce Data, and may perfectly agree with the theoretical capacity.

Table 1
Towboat Classifications

Type	Description	Avg. HP	Length (ft)	Width (ft)
1	0 - 1200	905	68	23
2	1201 - 1750	1582	93	28
3	1751 - 2100	1857	95	29
4	2101 - 2750	2329	109	33
5	2751 - 2750	3199	126	34
6	3801 - 4800	4191	141	36
7	4801 - 5800	5402	158	42
8	5801 -10000	6001	150	45
9	Recreation Boat	100	20	10

Table 2
Barge Classifications

Type	Description	Capacity (Ktons)	Length (ft)	Width (ft)
Hopper				
1	Irregular	867	135	27
2	Regular	1069	175	26
3	Stumbo	1121	195	26
4	Jumbo	1669	195	35
5	Covered Jumbo	1764	195	35
6	Super Jumbo	2106	245	35
7	Giant Jumbo	3329	260	52
Tanker				
8	Jumbo Tanker	1454	195	35
9	Squat (147') Tanker	1711	147	52
10	Medium (175') Tanker	2317	175	54
11	Large (260') Tanker	2820	260	52
12	Super (290') Tanker	3295	290	54

1.3.2.2 Shipment List

The shipment list is a stream of demands which are input to the WAM during execution. It is produced by an external program, the shipment list generator program It contains the time the shipment enters the system, the ports of origin and destination, commodity type, tonnage, barge and towboat type, and the number of barges. Important fleet assumptions and operating procedures are built into the shipment list. This includes tow configuration distributions, tow boat arrival patterns, and recreation boat arrival patterns. The ultimate objective of the shipment list generator is to produce shipment lists that closely reflect known fleet characteristics such as barges per tow, tons per tow, tow arrivals per day, and recreation boat arrival patterns. Shipment lists were developed for all locks using 1992 LPMS and WCSC data, and therefore, reflect the characteristics of that year. A complete description of how the shipment lists are generated is provided in Section 4.4.

1.3.2.3 Downtime List

The third critical input into the WAM model is downtime. The WAM has the ability to model downtimes as an integral part of the modeling process. Downtime is defined as the time a chamber is unavailable for the lockage of vessels. It includes the time a chamber is "down" due to routine minor maintenance, hardware malfunction, weather, etc. Each lock on the Ohio River has it's own characteristic baseline downtime file. The LPMS data contains a historical record of downtime at each of the Corps' locks. The normal downtime just described is considered to be a baseline condition. This baseline condition amounts to 1 to 4 percent of downtime per year, depending on the lock.

For this study, downtime files were also developed which incorporate specifically selected closure durations. These durations were selected in concert with engineering and operations personnel to represent typical closure durations experienced during major maintenance events. The selected durations were added to the baseline downtime file described above. By running the WAM with all these downtime files, a family of curves was developed that represents the tonnage-transit time relations for full operation as well as many major maintenance event durations.

1.3.3 Simulation Module

The simulation module is the operational heart of the analysis. It initializes the waterway system based on the system and equipment descriptions discussed in Section 1.3.2.1, processes each shipment in the shipment list, records statistics for the generation of performance output reports, and creates files for post-processing by other programs. A Users Manual that describes this module in detail is available upon request.

1.3.4 WAM Output Reports

The statistics that are gathered during the simulation process are used to generate reports on lock utilization and delay, towboat and barge utilization, port activity and detailed traffic summaries. The statistics gathering function is distributed throughout the model and effectively operates in parallel with the simulated activity. For example, associated with each lock chamber are tow and barge counters and accumulators for totaling the chamber usage time. **Table 3** shown on the next 6 pages shows the type of information available from one run of the WAM. In addition to the summary data shown in Table 3, WAM also has the ability to create a lockage by lockage semicolon delimited file that can be imported into a database. This output option enables analysis of a run in minute detail.

Table 3
WAM Output Example

RUN 127 08/17/1999 14:12:40 U.S. ARMY CORPS OF ENGINEERS - INLAND NAVIGATION SIMULATION PAGE 1
Myers_Auxhb_00

R-1 LOCK UTILIZATION AND DELAY: Myers Without Project Condition (365.0 DAYS)

LOCK	CHAMBER OPERATIONS	TOWS	BARGES FULL	BARGES EMPTY	CARGO (KTONS)	LIGHT BOATS	RECR. CRAFT	DELAY (HR) (TOWS ONLY) AVG	DELAY (HR) (TOWS ONLY) MAX	QUEUE LENGTH (TOWS ONLY) AVG	QUEUE LENGTH (TOWS ONLY) MAX
SECTOR 1 Myers Existing 1											
1 Myers Existing	21698	12593	85423	54903	139688	3302	0	1.6	18.5	2.4	23
DOWNSTREAM	10849	6410	53163	17455	87711	1624	0	1.6	18.5	1.2	16
UPSTREAM	10849	6183	32260	37448	51978	1678	0	1.6	14.8	1.2	15
CHAMBER 1	13780	8319	59963	38070	97830	1724	0				
DOWNSTREAM	6890	4175	36945	11811	61064	869	0				
UPSTREAM	6890	4144	23018	26259	36766	855	0				
CHAMBER 2	7918	4274	25460	16833	41858	1578	0				
DOWNSTREAM	3959	2235	16218	5644	26647	755	0				
UPSTREAM	3959	2039	9242	11189	15212	823	0				

Table 3 (continued)
WAM Output Example

RUN 127 08/17/1999 14:12:40 U.S. ARMY CORPS OF ENGINEERS - INLAND NAVIGATION SIMULATION PAGE 2
Myers_Auxhb_00

R-1A LOCK/CHAMBER UTILIZATION REPORT (365.0 DAYS)

LOCK	PERCENT OF SIMULATION PERIOD LOCKAGE	+ INTERFERE	+ WAIT 4 TOW	+ TURNBACK	+ DOWNTIME	= TOTAL UTILIZATION	UNAVAILABILITIES NUMBER OF EVENTS	AVE DURA (DAYS)
SECTOR 1 Myers Existing 1								
1 Myers Existing	64.1	7.2	1.4	7.9	0.	80.5	0	0.
CHAMBER 1	65.3	10.5	2.1	8.7	0.	86.6	0	0.
CHAMBER 2	62.9	3.9	.6	7.1	0.	74.5	0	0.

Table 3 (continued)
WAM Output Example

RUN 127 08/17/1999 14:12:40 U.S. ARMY CORPS OF ENGINEERS - INLAND NAVIGATION SIMULATION PAGE 3
Myers_Auxhb_00

R-2 DETAILED LOCKAGE REPORT FOR SECTOR 1 LOCK 1 Myers Existing - CHAMBER 1 (365.0 DAYS)

LOCKAGE TYPE	NUM-BER	TOWS	BARGES FULL	BARGES EMPTY	BARGES TOTAL	CARGO (KTONS)	LIGHT BOATS	RECR. CRAFT	ENTRIES FLY	ENTRIES EXCHG	ENTRIES TRNBK	EXITS FLY	EXITS EXCHG	EXITS TRNBK	TIME (MIN) AVG	TIME (MIN) STD
SINGLE	8184	8184	59700	37697	97397	97392	110	529	1381	2404	4399	1582	2187	4415	39.94	12.58
DOWN	4127	4127	36768	11757	48525	60777	57	287	712	1201	2214	808	1103	2216	40.85	12.85
UP	4057	4057	22932	25940	48872	36615	53	242	669	1203	2185	774	1084	2199	39.01	12.23
DOUBLE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
DOWN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
MULTI-TOW	67	135	263	373	636	438	1	9	0	15	52	1	13	53	41.52	11.14
DOWN	24	48	177	54	231	287	0	4	0	6	18	1	5	18	45.04	12.43
UP	43	87	86	319	405	151	1	5	0	9	34	0	8	35	39.56	9.96
OPEN PASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
DOWN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
LIGHT/RECR	700	0	0	0	0	0	140	935	0	0	0	0	0	0	19.26	1.74
DOWN	343	0	0	0	0	0	70	451	0	0	0	0	0	0	19.30	1.83
UP	357	0	0	0	0	0	70	484	0	0	0	0	0	0	19.23	1.64
TOTAL	8951	8319	59963	38070	98033	97830	251	1473	1381	2419	4451	1583	2200	4468	38.33	13.30
DOWN	4494	4175	36945	11811	48756	61064	127	742	712	1207	2232	809	1108	2234	39.23	13.63
UP	4457	4144	23018	26259	49277	36766	124	731	669	1212	2219	774	1092	2234	37.43	12.89

VESSEL TYPE	NUMBER DELAYED	DELAY TIME (HR) ALL VESSELS AVG	ALL VESSELS STD	ALL VESSELS MAX	DELAYED VESSELS AVG	DELAYED VESSELS STD
TOWS	7036	1.64	1.94	18.53	1.94	1.96
DOWN	3498	1.63	1.97	18.53	1.94	2.00
UP	3538	1.66	1.91	14.83	1.94	1.93
LIGHT BOATS	232	2.73	3.02	16.25	2.95	3.03
DOWN	117	2.76	3.04	16.25	3.00	3.05
UP	115	2.69	3.01	14.65	2.90	3.03

Table 3 (continued)
WAM Output Example

RUN 127 08/17/1999 14:12:52 U.S. ARMY CORPS OF ENGINEERS - INLAND NAVIGATION SIMULATION PAGE 4
Myers_Auxhb_00

R-2 DETAILED LOCKAGE REPORT FOR SECTOR 1 LOCK 1 Myers Existing - CHAMBER 2 (365.0 DAYS)

LOCKAGE TYPE	NUM-BER	TOWS	BARGES FULL	BARGES EMPTY	BARGES TOTAL	CARGO (KTONS)	LIGHT BOATS	RECR. CRAFT	ENTRIES FLY	ENTRIES EXCHG	ENTRIES TRNBK	EXITS FLY	EXITS EXCHG	EXITS TRNBK	TIME (MIN) AVG	TIME (MIN) STD
SINGLE	1466	1466	2865	2702	5567	5465	9	66	653	289	524	673	279	514	36.86	12.24
DOWN	783	783	1698	1339	3037	3006	3	32	335	174	274	358	141	284	36.21	11.67
UP	683	683	1167	1363	2530	2459	6	34	318	115	250	315	138	230	37.61	12.83
DOUBLE	2806	2806	22593	14130	36723	36390	0	0	505	774	1527	541	664	1601	90.15	18.05
DOWN	1452	1452	14520	4305	18825	23640	0	0	257	380	815	273	333	846	93.03	18.98
UP	1354	1354	8073	9825	17898	12750	0	0	248	394	712	268	331	755	87.07	16.44
MULTI-TOW	1	2	2	1	3	3	0	0	0	0	1	0	0	1	59.00	0.
DOWN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
UP	1	2	2	1	3	3	0	0	0	0	1	0	0	1	59.00	0.
OPEN PASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
DOWN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
UP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.
LIGHT/RECR	1217	0	0	0	0	0	255	1248	0	0	0	0	0	0	19.19	2.02
DOWN	592	0	0	0	0	0	128	592	0	0	0	0	0	0	19.21	1.85
UP	625	0	0	0	0	0	127	656	0	0	0	0	0	0	19.17	2.16
TOTAL	5490	4274	25460	16833	42293	41858	264	1314	1158	1063	2052	1214	943	2116	60.19	34.41
DOWN	2827	2235	16218	5644	21862	26647	131	624	592	554	1089	631	474	1130	61.83	35.86
UP	2663	2039	9242	11189	20431	15212	133	690	566	509	963	583	469	986	58.44	32.72

VESSEL TYPE	NUMBER DELAYED	DELAY TIME (HR) ALL VESSELS AVG	ALL VESSELS STD	ALL VESSELS MAX	DELAYED VESSELS AVG	DELAYED VESSELS STD
TOWS	3554	1.64	2.00	17.07	1.97	2.04
DOWN	1896	1.66	2.02	17.07	1.95	2.05
UP	1658	1.62	1.98	14.22	2.00	2.02
LIGHT BOATS	141	.98	1.79	10.65	1.83	2.11
DOWN	66	.83	1.47	7.63	1.65	1.72
UP	75	1.12	2.05	10.65	1.99	2.40

Table 3 (continued)
WAM Output Example

R-7 INTERFERENCE REPORT (365.0 DAYS)

INTERFERENCE OCCURRING WHILE TOWS ARE APPROACHING

LOCK	TOTAL # OF TOWS	APPROACH AREA # OF TOWS	APPROACH AREA % OF ALL	APPROACH AREA AVE TIME (MIN)	GATE AREA # OF TOWS	GATE AREA % OF ALL	GATE AREA AVE TIME (MIN)	AVERAGE APPROACH TIMES WITH INT (MIN)	AVERAGE APPROACH TIMES WITHOUT INT (MIN)	AVERAGE APPROACH TIMES DIFFERENCE (MIN)
SECTOR 1 Myers Existing 1										
1 Myers Existing	12593	3503	27.82	13.65	261	2.07	22.14	16.63	12.38	4.25
DOWNSTREAM	6410	1876	29.27	13.42	222	3.46	23.15	17.51	12.78	4.73
UPSTREAM	6183	1627	26.31	13.91	39	.63	16.38	15.73	11.96	3.76
CHAMBER 1	8319	1618	19.45	16.24	156	1.88	19.41	15.73	12.21	3.52
DOWNSTREAM	4175	801	19.19	16.56	117	2.80	20.42	16.53	12.78	3.75
UPSTREAM	4144	817	19.72	15.91	39	.94	16.38	14.93	11.64	3.29
CHAMBER 2	4274	1885	44.10	11.42	105	2.46	26.19	18.38	12.70	5.68
DOWNSTREAM	2235	1075	48.10	11.08	105	4.70	26.19	19.34	12.78	6.56
UPSTREAM	2039	810	39.73	11.88	0	0.	0.	17.34	12.62	4.72

R-7 INTERFERENCE REPORT (365.0 DAYS)

INTERFERENCE OCCURRING WHILE TOWS ARE CHAMBERING

LOCK	TOTAL # OF TOWS	# OF TOWS	% OF ALL	AVE TIME (MIN)	AVERAGE CHAMBERING TIMES WITH INT (MIN)	AVERAGE CHAMBERING TIMES WITHOUT INT (MIN)	AVERAGE CHAMBERING TIMES DIFFERENCE (MIN)
SECTOR 1 Myers Existing 1							
1 Myers Existing	12593	0	0.	0.	19.77	19.77	0.
DOWNSTREAM	6410	0	0.	0.	20.18	20.18	0.
UPSTREAM	6183	0	0.	0.	19.34	19.34	0.
CHAMBER 1	8319	0	0.	0.	9.90	9.90	0.
DOWNSTREAM	4175	0	0.	0.	9.98	9.98	0.
UPSTREAM	4144	0	0.	0.	9.82	9.82	0.
CHAMBER 2	4274	0	0.	0.	38.97	38.97	0.
DOWNSTREAM	2235	0	0.	0.	39.23	39.23	0.
UPSTREAM	2039	0	0.	0.	38.69	38.69	0.

Table 3 (continued)
WAM Output Example

R-7 INTERFERENCE REPORT (365.0 DAYS)

INTERFERENCE OCCURRING DURING CHAMBER TURNBACKS

LOCK	TOTAL # OF CHTB	# OF CHTB	% OF ALL	AVE TIME (MIN)	AVERAGE TURNBACK TIMES WITH INT (MIN)	WITHOUT INT (MIN)	DIFFERENCE (MIN)
SECTOR 1 Myers Existing 1							
1 Myers Existing	7257	0	0.	0.	11.44	11.44	0.
EMPTY	3551	0	0.	0.	11.00	11.00	0.
FILL	3706	0	0.	0.	11.87	11.87	0.
CHAMBER 1	4829	0	0.	0.	9.47	9.47	0.
EMPTY	2408	0	0.	0.	9.51	9.51	0.
FILL	2421	0	0.	0.	9.44	9.44	0.
CHAMBER 2	2428	0	0.	0.	15.36	15.36	0.
EMPTY	1143	0	0.	0.	14.13	14.13	0.
FILL	1285	0	0.	0.	16.46	16.46	0.

R-7 INTERFERENCE REPORT (365.0 DAYS)

INTERFERENCE OCCURRING WHILE TOWS ARE EXITING

LOCK	TOTAL # OF TOWS	APPROACH AREA # OF TOWS	% OF ALL	AVE TIME (MIN)	GATE AREA # OF TOWS	% OF ALL	AVE TIME (MIN)	AVERAGE EXITING TIMES WITH INT (MIN)	WITHOUT INT (MIN)	DIFFERENCE (MIN)
SECTOR 1 Myers Existing 1										
1 Myers Existing	12593	1721	13.67	10.14	1280	10.16	26.08	15.28	11.25	4.04
DOWNSTREAM	6410	1045	16.30	10.45	121	1.89	19.75	13.36	11.28	2.08
UPSTREAM	6183	676	10.93	9.66	1159	18.74	26.74	17.28	11.21	6.07
CHAMBER 1	8319	997	11.98	10.87	1280	15.39	26.08	16.22	10.90	5.32
DOWNSTREAM	4175	575	13.77	11.85	121	2.90	19.75	12.71	10.51	2.20
UPSTREAM	4144	422	10.18	9.53	1159	27.97	26.74	19.74	11.29	8.45
CHAMBER 2	4274	724	16.94	9.13	0	0.	0.	13.47	11.92	1.55
DOWNSTREAM	2235	470	21.03	8.73	0	0.	0.	14.57	12.73	1.84
UPSTREAM	2039	254	12.46	9.88	0	0.	0.	12.27	11.04	1.23

1.4 DEVELOPMENT OF INPUT DATA

1.4.1 Data Sources

The primary sources of data for this analysis are the Lock Performance Monitoring System (LPMS) data, Waterborne Commerce Statistics Center (WCSC) data, interviews with lock personnel, and interviews with towboat pilots and other people that are familiar the navigation conditions. LPMS data is collected at each lock site by the Corps of Engineers and includes detailed information on many aspects of vessel lockages. WCSC data is reported by towing companies and compiled and maintained by the Corps of Engineers.

1.4.2 Lock Processing Time

Processing time is defined as the time a lock is devoted to serving a particular vessel. It does not include the time a vessel waits in queue while the lock is devoted to other vessels. Vessel processing is simulated in the WAM by four sequential periods of time. They are in order of occurrence, the approach, the entry, the chambering and the exit. A vessels total processing time, which is added to its delay time to get the transit time, is the sum of the approach, entry, chambering and exit times. **Table 4** shows the correlation between LPMS recorded times, and WAM component times.

Table 4
WAM – LPMS Correlation

WAM Component	LPMS Times Used
Approach	Start of Lockage to Bow Over Sill
Entry	Bow Over Sill to End of Entry
Chambering	End of Entry to Start of Exit
Exit	Start of Exit to End of Lockage

The Lock Performance Monitoring System, which collects data at every lock, provides the detailed processing times used by WAM. Processing time data is retrieved from the LPMS system and grouped in the following manner. Fly and exchange approaches are combined and referred to as long approaches. Turnback approaches are referred to as short approaches. Similarly, fly and exchange exits are combined and referred to as long exits. Turnback exits are referred to as short exits. A total of six processing time groups must be developed for each chamber, direction and lockage type, meaning a total of 36 groups must be developed for the typical Ohio River lock, 12 for the main chamber, which has only single cut lockages, and 24 for the auxiliary chamber, which has single and double cut lockages. In addition, special groups are developed for recreational lockages, chamber turnbacks, knockout and setover lockages, and multi-vessel lockages.

Each processing time group is analyzed by a software program that "fits" the sample data to mathematical probability distributions. The software performs several "goodness-of-fit" tests, and ranks the "fit" distributions. The analyst then reviews the results and selects the "best fit" distribution.

Processing time distributions were developed from several different years of LPMS data. Generally, 1990 was used for main chamber distributions for Huntington and Pittsburgh District locks, since 1990 was the most recent year available in which accurate *detailed* LPMS times were recorded. In Louisville District, 1992 was used as the base year because it was the most recent year available, and it coincided with the Waterborne Commerce Statistics year used to create the shipment list. Many different years were used to develop auxiliary chamber distributions. Double cut lockages occur only in years when the main chamber is down for major maintenance. Therefore, auxiliary chamber distributions were developed from data in years where the main chamber was down for maintenance.

1.4.3 Lock Interference Characteristics

The WAM has the ability to account for interference that may occur between vessels at multi-chamber locks. Interference parameters are site specific, and are generally determined through interviews with people that know the facility very well, such as lock operators and lock masters, or pilots that transit the area frequently. Two general types of interference were modeled in this study, approach area interference, and gate area interference. The WAM also has the ability to model interference between the filling and/or emptying cycles of the chambers, but this ability was not needed for this study.

Approach area interference occurs in the area between the arrival point and the lock walls. In most cases this "approach area" is a "one-tow-at-a-time" area. For example, if a downbound tow is making an approach to the main chamber, an upbound tow will usually not be able to make an exit from the auxiliary chamber until the approaching tow is on the guard wall, and is therefore, out of the approach area. Approach area interference is a Yes or No proposition, either a prudent navigator will take the action, or they will not.

Gate area interference occurs when a tow, or part of a tow, is waiting along the wall near the gates. This occurs during turnback approaches, and during multi-cut lockages. Gate area interference is not a Yes or No proposition. The determination of whether an action can occur is associated with the length of vessel that is waiting at the gates. For example, it may be reasonable for a downbound vessel to approach the main chamber if a vessel is waiting at the upper gates of the auxiliary chamber, but only if the vessel at the auxiliary is less than 600 feet long.

Note that interference can only occur between two tows. Recreational vessels 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.

All interference information was obtained through face-to-face interviews with at least the lock master from each lock. In many cases, other lock operators with many years experience at the site were also included in the interviews.

Addendum 1 presents a sample interference questionnaire that is used during the interview process. It also contains other questions which the analyst uses to better understand the operation of the lock and identify site specific problems that may need to be addressed.

Table 5 presents the gate interference parameters used for Myers and Greenup. The questions should be read as "an action can take place if the length of tow at the other gate is less than or equal to the length indicated". The approach areas at Myers and Greenup is a one-tow-at-a-time area.

Table 5
Gate Area Interference Parameters

Gate Area Interference Question	Myers	Greenup
1. Upbound Exit from Main – Length at Upper Aux Gate	400	600
2. Downbound Exit from Main – Length at Lower Aux Gate	600	600
3. Upbound Exit from Aux – Length at Upper Main Gate	1200	1200
4. Downbound Exit from Aux – Length at Lower Main Gate	1200	1200
5. Upbound Approach to Main – Length at Lower Aux Gate	600	600
6. Downbound Approach to Main – Length at Upper Aux Gate	600	600
7. Upbound Approach to Aux – Length at Lower Main Gate	1200	1200
8. Downbound Approach to Aux – Length at Upper Main Gate	1200	0

1.4.4 Fleet Characteristics

The important characteristics of the vessel fleet are the dimensions of the barges and their distribution by type, the average tonnage per loaded barge, the average number of barges per tow, the percent of barges that are empty, the average tons per tow, and the number of recreation boats. **Table 6** is a summary of the 1992 Myers and Greenup vessel fleets.

TABLE 6
Characteristics of the Vessel Fleet

Item	J. T. Myers	Greenup
Tons/Loaded Barge	1,554	1,538
Barges/Tow	11.3	10.9
% Empty Barges	38.8%	38.9%
Tons per Tow	10,725	10,282
Number Lightboats	515	486
Number Rec Boats	2,724	720

Source Data 1992 LPMS

1.4.4.1 Barge Types

The predominant barge type at Myers and Greenup is the jumbo. These barges measure 195 feet in length and 35 feet in width and account for 68 and 85 percent, respectively. While the fleet consists largely of jumbo barges, other types of barges move through these two locks. Most numerous among these are the covered jumbo and tanker barges which vary in length from 147 feet to 297 feet and width from 35 feet to 54 feet. **Table 7** shows the barge loadings by barge type and Myers and Greenup.

TABLE 7
Barge Loadings by Type

		J. T. Myers		Greenup	
		Tons per Barge		Tons per Barge	
Barge Type	Dimension	Upbound	Downbound	Upbound	Downbound
Hoppers					
Irregular	135' x 27'	514	304	561	625
Regular	175' x 26'	1,592	1,571	1,375	1,357
Stumbo	195' x 26'	1,050	1,301	1,222	1,114
Jumbo	195' x 35'	1,403	1,423	1,371	1,460
Covered Jumbo	195' x 35'	1,335	1,645	1,520	1,633
Super Jumbo	245' x 35'	-	2,521	-	1,612
Giant Jumbo	260' x 52'	-	2,902	-	2,198
Tankers					
Covered	195' x 35'	2,054	1,010	2,266	1,435
147	147' x 52'	2,106	1,860	2,088	2,632
175	175' x 54'	3,028	2,243	3,103	3,021
264	264' x 50'	2,950	2,523	1,540	2,186
297	297' x 54'	2,807	3,227	2,628	2,325

Source Data 1992 LPMS

1.4.4.2 Tow Size Distribution

In 1992, the average tow size at Myers and Greenup was 11.3 and 10.9 barges per tow, respectively. The input shipment list consists of uniform tows i.e., each tow contains only one barge type. In addition, the barges are either all loaded or all empty**. Table 8** shows the tow size distribution for each barge type for the existing fleet. The numbers in the upbound and downbound columns indicate, for each barge type and direction of movement, the percent of tows that moved with a particular size fleet.

TABLE 8
Tow Size Distribution

Barge Type	Barges per Tow	J. T. Myers Percent Upbound	J. T. Myers Percent Downbound	Greenup Percent Upbound	Greenup Percent Downbound
Irregular	1-4	40.5	48.3	71.1	66.7
	5-8	26.2	15.2	17.0	0.0
	9-12	9.4	19.6	0.0	33.3
	13-16	4.1	10.0	11.9	0.0
	17-36	19.8	6.9	0.0	0.0
Regular	1-4	57.1	56.0	100.0	33.3
	5-8	42.9	16.0	0.0	66.7
	9-12	0.0	0.0	0.0	0.0
	13-16	0.0	28.0	0.0	0.0
	17-36	0.0	0.0	0.0	0.0
Stumbo	1-4	0.0	12.6	0.0	0.0
	5-8	0.0	0.0	0.0	49.2
	9-12	0.0	0.0	0.0	49.2
	13-16	74.0	87.4	78.3	1.6
	17-36	26.0	0.0	21.7	0.0
Jumbo	1-4	5.7	2.1	5.4	28.9
	5-8	2.2	6.8	9.5	20.5
	9-12	4.1	18.9	25.8	19.7
	13-16	87.7	72.0	56.7	30.7
	17-36	0.3	0.2	2.6	0.2
Covered Junbo	1-4	4.6	8.6	16.4	46.9
	5-8	6.6	13.2	21.3	23.7
	9-12	13.2	24.2	16.4	12.6
	13-16	74.6	52.7	45.8	16.1
	17-36	1.0	1.3	0.1	0.7
Super Jumbo	1-4	0.0	0.0	0.0	0.0
	5-8	0.0	0.0	0.0	0.0
	9-12	100.0	100.0	0.0	0.0
Giant Jumbo	1-4	0.0	0.0	0.0	0.0
	5-8	100.0	100.0	100.0	100.0
	9-12	0.0	0.0	0.0	0.0

TABLE 8 (cont'd.)
Tow Size Distribution

Barge Type	Barges per Tow	J. T. Myers Percent Upbound	J. T. Myers Percent Downbound	Greenup Percent Upbound	Greenup Percent Downbound
Covered Tanker	1-4	2.4	18.4	50.4	52.3
	5-8	18.7	9.4	23.5	8.6
	9-12	34.4	38.6	23.0	23.2
	13-16	43.7	33.6	3.1	15.9
	17-36	0.8	0.0	0.0	0.0
147 Tanker	1-4	28.6	39.7	31.5	49.5
	5-8	26.9	13.4	44.7	28.6
	9-12	25.0	32.9	23.8	20.4
	13-16	19.5	14.0	0.0	1.5
175 Tanker	1-4	34.5	81.7	37.4	29.7
	5-8	44.1	10.1	29.2	39.6
	9-12	14.9	8.2	30.5	30.7
	13-16	6.5	0.0	2.9	0.0
264 Tanker	1-4	67.6	82.8	70.0	90.6
	5-8	26.2	17.0	30.0	9.4
	9-12	6.2	0.2	0.0	0.0
290 Tanker	1-4	84.8	85.8	35.6	50.1
	5-8	12.7	14.1	50.9	46.2
	9-12	2.5	0.1	13.5	3.7

1.4.4.3 Percent Empty

Percent empty indicates the level of backhaul opportunities. Fifty percent empty indicates the absence of backhauls, i.e., barges move loaded through the lock in one direction and return empty in the opposite direction. LPMS data indicates that 38.8 percent of all barges transiting Myers are empty and 38.9 percent of all barges transiting Greenup are empty. (See **Table 9**)

TABLE 9
Percent Empty

Barge Type		J. T. Myers			Greenup	
		Upbound	Downbound		Upbound	Downbound
Hoppers						
Irregular		28.3	57.8		58.6	34.9
Regular		23.8	42.9		2.3	69.2
Stumbo		50.5	8.3		58.8	64.0
Jumbo		69.5	62.3		58.2	18.2
Covered Jumbo		83.6	12.7		21.8	22.5
Super Jumbo *		100.0	100.0		100.0	100.0
Giant Jumbo		51.0	49.0		54.8	93.8
Tankers						
Covered		39.5	87.1		53.8	55.4
147		19.6	74.6		34.9	31.7
175		63.4	48.6		11.0	23.9
264		49.7	65.9		17.6	32.4
297		63.0	86.2		46.6	43.0

* Very small number of super jumbo barges to accurately determine percent empty

1.4.4.4 Operating Policies

The maximum number of cuts allowed at Myers and Greenup Projects are single cut through the main chamber and double cuts through the auxiliary chamber. This equates to a 15 jumbo barge tow as the largest size tow that can single cut through the main chamber. Double cuts are, currently, only allowed through the auxiliary chamber during periods of closure of the main. In 1992, 7,231 tows locked through Myers with 94 percent locking through the main chamber, the remaining 6 percent were smaller tows that single locked through the auxiliary.

1.4.5 Downtime

The normal downtimes used for these analyses represent a typical year, that is a year in which the chamber had no major maintenance. Periodically, the chamber must be dewatered for major maintenance. These major maintenance events, especially of the main chamber, greatly effect the operation of the facility. During the maintenance periods delays increase rapidly and remain high until the main chamber is reopened. These major maintenance events were handled by developing separate tonnage/transit time curves.

1.4.5.1 Normal Downtime

Because "normal" downtime can vary considerably from year to year, a normalized baseline downtime file was developed after a review of downtime events recorded in LPMS from 1990-1994. Month of occurrence, cause, and duration of outage were compiled. These data were converted into statistical probabilities, which were used to generate a list of downtime events by date, lock and duration. The result of this analysis was the development of baseline downtime file having a downtime of one percent to four percent for locks located on the Ohio River. Table 10 shows the number of events and percent of time that each chamber is down at Myers and Greenup.

Table 10
Normal Downtime, Myers and Greenup

Lock/Chamber	Number of Events	Percent Time Down
Myers Main	194	3.0%
Myers Auxiliary	45	0.7%
Greenup Main	37	1.3%
Greenup Auxiliary	15	0.4%

1.4.5.2 Maintenance Downtime

Maintenance related chamber closures can cause very high delays. For example, a 19 day Greenup main chamber closure in 1998 caused 1 ½ times as much delay as all of 1997. To more accurately reflect the impacts of such closures, tonnage-transit time curves are now developed for many closure durations. For example, if a three-day closure of a particular lock's main chamber is projected, a three day closure of the main chamber is added into the normal downtime file, and a tonnage-transit time curve is created. This curve is then used in the system economic model any year that the chamber experiences a three day closure.

All main chambers on the Ohio River, with the exception of Emsworth, have filling and emptying systems that have two culverts and valves for filling and two culverts and valves for emptying. This means that the chamber can continue to operate, albeit at half speed, when a filling or emptying valve is taken down for maintenance. Therefore, half-speed curves were also developed for chambers that have dual systems.

Curves corresponding to different closure durations and half speed durations have been developed for each project, resulting in a unique family-of-curves for each project on the Ohio River main stem. The tonnage-transit time curves developed from these runs are used in the economic analysis when periods of closure occur. **Table 11** shows the various downtime files, and tonnage-transit time curves, developed for each lock.

Table 11

OHIO RIVER MAIN STEM

LOCK MAINTENANCE CLOSURE PERIODS

	MAIN CHAMBER DAYS OF CLOSURE											HALF SPEED DAYS OF HALF SPEED		
Project	1	3	5	10	15	30*	45*	60*	90*	180	365	30	45	90
Emsworth	X	X	X	X	X	X	X	X	X	X	X			
Dashields	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Montgomery	X	X	X	X	X	X	X	X	X	X	X	X	X	X
New Cumberland	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pike Island	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hannibal	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Willow Island	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Belleville	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Racine	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Robert C. Byrd	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Greenup	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Meldahl	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Markland	X	X	X	X	X	X	X	X	X	X	X	X	X	X
McAlpine	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cannelton	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Newburgh	X	X	X	X	X	X	X	X	X	X	X	X	X	X
John T. Myers	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Smithland	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Olmsted	X	X	X	X	X	X	X	X	X	X	X	X	X	X

* Arrival Rescheduling Used

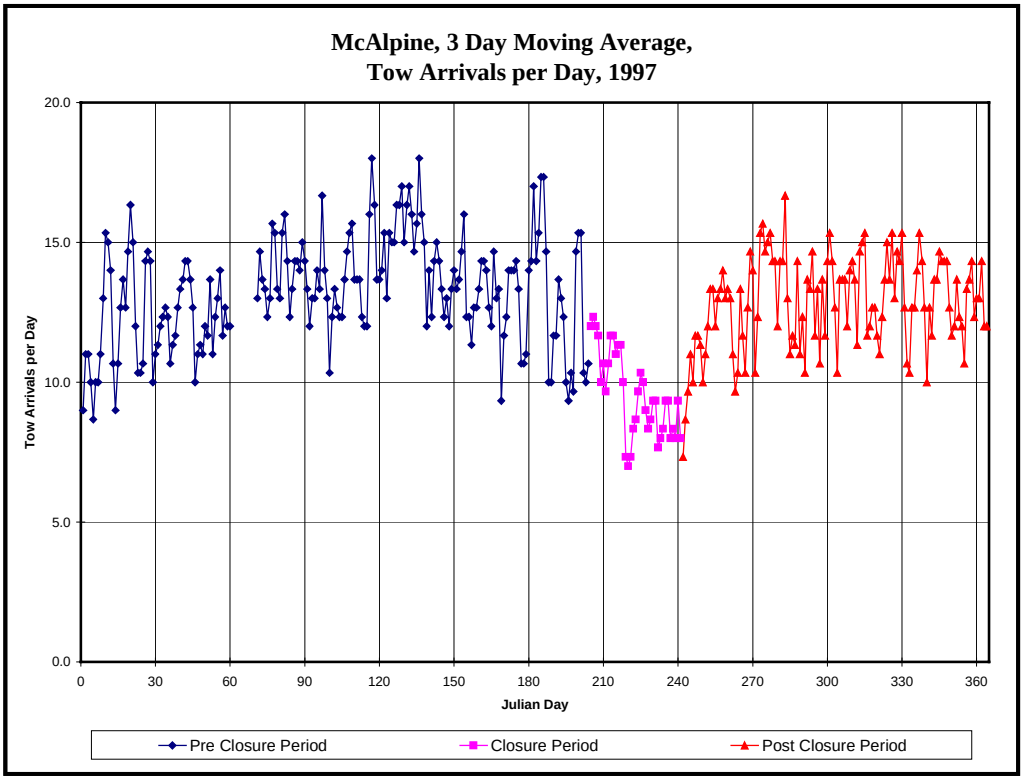
	AUXILLIARY CHAMBER DAYS OF CLOSURE											HALF SPEED DAYS OF HALF SPEED		
Project	1	3	5	10	15	30*	45*	60*	90*	180	365	30	45	90
Emsworth	X	X	X	X	X	X	X	X	X	X	X			
Dashields	X	X	X	X	X	X	X	X	X	X	X			
Montgomery	X	X	X	X	X	X	X	X	X	X	X			
New Cumberland	X	X	X	X	X	X	X	X	X	X	X			
Pike Island	X	X	X	X	X	X	X	X	X	X	X			
Hannibal	X	X	X	X	X	X	X	X	X	X	X			
Willow Island	X	X	X	X	X	X	X	X	X	X	X			
Belleville	X	X	X	X	X	X	X	X	X	X	X			
Racine	X	X	X	X	X	X	X	X	X	X	X			
Robert C. Byrd	X	X	X	X	X	X	X	X	X	X	X			
Greenup	X	X	X	X	X	X	X	X	X	X	X			
Meldahl	X	X	X	X	X	X	X	X	X	X	X			
Markland	X	X	X	X	X	X	X	X	X	X	X			
McAlpine	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cannelton	X	X	X	X	X	X	X	X	X	X	X			
Newburgh	X	X	X	X	X	X	X	X	X	X	X			
J.T. Myers	X	X	X	X	X	X	X	X	X	X	X			
Smithland	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Olmsted	X	X	X	X	X	X	X	X	X	X	X	X	X	X

* Arrival Rescheduling Used

1.4.5.3 Tow Arrival Rescheduling

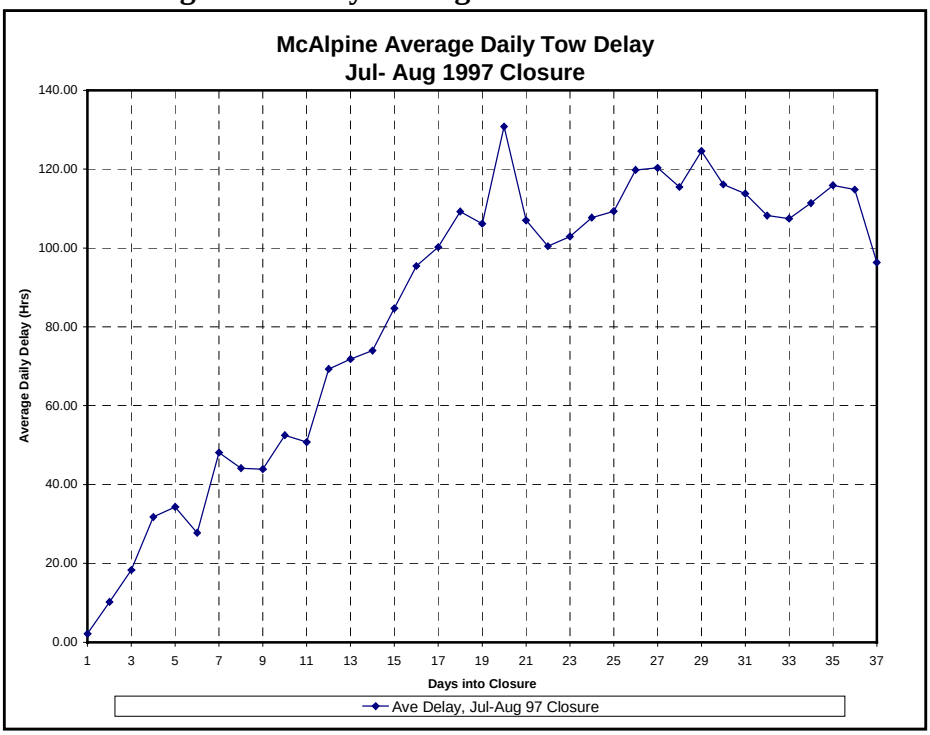
Shipment lists generated by the shipment list generator are valid for normal lock operation conditions. During normal lock operations tows arrive randomly, that is, the interarrival times are exponential random variables. When long, disruptive closures occur however, tow arrival patterns change. For example, in 1997 the main chamber at McAlpine was closed for maintenance for about 36 days. **Figure 6** shows a three-day moving average of the daily tow arrivals for all of 1997. It clearly shows that the number of tow arrivals decreased during the closure period, especially near the end of the closure.

Figure 6
McAlpine Tow Arrivals per Day, 1997



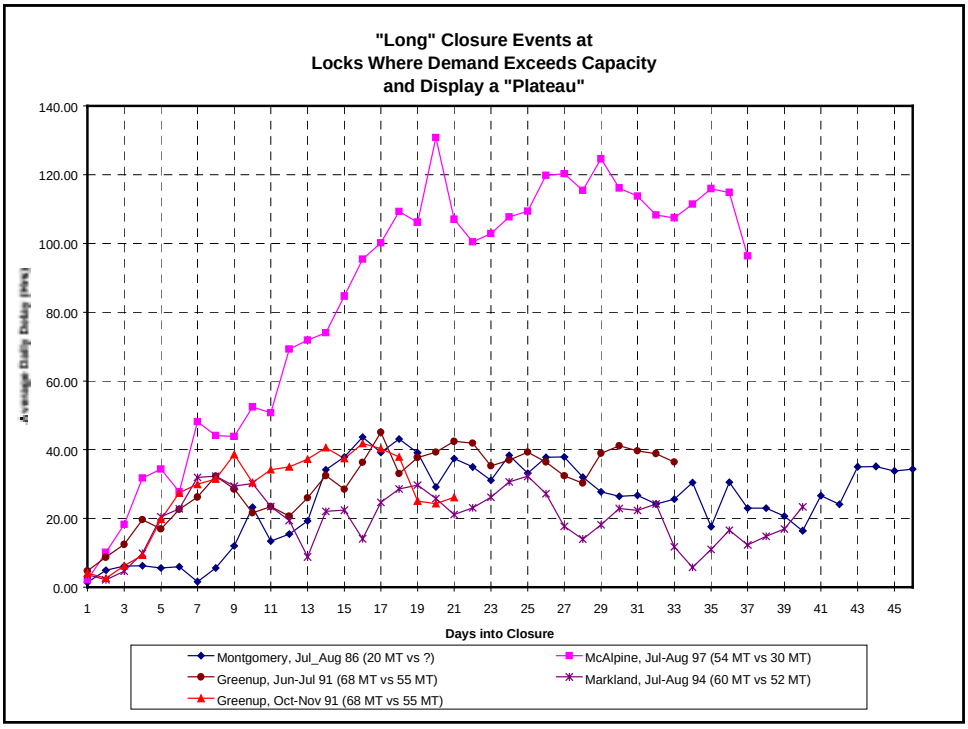
The decrease in arrivals late in the closure leads to a leveling-off of delays**. Figure 7** shows the average daily delay at McAlpine during the 1997 main chamber closure. The figure shows that delays increased rapidly until about the 20th day into the closure. From that point on, the average delay remains about the same. This plateau corresponds to the period in Figure 6 where the arrivals were the lowest.

Figure 7
Average Tow Delay During 1997 Maintenance Closure



The decreased number of tow arrivals near the end of long disruptive closures, and the associated delay plateau, is typical of long disruptive closures at Ohio River locks. **Figure 8** shows the average tow delay for several closure events.

Figure 8
Long Closures that Display a Plateau



What all this means from a simulation modeling point of view is that the shipment lists must be adjusted when long disruptive closures are being modeled. If the arrival rate is not decreased during the latter part of these closures, 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.

In order to determine the parameters and rules to use when making these adjustments, all Ohio River main chamber maintenance closures from the last 12 years were analyzed, a total of 35 events. In addition, several towing companies were interviewed to gauge how they reacted to the McAlpine closure of 1997, and how they would react to future long duration disruptive closures. The analysis and interviews resulted in several conclusions.

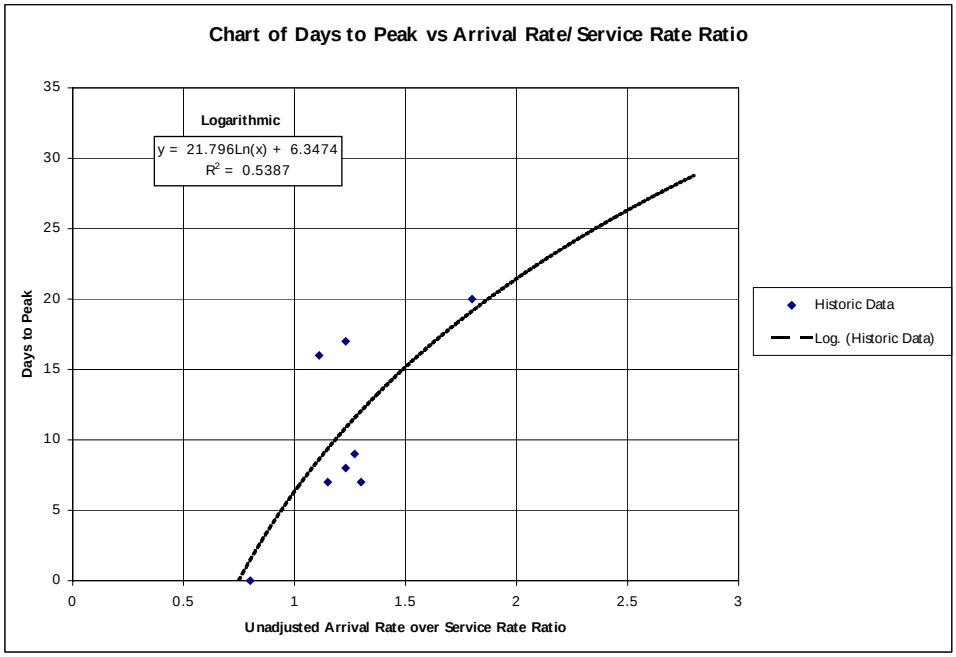
1. Anecdotal evidence from interviews with tow operators indicates that very little traffic diverts off the river. Some traffic reschedules so that it ships before the closure, some reschedules after the closure, and some cannot be rescheduled so it suffers the high delays.
2. Arrival patterns do not change for short duration events, even if the event is disruptive. This means that a short closure, say 5 days, will not result in tow rescheduling, even if the tow operators know that the closure will cause significant delays.
3. Arrival patterns do not change for non-disruptive events even if the duration is long. This means that a long closure, say 45 days, will not result in rescheduling if the project is able to serve the normal demand with minimal delays during the closure.
4. The buildup period, that time from the beginning of the event until rescheduling begins, is a function of the unadjusted demand and the service rate during the closure.
5. Fewer empty barges move through the project during the closure.

Based on the information developed from historic closures and the results of the interviews, the following method was developed to reschedule arrivals during closures.

After the shipment list is created, and before the WAM simulation begins, a program executes that determines whether shipments in the list need to be rescheduled. The program uses the shipment list, the downtime file, and a rules file. The rules file contains values for the trigger duration, the service level, the buildup duration, and the rescheduling window. The trigger duration marks the breakpoint between a closure event that would not cause rescheduling and one that *could*. The service level parameter represents the daily service rate of the facility, given the chamber closure. The buildup duration specifies parameters that allow the program to calculate the buildup duration, see **Figure 9**. The rescheduling window specifies where the rescheduled vessels move in time, either before or after the closure, or both.

The rescheduling program begins by reading the downtime file. If there are no chamber downtimes that exceed the trigger duration, the program terminates, and WAM begins execution using the unaltered shipment list. If the downtime file contains an event that exceeds the trigger duration, the program reads the shipment list and determines whether the arrival rate during the closure exceeds the service rate. If it does, the program determines the appropriate buildup duration, and randomly reschedules arrivals from the period between the end of the buildup and the end of the closures into the rescheduling window. This altered shipment list is then passed to the WAM.

Figure 9
Days to Peak vs Arrival Rate/Service Rate Ratio



The rules file parameter values were determined prior to production runs of the WAM. The trigger duration parameter was determined by review of the empirical data. In general it appears that closures longer than 15 days display some plateauing of delays, and those shorter than 15 do not display the plateau effect. Therefore, 16 days was selected as the trigger duration. This means that 15-day closure will not cause rescheduling, but 30-day closures will if the arrival rate exceeds the service rate. The buildup duration was determined to be a function of the relationship between the normal arrival rate and the service rate of the facility during the closure. The rescheduling window is assumed to be any other time during the year when a disruptive closure is not occurring.

1.5 VERIFICATION AND VALIDATION

This section presents describes the efforts made to verify that the analysis process is executing as designed, and producing valid estimates. According to Law and Kelton.[1] Verification is determining whether a simulation model performs as intended, i.e. debugging the program. Validation is determining whether a simulation model (as opposed to the computer program) is an accurate representation of the real world system under study.

The WAM has been used, modified and used again on navigation studies on the Ohio River and its tributaries for more than 15 years. During that time, detailed analysis of trace files, files that record the execution of the events that make up the simulation, has occurred many times. The program does execute as designed. It does not bomb. The components of the lockage do take place in the order they are intended. This detailed review of the operation of the program verifies that the program performs as intended.

[1] Simulation Modeling and Analysis Company, Tucson, Arizona

Validation of the WAM process is a more difficult undertaking. The analyst can only review the input and output and compare it to available data. For this study, the following measures were taken to insure the WAM process is producing valid results.

1. The shipment list was analyzed to insure the generated had the same characteristics of the actual 1992 fleet upon which it is based. This effort validates the shipment list generator.
2. Output was inspected to insure that the WAM was generating the correct processing times.
3. Output was inspected to insure that the WAM was predicting delays that compare well with measured delays.
4. Output was inspected to insure the tow arrival rescheduling program was performing as intended, and creating delays during disruptive closure that agree with measured data.

1.5.1 Fleet Validation

Table 12 shows a comparison between LPMS fleet data and shipment list generated data. It shows that the fleet generating program reproduced the tons per tow figure at Greenup very well, but missed the target by 3.6% at Myers. This means that WAM produced tonnages are 3.6% high, which will slightly understate the benefit of "with project" alternatives.

Table 12.
Fleet Validation Table

	Myers		Greenup	
Item	**LPMS**	**Generated**	**LPMS**	**Generated**
Tons/Loaded Barge	1,554	1,635	1,538	1,620
Barges/Tow	11.3	11.2	10.9	10.5
% Empty Barges	38.8%	39.4%	38.9%	39.4%
Tons per Tow	10,725	11,116	10,282	10,298
Number Lightboats	515	515	486	486
Number Rec Boats	2,724	2,787	720	776

1.5.2 Processing Time Validation

Table 13 compares the actual measured component processing times to those produced by WAM. The times compare quite well except for the auxiliary chamber 2 cut total processing times. There are two reason for this. First, 2 cut tows only occur when the main chamber is down. When the main chamber is down, queues build very quickly, and the service policy changes from First-In-First-Out to 6-Up 6-Down. This means that the vast majority of lockages occur with turnback approaches and turnback exits. Since turnback approaches and exits are so fast, the LPMS processing times are also fast. The second reason pertains only to Greenup. Historical LPMS data does not reflect the use of helper boats. Since helper boats have become a standard practice at high traffic locks, the times were adjusted to reflect what they would likely be with helper boats.

TABLE 13

WAM Simulation Component Processing Times (minutes)

Project	Chamber	No. of Cuts	Direction	Approach		Entry	Chamber	Exit		Total
				Long	Short			Long	Short	
J. T. Myers	Main	1	Up	21.2	3.7	9.5	9.1	9.1	7.7	43.5
		1	Down	21.9	4.8	9.4	9.1	10.2	8.0	44.7
	Auxiliary	1	Up	17.1	5.5	6.2	9.1	7.5	14.8	39.9
		1	Down	18.2	3.3	5.9	9.3	6.4	9.2	39.2
		2	Up	22.4	4.0	14.7	49.3	13.4	8.2	92.1
		2	Down	20.6	5.1	16.9	52.0	17.0	8.5	97.7
Greenup	Main	1	Up	18.8	4.6	10.2	10.8	10.9	9.7	46.4
		1	Down	20.0	9.5	10.4	10.9	11.1	9.9	49.2
	Auxiliary	1	Up	15.7	7.3	7.3	10.6	7.5	10.1	40.3
		1	Down	15.7	5.7	7.1	10.7	7.4	8.1	40.3
		2	Up	26.2	8.0	14.7	57.4	15.9	9.0	99.8
		2	Down	25.0	6.1	17.3	63.9	22.0	18.8	108.0

LPMS Data Component Processing Times (minutes)

Project	Chamber	No. of Cuts	Direction	Approach		Entry	Chamber	Exit		Total
				Long	Short			Long	Short	
J. T. Myers	Main	1	Up	20.2	4.1	11.9	8.3	11.5	8.5	42.2
		1	Down	21.6	5.0	11.7	8.0	11.9	9.4	44.0
	Auxiliary	1	Up	18.2	8.5	8.6	9.5	7.2	13.6	38.0
		1	Down	20.1	4.6	7.2	9.6	6.6	9.0	39.8
		2	Up	22.6	4.6	15.0	50.3	14.3	8.5	82.1
		2	Down	22.2	6.5	16.8	53.1	16.8	8.6	89.1
Greenup	Main	1	Up	18.5	4.6	10.3	10.8	10.9	9.8	47.4
		1	Down	20.1	9.4	10.4	10.9	11.1	10.1	50.1
	Auxiliary	1	Up	15.7	8.1	7.4	10.7	7.5	8.9	37.8
		1	Down	15.8	6.7	7.2	10.7	7.5	8.5	39.0
		2	Up	28.0	6.2	15.2	56.2	10.3	9.0	112.6
		2	Down	28.0 *	5.4	15.7	57.9	19.2	12.3	116.1

1.5.3 Delay Validation

As stated in section 1.3.1, the primary items of interest from any single WAM run are the transit time and tonnage processed. Section 1.5.1 presents the validation of the tonnage processed statistic, and Section 1.5.2 presents the validation of the processing time portion of the transit time. This section compares historic delays to those produced by the WAM process. Table 14 presents LPMS recorded delays during the 1990's, and the delay WAM predicts at current traffic levels. ***Bold italic*** years indicate a major chamber closure occurred in that year. If we ignore those years and average the remaining, the LPMS recorded delays are nearly double what WAM predicts. The primary reason for this is that WAM is run with the most efficient policies, such as 6-Up 6-Down, and double cut lockages are allowed in the auxiliary at all times.

Table 14
Historical Tow Delays

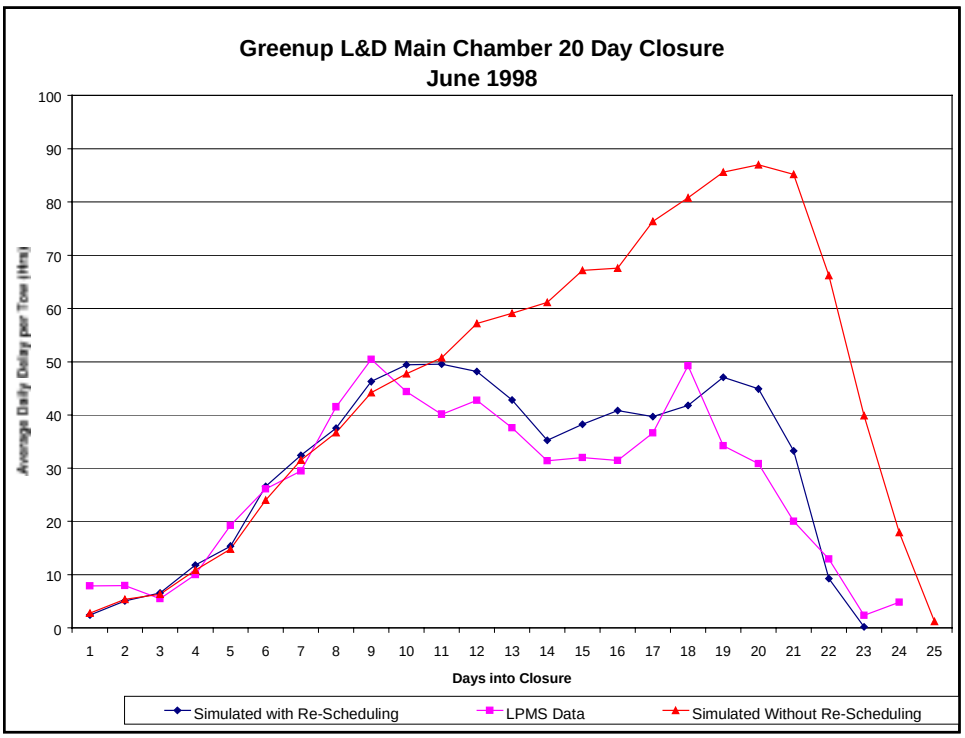
	1990	1991	1992	1993	1994	1995	1996	1997	1998	Average wo Closures	WAM
Myers	51.1	45.3	43.6	44.5	62.5	***63.8***	43.7	40.1	43.3	46.8	24.0
Greenup	25.0	***298.7***	35.8	41.4	***96.6***	45.0	44.5	52.7	***141.9***	40.7	20.0

Bold Italic indicates major closure year

1.5.4 Arrival Pattern Adjustment Validation

The WAM was run without arrival pattern adjustments and with arrival pattern adjustments. These results were compared to LPMS measured delays. Figure 10 shows the results of that comparison.

Figure 10
Arrival Pattern Adjustment Validation



1.6 RESULTS

1.6.1 Introduction

This section briefly describes alternatives analyzed for both without-project condition alternatives and with-project condition alternatives. The focus continues to be on J.T. Myers and Greenup Locks and Dams, though without-project capacity estimates were made for all Ohio River main stem locks. These estimates of without-project alternative capacities are critical inputs to system analyses aimed at identifying the most likely without-project condition for the main stem system.

1.6.2 Without-Project Alternatives

This study identified two measures that can be taken to insure that the locks are operating as efficiently as possible within the purview of the Corps of Engineers current authority. The two measures that can be taken are implementation of the optimum service policy and the use of the self help program. It was determined that the installation of mooring cells, which is within the authority of Corps and is a traditional without project alternative, would not reduce lock processing times.

1.6.2.1 Service Policy

Previous investigations have shown that the order in which vessels are served, known as the service policy, affects the tonnage-transit time characteristics of the facility. There are three types of service policy.

First In - First Out (FIFO): This policy serves vessels on a first come first serve basis. No regard is given to the vessel's direction. This is the standard policy.

N Up - N Down (NU-ND): This policy serves vessels based on the direction they are traveling. A specified number of vessels are locked in one direction, six for example. Then the same number of vessels is served in the other direction. This policy is usually more efficient than FIFO when there are many vessels in queue. A variation on this policy is based on number of hours in each direction instead of number of lockages.

Up – Down: This policy is often used at facilities that have twin identically sized chambers. One chamber serves all vessels going upbound and the other chamber serves all vessels going downbound.

The optimum lockage policy was identified for Myers and Greenup Lock and Dams. The results indicate that as traffic level increases the optimum lockage policy is 6U-6D. **Table 15** shows the capacity for the various service policies.

Table 15
Capacities for Various Service Policies
(1,000 Ktons)

Project	FIFO		3U-3D		6U-6D
J. T. Myers	166,173		166,974		174,212
Greenup	154,593		155,854		158,044

1.6.2.2 Self-Help

The self-help program has become standard operating procedure on the Ohio River whenever disruptive chamber closures occur. The self-help program uses towboats that are waiting in queue as helper boats. It reduces the chambering and exit lockage time components. LPMS data indicates that helper boats can save in excess of 10 minutes per lockage for tows having to double cut through auxiliary chambers. Runs were made with and without helper boats at Greenup. They showed that the capacity increased from 151.8 to 158.0 Million tons. Since there is very little cost to this program, it was deemed that helper boats are justified whenever the main chamber is closed, and demand exceeds the capacity of the auxiliary chamber, or when the time comes that the auxiliary chambers will have to serve 2-cut tows on a regular basis.

1.6.2.3 Without-Project Capacities

Table 16 shows the without project capacities that were developed for every lock on the Ohio River. Each of these capacities assumes that the 6U-6D lockage policy is used, and the self-help program is implemented if appropriate.

Table 16

Without Project Capacities

Projects	Capacity (in millions of tons)			Ave. Processing Time (in minutes)		
	Main	Aux.	Both	Main	Aux.	Both
Emsworth	31,530	14,971	40,430	68.7	133.5	63.8
Dashields	37,060	16,454	43,820	64.6	151.3	61.5
Montgomery	37,590	15,730	41,671	72.4	167.3	71.7
New Cumberland	85,416	40,950	119,511	50.6	87.4	60.1
Pike Island	104,006	51,766	147,323	43.3	74.7	52.1
Hannibal	114,366	63,418	169,704	48.1	82.6	58.0
Willow Island	118,200	59,113	159,800	46.2	88.8	58.4
Belleville	118,132	59,340	159,253	46.4	86.8	57.0
Racine	127,741	62,785	181,918	45.5	86.3	56.5
Byrd	98,568	59,407	148,468	49.6	84.0	58.7
Greenup	111,500	60,000	158,044	44.5	83.9	54.6
Meldahl	105,587	56,934	145,731	48.8	93.8	61.6
Markland	106,105	62,687	155,386	46.1	82.7	56.8
McAlpine	119,755	123,012	225,500	45.0	43.8	44.9
Cannelton	125,517	61,841	164,060	45.6	85.2	57.0
Newburgh	138,980	64,966	183,040	39.8	78.6	50.9
Myers	136,735	66,741	174,212	38.5	76.6	49.7
Smithland	128,301	128,957	246,699	40.1	39.9	43.9
Olmsted *	NA	NA	274,931	NA	NA	NA

1.6.2.4 Without Project Condition, Tonnage-Transit Time Families of Curves, Myers and Greenup

Figures 11-14 shows the families of curves that were developed for Myers and Greenup.

Figure 11
Myers Without Project Condition, Main Chamber Closure Family

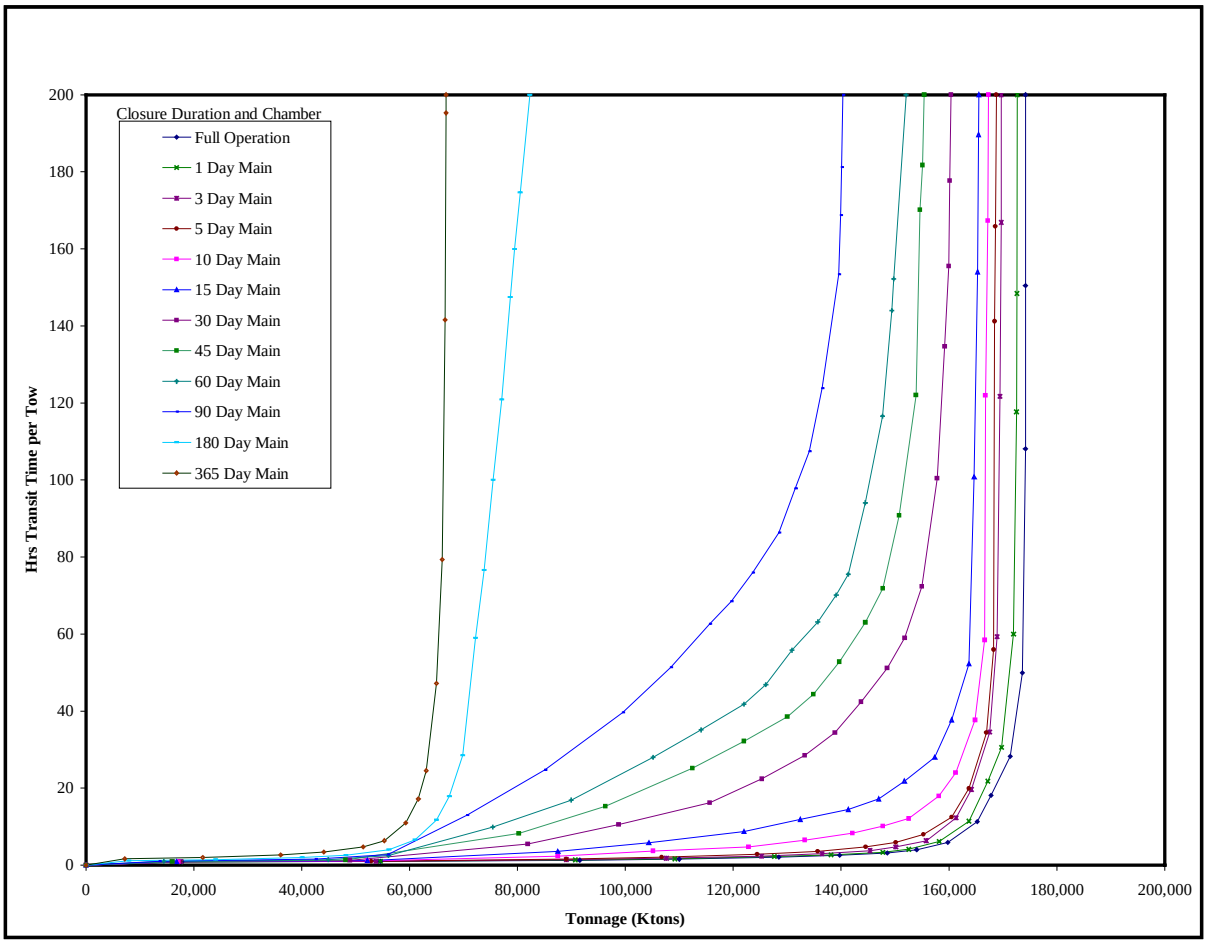


Figure 12
Myers Without Project Condition, Auxiliary Chamber Closure Family

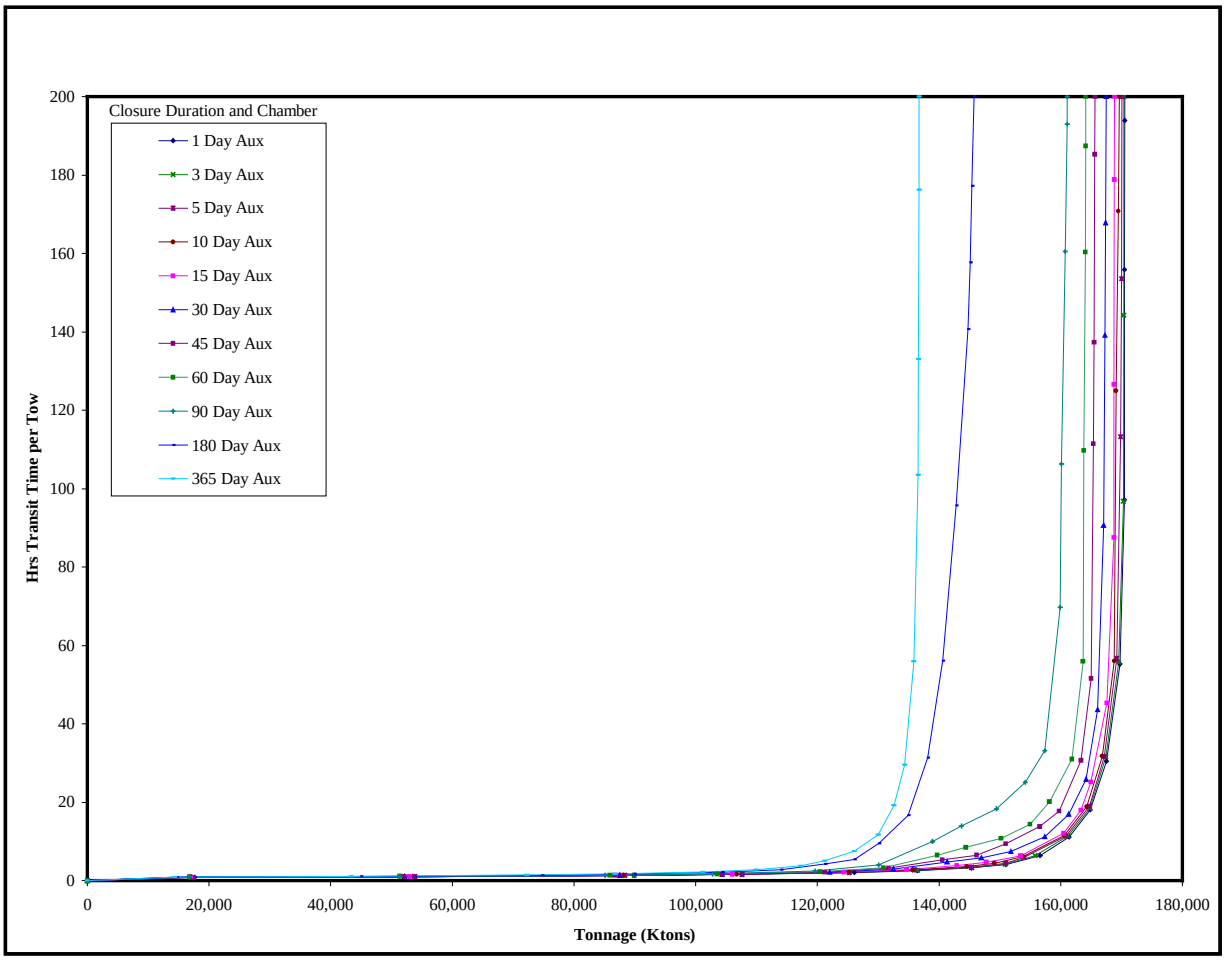


Figure 13
Greenup Without Project Condition, Main Chamber Closure Family

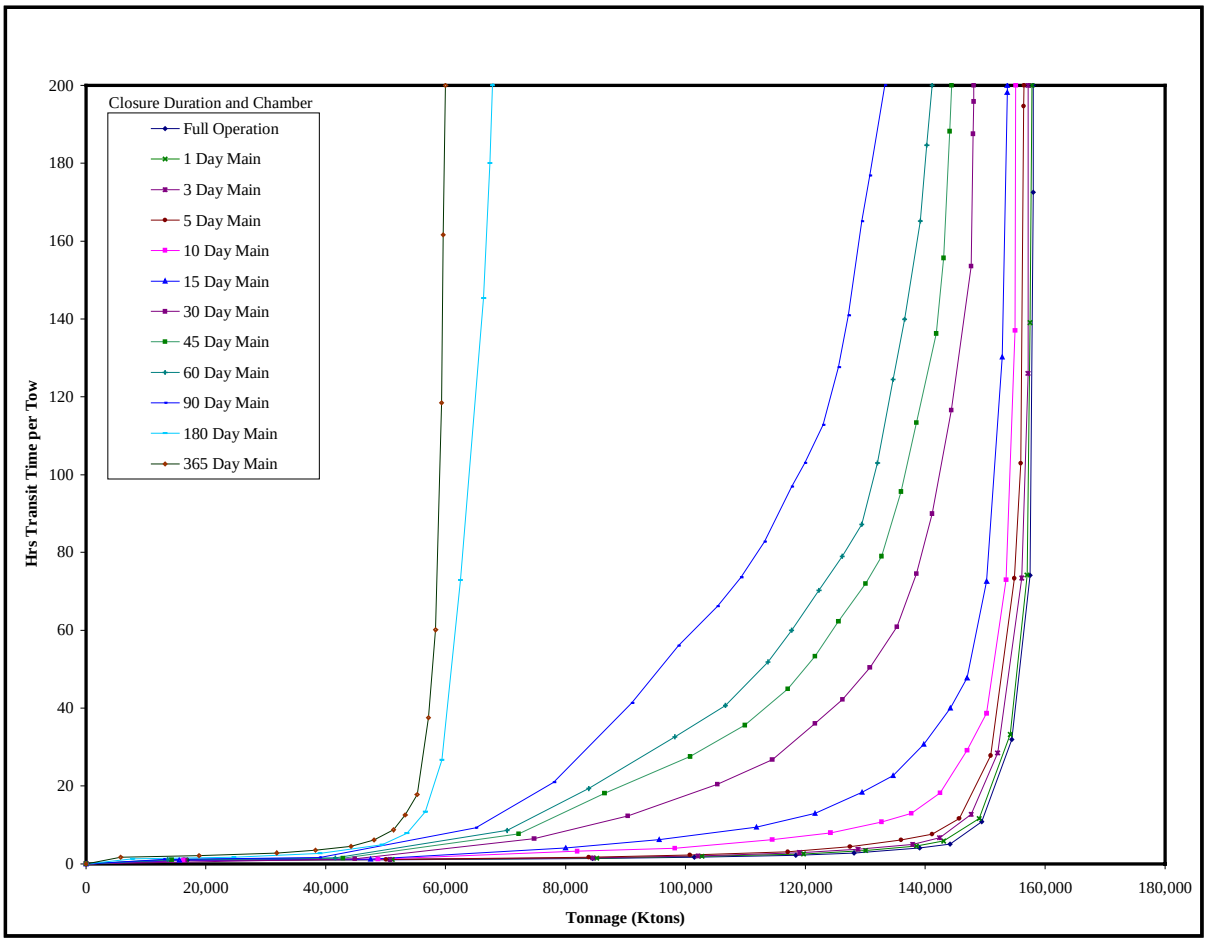
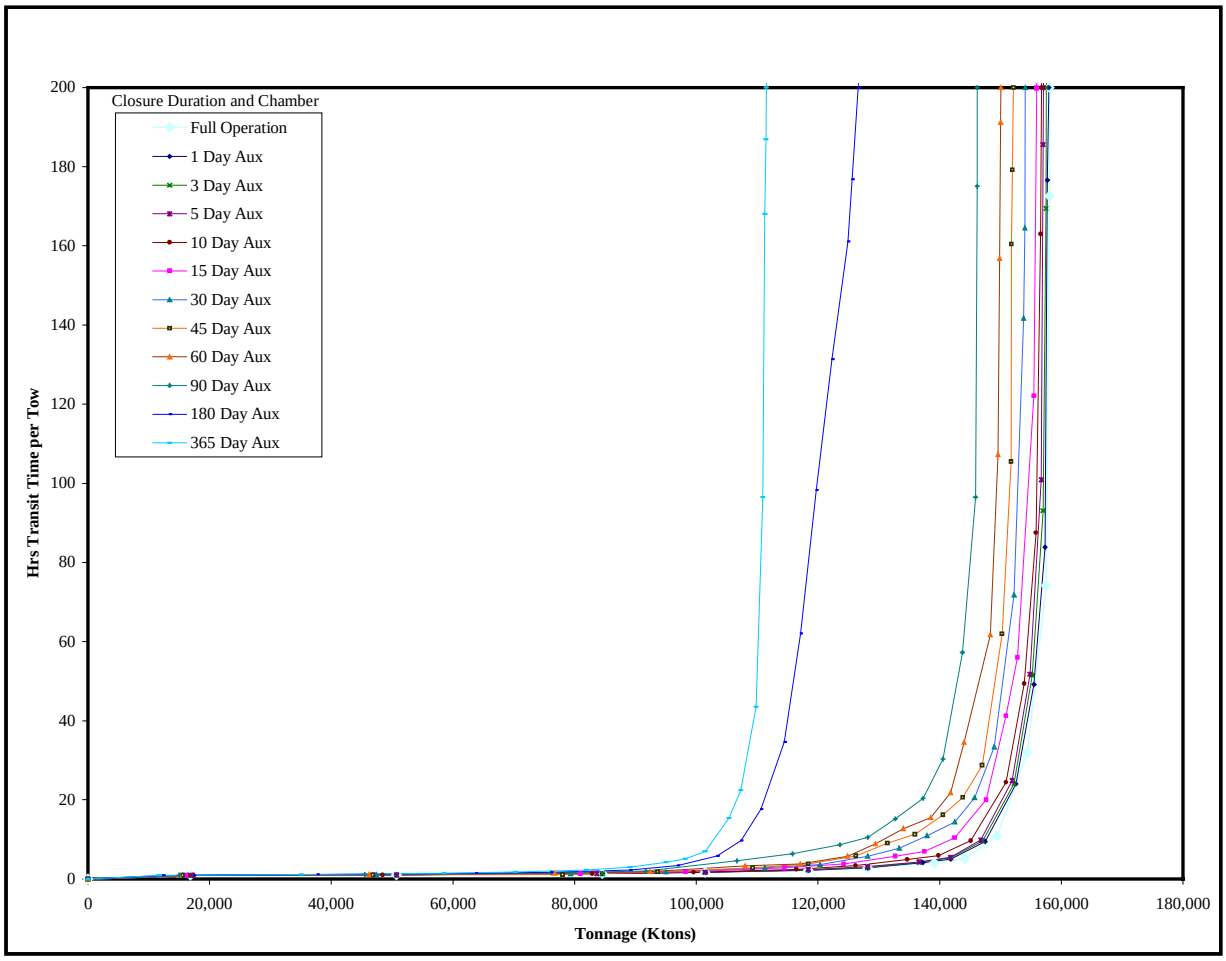


Figure 14
Greenup Without Project Condition, Auxiliary Chamber Closure Family



1.6.4 With-Project Alternatives

This interim report investigated seven with-project alternatives. They are, in order of added efficiency, guide/guard wall extension, the gate change-out system and Plans 1-5. Each of these alternatives is described in detail in the main report. Plan 3 and Plan 5 at Myers met all criteria required, and Plan 3 at Greenup met all criteria. Their family of curves are shown in Figures 15-20. **Table 17** is a summary of with-project simulation results for Myers and Greenup.

Table 17
With-Project Condition Alternatives
Summary of Simulation Results for Myers and Greenup

Projects	Capacity (in millions of tons)			Ave. Processing Time (in minutes)		
	Main Only	Aux. Only	Both	Main Only	Aux. Only	Both
A. J.T. Myers						
Plan 3	136,827	136,785	242,700	38.5	38.5	39.1
Plan 5	136,827	136,827	248,261	38.5	76.6	38.8
B. Greenup						
Plan 3	111,237	111,842	213,865	43.9	43.9	44.3
Plan 5	NA	NA	NA	NA	NA	NA

Figure 15
Myers Plan 3, Main Chamber Closure Family

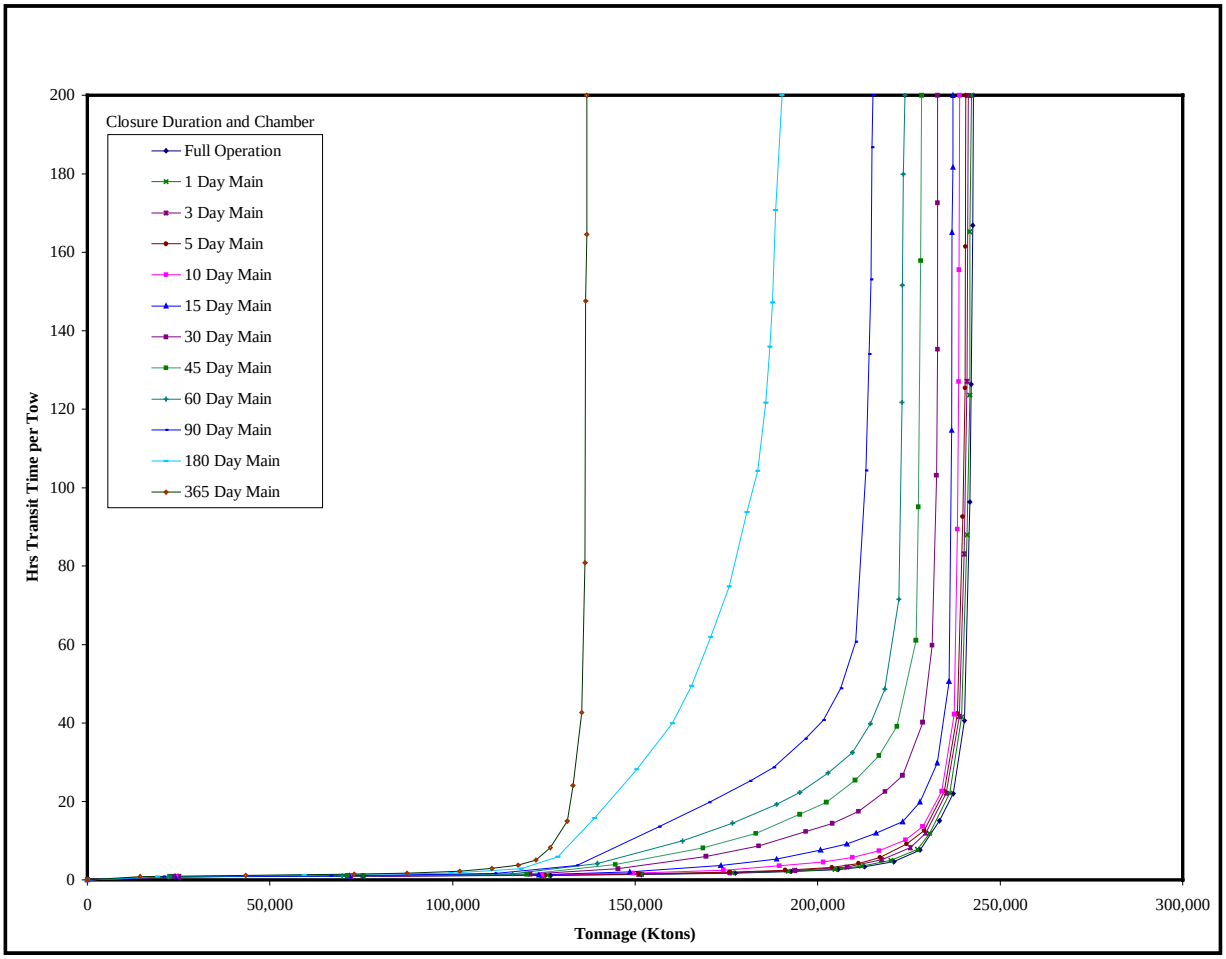


Figure 16
Myers Plan 3, Auxiliary Chamber Closure Family

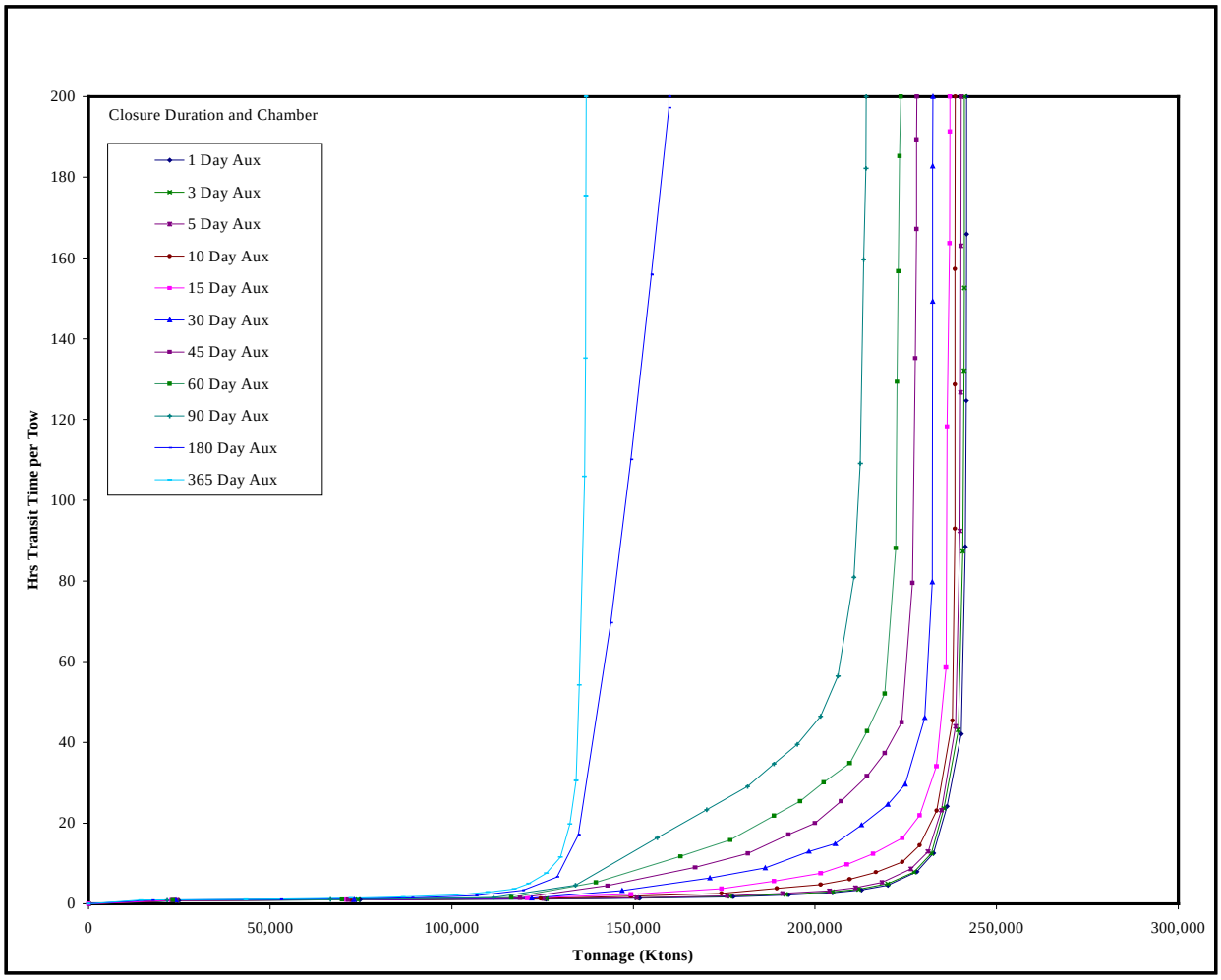


Figure 17
Myers Plan 5, Main Chamber Closure Family

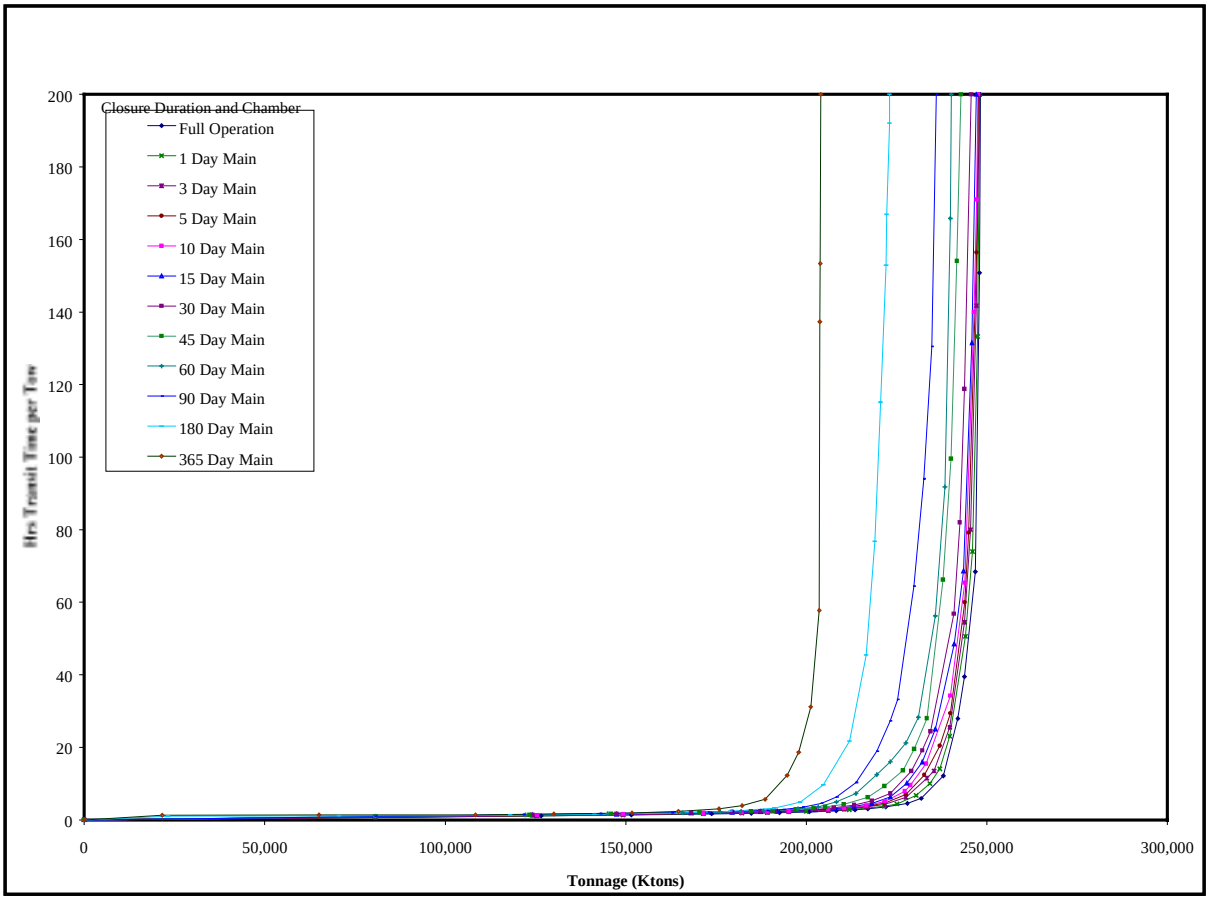


Figure 18
Myers Plan 5 Auxiliary Chamber Closure Family

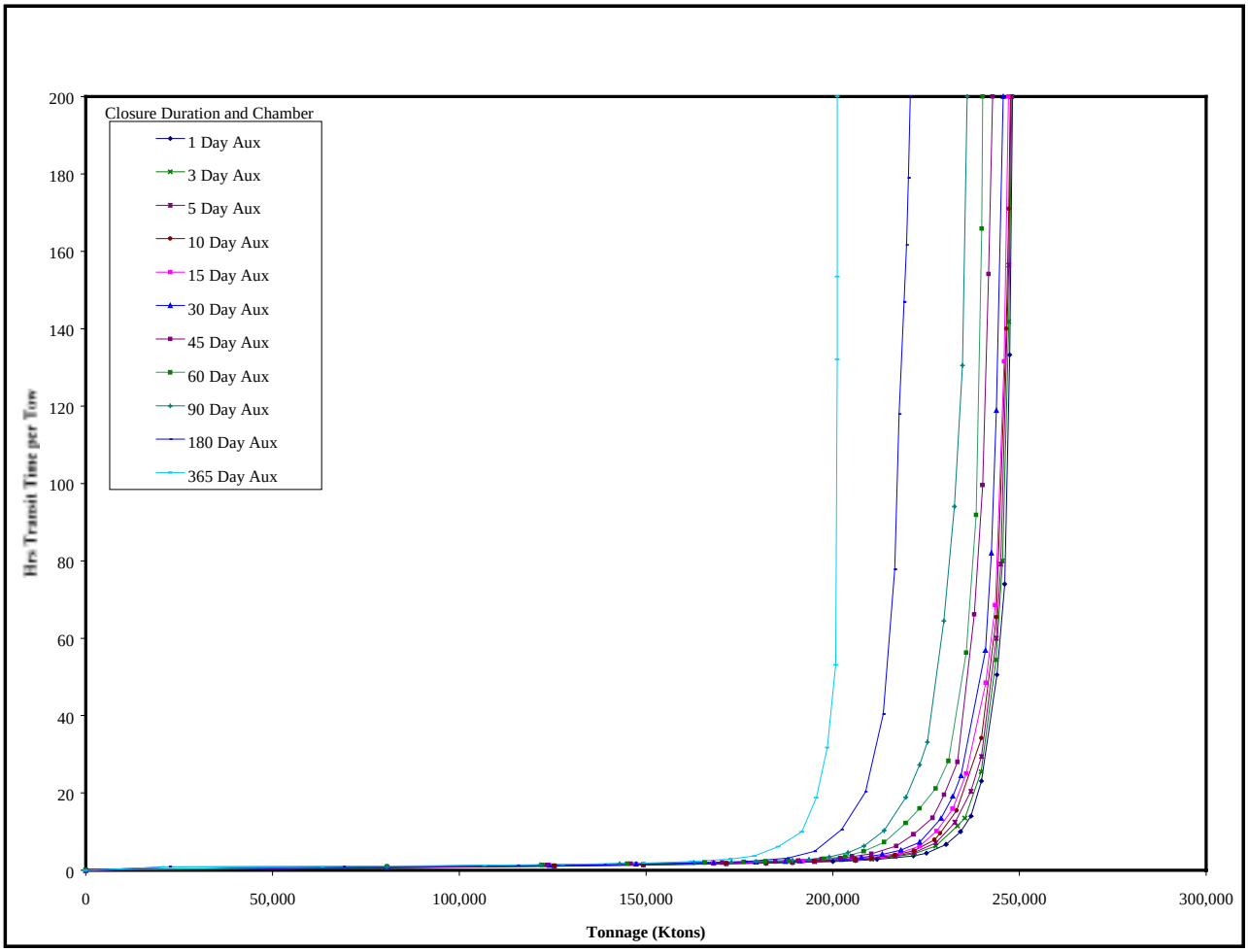


Figure 19
Greenup Plan 3, Main Chamber Closure Family

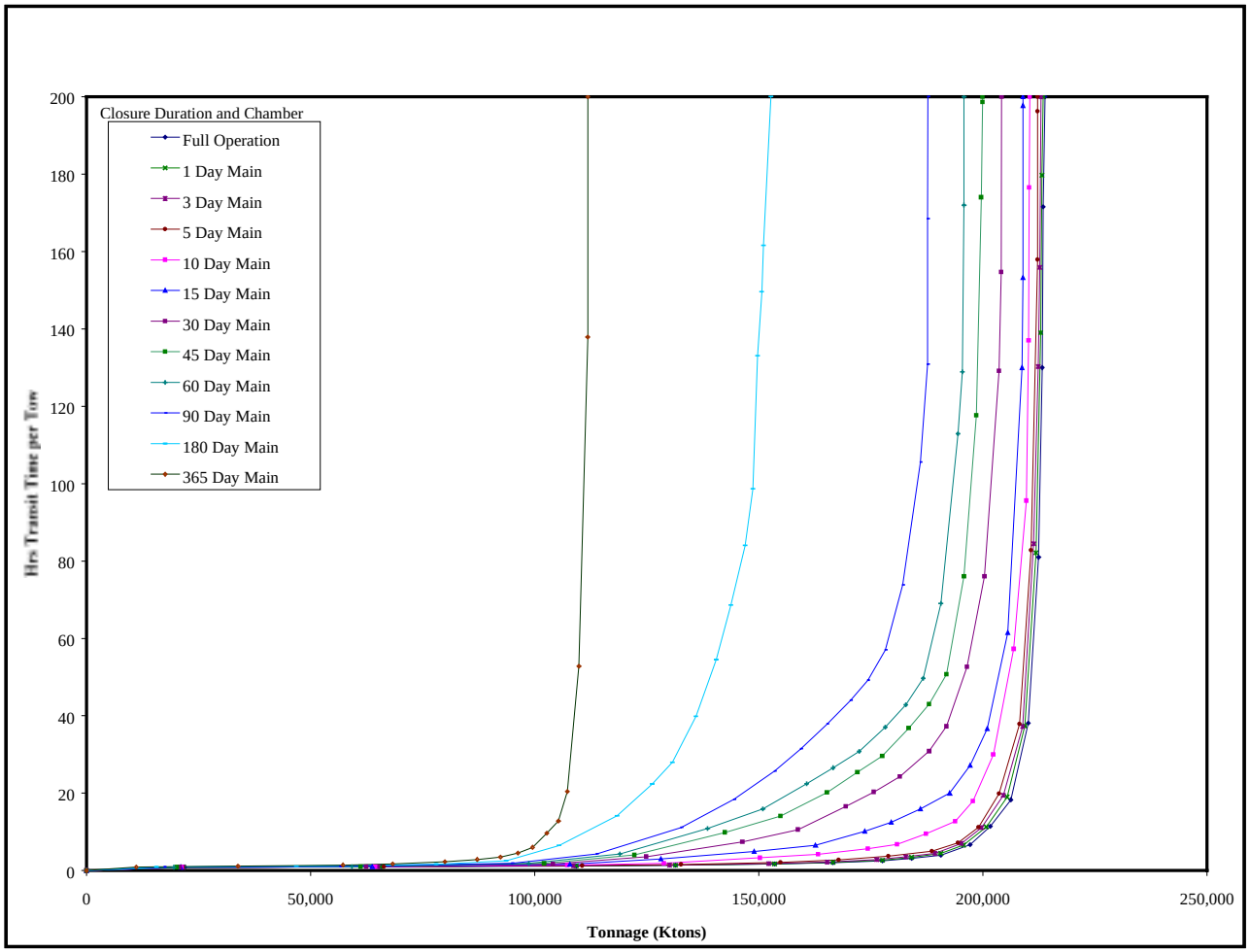
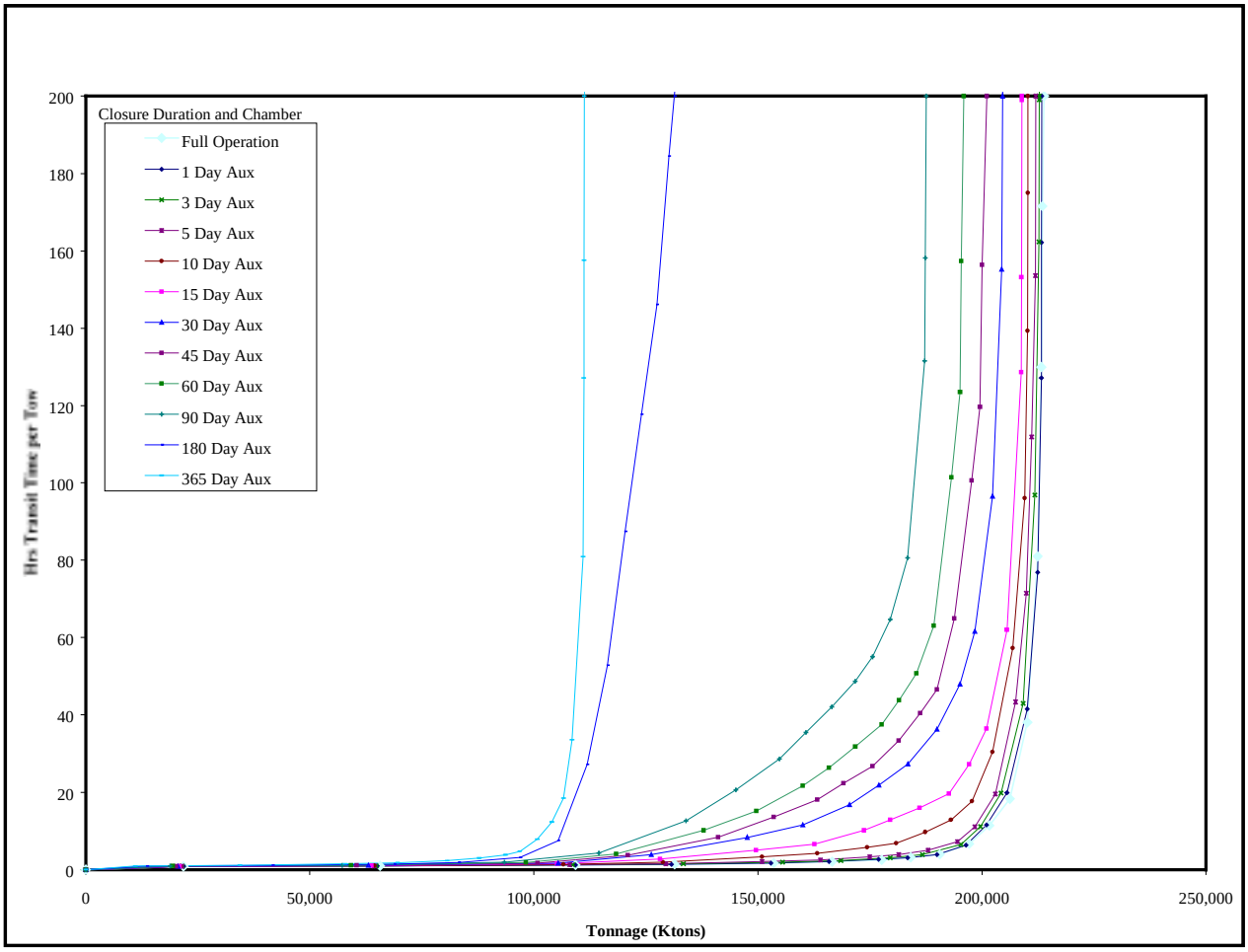


Figure 20
Greenup Auxiliary Chamber Closure Family



ATTACHMENT 2

LIFE CYCLE LOCK MODEL

2.1 INTRODUCTION

2.1.1 General

The Life Cycle Lock Model (LCLM) is a computer model designed to link engineering reliability with economic consequences and express the output as a single overall "economic" cost, which includes both repair costs and industry delay costs. The model is capable of performing calculations for a range of investment alternatives from fix-as-fails to up-front replacement. The least cost alternative is the economically preferred plan. LCLM results can be considered, along with other decision making criteria, in selecting a recommended plan for future operations, maintenance, and construction, on the Ohio River navigation system.

2.1.2 Guidance

Guidance on the evaluation of maintenance alternatives is provided in CECW-O, ER 1130-2-500 entitled "Project Operations, Partners and Support, Work Management Guidance and Procedures", dated 27 December 1996, Chapter 3, and Appendices B through F.

2.1.3 Methodology

The Guidance specifies consideration of the following in the evaluation of project features: 1) current condition and reliability, 2) the expected future condition and reliability, and 3) the consequences of unreliable performance. Six study steps were specified in the Guidance and are listed below, along with the manner of compliance in the ORMSS study:

(1) Step 1 – "estimate the probability of unsatisfactory performance for each feature". Engineering models were developed to generate reliability factors for each feature. Documentation of the hazard function models is provided in Engineering Appendices.

(2) Step 2 – “describe the consequences of failure”. Engineering, Operations, and Construction personnel with extensive backgrounds in lock and dam designs, operations, and construction developed the consequences of failure. The consequences are documented in Engineering Appendices and are displayed as values on the event trees.

(3) Step 3 – “develop an event tree that describes the possible outcomes from some initiating event”. The same personnel that developed the hazard functions developed event trees for each project feature. The event trees are graphical depictions of the paths of possible futures with some chance of occurrence.

(4) Step 4 – “estimate repair costs”. Cost engineers developed repair costs.

(5) Step 5 – “estimate the economic costs for each disruption”. The economic costs were estimated for each disruption by adding industry costs to repair costs. Industry costs were obtained from data developed by the Navigation Planning Center. Industry costs are the additional costs imposed on industry; these costs are most often represented by tow delay costs, though these are not the only category of impacts on industry that could be measured

(6) Step 6 – “combine the frequency of service disruption with the consequences of disruption”. Service disruptions were combined with the consequences of disruption through simulation modeling. The simulation model was designated the Life Cycle Lock Model (LCLM) and is documented in this appendix.

2.1.4 Alternatives

2.1.4.1 General Definitions

The analysis requires consideration of all reasonable alternatives with respect to the magnitude and timing of work. All alternatives are to be measured against the baseline condition, which is a fix-as-fails scenario. The baseline, or base condition as defined in the Guidance, is defined below. The definition was adhered to with the exception that it was not assumed to represent the without-project condition as it would in a “traditional” rehabilitation study. The baseline is:

> …the alternative which all other plans will be measured against. In comparison to other Corps planning studies, the base condition is synonymous with the "without-project” condition. The base condition assumes that the project will be operated in the most efficient manner possible without the proposed rehabilitation. Should the project benefit stream be interrupted due to unsatisfactory feature performance, it is assumed that emergency funds will be available to fix the feature. For the economic analysis, allowance must be made for the effect of the repair on the reliability of the feature. Considerable risk and uncertainty is inherent in the base condition. The timing, frequency, and consequences of system

disruption are all unknown and must be estimated. The analysis should explicitly show the effects of reasonable alternative assumptions concerning these variables.

Alternatives to the baseline are plans that vary in the timing and scope of repairs and "…give consideration to the choice of timing and extent of rehabilitation. Therefore, the approach is to develop alternatives to solve the problems."

2.1.4.2 Application in ORMSS

The baseline is a scenario in which it is assumed that normal operation and maintenance will continue, but extra-ordinary maintenance is not scheduled. Scheduled extra-ordinary maintenance is an alternative to the baseline and is represented as several variations that differ in the extent, frequency, and timing of the work. The economic evaluation measures the trade-off between scheduled expenditures of funds and delay costs to industry. The alternative that involves the least costs (expenditures plus delays) is the economically preferred alternative. The outer bounds of the alternatives are fix-as-fails, which has no scheduled extra-ordinary maintenance, and total up-front replacement, which maximizes scheduled extra-ordinary maintenance costs. Less extreme alternatives include repairs of less than total replacement and/or scheduling the work further into the future. All of these alternatives were analyzed using the LCLM.

A summary of the general categories of alternatives that were analyzed is provided in **Table 2-1**. Initially, each lock component was analyzed separately. The results were reviewed and different components were "bundled" for analysis as rehabilitation alternatives.

2.2 PROJECT FEATURES

The three major features of Ohio River navigation projects are the main lock chamber, the auxiliary lock chamber, and the dam. These three features, in turn, are composed of numerous systems such as the structural system of monoliths, electrical, mechanical, and other systems. The major systems, in turn, are comprised of multiple components that work as a series to allow the system to function, but which are generally independent of the reliability of other major systems. For example, the components in the electrical system include junction boxes, which, if one of them fails, could result in electrical problems throughout the project. However, it would have little or no effect on the condition of the valves, which is a separate project system. Based on a consideration of what could be considered "independent" systems, seven features were identified for independent reliability analysis (listed below). They are listed in **Table 2-2**.

TABLE 2-1
Alternative Maintenance Policies

Alternative	Repair	Synopsis
1. Baseline (Without-Project)		
Existing	more reactive than proactive	continue current practices into the future, reliability decreases so probability of failure increases
2. Component Replacement (With-Project)		
Upfront	more proactive than reactive	replace in year 2010 or sooner
Deferred	longer deferred, the more reactive	replace after year 2010
3. Rehabilitation (With-Project)		
Upfront	more proactive than reactive	replace more than one component in year 2010 or sooner
Deferred	longer deferred, the more reactive	replace more than one component after year 2010

TABLE 2-2
Project Features Evaluated for Reliability

Feature
1. Monoliths
2. Gates
3. Anchorages
4. Sills
5. Valves
6. Electrical System
7. Mechanical System
a. Gate Machinery
b. Valve Machinery
c. Hydraulic System

2.3 RELIABILITY

2.3.1 Probability of Failure

Reliability is estimated based on the output of engineer-developed models that mimic the operation of a structure and/or equipment. The models include all of the relevant forces and factors that affect the performance and survival of the item under investigation. Following an initial assessment, and generally concurrent with model development, is the acquisition of input data, which falls into three categories: 1) cycles of usage; 2) the site environment; and 3) original construction. Cycles of usage include items such as the number of times the lock is opened/closed to process traffic. The site environment include items such as freeze/thaw cycles, hydraulics, and water quality (e.g. acidity). Original construction includes items such as the use of non-air entrained concrete. Some project features are affected by all three factors; others by only one or two.

The models are run and failures by year are recorded for each of 50,000 or so life cycle runs. The total number of survivors in each year is divided by the number of runs to compute the probability of survival. The difference between a 100 percent chance of survival and the simulated survival rate is the probability of failure. The annual reliability probabilities were used to calculate hazard values, which are the probabilities of unsuccessful performance in a year, given that it survived up to that year. Specifically, hazard values are the conditional probabilities that, given that the item has survived up to year (t-1), express the probability that it will fail in year (t). A more detailed discussion of reliability and hazard values is provided in **Addendum 1**. The hazard values by component, chamber, and decade for Myers and Greenup are listed in **Table 2-3** and in **Addendum 2**.

2.3.2 Consequences of Failure

2.3.2.1 General

Failure of a major project feature would shutdown one or both chambers until repairs could be made and would require funds to make the repairs. The type of failure and its consequential effects can vary over a wide range of possibilities from relatively minor to the catastrophic. The task was to select types of failure and consequential effects that were reasonable, comprehensive, and, to the extent possible, verifiable. Possible levels of failures and consequential effects are depicted graphically on an event tree.

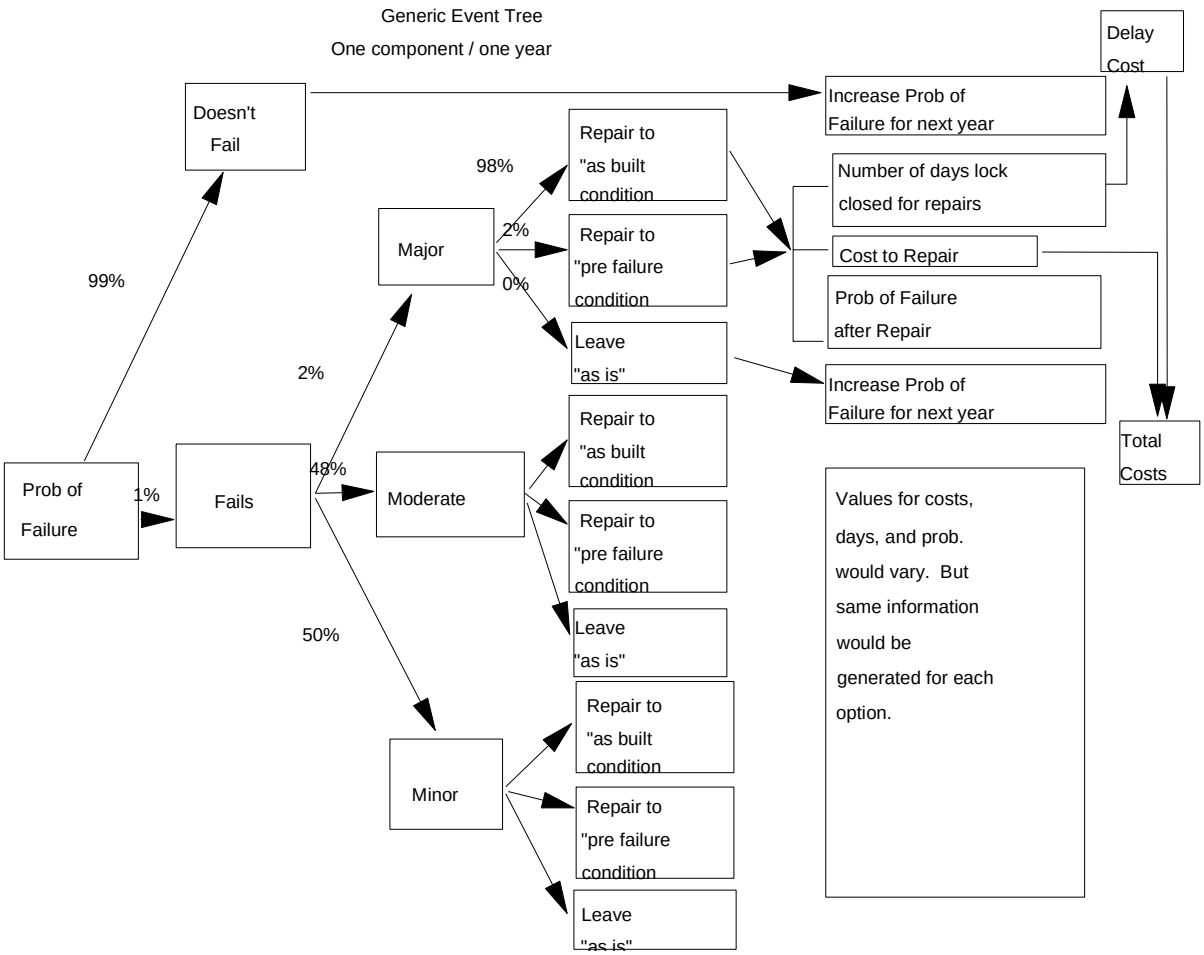
TABLE 2-3
Hazard Values by Component, Chamber, and Decade

Chamber	Year	Monoliths	Gates	Anchorage	Sills	Valves	Electrical System	Gate Machinery	Valve Machinery	Hydraulic System
Myers Main	2000	0	0	0	0	0.00316	0.02062	0.00164	0.00339	0.15186
	2010	0	0	0	0	0.02748	0.02329	0.00262	0.00405	0.27499
	2020	0	0	0	0	0.04632	0.02674	0.00380	0.00483	0.40971
	2030	0	0	0	0	0.07068	0.03097	0.00519	0.00574	0.53526
	2040	0	0	0	0	0.08912	0.03598	0.00679	0.00677	0.64735
	2050	0	0.0002	0	0	0.10175	0.04173	0.00859	0.00792	0.74340
Myers Auxiliary	2000	0	0	0	0	0.00000	0.02058	0.00028	0.00124	0.01834
	2010	0	0	0	0	0.00229	0.02323	0.00042	0.00136	0.02470
	2020	0	0	0	0	0.01614	0.02666	0.00058	0.00148	0.03480
	2030	0	0	0	0	0.02799	0.03085	0.00077	0.00161	0.05017
	2040	0	0	0	0	0.04147	0.03581	0.00098	0.00176	0.07121
	2050	0	0	0	0	0.04353	0.04152	0.00121	0.00192	0.09683
Greenup Main	2000	0	0	0	0	0	0.03642	0.00269	0.00397	0.05327
	2010	0	0.06535	0	0	0	0.04267	0.00387	0.00454	0.06729
	2020	0	0.24459	0	0	0.00004	0.04946	0.00524	0.00524	0.08801
	2030	0	0.70769	0	0	0.00046	0.05682	0.00681	0.00605	0.11321
	2040	0	1	0	0	0.00135	0.0648	0.00858	0.00699	0.14008
	2050	0	1	0	0	0.00498	0.07344	0.01054	0.00805	0.167
Greenup Auxiliary	2000	0	0	0	0	0	0.03628	0.00045	0.00153	0.01912
	2010	0	0	0	0	0	0.04242	0.00061	0.0016	0.02035
	2020	0	0	0	0	0	0.049	0.00081	0.00168	0.02164
	2030	0	0.01093	0	0	0	0.05597	0.00102	0.00177	0.02318
	2040	0	0.06158	0	0	0	0.06332	0.00125	0.00188	0.02516
	2050	0	0.11499	0	0	0	0.071	0.00151	0.002	0.02779

2.3.2.2 Event Tree

A generic event tree developed for the ORMSS study is shown on **Figure 2-1**; the complete set of event trees for all components is provided in **Addendum 3**. Depending on the component, the actual event trees can be more or less complicated than the generic tree. The event tree depicts one year in the life of a project feature.

FIGURE 2-1
Generic Event Tree



2.3.2.3 Event Tree Branches

The first decision point, or branch, in the event tree is whether or not a failure occurs, which is linked to the probability of failure as represented by the hazard value. Then, if a failure occurs, the generic model allowed three possible outcomes regarding the degree of failure - major, moderate, or minor; although even a minor failure is something of consequence and more serious than, for example, a burned out light bulb. The types of repair can also range from a "minor" patch up job to total replacement. Associated with the type of repair is the amount of time the chamber would be closed for the "repair" to be made, the cost of the work, and its effect on the reliability. Minor repairs can be done quickly and cheaply, but may have little or no effect on reliability. Major repairs are more time-consuming and costly, but can make the component highly reliable. The probabilistic values for different types of failures and repairs, the repair cost, the number of days of lock closure, and the effect of the repair on reliability as estimated by the study team are shown in the table for each of the seven components and two lock chambers.

Also listed in the table are the costs and days of closure for planned replacements (listed under rehabilitation) which, depending on the costs, could be classified as scheduled rehabilitation or scheduled replacement. The cost and time for scheduled work are less than the

cost and time of the same type of work performed under emergency (failure) conditions for obvious reasons related to preparation and scheduling.

Table 2-4
Component Rehabilitation Costs, Consequences of Unsatisfactory Performance, and Cost of Repairs
(Costs in thousands of dollars)

Chamber/Component	Rehabilitation Cost	Rehabilitation Days	Tree Branch	Percent	Cost	Days Closed	Reset of Reliability
Main Chamber							
1. Monoliths							
2. Gates	$ 5,845	30 1/	1-100%	35%	$ 1,868	45	5
				5%	$ 7,335	180	100
				60%	$ 7,335	90	100
3. Anchorages							
4. Sills							
5. Valves	$ 5,800	90hs	1-100%	49%	$ 3,100	30/90 hs	100
				1%	$ 3,650	45/90	100
				50%	$ 600	15	5
6. Electrical System	$ 2,500	30	1-75%	90%	$ 110	10	-
				10%	$ 1,525	30	10
			2-25%	25%	$ 1,787	45	10
				5%	$ 4,575	90	100
				70%	$ 412	15	-
7. Mechanical System							
a. Gate Mach	$ 2,500	30	1-75%	90%	$ 128	5	-
				10%	$ 943	15	10
			2-25%	4%	$ 1,888	45	10
				1%	$ 6,588	90	100
				95%	$ 240	15	-
b. Valve Mach	$ 2,500	60 hs/	1-75%	90%	$ 98	5	-
				10%	$ 875	30	10
			2-25%	4%	$ 1,388	45	10
				1%	$ 4,350	90	100
				95%	$ 190	10	-
c. Hydraulic Sys	$ 2,115	60	1-75%	90%	$ 91	5	-
				10%	$ 675	30	10
			2-25%	4%	$ 1,088	45	10
				1%	$ 3,803	90	100
				95%	$ 181	10	-

1/ Greenup requires 60 days

hs = half speed

Table 2-4 (cont'd)
Component Rehabilitation Costs, Consequences of Unsatisfactory Performance, and Cost of Repairs
(Costs in thousands of dollars)

Chamber/Component	Rehabilitation Cost	Rehabilitation Days	Branch	Percent	Cost	Days Closed	Reset of Reliability
Auxiliary Chamber							
1. Monoliths							
2. Gates	$ 5,845	30 1/	1-100%	35%	$ 1,868	45	5
				5%	$ 7,335	180	100
				60%	$ 7,335	90	100
3. Anchorages							
4. Sills							
5. Valves	$ 2,900	60	1-100%	49%	$ 3,950	30/60hs	100
				1%	$ 4,150	180	100
				50%	$ 1,575	45	5
6. Electrical System	$ 2,500	30	1-75%	90%	$ 110	10	-
				10%	$ 1,525	30	10
			2-25%	25%	$ 1,787	45	10
				5%	$ 4,575	90	100
				70%	$ 413	15	-
7. Mechanical System							
a. Gate Mach	$ 2,500	30	1-75%	90%	$ 128	5	-
				10%	$ 943	15	10
			2-25%	4%	$ 1,888	45	10
				1%	$ 6,588	90	100
				95%	$ 240	15	-
b. Valve Mach	$ 1,250	30	1-75%	90%	$ 98	5	-
				10%	$ 437	15	10
			2-25%	4%	$ 825	30	10
				1%	$ 2,700	60	100
				95%	$ 190	10	-
c. Hydraulic Sys	$ 1,442	45	1-75%	90%	$ 91	5	-
				10%	$ 363	15	10
			2-25%	4%	$ 725	30	10
				1%	$ 2,416	60	100
				95%	$ 181	10	-

1/ Greenup requires 60 days
hs = half speed

As with the event tree, the figures in the table are considered reasonable in magnitude but generic in scope. The data were intended to provide a consistent set of basic information that could be applied to all projects such that work could be prioritized throughout the system. Because of the apparent needs for improvements at Myers and Greenup, the generic data were reviewed and modified as appropriate for these specific sites. As a result, one additional set of runs were made; i.e. closure of the main chamber at Greenup for a scheduled replacement of the lock gate for 60 days as well as the system norm of 30 days. The work sequence is as follows. In

the first year, the first item of work will be the extraction and repair of a set of emergency gates that are maintained at the site. The gate leafs are lifted from the lock floor and worked on one at a time, because of space limitations in the chamber. The work is estimated to take 45 days, during which the lower set of lock gates will be worked on simultaneously. Upon completion of this work, the second set of emergency gates will be lifted and repaired, which requires another 45 days to complete. Total closure time is 90 days. In the second year, the upper set of gates will be rehabilitated and the wall quoins will be replaced. Total time to accomplish this work is estimated at 60 days. Because the work on the emergency gates was not evaluated using reliability analysis, only the effects of 60 of the 90 days of closure in the first year were factored into the analysis. The results using either 30 or 60 days both indicated the early need for a scheduled replacement of the gates. The results of both sets of runs are provided in **Addendum 7**.

2.4 INDUSTRY DELAY/DIVERSION TABLES

The key inputs to the LCLM are the industry delay/diversion cost tables, the hazard values, and the probabilities and possible outcomes of failure. These data were developed independently of the LCLM by engineering and economic teams with expertise in the areas of inland navigation economics and structural reliability. Hazard values and event trees were discussed previously; therefore, the following discussion is limited to the assumptions and models underlying the development of the industry cost data.

Industry closure costs were computed as the incremental transportation costs to industry with closure of a lock over a no-closure scenario. For shipments that elect to continue to move on the waterway during a service disruption, the added costs are most often the costs of waiting at the lock for processing or processing through a smaller auxiliary lock. For shipments that opt to use other modes, the added costs are the higher costs of shifting to and using these other modes. The costs to industry were developed from data provided by the Navigation Planning Center. The data are developed by the Navigation Center as the intermediate output of a series of investigation and model runs.

Step 1 is the development of traffic forecasts, which is accomplished using a top-down bottom-up method of analysis. Top-down refers to the acquisition of macro-level data such as population, income, earnings in industry, etc. at the Bureau of Economic Analysis (BEA) level from the Department of Commerce. Bottom-up refers to the acquisition of electricity demand forecasts from individual electric generating companies. The BEA forecasts typically extend out for 50-years, while the company forecasts are for a 10-year period. The 10-year overlap period between the forecasts is used to develop adjustment factors so that the BEA forecasts replicate the company forecasts. The adjustment factors are then applied to the longer-term forecasts to obtain long-term company level forecasts. These forecasts are then disaggregated amongst the different generating plants to obtain plant forecasts. The forecasts for coal-fired plants are converted into coal burns based on the historic conversion factor. Coal burns are translated into waterway traffic based on the historic modal split. Forecasts of other commodities are developed in a similar manner. The

development of Ohio River System traffic forecasts is described in a two volume document entitled "Forecast of Future Ohio River Basin Waterway Traffic 1990-2050." Independent Technical Experts reviewed the development of the forecasts and the use of the forecasts in navigation studies was approved.

The demand forecasts were run through the system model assuming that traffic is limited by the capacity of the projects, but that there are no closure of the locks for inspections or repairs. The resulting amount of traffic that is projected for Myers and Greenup is summarized below and listed in-detail in **Addendum 4**.

TABLE 2-5
Traffic Projections
(thousands of tons)

Year	Forecast Demand	
	Myers	Greenup
2000	86,191	72,118
2010	101,188	84,505
2020	113,817	94,069
2030	126,465	103,762
2040	142,037	115,840
2050	157,067	126,826

Step 2 is the development of traffic - delay curves at each Ohio River navigation project. Again, this is done by the Navigation Planning Center using actual towboat statistics and a project simulation model called the WAM (Waterway Analysis Model). The navigation statistics are used to create a list of tow movements through the project, which is then input to WAM. WAM simulates the operation of the project and calculates the delay per tow. The WAM delay per tow is compared with the actual delay per tow to ensure that the model is operating correctly. The model is considered "calibrated" when the simulated delay is not significantly different from actual delay. Traffic is then increased by some amount (10%) by increasing the number of tow movements by 10 percent and input to the WAM. The process is repeated and the delay at each traffic level is recorded to produce a traffic - delay curve. The model is also run assuming the same amount of traffic, but with closure-reduced capacities, to obtain estimates of delays attributable to closures. WAM is documented in a report entitled the "Waterway Analysis Model Users Guide". Like the forecasts, Independent Technical Experts reviewed the traffic-delay curve analysis before being used in navigation studies. The "no closure" set of tonnage-delay points for Greenup and Myers are listed below. Interpolation is accomplished using a spline equation. At current traffic levels, delays average less than one hour per tow when both chambers are operational. As traffic increases, delays increase as tows are forced to wait in queue for lockage. Based on experience, capacity is usually defined as the traffic level that results in 200 hours of delay per tow. The capacity of Greenup is 158.0 million tons and the capacity of Myers is 174.2 million tons.

TABLE 2- 6
Tonnage-Delay Points for Greenup and Myers
(Traffic in thousands of tons; delays in hours per tow)

Traffic	Average Tow Delay	
	Greenup	Myers
-	-	-
64,941	0.95	-
80,068	-	1.00
113,496	1.98	-
118,848	-	1.84
131,500	3.16	2.22
138,812	4.46	2.57
146,686	14.32	3.32
156,487	83.55	5.73
157,453	186.90	-
157,535	200.00	7.30
163,600	-	15.74
167,794	-	40.89
169,601	-	200.00

Step 3 is to input the WAM traffic - delay values and projected traffic levels to a system economic model referred to as the Tow Cost Model (TCM), and run the TCM. The TCM calculates the delay at each project, given projected traffic levels and transportation costs. The amount of traffic that could move through each project, assuming no closures, was extracted from TCM output files and input to a pre-processor model of the LCLM. The TCM has also been independently reviewed and approved. A typical TCM output file is provided as the table below.

TABLE 7
TCM Output File

EQ 77 File - Navigation Center
THIS RUN STARTED Fri Oct 23 11:42:05 1998
1 Concept Rehab, No Closures

LOCK & DAM NAME	UTILIZATION (KTONS)	DELAY (HR/TOW)	CLOSURE CAPACITY (KTONS)	NO. TOWS	DELAY DAYS	COSTS ($1000) TOTAL	COSTS ($1000) DELAY	SAVINGS ($1000)	COSTS $/TON TOTAL	COSTS $/TON DELAY	SAVINGS $/TON	BARGES /TOW
1 OLMSTEAD L/D (O	97526.	.70	274931.	11893.	347.8	339815.40	2290.71	1476953.00	3.48	.02	15.14	8.36
2 LOCK & DAM 52 (O	105393.	.00	999999.	12698.	.0	358836.40	.00	1442298.00	3.40	.00	13.68	8.72
3 SMITHLAND L/D	94382.	.81	233984.	10224.	344.1	317553.40	2375.41	1227748.00	3.36	.03	13.01	9.25
4 UNIONTOWN L/D	86191.	1.23	173280.	8655.	443.2	309436.00	3271.55	1207917.00	3.59	.04	14.01	9.71
5 NEWBURGH L/D	79250.	1.03	182315.	8274.	354.0	287020.30	2395.38	1094904.00	3.62	.03	13.82	9.34
6 CANNELTON L/D	69101.	1.19	169388.	7105.	352.0	267841.20	2416.31	1027415.00	3.88	.03	14.87	8.92
7 MCALPINE L/D	61589.	.73	226511.	5726.	173.2	251535.00	1281.75	995570.10	4.08	.02	16.16	9.24
8 MARKLAND L/D	62742.	1.13	151377.	5789.	273.0	232499.10	2003.86	1010829.00	3.71	.03	16.11	10.07
9 MELDAHL L/D	66097.	1.20	150751.	6489.	324.6	224620.00	2292.90	980142.00	3.40	.03	14.83	9.88
10 MARKLAND L/D	72118.	1.08	157536.	7450.	335.9	229876.00	2349.29	981949.70	3.19	.03	13.62	9.65
11 GALLIPOLIS L/D	60194.	1.04	147023.	6518.	282.2	176763.30	1794.66	741978.30	2.94	.03	12.33	9.48
12 RACINE L&D	53341.	.84	166001.	4925.	173.0	152644.80	1237.94	671098.10	2.86	.02	12.58	11.83
13 BELLEVILLE L&D	52052.	.89	165676.	4710.	174.1	151889.60	1272.58	656140.10	2.92	.02	12.61	12.08
14 WILLOW ISLAND L&	48850.	.86	166131.	3918.	141.2	124676.60	1058.47	604515.20	2.55	.02	12.37	13.82
15 HANNIBAL L&D	51334.	.83	169438.	4475.	155.4	122581.00	1067.73	596424.30	2.39	.02	11.62	12.62
16 PIKE ISLAND L&D	49062.	.85	148231.	6221.	219.4	91294.73	1205.39	548379.60	1.86	.02	11.18	9.41
17 NEW CUMBERLAND L	42335.	.82	126201.	5584.	191.8	88837.80	1028.60	486915.90	2.10	.02	11.50	9.08
18 MONTGOMERY L&D	30732.	2.99	44738.	6682.	831.8	35522.54	3847.35	409086.80	1.16	.13	13.31	6.29
19 DASHIELDS L&D	27122.	1.87	47211.	6537.	509.6	35153.50	2267.91	350317.60	1.30	.08	12.92	6.00
20 EMSWORTH L&D	25254.	2.08	42795.	6367.	551.1	34726.79	2438.65	329946.40	1.38	.10	13.07	5.86

and so on thru

TOTAL SYSTEM	275745.				7158.9	1006759.00	42041.55	2384284.00	3.65	.15	8.65	7.13
OHIO RIVER -	242571.				6177.4	963324.80	37896.44	2246262.00	3.97	.16	9.26	7.73

THIS RUN ENDED Fri Oct 23 11:42:56 1998
Solution found after 2 iterations.
There are no negative movements in the 73 file.

The WAM traffic - delay points are input to the LCLM pre-processor model to calculate expected delays for the fully operational (no closures) project, and for projects with closures of duration: 1, 3, 5, 10, 15, 30, 45, 60, 90, 180, and 365 days. Diverted traffic is computed as the excess of project traffic which could move through the project if it were fully operational (no closures), over the reduced capacity of the project when closures are factored into its availability. Delays and diversions are converted into delay cost and diversion cost tables by multiplying delays and diversions by the time cost of tows and waterway savings per ton, respectively. A detailed description of the procedure and the data inputs is provided in greater detail in **Addendum 4**. The delay and diversion tables for Myers and Greenup are provided in **Addendum 5**.

A portion of an industry table is shown in **Table 2-8**. The general rules are: 1) industry costs are higher when the main is closed since all traffic must then pass through the smaller auxiliary; 2) delay costs increase over time as traffic increases, although the costs often reach a maximum if traffic equals capacity; and 3) the longer the closure, the higher the costs although, once again, there are exceptions depending on the interaction of traffic and capacity.

TABLE 2-8
Lock Closure and Industry Cost
(thousands of dollars)

Year	Main Closed		Auxiliary Closed	
	1 Day	45 Days	1 Day	45 Days
2000	$ 66	$ 8,578	$ 48	$ 717
2001	$ 67	$ 9,561	$ 49	$ 748
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
2049	$ 112	$ 134,043	$ 87	$ 13,646

2.5 LCLM

2.5.1 Description

The LCLM, or Life Cycle Lock Model, is a computer model developed by the ORMSS economics study team to perform a life cycle evaluation of the reliability of the features of the Ohio River navigation projects. The core of the model is computer code that replicates the logic of the event tree, which is a depiction of possible outcomes of failure. Overlaying the core of the model is a loop that allows passage through the event tree for each year from 2000 to 2059. A second loop

allows the evaluation of up to 30 separate project features. Finally, a third loop allows for up to 50,000 iterations of the life cycle.

The LCLM operates by generating random numbers between zero and one and comparing them with probabilities in the event tree to determine the order of progression through the event tree. The first random number is compared to the probability of unsatisfactory performance (failure) to determine failure or non-failure. If failure, then a second random number is selected and compared to probabilities of different degrees of failure to determine the "level of failure". The process continues through all decision points in the event tree. The final step is to reset the probability of failure for the following year – either increase it if there was not a failure, or decrease it if there was a failure, and the repair improved reliability. The same procedure is duplicated for all 50-years in the project life (50 years equals one life cycle, sometimes referred to as an iteration).

LCLM calculates the economic costs in each year and accumulates them over all 20 to 50 thousand iterations. The cumulative cost in each year was then divided by the number of failures to get the average cost per year given a failure occurred, and also divided by the number of iterations to get the average life-cycle cost per year. The present value of the average life-cycle costs in each year was computed using a base year of 2010 and a discount rate of 6 7/8 %. The present value numbers were then added together to get the cumulative present value. The cumulative present value was converted into an average annual equivalent value using the discount rate of 6 7/8 % and a 50-year economic life. A simple example of the expected value calculations is provided as follows; while the actual simulation is more complicated, the basic concept is the same. A detailed example is provided in **Addendum 6**.

Component -	widget
Discount rate -	6 7/8%
Interest and amortization rate - (6 7/8 % over 50 years)	.0713168
Probability of failure -	1 percent in year 2000 and every year through 2049
Base Year -	2000
Repair Costs -	$10 in year 2000 and every year through 2049
Industry Costs -	$100 in year 2000 and every year through 2049

Year	Prob of Failure	Repair Costs	Industry Costs	Total Costs	Present Value Costs
2000	.01	$ 10	$ 100	$ 110	$ **106**
•					
•			and so on through		
•		only difference is in present value of costs			
2049	.01	$ 10	$ 100	$ 110	$ **4**
Cumulative					$ 1,595
Ave Ann. ($1,595 x .0713168)					$ 114

The model is a single component simulator - it simulates the future performance of each project feature separately. It was developed as a single feature simulator based on an assessment by

engineering experts both within and outside the Corps, that the linkage between the reliability of most features is insignificant and not worth the time and effort to model. This approach or assumption was used in the Upper Mississippi and other Corps rehabilitation studies that were reviewed.

While the model is a single feature simulator, it has the capability of sequentially running up to 30 separate features and aggregating the results by lock chamber. However, for this study, there was no advantage for making multi-feature runs.

2.5.2 Key Features of the LCLM

A listing of the key features and options of the LCLM is as follows:

1) simulation begins in year 2000. This allows failures from the current (approximate) year, which is the year through which the components have survived, per hazard functions.

2) scheduled work would be deferred if failure occurred prior to the scheduled work year, and the repair effort would extend the component life by 10 or more years. For example, if the schedule was to replace the component in 2020, but it failed in 2015, and the repair extended its life by at least 10 years, then the work would be rescheduled from 2020 back to 2025 (2015 + 10).

3) there is an option to allow the probability that failures are major to increase over time. For example, if the component failed today, the probability that the failure was of a major type might be 25%; as the component survived into the future, the probability that, if it failed, the failure would be major could increase up to 100% by some year, such as 2070. There would be corresponding decreases in the probabilities of less severe failures.

4) days of closure and costs of closure were treated as variables selected from triangular distributions. Industry costs provided by economics staff were allowed to vary by +/- 15 percent to reflect the typical variation in arrival patterns due to seasonality, weather, and economic cycles. Repair costs provided by engineering staff varied from - 10 percent to + 20 percent to reflect typical variations due to uncertainty over working conditions and availability of parts. Days of closure varied from - 5 percent to + 20 percent to reflect uncertainty over working conditions. In summary:

	Lower	Upper
a. Delay/Diversion Costs	-15%	+15%
b. Repair/Rehab Costs	-10%	+20%
c. Days of closure	- 5%	+20%

5) industry closure costs for periods greater than a year were computed by pro-rating the costs for a year according to the number of days the closure exceeds a year.

6) if there are a number of the same type of component at a project (ex. gates), then the results for one were used as a proxy for the “component”. For example, if the results indicate that one set of gates in a chamber should be replaced in 2000, then the other set of gates in the chamber would be also be economically justified for replacement in the same year (2000).

7) the base year for the economic analysis is the year 2010. All costs incurred prior to 2010 were adjusted upward and all costs after the year 2010 were adjusted downward to obtain present value numbers for 2010, using standard discounting techniques:

present value (2010) = (1 + i) ** (2010 – t)

8) all alternatives are ultimately reduced to a single average annual cost number, which was computed by first, calculating the present value of all future costs; second, summing to obtain the cumulative present value (cpv); and third, converting the cpv to an average annual value using the standard economic formula:

avg. ann. value = (cpv(2010) * i) / (1-(1/((1+i)**50))))

9) the economic analysis was incremental cost analysis. Incremental costs were computed as the difference of the costs of the alternative plans over the costs of the "baseline" (fix-as-fail) alternative.

10) The price level of all dollar values is October 1998; the base is the year 2010, the project life is 50 years, and the discount rate is the FY 99 rate of 6 7/8 %.

11) the model has the option of factoring down (or up) the industry costs if circumstances indicate that it is prudent to do so. For the interim study, delay costs were factored down by 50 percent. The reasons for this were two-fold: 1) the lock capacities are being re-estimated with a queue limit which is likely to result in lower delays than currently available; and 2) the systemic effects of closure are likely to be lower than those estimated when focusing on a single project due to capacity limits at other projects.

12) multi-year repairs are allowed in the base condition and for the advanced maintenance / scheduled repair alternatives. Thus, the lock can be closed one year for short-term emergency repairs and then the following year for more extensive repairs.

2.5.3 Input Files

2.5.3.1 Industry Cost Files

Three files are input to the LCLM: the first contains the hazard values and event tree data (probability of different failures, repair costs, etc); the second contains the industry delay costs; and the third contains the industry diversion costs. The delay and diversion cost tables are project and lock specific, and the formats are identical. A partial listing of a representative delay cost table is provided again in **Table 2-9**.

TABLE 2-9
Lock Closures and Industry Delay Costs
(thousands of dollars)

Year	Main Closed		Auxiliary Closed	
	1 Day	45 Days	1 Day	45 Days
2000	$ 66	$ 8,578	$ 48	$ 717
2001	$ 67	$ 9,561	$ 49	$ 748
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
2049	$ 112	$ 134,043	$ 87	$ 13,646

2.5.3.2 Engineering Data File

The event trees are provided with values for possible outcomes of failure. These data, along with the hazard values, are entered into a file that is then input to the LCLM. A partial listing of the input file for the gate in the main chamber at a typical project is listed in **Table 2-10**.

TABLE 2-10
LCLM Input File for Gates - Typical Project - Main Chamber

Record	Data	Input Description
1	8	TCM identification number
2	2000	Year to start considering failures (current year)
3	2010	Base Year for Discounting
4	20000	Number of Iterations
5	0.06878	Discount Rates
6	Baseline	Run identifier
7	MA12FF	Seven letter identifier for output files
8	1	Number of components
9	12	Component ID Number
10	0	Option number, 0=fix as fail; 1=scheduled repair
11	2010	Year for options 1, can be any year from 2000 to 2060
12	0	Frequency of cyclinical repairs
13	0.050 0.400 1.000	Probabilities of different degrees of failure
14	100 0.60	Expected age when major failures become 98%
15	0.000 0.000 1.000	Major failure - Prob of minor, moderat, major fix
16	0.000 1.000 1.000	Moderate failure - Prob of minor, moderate, major fix
17	0.000 0.000 1.000	Minor failure - Prob. of minor, moderate, major fix
18	00 0180	Major - Days lock closed to make repairs
19	00 45 00	Moderate
20	000 00 90	Minor
21	000000 00000 7335000	Major - cost of repairs, except repair fleet
22	0000000 1868000 0000000	Modetate
23	0000000 0000000 7335000	Minor
24	0 00 100	Major - Years that repairs extend component life
25	0 05 00	Moderate
26	000 00 100	Minor
27	30	Days lock closed for rehab/maintenance
28	5845000	Cost of rehab/maintenance, except repair fleet
29	100	Years that rehab/maintenance extends life
30	1	Chamber 1=main 2=aux 3=both
31		Hazard Function Values
32	21958 2070	Two curves; first stops in 2070
33	1958 .000000	
34	thru 2070	
35	2070 1.000000	
36	2 1959 1959	Two curves; first stops in 2070
37	1959 0.00000	

2.5.4 Output File

Statistics on failures, repair costs, and delay costs are accumulated for each year in the simulation until all iterations are complete. The repair and delay costs are then added, discounted to present value, and annualized to a single "economic cost", which is the basis for decision-making. The principal output file of the LCLM lists the input hazard values and the output number of failures and costs, along with the annualized economic cost. The output file for the gates in the main chamber at a typical project, baseline condition, is shown in **Table 2-11**. The key items are discussed following the table.

TABLE 2-11
LCLM Output Table for Gates - Main Chamber

							Averaged Over Failures (Thousands of Dollars)			
					Delay					Avg
Year	Hazard Function	Scheduled Replace	# of Failures	% of Fails	Days	Costs	Divert Costs	Repair Costs	Total Costs	Over Iters
2000	0.13111	0	2,612	8	78	$ 11,794	$ -	$ 5,737	$ 17,531	$ 2,290
2001	0.15858	0	2,860	9	78	$ 13,480	$ -	$ 5,677	$ 19,157	$ 2,740
2002	0.18229	0	2,771	9	78	$ 15,171	$ -	$ 5,701	$ 20,872	$ 2,892
2003	0.18005	0	2,431	8	79	$ 18,057	$ -	$ 5,744	$ 23,801	$ 2,893
2004	0.20448	0	2,311	8	78	$ 19,895	$ -	$ 5,657	$ 25,552	$ 2,953
.										
and so on through										
.										
2054	1.00000	0	0	0	0	$ -	$ -	$ -	$ -	$ -
2055	1.00000	0	0	0	0	$ -	$ -	$ -	$ -	$ -
2056	1.00000	0	1	0	90	$ 322,899	$ 181,665	$ 8,700	$ 513,264	$ 26
2057	1.00000	0	0	0	0	$ -	$ -	$ -	$ -	$ -
2058	1.00000	0	0	0	0	$ -	$ -	$ -	$ -	$ -
2059	1.00000	0	0	0	0	$ -	$ -	$ -	$ -	$ -
Total		0	30,809							

2.5.4.1 Hazard Values

The first column in the output table is the year, and the second column is the hazard value. The hazard values listed on the table are the input value and not the values that would be generated during the simulation process. For example, if the gates failed in the year 2010 and repairs were made, then the values from 2011 onward would reflect the effect of the repairs on reliability, i.e. the component would be more reliable in the future because of the repairs. The exact values of future reliability would depend on the magnitude of the repair, as depicted on the event tree.

2.5.4.2 Number of Failures

The first item of output from the simulation is the number of failures, which initially increases commensurate with the hazard values, but then decreases as the probability of survival into the future diminishes. The number of failures in the year 2000 is 2,612 out of 20 thousand iterations. The expected number of failures can be calculated by multiplying the hazard value by the number of iterations, i.e. .13111 x 20,000 which equals 2,622, or nearly the same number as generated by simulation.

2.5.4.3 Delays - Days and Costs

The second output item of interest are the days of delay which, in the year 2000, average 78 days, given that a failure occurred. The expected number of days is 79, or nearly the same (.05 x 180 + .35 x 45 + .6 x 90). The cost of delays is $11,794,000; the expected cost of delays is $10,768,950 ((.05 x 77,755 + .35 x 8,578 + .6 x 24,413) / 2).

2.5.4.4 Repair Cost

The third output item of interest is the repair cost, which in the year 2000 averages $5,737,000. The expected repair cost is $5,421,550 (.05 x 7,335 + .35 x 1868 + .6 x 7,335).

2.5.4.5 Total Cost

Total costs, given a failure, are the sum of delay and repair costs, or $17,531,000 (11,794 + 5,737).

2.5.4.6 Average (Expected) Cost

The cost averaged over all iterations is equivalent to the expected cost, since it factors in the probability of failure. It can be computed as follows: the number of failures multiplied by the total cost averaged over failures gives the total cost, i.e. $45,791 million (2,612 x 17,531,000). The total cost divided by the number of iterations gives the expected cost, i.e. $2,290,000 ($45,791 million / 20,000). The $2,290,000 for the year 2000 and the comparable numbers for the other years are the cost used in the calculation of the average annual cost of the alternative.

2.5.4.7 Average Annual Costs

The cost averaged over all iterations is the equivalent of the expected cost that would be invested in the component given its probability of failure and the probability and costs of different degrees of failure and repairs. The costs averaged over all iterations are the economic costs of maintaining the component, given the maintenance strategy (baseline, scheduled replacement in 2000, 2001, or any future year). The economic costs were converted into present value costs using a discount rate of 6 7/8%, a 50-year economic life, and mid-year discounting. The computation for the baseline condition - gates – is shown in **Table 2-12**. The same technique as shown below was used to compute the average annual costs of all maintenance/replacement alternatives.

TABLE 2-12
Computation of Average Annual Costs
(thousands of dollars)

Lock Gates - Baseline Condition

0.06875 Interest Rate
0.071317 Interest and Amortization Rate
2010 Base Year for Present Value Calculations

Year	Avg All Iters ($K)	Years From Bas Years	Present Value Index	Present Value
2000	$ 2,290	9.5	1.881	4,307
2001	$ 2,740	8.5	1.760	4,822
2002	$ 2,892	7.5	1.647	4,762
and so on through				
2056	$ 26	-46.5	0.045	1
2057	$ -	-47.5	0.042	0
2058	$ -	-48.5	0.040	0
2059	$ -	-49.5	0.037	0

Cumulative Present Value $ 58,199

Average Annual $ 4,151

2.5.4.8 Limitation of Expected Value Calculations

The expected calculations work for the year 2000, but not in future years unless all repairs following failure make the component 100% reliable in the future. This is not typically the case.

2.5.5 Post-Processor - Bundling of Components

A post-processor was developed to take the outputs of fix-as-fails LCLM runs and calculate a quick approximation of the economics of with-project alternatives, and also to calculate the economics of "bundling" the work on several components during one closure period. It is possible to approximate the average annual cost of each year's scheduled work in one computer run, rather than in 50 separate runs. The results will be an approximation for two reasons: 1) the method does not allow failures after replacement, which is not a major problem since replacement reduces the probability of future failures to, or near, zero for all years up through the end-year of the analysis period (2059); and 2) more significantly, the method does not allow the rescheduling of

The modeling alternative involves the use of the bundling program described in Addendum 7 for a single component, rather than for multiple components as described. The basic procedure is this:

1) run the LCLM for the base-line condition for each component.
2) then, scheduled replacement in a given year would be the sum of the cost of the work (repair plus delay costs), and the costs of expected failures up to the year preceding the year of scheduled repairs.

For example, the alternative that considers scheduled replacement in 2010 would involve the cost of replacement (including delays while the lock is closed for repairs) plus the expected failure costs up through 2009. Replacement in 2011 would be calculated in the same manner, with expected failure costs up through 2010. The results are different from those generated by the LCLM. The principal reason for the difference is that the alternative assumes the scheduled replacement will occur in the designated year regardless of prior year failures and repairs. The LCLM assumes the replacement will occur only if component did not fail in a prior year or, if it did fail, that the repair had less than a 10-year effect on reliability.

The same post-processor can be used to evaluate the economics of "bundling" the work during a single closure. Bundling typically involves doing work on two or more components during a single closure, rather than during individual closures in different years. The bundling routine calculates the tradeoff between the higher present value of possibly doing some work earlier than separately warranted and the lower costs to industry of having one closure rather than two or more. The repair cost may also be lower due to savings in construction mobilization and demobilization, and repair fleet costs. The tradeoffs are considered for all possible years with the year that provides the lowest economic cost being deemed the optimum year, provided the cost is less than the sum of the cost of performing the work separately.

2.6 RESULTS

2.6.1 General

The LCLM was run separately for each component for the Greenup and Myers and four other high traffic projects on the Ohio River. The other main stem projects will be evaluated in the future. The results were used in two ways: 1) to ensure that the scheduled closures for major replacement work was supported by the results of the reliability analysis; and 2) to include the expected costs of failure for components when the results indicated that the optimum plan was to continue "business as usual", and not schedule any future replacements. Item one, verification and modification of the closure matrix, are important since the benefits of lock extensions are largely dependent on the timing and duration of future closures of the locks. Item two, inclusion of expected costs in the cost of the "without" alternative, is important since all costs must be quantified and included in the analysis so that the alternatives can be compared and ranked.

2.6.1.1 Monoliths

Stability of the monoliths is not considered a problem at the six projects evaluated for reliability. Monoliths were included in the reliability analysis because of suspected problems at the Upper River projects of Emsworth, Dashields, and Montgomery, which are undergoing a separate evaluation.

2.6.1.2 Lock Gates

The component considered least reliable is the lock gates, particularly at Markland, Meldahl, and Greenup. The reliability analysis indicated that near-term replacement of the gates in the main chamber at Greenup is warranted around 2005, and around 2020 in the auxiliary chamber. The gates at Myers are considered to be reliable for continued use over the next several decades, provided that there are no "unforeseen" problems that cause their deterioration beyond normal wear and tear.

2.6.1.3 Anchorages

The initial expectation was that the anchorages would be a prime reliability problem because of its transitional function between the gates and walls, and the cycles of openings/closings. However, investigations indicated that normal maintenance keeps the reliability at high levels.

2.6.1.4 Valves

Valves are second only to gates as potential reliability problems at most navigation structures. The valves at Greenup appear to be in good working condition and the results of the reliability analysis do not indicate any need for near-term replacement. However, the analysis indicates that the valves at Myers are unreliable and in need of near-term replacements.

2.6.1.5 Electrical System

The electrical systems at Greenup and Myers are in good working order. The only replacement need based on the results of the reliability analysis is the replacement of the electrical system in the auxiliary chamber at Myers in about the year 2030.

2.6.1.6 Gate Machinery

The machinery that operates the lock gates at both Greenup and Myers is in good working condition and, based on the reliability analysis, there are no needs to schedule replacement of the machinery over the next several decades.

2.6.1.7 Valve Machinery

The machinery that opens and closes the valves in the chambers at Greenup and Myers is in good working condition. However, the reliability analysis indicates that replacement of the valve machinery in the main chamber at Myers may be required around the year 2040.

2.6.1.8 Hydraulic System

The hydraulic system converts electrical energy into the mechanical energy that operates the gates and valves machinery. The hydraulic system consists of pumps and delivery lines that move the hydraulic fluid that "moves" the operating equipment. The reliability analysis indicated that the hydraulic system at Greenup will not require replacement in the foreseeable future, but the system at Myers will need to be replaced in about the year 2020.

2.6.2 Optimum Timing of Work

The summary results of the LCLM runs for the six high traffic projects are listed in **Table 2-13**. The results are displayed in terms of if, and when, scheduled repairs are economically justified. The "with" results are shown for decades, although intervening years were modeled for features with near term replacement needs. The projected closure schedule that is used in the "systems" economic analysis was adjusted based on the results of the LCLM runs.

TABLE 2-13
Optimum Timing for Work on Major Components at Six Projects

Feature	Chamber	Myers	Newburgh	Cannelton	Markland	Meldahl	Greenup
Monoliths	main		all considered reliable - not modeled				
	auxiliary		all considered reliable - not modeled				
Gates	main	faf	faf	2030	2003	2010	2004
	auxiliary	nmr	nmr	faf	2020	2030	2030
Anchorages	main		all considered reliable - not modeled				
	auxiliary		all considered reliable - not modeled				
Valves	main	2010	nmr	nmr	2003	nmr	faf
	auxiliary	2030	nmr	nmr	2020	nmr	2030
Electrical Sys	main	faf	faf	faf	faf	faf	faf
	auxiliary	2030	faf	faf	faf	faf	faf
Gate Mach.	main	faf	faf	faf	faf	faf	faf
	auxiliary	faf	faf	faf	faf	faf	faf
Valve Mach.	main	faf	faf	faf	faf	faf	faf
	auxiliary	faf	faf	faf	faf	faf	faf
Hydraulic Sys	main	2020	faf	faf	faf	faf	faf
	auxiliary	2030	faf	faf	faf	faf	faf

faf - fix as fail
nmr - no LCLM model runs
date - approximate year that scheduled replacement is optimized

2.6.3 Major Work at Greenup and Myers

The results of the reliability analysis for Greenup and Myers are displayed in **Table 2-14**. Because of the deficiencies with the lock gates, the problems are much more severe and require more immediate action at Greenup.

TABLE 2-14
Major Work at Greenup and Myers

Project	Chamber	Component	Year	Days of Closure	Repair Cost ($ K)
Greenup	main	lock gates	2003	60	$ 5,845
	main	lock gates	2004	60	$ 5,845
	aux	lock gates	2029	60	$ 5,845
	aux	lock gates	2030	60	$ 5,845
Myers	main	culvert valves	2010	90h.s.	$ 5,800
	aux	culvert valves	2030	60	$ 2,900
	main	hydraulics	2020	60	$ 2,115
	aux	hydraulics	2030	45	$ 1,442
	aux	electrical sys	2030	30	$ 2,500

h.s. refers to operation of the chamber filling and emptying system at half speed rather than a full chamber closure.

2.6.4 Economic Cost of Fix-as-Fail and Deferred Replacement

Features that are not justified for scheduled replacements based on the reliability analysis have costs associated with them that are not captured elsewhere in the analysis. The same is also true for a component scheduled for future replacement, i.e., there is a chance they may fail prior to the year of scheduled replacement. The LCLM outputs per year, which are roughly equivalent to expected costs, were discounted, summed, and annualized to compute the average annual economic cost. The results for the fix as fail features are listed below. The actual costs by year were included in the economic cost of each alternative.

Each chamber has two sets of gates, one upstream and one downstream, even though only one set was modeled. The two sets are considered to be sufficiently similar that the simulation results for one are considered applicable to the other. The same is true for the gate machinery and the valves in the auxiliary chamber. The number of each component in a chamber is listed in the following table, along with the "expected" cost of failures, which were adjusted from LCLM outputs by multiplying by the number of the components.

The expected costs of failure for those components where scheduled replacement is not economically justified or, for the years prior to scheduled replacement, are expressed as average annual dollars. The costs at Greenup are $1,947,000 and at Myers are $2,248,000; the cost breakdown by chamber is listed in **Table 2-15**.

TABLE 2-15
Cost of Fix as Fail to Year of Replacement or End of Period of Analysis
(thousands of dollars, annualized)

Feature	Chamber	Myers	Newburgh	Cannelton	Markland	Meldahl	Greenup
Monoliths	main	all considered reliable - not costed					
	auxiliary	all considered reliable - not costed					
Gates	main (2)	$ 90	$ 5	$ 161	$ 1,980	$ 209	$ 43
	auxiliary (2)			$ 1	$ 191	$ 3	
Anchorages	main	all considered reliable - not costed					
	auxiliary	all considered reliable - not costed					
Valves	main (1)				$ 63		$ 26
	auxiliary (1)				$ 37		
Electrical Sys	main (1)	$ 902	$ 510	$ 377	$ 387	$ 43	$ 901
	auxiliary (1)	$ 35	$ 40	$ 40	$ 62	$ 37	$ 226
Gate Mach.	main (2)	$ 88	$ 46	$ 15	$ 30	$ 20	$ 51
	auxiliary (2)	$ 2					$ 2
Valve Mach.	main (1)	$ 62	$ 22	$ 14	$ 56	$ 17	$ 34
	auxiliary (1)		$ 1	$ 6	$ 13		$ 4
Hydraulic Sys.	main (1)	$ 1,096	$ 1,906	$ 1,118	$ 610	$ 296	$ 623
	auxiliary (1)	$ 12	$ 64	$ 20	$ 21	$ 12	$ 36
Total	main	$ 2,239	$ 2,489	$ 1,684	$ 3,125	$ 584	$ 1,679
	auxiliary	$ 49	$ 106	$ 67	$ 323	$ 51	$ 268

2.7 SENSITIVITY ANALYSIS

2.7.1 General

Sensitivity analyses were performed on those variables that were suspected of having the greatest effect on the results. The variables are: discount rate, number of iterations, costs to industry during closure, and the hazard rates. The component selected for the sensitivity test was the gates in the main chamber at Markland Locks and Dam.

2.7.2 Discount Rate

The sensitivity of the results was determined by re-generating the results assuming discount rates of 5 percent and 10 percent. The discount rate has a significant effect on the annual costs due to discounting, but did not change the conclusion that replacement of the gates in the year 2000 is the economically preferred solution. **Table 2-16** displays sensitivity to the discount rate.

TABLE 2-16
Sensitivity to Discount Rate

Sensitivity	Baseline	Replace in 2000	Replace in 2001
Low - 5%	$ 3,063	$ 765	$ 883
Base - 6 7/8%	$ 4,150	$ 1,178	$ 1,342
High - 10%	$ 6,397	$ 2,191	$ 2,440

2.7.3 Number of Iterations

The program is set to run a maximum of 50 thousand iterations; 20,000 iterations were performed for the Markland gates. The baseline for the gates in the main chamber were re-run for 10 thousand iterations. The results were insignificantly different, implying that the results using 20 thousand iterations is more than sufficient to capture all variations of events and consequences.

TABLE 2-17
Sensitivity to the Number of Iterations

Thousand Iterations	Results - (avg ann)
10	$ 4,162
20	$ 4,150
% Difference	0.27%

2.7.4 Industry Costs

Industry costs are a key input to the simulation analysis and the results are highly dependent on these costs. For the gates in the main chamber, industry costs exceed the cost of repairs by factors of 2 to 1 up to 10 to 1, depending on the year.

Recognizing the importance of delay costs, and being knowledgeable of investigations into the tonnage-delay relationships, it was decided at the on-set of the study to reduce industry delay

costs by 50 percent from the numbers generated using the tonnage delay-curves that were then available from the Navigation Center. Preliminary results of the Center's investigations indicated that the delay per tow per ton of traffic would probably be reduced by between 20 and 60 percent. To reflect this expected reduction and to avoid generating results that would be out-of-date before transmittal of the report to HQ, the delay costs used in the study were reduced by 50 percent.

The effect of using the full 100 percent delay cost values is shown in **Table 2-18**. Using 100 percent rather than 50 percent significantly increases the benefits of early replacement of the gates. The baseline, or fix-as-fail alternative, is 3.5 times as expensive as replacement in 2000 using the 50% delay cost figures and 4.9 times as expensive using the unadjusted (100%) costs.

TABLE 2-18
Sensitivity to Delay Costs

	Baseline	Replace in 2000	Ratio
Base - 50%	$ 4,150.4	$ 1,178.0	3.5
Sensitivity - 100%	$ 7,495.4	$ 1,525.5	4.9

2.7.5 Hazard Rates

The expectation is that lower hazard rates would reduce the need for near-term rehabilitation of the project. However, given the low reliability of the gates, even reducing the hazard in half does not affect the optimum time for replacement. The results are summarized in **Table 2-19**. They show that a 50 percent reduction in the hazard values actually caused some small increase in the baseline costs. The reason is that fewer fails early in the project life mean more later in the project life when the delay costs due to traffic growth are higher. The impact of higher delays per failure is greater than the reduction in near-term failures due to lower hazard values. The cost for replacement in the year 2000 is unaffected by the hazard rate, since the replacement takes place before failures occur.

TABLE 2-19
Sensitivity to Hazard Rates

	Baseline	Replace in 2000
Base	$ 4,150	$ 1,178
Haz Rates - 50%	$ 4,180	$ 1,178

2.7.6 Conclusions

The results of the sensitivity tests indicate that the conclusions of the study are not sensitive to changes in any one of the major factors that determine the answers. Rather, it is the combination of factors, particularly low reliability and high traffic delays, that drives the decision towards early replacement.

ADDENDUM 1

Reliability Functions

To

ATTACHMENT 2

LCLM

On file in the offices of the Planning Division, Pittsburgh District, U.S. Army Corps of Engineers

Developed by
USACE Pittsburgh District
Plan Formulation
October 1999

ADDENDUM 2

Event Trees

To

ATTACHMENT 2

LCLM

Developed by
USACE Pittsburgh District
Plan Formulation
October 1999

Component	Annual Hazard Rate	Level of Repair	Closure/Cost	Effect on Component Reliability
Horizontally-Miter Gate	Annual Reliability (1 - Annual Hazard			
		New Gate 5%	180 Days/$7,335,000	Assume R = 1.0 for All Future
	Annual Hazard Rate	Major Repair 35%	45 Days/$1,868,000	Move Back 5 Years
		Temporary Repair with New Gates 60%	90 Days/$7,335,000	Assume R = 1.0 for All Future

Scheduled Replacement Will Take 30 Days at a Cost of and Future Reliability Will Equal 1.0 After

Figure 4. Horizontally-Framed Miter Gate Event Tree

Main Chamber Reverse Tainter Culvert Valve Event Tree

Component	Hazard Rate	Damage/Level of Repair		Repair Cost	Chamber Closure	Future Reliability
Main Chamber Horiz.-Framed Culvert Valve	Annual Hazard Rate (AHR)	Catastrophic Failure Chamber Closed	1%	$3,650,000	Closed 45 days in year of failure	R = 1.0 for All
		Fabricate and Install 4 New Culvert Valves		Split Over 2 Years	90 days half-speed following year	Future Years
		Temporary Repair to Open Chamber	49%	$3,100,000	Closed 30 days in year of failure	R = 1.0 for All
		Fabricate and Install 2 New Culvert Valves		Split Over 2 Years	90 days half-speed following year	Future Years
		Major Damage	50%	$600,000	Closed 15 days in year of failure	Move Back
		Major Repairs to Valves				5 Years
	1- (AHR)					

Scheduled Replacement of Culvert Valves for Main Chamber
Cost = 4*(400,000) + 4*(30)*(10,000) = **$2,900,000**
No Chamber Closure But **90 Days of Half-Speed Operation**

Auxiliary Chamber Reverse Tainter Culvert Valve Event Tree

Component	Hazard Rate	Damage/Level of Repair		Repair Cost	Chamber Closure	Future Reliability
Auxiliary Chamber Horiz.-Framed Culvert Valve	Annual Hazard Rate (AHR)	Catastrophic Failure Chamber Closed	1%	$4,150,000	Closed 180 days in year of failure	R = 1.0 for All Future Years
		Fabricate and Install 2 New Culvert Valves				
		Temporary Repair to Open Chamber	49%	$3,950,000	Closed 30 days in year of failure	R = 1.0 for All Future Years
		Fabricate and Install 2 New Culvert Valves		Split Over 2 Years	Closed 60 days in following year	
		Major Damage	50%	$1,575,000	Closed 45 days in years of failure	Move Back 5 Years
		Major Repairs to Valves				
	1- (AHR)					

Scheduled Replacement of Culvert Valves for Auxiliary Chamber
Cost = 2*(400,000) + 60*(35,000) = **$2,900,000**
Closure Time Would Be **60 Days**

Electrical System Event Tree

Scheduled Replacement Should be Assumed to Cost $2,500,000 and Take 30 days
Future Reliability will be equal to 1.0 for all future years after replacement

Component	Annual Time Dependent Probabilities		Repair Level		Cost	Closure	Effect on Reliability
Electrical System for Hydraulic Power Units	Satisfactory (1 - AHR)						
	Annual Hazard Rate	Major 25%	Unplanned New Electrical System	5.00%	$4,575,000	90 days	R=1 all future yea
			Major Overhaul	25.00%	$1,787,500	45 days	Back 10 years
			Replace Major Component	70.00%	$412,500	15 days	No Change
		Minor 75%	Major Overhaul	10.00%	$1,525,000	30 days	Back 10 years
			Replace Component	90.00%	$110,000	10 days	No Change

Miter Gate Machinery for Both Chambers

Component	Annual Time Dependent Probabilities			Repair Level		Cost	Closure (days)	Effect on Reliability
Miter Gate Machinery	Satisfactory Table Values			Unplanned New Miter Gate Machinery	1.00%	$6,588,000	90	R=1.0 for all future yrs
	Annual Unsatisfactory Table Values	Major 25%		Major Overhaul	4.00%	$1,887,500	45	Back 10 years
				Replace Major Component	95.00%	$240,000	10	No effect
		Minor 75%		Major Overhaul	10.00%	$942,500	15	Back 10 years
				Replace Minor Component	90.00%	$127,500	5	No effect

Planned Replacement of Miter Gate Machinery Will Be 30 Days of Closure and $2,500,000
Reliability Will Equal 1.0 For All Future Years

Main Chamber Culvert Valve Machinery

Component	Annual Time Dependent Probabilities		Repair Level	Cost	Half Speed (days)	Effect on Reliability
Valve Machinery	Satisfactory Table Values		Unplanned New Valve Machinery	1.00%	$4,350,000	90	R=1.0 for all future yrs
	Annual Unsatisfactory Table Values	Major 25%	Major Overhaul	4.00%	$1,387,500	45	Back 10 years
			Replace Major Component	95.00%	$190,000	10	No effect
		Minor 75%	Major Overhaul	10.00%	$875,000	30	Back 10 years
			Replace Minor Component	90.00%	$97,500	5	No Effect

Planned Replacement of Valve Machinery
Will Take 60 Days of **Half Speed** and $2,500,000
Reliability Will Equal 1.0 For All Future Years

Auxiliary Chamber Culvert Valve Machinery

Component	Annual Time Dependent Probabilities			Repair Level		Cost	Aux Closure Days	Effect on Reliability
Valve Machinery	Satisfactory Table Values			Unplanned New Valve Machinery	1.00%	$2,700,000	60	R=1.0 for all future yrs
		Major 25%		Major Overhaul	4.00%	$825,000	30	Back 10 years
				Replace Major Component	95.00%	$190,000	10	No effect
	Annual Unsatisfactory Table Values			Major Overhaul	10.00%	$437,500	15	Back 10 years
		Minor 75%		Replace Minor Component	90.00%	$97,500	5	No Effect

Planned Replacement of Valve Machinery
Will Take 30 Days of Closure and $1,250,000
Reliability Will Equal 1.0 For All Future Years

Hydraulic System for Main Chamber

Component	Annual Time Dependent Probabilities			Repair Level		Cost	Closure (days)	Effect on Reliability
Hydraulic System	Satisfactory Table Values			Unplanned New Hydraulic System	100.0%	$3,803,000	90	R=1.0 for all future yrs
		Major 25%		Major Overhaul	40.0%	$1,087,500	45	Back 10 years
				Replace Major Component	95.00%	$181,000	10	No Effect
	Annual Unsatisfactory Table Values			Major Overhaul	100.0%	$675,000	30	Back 10 years
		Minor 75%		Replace Minor Component	90.00%	$90,500	5	No Effect

Planned Replacement of Hydraulic System
Will Be 60 Days of Closure and $2,115,000
Reliability Will Equal 1.0 For All Future Years

Hydraulic System for Auxiliary Chamber

Component	Annual Time Dependent Probabilities		Repair Level		Cost	Closure (days)	Effect on Reliability
Hydraulic System	Satisfactory Table Values		Unplanned New Hydraulic System	1.00%	$2,416,000	60	R=1.0 for all future yrs
	Annual Unsatisfactory Table Values	Major 25%	Major Overhaul	4.00%	$725,000	30	Back 10 years
			Replace Major Component	95.00%	$181,000	10	No Effect
		Minor 75%	Major Overhaul	10.00%	$362,500	15	Back 10 years
			Replace Minor Component	90.00%	$90,500	5	No Effect

Planned Replacement of Hydraulic System
Will Be 45 Days of Closure and $1,442,000
Reliability Will Equal 1.0 For All Future Years

ADDENDUM 3

Procedure to Develop Industry Cost Tables

To

ATTACHMENT 2

LCLM

On file in the offices of the Planning Division, Pittsburgh District, U.S. Army Corps of Engineers

ADDENDUM 4

Industry Cost Tables for Myers and Greenup

To

ATTACHMENT 2

LCLM

Developed by
USACE Pittsburgh District
Plan Formulation
October 1999

Table 5-1

11 13 1998

Incremental Costs - Delayed Traffic Thousands of Dollars - Closure Scenario Union town

Main Chamber Closed

		0	1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	86191	0	163	400	707	2686	4920	23811	47631	86723	180689	204138	301708	428638	323253	88	290	568
2001	87303	0	165	404	719	2775	5074	24475	49004	89630	188163	214695	322636	433902	323054	91	288	571
2002	88468	0	168	409	731	2869	5240	25182	50520	92916	196565	226764	345694	437656	322675	94	286	574
2003	89967	0	170	413	745	2983	5445	26039	52469	97306	207794	243147	373764	435385	321000	98	283	578
2004	91132	0	172	418	760	3083	5631	26821	54313	101477	218181	257977	395326	434941	320673	102	283	583
2005	92244	0	174	423	774	3183	5820	27613	56256	105938	229136	273399	418909	434631	320445	107	283	589
2006	93920	0	177	430	799	3337	6123	28872	59516	113570	247444	298784	462290	433948	319941	114	287	600
2007	95641	0	180	438	827	3500	6461	30258	63340	122697	268551	327489	469683	432954	319208	122	294	615
2008	97691	0	183	449	864	3696	6890	32002	68519	134932	296350	364461	477221	430672	317526	134	308	639
2009	99412	0	186	460	903	3880	7310	33707	73793	146531	323287	398043	483989	429789	316875	145	327	667
2010	101088	0	189	473	948	4070	7765	35552	79735	158421	352288	428921	483254	429136	316393	158	352	701
2011	102242	0	192	484	983	4208	8107	36931	84278	166745	373826	451928	482836	428765	316120	168	374	730
2012	103427	0	194	496	1022	4355	8484	38430	89283	175283	397014	480626	482437	428410	315858	179	400	764
2013	104938	0	196	511	1075	4537	8976	40318	95791	185636	424916	517161	480382	426586	314513	194	439	811
2014	106123	0	199	526	1124	4697	9412	41958	101388	194317	446295	522444	479870	426131	314177	208	476	855
2015	107277	0	203	543	1178	4865	9873	43647	107139	203202	469203	528068	479817	426084	314143	224	517	904
2016	108501	0	208	563	1239	5049	10379	45440	113305	212790	497919	533473	479258	425588	313777	243	563	960
2017	109759	0	215	585	1309	5251	10927	47322	119783	223175	530479	539050	478717	425108	313423	266	613	1021
2018	111335	0	225	614	1400	5508	11617	49568	127633	236263	535780	539857	476658	423278	312074	296	676	1099
2019	112593	0	235	640	1482	5744	12220	51482	134213	247310	541270	539295	476161	422837	311749	322	726	1165
2020	113817	0	247	666	1566	5990	12828	53347	140643	257495	546585	538736	475666	422398	311425	350	772	1229
2021	114971	0	259	690	1651	6243	13424	55142	146819	266542	551827	538445	475407	422168	311256	376	813	1289
2022	116185	0	272	715	1742	6524	14059	57021	153309	277074	555924	537827	474860	421682	310898	405	849	1349
2023	117683	0	290	743	1857	6885	14828	59245	161073	292473	553800	535774	473046	420071	309710	440	883	1414
2024	118897	0	307	765	1956	7214	15499	61200	167782	305330	553060	535059	472413	419509	309295	467	906	1463
2025	120051	0	322	784	2053	7553	16171	63163	174443	317229	552783	534793	472176	419299	309140	489	923	1504
2026	121258	0	334	801	2153	7920	16894	65251	181512	329309	552176	534207	471657	418838	308801	506	935	1539
2027	122497	0	343	815	2255	8309	17677	67493	189086	342069	551599	533652	471164	418401	308478	520	945	1568
2028	124019	0	347	830	2373	8782	18666	70319	198548	359972	549734	531850	469571	416985	307435	529	957	1595
2029	125258	0	344	845	2471	9183	19561	73062	207119	378256	549007	531149	468950	416434	307028	535	975	1618
2030	126465	0	337	863	2565	9577	20503	76209	216183	396664	548433	530597	468459	415998	306707	539	1002	1649
2031	127902	0	322	891	2676	10042	21727	80762	228082	417899	547846	530032	467958	415553	306378	544	1051	1716
2032	129399	0	296	932	2789	10509	23126	86423	241806	449720	547013	529229	467246	414920	305912	554	1124	1843
2033	131148	0	258	998	2916	11024	24920	93290	258943	491030	544949	527236	465482	413354	304757	591	1242	2086
2034	132645	0	242	1084	3048	11566	26706	100048	275034	514851	544012	526332	464681	412643	304233	668	1382	2362
2035	134082	0	256	1193	3205	12265	28646	108089	291400	542565	543521	525860	464261	412270	303958	789	1562	2647
2036	135595	0	303	1318	3396	13263	30808	116799	309898	619735	542713	525082	463571	411657	303506	937	1812	2959
2037	137147	0	383	1438	3611	14645	33034	123798	331577	770522	541856	524256	462838	411007	303027	1044	2083	3352
2038	138972	0	455	1506	3810	16472	35513	131249	359838	770675	539878	522348	461148	409506	301920	1037	2209	3978
2039	140524	0	451	1475	3893	17954	37672	139806	385513	769486	538981	521486	460381	408824	301418	1049	2518	4752
2040	142037	0	427	1438	3940	19341	39736	149502	413123	768258	538051	520593	459586	408119	300897	1311	3532	5848
2041	143559	0	438	1487	4024	20799	41740	160003	445121	767463	537422	519991	459048	407641	300545	2050	4929	7346
2042	145129	0	488	1626	4080	22559	44295	171104	481076	766136	536415	519023	458186	406876	299981	3234	6299	9137
2043	147013	0	515	1738	3801	25427	48910	184912	528104	763169	534221	516911	456311	405210	298753	4530	7963	11487
2044	148583	0	568	1760	3595	28158	52289	196804	581101	761676	533065	515803	455322	404332	298106	5663	9512	14154
2045	150101	0	779	1798	4050	30288	54402	208737	644439	760776	532333	515104	454696	403776	297696	7509	11239	18042
2046	151406	0	936	2082	4754	31757	57169	221638	695255	759893	531637	514438	454101	403248	297306	9689	13098	22240
2047	152766	0	803	2910	5130	33627	61620	240445	799728	758699	530725	513562	453320	402555	296795	12028	15696	23866
2048	154402	0	814	3816	5630	37201	68462	271614	803051	755946	528686	511600	451578	401007	295654	14422	19455	28031
2049	155762	0	1499	3567	6956	41877	74716	295709	801309	754358	527436	510403	450508	400057	294954	16724	22640	42049
2050	157067	0	1671	2676	9768	46680	80192	332194	799471	752701	526079	509108	449347	399026	294194	19358	25659	41639
2051	158528	0	2000	1865	14729	50397	84565	428211	796444	749967	523854	506984	447442	397335	292947	22553	29185	32362
2052	160025	0	3500	2948	17273	52377	88725	587455	793100	746957	521376	504620	445321	395451	291558	26419	35118	44474
2053	161838	0	5149	10139	10624	54573	118309	467402	788453	742694	518092	501470	442513	392958	289719	34643	41730	50000
2054	163335	0	5223	12065	34211	67839	168577	466195	787030	741392	517081	500501	441648	392190	289153	42102	57882	65837

2055	164796	0	6000	14772	74486	92442	219759	460438	781463	736406	512906	496525	438074	389016	286813	53160	66440	79949
2056	166345	0	7297	16570	79000	105279	261438	440239	761988	718968	498290	482604	425561	377904	278621	64557	70012	79348
2057	167849	0	9000	10891	89227	119095	365337	386676	710614	672997	459673	445831	392499	348545	256975	65374	71928	84981
2058	168304	0	10000	22434	280755	120000	390771	364767	688434	653023	443257	430170	378449	336068	247776	76000	78085	88602
2059	168737	0	11000	31574	305945	121000	397738	350145	673982	640044	432488	419905	369230	327881	241740	77000	82513	91342
2060	168953	0	14639	67783	190533	122000	754140	346189	669852	636312	429457	417011	366636	325578	240042	78000	88086	99998

11 13 1998

Table 5-2

Incremental Costs - Delayed Traffic Thousands of Dollars - Closure Scenario Union town

			Auxiliary Chamber Closed															
		Both Cl	1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	86191	1207917	48	166	285	430	539	719	1045	1440	1810	1958	2283	2671	3845	0	0	0
2001	87303	1229556	47	169	281	430	541	721	1059	1469	1847	1999	2335	2742	3964	0	0	0
2002	88468	1252396	47	172	277	430	543	724	1073	1499	1887	2043	2390	2818	4090	0	0	0
2003	89967	1281577	45	175	272	430	545	726	1087	1533	1931	2092	2457	2912	4241	0	0	0
2004	91132	1304390	44	178	269	431	549	731	1102	1565	1973	2139	2519	2997	4374	0	0	0
2005	92244	1325973	43	180	268	433	554	737	1118	1597	2014	2186	2583	3084	4505	0	0	0
2006	93920	1351636	42	184	267	438	564	748	1143	1647	2078	2260	2685	3219	4701	0	0	0
2007	95641	1377922	40	187	270	445	577	764	1171	1702	2147	2340	2796	3362	4887	0	0	0
2008	97691	1410780	38	189	278	458	598	788	1208	1770	2231	2439	2931	3533	5271	0	0	0
2009	99412	1437029	37	191	292	475	624	818	1247	1838	2313	2536	3060	3691	6167	0	0	0
2010	101088	1462625	35	192	311	497	656	857	1293	1912	2402	2640	3194	3854	6843	0	0	0
2011	102242	1479696	35	193	328	516	683	888	1328	1968	2468	2717	3291	3970	9160	0	0	0
2012	103427	1497411	34	193	350	539	715	926	1369	2030	2541	2799	3394	4093	14542	0	0	0
2013	104938	1521179	33	193	382	572	760	980	1423	2109	2630	2901	3519	4240	22402	0	0	0
2014	106123	1538878	32	193	413	603	803	1031	1474	2179	2710	2991	3628	4369	28660	0	0	0
2015	107277	1555916	32	192	449	639	850	1087	1529	2254	2794	3085	3740	4500	35331	0	0	0
2016	108501	1577223	32	191	490	679	904	1151	1591	2333	2884	3184	3858	4631	43323	0	0	0
2017	109759	1599097	32	190	536	725	962	1219	1658	2416	2978	3288	3981	4759	52270	0	0	0
2018	111335	1627226	33	189	594	781	1034	1302	1738	2512	3087	3408	4124	4905	63609	0	0	0
2019	112593	1649062	35	189	641	829	1092	1368	1806	2591	3179	3509	4245	5255	73548	0	0	0
2020	113817	1670286	37	189	686	873	1145	1428	1870	2664	3265	3605	4358	5881	88541	0	0	0
2021	114971	1689131	41	191	726	914	1192	1479	1928	2728	3344	3692	4459	6354	107373	0	0	0
2022	116185	1708999	46	194	763	952	1234	1522	1982	2786	3419	3776	4549	6741	127641	0	0	0
2023	117683	1734842	54	199	798	990	1270	1555	2034	2840	3493	3860	4624	9347	162586	0	0	0
2024	118897	1754658	62	205	819	1014	1290	1567	2069	2877	3548	3924	4751	14545	198322	0	0	0
2025	120051	1773414	72	214	830	1030	1298	1566	2095	2904	3593	3977	5127	20450	664124	0	0	0
2026	121258	1792877	83	225	832	1038	1295	1550	2114	2919	3626	4016	5682	26518	0	0	0	0
2027	122497	1812861	97	237	823	1037	1285	1525	2129	2924	3649	4039	6028	32959	0	0	0	0
2028	124019	1838191	114	253	799	1026	1266	1488	2147	2913	3655	4034	6725	41687	0	0	0	0
2029	125258	1857282	127	265	775	1014	1256	1464	2173	2905	3653	4030	9466	49754	0	0	0	0
2030	126465	1875117	139	276	747	1001	1254	1451	2213	2908	3641	4179	14711	58126	0	0	0	0
2031	127902	1896413	151	284	713	987	1268	1458	2287	2953	3610	4712	21913	68309	0	0	0	0
2032	129399	1918129	159	288	678	978	1311	1500	2404	3076	3637	5206	29350	79337	0	0	0	0
2033	131148	1946145	159	280	644	979	1405	1608	2601	3362	4131	5722	38657	99742	0	0	0	0
2034	132645	1971487	151	263	636	1002	1533	1752	2845	3767	4698	8662	47876	122792	0	0	0	0
2035	134082	1995444	137	241	653	1043	1688	1922	3149	4299	4938	14888	57607	150125	0	0	0	0
2036	135595	2020578	122	227	684	1088	1860	2100	3526	4939	6333	22379	68185	182473	0	0	0	0
2037	137147	2046481	115	240	717	1117	2018	2250	3955	6009	11351	29971	79081	250700	0	0	0	0
2038	138972	2077651	128	314	737	1101	2112	2355	4377	9284	20050	39481	97125	0	0	0	0	0
2039	140524	2103300	163	429	752	1065	2108	2426	4601	12956	27393	48758	121255	0	0	0	0	0
2040	142037	2128012	213	554	819	1134	2157	2618	4913	16352	34830	58614	144039	0	0	0	0	0
2041	143559	2153059	274	659	1002	1448	2421	3093	5615	20027	43212	68922	182222	0	0	0	0	0
2042	145129	2174956	327	732	1292	2048	2944	3810	7237	24363	52898	79501	206425	0	0	0	0	0
2043	147013	2206855	327	795	1603	2905	3676	4484	11354	30169	65080	96539	821306	0	0	0	0	0
2044	148583	2232617	281	823	1900	3633	4365	5145	16387	35619	75294	120016	0	0	0	0	0	0
2045	150101	2257163	241	811	2428	4343	5224	6541	21690	41432	86346	141162	0	0	0	0	0	0
2046	151406	2279025	223	940	3163	5231	6306	8333	26253	46613	100535	171690	0	0	0	0	0	0
2047	152766	2302062	220	1534	4223	6810	7947	10634	31067	52617	121546	196590	0	0	0	0	0	0
2048	154402	2330281	362	2886	5769	8700	9840	16642	36858	61535	144151	265346	0	0	0	0	0	0
2049	155762	2352798	790	4306	7057	9214	10620	26558	41673	68465	176267	867082	0	0	0	0	0	0
2050	157067	2373345	1906	5486	7675	8857	11897	35257	46309	81507	197881	0	0	0	0	0	0	0
2051	158528	2396727	4810	5815	7013	8215	15992	36407	51781	103160	245476	0	0	0	0	0	0	0

2052	160025	2420227	8430	5614	6548	8779	22714	35522	59551	213905	848073	0	0	0	0	0	0	0
2053	161838	2448996	9657	8311	11042	14655	33071	50634	76908	268943	0	0	0	0	0	0	0	0
2054	163335	2471113	10604	15094	24232	27805	40776	72672	117032	325281	0	0	0	0	0	0	0	0
2055	164796	2489427	11500	21694	30009	37583	48358	83825	179431	472580	0	0	0	0	0	0	0	0
2056	166345	2498745	13935	22547	35829	44412	74553	84415	226156	553119	0	0	0	0	0	0	0	0
2057	167849	2476867	24668	40560	40480	50734	88716	167064	666748	498273	0	0	0	0	0	0	0	0
2058	168304	2491317	25111	54305	42844	49864	89690	253031	786040	475488	0	0	0	0	0	0	0	0
2059	168737	2499301	32550	62120	50712	54343	119126	356150	771678	460388	0	0	0	0	0	0	0	0
2060	168953	2513645	40517	61749	57499	64575	149449	398813	767119	456236	0	0	0	0	0	0	0	0

Table 5-3

11 13 1998

Incremental Costs - Diverted Traffic Thousands of Dollars - Closure Scenario Union town
Main Chamber Closed

		0	1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	86191	0	0	0	0	0	0	0	0	0	0	0	0	0	296674	0	0	0
2001	87303	0	0	0	0	0	0	0	0	0	0	0	0	0	314472	0	0	0
2002	88468	0	0	0	0	0	0	0	0	0	0	0	0	4345	333246	0	0	0
2003	89967	0	0	0	0	0	0	0	0	0	0	0	0	25631	354531	0	0	0
2004	91132	0	0	0	0	0	0	0	0	0	0	0	0	42471	373688	0	0	0
2005	92244	0	0	0	0	0	0	0	0	0	0	0	0	58781	392314	0	0	0
2006	93920	0	0	0	0	0	0	0	0	0	0	0	0	82915	416448	0	0	0
2007	95641	0	0	0	0	0	0	0	0	0	0	0	0	107698	441230	0	0	0
2008	97691	0	0	0	0	0	0	0	0	0	0	0	0	137218	470750	0	0	0
2009	99412	0	0	0	0	0	0	0	0	0	0	0	1914	163125	498974	0	0	0
2010	101088	0	0	0	0	0	0	0	0	0	0	0	26216	187427	523276	0	0	0
2011	102242	0	0	0	0	0	0	0	0	0	0	0	42949	204160	540009	0	0	0
2012	103427	0	0	0	0	0	0	0	0	0	0	0	60132	221343	557192	0	0	0
2013	104938	0	0	0	0	0	0	0	0	0	0	0	82041	243252	579101	0	0	0
2014	106123	0	0	0	0	0	0	0	0	0	0	0	99224	260435	596284	0	0	0
2015	107277	0	0	0	0	0	0	0	0	0	0	0	115957	277168	613017	0	0	0
2016	108501	0	0	0	0	0	0	0	0	0	0	0	133705	294916	630765	0	0	0
2017	109759	0	0	0	0	0	0	0	0	0	0	0	152993	315316	653481	0	0	0
2018	111335	0	0	0	0	0	0	0	0	0	0	13680	176003	338326	676491	0	0	0
2019	112593	0	0	0	0	0	0	0	0	0	0	32047	194370	356693	694858	0	0	0
2020	113817	0	0	0	0	0	0	0	0	0	0	50259	213694	377129	717610	0	0	0
2021	114971	0	0	0	0	0	0	0	0	0	0	67223	230658	394092	734574	0	0	0
2022	116185	0	0	0	0	0	0	0	0	0	3337	85069	248504	411938	752420	0	0	0
2023	117683	0	0	0	0	0	0	0	0	0	25358	107090	270524	433959	774440	0	0	0
2024	118897	0	0	0	0	0	0	0	0	0	43497	125785	290332	454878	797676	0	0	0
2025	120051	0	0	0	0	0	0	0	0	0	60576	142864	307411	471957	814755	0	0	0
2026	121258	0	0	0	0	0	0	0	0	0	78440	160728	325274	489821	832618	0	0	0
2027	122497	0	0	0	0	0	0	0	0	0	96777	179065	343612	508158	850956	0	0	0
2028	124019	0	0	0	0	0	0	0	0	0	119303	201591	366137	530684	873481	0	0	0
2029	125258	0	0	0	0	0	0	0	0	0	137640	219928	384474	549021	891818	0	0	0
2030	126465	0	0	0	0	0	0	0	0	0	155504	237792	402338	566884	909682	0	0	0
2031	127902	0	0	0	0	0	0	0	0	0	176771	259059	423606	588152	930950	0	0	0
2032	129399	0	0	0	0	0	0	0	0	0	198927	281215	445761	610308	953105	0	0	0
2033	131148	0	0	0	0	0	0	0	0	0	224812	307100	471646	636193	978990	0	0	0
2034	132645	0	0	0	0	0	0	0	0	0	248636	331480	497139	662797	1007911	0	0	0
2035	134082	0	0	0	0	0	0	0	0	0	270048	352892	518550	684208	1029322	0	0	0
2036	135595	0	0	0	0	0	0	0	0	0	292591	375435	541094	706752	1051866	0	0	0
2037	137147	0	0	0	0	0	0	0	0	0	315716	398560	564218	729877	1074990	0	0	0
2038	138972	0	0	0	0	0	0	0	0	19534	342909	425753	591411	757069	1102183	0	0	0
2039	140524	0	0	0	0	0	0	0	0	42945	368490	451890	618660	785430	1132860	0	0	0
2040	142037	0	0	0	0	0	0	0	0	65640	391185	474585	641355	808125	1155555	0	0	0
2041	143559	0	0	0	0	0	0	0	0	88470	414015	497415	664185	830955	1178385	0	0	0
2042	145129	0	0	0	0	0	0	0	0	112020	437565	520965	687735	854505	1201935	0	0	0
2043	147013	0	0	0	0	0	0	0	0	140280	465825	549225	715995	882765	1230195	0	0	0
2044	148583	0	0	0	0	0	0	0	0	163830	489375	572775	739545	906315	1253745	0	0	0
2045	150101	0	0	0	0	0	0	0	0	186600	512145	595545	762315	929085	1276515	0	0	0
2046	151406	0	0	0	0	0	0	0	0	207550	535265	619221	787103	954984	1304731	0	0	0
2047	152766	0	0	0	0	0	0	0	0	228086	555801	639757	807639	975520	1325267	0	0	0
2048	154402	0	0	0	0	0	0	0	6553	252789	580504	664460	832342	1000224	1349970	0	0	0
2049	155762	0	0	0	0	0	0	0	27089	273325	601040	684996	852878	1020760	1370506	0	0	0
2050	157067	0	0	0	0	0	0	0	46795	293031	620746	704702	872584	1040466	1390212	0	0	0

2051	158528	0	0	0	0	0	0	0	68856	315092	642807	726763	894645	1062527	1412273	0	0	0
2052	160025	0	0	0	0	0	0	0	91461	337696	665412	749368	917250	1085131	1434878	0	0	0
2053	161838	0	0	0	0	0	0	3579	118837	365073	692788	776744	944626	1112508	1462254	0	0	0
2054	163335	0	0	0	0	0	0	26183	141442	387677	715393	799349	967231	1135112	1484859	0	0	4772
2055	164796	0	0	0	0	0	0	48245	163503	409739	737454	821410	989292	1157173	1506920	0	0	26833
2056	166345	0	0	0	0	0	0	71160	185655	430260	755805	839205	1005975	1172745	1520175	0	0	49890
2057	167849	0	0	0	0	0	0	92470	205439	446782	767987	850275	1014821	1179368	1522165	0	20217	71484
2058	168304	0	0	0	0	0	0	99204	212173	453516	774721	857009	1021555	1186102	1528899	4484	26951	78218
2059	168737	0	0	0	0	0	0	105613	218581	459925	781129	863417	1027964	1192510	1535308	10893	33359	84626
2060	168953	0	0	0	0	0	60	109545	223277	466251	789626	872470	1038128	1203786	1548900	14185	36803	88417

Table 5-4

11 13 1998

Incremental Costs - Diverted Traffic Thousands of Dollars - Closure Scenario Union town

Auxiliary Chamber Closed

		Both Cl	1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	86191	1207917	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	87303	1229556	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	88468	1252396	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	89967	1281577	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	91132	1304390	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	92244	1325973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	93920	1351636	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	95641	1377922	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	97691	1410780	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	99412	1437029	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	101088	1462625	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	102242	1479696	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	103427	1497411	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	104938	1521179	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	106123	1538878	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	107277	1555916	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	108501	1577223	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	109759	1599097	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	111335	1627226	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	112593	1649062	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	113817	1670286	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	114971	1689131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	116185	1708999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2023	117683	1734842	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2024	118897	1754658	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2025	120051	1773414	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2026	121258	1792877	0	0	0	0	0	0	0	0	0	0	0	15673	0	0	0	0
2027	122497	1812861	0	0	0	0	0	0	0	0	0	0	0	34010	0	0	0	0
2028	124019	1838191	0	0	0	0	0	0	0	0	0	0	0	56536	0	0	0	0
2029	125258	1857282	0	0	0	0	0	0	0	0	0	0	0	74873	0	0	0	0
2030	126465	1875117	0	0	0	0	0	0	0	0	0	0	0	92737	0	0	0	0
2031	127902	1896413	0	0	0	0	0	0	0	0	0	0	0	114004	0	0	0	0
2032	129399	1918129	0	0	0	0	0	0	0	0	0	0	0	136160	0	0	0	0
2033	131148	1946145	0	0	0	0	0	0	0	0	0	0	0	162045	0	0	0	0
2034	132645	1971487	0	0	0	0	0	0	0	0	0	0	0	185445	0	0	0	0
2035	134082	1995444	0	0	0	0	0	0	0	0	0	0	0	206857	0	0	0	0
2036	135595	2020578	0	0	0	0	0	0	0	0	0	0	0	229400	0	0	0	0
2037	137147	2046481	0	0	0	0	0	0	0	0	0	0	0	252525	0	0	0	0
2038	138972	2077651	0	0	0	0	0	0	0	0	0	0	8806	279718	0	0	0	0
2039	140524	2103300	0	0	0	0	0	0	0	0	0	0	32145	304875	0	0	0	0
2040	142037	2128012	0	0	0	0	0	0	0	0	0	0	54840	327570	0	0	0	0
2041	143559	2153059	0	0	0	0	0	0	0	0	0	0	77670	350400	0	0	0	0
2042	145129	2174956	0	0	0	0	0	0	0	0	0	0	101220	373950	0	0	0	0
2043	147013	2206855	0	0	0	0	0	0	0	0	0	0	129480	402210	0	0	0	0
2044	148583	2232617	0	0	0	0	0	0	0	0	0	0	22110	153030	425760	0	0	0
2045	150101	2257163	0	0	0	0	0	0	0	0	0	0	44880	175800	448530	0	0	0
2046	151406	2279025	0	0	0	0	0	0	0	0	0	0	64885	196678	471226	0	0	0
2047	152766	2302062	0	0	0	0	0	0	0	0	0	0	85421	217214	491762	0	0	0
2048	154402	2330281	0	0	0	0	0	0	0	0	0	0	110124	241917	516465	0	0	0
2049	155762	2352798	0	0	0	0	0	0	0	0	0	0	130660	262453	537001	0	0	0

2050	157067	2373345	0	0	0	0	0	0	0	0	0	18573	150366	282159	556707	0	0	0
2051	158528	2396727	0	0	0	0	0	0	0	0	0	40634	172427	304220	578768	0	0	0
2052	160025	2420227	0	0	0	0	0	0	0	0	0	63239	195032	326824	601373	0	0	0
2053	161838	2448996	0	0	0	0	0	0	0	0	24719	90615	222408	354201	628749	0	0	0
2054	163335	2471113	0	0	0	0	0	0	0	0	47323	113220	245013	376805	651354	0	0	0
2055	164796	2489427	0	0	0	0	0	0	0	0	69385	135281	267074	398867	673415	0	0	0
2056	166345	2498745	0	0	0	0	0	0	0	17790	92160	157620	288540	419460	692190	0	0	0
2057	167849	2476867	0	0	0	0	0	0	0	39812	113190	177778	306952	436126	705220	0	0	0
2058	168304	2491317	0	0	0	0	0	0	0	46546	119924	184512	313686	442860	711954	0	0	0
2059	168737	2499301	0	0	0	0	0	0	1598	52954	126333	190920	320094	449269	718362	0	0	0
2060	168953	2513645	0	0	0	0	0	0	4828	56531	130405	195428	325476	455523	726435	0	0	0

Table 5-5

11 13 1998

Incremental Costs - Delayed Traffic Thousands of Dollars - Closure Scenario Green up

Main Chamber Closed

		0	1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	72118	0	81	369	672	1913	2785	10374	28733	51986	90714	114565	180154	284453	250471	197	361	561
2001	73210	0	79	380	690	2007	3003	11308	30933	56734	99236	124758	193793	308781	250108	195	360	560
2002	74337	0	78	391	709	2109	3241	12319	33325	61786	108579	135913	208473	313158	249808	193	359	559
2003	75729	0	75	404	730	2231	3536	13573	36296	67910	120386	149929	227748	317270	248436	190	357	556
2004	76856	0	74	415	749	2340	3798	14674	38935	73154	130900	162315	245703	321543	248090	189	356	556
2005	77948	0	72	427	769	2449	4065	15788	41625	78327	141700	174870	263714	325820	247868	187	357	557
2006	79193	0	71	440	792	2579	4384	17106	44840	84275	154700	189718	286302	329015	247639	186	358	559
2007	80466	0	70	454	816	2716	4725	18504	48282	90357	168659	205363	310498	328667	247377	186	360	563
2008	81987	0	69	470	843	2878	5139	20180	52460	97308	185608	224074	342483	327306	246353	186	363	569
2009	83260	0	70	484	869	3025	5513	21674	56243	103322	200739	241662	347354	326885	246036	187	369	578
2010	84505	0	71	499	896	3176	5900	23199	60157	109352	216145	261037	352405	326752	245936	190	377	590
2011	85334	0	72	509	914	3277	6164	24227	62830	113385	226537	274422	355616	326526	245766	192	383	600
2012	86188	0	74	519	933	3383	6440	25293	65625	117554	237515	288256	358745	326135	245472	195	391	612
2013	87290	0	76	531	956	3514	6792	26633	69179	122787	252185	306707	361942	324887	244532	200	402	629
2014	88144	0	79	541	977	3625	7085	27737	72132	127188	265021	323178	365046	324517	244254	205	413	646
2015	88973	0	82	552	997	3737	7380	28842	75108	131670	278209	338353	364863	324354	244131	210	425	664
2016	89933	0	87	565	1022	3867	7728	30130	78597	136989	293605	356262	364472	324006	243869	218	440	688
2017	90909	0	92	578	1048	4003	8090	31459	82215	142613	309773	380234	364027	323610	243571	227	457	715
2018	92132	0	99	593	1080	4165	8532	33069	86626	149566	331529	383717	362483	322238	242539	239	479	749
2019	93108	0	105	607	1108	4308	8912	34452	90416	155640	349553	387341	362070	321871	242262	249	497	779
2020	94068	0	111	621	1138	4451	9293	35834	94209	161741	366557	390876	361646	321493	241978	261	515	809
2021	94969	0	118	635	1168	4589	9659	37164	97853	167597	387830	394286	361340	321221	241773	272	530	837
2022	95910	0	124	650	1199	4733	10040	38548	101648	173647	391048	397558	360763	320708	241387	283	545	865
2023	97064	0	131	669	1238	4906	10499	40221	106238	180823	394424	400992	359552	319631	240576	296	559	896
2024	98005	0	136	686	1273	5059	10893	41671	110215	186908	397768	402279	359119	319245	240286	307	568	921
2025	98906	0	141	704	1309	5209	11279	43108	114138	192747	401111	401966	358838	318996	240098	318	574	942
2026	99813	0	145	722	1347	5364	11672	44602	118174	198612	404493	401672	358575	318762	239922	327	576	960
2027	100759	0	148	742	1387	5523	12075	46191	122378	204596	407689	401046	358016	318265	239548	336	573	975
2028	101909	0	150	766	1436	5715	12554	48174	127456	211719	411046	399787	356891	317264	238795	345	563	986
2029	102855	0	150	788	1481	5883	12971	49984	131923	218036	411611	399315	356469	316889	238512	351	552	994
2030	103762	0	150	810	1527	6051	13381	51859	136371	224401	411327	399040	356223	316670	238347	355	541	1000
2031	104910	0	148	837	1587	6267	13901	54388	142069	232691	410689	398423	355671	316178	237978	357	527	1004
2032	106097	0	145	866	1654	6507	14453	57268	148150	241860	410079	397832	355143	315709	237624	358	515	1009
2033	107497	0	141	899	1739	6805	15097	60945	155203	253143	408606	396405	353867	314574	236770	355	510	1015
2034	108684	0	139	929	1822	7098	15685	64509	161506	264059	408017	395835	353357	314121	236429	351	518	1026
2035	109832	0	139	959	1910	7416	16279	68234	167668	275687	407543	395377	352948	313756	236154	345	540	1043
2036	110974	0	141	989	2008	7772	16897	72158	173815	288466	407158	395005	352614	313459	235931	338	580	1067
2037	112144	0	147	1019	2117	8171	17563	76280	179927	302715	406497	394366	352043	312951	235548	332	636	1098
2038	113528	0	158	1055	2259	8665	18428	81140	186702	320610	405098	393011	350831	311873	234737	332	712	1138
2039	114698	0	173	1088	2398	9112	19314	85372	192489	337118	404498	392431	350312	311411	234390	345	774	1173
2040	115840	0	188	1120	2548	9553	20340	89493	198313	354351	404138	392083	350001	311134	234181	367	817	1200
2041	116888	0	201	1145	2693	9942	21433	93188	204219	371271	403785	391742	349695	310862	233976	397	831	1224
2042	117974	0	208	1164	2848	10312	22690	97142	211387	390342	403290	391263	349267	310480	233689	435	825	1273
2043	119298	0	206	1176	3031	10716	24290	102510	221455	415113	401982	389998	348135	309474	232931	484	813	1400
2044	120384	0	201	1184	3174	11109	25697	107633	230737	437076	401467	389501	347689	309077	232632	520	822	1583
2045	121428	0	203	1197	3301	11602	27214	112897	239715	458629	401118	389165	347388	308808	232430	545	870	1802
2046	122437	0	220	1219	3407	12230	28934	118069	247864	479134	400703	388765	347029	308488	232189	560	971	2023
2047	123483	0	256	1252	3501	13062	31036	123327	256459	499744	400179	388260	346576	308084	231885	563	1146	2257
2048	124771	0	280	1291	3671	14331	33747	129436	268910	523515	398777	386905	345363	307005	231073	552	1431	2585
2049	125817	0	255	1321	3940	15556	35870	134830	283067	546050	398240	386388	344898	306591	230761	543	1696	2923

2050	126826	0	225	1348	4284	16836	37708	140548	300182	573547	397659	385828	344396	306143	230424	542	1971	3338
2051	127972	0	242	1387	4742	18364	39889	148052	322948	612021	397252	385438	344045	305830	230188	566	2306	3949
2052	129150	0	356	1433	5254	20081	42577	156498	348064	636155	396608	384817	343488	305333	229815	648	2668	4592
2053	130556	0	493	1480	5959	22981	46634	166869	376067	640925	395201	383458	342270	304250	228999	864	3132	5119
2054	131734	0	423	1562	6693	26288	50931	176238	400525	642109	394522	382805	341684	303727	228606	1179	3569	6366
2055	132880	0	205	1782	7558	29840	55367	186493	429621	641237	393905	382212	341150	303251	228248	1560	4066	7822
2056	134075	0	0	2230	8602	33709	59557	198907	459642	640127	393123	381462	340475	302649	227794	1962	4861	7769
2057	135311	0	0	2933	9461	37866	63388	213272	489954	638765	392168	380543	339649	301912	227240	2604	6289	10874
2058	136737	0	703	4269	10374	42982	67732	230558	530168	635605	390110	378556	337869	300328	226047	3935	8878	24305
2059	137911	0	1803	5440	11714	47049	71497	244353	568568	631623	387527	376060	335634	298338	224550	4820	11330	36198
2060	139106	0	2593	7064	13967	50584	75935	259013	610436	629358	385833	374438	334172	297032	223567	4713	14057	24785

Table 5-6

11 13 1998

Incremental Costs - Delayed Traffic Thousands of Dollars - Closure Scenario Green up

Auxiliary Chamber Closed

	Both Cl		1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	72118	981949	59	140	224	1913	432	561	575	833	960	1086	1351	1628	2531	0	0	0
2001	73210	998753	59	142	223	2007	425	569	576	863	996	1124	1393	1670	2754	0	0	0
2002	74337	1016439	60	145	222	2109	418	577	578	895	1033	1164	1435	1713	3039	0	0	0
2003	75729	1038985	60	147	220	2231	407	583	579	929	1075	1208	1481	1757	3435	0	0	0
2004	76856	1056636	61	149	218	2340	400	589	583	959	1113	1247	1521	1801	3790	0	0	0
2005	77948	1073365	62	150	217	2449	394	595	588	987	1149	1284	1559	1852	4139	0	0	0
2006	79193	1092923	62	152	215	2579	388	601	596	1018	1190	1326	1602	1928	4517	0	0	0
2007	80466	1112897	63	154	214	2716	384	607	606	1048	1231	1368	1643	2033	4857	0	0	0
2008	81987	1138012	64	156	212	2878	380	611	621	1077	1276	1413	1693	2200	5466	0	0	0
2009	83260	1157959	65	157	211	3025	380	614	638	1102	1314	1451	1751	2397	6821	0	0	0
2010	84505	1177468	66	159	210	3176	383	618	660	1124	1352	1488	1829	2648	9524	0	0	0
2011	85334	1190759	67	159	210	3277	386	620	677	1136	1376	1512	1894	2847	12326	0	0	0
2012	86188	1204587	67	160	211	3383	391	621	696	1147	1399	1538	1974	3073	16105	0	0	0
2013	87290	1222890	68	161	211	3514	400	621	723	1155	1424	1573	2099	3381	22239	0	0	0
2014	88144	1236700	69	161	212	3625	409	621	749	1162	1447	1609	2223	3637	27580	0	0	0
2015	88973	1249963	70	162	214	3737	421	622	777	1169	1473	1653	2366	3892	32804	0	0	0
2016	89933	1266916	72	162	216	3867	437	623	813	1177	1506	1716	2563	4182	39004	0	0	0
2017	90909	1284120	73	163	219	4003	455	624	853	1187	1549	1795	2794	4464	45820	0	0	0
2018	92132	1306309	75	163	223	4165	480	625	908	1201	1613	1917	3112	4772	55176	0	0	0
2019	93108	1323460	76	164	227	4308	502	630	960	1222	1684	2045	3390	5013	63486	0	0	0
2020	94068	1340295	78	165	232	4451	524	636	1015	1248	1770	2196	3672	5381	72262	0	0	0
2021	94969	1354923	79	167	237	4589	545	645	1071	1281	1868	2365	3939	6013	81039	0	0	0
2022	95910	1370263	81	168	243	4733	566	656	1133	1323	1990	2567	4208	7141	90653	0	0	0
2023	97064	1390171	83	171	250	4906	589	673	1215	1388	2170	2843	4510	9440	103104	0	0	0
2024	98005	1405456	85	174	256	5059	606	692	1289	1457	2349	3090	4736	12286	114269	0	0	0
2025	98906	1419974	86	178	262	5209	620	715	1365	1537	2545	3337	4943	15888	125919	0	0	0
2026	99813	1434738	88	182	269	5364	631	742	1446	1633	2761	3590	5247	20400	138629	0	0	0
2027	100759	1449959	89	188	275	5523	639	775	1537	1750	2999	3848	5809	25887	152889	0	0	0
2028	101909	1468553	91	195	283	5715	642	823	1663	1917	3295	4144	7057	32887	173686	0	0	0
2029	102855	1481920	92	202	289	5883	643	873	1789	2083	3545	4373	8760	38700	195030	0	0	0
2030	103762	1493322	93	208	295	6051	644	930	1934	2268	3782	4571	11130	44507	214221	0	0	0
2031	104910	1506069	95	215	302	6267	646	1018	2158	2539	4065	4807	15264	52451	243962	0	0	0
2032	106097	1517955	96	221	309	6507	653	1132	2449	2872	4329	5231	20920	61511	296033	0	0	0
2033	107497	1536384	96	226	317	6805	672	1298	2883	3332	4588	6328	28999	73109	352961	0	0	0
2034	108684	1556217	97	229	325	7098	702	1475	3351	3799	4913	8111	36181	83880	458848	0	0	0
2035	109832	1574931	97	229	333	7416	747	1682	3903	4320	5566	10869	43240	95007	620568	0	0	0
2036	110974	1593906	96	226	341	7772	811	1926	4562	4922	6785	14791	50755	106766	620027	0	0	0
2037	112144	1613524	95	219	352	8171	900	2218	5353	5702	8876	20062	59177	119616	619069	0	0	0
2038	113528	1637157	93	207	366	8665	1043	2621	6434	6980	12766	27739	70008	136089	616993	0	0	0
2039	114698	1656637	91	198	385	9112	1205	3021	7487	8509	17392	34740	80034	151658	616128	0	0	0
2040	115840	1675371	90	197	410	9553	1399	3460	8631	10507	23113	41606	90524	168296	615629	0	0	0
2041	116888	1692962	89	207	439	9942	1609	3904	9779	12830	29147	48152	100689	185887	615140	0	0	0
2042	117974	1702326	90	233	475	10312	1856	4401	11145	15769	35605	55440	111736	208632	614442	0	0	0
2043	119298	1725496	94	291	525	10716	2172	5052	13238	20115	43416	65041	125938	236446	612529	0	0	0
2044	120384	1743758	101	352	573	11109	2422	5683	15504	24265	50172	73644	138737	260984	611819	0	0	0
2045	121428	1760914	109	411	630	11602	2634	6461	18040	28103	57192	82472	152101	297438	611368	0	0	0
2046	122437	1777976	118	460	696	12230	2813	7418	20443	31317	64488	91463	165953	345510	610822	0	0	0
2047	123483	1795904	126	493	762	13062	2976	8632	22543	34556	72556	101231	181438	388917	610122	0	0	0
2048	124771	1818329	136	491	796	14331	3155	10434	24978	39083	83032	113681	204111	457000	608117	0	0	0
2049	125817	1835867	151	455	771	15556	3306	12202	27307	43536	92195	124572	226887	638979	607410	0	0	0

2050	126826	1852290	177	416	726	16836	3471	14179	29777	48479	101467	135739	247586	698481	606635	0	0	0
2051	127972	1871310	221	404	696	18364	3718	16769	32805	54854	112586	149497	273195	697912	606141	0	0	0
2052	129150	1890532	258	452	726	20081	4062	19772	36333	61835	124621	164759	314120	696930	605288	0	0	0
2053	130556	1913975	258	488	879	22981	4576	23649	41563	70270	139880	184312	379701	694648	603306	0	0	0
2054	131734	1932605	246	368	1110	26288	4998	27007	46709	77859	153967	203679	420225	693634	602425	0	0	0
2055	132880	1949373	255	176	1346	29840	5392	30194	51605	86104	168779	227171	511463	692748	601656	0	0	0
2056	134075	1963054	277	107	1523	33709	6047	33437	56082	96360	185321	252188	784348	691619	600675	0	0	0
2057	135311	1964899	247	441	1961	37866	7354	36849	60266	109682	204843	277480	733795	690230	599470	0	0	0
2058	136737	1982350	672	1939	3881	42982	10181	41219	65128	127644	233048	322311	730251	686897	596574	0	0	0
2059	137911	1995283	1685	3686	6383	47049	13177	44999	69498	141630	255882	374856	725778	682690	592921	0	0	0
2060	139106	2009679	2782	4976	8331	50584	16034	48890	74750	156055	279012	421450	723401	680454	590979	0	0	0

Table 5-7

11 13 1998

Incremental Costs - Diverted Traffic Thousands of Dollars - Closure Scenario Green up

Main Chamber Closed

		0	1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	72118	0	0	0	0	0	0	0	0	0	0	0	0	0	174338	0	0	0
2001	73210	0	0	0	0	0	0	0	0	0	0	0	0	0	189190	0	0	0
2002	74337	0	0	0	0	0	0	0	0	0	0	0	0	0	206021	0	0	0
2003	75729	0	0	0	0	0	0	0	0	0	0	0	0	0	225091	0	0	0
2004	76856	0	0	0	0	0	0	0	0	0	0	0	0	0	242287	0	0	0
2005	77948	0	0	0	0	0	0	0	0	0	0	0	0	0	257356	0	0	0
2006	79193	0	0	0	0	0	0	0	0	0	0	0	0	5630	274537	0	0	0
2007	80466	0	0	0	0	0	0	0	0	0	0	0	0	23198	292105	0	0	0
2008	81987	0	0	0	0	0	0	0	0	0	0	0	0	44508	315363	0	0	0
2009	83260	0	0	0	0	0	0	0	0	0	0	0	0	62203	333058	0	0	0
2010	84505	0	0	0	0	0	0	0	0	0	0	0	0	79508	350363	0	0	0
2011	85334	0	0	0	0	0	0	0	0	0	0	0	0	91031	361887	0	0	0
2012	86188	0	0	0	0	0	0	0	0	0	0	0	0	103642	376446	0	0	0
2013	87290	0	0	0	0	0	0	0	0	0	0	0	0	119070	391874	0	0	0
2014	88144	0	0	0	0	0	0	0	0	0	0	0	70	131026	403830	0	0	0
2015	88973	0	0	0	0	0	0	0	0	0	0	0	11759	143651	418403	0	0	0
2016	89933	0	0	0	0	0	0	0	0	0	0	0	25295	157187	431939	0	0	0
2017	90909	0	0	0	0	0	0	0	0	0	0	0	39057	170948	445701	0	0	0
2018	92132	0	0	0	0	0	0	0	0	0	0	0	56701	189527	466229	0	0	0
2019	93108	0	0	0	0	0	0	0	0	0	0	0	70560	203387	480088	0	0	0
2020	94068	0	0	0	0	0	0	0	0	0	0	0	84785	218547	497197	0	0	0
2021	94969	0	0	0	0	0	0	0	0	0	0	0	97669	231431	510081	0	0	0
2022	95910	0	0	0	0	0	0	0	0	0	0	0	111125	244888	523537	0	0	0
2023	97064	0	0	0	0	0	0	0	0	0	0	0	127628	261390	540040	0	0	0
2024	98005	0	0	0	0	0	0	0	0	0	0	7322	141084	274846	553496	0	0	0
2025	98906	0	0	0	0	0	0	0	0	0	0	20347	155045	289742	570341	0	0	0
2026	99813	0	0	0	0	0	0	0	0	0	0	33408	168106	302803	583402	0	0	0
2027	100759	0	0	0	0	0	0	0	0	0	0	47030	181728	316426	597024	0	0	0
2028	101909	0	0	0	0	0	0	0	0	0	0	63590	198288	332986	613584	0	0	0
2029	102855	0	0	0	0	0	0	0	0	0	9864	77213	211910	346608	627206	0	0	0
2030	103762	0	0	0	0	0	0	0	0	0	22925	90274	224971	359669	640267	0	0	0
2031	104910	0	0	0	0	0	0	0	0	0	39456	106805	241502	376200	656798	0	0	0
2032	106097	0	0	0	0	0	0	0	0	0	56156	123037	256799	390562	669211	0	0	0
2033	107497	0	0	0	0	0	0	0	0	0	76176	143057	276819	410582	689231	0	0	0
2034	108684	0	0	0	0	0	0	0	0	0	93150	160031	293794	427556	706206	0	0	0
2035	109832	0	0	0	0	0	0	0	0	0	109567	176448	310210	443972	722622	0	0	0
2036	110974	0	0	0	0	0	0	0	0	0	126778	194126	328824	463522	744120	0	0	0
2037	112144	0	0	0	0	0	0	0	0	0	143626	210974	345672	480370	760968	0	0	0
2038	113528	0	0	0	0	0	0	0	0	0	163555	230904	365602	500299	780898	0	0	0
2039	114698	0	0	0	0	0	0	0	0	0	180403	247752	382450	517147	797746	0	0	0
2040	115840	0	0	0	0	0	0	0	0	0	198215	266032	401665	537298	819845	0	0	0
2041	116888	0	0	0	0	0	0	0	0	0	213411	281228	416861	552494	835041	0	0	0
2042	117974	0	0	0	0	0	0	0	0	0	227578	294926	429624	564322	844920	0	0	0
2043	119298	0	0	0	0	0	0	0	0	0	248356	316173	451806	587439	869986	0	0	0
2044	120384	0	0	0	0	0	0	0	0	0	264103	331920	467553	603186	885733	0	0	0
2045	121428	0	0	0	0	0	0	0	0	0	279241	347058	482691	618324	900871	0	0	0
2046	122437	0	0	0	0	0	0	0	0	0	293872	361688	497321	632954	915501	0	0	0
2047	123483	0	0	0	0	0	0	0	0	0	309039	376855	512488	648121	930668	0	0	0
2048	124771	0	0	0	0	0	0	0	0	0	329975	398259	534827	671396	955891	0	0	0
2049	125817	0	0	0	0	0	0	0	0	0	345246	413530	550099	686667	971163	0	0	0

2050	126826	0	0	0	0	0	0	0	0	0	359978	428262	564830	701399	985894	0	0	0
2051	127972	0	0	0	0	0	0	0	0	0	376709	444993	581562	718130	1002626	0	0	0
2052	129150	0	0	0	0	0	0	0	0	0	393908	462192	598761	735329	1019825	0	0	0
2053	130556	0	0	0	0	0	0	0	0	0	417274	486026	623530	761034	1047478	0	0	0
2054	131734	0	0	0	0	0	0	0	0	10819	434591	503343	640847	778350	1064795	0	0	0
2055	132880	0	0	0	0	0	0	0	0	27665	451437	520189	657693	795197	1081641	0	0	0
2056	134075	0	0	0	0	0	0	0	0	44924	465813	534097	670666	807234	1091730	0	0	0
2057	135311	0	0	0	0	0	0	0	0	62539	480545	548361	683994	819627	1102174	0	0	0
2058	136737	0	0	0	0	0	0	0	0	83216	501222	569038	704671	840304	1122851	0	0	0
2059	137911	0	0	0	0	0	0	0	0	100239	518245	586061	721694	857327	1139874	0	0	0
2060	139106	0	0	0	0	0	0	0	0	116755	531878	599227	733925	868622	1149221	0	0	0

Table 5-8

11 13 1998

Incremental Costs - Diverted Traffic Thousands of Dollars - Closure Scenario Green up

Auxiliary Chamber Closed

	Both Cl		1	3	5	10	15	30	45	60	90	120	180	240	365	32	42	92
2000	72118	981949	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001	73210	998753	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002	74337	1016439	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003	75729	1038985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004	76856	1056636	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2005	77948	1073365	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2006	79193	1092923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007	80466	1112897	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2008	81987	1138012	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009	83260	1157959	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2010	84505	1177468	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	85334	1190759	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	86188	1204587	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	87290	1222890	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	88144	1236700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	88973	1249963	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	89933	1266916	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	90909	1284120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	92132	1306309	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	93108	1323460	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	94068	1340295	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	94969	1354923	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	95910	1370263	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2023	97064	1390171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2024	98005	1405456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2025	98906	1419974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2026	99813	1434738	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2027	100759	1449959	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2028	101909	1468553	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2029	102855	1481920	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2030	103762	1493322	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2031	104910	1506069	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2032	106097	1517955	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2033	107497	1536384	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2034	108684	1556217	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2035	109832	1574931	0	0	0	0	0	0	0	0	0	0	0	0	458	0	0	0
2036	110974	1593906	0	0	0	0	0	0	0	0	0	0	0	0	16906	0	0	0
2037	112144	1613524	0	0	0	0	0	0	0	0	0	0	0	0	33754	0	0	0
2038	113528	1637157	0	0	0	0	0	0	0	0	0	0	0	0	53683	0	0	0
2039	114698	1656637	0	0	0	0	0	0	0	0	0	0	0	0	70531	0	0	0
2040	115840	1675371	0	0	0	0	0	0	0	0	0	0	0	0	87580	0	0	0
2041	116888	1692962	0	0	0	0	0	0	0	0	0	0	0	0	102776	0	0	0
2042	117974	1702326	0	0	0	0	0	0	0	0	0	0	0	0	117706	0	0	0
2043	119298	1725496	0	0	0	0	0	0	0	0	0	0	0	0	137721	0	0	0
2044	120384	1743758	0	0	0	0	0	0	0	0	0	0	0	0	153468	0	0	0
2045	121428	1760914	0	0	0	0	0	0	0	0	0	0	0	0	168606	0	0	0
2046	122437	1777976	0	0	0	0	0	0	0	0	0	0	0	0	183237	0	0	0
2047	123483	1795904	0	0	0	0	0	0	0	0	0	0	0	0	198404	0	0	0
2048	124771	1818329	0	0	0	0	0	0	0	0	0	0	0	0	218577	0	0	0
2049	125817	1835867	0	0	0	0	0	0	0	0	0	0	0	0	233848	0	0	0

2050	126826	1852290	0	0	0	0	0	0	0	0	0	0	0	5694	248580	0	0	0
2051	127972	1871310	0	0	0	0	0	0	0	0	0	0	0	22426	265311	0	0	0
2052	129150	1890532	0	0	0	0	0	0	0	0	0	0	0	39624	282510	0	0	0
2053	130556	1913975	0	0	0	0	0	0	0	0	0	0	0	60564	305113	0	0	0
2054	131734	1932605	0	0	0	0	0	0	0	0	0	0	0	77881	322430	0	0	0
2055	132880	1949373	0	0	0	0	0	0	0	0	0	0	0	94727	339276	0	0	0
2056	134075	1963054	0	0	0	0	0	0	0	0	0	0	0	111529	354415	0	0	0
2057	135311	1964899	0	0	0	0	0	0	0	0	0	0	12891	128688	369910	0	0	0
2058	136737	1982350	0	0	0	0	0	0	0	0	0	0	33568	149365	390587	0	0	0
2059	137911	1995283	0	0	0	0	0	0	0	0	0	0	50591	166388	407610	0	0	0
2060	139106	2009679	0	0	0	0	0	0	0	0	0	0	67450	182448	422006	0	0	0

ADDENDUM 5

Example of Simulation Computations

To

ATTACHMENT 2

LCLM

On file in the offices of the Planning Division, Pittsburgh District, U.S. Army Corps of Engineers

ADDENDUM 6

Bundling Routine

To

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On file in the offices of the Planning Division, Pittsburgh District, U.S. Army Corps of Engineers

ADDENDUM 7

LCLM Results by Component, Chamber and Decade for Myers and Greenup

To

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LCLM

Developed by
USACE Pittsburgh District
Plan Formulation
October 1999

	Monoliths	Gates	Anchora	Sills	Valves	Electrical System	Gate Machinery	Valve Machinery	Hydraulic System
					Myers Main Chamber				
Baseline		45	0	0	580.9	904.5	45.2	64.7	4169.5
Replace in	0	0	0	0	433.1	0	0	0	0
2000	0	0	0	0	279.1	2128.8	2128.8	361.7	6760.1
2010	0	0	0	0	285.4	1664.2	1545.9	196.7	4546.1
2020	0	0	0	0	332.2	1398.5	1150.1	120.5	3640.5
2030	0	854.3	0	0	405.0	1209.9	823.9	79.7	2778.8
2040	0	821.9	0	0	0	1304.1	813.8	66.8	2340.7
2050	0	914.5	0	0	0	0	0	0	0

	Monoliths	Gates	Anchora	Sills	Valves	Electrical System	Gate Machinery	Valve Machinery	Hydraulic System
					Auxiliary Chamber				
Baseline	0	0	0	0	393.4	99.6	1.5	2.4	95.2
Replace in									
2000	0	0	0	0	333.6	408.8	408.8	231.2	282.8
2010	0	0	0	0	197.1	227.2	215.6	124.5	159.7
2020	0	0	0	0	133.1	145.4	122.4	75.7	102.6
2030	0	0	0	0	98.2	98	63.4	39.8	70.4
2040	0	0	0	0	183.8	81.6	38.9	27.2	65.9
2050	0	0	0	0	0	0	0	0	0

	Monoliths	Gates	Anchora	Sills	Greenup Main Chamber Valves	Electrical System	Gate Machinery	Valve Machinery	Hydraulic System
Baseline	0	8718.7	0	0	26.9	903.2	26.6	35.7	625.8
Replace in									
2000	0	1375.8	0	0	439.7	1127.9	1127.9	369.9	4172.6
2010	0	2084.4	0	0	227.1	1229.2	1073.1	197.6	4250.7
2020	0	1130.1	0	0	121.2	1130.1	805.7	113.4	3146.5
2030	0	0	0	0	64.6	1048.4	580.8	71.5	2246.8
2040	0	0	0	0	36.5	1083.1	500.4	52.5	1822.7
2050	0	0	0	0	0	0	0	0	0

	Monoliths	Gates	Anchora	Sills	Auxiliary Chamber Valves	Electrical System	Gate Machinery	Valve Machinery	Hydraulic System
Baseline	0	269.3	0	0	0	227.6	1.7	3	38.3
Replace in									
2000	0	645	0	0	0	397.1	397.1	219.5	247.8
2010	0	338.8	0	0	0	258.1	206.7	115.7	139.6
2020	0	172.1	0	0	0	207.3	107.2	61	91.6
2030	0	94	0	0		0	194.9	58.5	35.4
2040	0	87.2	0	0	0	207.3	43.9	32.7	84.9
2050	0	173.9	0	0	0	0	0	0	0

Greenup - main chamber - gates - 60 day closure for scheduled replacement.

Baseline	9,524.0
Replace in	
2000	4,393.2
2001	4,319.6 * least cost
2002	4,342.2
2003	4,402.3
2004	4,402.2
2005	4,391.5

ADDENDUM 8

LCLM Output Files for Greenup Gates

To

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LCLM

Developed by
USACE Pittsburgh District
Plan Formulation
October 1999

Greenup - Gates - Main Chamber

Baseline
Iterations: 20000

Year	Hazard Function	Sched. Replace	Failures	% of Fails	Days of Delay	Averaged over Failures (Thousands of Dollars) Delay Costs	Divert Costs	Repair Costs	Total Costs	Ave Over Iters
2000	.00000	0	0	0	0	0	0	0	0	0
2001	.00000	0	0	0	0	0	0	0	0	0
2002	.00036	0	12	0	82	58055	0	5744	63799	38
2003	.00270	0	52	0	64	45820	0	4300	50120	130
2004	.00490	0	104	0	77	60688	0	5444	66132	344
2005	.01026	0	211	1	78	69990	0	5963	75953	801
2006	.01856	0	345	1	80	76588	0	5827	82415	1422
2007	.02530	0	458	1	78	82154	0	5736	87890	2013
2008	.03967	0	721	2	77	87573	0	5650	93223	3361
2009	.05304	0	967	3	79	97467	0	5793	103260	4993
2010	.06535	0	1137	4	78	103758	0	5800	109558	6228
2011	.08698	0	1435	5	78	106324	0	5736	112060	8040
2012	.09768	0	1437	5	79	111838	0	5765	117603	8450
2013	.13176	0	1882	6	77	116339	0	5653	121992	11479
2014	.12409	0	1511	5	79	124763	5	5800	130568	9864
2015	.15902	0	1787	6	77	128358	587	5723	134668	12033
2016	.18466	0	1805	6	78	134573	1574	5717	141864	12803
2017	.20613	0	1816	6	79	140415	2996	5680	149091	13537
2018	.17196	0	1460	5	79	154268	3461	5833	163562	11940
2019	.23729	0	1503	5	77	156941	3511	5702	166154	12487
2020	.24459	0	1534	5	78	167272	4744	5771	177787	13636
2021	.26466	0	1399	5	79	175455	6219	5839	187513	13117
2022	.27785	0	1228	4	77	171707	6712	5612	184031	11300
2023	.26558	0	1003	3	77	177033	6825	5694	189552	9506
2024	.37821	0	1085	4	76	174690	6510	5558	186758	10132
2025	.37778	0	864	3	77	181396	7406	5707	194509	8403
2026	.35000	0	777	3	78	185785	9679	5739	201203	7817
2027	.49137	0	736	2	78	187968	9730	5789	203487	7488
2028	.55556	0	518	2	75	184480	7794	5541	197815	5123
2029	.54861	0	560	2	79	197303	17431	6001	220735	6181
2030	.70769	0	419	1	78	188889	30199	5715	224803	4710
2031	.89474	0	340	1	78	194300	42867	5840	243007	4131
2032	1.00000	0	335	1	79	191288	58690	5771	255749	4284
2033	1.00000	0	235	1	81	195925	79465	5982	281372	3306
2034	1.00000	0	186	1	79	201032	89883	5950	296865	2761
2035	1.00000	0	208	1	80	200786	105449	5990	312225	3247
2036	1.00000	0	125	0	77	207877	110027	5789	323693	2023
2037	1.00000	0	113	0	78	200917	123877	5891	330685	1868
2038	1.00000	0	76	0	78	195976	143918	5662	345556	1313
2039	1.00000	0	99	0	78	197377	151354	5671	354402	1754
2040	1.00000	0	61	0	85	214752	203673	6410	424835	1296
2041	1.00000	0	54	0	76	202403	179285	5785	387473	1046
2042	1.00000	0	40	0	84	197089	209843	5749	412681	825
2043	1.00000	0	34	0	82	216269	224261	6086	446616	759
2044	1.00000	0	24	0	82	219709	262913	6270	488892	587
2045	1.00000	0	19	0	63	186188	150680	4482	341350	324
2046	1.00000	0	16	0	84	219287	291493	6912	517692	414
2047	1.00000	0	17	0	71	214145	194323	5433	413901	352
2048	1.00000	0	11	0	90	207967	324061	5713	537741	296
2049	1.00000	0	12	0	78	221716	235776	5518	463010	278
2050	1.00000	0	6	0	82	253363	374793	7035	635191	191
2051	1.00000	0	8	0	101	231649	475042	7909	714600	286
2052	1.00000	0	4	0	67	183225	256608	4680	444513	89
2053	1.00000	0	2	0	45	238939	0	2022	240961	24
2054	1.00000	0	1	0	90	241248	563438	6819	811505	41
2055	1.00000	0	3	0	105	227899	508845	5660	742404	111
2056	1.00000	0	4	0	67	236582	251989	4896	493467	99
2057	1.00000	0	2	0	90	269542	613414	7303	890259	89
2058	1.00000	0	1	0	45	254548	0	1994	256542	13
2059	1.00000	0	0	0	0	0	0	0	0	0
Total		0	30802							

Annualized Costs and Confidence Interval
(Thousands of Dollars)

Component	Mean	95% Confidence Interval Lower	Upper
12 12. Gates - Main Cha	9524.0	9496.2	9551.8

Greenup - Gates - Main Chamber

Scheduled repair in 2003
Iterations: 20000

Year	Hazard Function	Sched. Replace	Failures	% of Fails	Days of Delay	Delay Costs	Divert Costs	Repair Costs	Total Costs	Ave Over Iters
					Averaged over Failures (Thousands of Dollars)					
2000	.00000	0	0	0	0	0	0	0	0	0
2001	.00000	0	0	0	0	0	0	0	0	0
2002	.00036	0	5	100	81	52423	0	6954	59377	15
2003	.00270	19996	0	0	60	34230	0	5849	40079	40071
2004	.00490	0	0	0	0	0	0	0	0	0
2005	.01026	0	0	0	0	0	0	0	0	0
2006	.01856	0	0	0	0	0	0	0	0	0
2007	.02530	0	0	0	0	0	0	0	0	0
2008	.03967	0	0	0	0	0	0	0	0	0
2009	.05304	0	0	0	0	0	0	0	0	0
2010	.06535	0	0	0	0	0	0	0	0	0
2011	.08698	0	0	0	0	0	0	0	0	0
2012	.09768	0	0	0	0	0	0	0	0	0
2013	.13176	0	0	0	0	0	0	0	0	0
2014	.12409	0	0	0	0	0	0	0	0	0
2015	.15902	0	0	0	0	0	0	0	0	0
2016	.18466	0	0	0	0	0	0	0	0	0
2017	.20613	0	0	0	0	0	0	0	0	0
2018	.17196	0	0	0	0	0	0	0	0	0
2019	.23729	0	0	0	0	0	0	0	0	0
2020	.24459	0	0	0	0	0	0	0	0	0
2021	.26466	0	0	0	0	0	0	0	0	0
2022	.27785	0	0	0	0	0	0	0	0	0
2023	.26558	0	0	0	0	0	0	0	0	0
2024	.37821	0	0	0	0	0	0	0	0	0
2025	.37778	0	0	0	0	0	0	0	0	0
2026	.35000	0	0	0	0	0	0	0	0	0
2027	.49137	0	0	0	0	0	0	0	0	0
2028	.55556	0	0	0	0	0	0	0	0	0
2029	.54861	0	0	0	0	0	0	0	0	0
2030	.70769	0	0	0	0	0	0	0	0	0
2031	.89474	0	0	0	0	0	0	0	0	0
2032	1.00000	0	0	0	0	0	0	0	0	0
2033	1.00000	0	0	0	0	0	0	0	0	0
2034	1.00000	0	0	0	0	0	0	0	0	0
2035	1.00000	0	0	0	0	0	0	0	0	0
2036	1.00000	0	0	0	0	0	0	0	0	0
2037	1.00000	0	0	0	0	0	0	0	0	0
2038	1.00000	0	0	0	0	0	0	0	0	0
2039	1.00000	0	0	0	0	0	0	0	0	0
2040	1.00000	0	0	0	0	0	0	0	0	0
2041	1.00000	0	0	0	0	0	0	0	0	0
2042	1.00000	0	0	0	0	0	0	0	0	0
2043	1.00000	0	0	0	0	0	0	0	0	0
2044	1.00000	0	0	0	0	0	0	0	0	0
2045	1.00000	0	0	0	0	0	0	0	0	0
2046	1.00000	0	0	0	0	0	0	0	0	0
2047	1.00000	0	0	0	0	0	0	0	0	0
2048	1.00000	0	0	0	0	0	0	0	0	0
2049	1.00000	0	0	0	0	0	0	0	0	0
2050	1.00000	0	0	0	0	0	0	0	0	0
2051	1.00000	0	0	0	0	0	0	0	0	0
2052	1.00000	0	0	0	0	0	0	0	0	0
2053	1.00000	0	0	0	0	0	0	0	0	0
2054	1.00000	0	0	0	0	0	0	0	0	0
2055	1.00000	0	0	0	0	0	0	0	0	0
2056	1.00000	0	0	0	0	0	0	0	0	0
2057	1.00000	0	0	0	0	0	0	0	0	0
2058	1.00000	0	0	0	0	0	0	0	0	0
2059	1.00000	0	0	0	0	0	0	0	0	0
Total		19996	5							

Annualized Costs and Confidence Interval
(Thousands of Dollars)

Component	Mean	95% Confidence Interval Lower	Upper
12 12. Gates - Main Cha	4404.4	4400.0	4408.8

Greenup - Gates - Auxiliary Chamber

Baseline
Iterations: 20000

Year	Hazard Function	Sched. Replace	Failures	% of Fails	Days of Delay	Delay Costs	Divert Costs	Repair Costs	Total Costs	Ave Over Iters
					Averaged over Failures (Thousands of Dollars)					
2000	.00000	0	0	0	0	0	0	0	0	0
2001	.00000	0	0	0	0	0	0	0	0	0
2002	.00000	0	0	0	0	0	0	0	0	0
2003	.00000	0	0	0	0	0	0	0	0	0
2004	.00000	0	0	0	0	0	0	0	0	0
2005	.00000	0	0	0	0	0	0	0	0	0
2006	.00000	0	0	0	0	0	0	0	0	0
2007	.00000	0	0	0	0	0	0	0	0	0
2008	.00000	0	0	0	0	0	0	0	0	0
2009	.00000	0	0	0	0	0	0	0	0	0
2010	.00000	0	0	0	0	0	0	0	0	0
2011	.00000	0	0	0	0	0	0	0	0	0
2012	.00000	0	0	0	0	0	0	0	0	0
2013	.00000	0	0	0	0	0	0	0	0	0
2014	.00000	0	0	0	0	0	0	0	0	0
2015	.00000	0	0	0	0	0	0	0	0	0
2016	.00000	0	0	0	0	0	0	0	0	0
2017	.00000	0	0	0	0	0	0	0	0	0
2018	.00000	0	0	0	0	0	0	0	0	0
2019	.00000	0	0	0	0	0	0	0	0	0
2020	.00000	0	0	0	0	0	0	0	0	0
2021	.00000	0	0	0	0	0	0	0	0	0
2022	.00028	0	8	0	78	1032	0	6123	7155	3
2023	.00038	0	8	0	84	1105	0	5579	6684	3
2024	.00108	0	30	0	78	1122	0	5830	6952	10
2025	.00164	0	30	0	73	1191	0	5264	6455	10
2026	.00271	0	53	0	78	1370	0	5672	7042	19
2027	.00473	0	87	0	78	1453	0	5884	7337	32
2028	.00657	0	140	1	75	1542	0	5648	7190	50
2029	.00924	0	164	1	77	1725	0	5771	7496	61
2030	.01093	0	206	1	81	2027	0	5766	7793	80
2031	.01612	0	336	1	78	2183	0	5753	7936	133
2032	.01841	0	337	1	80	2621	0	5888	8509	143
2033	.02232	0	434	2	78	2857	0	5742	8599	187
2034	.02543	0	436	2	79	3380	0	5813	9193	200
2035	.03137	0	589	2	77	3806	0	5577	9383	276
2036	.03686	0	674	3	79	4775	0	5753	10528	355
2037	.04468	0	753	3	78	5748	0	5622	11370	428
2038	.04824	0	829	3	78	7187	0	5782	12969	538
2039	.05678	0	928	4	77	9178	0	5724	14902	691
2040	.06158	0	969	4	78	11796	0	5799	17595	853
2041	.06553	0	920	4	78	14301	0	5683	19984	919
2042	.07280	0	931	4	79	17561	0	5871	23432	1091
2043	.07858	0	1019	4	78	20443	0	5686	26129	1331
2044	.08528	0	1040	4	78	23481	0	5719	29200	1518
2045	.09249	0	1072	4	79	27090	0	5703	32793	1758
2046	.09285	0	1016	4	80	31586	0	5848	37434	1902
2047	.10180	0	1101	4	76	32132	0	5494	37626	2071
2048	.11022	0	1055	4	78	38434	0	5723	44157	2329
2049	.11480	0	1028	4	79	42959	0	5771	48730	2505
2050	.11499	0	953	4	78	45973	0	5659	51632	2460
2051	.12282	0	985	4	76	49740	0	5637	55377	2727
2052	.13429	0	962	4	78	57150	0	5714	62864	3024
2053	.13640	0	915	4	77	63760	0	5651	69411	3176
2054	.15514	0	946	4	79	72754	0	5850	78604	3718
2055	.13390	0	770	3	80	83263	0	5946	89209	3435
2056	.17607	0	795	3	78	91816	0	5798	97614	3880
2057	.14785	0	717	3	79	101487	706	5823	108016	3872
2058	.17729	0	754	3	79	114589	2286	5752	122627	4623
2059	.17084	0	687	3	77	114967	2303	5661	122931	4223
Total		0	24677							

Annualized Costs and Confidence Interval
(Thousands of Dollars)

Component	Mean	95% Confidence Interval Lower	Upper
14 14. Gates - Aux Cham	273.1	270.5	275.6

Greenup - Gates - Auxiliary

Replace in 2030

Iterations: 20000

Year	Hazard Function	Sched. Replace	Failures	% of Fails	Days of Delay	Delay Costs	Divert Costs	Repair Costs	Total Costs	Ave Over Iters
					Averaged over Failures (Thousands of Dollars)					
2000	.00000	0	0	0	0	0	0	0	0	0
2001	.00000	0	0	0	0	0	0	0	0	0
2002	.00000	0	0	0	0	0	0	0	0	0
2003	.00000	0	0	0	0	0	0	0	0	0
2004	.00000	0	0	0	0	0	0	0	0	0
2005	.00000	0	0	0	0	0	0	0	0	0
2006	.00000	0	0	0	0	0	0	0	0	0
2007	.00000	0	0	0	0	0	0	0	0	0
2008	.00000	0	0	0	0	0	0	0	0	0
2009	.00000	0	0	0	0	0	0	0	0	0
2010	.00000	0	0	0	0	0	0	0	0	0
2011	.00000	0	0	0	0	0	0	0	0	0
2012	.00000	0	0	0	0	0	0	0	0	0
2013	.00000	0	0	0	0	0	0	0	0	0
2014	.00000	0	0	0	0	0	0	0	0	0
2015	.00000	0	0	0	0	0	0	0	0	0
2016	.00000	0	0	0	0	0	0	0	0	0
2017	.00000	0	0	0	0	0	0	0	0	0
2018	.00000	0	0	0	0	0	0	0	0	0
2019	.00000	0	0	0	0	0	0	0	0	0
2020	.00000	0	0	0	0	0	0	0	0	0
2021	.00000	0	0	0	0	0	0	0	0	0
2022	.00028	0	8	1	90	1252	0	6324	7576	3
2023	.00038	0	8	1	95	1434	0	7026	8460	3
2024	.00108	0	26	5	74	1101	0	5394	6495	8
2025	.00164	0	44	8	80	1297	0	5760	7057	16
2026	.00271	0	56	10	75	1275	0	5348	6623	19
2027	.00473	0	110	19	74	1409	0	5563	6972	38
2028	.00657	0	136	24	79	1631	0	5914	7545	51
2029	.00924	0	178	31	77	1711	0	5774	7485	67
2030	.01093	19633	0	0	30	517	0	6188	6705	6583
2031	.01612	0	0	0	0	0	0	0	0	0
2032	.01841	0	0	0	0	0	0	0	0	0
2033	.02232	0	0	0	0	0	0	0	0	0
2034	.02543	0	0	0	0	0	0	0	0	0
2035	.03137	0	0	0	0	0	0	0	0	0
2036	.03686	0	0	0	0	0	0	0	0	0
2037	.04468	0	0	0	0	0	0	0	0	0
2038	.04824	0	0	0	0	0	0	0	0	0
2039	.05678	0	0	0	0	0	0	0	0	0
2040	.06158	0	0	0	0	0	0	0	0	0
2041	.06553	0	0	0	0	0	0	0	0	0
2042	.07280	0	0	0	0	0	0	0	0	0
2043	.07858	0	0	0	0	0	0	0	0	0
2044	.08528	0	0	0	0	0	0	0	0	0
2045	.09249	0	0	0	0	0	0	0	0	0
2046	.09285	0	0	0	0	0	0	0	0	0
2047	.10180	0	0	0	0	0	0	0	0	0
2048	.11022	0	0	0	0	0	0	0	0	0
2049	.11480	0	0	0	0	0	0	0	0	0
2050	.11499	0	0	0	0	0	0	0	0	0
2051	.12282	0	0	0	0	0	0	0	0	0
2052	.13429	0	0	0	0	0	0	0	0	0
2053	.13640	0	0	0	0	0	0	0	0	0
2054	.15514	0	0	0	0	0	0	0	0	0
2055	.13390	0	0	0	0	0	0	0	0	0
2056	.17607	0	0	0	0	0	0	0	0	0
2057	.14785	0	0	0	0	0	0	0	0	0
2058	.17729	0	0	0	0	0	0	0	0	0
2059	.17084	0	0	0	0	0	0	0	0	0
Total		19633	566							

Annualized Costs and Confidence Interval
(Thousands of Dollars)

Component	Mean	95% Confidence Interval Lower	Upper
14 14. Gates - Aux Cham	124.6	124.4	124.8

ATTACHMENT 3

ORS TRAFFIC DEMAND FORECASTS

3.1 GENERAL

This attachment begins with a very brief discussion of the U.S. Department of Commerce BEA-level projections of population, employment and earnings referred to as the OBERS projections (see Section 3.2). These projections of economic activity figure into the long-term projection of commodity movements. Section 3.3 focuses on the development of utility coal projections and then Section 3.4 on export coal. Section 3.5 discusses the development of traffic demand projections for all other commodities. Section 3.6 presents the results of the traffic demand analysis. The final section, Section 3.7, selects the most probable waterway traffic demands.

The ORS traffic demand forecasts presented here represent a substantial update of the previous forecasts prepared in December 1995. The updating of these forecasts focused on utility and export coal. All other commodity traffic was left unchanged from the December 1995 data set. Adjustments to the utility coal forecasts were necessitated by the far-reaching regulatory changes currently affecting the electric utility industry. Revision of export coal traffic demands was necessitated by changing conditions in world coal markets and observed changes in export coal traffic moving on the ORS. Uncertainty is an ever-present aspect of fifty-year projections of waterway traffic demand. Because coal is the dominant commodity, efforts to describe this uncertainty focused on coal. Four scenarios were constructed around four major issues facing coal producers and consumers. These scenarios are discussed in subsequent sections of this attachment.

The basic forecasting framework for developing waterway traffic demand forecasts is similar for all commodities, with the exception of export coal. The procedure starts with a set of base-year waterway traffic commodity flows and information about the economic prospects of the industries consuming these waterborne commodities. The first steps in projecting waterway traffic demands are to identify the industry and market that each dock served and to adjust commodity flows to these docks to represent base-level expectations for each facility. Industry and market prospects are then analyzed by means of shipper surveys and examination of relevant forecasts. Using the survey information and the applicable forecasts, future traffic demands are generated. Information and data on industry and market prospects are developed at the company level for all commodities moving to electric generating stations (utility coal, and lime and

limestone used in coal desulfurization) and at the more global industry or market level for all other destinations.

3.2 THE OBERS BEA REGIONAL PROJECTIONS

The current ORS waterway traffic demand forecasts, particularly over the long term, rest heavily upon the demographic and economic forecasts prepared by the U. S. Department of Commerce, Bureau of Economic Analysis (the OBERS forecasts). BEA prepares top-down forecasts of both employment and earnings by industry. Employment forecasts are computed using demographic forecasts and projected labor force participation rates. Earnings forecasts are derived from national-level earnings forecasts which have been distributed to the various industry sectors through the use of an input/output model. State and county projections, in turn, are based on the projection of ratios of state employment growth to national growth, and county ratios of employment to state totals.

3.3 ORS UTILITY COAL FORECASTS

3.3.1 General

3.3.1.1 Background

Among the issues currently facing the electric utility industry, the two that stand out are the environmental concerns associated with the emission of sulfuric and nitrogenous gases, which are believed to cause acid rain deposition and increasing deregulation of the electric utility industry. These two issues, as well, have the greatest potential bearing on waterway commodity flows.

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 is designed to cap sulfur emissions, the largest source 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 always 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 during or after combustion, but at considerable cost to the electric utility. Use of this equipment allows utilities to continue buying coal from local, high sulfur coal producers, thereby guaranteeing continued employment and production for the region’s miners. However, utilities often find that the least costly option for reducing sulfur emissions is not to build or

install these expensive clean coal devices, but to find sources of lower sulfur 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.

Environmental issues facing coal consumption tend to discourage, in greatly varying degrees, coal consumption by making it more expensive to use in electricity generation. De-regulation of the utility industry has a less apparent effect. De-regulation favors low-cost electricity producers--producers who tend to be in the Ohio Valley, use or have access to waterway transportation, and rely heavily on coal to fire their steam generators. Treatment of these issues form the basis for the development of four ORS waterway traffic demand scenarios.

3.3.1.2 Scenario Framework

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 is attributable to the behavior and policies of governments, rather than that of individual consumers. In the ORS this is especially manifest in the application of federal government regulations and policies directed at electric utilities. For this reason, uncertainty descriptions have focused upon coal and the major issues facing producers and consumers of coal. Four scenarios have been built around four central issues: the Clean Air Act Amendments of 1990, the Energy Policy Act of 1992 that de-regulates electric utilities, plans for future operation of nuclear power plants, and treaty negotiations for limits on carbon-related emissions.

The CAAA scenario is built with the Coal Model, which is described in **Addendum 1** of the attachment. Generally, this model relies upon plant-specific information on electricity generation, generation by fuel, coal sources, and coal transportation plans as provided to the Corps of Engineers by the electric utilities in a May 1998 survey. These responses provide an industry-based forecast of waterway usage by electric utilities, a forecast extended by indexing to OBERS economic and demographic variables. The Deregulation and Nuclear Re-licensing scenarios are largely adjustments to results from Coal Model runs completed for the CAAA scenario. The Carbon Limit scenario differs from the other three in that it is based almost entirely upon the U.S. Department of Energy, Energy Information Administration (DOE\EIA) carbon limit coal projections. All four scenarios share the same export coal and non-coal commodity forecasts. The relative likelihood of these scenarios is discussed in Section 6.5.6 below.

3.3.2 The Clean Air Act

3.3.2.1 The Law Prior to 1990

The evolution of clean air legislation (**Table 3-1**), 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 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 which 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 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 requires all new or extensively modified coal-fired electric generating stations to be equipped with some form of clean coal technology.

Table 3-1

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, NO2, & 6 other pollutants. States required to develop State Implementation Plans (SIPS) describing measures to meet standards.			
1971	EPA – New Source Performance Standards	As of 17 August 1971 emissions not to exceed 1.2 lbs./mmBtu. <----------MUST SCRUB---------->			Must use Reasonable Available Technology (RACT)
1977	Amendment to CAA	Best Available Control Technology (BACT) must be used, emissions not to Exceed 1.2 lbs./mmBtu. <----------MUST SCRUB---------->			
1979	EPA – Revised New Source Performance Standards (RNSPS)	As of 18 Sept. 1978, 1.2 lbs./mmBtu limit. For all Coals, must remove 90% of sulfur (exception for Coals with <0.6 lbs./mmBtu, remove 70-90%). <----------MUST SCRUB---------->			SWITCH OR SCRUB
1990	Amendment to CAA (CAAA '90)	Instituted strict emission limits on sulfur dioxide and nitrous oxides. Establishes successively stricter SO2 emission levels in 1995 and again in 2000. Creates an emission allowance\credit system for Achieving reduced emissions.			
1995	Phase I of CAAA '90	**Phase I** - Allowances issued permitting SO2 emissions up to 2.5 lbs./mmBtu 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 '90	**Phase II** - Allowances issued permitting SO2 emissions up to 1.2 lbs./mmBtu as of 1 Jan 2000. Applies to all plants of 25MW or more. Three year extension granted if clean coal system installed. Emission cap of 8.9 mmtons SO2/year. <----------MUST SCRUB---------->			

3.3.2.2 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.

3.3.2.2.1 Phase I Requirements. 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. Since allowances are, in effect, authorizations to emit sulfur dioxide, a plant's emissions cannot exceed its allowances. Several strategies are available for reducing emissions to allowable levels. These include 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. As a result, utilities have the opportunity to reallocate their total emission reduction obligations among their plants in the most efficient and cost-effective way possible.

Any new utility plants remain subject to the RNSPS and are required to hold allowances equal to the amount of their expected annual sulfur dioxide emissions. In practical terms this means that utilities bringing new plants on-line must equipped with some form of clean coal technology and will have to have sufficient allowances in-hand to cover expected emissions. The utility can get these allowances by over-complying at other plants in their system or by purchasing allowances from other utilities. EPA does not distribute allowances to new units.

Under Phase I, utilities elected to install FGD systems (scrubbers) as a means of achieving compliance at seventeen of the 110 Phase I-affected plants. Six of these are on the Ohio River System and ten are in the Ohio River Basin. The remaining plants are primarily relying on switching to lower-sulfur coals or lower-sulfur coal blends. In many instances, the decision to scrub units at a plant causes over-compliance at these units, allowing the operating utility to apply the excess allowances to other units and plants in their system (utilities can also sell excess allowances to other utilities or companies).

3.3.2.2.2 Phase II Requirements. By 1 January 2000, the target date under Phase II of the amendments, affected plants (any plant of 25 megawatt capacity or greater) will be required to emit on average less that 1.2 pounds of sulfur dioxide per million Btus of energy input from coal. Additionally, utility plant emissions are capped at 8.9 million tons of sulfur dioxide, a steep reduction from 1985 emissions of 16.1 million tons. Obviously, this represents a substantial tightening of the Phase I requirements with respect to sulfur dioxide emissions.

3.3.2.3 The "NOx" Regulations

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 1997. 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 particulate matter in mid-1997.

The 1997 regulations result in much more stringent sulfur dioxide and nitrogen oxide restrictions than those flowing from the Phase II regulations. The implementation of these regulations is in dispute and specific utility reactions to these restrictions are unknown. Implementation of the nitrogen oxide limitations is now scheduled for 2003, while the sulfur dioxide limitations are scheduled for implementation in 2008.

3.3.2.4 Traffic Effects of the CAAA

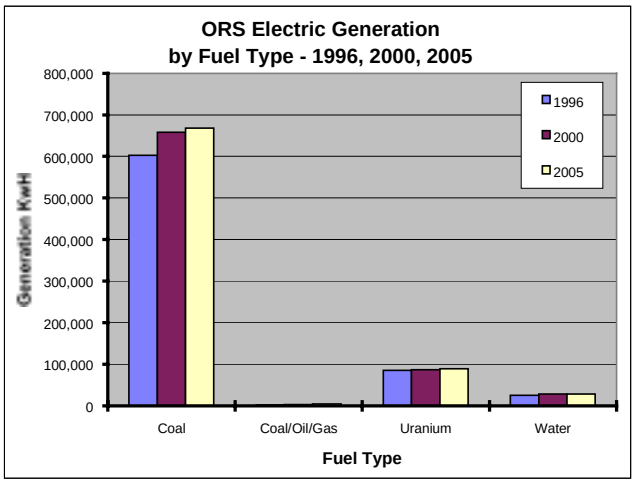
Dealing with these issues has caused utilities to deviate somewhat from their historical strategy of burning locally available coals to minimize transportation and generating costs. For example, mid-to-high sulfur coals dominate the upper and lower reaches of the ORS. Since implementation of Phase I, greater amounts of coal have been moving from the mid-section of the basin, where low-sulfur coals are available, to these destinations, while movements within the upper and lower reaches have diminished. In addition, it is evident that the extremely low sulfur coals of Wyoming's Powder River Basin (PRB) have made further in-roads into the ORB (See **Table 3-2**). These low Btu coals move by rail to river terminals on the upper Mississippi, lower Ohio, and lower Tennessee rivers where they are often blended with local coals before trans-loading onto barges for final delivery.

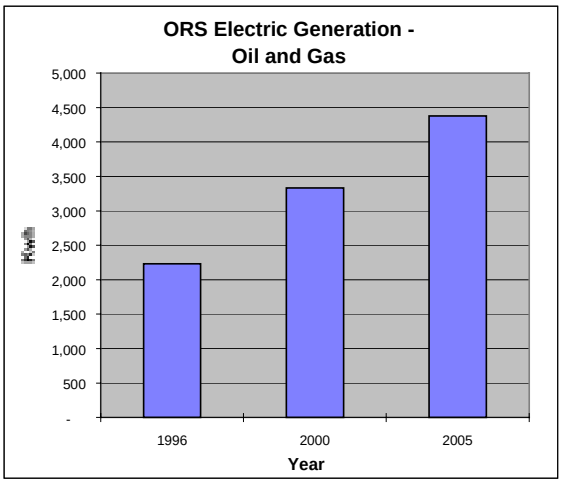
TABLE 3-2
ORS Receipts of Western Coal or Western Coal in Blends

Year	Tons (millions)
1996	18.3
Projected 2000	35.6
Projected 2005	36.5

Finally, utilities nationally and within the basin will rely more upon natural gas to generate electricity. ORS utilities reported this shift in projected fuel mix in the March 1998 electric utility survey conducted as part of this study. Shippers plan to increase their use of natural gas by 96% between 1996 and 2005; however, this leaves natural gas' share of total fuel still very small relative to coal's share of total generation for ORS utilities (see **Figure 3-1**).

FIGURE 3-1
ORS Electricity Generation by Fuel Type





3.3.3 Utility Industry Deregulation

The issue of deregulation is one that is causing many fundamental adjustments in the electric utility industry. The industry is currently in the midst of 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 would be more efficient in a competitive environment, and that only the transmission and distribution segments should remain regulated and noncompetitive.

The move away from strict utility company regulation began with passage of the Public Utilities Regulatory Policies Act of 1978 (PURPA). PURPA originated in the aftermath of the Arab Oil Embargo. As a result of the embargo, energy prices skyrocketed and inflation increased. An increased public awareness of energy issues lead to the five-part National Energy Act, which included PURPA. The main goal of the National Energy Act was to reduce U. S. dependence on imported oil and the resulting vulnerability to interruptions in energy supply, while developing alternative and renewable energy supplies. Among other features, PURPA called for a program to improve the wholesale distribution of electricity, which inherently promotes competition. PURPA requires a utility to interconnect with and purchase energy from any non-utility generating facility meeting the criteria for a Qualifying Facility (QF). PURPA requires that the utility pay for the QF-produced power at the utility’s own avoided cost of production.

Further movement in the direction of electric utility deregulation came about as a result of the passage of the Energy Policy Act of 1992 (EPACT). In essence, EPACT created a more competitive environment by promoting non-utility generation of power. EPACT changed some important features of the Public Utilities Holding Company Act of 1935 (PUHCA), which was a primary piece of legislation establishing strict regulation of utility companies. EPACT exempted certain non-utility generators, referred to as Exempt Wholesale Generators (EWGs), from the requirements of PUHCA, making it easier for those generators to enter the wholesale market. Because EPACT exempted the EWGs from PUHCA's requirements, they could be either utility-affiliated or nonaffiliated. Under EPACT EWGs are not required to adhere to co-generation and renewable fuel limitations, but utility companies are also not required to purchase power from EWGs.

Another important means for promoting competition in the electric utility industry has been the directives of the Federal Energy Regulatory Commission (FERC). Recognizing that access to transmission lines is an essential ingredient to providing for a competitive environment in the electric generation industry, FERC issued Order 888, which, among other things, establishes open access to transmission lines for non-utilities. FERC Order 889 stipulates that electric utilities must establish electronic systems in order to share information concerning the amount of available transmission capacity. The purpose of Orders 888 and 889 is to do away with the impediments that are perceived to be barriers to competitive wholesale electric sales, while at the same time enhancing efficiency and providing for a lower cost for the final end-use customers.

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. 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 have indicated that deregulation in the electric utility industry is an issue that is likely to impact ORS waterway commodity flows, particularly given the natural competitive advantages of waterside coal-fired plants in the Ohio River Basin. Utility industry executives feel that companies with coal-fired waterside plants will be in a good position to market electricity to other locations, both inside and outside of the ORB, as deregulation progresses.

3.3.4 Nuclear Plant Re-Licensing

In 1996, generation from nuclear facilities in the United States accounted for about 22 percent of total generation. The last nuclear plant licensed to operate was Watts Bar I, on the Tennessee River, in February 1996. Since that opening, six nuclear plants have closed, no plant license applications have been made and no plans for new nuclear plants have been announced. That leaves the total number of operating nuclear units in the country at 106.

The majority of U. S. nuclear plants were built in the late 1960s and the 1970s, and had operating licenses valid for 40 years, meaning that most of the licenses should expire before 2020. Given the strong bias against nuclear power in this country, it is currently considered doubtful that many of the nuclear facilities will be re-licensed once their licenses expire. If that happens, the only practical alternatives for providing baseload capacity in most parts of the country are gas and coal.

3.3.5 Carbon Limits and Global Warming

In December 1997, 159 nations, meeting in Japan at the Third Conference of Parties to the UN Framework Convention on Climate Change, agreed to binding limits on the emissions of six greenhouse gases, including carbon dioxide. The agreement, termed the "Kyoto Protocol", set emission limits on 39 industrialized nations designed to provide an overall 5.2 percent reduction from a baseline set at the actual level of emissions during the year 1990. Developing countries, under the same agreement, are excluded from any requirement to reduce emissions.

The Kyoto Protocol, although signed by the Administration, has generated considerable controversy, partly because of the exclusion of developing countries from emission limitations, and partly because of expected serious economic impacts in the U. S. Congress has not yet ratified this agreement, and is considered unlikely to do so in its present form. In fact, Congress has taken steps to insure that EPA does not attempt to implement the agreement through its regulatory function. If implemented, it is expected that the agreement would have serious adverse impacts on the use of coal by electric utilities.

In response to a congressional request, the U.S. Department of Energy, Energy Information Administration (DOE\EIA), completed an analysis of the *Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity* in October 1998. Because the rules governing final implementation are not known, EIA examined six carbon-related emission reduction cases, each expressed as a percent change in carbon-related emissions above or below 1990 emission levels. In all of these cases, coal production in the U.S. remains around 1 billion tons (+ or – 200 million tons) through the year 2005, but by the year 2020 coal production falls dramatically—down 200 million tons in the +24% case to 900 million tons in the –3% case. The –3% case represents a scenario where coal consumption for electric generation all but ends, U.S. coal production almost exclusively serving the export market.

3.3.6 Forecasting Methodology

3.3.6.1 Clean Air Act Amendments (CAAA) Scenario

The utility coal forecasting methodology was similar, in many respects, to the general methodology described in paragraph 1. What makes utility coal unique was that the forecast was the product of a fairly extensive modeling effort. The base year for forecasting utility coal movements was calendar year 1996. A extensive survey of ORS utilities was conducted to both confirm the reasonableness of the 1996 coal flows and to gather specific generation and coal movement information through year 2005. The coal model was used to forecast electricity generation by NERC region; to allocate generation to plants by type of generation; to estimate coal burns at coal-fired facilities; and finally, to estimate waterborne coal receipts at waterside coal-fired facilities.

3.3.6.1.1 Utility Survey. The utility survey, conducted in the spring of 1998 was aimed at capturing ORS-dependent utilities' expected responses to implementation of Phase II of the CAAA; their reactions to other impending environmental regulations, especially the so-called "NOx" regulations; and any plans they may have concerning deregulation in the electric utility industry. In March, 1998 questionnaires were distributed to 19 utilities that received ORS coal in 1996. The utilities were asked to provide their 1996 and projected 2000 and 2005 generation by plant for all fuel types; expected coal consumption at each coal-fired plant for these years; and coal source and routing information.

The utility responses reflected their expectations concerning deregulation and the evolving environmental regulations as of the date of the survey. Out of 19 companies contacted, responses were received from 13 companies. The responding companies moved 109 million tons of coal in 1996, which was about 86 percent of utility coal moving on the system and about 41 percent of total traffic. The responding companies moved about 37 percent of total traffic at Greenup (78 percent of utility coal) and 38 percent of total traffic at Myers (94 percent of utility coal). Respondents to the utility survey indicated a near doubling in waterborne receipts of Western coal by year 2005.

3.3.6.1.2 The Coal Model. The utility coal forecasts were the output of a coal model that relies on extensive databases developed by the utilities and compiled by state public utility commissions, electric reliability councils, and the U. S. Department of Energy. Other important data inputs to the modeling process were the OBERS economic and demographic projections prepared by the U. S. Department of Commerce, Bureau of Economic Analysis, and the data provided by the ORS-dependent utilities during the utility survey.

The Coal Model operates within a context of several key assumptions and procedures. These assumptions/procedures are described below:

(1) The Coal Model projects short-term (1995 to 2005) electricity demand growth of 1.71 percent annually and long-term (2005 to 2045) growth of 1.37 percent annually, with the short-term rate derived from utility-supplied information and the long-term rate computed using the OBERS projections.

(2) The impact of the relative prices of coal, gas, and oil on coal's share of total electric generation is not explicitly modeled in the Coal Model. However, this relationship is reflected in the Coal Model, being implicit in two key data elements: (a) electric utilities' projections of

generation by fuel type as reported in survey responses and (b) planned capacity additions and retirements as reported to the Department of Energy.

(3) Public utilities are assumed to make the maximum practical use of existing generating capacity before adding new generating units. When energy demands exceed the maximum practical use of existing capacity, new generating units are added.

(4) Planned retirements and capacity additions reported to the Department of Energy are included in baseline projections. The impact of these retirements and additions on the coal/non-coal split in power generation is reflected in future capacity additions.

(5) Future capacity is assumed to be added at sites where distribution infrastructure already exists, e.g., at existing plant sites, and in proportion to the geographic distribution existing at the time of the capacity shortfall.

(6) Bulk power transfers are held constant at 1995 levels, except as explicitly modeled in the deregulation scenarios.

(7) The geographic distribution of coal sourcing is based on projections provided by the electric utilities, and also reflects historical transportation patterns, projected impacts of deregulation from Hill and Associates, and analysis by the Navigation Planning Center.

The model, as currently configured, operates in four steps. First of all, the model estimates long-term electricity demands for each utility based on ten-year NERC region forecasts and the long-term OBERS economic and demographic projections. Secondly, the model makes plant-specific estimates of future electric generation by allocating demands to individual plants by type of generation. Next, the model converts plant-specific estimates of generation at coal-fired plants into coal burns. Finally, for the waterside plants, the model estimates waterborne coal receipts based on historic shares and sources.

The projections of electricity demands were based on the utilities' own ten-year projections of demands as reported to state public utility commissions and the U. S. Department of Energy. The forecasts were aggregated to the NERC region level and extended beyond 2005 using population and personal income data from the 1995 OBERS projection set.

Electricity demands were converted to plant-specific estimates of generation, by type of generation – coal, gas, nuclear, or hydropower. For plants included in the utility survey, the near-term generation estimates (through 2005) were maintained at the levels estimated by the utilities. The generating capacity of a plant was based on the maximum utilization rates observed for all plants of that size and type. Baseload plants were allowed to continue operating at historical levels, with future increments of demand apportioned among the utility's plants in proportion to the remaining capacity at its plants. Thus, low-cost, base-load plants are utilized first in the firing order, with high-cost plants brought on-line as needed to accommodate growth in demands. Except for capacity additions reported in DOE and NERC publications, no new capacity was added until a utility was making full use of its existing generating capacity. Once this happened, new units were brought on-line in proportion to the existing coal/noncoal fuel mix, except that no new nuclear or hydropower capacity was added.

The final two steps in the modeling process yielded waterway shipments. Electricity generation at coal-fired plants was converted to coal burns based on the historical conversion rates for those plants. For plants included in the utility survey, near-term coal burns (through 2005) were maintained at the levels estimated by the utilities. Barge receipts of coal were based on the share of 1996 coal burns received by barge at each plant unless otherwise indicated in the utility survey. Likewise, sourcing was based on historical patterns unless a departure from traditional sources was indicated by the utility survey.

A more detailed description of the coal model, its operations and outputs is contained in the addendum to this attachment.

3.3.6.2 Deregulation Scenario

The high level of uncertainty surrounding the outcome of utility industry deregulation prompted a closer examination of this issue, and in particular, its impact on ORS-dependent utilities. The concern was that, given the fact that ORS utilities are relatively low-cost electricity producers, the potential favorable impacts of deregulation on those utilities are not fully reflected in the traffic forecasts.

In the fall of 1998, several meetings were held with utility company representatives to discuss deregulation. The utility industry representatives agreed that deregulation could be quite favorable to the utilities with waterside coal-fired plants, but they provided no specific information that could be applied in the formulation of a specific deregulation traffic forecast. Several of the utility representatives referred to the work of Hill and Associates, a utility industry consulting firm, for information on deregulation.

Hill and Associates produced a multi-client report entitled Electricity Price Forecast – Outlook for Electricity Market Prices in a Deregulated Environment: 1997-2007 in October 1997. The purpose of this report was to examine the behavior of a completely deregulated power market, particularly as reflected in electricity prices.

Hill and Associates' analyses of the electric utility industry are based on the output of their National Power Model. The National Power Model was developed to simulate competitive electricity markets and to evaluate winners and losers under various planning scenarios. The model is a linear program-based model capable of determining the impact of numerous variables on such things as generation costs, power flows, plant-specific generation levels, and market clearing prices. The model includes plant-level data as well as information on supply, demand, and transmission constraints for 72 control areas or nodes.

The Hill and Associates report contains model results for a Base Case and seven other alternative scenarios. The Base Case assumes electricity demand growth of 1.86 percent per year through 2007, with regional variation. Delivered coal prices are assumed to be flat to declining in real terms; gas prices are assumed to increase by 0.5 percent per year; and oil prices are assumed to remain flat. No plant retirements are forecast over the 10-year period. Carbon dioxide and nitrogen oxide emission limits are assumed to remain as stipulated in Title IV of the 1990 Clean Air Act Amendments. Average conditions for hydropower production were assumed to prevail for all years of the forecast.

The Hill report provided plant specific generation estimates for coal-fired facilities under the Base Case scenario for selected years in the forecast period. The generation estimates from the Hill report were compared with the future generation estimates provided by the utilities during the course of the utility survey. Some of the generation estimates were higher than the estimates provided in the utility survey and some were lower, but on balance, the Hill report's generation estimates for ORS waterside facilities were higher than those supplied by the utilities. The Hill estimates, in short, reflected a more optimistic outlook for the waterside coal-fired facilities under deregulation than the utility-supplied information.

In order to reflect this more optimistic outlook in the traffic demand forecast, the Hill report generation estimates for the ORS plants were simply substituted for the utility-supplied short-term generation estimates in the coal model. This procedure resulted in utility coal traffic demand forecasts for the ORS that were about 20 million tons higher in 2005 and 39 million tons higher in 2055.

3.3.6.3 Nuclear Plant Re-Licensing

As discussed in paragraph 3.3.4, most of the currently-operating nuclear plants were built in the late 1960s and the 1970s, with normal operating licenses valid for 40 years. That means that most of the licenses will expire between 2010 and 2020. Memories of the Three Mile Island and Chernobyl nuclear accidents persist and have produced a strong bias against nuclear power in this country. As a result, it is currently considered doubtful that many of the nuclear facilities will be re-licensed once their licenses expire. The only practical alternatives for providing baseload capacity in most parts of the country, in that case, are gas and coal.

To reflect the possibility of limitations on nuclear plant re-licensing, a third alternative forecast was developed. This forecast is a modification of the alternative deregulation forecast discussed in previous paragraphs. To reflect limitations on nuclear plant re-licensing in the modeling context, it was assumed that nuclear power would be reduced gradually beginning in 2015. This approach resulted in system forecasts that were about 5 million tons higher than the alternative deregulation scenario in 2030 and 8 million tons higher in 2060.

3.3.6.4 Carbon Emissions Limits

All cases developed by EIA result in lower expectations for future U. S. coal production. Lower grade sub-bituminous and lignite coals derive higher proportions of their energy from carbon than do bituminous and anthracite coals, therefore the western regions producing these lower grade coals experience more serious impacts than do eastern coal fields. This information was used in developing ORS waterway flows under a fourth alternative scenario – a carbon-related emission limitation scenario. While taking this into account does ameliorate the effects of carbon limits on ORS coal flows, these flows still decline substantially.

3.4 EXPORT COAL FORECASTS

3.4.1 Background

Among all coal markets, the export market continues to be the most volatile and difficult market to forecast. The most important factors contributing to uncertainty in this market are world oil prices and economic growth. World economic growth affects the demand for electricity and steel, the major end products of steam and metallurgical coal use, respectively. World oil prices affect coal markets directly as a competing fuel and indirectly through their impact on economic growth. Other salient factors include technological changes, environmental regulations, changes in government policies, the cost of mining in various countries, fluctuations in currency exchange rates, and overall trade balances.

The U. S., over a number of years, has functioned as a swing supplier in the world coal market, particularly in steam coal markets. High quality coal and a stable political climate assure U. S. producers a share of the world market, but the relatively high cost of production and transportation to port act to inhibit the expansion of this share. U. S. coal exporters routinely supply about 20 percent of the world market. Foreign producer subsidies continue to limit opportunities for U. S. coal in Western Europe, its major export market. Primary competitors continue to be South Africa, Columbia, and Venezuela in European markets and Australia and Indonesia in Asian markets.

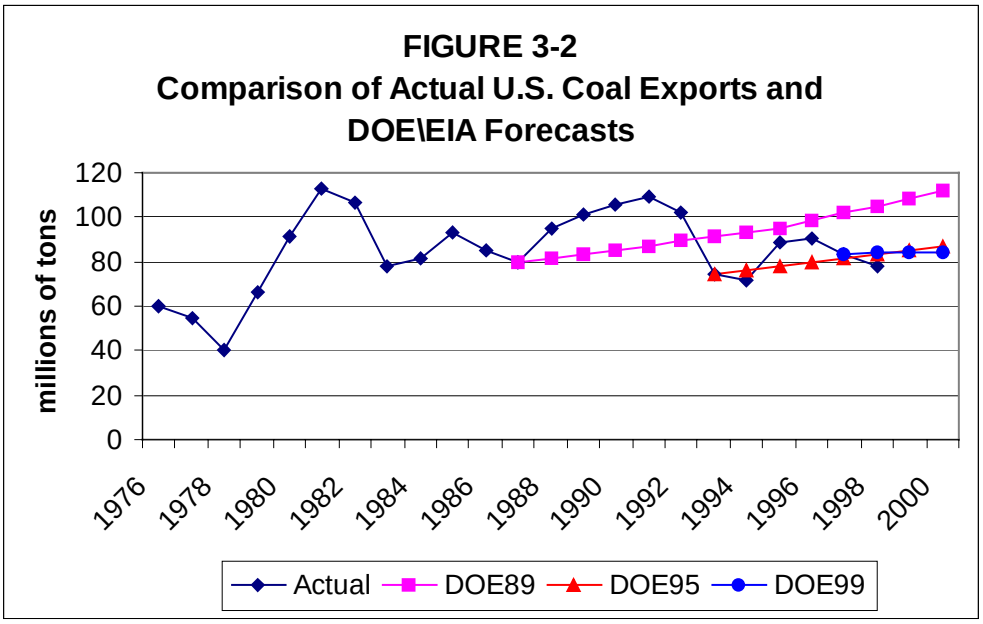
The export of ORS coal gained some importance in the late 1970s and early 1980s as labor unrest in several leading world coal exporting countries brought European and Asian steam coal purchasers to the U. S. Increasing amounts of ORS coal began to move to the export market through New Orleans. The Port of New Orleans quickly became a major exporting port, picking up the slack left by insufficient capacity of both the East Coast ports and of the railroads that served them. The export market for ORS coal remained strong throughout the 1980s and the early 1990s, but examination of later data suggests that the export market for ORS coal is in decline.

In recent years, U. S. exports have been adversely affected by a number of factors. Exchange rates have favored competitors, and substitution of natural gas for coal has reduced the demand for U.S. coal in the European utility sector. Export markets for metallurgical coal have been declining over the past few years because of the expansion of new steel-making technologies requiring less high-grade coking coal and the improved competitiveness of Australian producers. The economic downturns in Asia and Eastern Europe have reduced demands for both metallurgical and steam coal in these areas, resulting in over capacity in coal-exporting countries.

In this climate the U.S. Department of Energy, Energy Information Administration's (DOE\EIA) 1999 long-term outlook for coal exports calls for moderated growth. Metallurgical coal markets are expected to decline, causing overall U.S. export growth of only 0.5 precent annually between 1997 and 2020. European steam coal markets, which account for approximately 55 percent of Ohio River System (ORS) coal exports, are expected to grow at an annual rate of 1.9%. Asian steam coal markets, 24 percent of the ORS coal export market, are expected to grow at 3.8 percent. DOE\EIA projects the metallurgical market to decrease at a rate

of –6.3 percent annually; however, this market represents less than 1 percent of the ORS coal export market.

Among major forecasters, DOE\EIA's 2015 forecast of 84 million tons lies alongside DRI's forecast of 79 million tons, and somewhere between WEFA99 forecasts of 103 million tons and Hill\GRI99 forecast of 59 million tons.[1] This wide spread in coal export forecasts is understandable given the volatility of a market that is dramatically affected by exchange rates, world oil prices, labor conditions, world economic growth, and government policy at home and abroad. **Figure 3-2** compares actual U.S. coal exports with DOE\EIA forecasts presented in 1989, 1995, and 1999 (DOE89, DOE95, and DOE99, respectively). Over the past ten-years, DOE\EIA reference case forecasts have tended to underestimate coal exports in the short-term, while performing better in the longer-term. In a commodity market capable of growing from 40 million tons to 112 million tons in three years, short-term trends are unreliable predictors of long-term trends. The persistence of key determinant trends, like exchange rate based competitive advantage, productivity growth, economic growth or decline, competitive energy prices, and a host of government policies, needs to be addressed. DOE\EIA does this by modifying key assumptions and presenting alternative scenarios. This same kind of approach was used in developing the ORS coal export forecasts.



3.4.2 Forecasting Methodology

Coal export forecasts for the ORS are based on forecasts prepared under contract by Jack Faucett Associates and documented in a report entitled *Forecast of Ohio River System Coal Exports*. The export coal forecasting methodology used by Faucett was a top down approach, beginning with a forecast of total world energy consumption by world region. The forecast was further broken down by major consuming countries and then into energy demand by fuel type. Using the resulting projections of coal demand, an analysis of other published coal trade

[1] All forecast values are presented in DOE\EIA's *Annual Energy Outlook 1999*.

forecasts, and an analysis of the major coal importing and exporting countries' prospects, projections were made of the percentage of each importing country's coal demand accounted for by imports and the percentage of those imports which would originate in the U. S.

Coal export movements on the Ohio River System were analyzed for the years 1990-1994. The results of this analysis, combined with information from experts in the coal and shipping industries were used to project the percentage of total U. S. coal exports that would originate on the Ohio River System. Total U. S. and ORS coal exports were broken down by steam and metallurgical coal and by country of destination. Major docks of origin for this traffic were also identified.

Jack Faucett Associates produced a reference case forecast and three alternative forecasts by varying assumptions with respect to such variables as world energy consumption, world coal demand, economic growth rates in consuming countries, and alternate fuel prices. The Waterborne Commerce data show ORS export coal movements totaling about 6.3 million tons in 1996. The Faucett forecasts for ORS export coal for year 2000 range between 10.8 and 12.3 million tons. For year 2050 the forecasts range between 28.2 and 42.4 million tons.[2]

3.5 OTHER COMMODITY FORECASTS

3.5.1 General

Other commodity traffic is comprised of industrial coal and coke and the non-coal commodities. Industrial users of coal and coke are small in number, accounting for 3.2 percent of total ORS traffic, and very little of this traffic moves through either Greenup or Myers locks and dams. Conversely, non-coal traffic is important at both Myers and Greenup. Nevertheless, utility coal and export coal were the only commodities that were revised in the current forecast. All other commodities, as indicated in the preceding paragraphs, were left unchanged from the December 1995 forecast. For the commodities categorized as "other" commodity traffic, calendar year 1990 was the base year for forecasting purposes. These 1995 forecasts were judged to be reasonable based upon their performance relative to actual traffic (see **Table 3-3**).

[2] An alternative scenario based upon DOE99 coal export forecasts was prepared and used in a limited sensitivity test. This lower traffic scenario resulted in reduced, but positive net benefits for the proposed improvements at Myers and Greenup locks (benefit-cost ratios were 1.2 and 1.3, respectively).

TABLE 3-3 Performance of December 1995 ORS Non Coal Projections (traffic in mmtons)		
Year	**Actual**	**Projected**
1990	96.6	96.6
1996	110.0	110.3
1997	112.2	112.6
2000	N\A	119.5

3.5.2 Forecast Methodology

Historic and existing traffic levels and patterns were analyzed in an effort to determine if existing, or base year, traffic was representative of normal traffic flows. Because base year flows generally define origin-destination patterns throughout the forecast period, it was also important that deviations from current or historic patterns be incorporated as adjustments to the base year. Changes to the base year were made only when evidence suggesting new patterns was uncovered, reflecting, for example, near-term shipper plans. These changes, for the most part, were based on responses to shipper surveys conducted for each of the commodity groups. The information gathered in the shipper surveys provided a basis for making adjustments to base year traffic levels and for altering origin/destination traffic patterns. These surveys also provided verification that system constraints were not masking traffic demands. Since system constraints reduce traffic flows in affected areas, they can, if not accounted for, result in understated levels of demand.

Identification of the commodity end use markets was a highly important element in the forecasting effort for commodities in the “other” category. Concerted efforts were made to identify and categorize each of the unique origin-destination commodity movements on the ORS by end-use and geographic markets. This involved identifying the commodity recipient and determining the primary market(s) served. When sizeable movements were involved, receiving docks were contacted. By keying each movement to a particular market, traffic projections for any one commodity became the product of forecasts for a multitude of industries representing both end-use and geographic markets.

The objective in classifying movements according to the market served was to allow the analyst to develop growth indices from available economic forecasts. The forecasts used included those prepared by the Bureau of Economic Analysis (the OBERS forecasts), other government agencies, industry associations, and private consultants. The forecasts from the other government agencies, industry associations, and private consultants were generally short-term forecasts prepared at the national level for specific industries. For the most part, these forecasts were relied upon in developing near-term traffic growth indices. The OBERS series from the Bureau of Economic Analysis provides long-term (through 2040) population, earnings, and employment forecasts at the BEA area level for major industrial sectors. These forecasts were used in developing long-term traffic growth indices. **Table 3-4** is a listing of the specific forecasts used by commodity group.

3.6 FORECAST RESULTS

For the purposes of the current effort, only the ORS utility and export coal forecasts were updated. The traffic demand projections presented in this section capture the effects of implementation of Phase II of the Clean Air Act Amendments, including the recent NOx reduction requirements; deregulation in the electric utility industry; expected limitations on nuclear plant re-licensing; and limitations on carbon emissions.

Table 3-5 shows the results of the ORS traffic demand forecasts under the CAAA, Deregulation, Nuclear and Carbon Limits scenarios. In year 2010, the forecasts range between 320.4 million tons under the Carbon Limits scenario and 356.8 million tons under the Nuclear scenario. For year 2060, the forecasts range from 333.7 million to 547.2 million tons. The Nuclear scenario reflects the fact that nuclear plant re-licensing only begins to be problematic in the 2010-2020 time frame. Three of the four scenarios show growth rates of 1.0 percent or higher in the 1996-2060 time frame. The Carbon Limits scenario shows growth of 0.4 percent per annum, which is identical to the 1990-96 growth rate, but a substantial departure from long-term growth rates.

Table 3-4
Summary of Industry Forecasts and OBERS-Based Variables Used in Waterway Projections

Commodity Group	Short-Term Variable	Long-Term Variable
Coal	Operating Utility Steel Industry - WEFA Industrial - U. S. DOE	Population Personal Income Durable Earnings
Petroleum Fuels	Population	Population
Crude Petroleum	Population	Population
Aggregates	Construction Earnings Cement - Industrial Outlook Lime - Industrial Outlook Operating Utility	Construction Earnings Nondurable Earnings Durable Earnings
Grains	Agriculture Domestic - WEFA Agriculture Export - WEFA	Population Agricultural Svcs Earnings
Chemicals	Chemicals Earnings Inorganics - Industrial Outlook Organics - Industrial Outlook Fertilizer - WEFA	Chemicals Earnings Farm Earnings
Ores & Minerals	Metals - WEFA Raw Steel - WEFA Construction Earnings Population	Durable Earnings Primary Metals Earnings Total Earnings Construction Earnings Population
Iron and Steel	Raw Steel - WEFA Scrap Steel - WEFA Service Center - WEFA Construction Earnings	Primary Metals Earnings Durable Earnings Construction Earnings
Others	Agriculture - WEFA Population Paper Industry - USDA Construction Earnings Raw Steel - WEFA Organics - Industrial Outlook Durable Earnings	Farm Earnings Population Agricultural Svcs Earnings Construction Earnings Durable Earnings Total Earnings

Table 3-5

Projected ORS Traffic Demand

Forecast	Actual 1990	Actual 1996	2010	2030	2060	Annual % Growth Actual 1990-96	Annual % Growth Projected 1996-60
CAAA	260.6	266.7	334.0	393.6	498.4	0.4	1.0
Deregulation	260.6	266.7	355.9	422.3	539.3	0.4	1.1
Nuclear Limits	260.6	266.7	356.8	427.5	547.2	0.4	1.1
Carbon Limits	260.6	266.7	320.4	301.8	333.7	0.4	0.4
Dec95	260.6	266.7	339.3	413.1	522.6	0.4	1.1

Table 3-5 also compares the results of the forecasts with the previous system forecast completed in December of 1995 (referred to as the Dec95 forecast). At the system level, all but the Carbon Limits scenario are similar to the Dec95 forecast. Owing to substantial re-sourcing of coal supplies by electric utilities, however, the similarities in the forecasts do not extend to the individual waterways or to the locks. Similar quantities of coal are shown to move on the system, but traffic patterns are different because of changing environmental requirements at utility plants.

Table 3-6 shows the utility, export, and all other coal forecasts for the alternative projection scenarios. The major point of variation in all of these forecasts except Carbon Limits is in utility coal. Export and all other coal traffic are held the same in all but that scenario. The CAAA utility coal forecasts reflect the outlook of the utility industry itself, as represented in the utility industry survey, concerning its reaction to implementation of Phase II of the Clean Air Act Amendments and associated environmental initiatives, including the “NOx” regulations. The Deregulation scenario is handled as an adjustment to the CAAA scenario, and reflects an alternative outlook regarding the effects of utility industry deregulation on ORS utilities. The Nuclear scenario is handled as an adjustment to the Deregulation scenario, reflecting limitations on the re-licensing of nuclear generating facilities. The Carbon Limits scenario reflects diminishing coal traffic consistent with proposed limitations on carbon emissions.

Table 3-6

Projected Coal Traffic Demand by Major Category

Scenario/ Coal Traffic	1996	2010	2030	2060	Annual % Growth 1996-2060
CAAA					
- Utility	118.4	150.0	183.4	234.9	1.1
- Export	6.3	14.0	21.4	38.1	2.9
- Other	31.4	38.5	41.3	46.0	0.6
Total	156.1	202.5	246.1	319.0	1.1
Deregulation					
- Utility	118.4	171.9	212.1	275.9	1.3
- Export	6.3	14.0	21.4	38.1	2.9
- Other	31.4	38.5	41.3	46.0	0.6
Total	156.1	224.4	274.8	360.0	1.3
Nuclear Limits					
- Utility	118.4	172.8	217.3	283.7	1.4
- Export	6.3	14.0	21.4	38.1	2.9
- Other	31.4	38.5	41.3	46.0	0.6
Total	156.1	225.3	280.0	367.8	1.3
Carbon Limits					
- Utility	118.4	145.2	118.7	118.7	0.0
- Export	6.3	9.1	7.5	7.5	0.3
- Other	31.4	34.5	28.2	28.2	-0.2
Total	156.1	188.9	154.4	154.4	0.0

The utility coal forecasts for year 2010 range from 145.2 million tons under the Carbon Limits scenario to 172.8 million tons under the Nuclear scenario. By 2055, the range is from 118.7 to 283.7 million tons. Between 1996 and 2055, utility coal traffic is projected to remain flat under Carbon Limits, while the Nuclear scenario shows annual growth of 1.4 percent. All of the forecast scenarios reflect growth rates that are considerably below historical growth rates for utility coal on the ORS.

Export coal is shown to increase from a level of 6.3 million tons in 1996 to about 38.1 million tons in 2060 under all but the Carbon Limits scenario. With Carbon Limits, export coal is shown to grow from 6.3 to only 7.5 million tons. The expected annual growth rate of 2.9

percent for export coal, under all but the Carbon Limits scenario, reflects moderate growth in European export markets and more rapid growth in Asian markets, resulting from their eventual economic recovery.

Table 3-7 shows projected ORS traffic demand for the coal and non-coal groupings. Coal traffic demand is displayed by forecast scenario. The non-coal commodity forecasts are taken from the December 1995 forecast and are the same for each forecast scenario. The projected growth rates for total traffic are most heavily influenced by coal traffic.

The traffic demand forecasts for the mainstem locks are displayed in **Table 3-8**. All of the forecast scenarios reflect the effects of coal switching by ORS utility plants to meet the requirements of existing and impending environmental regulations. As a result, the forecast growth rates are the highest for projects in the middle and lower river. This reflects the decisions of ORS utilities to switch to Central Appalachian and western low-sulfur coal sources. In most cases, the coal switching doesn't mean a complete switch, but a change in coal blending, utilizing more coal from low-sulfur sources. The lowest growth rates for traffic demand at mainstem locks occurs at locks on the upper Ohio. This is a result of decisions by utility companies with plants on the upper Ohio to switch away from Monongahela River coal sources to Central Appalachian, particularly Kanawha River, sources.

Table 3-9 and **Table 3-10** present the detailed traffic demand forecasts at the Greenup and Myers projects. At the Greenup project, traffic demands range from 79.1 to 91.4 million tons in year 2010, while the range in year 2060 is between 81.6 and 160.9 million tons. Annual growth rates for Greenup are forecast to be between 0.2 and 1.3 percent. The traffic at Greenup is most heavily influenced by the decisions of utility companies in the middle river to switch to Central Appalachian coals and away from Illinois Basin coals. Greenup traffic is also affected by increases in export coal traffic, since most of the export coal tonnage from the ORS originates in the Greenup pool.

Table 3-7

Projected ORS Traffic Demand

Commodity	1996	2010	2030	2060	Annual % Growth 1996-2060
Coal (by scenario):					
- CAAA	156.1	202.5	246.1	319.0	1.1
- Deregulation	156.1	224.4	274.8	360.0	1.3
- Nuclear Limits	156.1	225.3	280.0	367.8	1.3
- Carbon Limits	156.1	188.9	154.4	154.4	0.0
Non-Coal (all scenarios):					
Petroleum Fuels	13.8	15.7	16.3	16.8	0.3
Crude Petroleum	0.2	0.6	0.7	0.8	2.2
Aggregates	43.5	43.6	48.7	62.6	0.6
Grains	11.9	16.9	20.1	24.9	1.2
Chemicals	9.8	12.6	14.0	16.1	0.8
Ores & Minerals	7.2	6.3	6.9	7.8	0.1
Iron & Steel	9.8	10.6	11.1	12.3	0.4
Others	14.3	25.3	29.6	38.1	1.5
Total	110.5	131.6	147.4	179.4	0.8
Total Traffic:					
- CAAA	266.6	334.1	393.5	498.4	1.0
- Deregulation	266.6	356.0	422.2	539.4	1.1
- Nuclear Limits	266.6	356.9	427.4	547.2 0	1.1
- Carbon Limits	266.6	320.5	301.8	333.8	0.4

At the Myers facility, the traffic demand forecasts range between 89.6 and 100.6 million tons in year 2010, while the range in year 2060 is between 95.7 and 154.9 million tons. The forecasts show annual growth rates ranging from 0.3 to 1.1 percent. Traffic demand growth at Myers is most heavily influenced by increases in upbound Western utility coal and increases in downbound Central Appalachian utility coal. Both sources have become increasingly attractive to utility companies in the face of current environmental regulations. Myers traffic demand is also affected by increases in export coal tonnage.

Table 3-8

Projected Lock Traffic Demand

Project/Scenario	1996	2010	2030	2060	Annual % Growth 1996-2060
Emsworth					
- CAAA	23.5	27.7	31.1	38.0	0.8
- Deregulation	23.5	29.4	33.1	40.4	0.9
- Nuclear Limits	23.5	29.5	33.4	41.1	0.9
- Carbon Limits	23.5	26.2	23.3	25.1	0.1
Dashields					
- CAAA	24.5	29.7	33.1	40.3	0.8
- Deregulation	24.5	31.4	35.1	42.7	0.9
- Nuclear Limits	24.5	31.4	35.5	43.3	0.9
- Carbon Limits	24.5	28.2	25.4	27.3	0.2
Montgomery					
- CAAA	27.3	32.4	35.4	41.7	0.7
- Deregulation	27.3	34.0	37.4	44.1	0.8
- Nuclear Limits	27.3	34.1	37.7	44.6	0.8
- Carbon Limits	27.3	30.8	28.2	30.5	0.2
New Cumberland					
- CAAA	37.4	39.8	43.6	51.1	0.5
- Deregulation	37.4	41.6	45.6	53.6	0.6
- Nuclear Limits	37.4	41.6	45.9	54.1	0.6
- Carbon Limits	37.4	37.7	34.5	37.8	0.0
Pike Island					
- CAAA	45.3	46.2	50.1	58.3	0.4
- Deregulation	45.3	48.7	53.0	61.8	0.5
- Nuclear Limits	45.3	49.0	53.4	62.4	0.5
- Carbon Limits	45.3	44.4	40.5	44.4	0.0
Hannibal					
- CAAA	48.8	58.2	65.4	79.7	0.8
- Deregulation	48.8	61.7	69.4	84.6	0.9
- Nuclear Limits	48.8	61.8	70.4	86.2	0.9
- Carbon Limits	48.8	55.6	50.0	54.4	0.2
Willow Island					
- CAAA	46.2	56.3	63.9	78.8	0.8
- Deregulation	46.2	58.7	66.7	82.4	0.9
- Nuclear Limits	46.2	58.9	67.6	83.8	0.9
- Carbon Limits	46.2	53.1	48.8	54.3	0.3

Table 3-8 (cont)

Projected Lock Traffic Demand

Project/Scenario	1996	2010	2030	2060	Annual % Growth 1996-2060
Belleville					
- CAAA	49.7	59.8	67.6	83.2	0.8
- Deregulation	49.7	62.1	70.4	86.6	0.9
- Nuclear Limits	49.7	62.3	71.4	88.0	0.9
- Carbon Limits	49.7	56.5	52.5	58.4	0.3
Racine					
- CAAA	50.8	61.4	69.4	85.1	0.8
- Deregulation	50.8	63.7	72.1	88.5	0.9
- Nuclear Limits	50.8	63.9	73.1	90.0	0.9
- Carbon Limits	50.8	57.9	54.0	60.1	0.3
Byrd					
- CAAA	61.9	66.9	78.2	101.7	0.8
- Deregulation	61.9	70.1	82.2	107.4	0.9
- Nuclear Limits	61.9	70.2	83.3	109.1	0.9
- Carbon Limits	61.9	62.9	59.2	66.4	0.1
Greenup					
- CAAA	70.8	86.4	107.7	149.3	1.2
- Deregulation	70.8	91.3	113.8	158.4	1.3
- Nuclear Limits	70.8	91.6	115.5	160.8	1.3
- Carbon Limits	70.8	78.5	72.9	80.7	0.2
Meldahl					
- CAAA	64.0	78.5	98.8	137.0	1.2
- Deregulation	64.0	83.1	104.7	146.2	1.3
- Nuclear Limits	64.0	83.3	106.4	148.7	1.3
- Carbon Limits	64.0	70.7	65.3	69.4	0.1
Markland					
- CAAA	55.4	71.0	87.7	120.3	1.2
- Deregulation	55.4	73.8	91.5	126.6	1.3
- Nuclear Limits	55.4	74.0	92.3	127.7	1.3
- Carbon Limits	55.4	64.1	62.7	69.0	0.3
McAlpine					
- CAAA	54.5	71.6	88.1	120.3	1.2
- Deregulation	54.5	74.1	91.4	126.2	1.3
- Nuclear Limits	54.5	74.2	92.2	127.2	1.3
- Carbon Limits	54.5	64.2	63.0	69.5	0.4

Table 3-8 (cont)

Projected Lock Traffic Demand

Project/Scenario	1996	2010	2030	2060	Annual % Growth 1996-2060
Cannelton					
- CAAA	56.3	79.6	99.0	135.8	1.4
- Deregulation	56.3	85.9	108.5	151.7	1.6
- Nuclear Limits	56.3	86.2	109.9	153.8	1.6
- Carbon Limits	56.3	73.9	71.1	77.8	0.5
Newburgh					
- CAAA	69.2	90.7	108.7	143.5	1.1
- Deregulation	69.2	95.9	116.0	155.3	1.3
- Nuclear Limits	69.2	96.1	117.0	156.7	1.3
- Carbon Limits	69.2	83.9	80.5	87.9	0.4
Myers					
- CAAA	78.9	97.3	115.1	149.1	1.0
- Deregulation	78.9	100.5	118.6	154.4	1.1
- Nuclear Limits	78.9	100.5	119.0	155.0	1.1
- Carbon Limits	78.9	88.8	86.2	94.9	0.3
Smithland					
- CAAA	84.5	105.2	126.0	162.8	1.0
- Deregulation	84.5	109.2	130.6	169.1	1.1
- Nuclear Limits	84.5	109.3	131.2	170.2	1.1
- Carbon Limits	84.5	95.9	91.9	100.5	0.3
L/D 52					
- CAAA	93.3	117.1	137.1	174.7	1.0
- Deregulation	93.3	121.0	141.6	180.9	1.0
- Nuclear Limits	93.3	121.1	142.0	181.5	1.0
- Carbon Limits	93.3	109.6	109.9	123.3	0.4

Table 3-9

Projected Traffic Demand at Greenup L/D

Commodity	1996	2010	2030	2060	Annual % Growth 1996-2060
Coal (by scenario):					
- CAAA	44.2	56.1	73.9	107.7	1.4
- Deregulation	44.2	60.9	80.0	116.7	1.5
- Nuclear Limits	44.2	61.2	81.7	119.2	1.6
- Carbon Limits	44.2	48.9	39.9	39.9	-0.2
Non-Coal (all scenarios):					
Petroleum Fuels	5.0	4.7	4.9	5.1	0.0
Crude Petroleum	-	-	-	0.1	-
Aggregates	7.1	7.0	8.3	12.3	0.9
Grains	0.1	-	-	-	-
Chemicals	3.3	4.2	4.8	5.5	0.8
Ores & Minerals	2.8	2.1	2.2	2.5	-0.2
Iron & Steel	4.6	5.9	6.3	7.0	0.7
Others	3.8	6.3	7.2	9.2	1.4
Total	26.7	30.2	33.7	41.7	0.7
Total Traffic:					
- CAAA	70.9	86.3	107.6	149.4	1.2
- Deregulation	70.9	91.1	113.7	158.4	1.3
- Nuclear Limits	70.9	91.4	115.4	160.9	1.3
- Carbon Limits	70.9	79.1	73.6	81.6	0.2

Table 3-10

Proiected Traffic Demand at Mvers L/D

Commodity	1996	2010	2030	2060	Annual % Growth 1996-2060
Coal (by scenario):					
- CAAA	42.4	51.0	63.4	88.7	1.2
- Deregulation	42.4	54.2	66.9	94.0	1.3
- Nuclear Limits	42.4	54.3	67.3	94.6	1.3
- Carbon Limits	42.4	43.3	35.4	35.4	-0.3
Non-Coal (all scenarios):					
Petroleum Fuels	4.0	5.1	5.3	5.5	0.5
Crude Petroleum	0.0	0.1	0.1	0.1	-
Aggregates	2.6	3.2	3.5	3.9	0.6
Grains	5.6	9.1	11.1	14.1	1.5
Chemicals	6.4	8.3	9.2	10.6	0.8
Ores & Minerals	5.5	4.4	4.7	5.3	-0.1
Iron & Steel	7.8	9.1	9.5	10.5	0.5
Others	4.6	7.0	8.2	10.3	1.3
Total	36.5	46.3	51.6	60.3	0.8
Total Traffic:					
- CAAA	78.9	97.3	115.0	149.0	1.0
- Deregulation	78.9	100.5	118.5	154.3	1.1
- Nuclear Limits	78.9	100.6	118.9	154.9	1.1
- Carbon Limits	78.9	89.6	87.0	95.7	0.3

3.7 SELECTION OF MOST PROBABLE DEMANDS

The initial forecasting approach, referred to as the Clean Air Act Amendments scenario, relied directly on the input of the utilities themselves concerning their own generation plans. The initial approach begins with the assumption that each of the utilities will continue in operation

and that each will at least maintain its level of generation. This approach ignores interrelationships and the fact that there will be "winners" and "losers" in a de-regulated environment.

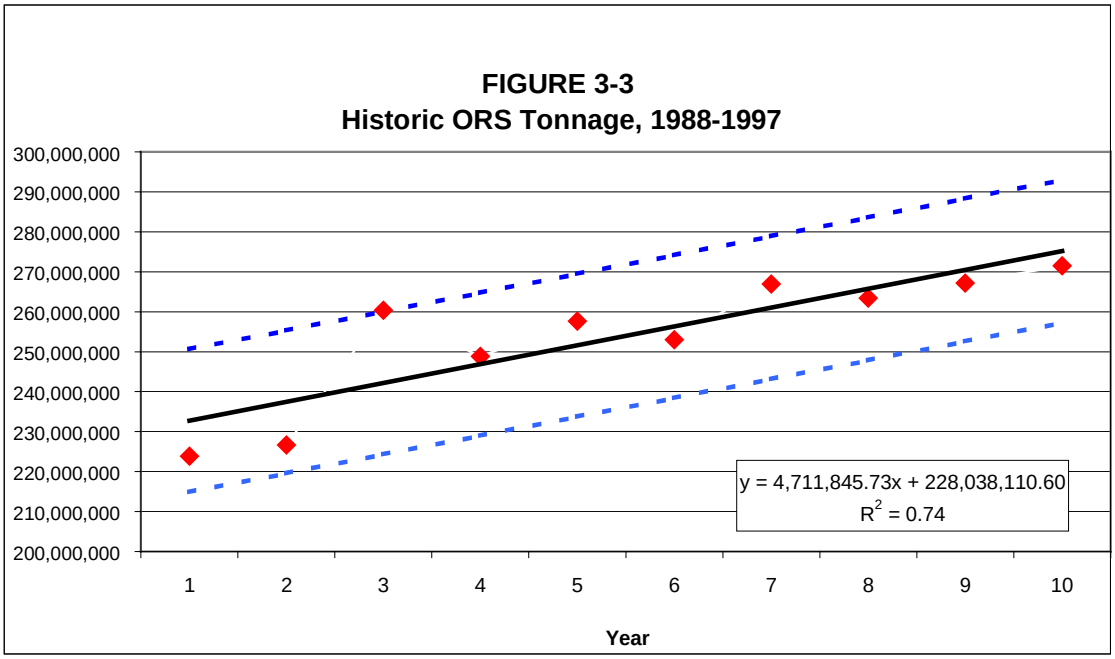
Concerning the possibility of limitations on nuclear plant re-licensing, this approach ignores the possibility of technological advances that would increase the safety of nuclear power plants. It also ignores the possibility that, in the face of limited power supply options and increasing costs, public opinion could shift toward greater acceptance of the nuclear power option. In addition, the assumed tapering of nuclear power supply in the alternative forecast results in only a small incremental increase in traffic spread over the entire ORS.

The greatest uncertainty surrounds the carbon limits scenario based upon analyses prepared by DOE\EIA in an attempt to quantify the impact of Kyoto Protocol implementation on energy markets and the domestic economy. Meeting these requirements can be accomplished by reducing electricity demand, adopting the use of more energy-efficient equipment, and switching to less carbon-intensive of non-carbon fuels. In their analysis, DOE assumed reductions in demand would be forced through increased electricity prices, which should lead to investment in more energy-efficient equipment. However, meeting demands will still require increasing our reliance on renewable fuels (like wood waste products, biomass, wind, hydropower, and so forth), natural gas, and nuclear power, regardless of scenario. The technologies involved are assumed to mature as needed, as is the public's acquiescence to higher energy prices and greater dependence on power sources that possess their own unique liabilities. Finally, the U.S. Congress has not ratified the Kyoto Protocol, leaving it lacking the force of law.

In light of these factors, and particularly in light of the fact that the alternative deregulation scenario, referred to simply as the deregulation scenario, accounts for "winners" and "losers" in the deregulation process, this scenario was selected as the most probable traffic demand scenario.

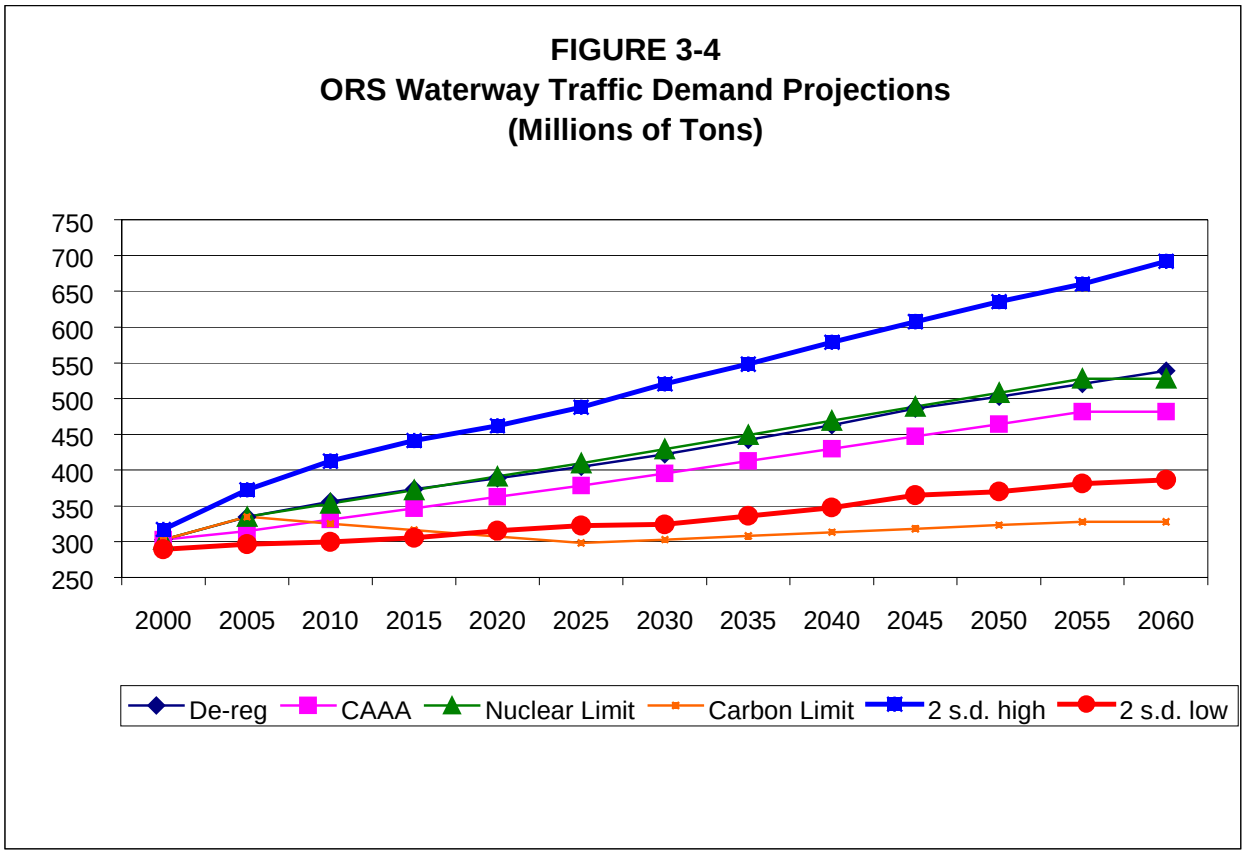
A simple stochastic time-series model was developed to simulate the increasing uncertainty in the forecasts through time and test the level of uncertainty associated with the scenarios developed above. Assuming that 1) each forecasted year's tonnage is normally distributed and are correlated with each other according to a simple first-order Markov process; and 2) that stochastic properties (from historic data) are assumed to be invariant with respect to time (stationary), possible future tonnage series (y_1, y_2, …, y_T) could be simulated. From the simulated results, the 5th and 95th percentile tonnage for each forecasted year could be calculated.

The two major inputs in this time-series simulation were 1) the historic system tonnage variability; and 2) the most-likely traffic forecasts year-to-year growth rates. Historic ORS tonnage variability shows a standard deviation of 8,936,967 tons about the ordinary least-squares trend line (The least-squares regression technique assumes normality, homoscedasticity, independence and linearity). The original observations, the trend line, the 95% confidence interval ranges and the regression equation are shown in **Figure 3-3** below.



The first year of the simulation, a tonnage is picked from a normal distribution with mean of 303,078,818 (the most-likely year-1 tonnage demand) and standard deviation of 8,936,967 tons. In the second year of the simulation, the tonnage selected in the first year of the simulation is increased by the most-likely year-1 to year-2 growth rate (i.e. 1.0256). This calculated tonnage is then used as the mean value for the tonnage distribution in the second year of the simulation (the standard deviation remains the same). The tonnage for the second year of the simulation is then picked from this new distribution and the cycle continues through all 60-years of the analysis period until a complete series of tonnage are selected (y_1, y_2, …, y_T).

The time-series model was developed using Palisade Corporation's @RISK software (an EXCEL add-in). Once all simulations were completed and convergence obtained the 5th and 95th percentiles were extracted by year as shown in **Figure 3-4**.



The 5th and 95th percentile tonnage were then used to index down and up the most-likely traffic forecasts on a movement to movement level. As a result, we are 95% confident that the system demand will lie between these upper and lower bounds (2 s.d. high and 2 s.d. low in **Figure 3-4** above). The Deregulation, CAAA and Nuclear Limit scenarios all lie well within the 95% confidence bounds. Only the Carbon Limit scenario lies outside these bounds, underscoring the radical nature of this scenario as a departure from historic and current patterns. The Carbon Limit scenario was not used in the economic modeling.

ADDENDUM 1

Ohio River Navigation System
Coal Transportation Projection Model
[CTPM]

to

ATTACHMENT 3

WATERWAY TRAFFIC FORECASTS

Developed by
USACE Charleston District
Economics and Plan Formulation Section
April 1999

Ohio River Navigation System
Coal Transportation Projection Model
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Section 1: Introduction

The Ohio River Navigation System consists of 2,400 miles of waterway and 50 lock and dam structures, and accommodates the transportation of about 300 million tons of commerce annually. Many of these lock and dam structures are more than 50 years old, with lock sizes that are too small to accommodate the large tows that now move on the river system without significant delays.

The replacement of these aging locks will improve the operation of the system as a whole. However, the scarcity of Federal and non-Federal funds for replacing these structures requires prioritization based on the net contribution to national economic development. A fair assessment of the relative importance of these infrastructure improvements requires that they be placed on a common analytical footing.

The projections of coal traffic described in this report are part of a larger database designed to provide a this common analytical footing. Other major components of the database include projected future vessel fleets, transportation networks, and vessel operating costs.

Section 2: Overview of Projection Methodology

This report describes the methodology that was used to project future waterborne movements of coal to electric power plants located throughout the eastern United States. The methodology described herein integrates two distinct analytical processes for projecting the volume and geographic distribution of coal shipments. First, a top-down computational process used projections of regional demands for electricity to project the generation of electricity at the plant level. Plant-specific projections of power generation were then used to project coal burns and waterborne deliveries of coal at coal-fired plants. The entire process was formalized in the Coal Transportation Projection Model [CTPM], consisting of a series of databases and computer programs. Second, analysts developed detailed short-run estimates of coal burns and coal delivery patterns from extensive surveys, literature reviews, and analyses of the electric utility industry and, more particularly, its acquisition and consumption of coal. This information was developed for a majority of the power plants that were evaluated and was integrated into the computational process.

The current state of the CTPM is the product of twenty years of development by the Huntington District's Navigation Planning Center. The conceptual framework for the CTPM is based largely on work performed during the mid-1980s by Arthur D. Little Associates, under contract for the Navigation Center. The methodology was formalized as a series of Fortran programs in the late-1980's and was converted to dBase IV programs in the early 1990's. The computational model consists of four main modules, as shown in the flow chart in Figure 1.

In the Electric Demands Module, projections of electricity demands are extrapolated to 2045. In the past, demand projections for each electric utility company were analyzed separately. However, the increased interdependence of utilities requires the consideration of demands within a broader geographic context. For this reason, the projections described in this manual generally reflect energy demands at the NERC[1] region or subregion level of geographic aggregation.

The Electric Generation Module estimates generation at the plant level based on projected electricity demands and a wide array of power generation data. This plant-specific database includes nameplate capacities, historical generation levels, estimates of maximum sustainable generation, and anticipated capacity additions. In this module, bulk power transfers are held constant at the 1995 level. This is accomplished by estimating generation as the sum of current generation levels [within which current bulk power transfers are inherent] and marginal electric power generation.

Once future generation levels have been projected for each power plant, coal-fired plants are singled out for analysis. The Coal Consumption Module uses historical plant-specific generation to burn ratios to estimate the volume of coal that will be required to generate the projected level of electric power.

[1] National Energy Reliability Council.

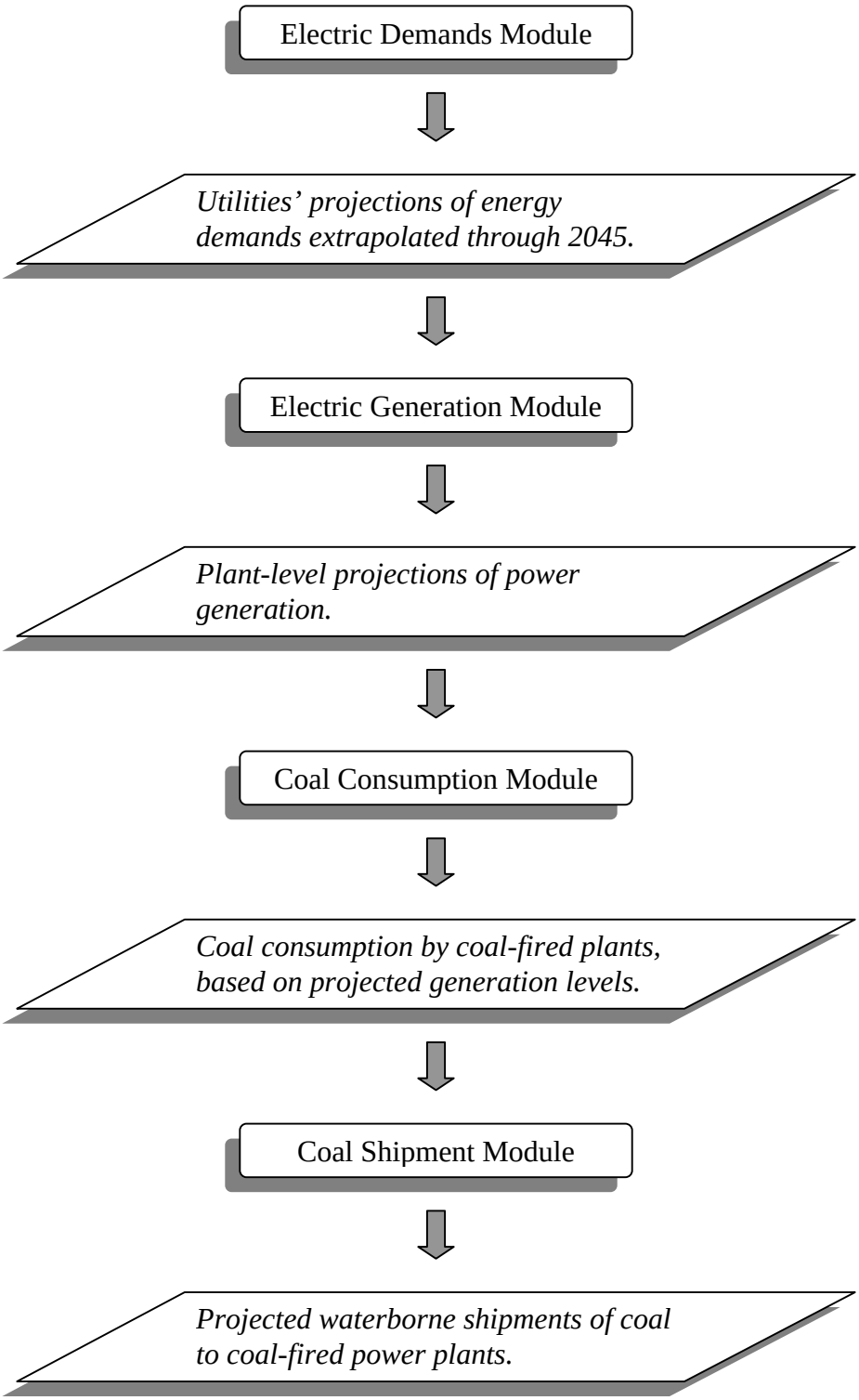


Figure 1, ORNS Coal Transportation Projection Model

The final step in the CTPM is the Coal Shipment Module, which is used to project future delivery patterns given projected coal consumption levels. In the past, this module used

historical origins, destinations and delivery modes to develop a list of waterborne coal movements that satisfy the projected demands of coal-fired power plants. In the current set of projections, however, extensive user surveys generated detailed information about anticipated future coal delivery patterns. Survey responses, supplemented by estimates developed by the Navigation Center, are the source of all projected of coal shipments for 2000 and 2005. These in turn were used with projected future coal burns to estimate future coal delivery patterns.

All programs are written in the dBase IV programming language. Key sources of data include the US Department of Energy, Energy Information Administration; the US Department of Commerce, Bureau of Economic Analysis; and the US Army Corps of Engineers, Waterborne Commerce Statistical Center. A summary of key model components is shown in Figure 2.

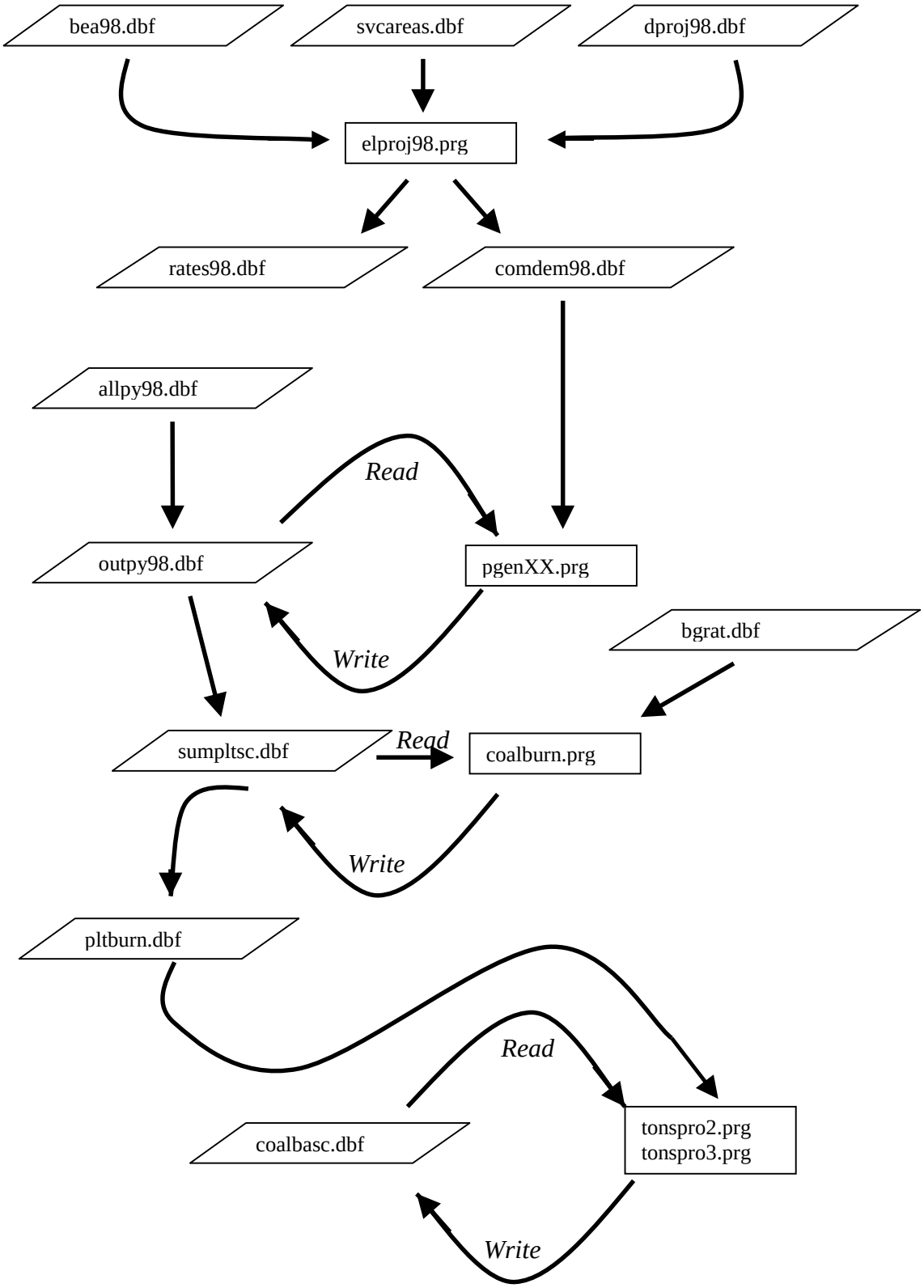


Figure 2 – Overview of Coal Transportation Projection Model.

Section 3: Electric Demands Module

3.1 Structure. In the Electric Demands Module, the projections of electric power demands that were developed by the public utilities were extrapolated to the year 2045. Three database files are used by the dBase IV program ELPROJ98.PRG (shown in Exhibit A) to generate two output files. A flow chart for this module is shown in Figure 3 and the input and output files are described in Table 1.

Ten-year energy demand projections developed by electric utility companies are contained in DPROJ98.DBF. Unlike the 1994 projections, where all projections were utility-specific, ten-year energy demands projections are usually aggregated to the NERC-region or subregion level of detail. These aggregate service areas are enumerated and defined geographically in SVCAREAS.DBF.

The file BEA98.DBF contains the OBERS state-level projections of total personal income through 2045 that were used to extrapolate the energy demand projections contained in DPROJ98.DBF.

This module generates two output files. The first, COMDEM98.DBF contains projections of energy demands extrapolated through 2045, which serve as input into the Electric Generation Module. The second, RATES98.DBF, contains a list of growth rates reflected in COMDEM98.DBF.

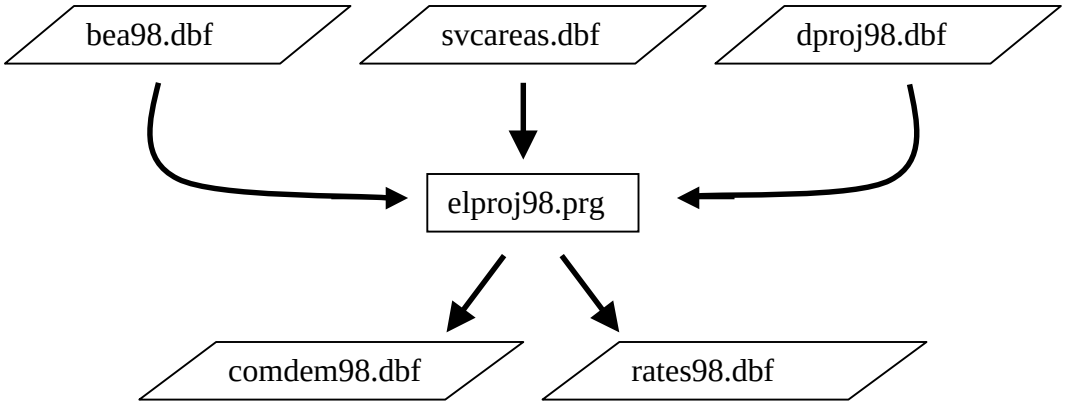


Figure 3 – ORNS Coal Transportation Projection Model, Electric Demands Module.

Table 1

ELPROJ98.PRG Input & Output Files

Filenames	Input/ Output	Description
BEA98.DBF	Input	OBERS projections, 1995 to 2045, state level.
SVCAREAS.DBF	Input	Utility service areas defined by constituent states.
DPROJ98.DBF	Input	10-year demand forecasts, various geographic levels
COMDEM98.DBF	Output	Extrapolations of demand forecasts from DPROJ98.DBF to 2045.
RATES98.DBF	Output	Listing of growth rates used in generating COMDEM98.DBF.

Source: 19__ OBERS Projections, U.S. Department of Commence; Charleston District, US Army Corps of Engineers, 1998.

3.2 Methods and Assumptions. DPROJ98.DBF contains ten-year [1995-2005] electric demand projections for all utilities served by power plants that receive coal via the Ohio River Navigation System. As noted above, these projections have historically been available at the utility level, but now are provided at various levels of geographic aggregation.

Generally, the regions which account for the largest volume of traffic on the Ohio River Navigation System (ORNS) are reported at the greatest level of geographic aggregation. The East Central Area Reliability Coordination Agreement (ECAR) area surrounds the central portion of the ORNS. Projections for public utilities within ECAR are reported as a total for the entire NERC region, as are those of the Mid-Atlantic Area Council (MAAC). In the Southeastern Electric Reliability Council (SERC), projections are reported for four subregions: (1) Florida, (2) Virginia/Carolinas, (3) Tennessee Valley Authority, and (4) the Southern subregion. The only important NERC region for which electric demand projections are reported at the utility level is the Mid-America Interconnected Network (MAIN).

Projected electric demands contained in DPROJ98.DBF were extrapolated to 2045 using 1995 OBERS projections of total personal income for each service area, approximated at the state level. Obviously, the service areas of two utilities may be best approximated by the same set of states and yet have markedly different future growth rates. To address this fact, growth rates derived from the OBERS projections were adjusted to reflect the

difference between the projected rate of growth in total personal income from 1995 to 2005 and that reflected in the ten-year projections of energy demands over the same period. The derivation of the adjustment factor is described in Section 7. Adjusted growth rates were used to extrapolate ten-year energy demand projections to the year 2045.

3.3 Summary of Output. The projected energy demands by service area contained in COMDEM98.DBF are shown in Table 2. These service areas range from the very large--ECAR's projected energy demands grow from 521 gigawatt-hours in 1995 to more than 1,000 gigawatt-hours in 2045-- to the very small. Most of the small utility systems are served by a few plants receiving small volumes of coal via the Ohio River System. Thus, it was undesirable to model additional NERC regions to account for marginal additions to the total system traffic.

The adjustment factors described in Section 3.2 and the resulting projected growth rates are shown in Table 3. From 2005 to 2010, these growth rates range in magnitude from just under 2 percent annually in the Florida, VACAR, and Southern subregions of SERC and Central Illinois Public Service to almost flat growth in Wisconsin Public Service Corporation and Soyland Power. Electric demands in ECAR, the largest entity represented in this modeling effort, are projected to grow at 1.4 percent annually over the same period. These data are also contained in the output file RATES98.DBF.

Table 2
Projected Net Energy for Load
From the Output File COMDEM98.DBF
(Million Megawatt-Hours)

Company Number	Company Name	1995	2000	2005	2010	2015	2025	2045
03252	Central Illinois Light Co.	5,897	6,473	7,021	7,631	8,234	9,438	12,633
03253	Central Illinois Public Service	9,286	10,688	11,317	12,438	13,558	15,828	22,030
04110	Commonwealth Edison Co.	89,163	92,450	99,600	105,006	110,194	120,155	144,559
04716	Dairyland Power Coop	3,712	4,023	4,287	4,592	4,890	5,473	6,961
05599	ECAR	521,247	560,274	605,289	649,273	693,649	784,863	1,018,234
17632	Southern Illinois Power Coop	1,029	1,119	1,235	1,347	1,459	1,683	2,283
19436	Union Electric Co.	35,829	39,133	42,680	46,339	49,976	57,355	75,858
20856	Wisconsin Power & Light Co.	11,585	12,300	13,643	14,658	15,651	17,614	22,472
40307	Soyland Power Coop, Inc.	1,448	1,467	1,542	1,589	1,633	1,715	1,905
B2692	Illinois Power/Soyland Power P	19,866	20,550	20,363	20,605	20,828	21,233	22,127
B2707	MAAC	243,043	257,992	276,054	293,882	311,350	345,827	430,170
Q3043	SERC, FL	169,021	188,485	210,751	232,646	254,264	297,405	390,412
B2714	SERC, STHRN	181,320	201,934	222,224	244,531	266,822	312,037	427,488
B2716	SERC, VACAR	249,236	280,886	310,217	342,270	374,374	439,572	599,056
U5733	SERC, TVA	142,031	157,256	173,586	188,252	202,463	230,439	297,841
20847	Wisconsin Electric Power Co.	54,606	58,502	62,818	66,803	70,657	78,183	96,324
20860	Wisconsin Public Service Corp.	21,720	22,134	22,356	22,641	22,904	23,386	24,411

Table 3

Projected Growth Rates for Electric Power Demands
From the Output File RATES98.DBF

Company Name	Adjustment Factor	Projected Annual Growth Rate (Percent)					
		1995 - 2000	2000 - 2005	2005 -2010	2010-2015	2015-2025	2025-2045
Central Illinois Light Co.	1.043	1.663	1.857	1.680	1.532	1.374	1.469
Central Illinois Public Service	1.183	1.888	2.108	1.907	1.739	1.560	1.667
Commonwealth Edison Co.	0.659	1.052	1.174	1.063	0.969	0.869	0.929
Dairyland Power Coop	0.859	1.371	1.531	1.385	1.263	1.133	1.210
ECAR	0.920	1.512	1.500	1.413	1.331	1.243	1.310
Southern Illinois Power Coop	1.091	1.740	1.943	1.758	1.603	1.438	1.537
Union Electric Co.	0.969	1.729	1.801	1.659	1.523	1.387	1.408
Wisconsin Power & Light Co.	0.829	1.708	1.590	1.446	1.318	1.189	1.226
Soyland Power Coop, Inc.	0.374	0.596	0.666	0.602	0.549	0.493	0.526
Illinois Power/Soyland Power	0.147	0.234	0.261	0.236	0.215	0.193	0.206
MAAC	0.792	1.194	1.370	1.260	1.161	1.056	1.097
SERC, FL	0.822	2.205	2.257	1.996	1.793	1.580	1.370
SERC, STHRN	1.034	2.009	2.101	1.932	1.760	1.578	1.586
SERC, VACAR	1.002	2.264	2.161	1.986	1.809	1.618	1.560
SERC, TVA	0.845	2.251	1.803	1.635	1.466	1.303	1.291
Wisconsin Electric Power Co.	0.710	1.461	1.360	1.238	1.128	1.017	1.049
Wisconsin Public Service Corp.	0.145	0.299	0.279	0.254	0.231	0.208	0.215

Section 4: Electric Generation Module

4.1 Structure. The Electric Generation Module is used to project future electric generation at the plant level. For the power plants serving the areas that were evaluated in the Electric Demands Module, electric generation is projected based on the projected energy demands of the service area and the available capacity of each plant. This module is driven by the dBase IV programs PGENXX.PRG [shown in Exhibit B], where XX is the future year for which projections are being developed.

In this module, the programs PGENXX.PRG use the COMDEM98.DBF [generated in the Electric Demand Module] to update OUTPY98.DBF, from which SUMPLTSC.DBF is later extracted. A flow chart for this module is shown Figure 4 and the input and output files are described in Table 4.

The file ALLPY98.DBF is the primary input file and contains a list of the power plants being evaluated, showing the plant, utility and NERC region names and numbers, fuel type, nameplate capacity, and other relevant information for each plant. Projected energy demands in the file COMDEM98.DBF, described above, are apportioned among the power plants listed in ALLPY98.DBF based on estimates of the available capacity of each plant. To preserve the integrity of ALLPY98.DBF, OUTPY98.DBF, an exact copy of ALLPY98.DBF, is read and modified in this module. After the series of programs has been run, records for coal-fired power plants are copied into SUMPLTSC.DBF, which is used as input into the Coal Consumption Module.

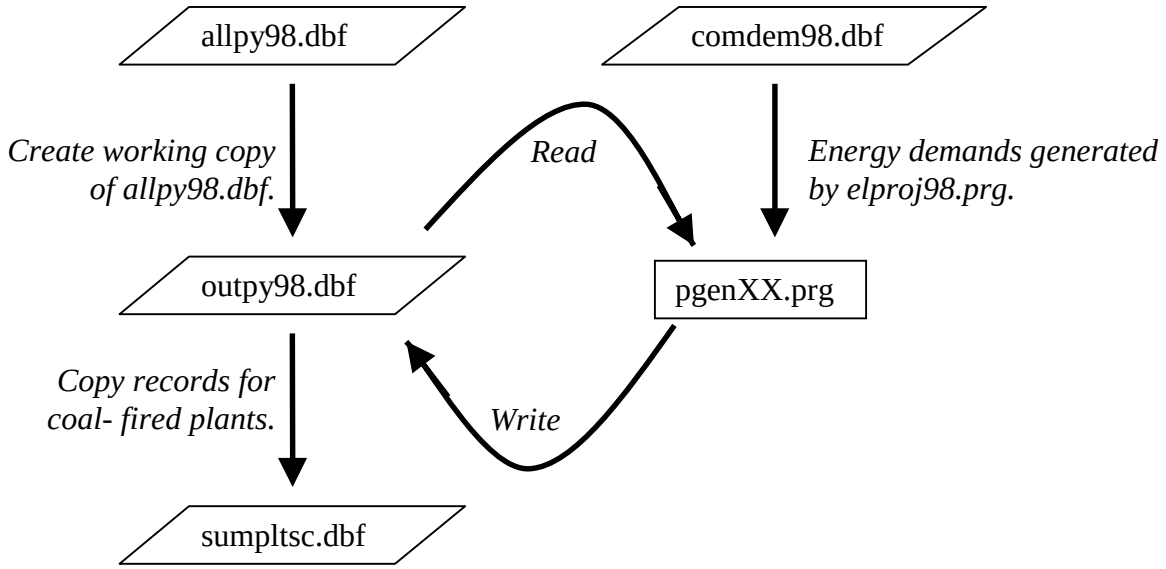


Figure 4 – ORNS Coal Transportation Projection Model, Electric Generation Module.

Table 4
PGENXX.PRG Input & Output Files

Filenames	Input/ Output	Description
ALLPY98.DBF	Input	List of power plants, with historical generation and maximum long-term generation capacity.
COMDEM98.DBF	Input	Extrapolations of demand forecasts from DPROJ98.DBF to 2045.
OUTPY98.DBF	Output	Copy of ALLPY98.DBF into which projected generation was written. A copy of ALLPY98.DBF was used to preserve the integrity of the input data.
SUMPLTSC.DBF	Output	Records for coal-fired plants copied from OUTPY98.DBF, modified to include space for coal burns and used as input into the Coal Consumption Module.

4.2 Methods and Assumptions. Projections of electric generation are developed by distributing a demand region's marginal increase in electric demands among its generating plants, based on the remaining capacity of those plants. Marginal increases in demands are determined by comparing electric demands for the current period with those of the preceding period. In apportioning this demand among a demand region's generating plants, transmission losses of 5 percent are assumed.

ALLPY98.DBF lists all the power plants serving the electric demand regions described in Secton 3, showing basic information such as the plant, utility and NERC region names and numbers, fuel type, and nameplate capacity of each plant. This information was derived from the Powerdat database, developed by Resource Data International, Inc.

This file also contains historical generation levels, maximum sustainable generation, and the available capacity of each plant. The maximum sustainable generation of a plant is a function of the plant's nameplate capacity and estimated maximum sustained utilization rates for nine broad classes of power plants delineated by fuel type and plant size, as shown in Table 5. For years prior to 2005, maximum sustainable utilization rates are based on the 90th percentile level of operation for each class of plants during the years 1994 - 1997. For the year 2005 and beyond, these utilization rates were modified as required to reflect changes in plant utilization rates projected by the Department of Energy and the National Energy Regulatory Commission.

Table 5
Estimated Maximum Sustained Utilization Rates

Year	Fuel Type	Nameplate Capacity	Percent Utilization	Nameplate Capacity	Percent Utilization
1995	Coal	<1,500 MW	65.44	1,500+ MW	75.49
2000	Coal	<1,500 MW	65.44	1,500+ MW	75.49
2005	Coal	<1,500 MW	76.00	1,500+ MW	76.00
2010	Coal	<1,500 MW	76.00	1,500+ MW	76.00
2015	Coal	<1,500 MW	76.00	1,500+ MW	76.00
2025	Coal	<1,500 MW	80.00	1,500+ MW	80.00
2045	Coal	<1,500 MW	80.00	1,500+ MW	80.00
1995	Gas	<1,500 MW	13.51	1,500+ MW	47.82
2000	Gas	<1,500 MW	13.51	1,500+ MW	47.82
2005	Gas	<1,500 MW	13.51	1,500+ MW	47.82
2010	Gas	<1,500 MW	13.51	1,500+ MW	47.82
2015	Gas	<1,500 MW	13.51	1,500+ MW	47.82
2025	Gas	<1,500 MW	13.51	1,500+ MW	47.82
2045	Gas	<1,500 MW	13.51	1,500+ MW	47.82
1995	Oil	<1,500 MW	5.72	1,500+ MW	36.35
2000	Oil	<1,500 MW	5.72	1,500+ MW	36.35
2005	Oil	<1,500 MW	5.72	1,500+ MW	36.35
2010	Oil	<1,500 MW	5.72	1,500+ MW	36.35
2015	Oil	<1,500 MW	5.72	1,500+ MW	36.35
2025	Oil	<1,500 MW	5.72	1,500+ MW	36.35
2045	Oil	<1,500 MW	5.72	1,500+ MW	36.35
1995	Uranium	All	62.51		
2000	Uranium	All	76.00		
2005	Uranium	All	85.00		
2010	Uranium	All	85.00		
2015	Uranium	All	85.00		
2025	Uranium	All	89.00		
2045	Uranium	All	89.00		
1995	Water	All	74.50		
2000	Water	All	51.00		
2005	Water	All	51.00		
2010	Water	All	39.00		
2015	Water	All	39.00		
2025	Water	All	39.00		
2045	Water	All	39.00		
1995	Other	All	57.10		
2000	Other	All	57.10		
2005	Other	All	57.10		
2010	Other	All	57.10		
2015	Other	All	57.10		
2025	Other	All	57.10		
2045	Other	All	57.10		

Each plant's share of the new generation demands is based on its available capacity, computed as the difference between its level of generation in the previous period and its maximum sustainable generation. If, for example, the adjusted marginal demands for a demand region are equal to 9 percent of the sum of the available capacities of all of its plants, then each plant's share of the new generation is equal to 9 percent of its available capacity. Plants that are already operating at a level that is close to capacity will have very little remaining capacity and thus will receive very little of the new generation, as compared with plants that are not operating at levels close to capacity.

As already noted, the ORD Navigation Planning Center conducted extensive surveys of the utilities that use the Ohio River Navigation System. When the utilities provided projections of electric generation for particular plants, those data appear in the output file. The methodology described above was then used to distribute remaining generation demands among the unsurveyed plants.

When future demands exceed capacity, the PGENXX.PRG programs abort their execution and notify the analyst of the shortfall in capacity. At that point, OUTPY98.DBF is modified by the analyst, with sufficient generating units added to meet current and projected future shortfalls. Given the uncertainty about the geographic distribution of future capacity additions, new generating units are added such that the proportion of coal to non-coal plants is unchanged, with new units added to each coal-fired plant in proportion to the current capacity of that plant. Thus, if coal accounts for 60 percent of the generation within a demand region before capacity additions, it will account for 60 percent of the generation after capacity additions. Similarly, if an individual coal-fired plant accounted for 8 percent of a demand region's total generating capacity before capacity additions, it will account for 8 percent of the generation after capacity additions. The completion of this module is an iterative process involving the identification of capacity shortfalls, the addition of capacity, and rerunning of the PGENXX.PRG program which identified the capacity shortfall.

In 2005, for example, PGEN05.PRG stopped, noting that energy demands exceed the capacity of Soyland Power Cooperative by 51,700 mwh. Looking at COMDEM98.DBF, it was determined that another 363,000 mwh will be needed through 2045, for a total of 414,700 mwh. In 2005, 89 percent of Soyland's power was generated in coal-fired plants. Capacity additions allowing an added 415,000 mwh of generation were distributed so that 89 percent (370,000) was coal-fired capacity. A total of about 53 MW of capacity were added.

The output from the power generation module [OUTPY98.DBF] was filtered to show only coal-fired power plants. These 514 records were copied to SUMPLTSC.DBF, which was modified by the analyst to include blank fields into which coal burns will be written in the Coal Consumption Module.

4.3 Summary of Output. Output from OUTPY98.DBF was summed by demand region and is displayed in Table 6 below.

Table 6
Projected Electric Power Generation by Demand Region

Demand Region	Electric Generation					
	2000	2005	2010	2015	2025	2045
Central Illinois Light Co.	6,251	6,826	7,467	8,100	9,364	12,719
Central Illinois Public Service Co.	12,077	12,737	13,914	15,090	17,474	23,986
Commonwealth Edison Co.	100,573	108,082	113,763	119,215	129,679	155,308
Dairyland Power Coop	4,073	4,351	4,686	5,014	5,641	7,218
ECAR	547,082	594,412	641,037	688,073	784,938	1,030,419
Southern Illinois Power Coop	1,125	1,247	1,364	1,482	1,717	2,347
Union Electric Co.	37,572	41,690	46,147	50,580	58,943	78,986
Wisconsin Power & Light Co.	11,221	12,675	13,825	14,953	17,099	22,285
Soyland Power Coop, Inc.	138	216	266	312	398	598
Illinois Power/Soyland Power Pool	20,587	20,470	20,724	20,958	21,384	22,322
MAAC	213,766	232,774	251,696	270,239	306,642	395,404
SERC, FL	150,057	173,437	196,432	219,137	264,441	362,105
SERC, STHRN	192,208	213,702	244,812	275,905	331,068	459,979
SERC, VACAR	263,902	295,382	330,381	365,433	435,234	604,036
SERC, TVA	161,930	182,360	203,681	224,524	259,820	336,514
Wisconsin Electric Power Co.	27,977	32,572	36,900	41,091	49,137	68,329
Wisconsin Public Service Corp.	9,854	10,147	10,550	10,929	11,538	12,717

Section 5: Coal Consumption Module

5.1 Structure. The Coal Consumption Module projects coal consumption at the plant level based on the projected electric power generation of each plant and plant-specific burn-to-generation ratios. The dBase IV program COALBURN.PRG [shown in Exhibit C] uses BGRAT.DBF as input, and reads and updates SUMPLTSC.DBF, from which PLTBURN.DBF is later extracted. A flow chart for this module is shown in Figure 5 and the input and output files are described in Table 7.

SUMPLTSC.DBF, developed in the Electric Generation Module, is read and modified in this module. It contains blank fields into which projections of coal consumption, generated by the program COALBURN.PRG, are written. Projected coal consumption is based on projected electric power generation, also contained in SUMPLTSC.DBF, and the plant-specific burn-to-generation ratios contained in BGRAT.DBF. Finally, coal burns were summed at the plant level and written to the output file [PLTBURN.DBF].

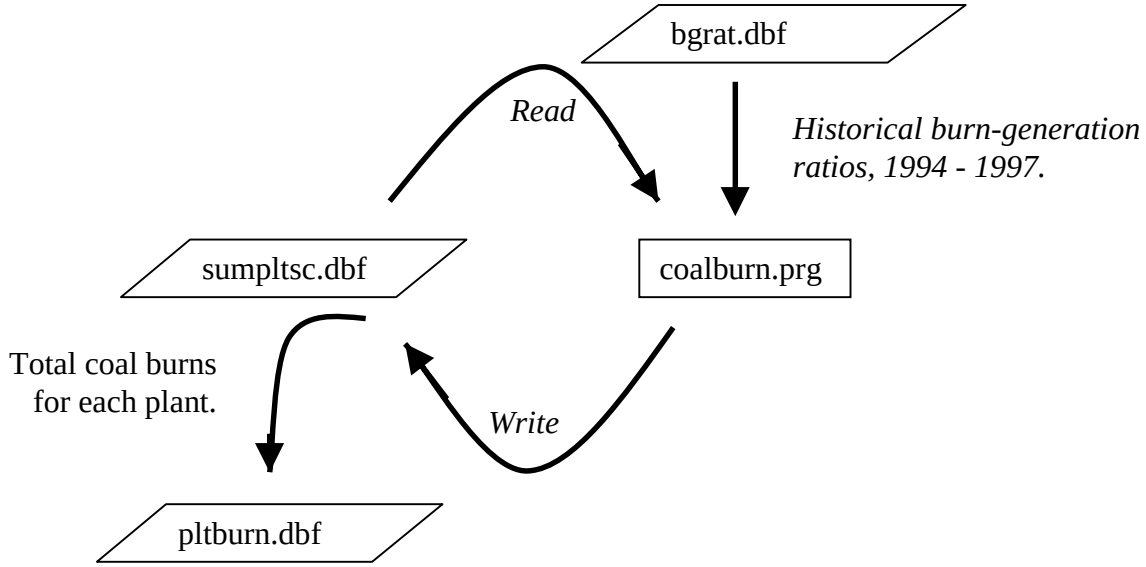


Figure 5 – ORNS Coal Transportation Projection Model, Coal Consumption Module.

Table 7
COALBURN.PRG Input & Output Files

Filenames	Input/ Output	Description
SUMPLTSC.DBF	Input/ Output	List of power plants, with historical generation and maximum long-term generation capacity.
BGRAT.DBF	Input	Extrapolations of demand forecasts from DPROJ98.DBF to 2045.
PLTBURN.DBF	Output	Coal burns from SUMPLTSC.DBF, summed at the plant level.

5.2 Methods and Assumptions. Three data fields containing burn-to-generation ratios were created. The first [bgrath] is based on historical burns and generation from 1994-1997, as reported in the Powerdat database. For plants that were operational during this period, total burns for the period were divided by total generation to compute the burn-to-generation ratio. For new plants, the 95th percentile efficiency level [0.38 tons per mwh] was used.

The other two fields [bgrat00 and bgrat05] contain burn-to-generation ratios based on the surveys conducted by the Navigation Center in 1998. Estimates of future burns and generation levels from the survey response were used to compute burn-to-generation ratios as described above.

The program COALBURN.PRG was used to estimate future coal burns at coal-fired plants using the burn-to-generation ratios described above. For the years 2000 and 2005, ratios from the survey responses were used for all plants for which they existed. For all other plants, burn-to-generation ratios derived from the Powerdat database were used. The ratios used in 2005 were used to estimate coal burns for all years beyond 2005.

5.3 Summary of Output. A listing of data from the file SUMPLTSC.DBF is shown in Table 8 below. This table shows projections of electric generation at coal-fired plants, developed as described in Section 4 above, and projections of coal consumption at each coal-fired plant. As noted in Section 4, when demands for electricity exceed capacity, new plants were added in proportion to the coal/noncoal split at the future year during which the shortfall occurred. New coal plants are designated in Table 8 by a "Y" in the footnoted column.

Table 8
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Albright	1,305	1,410	1,483	1,554	1,731	2,180		576	623	655	686	764	962
Amos	18,700	21,200	21,200	21,200	21,200	21,200		7,200	8,300	8,300	8,300	8,300	8,300
Armstrong	2,063	2,063	2,063	2,084	2,175	2,406		844	844	844	853	890	984
Ashtabula	569	1,428	1,676	1,916	2,439	3,763		225	561	658	753	958	1,478
Avon Lake	3,268	3,525	4,343	5,139	6,838	11,145		1,250	1,336	1,646	1,948	2,592	4,224
Bailly	2,926	3,151	3,308	3,459	3,842	4,812		1,401	1,510	1,584	1,657	1,840	2,305
Bay Shore	2,076	2,560	2,840	3,112	3,725	5,279		783	953	1,057	1,159	1,387	1,965
Beckjord	6,833	7,608	7,692	7,773	8,118	8,991		2,676	2,965	2,997	3,029	3,163	3,504
Belle River	8,978	9,038	9,079	9,119	9,413	10,159		4,939	4,972	4,994	5,016	5,178	5,588
Big Sandy	7,850	7,240	7,341	7,438	7,623	8,090		3,100	2,900	2,941	2,980	3,054	3,241
Brown (IN)	2,430	3,322	3,938	4,537	5,833	9,116		1,131	1,547	1,834	2,113	2,716	4,245
Brown (KY)	2,374	2,865	3,205	3,535	4,272	6,142		1,035	1,249	1,398	1,541	1,863	2,679
Burger	1,778	2,192	2,413	2,629	3,118	4,357		764	929	1,023	1,114	1,321	1,847
Campbell	7,299	8,740	9,864	10,957	13,016	18,236		2,991	3,581	4,041	4,489	5,333	7,471
Cane Run	2,541	1,870	2,516	3,145	4,465	7,811		1,449	950	1,278	1,597	2,268	3,968
Cardinal	9,426	10,780	11,175	11,560	12,284	14,120		3,820	4,325	4,484	4,638	4,928	5,665
Cayuga	7,119	7,493	7,493	7,493	7,493	7,493		3,195	4,434	4,434	4,434	4,434	4,434
Cheswick	2,890	2,888	3,032	3,172	3,525	4,418		1,194	1,191	1,250	1,308	1,454	1,822
Clifty Creek	10,200	10,100	10,116	10,133	10,163	10,239		5,530	5,400	5,409	5,418	5,434	5,475
Clinch River	5,400	4,942	5,018	5,091	5,229	5,580		2,050	1,860	1,889	1,916	1,968	2,100
Cobb	1,983	2,255	2,444	2,627	3,053	4,131		974	1,108	1,201	1,291	1,500	2,030
Coleman	2,900	2,900	2,949	2,996	3,161	3,578		1,300	1,300	1,322	1,343	1,417	1,604
Conesville	8,380	9,754	10,659	11,539	13,196	17,397		3,750	4,300	4,698	5,086	5,817	7,669
Cooper	1,746	1,821	1,873	1,924	2,069	2,438		719	750	771	792	852	1,004
Crawfordsville	11	56	88	119	182	343		9	46	72	97	150	282

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Culley	2,111	2,236	2,323	2,407	2,631	3,199		1,031	1,092	1,135	1,176	1,285	1,563
Dale	748	830	886	941	1,072	1,404		366	406	434	460	524	687
Dover	66	118	155	190	265	455		46	83	108	133	186	318
East Bend	4,649	5,020	6,512	7,962	10,695	17,621		1,815	1,988	2,579	3,153	4,235	6,978
Eastlake	5,964	7,116	7,323	7,523	8,099	9,557		2,225	2,681	2,759	2,835	3,052	3,601
Eckert	593	959	1,213	1,459	1,982	3,308		283	459	580	698	948	1,582
Edwardsport	345	257	-	-	-	-		192	146	-	-	-	-
Elrama	2,310	2,325	2,502	2,674	3,078	4,101		1,034	1,059	1,140	1,218	1,402	1,868
Endicott	143	186	216	245	308	467		82	107	124	141	177	268
Erickson	1,042	1,258	1,407	1,552	1,876	2,697		408	493	551	608	735	1,057
Fort Martin	5,680	6,063	6,328	6,585	7,251	8,939		2,117	2,260	2,358	2,454	2,703	3,332
Gallagher	2,703	2,392	2,656	2,913	3,491	4,957		1,105	980	1,088	1,194	1,430	2,031
Gavin	17,500	18,500	18,500	18,500	18,500	18,500		7,501	7,500	7,500	7,500	7,500	7,500
Ghent	11,785	12,369	12,902	13,420	14,396	16,869		4,911	5,154	5,376	5,592	5,999	7,029
Gibson	24,102	22,824	23,035	23,240	23,626	24,604		10,718	10,152	10,246	10,337	10,509	10,944
Glen Lyn	1,200	1,240	1,481	1,715	2,219	3,498		500	525	627	726	940	1,481
Green	3,300	3,300	3,300	3,300	3,342	3,448		1,600	1,600	1,600	1,600	1,620	1,672
Green River	737	933	1,069	1,200	1,490	2,224		373	472	540	607	753	1,125
Harbor Beach	176	297	381	463	635	1,072		86	146	187	227	312	527
Harrison	13,543	13,566	13,700	13,831	14,077	14,700		5,309	5,318	5,370	5,422	5,518	5,763
Hatfield Power Station	8,588	9,150	9,638	10,112	11,006	13,273		3,290	3,505	3,692	3,874	4,217	5,085
Henderson Station II	2,200	2,200	2,227	2,253	2,357	2,622		990	990	1,002	1,014	1,061	1,180
Henderson-Ky	48	107	149	189	273	487		32	73	101	129	186	331
Hutchings	530	672	1,016	1,350	2,044	3,804		255	324	490	651	986	1,834
James De Young	249	302	339	374	454	656		122	148	166	184	223	322

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Jasper 2	54	62	68	73	86	118		39	45	49	53	63	86
Kammer	3,200	3,380	3,605	3,823	4,347	5,674		1,200	1,300	1,386	1,470	1,672	2,182
Kanawha River	2,840	2,630	2,679	2,726	2,884	3,285		1,160	1,075	1,095	1,114	1,179	1,342
Karn	3,634	3,634	3,634	3,634	3,670	3,761		1,547	1,547	1,547	1,547	1,562	1,601
Killen	4,711	4,332	5,075	5,797	7,366	11,343		1,945	1,758	2,059	2,352	2,989	4,603
Kyger Creek	8,060	7,975	7,989	8,003	8,028	8,093		3,000	3,000	3,005	3,011	3,020	3,045
Logansport	149	175	194	211	252	354		90	107	118	128	153	215
Mansfield	17,750	18,160	18,333	18,502	18,819	19,623		7,180	7,340	7,410	7,478	7,607	7,932
Marysville	39	424	690	948	1,484	2,841		24	258	420	578	904	1,730
Merom	4,853	5,303	5,614	5,917	6,656	8,530		2,331	2,547	2,697	2,842	3,197	4,097
Miami Fort	5,902	7,718	8,188	8,645	9,506	11,687		2,388	3,189	3,383	3,572	3,928	4,829
Michigan City	2,765	2,930	3,044	3,155	3,449	4,195		1,547	1,640	1,704	1,766	1,930	2,348
Mill Creek	9,389	8,082	8,734	9,367	10,561	13,587		4,053	3,615	3,907	4,190	4,724	6,077
Mitchell (IN)	1,771	1,932	2,043	2,151	2,416	3,086		1,053	1,148	1,214	1,278	1,435	1,834
Mitchell (PA)	1,766	1,810	1,840	1,869	1,971	2,229		704	721	733	745	786	889
Mitchell (WV)	9,220	9,310	9,661	10,003	10,647	12,278		3,600	3,650	3,788	3,922	4,175	4,814
Monroe	19,957	20,318	20,758	21,185	21,990	24,030		8,881	9,042	9,237	9,427	9,786	10,694
Mountaineer	7,960	10,500	10,500	10,500	10,500	10,500		3,000	4,001	4,001	4,001	4,001	4,001
Muskingum River	6,900	7,100	7,697	8,277	9,370	12,141		2,700	2,825	3,063	3,293	3,728	4,831
New Castle	1,697	2,257	2,351	2,443	2,683	3,291		762	1,011	1,053	1,094	1,202	1,474
Niles	1,165	1,397	1,458	1,518	1,672	2,062		523	614	641	667	735	906
Noblesville	156	178	258	337	500	913		88	102	148	193	286	523
Orrville	299	355	394	431	516	730		187	222	247	270	323	457
Painesville	153	232	286	339	453	739		99	150	185	219	292	477
Peru	5	55	89	122	192	367		4	39	64	87	137	262

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Petersburg	10,514	10,891	11,259	11,618	12,293	14,004		4,916	5,092	5,264	5,431	5,747	6,547
Picway	280	306	443	576	854	1,558		140	150	217	282	419	764
Pineville	85	116	138	160	206	323		46	64	76	88	113	177
Piqua	26	95	143	189	286	531		36	133	199	264	398	739
Sammis	15,133	16,786	16,856	16,924	17,051	17,375		6,152	6,793	6,822	6,849	6,901	7,032
Schahfer	7,492	8,541	9,378	10,193	11,727	15,615		4,241	4,835	5,309	5,770	6,639	8,839
Shelby	88	119	141	162	207	322		59	79	94	108	138	215
Sims	386	421	445	468	525	670		200	218	230	242	272	347
Smith (KY)	2,218	2,324	2,397	2,469	2,669	3,175		1,021	1,070	1,104	1,137	1,229	1,462
Smith (MD)	191	358	474	587	825	1,427		88	165	218	270	379	656
Sporn	6,850	6,130	6,333	6,530	7,075	8,456		2,700	2,500	2,583	2,663	2,885	3,449
Spurlock	5,585	5,585	5,585	5,585	5,637	5,769		2,253	2,253	2,253	2,253	2,274	2,327
St. Clair	7,234	7,824	8,322	8,806	9,718	12,029		3,999	4,326	4,601	4,869	5,373	6,651
St. Marys	32	50	62	73	99	162		20	31	38	46	61	101
Stout	2,784	3,143	3,391	3,632	4,196	5,626		1,296	1,463	1,579	1,691	1,954	2,619
Stuart	16,557	16,809	16,858	16,905	16,995	17,221		6,889	6,697	6,716	6,735	6,771	6,861
Tanners Creek	6,030	6,450	6,594	6,734	7,171	8,277		2,500	2,700	2,760	2,819	3,002	3,465
Traverse (Bayside)	2	29	48	66	104	200		1	23	37	51	81	156
Trenton Channel	3,725	4,410	4,883	5,343	6,382	9,014		1,863	2,205	2,442	2,672	3,192	4,508
Trimble County	3,630	3,237	5,545	7,790	12,019	22,737		1,900	1,560	2,672	3,754	5,792	10,957
Tyrone	130	201	250	298	400	658		67	104	130	154	207	341
W.H. Zimmer	10,517	8,660	8,966	9,264	9,825	11,246		4,134	3,373	3,492	3,608	3,827	4,380
Wabash River	3,330	3,786	4,230	4,661	5,626	8,072		1,493	1,710	1,910	2,105	2,541	3,646
Warrick	1,057	1,268	1,413	1,555	1,872	2,676		486	583	649	714	860	1,230
Weadock	1,978	1,998	2,012	2,025	2,099	2,286		891	900	906	912	945	1,029

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Whitewater	575	589	599	609	642	727		296	303	308	313	330	374
Whiting	2,005	2,035	2,056	2,077	2,167	2,394		829	841	850	858	896	990
Willow Island	750	879	968	1,055	1,251	1,750		325	381	419	457	542	758
Wilson	3,000	3,000	3,471	3,930	4,931	7,470		1,380	1,380	1,597	1,808	2,268	3,436
Wyandotte	177	235	274	313	397	610		105	139	163	186	236	362
Hamilton	223	320	387	452	592	946		117	167	202	236	309	494
Lake Shore	296	556	745	929	1,316	2,297		187	348	467	582	824	1,438
Perry W	(0)	15	25	35	56	108		-	-	-	-	-	-
Perry	10	69	110	149	231	440		4	26	42	57	88	167
Baldwin	9,771	9,514	9,572	9,625	9,717	9,920		4,560	4,440	4,467	4,492	4,535	4,630
Coffeen	3,435	3,621	3,935	4,248	4,931	6,795		1,753	1,848	2,008	2,168	2,517	3,468
Columbia (WI)	7,006	7,006	7,006	7,006	7,044	7,137		4,266	4,266	4,266	4,266	4,289	4,346
Crawford	1,766	1,980	2,140	2,294	2,588	3,310		1,133	1,270	1,372	1,471	1,660	2,123
Dewey	1,140	1,162	1,180	1,197	1,245	1,361		639	651	661	671	697	762
Duck Creek	2,714	3,177	3,700	4,217	5,226	7,902		1,291	1,512	1,761	2,007	2,487	3,761
Edwards	3,513	3,587	3,666	3,743	3,923	4,401		1,509	1,541	1,575	1,608	1,686	1,891
Fisk	402	731	977	1,214	1,649	2,715		234	426	570	708	962	1,584
Grand Tower	430	481	568	654	835	1,330		210	235	277	319	408	650
Havana	1,346	1,161	1,193	1,223	1,279	1,402		655	565	581	595	622	682
Hennepin	1,619	1,451	1,461	1,470	1,488	1,528		770	690	695	699	707	727
Hutsonville	373	408	469	529	656	1,004		179	196	225	254	315	483
Joliet	4,875	5,253	5,536	5,808	6,343	7,656		2,824	3,043	3,207	3,365	3,675	4,436
Joliet 9	1,243	1,424	1,559	1,689	1,936	2,541		712	815	892	966	1,108	1,454
Kincaid	2,671	3,261	3,703	4,128	4,925	6,876		1,373	1,677	1,904	2,123	2,532	3,536
Labadie	13,448	13,894	14,569	15,241	16,296	18,824		7,459	7,707	8,082	8,454	9,039	10,442

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Meredosia	1,191	1,258	1,371	1,483	1,727	2,394		577	610	664	719	837	1,160
Newton	6,645	6,963	7,565	8,167	9,311	12,437		3,136	3,286	3,570	3,854	4,394	5,869
Pearl	124	126	127	128	130	137		75	76	77	77	79	82
Powerton	5,340	6,179	6,866	7,525	8,650	11,407		3,481	4,028	4,476	4,905	5,639	7,436
Rock River	807	829	847	864	908	1,014		477	491	501	511	537	600
Rush Island	6,290	6,649	7,032	7,414	8,318	10,486		3,565	3,769	3,986	4,202	4,715	5,943
Sioux	3,887	4,510	5,175	5,837	7,147	10,287		2,190	2,541	2,916	3,289	4,027	5,796
Waukegan	2,940	3,256	3,492	3,719	4,158	5,232		1,716	1,900	2,038	2,171	2,427	3,054
Will County	4,462	4,847	5,136	5,412	5,954	7,281		2,630	2,857	3,027	3,190	3,509	4,291
Wood River	1,938	1,794	1,818	1,840	1,882	1,975		875	810	821	831	850	892
Marion	1,125	1,247	1,364	1,482	1,717	2,347		647	717	784	852	987	1,349
Vermilion	593	548	659	761	937	1,325		330	305	367	423	521	737
Brandon Shores	9,091	9,095	9,100	9,103	9,273	9,687		3,587	3,589	3,591	3,592	3,659	3,822
Brunner Island	8,155	8,424	8,856	9,189	9,779	11,219		3,140	3,243	3,410	3,538	3,765	4,319
Conemaugh	11,841	11,917	12,125	12,284	12,569	13,261		4,519	4,547	4,627	4,688	4,796	5,060
Crane	1,732	1,845	1,986	2,095	2,336	2,923		670	713	768	810	903	1,130
Dickerson	3,790	4,128	4,552	4,877	5,574	7,272		1,395	1,520	1,675	1,795	2,052	2,677
England	1,781	1,806	1,838	1,863	1,943	2,137		766	777	790	801	835	919
Homer City	12,043	12,207	12,534	12,786	13,233	14,324		4,680	4,744	4,871	4,969	5,142	5,566
Hunlock Creek	350	367	388	403	440	530		237	248	261	272	297	358
Indian River	3,293	3,526	3,817	4,041	4,532	5,729		1,426	1,526	1,652	1,749	1,962	2,480
Keystone	11,696	11,789	12,019	12,196	12,510	13,276		4,550	4,586	4,675	4,744	4,866	5,164
Montour	9,221	9,415	9,755	10,017	10,483	11,617		3,616	3,692	3,825	3,928	4,110	4,555
Morgantown	6,721	6,916	7,162	7,350	7,835	9,016		2,405	2,475	2,562	2,630	2,803	3,226
Portland	1,513	1,674	1,876	2,031	2,357	3,154		606	670	751	813	944	1,263

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Potomac River	2,122	2,280	2,477	2,629	2,960	3,768		891	958	1,041	1,104	1,244	1,583
Seward	1,753	2,272	2,921	3,420	4,415	6,842		811	1,050	1,351	1,581	2,042	3,164
Shawville	3,780	3,832	3,897	3,947	4,111	4,511		1,588	1,610	1,638	1,659	1,727	1,896
Titus	1,073	1,124	1,189	1,239	1,354	1,634		446	468	495	515	563	680
Warren	348	400	464	514	616	864		207	238	276	305	366	514
Chalk Point	3,915	4,028	4,169	4,278	4,559	5,242		1,457	1,500	1,552	1,593	1,697	1,952
Hudson	2,155	2,426	2,766	3,027	3,571	4,895		905	1,019	1,162	1,272	1,500	2,056
Mercer	2,340	2,584	2,888	3,123	3,617	4,822		869	959	1,072	1,159	1,343	1,790
H.M. Down	81	94	111	124	151	217		45	52	62	69	84	121
Martins Creek	1,812	1,844	1,885	1,916	2,010	2,237		802	817	835	849	890	991
Wagner	3,002	3,038	3,083	3,117	3,237	3,529		1,130	1,144	1,161	1,173	1,219	1,329
Eddystone	2,266	2,562	2,933	3,218	3,810	5,252		989	1,119	1,281	1,405	1,663	2,293
Holtwood	519	541	568	589	639	761		380	396	416	431	468	557
Sunbury	2,351	2,397	2,454	2,498	2,625	2,935		1,387	1,414	1,448	1,474	1,549	1,732
Allen (NC)	4,091	4,673	5,302	5,919	7,240	10,436		1,645	1,879	2,132	2,381	2,912	4,197
Allen (TN)	5,230	5,790	5,898	6,013	6,283	6,873		2,180	2,310	2,353	2,399	2,507	2,742
Arkwright	-	-	-	-	-	-		-	-	-	-	-	-
Asheville	2,609	2,633	2,658	2,683	2,814	3,131		1,007	1,016	1,026	1,036	1,086	1,209
Barry	12,082	11,451	12,227	12,275	12,360	12,477		4,668	4,432	4,732	4,750	4,783	4,829
Belews Creek	12,566	12,860	13,335	13,801	14,613	16,578		4,603	4,710	4,884	5,055	5,353	6,072
Bowen	22,557	21,484	23,940	24,090	-	-		8,818	8,521	9,494	9,554	-	-
Bremo Bluff	1,357	1,411	1,470	1,528	1,682	2,056		577	600	625	649	715	874
Buck	777	1,050	1,344	1,634	2,216	3,626		342	462	592	719	975	1,596
Bull Run	6,590	6,450	6,469	6,489	6,538	6,646		2,420	2,290	2,296	2,304	2,321	2,359
Cape Fear	1,713	1,857	2,012	2,165	2,514	3,359		685	742	804	865	1,005	1,342

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Chesapeake Energy Center	3,313	3,477	3,653	3,827	4,268	5,334		1,280	1,344	1,412	1,479	1,650	2,061
Chesterfield	7,505	7,822	8,165	8,502	9,391	11,540		2,884	3,006	3,138	3,267	3,609	4,435
Cliffside	2,873	3,249	3,656	4,055	4,916	6,999		1,134	1,283	1,443	1,601	1,941	2,763
Clover	2,032	2,617	3,248	3,868	5,129	8,177		804	1,036	1,285	1,531	2,029	3,236
Colbert	8,480	8,620	8,670	8,723	8,938	9,413		3,260	3,240	3,259	3,279	3,360	3,538
Crist	5,448	4,584	6,991	7,138	-	-		2,408	1,982	3,023	3,087	-	-
Cross	8,548	9,601	10,904	12,183	14,410	19,798		3,257	3,658	4,154	4,642	5,490	7,543
Cumberland	19,460	19,520	19,534	19,549	19,571	19,625		7,751	8,021	8,027	8,033	8,042	8,064
Dan River	640	849	1,074	1,296	1,743	2,825		289	383	485	584	786	1,274
Gadsden	373	256	792	825	915	1,038		200	138	427	445	493	560
Gallatin	6,870	7,370	7,503	7,645	7,981	8,715		2,980	3,380	3,441	3,506	3,660	3,997
Gaston	11,029	9,964	13,316	13,521	13,892	14,397		4,195	4,031	5,388	5,471	5,621	5,825
Gorgas	6,785	5,931	8,161	8,297	8,833	9,565		2,690	2,336	3,215	3,268	3,480	3,768
Grainger	442	547	659	770	997	1,546		187	231	278	325	421	652
Greene County	3,990	3,518	3,900	3,923	3,966	4,023		1,598	1,411	1,564	1,574	1,591	1,614
Hammond	4,255	4,063	5,910	6,023	-	-		1,809	1,733	2,520	2,569	-	-
Harlee Branch	8,956	9,004	11,621	11,781	-	-		3,423	3,614	4,665	4,729	-	-
Jefferies	1,601	1,714	1,836	1,956	2,239	2,923		658	705	755	804	921	1,202
John Sevier	5,130	5,350	5,350	5,350	5,425	5,592		1,970	1,910	1,910	1,910	1,937	1,996
Johnsonville	7,250	7,740	8,029	8,339	8,943	10,257		3,410	3,320	3,444	3,577	3,836	4,399
Kingston	9,610	10,440	10,638	10,829	11,146	11,841		3,760	4,090	4,168	4,243	4,367	4,639
Lee (NC)	1,190	1,431	1,691	1,946	2,477	3,761		497	597	706	813	1,034	1,570
Lee (SC)	840	1,087	1,353	1,614	2,145	3,428		357	461	574	685	910	1,454
Lowman (Tombigbee)	2,905	3,371	3,375	3,375	3,488	3,642		1,257	1,458	1,460	1,460	1,509	1,576
Marshall (NC)	12,744	12,832	13,073	13,310	13,722	14,718		4,639	4,671	4,759	4,845	4,995	5,357

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Mayo	5,053	5,820	6,649	7,464	9,195	13,381		2,127	2,450	2,799	3,141	3,870	5,632
McDonough	3,699	3,572	-	-	-	-		1,503	1,461	-	-	-	-
McIntosh (GA)	408	2,329	2,344	2,345	2,425	2,534		189	1,078	1,085	1,085	1,122	1,173
McMeekin	1,556	1,621	1,690	1,759	1,941	2,381		577	601	627	652	720	883
Miller	21,258	21,460	21,460	21,460	21,460	21,460		12,289	12,430	12,430	12,430	12,430	12,430
Mitchell (GA)	636	395	1,252	1,304	-	-		301	197	624	650	-	-
Morrow	1,824	2,655	2,662	2,662	2,751	2,874		788	1,147	1,150	1,150	1,189	1,241
Mount Storm	11,252	11,252	11,335	11,417	11,559	11,903		4,543	4,543	4,577	4,610	4,667	4,806
Paradise	15,700	17,760	17,783	17,804	17,840	17,922		6,680	6,910	6,919	6,928	6,942	6,973
Riverbend	1,353	1,754	2,188	2,614	3,478	5,568		568	737	919	1,098	1,461	2,339
Robinson	851	936	1,028	1,118	1,318	1,804		346	380	418	454	536	733
Roxboro	13,768	14,296	15,053	15,797	17,091	20,223		5,502	5,713	6,015	6,312	6,830	8,081
Scherer	19,246	18,569	23,755	24,072	24,645	25,427		9,763	8,833	11,300	11,451	11,724	12,096
Scholz	327	196	565	-	-	-		160	103	297	-	-	-
Shawnee	9,710	10,250	10,521	10,782	11,215	12,161		4,420	4,730	4,856	4,976	5,176	5,612
Smith (FL)	2,451	1,491	2,326	2,377	-	-		815	656	1,023	1,046	-	-
Sutton	2,181	2,552	2,952	3,345	4,172	6,173		926	1,084	1,254	1,420	1,772	2,622
Victor J. Daniel	5,582	5,515	6,440	-	-	-		3,094	3,097	3,617	-	-	-
Wansley	11,507	11,820	13,053	13,128	13,265	-		4,408	4,561	5,037	5,066	5,119	-
Wateree	4,194	4,347	4,512	4,674	5,120	6,200		1,617	1,676	1,739	1,802	1,974	2,390
Watts Bar	(2,800)	(2,800)	(2,208)	(1,574)	(623)	1,636		-	-	-	-	-	-
Weatherspoon	409	521	642	761	1,003	1,589		192	245	302	358	472	747
Widows Creek	10,320	11,430	11,749	12,056	12,564	13,675		4,570	4,890	5,026	5,157	5,375	5,850
Williams-ST	3,248	3,404	3,573	3,738	4,161	5,183		1,213	1,271	1,334	1,396	1,554	1,935
Winyah	4,947	5,504	6,105	6,696	7,992	11,127		1,990	2,214	2,456	2,693	3,214	4,475

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Meramec	2,080	2,818	3,605	4,389	5,847	9,341		1,054	1,428	1,827	2,224	2,963	4,734
Oak Creek South	6,004	6,607	7,175	7,784	7,944	8,365		2,405	2,647	2,874	3,118	3,182	3,351
Pleasant Prairie	7,942	8,026	8,105	8,189	8,317	8,690		5,037	5,090	5,140	5,193	5,275	5,511
Port Washington	1,383	1,825	2,241	2,688	2,760	3,108		756	997	1,225	1,469	1,508	1,699
Presque Isle	3,302	3,570	3,822	4,092	4,173	4,352		1,790	1,935	2,072	2,218	2,262	2,359
Valley	1,102	1,324	1,532	1,756	1,799	1,968		611	734	850	974	998	1,092
Columbia (WI)	2,228	2,228	2,228	2,228	2,231	2,237		1,357	1,357	1,357	1,357	1,359	1,362
Future Generating Plant	975	1,121	1,295	1,459	1,720	2,226		560	644	744	838	988	1,278
Future Generating Plant	1,787	1,809	1,835	1,860	1,905	1,992		1,133	1,147	1,164	1,180	1,208	1,264
Future Generating Plant	2,824	2,831	2,839	2,847	2,868	2,909		1,739	1,744	1,749	1,754	1,767	1,792
Cumberland	266	468	721	915	1,296	2,223		-	-	-	-	-	-
Future Generating Plant	100	155	215	273	376	622		38	59	82	104	143	237
Powerton	35	87	126	164	228	384		23	57	82	107	149	251
Future Generating Plant	260	404	559	712	978	1,620		99	153	213	271	371	616
AES Warrior Run Inc.	(3)	241	409	573	881	1,662		(1)	92	155	218	335	632
Conners Creek	(3)	300	510	714	1,134	2,201		-	-	-	-	-	-
Nanticoke	323	538	809	1,017	1,386	2,287		-	-	-	-	-	-
NA 10	-	-	-	689	1,973	5,079		-	-	-	262	750	1,930
Under Evaluation	-	646	1,344	2,029	3,351	6,546		-	246	511	771	1,273	2,488
Polk	1,589	1,575	1,667	1,765	1,937	2,346		566	566	599	634	696	843
Reid	127	127	259	386	628	1,238		71	71	145	216	351	692
Phillips	-	-	-	672	1,938	5,146	Y	-	-	-	255	736	1,956
East Bend	-	-	-	672	1,938	5,146	Y	-	-	-	255	736	1,956

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Pearl	-	68	111	151	225	396	Y	-	26	42	57	85	151
Yates	4,879	4,340	8,842	-	-	-		2,088	1,937	3,946	-	-	-
Canadys	2,334	2,484	2,645	2,804	3,185	4,106		952	1,013	1,079	1,144	1,299	1,674
Crisp	(10)	82	83	83	86	90		(4)	31	32	32	33	34
Plant Kraft (Port Wentwo	311	1,374	1,382	1,383	1,430	1,494		146	646	650	650	672	702
Urquhart	1,425	1,464	1,506	1,547	1,671	1,973		585	601	618	634	686	809
Possum Point	2,482	2,482	2,482	2,482	2,482	2,482		976	976	976	976	976	976
Yorktown	3,588	4,361	5,197	6,017	7,713	11,815		1,391	1,691	2,015	2,333	2,991	4,582
Crystal River	14,768	15,627	15,810	16,005	16,348	17,161		5,619	5,946	6,016	6,090	6,220	6,530
Deerhaven	1,595	1,638	1,642	1,646	1,680	1,761		657	675	676	678	692	726
St. Johns River Power	9,191	9,191	9,191	9,191	9,291	-		3,536	3,536	3,536	3,536	3,574	-
McIntosh-Fl	2,664	2,664	2,664	2,664	2,664	2,664		1,056	1,056	1,056	1,056	1,056	1,056
Stanton Energy Center	4,162	5,325	5,431	5,543	5,841	6,548		1,635	2,092	2,134	2,178	2,295	2,573
Seminole	9,159	9,309	9,309	9,309	9,309	9,309		3,756	3,890	3,890	3,890	3,890	3,890
Big Bend	10,922	11,345	11,520	11,706	12,034	12,812		4,901	5,085	5,163	5,246	5,394	5,742
Gannon	5,356	5,810	6,160	6,532	7,331	9,221		2,761	2,998	3,179	3,371	3,783	4,758
Alma	573	760	985	1,206	1,615	2,645		321	426	552	676	905	1,482
Genoa	1,807	1,835	1,868	1,901	1,973	2,152		834	847	862	878	911	993
J.P. Madgett	1,593	1,640	1,696	1,750	1,861	2,138		1,066	1,097	1,134	1,171	1,245	1,430
Jack Watson	5,154	4,674	5,062	5,086	5,194	-		2,273	2,071	2,243	2,254	2,301	-
Colbert	-	594	1,369	2,116	3,354	6,030	Y	-	226	520	804	1,275	2,292
Widows Creek	-	866	1,997	3,086	4,892	8,795	Y	-	329	759	1,173	1,859	3,342
Paradise	-	1,173	2,706	4,182	6,628	11,916	Y	-	446	1,028	1,589	2,519	4,528
Shawnee	-	769	1,775	2,743	4,348	7,817	Y	-	292	675	1,042	1,652	2,971

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						\2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Allen (TN)	-	435	1,004	1,552	2,460	4,422	Y	-	165	382	590	935	1,680
Bull Run	-	435	1,004	1,552	2,459	4,422	Y	-	165	382	590	935	1,680
Cumberland	-	1,296	2,990	4,621	7,324	13,167	Y	-	492	1,136	1,756	2,783	5,003
Gallatin	-	552	1,273	1,968	3,119	5,607	Y	-	210	484	748	1,185	2,131
John Sevier	-	353	815	1,260	1,997	3,590	Y	-	134	310	479	759	1,364
Johnsonville	-	653	1,507	2,328	3,690	6,634	Y	-	248	572	885	1,402	2,521
Kingston	-	747	1,724	2,665	4,224	7,594	Y	-	284	655	1,013	1,605	2,886
Watts Bar	-	106	243	376	596	1,072	Y	-	40	93	143	227	407
Dewey	-	159	284	407	632	1,175	Y	-	60	108	155	240	447
Rock River	-	119	213	305	474	881	Y	-	45	81	116	180	335
Columbia (WI)	-	834	1,494	2,142	3,325	6,183	Y	-	317	568	814	1,263	2,349
Seminole	-	-	993	2,048	3,915	8,331	Y	-	-	377	778	1,488	3,166
St. Johns River Power	-	-	980	2,022	3,865	8,225	Y	-	-	373	769	1,469	3,126
Stanton Energy Center	-	-	660	1,361	2,602	5,536	Y	-	-	251	517	989	2,104
Crystal River	-	-	1,826	3,767	7,200	15,321	Y	-	-	694	1,432	2,736	5,822
Big Bend	-	-	1,363	2,811	5,371	11,430	Y	-	-	518	1,068	2,041	4,344
Gannon	-	-	925	1,907	3,645	7,757	Y	-	-	351	725	1,385	2,948
Deerhaven	-	-	178	367	702	1,494	Y	-	-	68	140	267	568
McIntosh-Fl	-	-	284	586	1,121	2,385	Y	-	-	108	223	426	906
Polk	-	-	248	512	978	2,081	Y	-	-	94	194	372	791
Barry	-	-	-	3,361	9,424	17,700	Y	-	-	-	1,277	3,581	6,726
Gadsden	-	-	-	249	698	1,310	Y	-	-	-	95	265	498
Gorgas	-	-	-	2,352	6,596	12,389	Y	-	-	-	894	2,507	4,708
Greene County	-	-	-	1,081	3,030	5,691	Y	-	-	-	411	1,151	2,163
Gaston	-	-	-	3,820	10,712	20,119	Y	-	-	-	1,452	4,071	7,645
Lowman (Tombigbee)	-	-	-	914	2,563	4,814	Y	-	-	-	347	974	1,829

Table 8, cont.
Coal Consumption at Coal-Fired Plants Served by the ORNS

Plant Name	Generation (Thousand MWH)						2	Coal Consumption (Thousand Tons)					
	2000	2005	2010	2015	2025	2045		2000	2005	2010	2015	2025	2045
Crist	-	-	-	2,047	5,740	10,780	Y	-	-	-	778	2,181	4,096
Scholz	-	-	-	-	-	-	Y	-	-	-	-	-	-
Smith (FL)	-	-	-	683	1,916	3,598	Y	-	-	-	260	728	1,367
Arkwright	-	-	-	-	-	-	Y	-	-	-	-	-	-
Bowen	-	-	-	6,640	18,619	34,970	Y	-	-	-	2,523	7,075	13,289
Hammond	-	-	-	1,718	4,818	9,049	Y	-	-	-	653	1,831	3,439
Harlee Branch	-	-	-	3,314	9,293	17,454	Y	-	-	-	1,259	3,532	6,633
McDonough	-	-	-	-	-	-	Y	-	-	-	-	-	-
Mitchell (GA)	-	-	-	394	1,104	2,073	Y	-	-	-	150	419	788
Yates	-	-	-	-	-	-	Y	-	-	-	-	-	-
Plant Kraft (Port Wentworth)	-	-	-	375	1,051	1,974	Y	-	-	-	142	399	750
Crisp	-	-	-	23	63	119	Y	-	-	-	9	24	45
Jack Watson	-	-	-	1,396	3,914	7,351	Y	-	-	-	530	1,487	2,793
Miller	-	-	-	5,812	16,297	30,608	Y	-	-	-	2,208	6,193	11,631
Wansley	-	-	-	3,613	10,133	19,031	Y	-	-	-	1,373	3,851	7,232
Morrow	-	-	-	721	2,022	3,798	Y	-	-	-	274	768	1,443
Victor J. Daniel	-	-	-	-	-	-	Y	-	-	-	-	-	-
McIntosh (GA)	-	-	-	636	1,783	3,349	Y	-	-	-	242	678	1,273
Scherer	-	-	-	6,764	18,967	35,624	Y	-	-	-	2,570	7,208	13,537
Presque Isle	-	-	-	-	696	2,235	Y	-	-	-	-	264	849
Port Washington	-	-	-	-	468	1,503	Y	-	-	-	-	178	571
Oak Creek South	-	-	-	-	1,327	4,264	Y	-	-	-	-	504	1,620
Valley	-	-	-	-	303	973	Y	-	-	-	-	115	370
Pleasant Prairie	-	-	-	-	1,373	4,413	Y	-	-	-	-	522	1,677

[2] New capacity additions during modeling process.

Section 6: Coal Shipment Module

6.1 <u>Structure</u>. The Coal Shipment Module projects coal shipments at the port-dock level based on projected coal consumption at each plant and projected short-term future coal delivery patterns developed by the Navigation Planning Center. The dBase IV program TONSPRO2.PRG [shown in Exhibit D] uses PLTBURN.DBF, developed in the Coal Consumption Module, as input and reads and updates COALBASC.DBF, writing baseline projections of coal shipments through the year 2075. TONSPRO3.PRB [shown in Exhibit E] also reads and updates COALBASC.DBF, generating projections for the deregulation scenario through 2075. A flow chart for this module is shown in Figure 6 and the input an d output files are shown in Table 9.

COALBASC.PRG contains projected movements of coal to electric power plants for the years 2000 and 2005, for baseline and deregulation scenarios. These data were developed by analysts in the Navigation Planning Center and are based on historical transportation patterns, survey responses, and projections of the impacts of derugulation developed by Hill and Associates. This file also contains blank fields into which projections of future coal movements, generated by the programs TONSPRO2.PRG and TONSPRO3.PRG, are written.

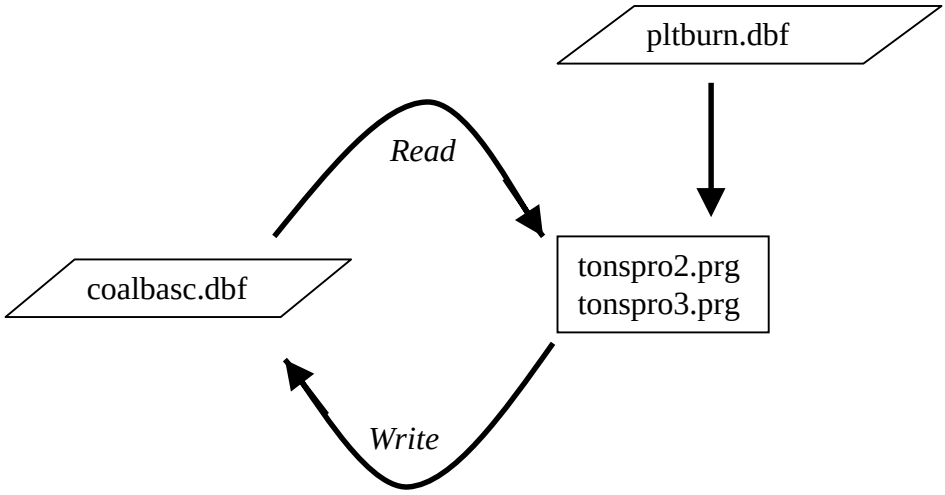


Figure 6 – ORNS Coal Transportation Projection Model, Coal Shipment Module.

Table 9
TONSPRO2.PRG & TONSPRO3.PRG Input & Output Files

Filenames	Input/ Output	Description
COALBASC.DBF	Input/ Output	Coal shipments to power plants derived from shippers surveys & adjusted coal shipments reflecting deregulation of the electric utility industry.
PLTBURN.DBF	Input	Coal burns from SUMPLTSC.DBF, summed at the plant level.
NOFIND.DBF	Output	Listing of plants with no waterborne shipments of coal.

6.2 Methods and Assumptions. In this module, separate dBase programs are used to project coal shipments under baseline and deregulation scenarios. First, TONSPRO2.PRG compares projected movements to projected coal burns and adjusts projected movements, if necessary, so that they do not exceed coal burns. This program then projects future coal traffic based on the projected origins, destinations, and tonnages in 2005 and growth rates derived from PLTBURN.DBF. Next, the program TONSPRO3.PRG projects traffic under the deregulation scenario by applying these same growth rates to the projected 2005 movements developed by the Navigation Planning Center.

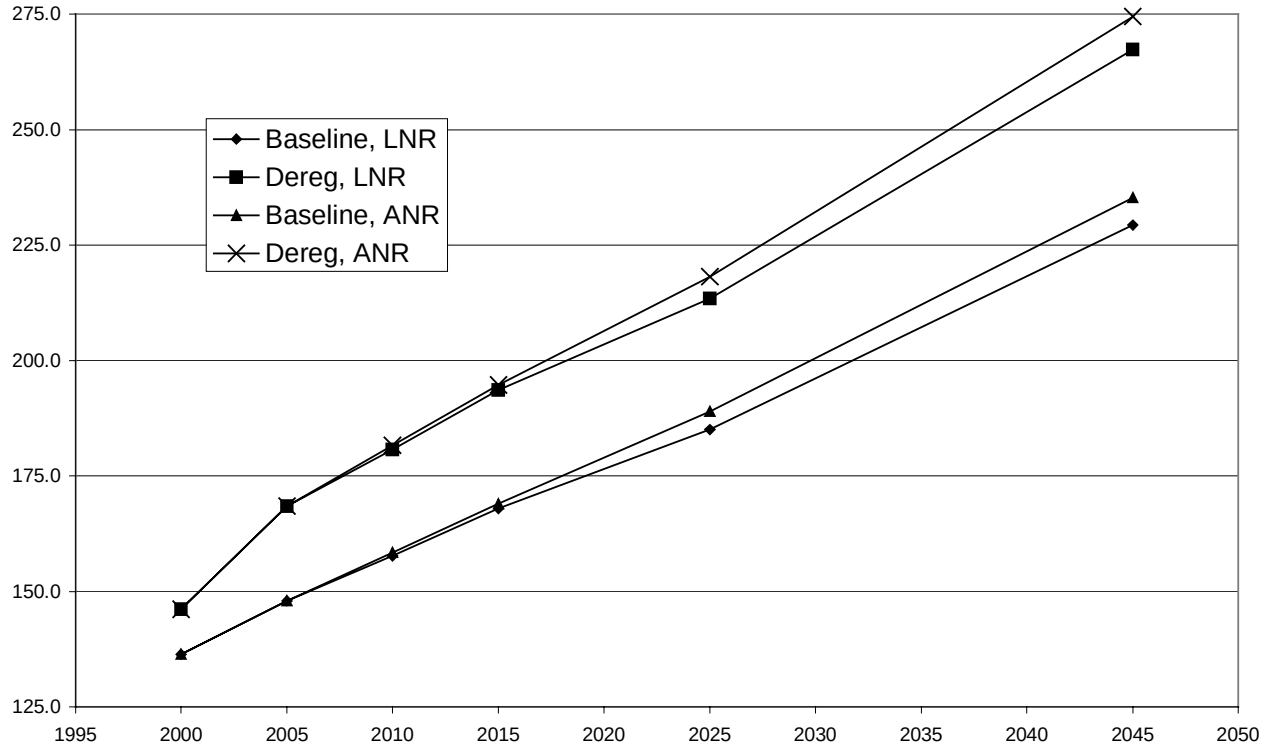
For the years 2005 through 2045, each power plant's traffic was allowed to grow at the same rate as its coal burns. Beyond 2045, however, traffic is constrained to grow at half of the 2025-2045 rate of growth.

6.3 Summary of Output. The traffic demands projected by this module are shown in Table 10 and Figure 7 below. Four scenarios are shown, reflecting two levels of nuclear power plant retirements, a baseline scenario and a deregulation scenario. These scenarios are described in greater detail in Section 7 below.

Table 10
Projected ORNS Coal Traffic Demands

Year	Limited Retirement of Nuclear Plants		Aggressive Retirement of Nuclear Plants	
	Baseline	Dereg	Baseline	Dereg
2000	136.4	146.1	136.4	146.1
2005	147.9	168.5	147.9	168.5
2010	157.7	180.7	158.4	181.6
2015	168.0	193.6	169.0	194.7
2025	185.1	213.4	189.0	218.2
2045	229.3	267.4	235.3	274.5

Figure 7
Projected ORNS Steam Coal Traffic



Section 7: Sample Computations

To illustrate the workings of the CTPM, sample computations for the Central Illinois Light Company (CILCO) are shown below. This utility was selected because it operates only 5 generating units, which greatly simplifies the computations. The example shows computations made within each of the four modules of the CTPM and explains the underlying assumptions and analysis.

The first of these four modules is the **Electric Demands Module**. In this module, ten-year projections of energy demands developed by the utility companies and reported to NERC are extrapolated through the year 2045 using OBERS state-level projections of total personal income. The 10-year forecasts of electricity demands produced by CILCO for their service area are listed in column 2 of Table 11. Demands are projected to increase from 5,897 thousand megawatts in 1995 to 7,021 in 2005. This equates to an equivalent annual growth rate of 1.7599% (column 3). The OBERS forecast of personnel income for Illinois are listed in column 4. The annual growth rate from 1995 to 2005 is 1.6881%, or 4.3% less than the NERC forecast. The adjustment factor shown in column 6 is a function of these two growth rates. The growth rate implicit in the OBERS forecast is multiplied by the adjustment factor listed in column 6, yielding the adjusted rate listed in column 7. These adjusted growth rates are multiplied by the utility's generation projected demands for year 2005 to obtain the long-term forecast of electricity demands in this service area (column 8).

Table 11
Electricity Demand Calculation

Year	Electric Demand Projections	Electric Demand Growth Rate, 1995-2005	OBERS Personal Income Projections	OBERS Personal Income Growth Rate	Adjustment Factor	Adjusted OBERS-Based Growth Rate	OBERS-Based Demand Projections
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1990			200,338				
1995	5,897		216,834				
2000	6,473		234,688				
2005	7,021	1.7599%	256,346	1.6881%	1.043	1.7599%	7,021
2010			277,680	1.6117%	1.043	1.6803%	7,631
2015			298,695	1.4698%	1.043	1.5323%	8,234
2015			340,485	1.3181%	1.043	1.3742%	9,438
2045			450,390	1.4085%	1.043	1.4685%	12,633

Algebraically, an adjustment factor, $F_{Adjustment,}$ was developed, such that

$F_{Adjustment} = i_{Utilites}/i_{OBERS}$, and

$Demand_{2005} = (1 + i_{OBERS} \text{ X } F_{Adjustment})^{10} \text{ X } Demand_{1995}$ where,

$Demand_{1995}$ = actual energy demands in 1995, as reported by the utility,
$Demand_{2005}$ = projected energy demands in 2005, as reported by the utility,
i_{OBERS} = the rate of growth of total personal income projected by OBERS, from 1995 to 2005,
$i_{Utilites}$ = the projected rate of growth of energy demands, as reported by the utility, and
$F_{Adjustment}$ = is the adjustment factor.

Again, for CILCO:

$F_{Adjustment} = 0.0176 / 0.0169 = 1.043$ and
$Demand_{2005} = [1 + (0.0169 \text{ X } 1.043)]^{10} \text{ X } 5{,}897 = 7{,}021$

This same adjustment factor was applied to OBERS-based growth rates to project energy demands for years beyond 2005.

The next module is the **Electric Generation Module**. In this module, projected future energy demands are allocated among a demand region's electric power plants based on available capacity. A list of the power plants owned by CILCO is shown in Table 12, along with each plant's nameplate capacity, capacity factor, adjusted (effective) capacity, the available capacity in 2005, and the percent that this available capacity represents of the utility's total available capacity. Adjusted capacity is a function of a plant's unadjusted capacity (at 100 percent utilization) and the capacity factor (maximum sustainable utilization rate). A plant's available capacity in any forecast year is computed by subtracting generation in the previous period from the total adjusted capacity during the forecast year. For example, generation at Duck Creek is projected to be 3,202 thousand mwh of electricity in 2000. Given an adjusted capacity of 13,189 thousand mwh in 2005, the available capacity in 2005 is 9,987 thousand mwh. This is the capacity that is available to meet 2005's projected marginal (over the year 2000) energy demands.

Table 12
Capacity Calculations

Plant Name	Fuel Type	Unadjusted Capacity	Capacity Factor	Adjusted Capacity	Available Capacity	Percent of Available Capacity
Duck Creek	Coal	17,354	0.760	13,189	9,987	84.9%
Edwards	Coal	6,835	0.760	5,195	1,604	13.6%
Midwest	Gas	183	0.135	25	3	0.0%
Sterling	Gas	315	0.135	43	37	0.3%
Unnamed	Gas	1,034	0.135	140	133	1.1%
Total				18,590	11,764	100.0%

Table 13 shows the derivation of projections of future generation by CILCO plants. Projected net energy demands for CILCO are projected to be 7,021.0 thousand mwh in 2005. Transmission losses of 351.1 thousand mwh yield total energy demands of 7,372.1 thousand mwh. This demand is projected to be met by generation of 6,826.5 thousand mwh and 545.6 thousand mwh to be purchased from other utilities. This amount is the same amount as implicit in the base year 1995 numbers, and remains the same throughout the forecast period.

Table 13
Calculation of CILCO Generation Projections
(Thousands of MWH)

Item	2005	2010	2015	2025	2045
Net Energy Demands	7,021.0	7,631.0	8,233.9	9,438.0	12,633.0
Generation for Transmission Losses (5%)	351.1	381.6	411.7	471.9	631.6
Total Energy Demands	7,372.1	8,012.6	8,645.6	9,909.9	13,264.6
Marginal Energy Demands		640.5	633.0	1,264.3	3,354.7
Total Generation	6,826.5	7,467.0	8,100.0	9,364.3	12,719.0
Assumed Purchase	545.6	545.6	545.6	545.6	545.6

Projected marginal generation was were allocated among CILCO's power plants based on their available capacity as shown in Table 14. Since Duck Creek has 84.9% of available capacity, then 84.9% of the 640.5 thousand mwh increase in projected electricity generation (543.8 thousand mwh) is allocated to the Duck Creek plant. Thus, total generation in 2010 is the sum of generation in 2005 and the marginal increase. If available capacity is insufficient to satisfy demands, then generation from all plants increase at the same rate as the increase in demands. This means that plants (and the fuel mix) will maintain their relative positions into the future.

Table 14
Allocation of Generation Among Power Plants

Plant Name	2005	Incremental Increase to 2010	2010
Duck Creek	3,202.0	543.8	3,745.8
Edwards	3,591.0	87.3	3,678.3
Midwest	21.8	0.2	22.0
Sterling Ave	5.2	2.0	7.2
Un-named	6.5	7.2	13.7
Total	6,826.5	640	7,467.0

The final steps are to convert generation into coal consumption and coal delivies by waterway. First, the existing relationship between the amount of coal consumed at the plant and the amount of electricity generated was computed based on historical information. These computations are performed in the **Coal Consumption Module** as shown in Table 15. Unless indicated otherwise by personnel from the electric companies, it was assumed that the relationship would remain the same in the future. For future coal-fired capacity additions, fuel consumption was based on the relatively high efficiency levels evident in recent capacity additions. Finally, projections of future waterborne movements of coal to each plant, by origin and destination port-dock code, were developed. Unless indicated otherwise by personnel from the electric companies, existing delivery patterns were assumed to persist into the future, with each movement growing at the same rate as total coal consumption at the destination plant.

Table 15
Computation of Coal Burns at Ducks Creek

Year	Generation (Thousand MWH)	Efficiency Factor	Coal Burn (Thousand Tons)
2005	3,202	0.476	1,523
2010	3,746	0.476	1,782
2025	4,283	0.476	2,037
2045	5,356	0.476	2,548

The **Coal Shipment Module** projects the volume of coal shipped by waterway to meet the demands of each plant. Duck Creek receives no waterway shipments of coal. However, to demonstrate the manner in which coal traffic is projected, we can assume that the Duck Creek plant responded in surveys that they plan to receive by waterway 500,000 tons of coal in 2000 from origin A and 250,000 tons from origin B as shown in Table 16. This equates to 58 percent of the projected 2000 coal burn of 1,291,374 tons, with the remainder of coal supplied by overland modes of transport. Holding these shares constant, projected future shipments of coal for Duck Creek would be:

Table 16
Hypothetical Waterway Shipments to Duck Creek

MOVEMENT	2000	2005	2010	2015	2025	2045
A	500,000	590,005	690,192	789,231	984,392	1,502,282
B	250,000	295,002	345,096	394,615	492,196	751,141

These movements, extrapolated to 2070 at half the projected 2025 - 2045 growth rate, are the final output of the CTPM.

Exhibit A
Electric Demands Module
ELPROJ98.PRG

```
* INITIALIZE
* PROGRAM ELPROJ98.PRG
* February 1999


clear
set talk off
set status off
set decimal to 5


SELECT 1  && INPUT FILE
USE BEA98 EXCL
* INDEX ON ST TAG B_ST
set ORDER to b_ST

SELECT 2  && INPUT FILE
USE SVCAREAS EXCL

SELECT 3  && input file
USE DPROJ98 EXCL
* INDEX ON COM_NO TO DP_COMNO
set index to dp_comno

select 4 && output file
use comdem98 excl
delete all
pack

select 5 && output file
use rates98 excl
delete all
pack

declare lsum[8]         && lsum[year], such that
                        && year 1: 1985
                        && year 2: 1990
                        && year 3: 2000
                        && year 4: 2005
                        && year 5: 2010
                        && year 6: 2015
                        && year 7: 2025
                        && year 8: 2045

declare st[6]           && stores NAMES of up to six STATES per service
area.

declare grrate[6]      && stores growth rates for four periods
                       && grrate [1]: 1990-2000
                       && grrate [2]: 2000-2005
                       && grrate [3]: 2005-2010
                       && grrate [4]: 2010-2015
                       && grrate [5]: 2015-2025
                       && grrate [6]: 2025-2045

SELECT 2
GO TOP
```

```
* DETERMINE NUMBER OF STATES AND ST ABBREV; READ AND SUM
* VALUES

do while .not. eof()

* Store STATE ABBREVIATIONS in 'st(m)'.  'st' holds name of field in
* beacos that ST numbers are read from.   ??? REVISIT, MAKE IT READ
STATES

m = 1
do while m < b->NO_STATES + 1
  mv_st = 'st' + ltrim(str(m))
  st[m] = &mv_st
  m = m + 1
enddo

do area_sum

* COMPUTE ELECTRIC DEMANDS

* Compute growth rates.
* Rate is calculated by total of higher year divided by total of lower
year,
*  and then taken to the power of 1 divided by the number of years in
*  the time period.

grrate[1] = (lsum[3]/lsum[1])**(1/10) -1   && growth rate 1990 - 2000
grrate[2] = (lsum[4]/lsum[3])**(1/5)  -1   && growth rate 2000 - 2005
grrate[3] = (lsum[5]/lsum[4])**(1/5)  -1   && growth rate 2005 - 2010
grrate[4] = (lsum[6]/lsum[5])**(1/5)  -1   && growth rate 2010 - 2015
grrate[5] = (lsum[7]/lsum[6])**(1/10) -1   && growth rate 2015 - 2025
grrate[6] = (lsum[8]/lsum[7])**(1/20) -1   && growth rate 2025 - 2045

* Apply growth rates [grrate] to appropriate demands.

select 3
seek b->com_no

mwh95   = nel_95
mwh05   = nel_05
total95 = nel_95
total00 = nel_00
total05 = nel_05
sttot00 = total95*((1 + grrate[1])**5)   && 5 years @ 1990-2000 rate
sttot05 = sttot00*((1 + grrate[2])**5)   && 5 year  @ 2000-2005 rate

**  Compare growth projected by NERCs and utilities through 2005 with
**  that computed above using growth rates.  adjfact is an adjustment
**  factor.

adjfact = ((total05/mwh95)**(.1)-1) / ((sttot05/mwh95)**(.1) - 1)
check05 = total95 * (1 + ((sttot05/mwh95)**(.1)-1) * adjfact)**10

** Growth rates are adjusted using adjfact and projections are
computed.
```

```
total10 = total05 *((1 + grrate[3] * adjfact)**5)   && 5 years  @ 2005
- 2010 rate
total15 = total10 *((1 + grrate[4] * adjfact)**5)   && 5 years  @ 2010
- 2015 rate
total25 = total15 *((1 + grrate[5] * adjfact)**10)  && 10 years @ 2015
- 2025 rate
total45 = total25 *((1 + grrate[6] * adjfact)**20)  && 20 years @ 2025
- 2045 rate

**  Insert a new record into the demcat98 output database, write
projections
**  for this company.

select 4
append blank
replace com_no  with b->com_no
replace com_na  with b->com_na
replace tot95   with total95
replace tot00   with total00
replace tot05   with total05
replace tot10   with total10
replace tot15   with total15
replace tot25   with total25
replace tot45   with total45

** Insert the st rates, company percentage difference and company
information
** into the rates output database

select 5
append blank
replace com_no    with b->com_no
replace com_na    with b->com_na
replace base_2005 with total05
replace bea_2005  with check05
replace adj_fact  with adjfact
replace rat90_00  with 1 + grrate[1] * adjfact
replace rat00_05  with 1 + grrate[2] * adjfact
replace rat05_10  with 1 + grrate[3] * adjfact
replace rat10_15  with 1 + grrate[4] * adjfact
replace rat15_25  with 1 + grrate[5] * adjfact
replace rat25_45  with 1 + grrate[6] * adjfact

* END MAIN PROGRAM

select 2
skip
enddo


close all
clear all
set status on



* Procedures**************************************************
```

```
PROCEDURE area_sum

select 1

* Initialize lsum[8]

l = 1
do while l < 9
    lsum[l] = 0
    l = l + 1
enddo

* Add STATE-values to service area totals for use
* in demand functions.

j = 1
do while j < b->no_states + 1
seek st[j]
   lsum[1] = lsum[1] + Y1990
   lsum[3] = lsum[3] + Y2000
   lsum[4] = lsum[4] + Y2005
   lsum[5] = lsum[5] + Y2010
   lsum[6] = lsum[6] + Y2015
   lsum[7] = lsum[7] + Y2025
   lsum[8] = lsum[8] + Y2045
j = j + 1
enddo

select 2

return
```

Exhibit B
Electric Generation Module
PGEN00S.PRG

```
*                                                       INPUT FILES:
OUTPY98F.dbf
*
COMDEM98.dbf

*                                                       OUTPUT FILE:
OUTPY98F.dbf
*
*                                                       PROGRAM NAME:
PGEN00F.dbf
*

*
*
SET TALK OFF
CLEAR

SELE 1
USE OUTPY98F EXCL
*INDEX ON FILT_NO+PLT_NO TAG COMPLTRM
SET ORDER TO COMPLTRM

replace all acap00 with (max00 - gen95)
replace all gen00 with 0 for sur00 <> "Y"
*DONE TO ASSURE NO DATA REMAINS FROM PRIOR RUNS.

SELE 2
USE COMDEM98 EXCL
*INDEX ON com_no TAG EPCOMCR
SET ORDER TO EPCOMCR

SELE 1
GO TOP
MVCOMNO = A->filt_no
TACAP00  = 0
N        = 0
DO WHILE .NOT. EOF()
     addcap     = 0
     surgen00 = 0
     SCAN WHILE MVCOMNO = A->filt_no
          IF SUR00 <> "Y"

          if acap00 < 0
               addcap = addcap - acap00
               replace acap00 with 0
               replace gen00 with max00
          endif

          TACAP00 = TACAP00 + ACAP00
          ENDIF

          if sur00 = "Y"
               surgen00 = surgen00 + (gen00 - gen95)
          endif
```

```
          N = N+1
     ENDSCAN
     SKIP -N
     SELE 2
     SEEK MVCOMNO


     NEWGEN00 = (((TOT00-TOT95) *1000) *1.05) + addcap - surgen00
     *Added energy demands (as compared with prior period), plus
generation
     *in prior period by plants now retired, less incremental generation
     * from surveys.

     addcap = 0

     IF NEWGEN00 >TACAP00
          EXCDEM = NEWGEN00 - TACAP00
          ? EXCDEM
          ? A->filt_no, A->filt_na
          WAIT
     ENDIF

     SELE 1

     SCAN WHILE MVCOMNO = A->filt_no
          IF MAX00 > 0 .and. sur00 <> "Y"
          REPLACE GEN00 WITH (GEN95 + ((ACAP00 / TACAP00) * NEWGEN00))
          ENDIF
     ENDSCAN

     MVCOMNO = filt_no
     TACAP00 = 0
     N       = 0
ENDDO

SET TALK ON
```

Exhibit C
Coal Consumption Module
COALBURN.PRG

```
* PROGRAM COALBURN.DBF
* FEBRUARY 1999

set talk off
sele 1
use sumpltsc excl
set order to plant

sele 2
use bgrat excl
set order to plant

sele 1
set relation to plt_no into b

* Compute burns based on historical burn rates, 1994- 1997, from
Powerdat.

replace all burn00 with b->bgrath * gen00
replace all burn05 with b->bgrath * gen05
replace all burn10 with b->bgrath * gen10
replace all burn15 with b->bgrath * gen15
replace all burn25 with b->bgrath * gen25
replace all burn45 with b->bgrath * gen45

* Overwrite burns for surveyed plants that responded for 2000, using
2000 burn ratio
* for all future years.

replace all burn00 with b->bgrat00 * gen00 for b->bgrat00 > 0
replace all burn05 with b->bgrat00 * gen05 for b->bgrat00 > 0
replace all burn10 with b->bgrat00 * gen10 for b->bgrat00 > 0
replace all burn15 with b->bgrat00 * gen15 for b->bgrat00 > 0
replace all burn25 with b->bgrat00 * gen25 for b->bgrat00 > 0
replace all burn45 with b->bgrat00 * gen45 for b->bgrat00 > 0

* Overwrite burns for surveyed plants that responded for 2005, using
2005 burn ratio
* for all future years.

replace all burn05 with b->bgrat05 * gen05 for b->bgrat05 > 0
replace all burn10 with b->bgrat05 * gen10 for b->bgrat05 > 0
replace all burn15 with b->bgrat05 * gen15 for b->bgrat05 > 0
replace all burn25 with b->bgrat05 * gen25 for b->bgrat05 > 0
replace all burn45 with b->bgrat05 * gen45 for b->bgrat05 > 0

* Overwrite burns for new units, using 95th percentile efficiency
ranking from Powerdat,
* or .38 tons / mwh.

replace all burn00 with .38 * gen00 for new = "Y"
replace all burn05 with .38 * gen05 for new = "Y"
replace all burn10 with .38 * gen10 for new = "Y"
replace all burn15 with .38 * gen15 for new = "Y"
replace all burn25 with .38 * gen25 for new = "Y"
replace all burn45 with .38 * gen45 for new = "Y"
```

```
total on plt_no to pltburn

set talk on
close all
```

Exhibit D
Coal Shipment Module
TONSPRO2.PRG

```
 Program:      tonspro2.prg
* Author:      JEA
* Date:   7 December 1998
* Baseline projections: deregulation not considered.


SET TALK OFF

SELE 1
USE pltburn excl
set order to plant
go top

*************************************************************************
********
* Contains coal burns through 2045.
     *
*************************************************************************
********

SELE 2
USE coalbasc EXCL
* index on plt_no + dpd tag pltpd
set order to pltpd

*************************************************************************
********
* input/output: list of od's for each plant, with historical and
projected     *
* deliveries; sorted by plant, then port-dock. Future shipments are
blank     *
* initially; the program estimates based on predited 2000/2005 pattern
in   *
* input file.  The data for 2000/2005 are based on surveys and
adjustments    *
* by Dale Kelz/Bill Frechione.                                          *
* tonsXXf:     baseline input                                           *
* tonsXXfa:    dereg input
     *
* tonsXXfb:    baseline output
     *
* tonsXXfc:    dereg output                                             *
*************************************************************************
********

SELE 3
USE nofind excl
dele all
pack

*************************************************************************
********
* output: name, number, and burns for plants from pltburns with no
     *
* waterway receipts of coal.                                            *
*************************************************************************
********
```

```
sele 1
DO WHILE .NOT. EOF()
SELE 2
SEEK A->plt_no
IF FOUND()
     tot00 = 0
     tot05 = 0
     n = 0

     scan while plt_no = a->plt_no
          tot00 = tot00 + tons00f
          tot05 = tot05 + tons05f
          n = n + 1
     endscan

*********************************************************************
********
* Total coal receipts in odlist.dbf for plant from pltburn.dbf.
          *
*********************************************************************
********

     if tot00 > a->burn00
          skip -n
          scan while plt_no = a->plt_no
               replace tons00fb with tons00f * a->burn00 / tot00
          endscan
     else
          skip -n

          scan while plt_no = a->plt_no
               replace tons00fb with tons00f
          endscan
     endif

     if tot05 > a->burn05
          skip -n
          scan while plt_no = a->plt_no
               replace tons05fb with tons05f * a->burn05 / tot05
          endscan
     else
          skip -n
          scan while plt_no = a->plt_no
               replace tons05fb with tons05f
          endscan
     endif

*********************************************************************
********
* adjust 2000 & 2005 shipments when total receipts for a plant exceed
total     *
* burns; else copy directly.                                        *
*********************************************************************
********

     skip -n
```

```
     scan while plt_no = a->plt_no
          if tot05 = 0
               replace tons05fb with ((tons00fb/a->burn00)*a->burn05)
          endif
          replace tons10fb with ((tons05fb/a->burn05)*a->burn10)
          replace tons15fb with ((tons05fb/a->burn05)*a->burn15)
          replace tons25fb with ((tons05fb/a->burn05)*a->burn25)
          replace tons45fb with ((tons05fb/a->burn05)*a->burn45)
     endscan
else
     sele 3
     append blank
     replace plt_no with a->plt_no
     replace plt_na with a->plt_na
     replace burn00 with a->burn00
     replace burn05 with a->burn05
ENDIF

*********************************************************************
********
* project deliveries 2010 - 2045 based on 2005 distribution, which
will, in  *
* turn be based on 2000 deliveries if no 2005 deliveries were
estimated. The *
* "else" statement lists the names and burns of plants with no waterway
          *
* deliveries.                                                      *
*********************************************************************
********



SELE 1
SKIP

ENDDO

SELE 2
GO TOP

SCAN WHILE .NOT. EOF()

REPLACE TONS20fb WITH TONS15fb*(1 +     ((TONS25fb/TONS15fb)^(1/10)-
1))^5
IF TONS45fb > 0
REPLACE TONS30fb WITH TONS25fb*(1 +     ((TONS45fb/TONS25fb)^(1/20)-
1))^5
REPLACE TONS35fb WITH TONS25fb*(1 +     ((TONS45fb/TONS25fb)^(1/20)-
1))^10
REPLACE TONS40fb WITH TONS25fb*(1 +     ((TONS45fb/TONS25fb)^(1/20)-
1))^15
REPLACE TONS50fb WITH TONS45fb*(1 +.5 * ((TONS45fb/TONS25fb)^(1/20)-
1))^5
REPLACE TONS55fb WITH TONS45fb*(1 +.5 * ((TONS45fb/TONS25fb)^(1/20)-
1))^10
REPLACE TONS60fb WITH TONS45fb*(1 +.5 * ((TONS45fb/TONS25fb)^(1/20)-
1))^15
```

```
REPLACE TONS65fb WITH TONS45fb*(1 +.5 * ((TONS45fb/TONS25fb)^(1/20)-
1))^20
REPLACE TONS70fb WITH TONS45fb*(1 +.5 * ((TONS45fb/TONS25fb)^(1/20)-
1))^25
ENDIF

*********************************************************************
********
* Interpolate for 2035 - 2040 and extrapolate beyond 2045 using half
the  *
* 2025-2045 growth rate.                                            *
*********************************************************************
********


ENDSCAN


SET TALK ON
```

Exhibit E
Coal Shipment Module
TONSPRO3.PRG

```
Program:  tonspro3.prg
* Author:      JEA
* Date:   7 December 1998
* Deregulation scenario.


SET TALK OFF

SELE 1
USE coalbasc EXCL

************************************************************************
********
* input/output: list of od's for each plant, with historical and
projected      *
* deliveries; sorted by plant, then port-dock. Future shipments are
blank     *
* initially; the program estimates based on predited 2000/2005 pattern
in   *
* input file.  The data for 2000/2005 are based on surveys and
adjustments    *
* by Dale Kelz/Bill Frechione.                                          *
* tonsXXf:     baseline input                                           *
* tonsXXfa:    dereg input
     *
* tonsXXfb:    baseline output
     *
* tonsXXfc:    dereg output                                             *
* tons00fc is based on Dale's dereg totals showing .2648 % of
     *
*       total gains over 2000 baseline by 2000.
     *
* tons00fd: dereg output, based on Dale's dereg, 2005dereg/2005base
     *
************************************************************************
********

replace all tons00fc with 0
replace all tons00fd with 0
replace all tons05fc with 0
replace all tons10fc with 0
replace all tons15fc with 0
replace all tons20fc with 0
replace all tons25fc with 0
replace all tons30fc with 0
replace all tons35fc with 0
replace all tons40fc with 0
replace all tons45fc with 0
replace all tons50fc with 0
replace all tons55fc with 0
replace all tons60fc with 0
replace all tons65fc with 0
replace all tons70fc with 0

replace all tons00fc with tons00f + (tons05fa - tons00f) * 0.2648

go top
```

```
scan while .not. eof()
if tons05f > 0
     replace tons00fd with tons00f * (tons05fa / tons05f)
else
     replace tons00fd with tons00f + (tons05fa - tons00f) * 0.2648
endif
endscan

replace all tons05fc with tons05fa
set filter to tons05fb > 0
replace all tons10fc with tons05fc * tons10fb/tons05fb
replace all tons15fc with tons05fc * tons15fb/tons05fb
replace all tons20fc with tons05fc * tons20fb/tons05fb
replace all tons25fc with tons05fc * tons25fb/tons05fb
replace all tons30fc with tons05fc * tons30fb/tons05fb
replace all tons35fc with tons05fc * tons35fb/tons05fb
replace all tons40fc with tons05fc * tons40fb/tons05fb
replace all tons45fc with tons05fc * tons45fb/tons05fb
replace all tons50fc with tons05fc * tons50fb/tons05fb
replace all tons55fc with tons05fc * tons55fb/tons05fb
replace all tons60fc with tons05fc * tons60fb/tons05fb
replace all tons65fc with tons05fc * tons65fb/tons05fb
replace all tons70fc with tons05fc * tons70fb/tons05fb


SET TALK ON
```

ATTACHMENT 4

TABLE 1
CALCULATION OF INTEREST DURING CONSTRUCTION

Discount Rate	0.06625
Discount method:	end of year
Base year and online date:	2008

J.T. MYERS -- 600' Auxiliary Lock Extension				
	Construction Expenditures Stream	PW Factor	PW of Expenditures	IDC
2006	86,500	1.0663	92,231	
2007	86,500	1.0000	86,500	
TOTAL	173,000		178,731	5,731

GREENUP -- 600' Auxiliary Lock Extension				
	Construction Expenditures Stream	PW Factor	PW of Expenditures	IDC
2006	87,750	1.0663	93,563	
2007	87,750	1.0000	87,750	
TOTAL	175,500		181,313	5,813

Atachment 4 - Table 2

WOPC Costs by Category and Year -- J.T. Myers

Main Chamber Closures and Costs

Year	Main. Item	F/E 1/2-speed	Closure Days – Uncsch. Closures – Unsch. Main.	Closure Days – Uncsch. Closures – Random Minor	Closure Days – Scheduled Closures – Cyc. Main.	Closure Days – Scheduled Closures – Comp. Repl.	Closure Days – Scheduled Closures – Major Rehab.	Costs – Uncsch. Closures – Unsch. Main.	Costs – Uncsch. Closures – Random Minor	Costs – Scheduled Closures – Cyc. Main.	Costs – Scheduled Closures – Comp. Repl.	Costs – Scheduled Closures – Major Rehab.	Total Costs
2000	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2001	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2002	-	-	-	5	-	-	-	$ -	$ 100	$ -	$ -	$ -	$ 100.00
2003	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2004	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2005	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2006	Maint. Dewater/Appr. Wall	-	-	-	60	-	-	$ -	$ -	$ 2,490	$ -	$ -	$2,490.00
2007	MG Repair and Paint	-	-	-	60	-	-	$ -	$ -	$ 2,100	$ -	$ -	$2,100.00
2008	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2009	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2010	-	-	-	10	-	-	-	$ -	$ 200	$ -	$ -	$ -	$ 200.00
2011	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2012	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2013	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00
2014	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2015	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2016	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2017	-	-	-	10	-	-	-	$ -	$ 200	$ -	$ -	$ -	$ 200.00
2018	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2019	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2020	Hydr. System	-	-	5	-	60	-	$ -	$ 100	$ -	$ 2,115	$ -	$2,215.00
2021	Maint Dewater	-	-	-	45	-	-	$ -	$ -	$ 1,868	$ -	$ -	$1,867.50
2022	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2023	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00
2024	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2025	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2026	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2027	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00
2028	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2029	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2030	Culvert Valves	90	-	5	-	-	-	$ -	$ 100	$ -	$ 2,800	$ -	$2,900.00
2031	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2032	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2033	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2034	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00
2035	Mgate Paint	-	-	-	45	-	-	$ -	$ -	$ 2,100	$ -	$ -	$2,100.00
2036	Maint. Dewater	-	-	-	45	-	-	$ -	$ -	$ 1,868	$ -	$ -	$1,868.00
2037	-	-	-	10	-	-	-	$ -	$ 200	$ -	$ -	$ -	$ 200.00
2038	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2039	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2040	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00
2041	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2042	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2043	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2044	-	-	-	10	-	-	-	$ -	$ 200	$ -	$ -	$ -	$ 200.00
2045	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2046	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2047	-	-	-	5	-	-	-	$ -	$ 100	$ -	$ -	$ -	$ 100.00
2048	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2049	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2050	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00
2051	Maint. Dewater	-	-	-	45	-	-	$ -	$ -	$ 1,868	$ -	$ -	$1,868.00
2052	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2053	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2054	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00
2055	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2056	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00
2057	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00
2058	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2059	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2060	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -

Auxiliary Chamber Closures and Costs / Other Project Costs

Year	Main. Item	Closure Days – Uncsch. Closures – Unsch. Main.	Closure Days – Uncsch. Closures – Random Minor	Closure Days – Scheduled Closures – Cyc. Main.	Closure Days – Scheduled Closures – Comp. Repl.	Closure Days – Scheduled Closures – Major Rehab.	Costs – Uncsch. Closures – Unsch. Main.	Costs – Uncsch. Closures – Random Minor	Costs – Scheduled Closures – Cyc. Main.	Costs – Scheduled Closures – Comp. Repl.	Costs – Scheduled Closures – Major Rehab.	Total Costs	Other Project Costs – Annual O&M Costs	LCLM Costs – Repair	LCLM Costs – Trans. Delay	Dam Cost	Dredge Costs
2000	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 46.00	$ 437.00	$ -	$156.00
2001	-	-	5	-	-	-	$0	$100	$0	$0	$0	$ 100.00	$1,824.00	$ 53.00	$ 513.00	$ -	$156.00
2002	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 49.00	$ 495.00	$ -	$156.00
2003	Maint. Dewater	-	-	45	-	-	$0	$0	$1,868	$0	$0	$ 1,868.00	$1,824.00	$ 52.00	$ 571.00	$ -	$156.00
2004	MG Paint	-	-	45	-	-	$0	$0	$2,100	$0	$0	$ 2,100.00	$1,824.00	$ 56.00	$ 613.00	$ -	$156.00
2005	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 61.00	$ 676.00	$ -	$156.00
2006	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 60.00	$ 675.00	$ -	$156.00
2007	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 64.00	$ 804.00	$ -	$156.00
2008	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 63.00	$ 859.00	$ -	$156.00
2009	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 65.00	$ 954.00	$ -	$156.00
2010	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 69.00	$ 1,091.00	$ -	$156.00
2011	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 64.00	$ 955.00	$ -	$156.00
2012	Inspection	-	-	15	-	-	$0	$0	$525	$0	$0	$ 525.00	$1,824.00	$ 73.00	$ 1,281.00	$ -	$156.00
2013	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 74.00	$ 1,287.00	$ -	$156.00
2014	-	-	1	-	-	-	$0	$20	$0	$0	$0	$ 20.00	$1,824.00	$ 78.00	$ 1,408.00	$ -	$156.00
2015	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 81.00	$ 1,575.00	$ -	$156.00
2016	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 79.00	$ 1,622.00	$ -	$156.00
2017	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 81.00	$ 1,712.00	$ -	$156.00
2018	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 87.00	$ 1,862.00	$ -	$156.00
2019	Maint Dewater	-	-	45	-	-	$0	$0	$1,868	$0	$0	$ 1,867.50	$1,824.00	$ 88.00	$ 2,048.00	$ -	$156.00
2020	-	-	10	-	-	-	$0	$200	$0	$0	$0	$ 200.00	$1,824.00	$ 23.00	$ 414.00	$ -	$156.00
2021	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 24.00	$ 457.00	$ -	$156.00
2022	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 23.00	$ 448.00	$ -	$156.00
2023	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 29.00	$ 573.00	$ -	$156.00
2024	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 30.00	$ 588.00	$ -	$156.00
2025	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 28.00	$ 601.00	$ -	$156.00
2026	Inspection	-	1	15	-	-	$0	$20	$525	$0	$0	$ 545.00	$1,824.00	$ 24.00	$ 552.00	$ -	$156.00
2027	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 28.00	$ 612.00	$ -	$156.00
2028	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 30.00	$ 807.00	$ -	$156.00
2029	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 29.00	$ 727.00	$ -	$156.00
2030	Hydr & Elec. System	-	-	-	60	-	$0	$0	$0	$3,642	$0	$ 3,642.00	$1,824.00	$ 14.00	$ 714.00	$ -	$156.00
2031	Culvert Valve	-	-	-	60	-	$0	$0	$0	$1,400	$0	$ 1,400.00	$1,824.00	$ 19.00	$ 977.00	$ -	$156.00
2032	-	-	3	-	-	-	$0	$60	$0	$0	$0	$ 60.00	$1,824.00	$ 17.00	$ 955.00	$ -	$156.00
2033	Maint. Dewater	-	-	45	-	-	$0	$0	$1,868	$0	$0	$ 1,868.00	$1,824.00	$ 18.00	$ 978.00	$ -	$156.00
2034	Mgate Paint	-	-	45	-	-	$0	$0	$2,100	$0	$0	$ 2,100.00	$1,824.00	$ 15.00	$ 803.00	$ -	$156.00
2035	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 17.00	$ 1,098.00	$ -	$156.00
2036	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 18.00	$ 1,134.00	$ -	$156.00
2037	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 21.00	$ 1,536.00	$ -	$156.00
2038	-	-	5	-	-	-	$0	$100	$0	$0	$0	$ 100.00	$1,824.00	$ 19.00	$ 1,411.00	$ -	$156.00
2039	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 20.00	$ 1,477.00	$ -	$156.00
2040	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 19.00	$ 1,660.00	$ -	$156.00
2041	Inspection	-	-	15	-	-	$0	$0	$525	$0	$0	$ 525.00	$1,824.00	$ 18.00	$ 1,617.00	$ -	$156.00
2042	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 21.00	$ 1,987.00	$ -	$156.00
2043	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 20.00	$ 2,258.00	$ -	$156.00
2044	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 20.00	$ 2,222.00	$ -	$156.00
2045	-	-	5	-	-	-	$0	$100	$0	$0	$0	$ 100.00	$1,824.00	$ 21.00	$ 2,459.00	$ -	$156.00
2046	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 22.00	$ 2,920.00	$ -	$156.00
2047	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 23.00	$ 3,129.00	$ -	$156.00
2048	Maint. Dewater	-	-	45	-	-	$0	$0	$1,868	$0	$0	$ 1,868.00	$1,824.00	$ 23.00	$ 3,271.00	$ -	$156.00
2049	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 24.00	$ 3,775.00	$ -	$156.00
2050	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 25.00	$ 4,477.00	$ 8,250.00	$156.00
2051	-	-	1	-	-	-	$0	$20	$0	$0	$0	$ 20.00	$1,824.00	$ 22.00	$ 3,990.00	$ 8,250.00	$156.00
2052	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 27.00	$ 5,829.00	$ 8,250.00	$156.00
2053	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 30.00	$ 6,160.00	$ 2,750.00	$156.00
2054	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 42.00	$ 9,243.00	$ -	$156.00
2055	Inspection	-	-	15	-	-	$0	$0	$525	$0	$0	$ 525.00	$1,824.00	$ 36.00	$ 9,335.00	$ -	$156.00
2056	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 44.00	$11,560.00	$ -	$156.00
2057	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 55.00	$14,054.00	$ -	$156.00
2058	-	-	10	-	-	-	$0	$200	$0	$0	$0	$ 200.00	$1,824.00	$ 55.00	$17,036.00	$ -	$156.00
2059	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 60.00	$18,532.00	$ -	$156.00
2060	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ -	$ -	$ -	$156.00

		Project Life 2008 to 2058		Pre-Project Life 2000 to 2007	
Year	n	factor	PW	factor	PW
2000	(7.0)	0.0000	$ -	1.5668	$ 4,682
2001	(6.0)	0.0000	$ -	1.4694	$ 3,888
2002	(5.0)	0.0000	$ -	1.3781	$ 3,616
2003	(4.0)	0.0000	$ -	1.2925	$ 5,779
2004	(3.0)	0.0000	$ -	1.2122	$ 5,757
2005	(2.0)	0.0000	$ -	1.1369	$ 3,089
2006	(1.0)	0.0000	$ -	1.0663	$ 5,550
2007	0.0	0.0000	$ -	1.0000	$ 4,948
2008	1.0	0.9379	$2,722	0.0000	$ -
2009	2.0	0.8796	$2,638	0.0000	$ -
2010	3.0	0.8249	$2,755	0.0000	$ -
2011	4.0	0.7737	$2,726	0.0000	$ -
2012	5.0	0.7256	$2,800	0.0000	$ -
2013	6.0	0.6805	$2,287	0.0000	$ -
2014	7.0	0.6382	$2,225	0.0000	$ -
2015	8.0	0.5986	$2,176	0.0000	$ -
2016	9.0	0.5614	$2,361	0.0000	$ -
2017	10.0	0.5265	$2,092	0.0000	$ -
2018	11.0	0.4938	$1,940	0.0000	$ -
2019	12.0	0.4631	$2,771	0.0000	$ -
2020	13.0	0.4343	$2,099	0.0000	$ -
2021	14.0	0.4074	$1,763	0.0000	$ -
2022	15.0	0.3820	$ 936	0.0000	$ -
2023	16.0	0.3583	$ 947	0.0000	$ -
2024	17.0	0.3360	$ 873	0.0000	$ -
2025	18.0	0.3152	$ 822	0.0000	$ -
2026	19.0	0.2956	$1,072	0.0000	$ -
2027	20.0	0.2772	$ 732	0.0000	$ -
2028	21.0	0.2600	$ 732	0.0000	$ -
2029	22.0	0.2438	$ 667	0.0000	$ -
2030	23.0	0.2287	$2,115	0.0000	$ -
2031	24.0	0.2145	$1,051	0.0000	$ -
2032	25.0	0.2012	$ 606	0.0000	$ -
2033	26.0	0.1887	$ 914	0.0000	$ -
2034	27.0	0.1769	$ 870	0.0000	$ -
2035	28.0	0.1659	$ 862	0.0000	$ -
2036	29.0	0.1556	$ 778	0.0000	$ -
2037	30.0	0.1460	$ 545	0.0000	$ -
2038	31.0	0.1369	$ 480	0.0000	$ -
2039	32.0	0.1284	$ 446	0.0000	$ -
2040	33.0	0.1204	$ 448	0.0000	$ -
2041	34.0	0.1129	$ 527	0.0000	$ -
2042	35.0	0.1059	$ 422	0.0000	$ -
2043	36.0	0.0993	$ 423	0.0000	$ -
2044	37.0	0.0932	$ 412	0.0000	$ -
2045	38.0	0.0874	$ 398	0.0000	$ -
2046	39.0	0.0819	$ 446	0.0000	$ -
2047	40.0	0.0768	$ 402	0.0000	$ -
2048	41.0	0.0721	$ 515	0.0000	$ -
2049	42.0	0.0676	$ 391	0.0000	$ -
2050	43.0	0.0634	$ 935	0.0000	$ -
2051	44.0	0.0595	$ 959	0.0000	$ -
2052	45.0	0.0558	$ 897	0.0000	$ -
2053	46.0	0.0523	$ 571	0.0000	$ -
2054	47.0	0.0490	$ 555	0.0000	$ -
2055	48.0	0.0460	$ 546	0.0000	$ -
2056	49.0	0.0431	$ 609	0.0000	$ -
2057	50.0	0.0405	$ 653	0.0000	$ -
2058	51.0	0.0379	$ 731	0.0000	$ -
2059	52.0	0.0000	$ -	0.0000	$ -
2060	53.0	0.0000	$ -	0.0000	$ -

Life

Total PW
$ 59,648.35

AAEC
$4,107.58

Pre-Life

Total PW
$ 37,308.39

AAEC
$2,569.18

Atachment 4 - Table 3

600' Extension in 2008 (w/qgco) Costs by Category and Year -- J.T. Myers

	Main Chamber Closures and Costs													Auxiliary Chamber Closures and Costs												Other Project Costs				
			Closure Days					Costs							Closure Days					Costs										
			Uncsch.Closures		Scheduled Closures			Uncsch. Closures		Scheduled Closures					Uncsch. Closures		Scheduled Closures			Uncsch. Closures		Scheduled Closures				Annual	LCLM Costs			
Year	Main. Item	F/E 1/2-speed	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Total Costs	Main. Item	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Total Costs	O&M Costs	Repair	Trans. Delay	Dam Cost	Dredge Costs
2000	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 46.00		$ -	$156.00
2001	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	3	-	-	-	$0	$60	$0	$0	$0	$ 60.00	$1,824.00	$ 53.00		$ -	$156.00
2002	-	-	-	5	-	-	-	$ -	$ 100	$ -	$ -	$ -	$ 100.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 49.00		$ -	$156.00
2003	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 52.00		$ -	$156.00
2004	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Inspection	-	-	15	-	-	$0	$0	$525	$0	$0	$ 525.00	$1,824.00	$ 56.00		$ -	$156.00
2005	Inspection	-	-	-	15	-	-	$ -	$ -	$ 525	$ -	$ -	$ 525.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 61.00		$ -	$156.00
2006	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Plan 3	-	-	-	(2)	-	$0	$0	$0	$0	$86,500	$83,000.00	$1,824.00	$ 60.00		$ -	$156.00
2007	-	-	-	5	-	-	-	$ -	$ 100	$ -	$ -	$ -	$ 100.00	Plan 3	-	-	-	(1)	-	$0	$0	$3,050	$0	$86,500	$86,050.00	$1,824.00	$ 64.00		$ -	$156.00
2008	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 63.00		$ -	$156.00
2009	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 65.00		$ -	$156.00
2010	MG Repair & App Wal	-	-	10	30	-	-	$ -	$ 200	$1,745	$ -	$ -	$1,945.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 69.00		$ -	$156.00
2011	MG 1 Paint	-	-	-	-	-	-	$ -	$ -	$1,650	$ -	$ -	$1,650.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 64.00		$ -	$156.00
2012	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 73.00		$ -	$156.00
2013	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00	Mgate 1	-	-	30	-	-	$0	$0	$1,745	$0	$0	$ 1,745.00	$1,824.00	$ 74.00		$ -	$156.00
2014	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 2 Paint	-	1	-	-	-	$0	$20	$1,650	$0	$0	$ 1,670.00	$1,824.00	$ 78.00		$ -	$156.00
2015	Mgate 2	-	-	-	30	-	-	$ -	$ -	$1,745	$ -	$ -	$1,745.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 81.00		$ -	$156.00
2016	MG 3 Paint	-	-	-	-	-	-	$ -	$ -	$1,650	$ -	$ -	$1,650.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 79.00		$ -	$156.00
2017	-	-	-	10	-	-	-	$ -	$ 200	$ -	$ -	$ -	$ 200.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 81.00		$ -	$156.00
2018	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Inspection	-	-	10	-	-	$0	$0	$415	$0	$0	$ 415.00	$1,824.00	$ 87.00		$ -	$156.00
2019	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 88.00		$ -	$156.00
2020	Inspection	-	-	5	10	-	-	$ -	$ 100	$ 415	$ -	$ -	$ 515.00	-	-	10	-	-	-	$0	$200	$0	$0	$0	$ 200.00	$1,824.00	$ 23.00		$ -	$156.00
2021	Hydr. System	-	-	-	-	60	-	$ -	$ -	$ -	$2,115	$ -	$2,115.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 24.00		$ -	$156.00
2022	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 23.00		$ -	$156.00
2023	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00	Mgate 3	-	-	15	-	-	$0	$0	$623	$0	$0	$ 622.50	$1,824.00	$ 29.00		$ -	$156.00
2024	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 4 Repair	-	-	-	-	-	$0	$0	$300	$0	$0	$ 300.00	$1,824.00	$ 30.00		$ -	$156.00
2025	Mgate 4	-	-	-	15	-	-	$ -	$ -	$ 623	$ -	$ -	$ 622.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 28.00		$ -	$156.00
2026	MG 5 Repair	-	-	-	-	-	-	$ -	$ -	$ 300	$ -	$ -	$ 300.00	-	-	1	-	-	-	$0	$20	$0	$0	$0	$ 20.00	$1,824.00	$ 24.00		$ -	$156.00
2027	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00	Mgate 5	-	-	15	-	-	$0	$0	$623	$0	$0	$ 622.50	$1,824.00	$ 28.00		$ -	$156.00
2028	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 1 Repair	-	-	-	-	-	$0	$0	$300	$0	$0	$ 300.00	$1,824.00	$ 30.00		$ -	$156.00
2029	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 29.00		$ -	$156.00
2030	Mgate 1	-	-	5	15	-	-	$ -	$ 100	$ 623	$ -	$ -	$ 722.50	Hydr & Elec System	-	-	-	60	-	$0	$0	$0	$3,642	$0	$ 3,642.00	$1,824.00	$ 14.00		$ -	$156.00
2031	MG 2 Repair	-	-	-	-	-	-	$ -	$ -	$ 300	$ -	$ -	$ 300.00	Culvert Valves	-	-	-	60	-	$0	$0	$0	$1,400	$0	$ 1,400.00	$1,824.00	$ 19.00		$ -	$156.00
2032	Culvert Valves	90	-	-	-	-	-	$ -	$ -	$ -	$2,800	$ -	$2,800.00	-	-	3	-	-	-	$0	$60	$0	$0	$0	$ 60.00	$1,824.00	$ 17.00		$ -	$156.00
2033	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 18.00		$ -	$156.00
2034	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00	Inspection	-	-	10	-	-	$0	$0	$415	$0	$0	$ 415.00	$1,824.00	$ 15.00		$ -	$156.00
2035	Inspection	-	-	-	10	-	-	$ -	$ -	$ 415	$ -	$ -	$ 415.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 17.00		$ -	$156.00
2036	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 18.00		$ -	$156.00
2037	-	-	-	10	-	-	-	$ -	$ 200	$ -	$ -	$ -	$ 200.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 21.00		$ -	$156.00
2038	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	5	-	-	-	$0	$100	$0	$0	$0	$ 100.00	$1,824.00	$ 19.00		$ -	$156.00
2039	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Mgate 2	-	-	15	-	-	$0	$0	$623	$0	$0	$ 622.50	$1,824.00	$ 20.00		$ -	$156.00
2040	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00	MG 3 Paint	-	-	-	-	-	$0	$0	$1,050	$0	$0	$ 1,050.00	$1,824.00	$ 19.00		$ -	$156.00
2041	Mgate 3	-	-	-	15	-	-	$ -	$ -	$ 623	$ -	$ -	$ 622.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 18.00		$ -	$156.00
2042	MG 4 Paint	-	-	-	-	-	-	$ -	$ -	$1,050	$ -	$ -	$1,050.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 21.00		$ -	$156.00
2043	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 20.00		$ -	$156.00
2044	-	-	-	10	-	-	-	$ -	$ 200	$ -	$ -	$ -	$ 200.00	Mgate 4	-	-	15	-	-	$0	$0	$623	$0	$0	$ 622.50	$1,824.00	$ 20.00		$ -	$156.00
2045	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 5 Paint	-	5	-	-	-	$0	$100	$1,350	$0	$0	$ 1,450.00	$1,824.00	$ 21.00		$ -	$156.00
2046	Mgate 5	-	-	-	15	-	-	$ -	$ -	$ 623	$ -	$ -	$ 622.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 22.00		$ -	$156.00
2047	MG 1 Paint	-	-	5	-	-	-	$ -	$ 100	$1,350	$ -	$ -	$1,450.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 23.00		$ -	$156.00
2048	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 23.00		$ -	$156.00
2049	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Inspection	-	-	10	-	-	$0	$0	$415	$0	$0	$ 415.00	$1,824.00	$ 24.00		$ -	$156.00
2050	-	-	-	1	-	-	-	$ -	$ 20	$ -	$ -	$ -	$ 20.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 25.00		$8,250.00	$156.00
2051	Inspection	-	-	-	10	-	-	$ -	$ -	$ 415	$ -	$ -	$ 415.00	-	-	1	-	-	-	$0	$20	$0	$0	$0	$ 20.00	$1,824.00	$ 22.00		$8,250.00	$156.00
2052	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 27.00		$8,250.00	$156.00
2053	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 30.00		$2,750.00	$156.00
2054	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00	Mgate 1	-	-	15	-	-	$0	$0	$623	$0	$0	$ 622.50	$1,824.00	$ 42.00		$ -	$156.00
2055	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 2 Paint	-	-	-	-	-	$0	$0	$1,350	$0	$0	$ 1,350.00	$1,824.00	$ 36.00		$ -	$156.00
2056	Mgate 2	-	-	-	15	-	-	$ -	$ -	$ 623	$ -	$ -	$ 622.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 44.00		$ -	$156.00
2057	MG 3 Repair	-	-	3	-	-	-	$ -	$ 60	$ 300	$ -	$ -	$ 360.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$1,824.00	$ 55.00		$ -	$156.00
2058	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	10	-	-	-	$0	$200	$0	$0	$0	$ 200.00	$1,824.00	$ 55.00		$ -	$156.00
2059	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Mgate 3	-	-	15	-	-	$0	$0	$623	$0	$0	$ 622.50	$1,824.00	$ 60.00		$ -	$156.00
2060	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 4 Repair	-	-	-	-	-	$0	$0	$300	$0	$0	$ 300.00	$1,824.00	$ -		$ -	$156.00

		Project Life 2008 to 2058		Pre-Project Life 2000 to 2007	
Year	n	factor	PW	factor	PW
2000	(7.0)	0.0000	$ -	1.5668	$ 3,997
2001	(6.0)	0.0000	$ -	1.4694	$ 3,076
2002	(5.0)	0.0000	$ -	1.3781	$ 2,934
2003	(4.0)	0.0000	$ -	1.2925	$ 2,626
2004	(3.0)	0.0000	$ -	1.2122	$ 3,104
2005	(2.0)	0.0000	$ -	1.1369	$ 2,917
2006	(1.0)	0.0000	$ -	1.0663	$ 94,406
2007	0.0	0.0000	$ -	1.0000	$ 91,694
2008	1.0	0.9379	$ 1,916	0.0000	$ -
2009	2.0	0.8796	$ 1,799	0.0000	$ -
2010	3.0	0.8249	$ 3,295	0.0000	$ -
2011	4.0	0.7737	$ 2,858	0.0000	$ -
2012	5.0	0.7256	$ 1,490	0.0000	$ -
2013	6.0	0.6805	$ 2,599	0.0000	$ -
2014	7.0	0.6382	$ 2,379	0.0000	$ -
2015	8.0	0.5986	$ 2,278	0.0000	$ -
2016	9.0	0.5614	$ 2,082	0.0000	$ -
2017	10.0	0.5265	$ 1,190	0.0000	$ -
2018	11.0	0.4938	$ 1,226	0.0000	$ -
2019	12.0	0.4631	$ 958	0.0000	$ -
2020	13.0	0.4343	$ 1,181	0.0000	$ -
2021	14.0	0.4074	$ 1,678	0.0000	$ -
2022	15.0	0.3820	$ 765	0.0000	$ -
2023	16.0	0.3583	$ 964	0.0000	$ -
2024	17.0	0.3360	$ 776	0.0000	$ -
2025	18.0	0.3152	$ 829	0.0000	$ -
2026	19.0	0.2956	$ 687	0.0000	$ -
2027	20.0	0.2772	$ 735	0.0000	$ -
2028	21.0	0.2600	$ 601	0.0000	$ -
2029	22.0	0.2438	$ 490	0.0000	$ -
2030	23.0	0.2287	$ 1,454	0.0000	$ -
2031	24.0	0.2145	$ 793	0.0000	$ -
2032	25.0	0.2012	$ 977	0.0000	$ -
2033	26.0	0.1887	$ 377	0.0000	$ -
2034	27.0	0.1769	$ 430	0.0000	$ -
2035	28.0	0.1659	$ 400	0.0000	$ -
2036	29.0	0.1556	$ 311	0.0000	$ -
2037	30.0	0.1460	$ 321	0.0000	$ -
2038	31.0	0.1369	$ 287	0.0000	$ -
2039	32.0	0.1284	$ 337	0.0000	$ -
2040	33.0	0.1204	$ 374	0.0000	$ -
2041	34.0	0.1129	$ 296	0.0000	$ -
2042	35.0	0.1059	$ 323	0.0000	$ -
2043	36.0	0.0993	$ 199	0.0000	$ -
2044	37.0	0.0932	$ 263	0.0000	$ -
2045	38.0	0.0874	$ 302	0.0000	$ -
2046	39.0	0.0819	$ 215	0.0000	$ -
2047	40.0	0.0768	$ 265	0.0000	$ -
2048	41.0	0.0721	$ 144	0.0000	$ -
2049	42.0	0.0676	$ 164	0.0000	$ -
2050	43.0	0.0634	$ 651	0.0000	$ -
2051	44.0	0.0595	$ 635	0.0000	$ -
2052	45.0	0.0558	$ 572	0.0000	$ -
2053	46.0	0.0523	$ 249	0.0000	$ -
2054	47.0	0.0490	$ 133	0.0000	$ -
2055	48.0	0.0460	$ 155	0.0000	$ -
2056	49.0	0.0431	$ 114	0.0000	$ -
2057	50.0	0.0405	$ 97	0.0000	$ -
2058	51.0	0.0379	$ 85	0.0000	$ -
2059	52.0	0.0000		0.0000	
2060	53.0	0.0000		0.0000	

Life

Total PW
$ 43,699.02

AAEC
$3,009.26

Pre-Life

Total PW
$ 204,754.42

AAEC
$14,100.05

Atachment 4 - Table 4

WOPC Costs by Category and Year -- Greenup

Main Chamber Closures and Costs

Year	Main. Item	F/E 1/2-speed	Closure Days – Uncsch. Closures – Unsch. Main.	Closure Days – Uncsch. Closures – Random Minor	Closure Days – Scheduled Closures – Cyc. Main.	Closure Days – Scheduled Closures – Comp. Repl.	Closure Days – Scheduled Closures – Major Rehab.	Costs – Uncsch. Closures – Unsch. Main.	Costs – Uncsch. Closures – Random Minor	Costs – Scheduled Closures – Cyc. Main.	Costs – Scheduled Closures – Comp. Repl.	Costs – Scheduled Closures – Major Rehab.	Total Costs
2000	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00
2001	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2002	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2003	MGate-S	-	-	10	15	-	-	$ -	$ 210	$ 315	$ -	$ -	$ 525.00
2004	SMR (MG, EG)	-	-	-	-	-	90	$ -	$ -	$ -	$ -	$12,975	$12,975.00
2005	SMR (MG Only)	-	-	-	-	-	60	$ -	$ -	$ -	$ -	$ 6,150	$ 6,150.00
2006	CValve-P	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00
2007	CValve-Q	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00
2008	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2009	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2010	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00
2011	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2012	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2013	-	-	-	5	-	-	-	$ -	$ 105	$ -	$ -	$ -	$ 105.00
2014	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2015	MGate-S	-	-	-	15	-	-	$ -	$ -	$ 315	$ -	$ -	$ 315.00
2016	MGate-U	-	-	10	45	-	-	$ -	$ 210	$1,238	$ -	$ -	$ 1,447.50
2017	CValve-P	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00
2018	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2019	CValve-Q	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00
2020	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2021	MGate-V	-	-	-	45	-	-	$ -	$ -	$1,238	$ -	$ -	$ 1,237.50
2022	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2023	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2024	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2025	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2026	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2027	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00
2028	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2029	MGate-S	-	-	-	15	-	-	$ -	$ -	$ 315	$ -	$ -	$ 315.00
2030	MGate-U	-	-	10	45	-	-	$ -	$ 210	$1,238	$ -	$ -	$ 1,447.50
2031	CValve-P	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00
2032	CValve-Q	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00
2033	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2034	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2035	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2036	MGate-V	-	-	-	45	-	-	$ -	$ -	$1,238	$ -	$ -	$ 1,237.50
2037	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00
2038	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00
2039	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00
2040	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2041	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00
2042	-	-	-	5	-	-	-	$ -	$ 105	$ -	$ -	$ -	$ 105.00
2043	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2044	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00
2045	MGate-S	-	-	-	15	-	-	$ -	$ -	$ 315	$ -	$ -	$ 315.00
2046	MGate-U	-	-	3	45	-	-	$ -	$ 60	$1,238	$ -	$ -	$ 1,297.50
2047	CValve-P	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00
2048	CValve-Q	45	-	10	-	-	-	$ -	$ 210	$ 990	$ -	$ -	$ 1,200.00
2049	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2050	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2051	MGate-V	-	-	-	45	-	-	$ -	$ -	$1,238	$ -	$ -	$ 1,237.50
2052	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2053	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2054	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00
2055	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2056	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2057	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2058	-	-	-	5	-	-	-	$ -	$ 105	$ -	$ -	$ -	$ 105.00
2059	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -
2060	MGate-S	-	-	-	15	-	-	$ -	$ -	$ 315	$ -	$ -	$ 315.00

Auxiliary Chamber Closures and Costs / Other Project Costs

Year	Main. Item	Closure Days – Uncsch. Closures – Unsch. Main.	Closure Days – Uncsch. Closures – Random Minor	Closure Days – Scheduled Closures – Cyc. Main.	Closure Days – Scheduled Closures – Comp. Repl.	Closure Days – Scheduled Closures – Major Rehab.	Costs – Uncsch. Closures – Unsch. Main.	Costs – Uncsch. Closures – Random Minor	Costs – Scheduled Closures – Cyc. Main.	Costs – Scheduled Closures – Comp. Repl.	Costs – Scheduled Closures – Major Rehab.	Total Costs	Annual O&M Costs	LCLM Costs – Repair	LCLM Costs – Trans. Delay	Dam Cost	Dredge Costs
2000	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 44.00	$ 201.00	$ -	$133.00
2001	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 45.00	$ 243.00	$ -	$133.00
2002	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 52.00	$ 294.00	$ -	$133.00
2003	MGate-U	-	-	45	-	-	$0	$0	$1,238	$0	$0	$1,237.50	$2,080.00	$ 75.00	$ 576.00	$ -	$133.00
2004	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 50.00	$ 310.00	$ -	$133.00
2005	SMR (EG)	-	3	-	-	90	$0	$60	$0	$0	$6,475	$6,535.00	$2,080.00	$ 46.00	$ 313.00	$ -	$133.00
2006	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 49.00	$ 358.00	$ -	$133.00
2007	CValve-R	-	-	45	-	-	$0	$0	$945	$0	$0	$ 945.00	$2,080.00	$ 51.00	$ 402.00	$ -	$133.00
2008	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 50.00	$ 403.00	$ -	$133.00
2009	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 56.00	$ 508.00	$ -	$133.00
2010	MGate-V	-	-	45	-	-	$0	$0	$1,238	$0	$0	$1,237.50	$2,080.00	$ 54.00	$ 495.00	$ -	$133.00
2011	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 56.00	$ 549.00	$ -	$133.00
2012	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 57.00	$ 569.00	$ -	$133.00
2013	MGate-T	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$2,080.00	$ 57.00	$ 658.00	$ -	$133.00
2014	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 58.00	$ 647.00	$ -	$133.00
2015	-	-	3	-	-	-	$0	$60	$0	$0	$0	$ 60.00	$2,080.00	$ 60.00	$ 702.00	$ -	$133.00
2016	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 57.00	$ 685.00	$ -	$133.00
2017	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 61.00	$ 727.00	$ -	$133.00
2018	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 57.00	$ 797.00	$ -	$133.00
2019	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 60.00	$ 865.00	$ -	$133.00
2020	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 64.00	$ 948.00	$ -	$133.00
2021	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 62.00	$ 903.00	$ -	$133.00
2022	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 66.00	$ 1,051.00	$ -	$133.00
2023	MGate-U	-	-	45	-	-	$0	$0	$1,238	$0	$0	$1,237.50	$2,080.00	$ 68.00	$ 1,029.00	$ -	$133.00
2024	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 72.00	$ 1,173.00	$ -	$133.00
2025	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 66.00	$ 1,117.00	$ -	$133.00
2026	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 72.00	$ 1,208.00	$ -	$133.00
2027	CValve-R	-	5	45	-	-	$0	$105	$945	$0	$0	$1,050.00	$2,080.00	$ 69.00	$ 1,260.00	$ -	$133.00
2028	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 73.00	$ 1,402.00	$ -	$133.00
2029	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 70.00	$ 1,329.00	$ -	$133.00
2030	SMR (MG, Elec)	-	-	-	-	60	$0	$0	$0	$0	$9,475	$9,475.00	$2,080.00	$ 72.00	$ 1,421.00	$ -	$133.00
2031	SMR (MG Only)	-	10	-	-	60	$0	$210	$0	$0	$6,150	$6,360.00	$2,080.00	$ 75.00	$ 1,674.00	$ -	$133.00
2032	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 78.00	$ 1,732.00	$ -	$133.00
2033	MGate-T	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$2,080.00	$ 79.00	$ 1,772.00	$ -	$133.00
2034	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 77.00	$ 1,855.00	$ -	$133.00
2035	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 75.00	$ 1,897.00	$ -	$133.00
2036	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 78.00	$ 2,123.00	$ -	$133.00
2037	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 83.00	$ 2,316.00	$ -	$133.00
2038	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 89.00	$ 2,678.00	$ -	$133.00
2039	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 85.00	$ 2,607.00	$ -	$133.00
2040	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 90.00	$ 2,969.00	$ -	$133.00
2041	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 91.00	$ 3,329.00	$ -	$133.00
2042	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 91.00	$ 3,243.00	$ -	$133.00
2043	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 98.00	$ 3,602.00	$ 8,250	$133.00
2044	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 95.00	$ 3,529.00	$ 8,250	$133.00
2045	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 97.00	$ 3,875.00	$ 8,250	$133.00
2046	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 99.00	$ 4,439.00	$ -	$133.00
2047	CValve-R	-	-	45	-	-	$0	$0	$945	$0	$0	$ 945.00	$2,080.00	$ 100.00	$ 4,378.00	$ -	$133.00
2048	MGate-U	-	-	45	-	-	$0	$0	$1,238	$0	$0	$1,237.50	$2,080.00	$ 101.00	$ 4,612.00	$ -	$133.00
2049	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 102.00	$ 4,912.00	$ -	$133.00
2050	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 101.00	$ 5,382.00	$ -	$133.00
2051	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 105.00	$ 5,603.00	$ -	$133.00
2052	MGate-V	-	-	45	-	-	$0	$0	$1,238	$0	$0	$1,237.50	$2,080.00	$ 108.00	$ 6,580.00	$ -	$133.00
2053	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 116.00	$ 7,398.00	$ -	$133.00
2054	MGate-T	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$2,080.00	$ 111.00	$ 7,673.00	$ -	$133.00
2055	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 118.00	$ 9,158.00	$ -	$133.00
2056	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$2,080.00	$ 115.00	$ 9,779.00	$ -	$133.00
2057	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 122.00	$10,700.00	$ -	$133.00
2058	-	-	5	-	-	-	$0	$105	$0	$0	$0	$ 105.00	$2,080.00	$ 125.00	$12,251.00	$ -	$133.00
2059	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ 125.00	$12,634.00	$ -	$133.00
2060	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$2,080.00	$ -	$ -	$ -	$133.00

Project Life 2008 to 2058 / **Pre-Proiect Life 2000 to 2007**

Year	n	Project Life factor	Project Life PW	Pre-Project Life factor	Pre-Project Life PW
2000	(7.0)	0.0000	$ -	1.5668	$ 4,180
2001	(6.0)	0.0000	$ -	1.4694	$ 3,675
2002	(5.0)	0.0000	$ -	1.3781	$ 3,816
2003	(4.0)	0.0000	$ -	1.2925	$ 5,980
2004	(3.0)	0.0000	$ -	1.2122	$ 18,847
2005	(2.0)	0.0000	$ -	1.1369	$ 17,346
2006	(1.0)	0.0000	$ -	1.0663	$ 3,849
2007	0.0	0.0000	$ -	1.0000	$ 4,601
2008	1.0	0.9379	$ 2,500	0.0000	$ -
2009	2.0	0.8796	$ 2,443	0.0000	$ -
2010	3.0	0.8249	$ 3,349	0.0000	$ -
2011	4.0	0.7737	$ 2,180	0.0000	$ -
2012	5.0	0.7256	$ 2,212	0.0000	$ -
2013	6.0	0.6805	$ 2,278	0.0000	$ -
2014	7.0	0.6382	$ 1,862	0.0000	$ -
2015	8.0	0.5986	$ 2,005	0.0000	$ -
2016	9.0	0.5614	$ 2,589	0.0000	$ -
2017	10.0	0.5265	$ 2,101	0.0000	$ -
2018	11.0	0.4938	$ 1,514	0.0000	$ -
2019	12.0	0.4631	$ 2,009	0.0000	$ -
2020	13.0	0.4343	$ 1,401	0.0000	$ -
2021	14.0	0.4074	$ 1,799	0.0000	$ -
2022	15.0	0.3820	$ 1,352	0.0000	$ -
2023	16.0	0.3583	$ 1,629	0.0000	$ -
2024	17.0	0.3360	$ 1,162	0.0000	$ -
2025	18.0	0.3152	$ 1,070	0.0000	$ -
2026	19.0	0.2956	$ 1,032	0.0000	$ -
2027	20.0	0.2772	$ 1,331	0.0000	$ -
2028	21.0	0.2600	$ 959	0.0000	$ -
2029	22.0	0.2438	$ 958	0.0000	$ -
2030	23.0	0.2287	$ 3,345	0.0000	$ -
2031	24.0	0.2145	$ 2,426	0.0000	$ -
2032	25.0	0.2012	$ 1,008	0.0000	$ -
2033	26.0	0.1887	$ 826	0.0000	$ -
2034	27.0	0.1769	$ 733	0.0000	$ -
2035	28.0	0.1659	$ 694	0.0000	$ -
2036	29.0	0.1556	$ 880	0.0000	$ -
2037	30.0	0.1460	$ 704	0.0000	$ -
2038	31.0	0.1369	$ 710	0.0000	$ -
2039	32.0	0.1284	$ 637	0.0000	$ -
2040	33.0	0.1204	$ 635	0.0000	$ -
2041	34.0	0.1129	$ 684	0.0000	$ -
2042	35.0	0.1059	$ 599	0.0000	$ -
2043	36.0	0.0993	$ 1,407	0.0000	$ -
2044	37.0	0.0932	$ 1,332	0.0000	$ -
2045	38.0	0.0874	$ 1,289	0.0000	$ -
2046	39.0	0.0819	$ 677	0.0000	$ -
2047	40.0	0.0768	$ 663	0.0000	$ -
2048	41.0	0.0721	$ 675	0.0000	$ -
2049	42.0	0.0676	$ 489	0.0000	$ -
2050	43.0	0.0634	$ 488	0.0000	$ -
2051	44.0	0.0595	$ 545	0.0000	$ -
2052	45.0	0.0558	$ 565	0.0000	$ -
2053	46.0	0.0523	$ 509	0.0000	$ -
2054	47.0	0.0490	$ 516	0.0000	$ -
2055	48.0	0.0460	$ 529	0.0000	$ -
2056	49.0	0.0431	$ 531	0.0000	$ -
2057	50.0	0.0405	$ 527	0.0000	$ -
2058	51.0	0.0379	$ 562	0.0000	$ -
2059	52.0	0.0000	$ -	0.0000	$ -
2060	53.0	0.0000	$ -	0.0000	$ -

Life

Total PW
$ 64,922.25

AAEC
$4,470.76

Pre-Life

Total PW
$ 62,294.31

AAEC
$4,289.79

Atachment 4 - Table 5

600' Extension in 2008 (w/qgco) Costs by Category and Year -- Greenup

	Main Chamber Closures and Costs													Auxiliary Chamber Closures and Costs												Other Project Costs				
			Closure Days					Costs							Closure Days					Costs										
			Uncsch. Closures		Scheduled Closures			Uncsch. Closures		Scheduled Closures					Uncsch. Closures		Scheduled Closures			Uncsch. Closures		Scheduled Closures				Annual	LCLM Costs			
Year	Main. Item	F/E 1/2-speed	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Total Costs	Main. Item	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Unsch. Main.	Random Minor	Cyc. Main.	Comp. Repl.	Major Rehab.	Total Costs	O&M Costs	Repair	Trans. Delay	Dam Cost	Dredge Costs
2000	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 44.00		$ -	$133.00
2001	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 45.00		$ -	$133.00
2002	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$ 2,080.00	$ 52.00		$ -	$133.00
2003	MG Repair	-	-	10	45	-	-	$ -	$ 210	$ 1,238	$ -	$ -	$ 1,447.50	Mgate U	-	-	45	-	-	$0	$0	$945	$0	$0	$ 945.00	$ 2,080.00	$ 75.00		$ -	$133.00
2004	CValve-P	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 50.00		$ -	$133.00
2005	CValve-Q	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	CValve-R	-	3	45	-	-	$0	$60	$945	$0	$0	$ 1,005.00	$ 2,080.00	$ 46.00		$ -	$133.00
2006	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Plan 3 - 600' ext	-	-	-	(2)	-	$0	$0	$0	$87,750	$0	$ 84,000.00	$ 2,080.00	$ 49.00		$ -	$133.00
2007	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Plan 3 - 600' ext	-	-	-	(1)	-	$0	$0	$0	$87,750	$0	$ 84,000.00	$ 2,080.00	$ 51.00		$ -	$133.00
2008	SMR (MG, EG)	-	-	-	-	-	90	$ -	$ -	$ -	$ -	$12,975	$12,975.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 50.00		$ -	$133.00
2009	SMR (MG)	-	-	3	-	-	60	$ -	$ 60	$ -	$ -	$ 6,150	$12,685.00	SMR (EG)	-	-	-	-	90	$0	$0	$0	$0	$6,775	$ 6,775.00	$ 2,080.00	$ 56.00		$ -	$133.00
2010	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 4 Paint	-	-	-	-	-	$0	$0	$1,650	$0	$0	$ 1,650.00	$ 2,080.00	$ 54.00		$ -	$133.00
2011	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MGate-T	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$ 2,080.00	$ 56.00		$ -	$133.00
2012	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$ 2,080.00	$ 57.00		$ -	$133.00
2013	-	-	-	5	-	-	-	$ -	$ 105	$ -	$ -	$ -	$ 105.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 57.00		$ -	$133.00
2014	MGate-S	-	-	-	15	-	-	$ -	$ -	$ 315	$ -	$ -	$ 315.00	Mgate Insp	-	-	10	-	-	$0	$0	$210	$0	$0	$ 210.00	$ 2,080.00	$ 58.00		$ -	$133.00
2015	Mgate 4	-	-	-	15	-	-	$ -	$ -	$ 413	$ -	$ -	$ 412.50	-	-	3	-	-	-	$0	$60	$0	$0	$0	$ 60.00	$ 2,080.00	$ 60.00		$ -	$133.00
2016	MG 6 Repair	-	-	10	-	-	-	$ -	$ 210	$ 300	$ -	$ -	$ 510.00	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$ 2,080.00	$ 57.00		$ -	$133.00
2017	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 61.00		$ -	$133.00
2018	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Mgate 6	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$ 2,080.00	$ 57.00		$ -	$133.00
2019	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 3 Repair	-	10	-	-	-	$0	$210	$1,650	$0	$0	$ 1,860.00	$ 2,080.00	$ 60.00		$ -	$133.00
2020	Mgate 3	-	-	-	15	-	-	$ -	$ -	$ 413	$ -	$ -	$ 412.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 64.00		$ -	$133.00
2021	MG 7 Repair	-	-	-	-	-	-	$ -	$ -	$ 300	$ -	$ -	$ 300.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 62.00		$ -	$133.00
2022	CValve-P	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$ 2,080.00	$ 66.00		$ -	$133.00
2023	CValve-Q	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 68.00		$ -	$133.00
2024	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Mgate 7	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$ 2,080.00	$ 72.00		$ -	$133.00
2025	Mgate Insp	-	-	-	10	-	-	$ -	$ -	$ 210	$ -	$ -	$ 210.00	MG 5 Repair	-	-	-	-	-	$0	$0	$300	$0	$0	$ 300.00	$ 2,080.00	$ 66.00		$ -	$133.00
2026	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 72.00		$ -	$133.00
2027	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00	CValve-R	-	5	45	-	-	$0	$105	$945	$0	$0	$ 1,050.00	$ 2,080.00	$ 69.00		$ -	$133.00
2028	MGate-S	-	-	-	15	-	-	$ -	$ -	$ 315	$ -	$ -	$ 315.00	MGate-T	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$ 2,080.00	$ 73.00		$ -	$133.00
2029	Mgate 5	-	-	-	15	-	-	$ -	$ -	$ 413	$ -	$ -	$ 412.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 70.00		$ -	$133.00
2030	MG 4 Hold only	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00	SMR (MG, Elec)	-	-	-	-	60	$0	$0	$0	$0	$8,975	$ 8,975.00	$ 2,080.00	$ 72.00		$ -	$133.00
2031	Mgate 8	Scrap MG3	-	-	15	-	-	$ -	$ -	$ 413	$ -	$ -	$ 412.50	SMR (MG Only)	-	10	-	-	60	$0	$210	$0	$0	$6,150	$ 6,360.00	$ 2,080.00	$ 75.00		$ -	$133.00
2032	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 6 Paint	-	-	-	-	-	$0	$0	$1,350	$0	$0	$ 1,350.00	$ 2,080.00	$ 78.00		$ -	$133.00
2033	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 79.00		$ -	$133.00
2034	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 77.00		$ -	$133.00
2035	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 75.00		$ -	$133.00
2036	CValve-Q	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 78.00		$ -	$133.00
2037	Mgate Insp	-	-	10	10	-	-	$ -	$ 210	$ 210	$ -	$ -	$ 420.00	Mgate Insp	-	-	10	-	-	$0	$0	$210	$0	$0	$ 210.00	$ 2,080.00	$ 83.00		$ -	$133.00
2038	CValve-P	45	-	10	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 89.00		$ -	$133.00
2039	-	-	-	3	-	-	-	$ -	$ 60	$ -	$ -	$ -	$ 60.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 85.00		$ -	$133.00
2040	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 90.00		$ -	$133.00
2041	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00	-	-	10	-	-	-	$0	$210	$0	$0	$0	$ 210.00	$ 2,080.00	$ 91.00		$ -	$133.00
2042	Mgate Insp	-	-	5	10	-	-	$ -	$ 105	$ 210	$ -	$ -	$ 315.00	Mgate 6	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$ 2,080.00	$ 91.00		$ -	$133.00
2043	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 7 Paint	-	-	-	-	-	$0	$0	$1,350	$0	$0	$ 1,350.00	$ 2,080.00	$ 98.00		$ 8,250.00	$133.00
2044	MGate-S	-	-	10	15	-	-	$ -	$ 210	$ 315	$ -	$ -	$ 525.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 95.00		$ 8,250.00	$133.00
2045	Mgate 7	-	-	-	15	-	-	$ -	$ -	$ 413	$ -	$ -	$ 412.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 97.00		$ 8,250.00	$133.00
2046	MG 5 Paint	-	-	3	-	-	-	$ -	$ 60	$ 1,350	$ -	$ -	$ 1,410.00	CValve-R	-	10	45	-	-	$0	$210	$945	$0	$0	$ 1,155.00	$ 2,080.00	$ 99.00		$ -	$133.00
2047	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Mgate 5	-	-	15	-	-	$0	$0	$413	$0	$0	$ 412.50	$ 2,080.00	$ 100.00		$ -	$133.00
2048	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	MG 9 Repair	-	-	-	-	-	$0	$0	$300	$0	$0	$ 300.00	$ 2,080.00	$ 101.00		$ -	$133.00
2049	Mgate 9	-	-	-	15	-	-	$ -	$ -	$ 413	$ -	$ -	$ 412.50	MGate-T	-	-	15	-	-	$0	$0	$315	$0	$0	$ 315.00	$ 2,080.00	$ 102.00		$ -	$133.00
2050	MG 8 Repair	-	-	-	-	-	-	$ -	$ -	$ 300	$ -	$ -	$ 300.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 101.00		$ -	$133.00
2051	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 105.00		$ -	$133.00
2052	CValve-Q	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 108.00		$ -	$133.00
2053	CValve-P	45	-	-	-	-	-	$ -	$ -	$ 990	$ -	$ -	$ 990.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 116.00		$ -	$133.00
2054	-	-	-	10	-	-	-	$ -	$ 210	$ -	$ -	$ -	$ 210.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 111.00		$ -	$133.00
2055	Mgate Insp	-	-	-	10	-	-	$ -	$ -	$ 210	$ -	$ -	$ 210.00	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 118.00		$ -	$133.00
2056	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	Mgate Insp	-	10	10	-	-	$0	$210	$210	$0	$0	$ 420.00	$ 2,080.00	$ 115.00		$ -	$133.00
2057	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 122.00		$ -	$133.00
2058	-	-	-	5	-	-	-	$ -	$ 105	$ -	$ -	$ -	$ 105.00	-	-	5	-	-	-	$0	$105	$0	$0	$0	$ 105.00	$ 2,080.00	$ 125.00		$ -	$133.00
2059	-	-	-	-	-	-	-	$ -	$ -	$ -	$ -	$ -	$ -	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ 125.00		$ -	$133.00
2060	Mgate 8	-	-	-	15	-	-	$ -	$ -	$ 413	$ -	$ -	$ 412.50	-	-	-	-	-	-	$0	$0	$0	$0	$0	$ -	$ 2,080.00	$ -		$ -	$133.00

Project Life

2008 to 2058

Pre-

Proiect Life
2000 to 2007

Year	n	factor	PW	factor	PW
2000	(7.0)	0.0000	$ -	1.5668	$ 3,865
2001	(6.0)	0.0000	$ -	1.4694	$ 3,318
2002	(5.0)	0.0000	$ -	1.3781	$ 3,411
2003	(4.0)	0.0000	$ -	1.2925	$ 6,050
2004	(3.0)	0.0000	$ -	1.2122	$ 3,943
2005	(2.0)	0.0000	$ -	1.1369	$ 4,836
2006	(1.0)	0.0000	$ -	1.0663	$ 95,975
2007	0.0	0.0000	$ -	1.0000	$ 90,014
2008	1.0	0.9379	$ 14,291	0.0000	$ -
2009	2.0	0.8796	$ 13,417	0.0000	$ -
2010	3.0	0.8249	$ 3,231	0.0000	$ -
2011	4.0	0.7737	$ 1,999	0.0000	$ -
2012	5.0	0.7256	$ 1,800	0.0000	$ -
2013	6.0	0.6805	$ 1,616	0.0000	$ -
2014	7.0	0.6382	$ 1,785	0.0000	$ -
2015	8.0	0.5986	$ 1,643	0.0000	$ -
2016	9.0	0.5614	$ 1,679	0.0000	$ -
2017	10.0	0.5265	$ 1,197	0.0000	$ -
2018	11.0	0.4938	$ 1,276	0.0000	$ -
2019	12.0	0.4631	$ 1,914	0.0000	$ -
2020	13.0	0.4343	$ 1,168	0.0000	$ -
2021	14.0	0.4074	$ 1,049	0.0000	$ -
2022	15.0	0.3820	$ 1,329	0.0000	$ -
2023	16.0	0.3583	$ 1,172	0.0000	$ -
2024	17.0	0.3360	$ 874	0.0000	$ -
2025	18.0	0.3152	$ 879	0.0000	$ -
2026	19.0	0.2956	$ 675	0.0000	$ -
2027	20.0	0.2772	$ 982	0.0000	$ -
2028	21.0	0.2600	$ 758	0.0000	$ -
2029	22.0	0.2438	$ 657	0.0000	$ -
2030	23.0	0.2287	$ 2,623	0.0000	$ -
2031	24.0	0.2145	$ 1,943	0.0000	$ -
2032	25.0	0.2012	$ 732	0.0000	$ -
2033	26.0	0.1887	$ 432	0.0000	$ -
2034	27.0	0.1769	$ 405	0.0000	$ -
2035	28.0	0.1659	$ 380	0.0000	$ -
2036	29.0	0.1556	$ 511	0.0000	$ -
2037	30.0	0.1460	$ 427	0.0000	$ -
2038	31.0	0.1369	$ 451	0.0000	$ -
2039	32.0	0.1284	$ 303	0.0000	$ -
2040	33.0	0.1204	$ 277	0.0000	$ -
2041	34.0	0.1129	$ 308	0.0000	$ -
2042	35.0	0.1059	$ 311	0.0000	$ -
2043	36.0	0.0993	$ 1,183	0.0000	$ -
2044	37.0	0.0932	$ 1,032	0.0000	$ -
2045	38.0	0.0874	$ 959	0.0000	$ -
2046	39.0	0.0819	$ 400	0.0000	$ -
2047	40.0	0.0768	$ 209	0.0000	$ -
2048	41.0	0.0721	$ 188	0.0000	$ -
2049	42.0	0.0676	$ 206	0.0000	$ -
2050	43.0	0.0634	$ 166	0.0000	$ -
2051	44.0	0.0595	$ 150	0.0000	$ -
2052	45.0	0.0558	$ 185	0.0000	$ -
2053	46.0	0.0523	$ 174	0.0000	$ -
2054	47.0	0.0490	$ 124	0.0000	$ -
2055	48.0	0.0460	$ 117	0.0000	$ -
2056	49.0	0.0431	$ 119	0.0000	$ -
2057	50.0	0.0405	$ 94	0.0000	$ -
2058	51.0	0.0379	$ 97	0.0000	$ -
2059	52.0	0.0000	$ -	0.0000	$ -
2060	53.0	0.0000	$ -	0.0000	$ -

Life

Total PW
$ 69,897.96

AAEC
$4,813.40

Pre-Life

Total PW
$ 211,412.78

AAEC
$14,558.56

ATTACHMENT 5

TRANSPORTATION RATES

5.1 GENERAL

This report documents and explains the methods used to update the Ohio River navigation system's (ORS) transportation rate matrix to a 1999 price level. The rate matrix estimates transportation cost savings for barge shipments on the ORS. The difference between the water-routing cost and the least-cost overland route is the transportation savings enjoyed by users of the system. The transportation rate matrix is 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 of the ORS.

In 1997, transportation rates and costs were estimated, based on a detailed rate study using a sample of 1990 ORS barge movements. Transportation rate specialists at the Tennessee Valley Authority (TVA) measured transportation rates and supplemental costs for the sample of commodity movements using a combination of shipper surveys, costing models, and Waybill data. TVA estimates rail rates with a model that uses actual Waybill parameters thus minimizing error and variability. For the waterway movements, a 5 percent contingency is added to the estimated barge rate in order to obtain a more conservative estimate. TVA estimates that this reduces transportation savings by a few pennies to a nickel per ton.

The Navigation Center accounts for uncertainty when estimating transportation rates for the unsampled waterway movements. At the commodity group level, the sample movement's transportation leg rates to and from line-haul points (barge dock or railhead) and the movement's loading/unloading charges are fit to probability distributions. Also at the commodity group level, regression equations are developed from the sample line-haul rate data. The regression equations assume line-haul rate a function of freight (ton-miles). The sample data, described in probabilistic terms, are used to estimate the unsampled movements. The transportation rate matrix is a combination of measured sample movements and estimated unsampled movements. Sources of error in this methodology include sampling, measuring and modeling. Attempts were made to minimize these errors via statistical random sampling at a 95 percent confidence level **(Section 7.3.4)**, adding a 5 percent contingency to barge rates to obtain a more conservative estimate, and utilizing statistically significant regression equations with standard errors ranging from .0001 to .0009.

For purposes of the benefit analysis in the ORMSS, the basin-wide rate matrix was updated to a 1999 price level. To accomplish this, the sample of waterborne commerce movements rated in 1997 was re-rated in 1999 and indices were developed to apply to the entire rate matrix. The indexing process is independent of the rate estimating methodology that describes sample rate data in probabilistic terms. Indexing results from a strict comparison of 1999 sample rate data relative to 1997 rate data at the movement level. Tonnage weighting to develop commodity group level indices aggregates movement level indices. Coal is aggregated based on origin to more accurately capture transportation legs to the river.

The most important goal of indexing is to capture any changes in rate structure that are likely to remain in the long run (over a project's life of 50 years). The rate analysts from TVA made every attempt to purge the data of anomalous or transitory influences and develop rates that portray normal market conditions. A full description of TVA's methods of research and rate construction, and supporting assumptions can be found in the LRD Navigation Center.

5.2 THE 1997 RATED SAMPLE

For rate analysis, a commodity movement is broken into three distinct parts: 1) leg to/from the ultimate origin/destination, 2) modal line-haul, and 3) accessorial (loading/unloading/transloading) charges. The overall rate is the sum of these three components. **Table 5-1** shows tonnage weighted average summary statistics from the 1997 rate sample. Overall, average savings per ton were estimated at $8.46. Waterway savings are driven by the lower barge line-haul rate.

TABLE 5-1
1997 Sample Summary Statistics

1997		Water Rate per Ton			Land Rate per Ton		
Commodity/Origin	**SPT**	**Barge LH**	**Access**	**Legs**	**Rail LH**	**Access**	**Legs**
Coal							
Elsewhere	$14.95	$5.75	$4.01	$4.65	$26.07	$3.31	$2.12
Upper Ohio	$6.58	$1.64	$3.00	$0.87	$8.77	$2.41	$1.07
Middle Ohio	$10.60	$3.04	$3.42	$5.29	$19.34	$2.87	$0.33
Lower Ohio	$7.72	$3.83	$3.44	$4.30	$14.07	$3.31	$1.96
Big Sandy	$11.45	$3.69	$4.13	$5.41	$18.59	$3.75	$2.10
Kanawha	$10.08	$5.71	$4.33	$4.77	$18.90	$4.10	$2.75
Monongahela	$3.87	$2.08	$3.42	$1.76	$7.98	$2.41	$0.58
Tennessee	$5.77	$4.13	$3.66	$6.04	$12.84	$3.15	$1.68
All Coal	$7.50	$3.35	$3.52	$3.67	$13.46	$3.09	$1.51
Petrol Prods	$7.94	$5.76	$1.52	$0.07	$13.38	$2.26	$0.12
Aggregates	$7.70	$2.78	$2.27	$1.52	$8.02	$3.39	$2.50
Grain	$7.95	$6.68	$4.16	$2.03	$14.09	$3.83	$0.85
Chemical	$21.27	$13.37	$2.65	$0.63	$40.81	$2.99	$0.57
Ores & Minerals	$26.46	$8.12	$3.78	$0.90	$32.33	$4.51	$0.66
Iron & Steel	$16.67	$7.70	$5.23	$4.33	$23.33	$5.68	$1.90
All Other	$10.97	$4.72	$3.51	$0.64	$13.57	$3.80	$1.48
All Commodities	$8.46	$3.79	$3.30	$3.01	$13.69	$3.20	$1.54

5.3 THE 1999 SAMPLE UPDATE

The same commodity movements rated in 1997 were re-rated in FY 1999. To improve the predictive value of the sample and more accurately adjust rates from a 1997 price level to a 1999 price level, it was deemed necessary to remove some movements from the rated sample. Movements that no longer existed or were no longer economical were deleted. Movements that, in the opinion of the rate specialists reflected short-run aggressive marketing activities to capture traffic and were unlikely to continue in the long run were also deleted. In all, 166 movements were deleted from both sample rate data sets (sample size was 1,619). The goal of the rate was to construct reliable indices using rate data that best reflected long-term rate changes for existing movements.

Table 5-2 shows the 1999 sample rate statistics. Overall, the tonnage weighted savings per ton for the sample has reduced slightly. This is because, in the FY99 update, two notable situations have emerged with respect to long-term cost efficiencies of rail transportation. First, the mergers of 1996, 1997, and 1998 have been completed. The result of these mergers has been the decrease in variable cost of the surviving carrier and the decrease in the rate structure, percent of variable cost, to reflect the surviving carrier's historic commodity rate levels. Second, the rail mode is gaining long-run efficiency through the continued deployment of larger, lighter

rail cars and the installation of heavier track capacity. More detail on these important changes are documented in the LRD Navigation Center.

TABLE 5-2
1999 Sample Summary Statistics

1999		Water Rate per Ton			Land Rate per Ton		
Commodity/Origin	**SPT**	**Barge LH**	**Access**	**Legs**	**Rail LH**	**Access**	**Legs**
Coal							
Elsewhere	$ 11.75	$ 6.06	$ 3.63	$ 4.62	$ 24.58	$ 3.49	$ 2.12
Upper Ohio	$ 6.71	$ 1.67	$ 3.00	$ 0.91	$ 8.81	$ 2.41	$ 1.07
Middle Ohio	$ 10.30	$ 3.14	$ 3.42	$ 5.57	$ 19.24	$ 2.87	$ 0.33
Lower Ohio	$ 7.49	$ 3.87	$ 3.44	$ 4.23	$ 13.75	$ 3.32	$ 1.96
Big Sandy	$ 8.94	$ 3.65	$ 4.13	$ 5.41	$ 18.57	$ 3.75	$ 2.10
Kanawha	$ 10.61	$ 5.54	$ 4.33	$ 4.86	$ 18.42	$ 4.10	$ 2.82
Monongahela	$ 3.58	$ 2.03	$ 3.43	$ 1.77	$ 7.82	$ 2.41	$ 0.58
Tennessee	$ 4.61	$ 3.93	$ 3.67	$ 5.85	$ 12.58	$ 3.19	$ 1.73
All Coal	$ 7.20	$ 3.34	$ 3.53	$ 3.68	$ 13.24	$ 3.09	$ 1.52
Petrol Prods	$ 7.93	$ 5.55	$ 1.52	$ 0.07	$ 12.59	$ 2.31	$ 0.12
Aggregates	$ 6.98	$ 2.79	$ 2.34	$ 1.46	$ 7.68	$ 3.48	$ 2.40
Grain	$ 5.66	$ 6.65	$ 4.23	$ 1.97	$ 13.76	$ 3.90	$ 0.85
Chemical	$ 27.98	$ 13.28	$ 2.66	$ 0.65	$ 40.99	$ 2.99	$ 0.58
Ores & Minerals	$ 22.64	$ 8.45	$ 3.78	$ 0.88	$ 30.59	$ 4.51	$ 0.66
Iron & Steel	$ 13.01	$ 7.86	$ 5.42	$ 4.17	$ 23.18	$ 5.67	$ 1.88
All Other	$ 9.44	$ 4.86	$ 3.46	$ 0.64	$ 13.12	$ 3.80	$ 1.48
All Commodities	$ 7.96	$ 3.78	$ 3.31	$ 3.00	$ 13.38	$ 3.22	$ 1.54

5.4 RATE INDICES

The transportation rate indices used to update the 1997 rate matrix are shown in **Table 5-3**. They were constructed by dividing the per ton component values in Table 2 by the values in Table 1. Variation in component cost ranged from –2.2 percent for rail line-haul to +0.59 percent for overland accessorial charges. This not inconsistent with railroads lower operating costs after merger and restructuring. The indices were applied to the ORS rate matrix to update it to a 1999 price level. Overall, the indices show waterway costs have remained fairly flat and the overland route shows a slight cost reduction due to rails' slightly more efficient cost structure.

TABLE 5-3
FY99 Transportation Rate Indices

Ratio of 1999 to 1997 rates							
		Water Indices			Land Indices		
Group	Comm/Origin	Barge LH	Access	Legs	Rail LH	Access	Legs
1	**Coal**						
	Elsewhere	1.052977	0.905126	0.993916	0.942837	1.054435	0.997987
	Upper Ohio	1.019399	1.000000	1.044511	1.003750	1.000000	1.000000
	Middle Ohio	1.033059	1.000000	1.052920	0.994960	1.000000	1.000000
	Lower Ohio	1.009147	1.000000	0.984055	0.977118	1.002505	1.002296
	Big Sandy	0.989018	0.999770	1.000517	0.998945	0.999487	1.000003
	Kanawha	0.970472	1.000000	1.018222	0.974962	1.000022	1.022657
	Monongahela	0.976812	1.003624	1.004467	0.979285	0.999892	1.002005
	Tennessee	0.951857	1.000250	0.968206	0.979687	1.011368	1.032987
	All Coal	0.996439	1.000639	1.001841	0.983508	1.001505	1.007245
2	**Petrol Prods**	0.964196	1.000000	1.000000	0.940876	1.021361	1.000000
3	**Aggregates**	1.003973	1.027822	0.959098	0.957504	1.025622	0.961581
4	**Grain**	0.995643	1.017231	0.968154	0.976593	1.018657	1.000000
5	**Chemical**	0.992964	1.003551	1.018747	1.004415	1.000213	1.020737
6	**Ores & Minerals**	1.040920	1.000000	0.979153	0.946269	1.000000	1.000000
7	**Iron & Steel**	1.020882	1.035795	0.964994	0.993734	0.998009	0.993340
8	**All Other**	1.029703	0.986834	0.991901	0.966750	1.000410	1.000450
	All Commodities	0.999346	1.004035	0.997335	0.977403	1.005858	0.996630

5.5 THE FY99 MATRIX

The sample derived rate indices were applied to the population of movements to produce the updated rate matrix. The transportation rate matrix used in the Tow Cost Model (TCM) contains three pieces of rate information. They are 1) the barge line-haul rate, 2) the overall waterway rate, and 3) the least-cost overland rate. **Table 5-4** compares the 1997 and 1999 transportation rate matrices.

TABLE 5-4
Comparison of Rate Matrices

Group	Mean Barge Line-Haul Rates 1997	Mean Barge Line-Haul Rates 1999	% Change
Coal	3.38	3.37	-0.4%
Petrol	9.41	9.07	-3.6%
Aggregates	3.30	3.31	0.4%
Grains	6.02	6.00	-0.4%
Chemicals	15.26	15.15	-0.7%
Ores & Minerals	7.27	7.57	4.1%
Iron & Steel	6.24	6.37	2.1%
Other	6.20	6.39	3.0%
Total	4.57	4.55	-0.3%

Group	Mean Water Routing Rates 1997	Mean Water Routing Rates 1999	% Change
Coal	12.29	12.26	-0.3%
Petrol	16.06	15.72	-2.1%
Aggregates	7.92	7.90	-0.3%
Grains	12.87	12.79	-0.7%
Chemicals	22.05	22.02	-0.2%
Ores & Minerals	14.08	14.31	1.7%
Iron & Steel	21.89	21.99	0.5%
Other	16.93	17.00	0.4%
Total	12.78	12.74	-0.3%

Group	Mean Overland Routing Rates 1997	Mean Overland Routing Rates 1999	% Change
Coal	19.46	19.23	-1.2%
Petrol	25.04	24.10	-3.7%
Aggregates	15.35	14.93	-2.7%
Grains	20.84	20.52	-1.5%
Chemicals	43.94	44.16	0.5%
Ores & Minerals	42.12	40.28	-4.4%
Iron & Steel	31.03	30.86	-0.5%
Other	30.44	29.78	-2.2%
Total	21.45	21.11	-1.6%

Table 5-5 compares per ton savings by commodity group between the two matrices. The updated FY99 matrix will show, on average, a $0.30 per ton reduction in transportation savings.

TABLE 5-5
Comparison of Mean Savings per Ton

Group	Mean Savings per Ton		% Change
	1997	1999	
Coal	7.17	6.97	-2.8%
Petrol	8.98	8.38	-6.7%
Aggregates	7.43	7.03	-5.3%
Grains	7.96	7.74	-2.8%
Chemicals	21.89	22.14	1.2%
Ores & Minerals	28.04	25.97	-7.4%
Iron & Steel	9.14	8.87	-2.9%
Other	13.51	12.78	-5.4%
Total	8.68	8.38	-3.5%

ATTACHMENT 6

EMPLOYMENT AND INCOME IMPACTS

6.1 GENERAL

Construction activities associated with modernization of J.T. Myers and Greenup Locks and Dams would entail considerable employment of skilled and unskilled labor resources from numerous construction-related professions. The predominate unskilled profession is laborer. Numerous skilled occupations are involved, including equipment operator, carpenter, cement mason and truck driver. Wage compensations would be substantial. The total wage compensations for constructing a 600' lock extension of the auxiliary chamber at either site approximates $32 million.

The primary source of labor for each of these projects is counties within a reasonable commuting distance of each L/D site. The labor markets are defined as all counties within that area. The Greenup market area consists of Adams, Jackson, Lawrence, Pike and Scioto in Ohio, and Boyd, Carter, Greenup and Lewis in Kentucky. The J.T. Myers market area comprises Gallatin, Hardin, and White in Illinois, Gibson, Pike Posey, Spencer, Vanderburg and Warrick in Indiana, and Daviess, Henderson, McLean, Union and Webster in Kentucky. For this study, two types of benefits were calculated based on projected employment and income from construction, National Economic Development (NED) and Regional Economic Development (RED) benefits. Construction employment in the Without Project Condition would be relatively negligible compared to modernization projects. Therefore, such benefits in the WOPC are assumed to be equal to zero and will only be calculated for plans with major lock construction activities.

The report "Evaluation of Employment Impacts Resulting From Lock Modernizations at J.T. Myers and Green Locks and Dams", September 1999 detailing the calculation of the NED and RED benefits is on file in the Pittsburgh District office.

6.2 NED Benefits

Labor drawn from any counties with substantial and persistent unemployment vis-à-vis the U.S. as a whole is accountable as a project benefit and is included in National Economic Development (NED) estimates. The criteria for defining qualifying counties and the conceptual rationale for including these benefits in the NED account are specified in ER 1105-2-100. The

counties in the Greenup market qualifying for these benefits include Adams, Pike and Scioto in Ohio and Boyd and Lewis in Kentucky. The eligible counties in the Myers market are White, Gallatin and Hardin in Illinois, and Mclean in Kentucky. Because of the dynamic nature of unemployment situations, eligibility will be reconsidered at the time funds are appropriated for construction. NED benefits are a function of both the magnitude and timing of wage compensations. **Table 6-1** contains pertinent values from the Unemployed or Underemployed NED calculation process and the total benefits for the 600' Auxiliary Lock Extension plan. **Table 6-2** addresses the analogous values for this plan at Greenup L/D. These estimates are based on the assumption that there is no "local hire rule" in effect at either job site. In general, for any site, these benefits are greater for plans with higher present value of wage compensation to construction industry workers.

TABLE 6-1
Unemployed and Underemployed Benefits for Final Plan at J.T. Myers ($000)

Total Wages	$	32,000
Labor Cost from Qualified Counties	$	2,016
Total Labor Cost Eligible for Benefits	$	675
Unemployment/Underemployment Benefits Discounted to Present Worth 1/	$	717
Average Annual Benefit	$	50

1/ Benefits calculated using the year 2008 as the base year and a discount rate of 6 5/8%.

TABLE 6-2
Unemployed and Underemployed Benefits for Final Plan at Greenup ($000)

Total Wages	$	32,000
Labor Cost from Qualified Counties	$	17,664
Total Labor Cost Eligible for Benefits	$	6,476
Unemployment/Underemployment Benefits Discounted to Present Worth 1/	$	7,479
Average Annual Benefit	$	516

1/ Benefits calculated using the year 2008 as the base year and a discount rate of 6 5/8%.

6.3 RED Benefits

The incomes of the workers at each of these projects will impact the economy of the regions around each site. The regions assumed to incur the particularly significant income and

employment effects is identical to the respective labor market area. Two measures of the effects of the construction at each site on the regional economies are regional income and regional employment. These values are included in the Regional Economic Development (RED) Account for each project.

Regional economic benefits were calculated for one alternative at each site through the use of the IMPLAN model (short for IMpact analysis for PLANing). This model is described in a report on file in Corps offices. Direct, indirect, and induced effects of construction expenditures in 1998 dollars are estimated. **Table 6-3** contains a summary of the RED impacts of the final plans at Myers and **Table 6-4** contains similar information for the final plans at Greenup. These values are based on IMPLAN analyses using prior estimates of wage compensation wage streams and revised accordingly based on prorating the IMPLAN generated values. The revised values in the tables below will be recalculated through IMPLAN model runs and incorporated into the final report.

TABLE 6-4

Unemployed and Underemployed Benefits for Final Plan at J.T. Myers ($000)

Total Industry Output ($millions)	Total Value Added ($millions)	Total Labor Income ($millions)	Total Employment
$ 135.7	$ 65.8	$ 52.1	1,718

[1] The total effects cannot be aggregated across the columns.

TABLE 6-4

Unemployed and Underemployed Benefits for Final Plan at J.T. Myers ($000)

Total Industry Output ($millions)	Total Value Added ($millions)	Total Labor Income ($millions)	Total Employment
$ 129.6	$ 59.7	$ 49.0	1,726

[1] The total effects cannot be aggregated across the columns.