

The Impacts of Unscheduled Lock Outages

Prepared for:

The National Waterways Foundation and
The U.S. Maritime Administration



Center for Transportation Research
The University of Tennessee

Vanderbilt Engineering Center for
Transportation and Operational Resiliency
Vanderbilt University

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*Cover Photograph courtesy of Andrew M. Turner
Clarion, Pennsylvania*

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Executive Summary

The summarized work is the result of a study commissioned by the National Waterways Foundation and the U.S. Department of Transportation's Maritime Administration (MARAD). The goal of this study is to highlight the economic benefits associated with reliable inland navigation.

E.1 PROJECT CONTEXT

America's inland waterway system was essential to the nation's early colonial prosperity and it has been vital to U.S. commerce ever since. As navigation more fully developed in the 20th century, the waterway network became a perennial contributor to the nation's economic success. Today, America's waterways quietly provide an irreplaceable transportation resource that is key to the nation's global success in the 21st century.

Unfortunately, toward the end of the 20th century, this fundamental part of U.S. transportation infrastructure became more visible, but for all the wrong reasons. Many of the nearly 200 infrastructure projects were reaching their design life of 50 years and choke points were adversely affecting more and more commercial users. The upper Mississippi's Locks & Dam 26 and the Ohio River's Locks & Dam 52 are examples.

Today, most navigation projects are more than 75 years old and have suffered from a persistent lack of reinvestment and environmental stresses associated with extreme weather events that magnify the system's vulnerability.

It is within this context that the National Waterways Foundation and MARAD commissioned this study to explore the expected impacts of an extended unscheduled outage at a number of important Lock and Dam projects.

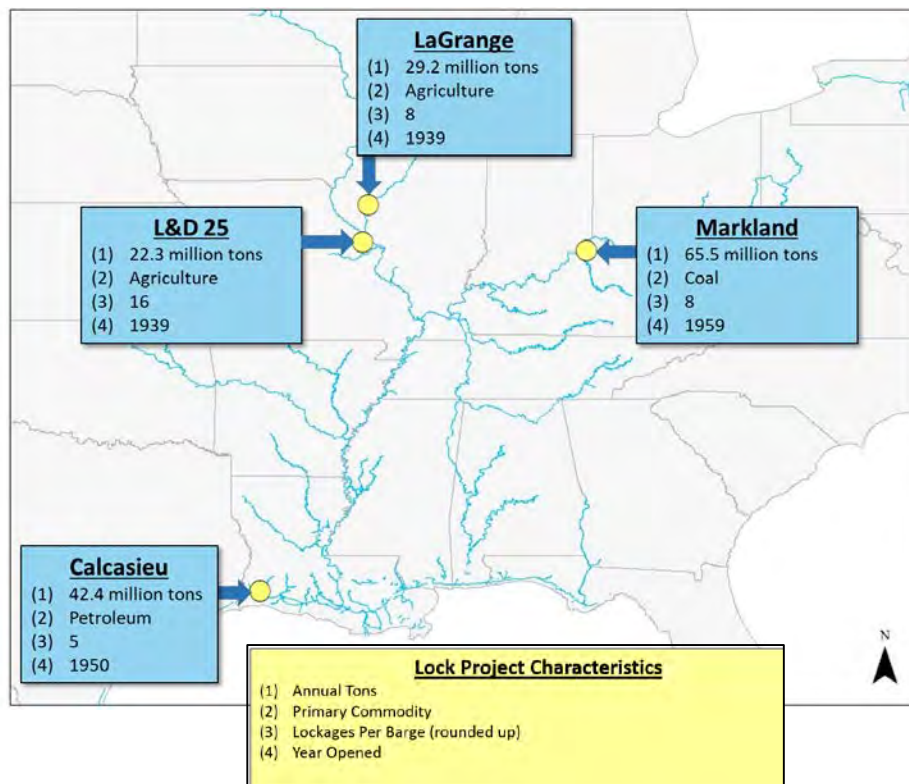
E.2 LOCK AND DAM PROJECTS SELECTED FOR DETAILED ANALYSIS

In order to assess the impact of lock availability and outages, the study team developed and used a methodology to identify a small subset of locks for closer analysis. The initial screening approach included a carefully reconciled cross-section of data describing the characteristics and performance of roughly 170 navigation locks located throughout the nation's interior navigation system. The study team prepared and presented this information to the study's sponsors who then selected four locks for further study based on their characteristics and

performance metrics. The map below indicates the locks selected and includes several of the key characteristics of the lock reliant traffic.

Of particular note were new metrics to assess a lock’s importance to the overall network. One such metric, noted on the map below for each project, describes the average number of locks on the system that an individual loaded barge traversing the subject lock passes through during a single movement (represented as System Lockages/Project Lockage). An additional measure shows the traffic in the pools above and below the lock that originates or terminate in the pool but does not transit the lock. While this study did not investigate the particular modalities of an unscheduled outage, it is possible that the outage could be accompanied by impacts on the pool traffic as well.

Figure E.1 – Study Projects and Summary Characteristics



E.3 DIRECT SHIPPER SUPPLY CHAIN COST BURDENS FROM AN UNSCHEDULED CLOSURE

Estimating the direct efficiency losses associated with an unplanned lock closure provided the core information on which further analysis is built. These cost estimates were derived through methods that adhere to the same *Principles and Guidelines* that govern U.S. Army Corps of Engineers’ navigation studies.

For each lock examined, the analysis compares an estimate of each shipper’s current costs for waterway-inclusive movements to the cost of the next best available modal alternative. Three existing models were employed that allowed a comparison of the costs associated with the use of barge service against the cost to make such a movement by rail and/or truck. For each of the four locks analyzed, the model estimates predicted the Direct Shipper Supply Chain Cost Burden if barge service becomes unavailable and, at each location, these costs would be expected to exceed \$1 billion per year, as described in the Table below:

Table E.1 – Estimated Direct Unplanned Closure Costs

COMMODITY	MARKLAND LOCKS & DAM		LAGRANGE LOCK & DAM	
	Total 2014 Tons	Total Direct Costs	Total 2014 Tons	Total Direct Costs
Coal	30,788,869	\$221,987,745	443,288	\$20,291,015
Petroleum Products	7,440,371	\$368,253,302	5,623,494	\$182,914,135
Chemicals	3,898,264	\$276,416,124	4,888,770	\$251,529,491
Crude Materials	14,339,508	\$242,729,791	3,401,419	\$208,236,345
Primary Manufactured Goods	4,896,902	\$160,394,481	3,344,289	\$103,524,351
Farm Products and Food	4,089,324	\$38,460,711	11,460,988	\$932,684,606
Equipment	55,525	\$1,818,681	5,632	\$477,986
TOTAL	65,508,763	1,310,060,835	29,167,880	1,699,657,928

COMMODITY	CALCASIEU LOCK		L&D 25	
	Total 2014 Tons	Total Direct Costs	Total 2014 Tons	Total Direct Costs
Coal	245,836	\$6,629,552	660,624	\$25,696,959
Petroleum Products	24,988,887	\$542,287,348	320,411	\$15,103,646
Chemicals	9,078,337	\$230,953,087	4,171,737	\$248,899,601
Crude Materials	3,937,379	\$179,789,257	3,082,613	\$208,863,996
Primary Manufactured Goods	2,744,157	\$120,009,771	1,667,149	\$38,225,955
Farm Products and Food	843,753	\$22,753,806	12,433,825	\$1,033,977,564
Equipment	9,222	\$248,693	6,602	\$542,606
Scrap and Waste	626,896	\$16,905,741		
TOTAL	42,474,467	1,119,577,255	22,342,961	1,571,310,327

E.4 GEOGRAPHIC DISTRIBUTION OF THE DIRECT AND REGIONAL IMPACTS

Using the information about the origins and destinations of the traffic relying on each lock, it was also possible to describe the system-wide nature of the impact which each individual lock’s closure is expected to have as illustrated on the four network maps below.

Figure E.2 – Markets Dependent on Markland Locks & Dam

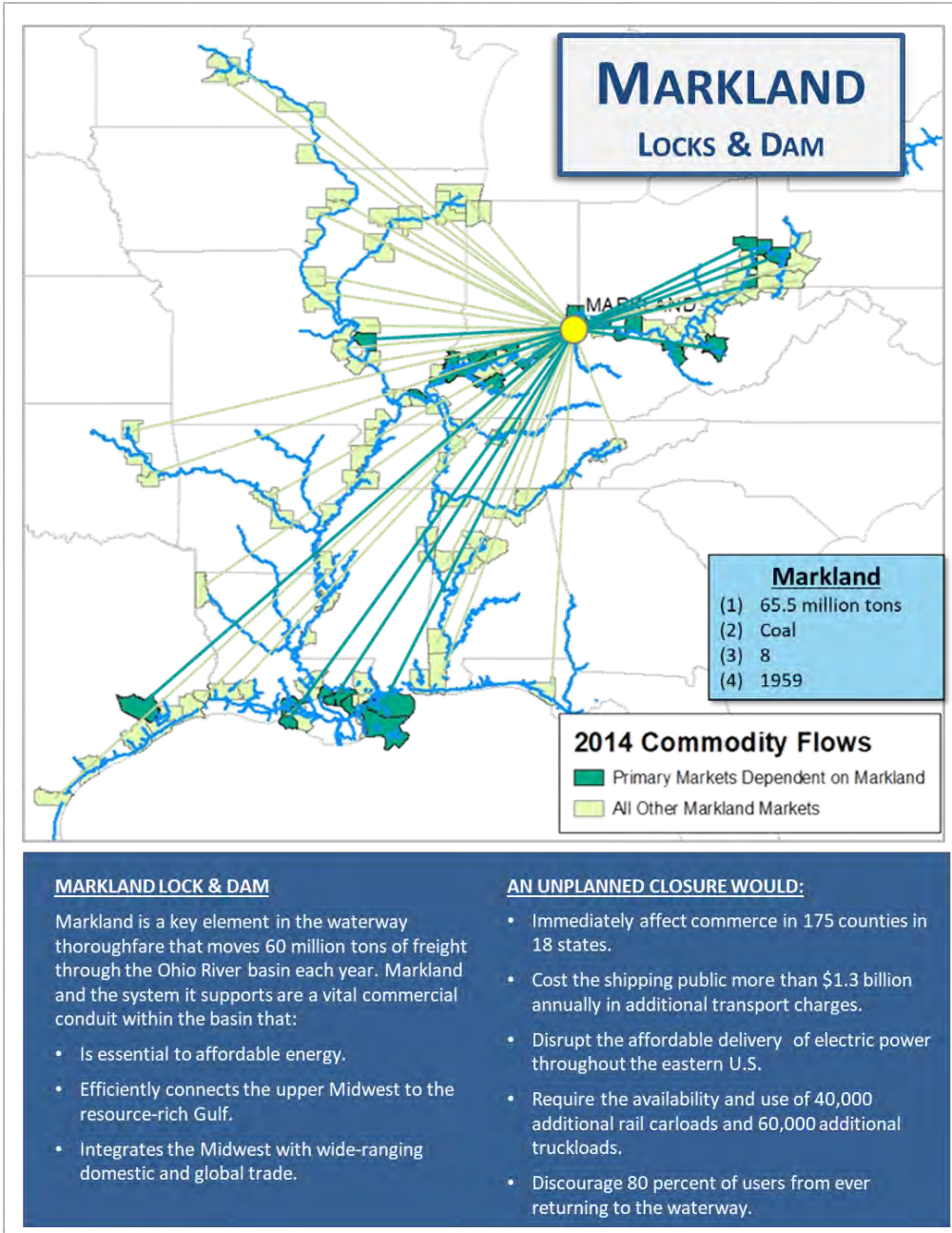
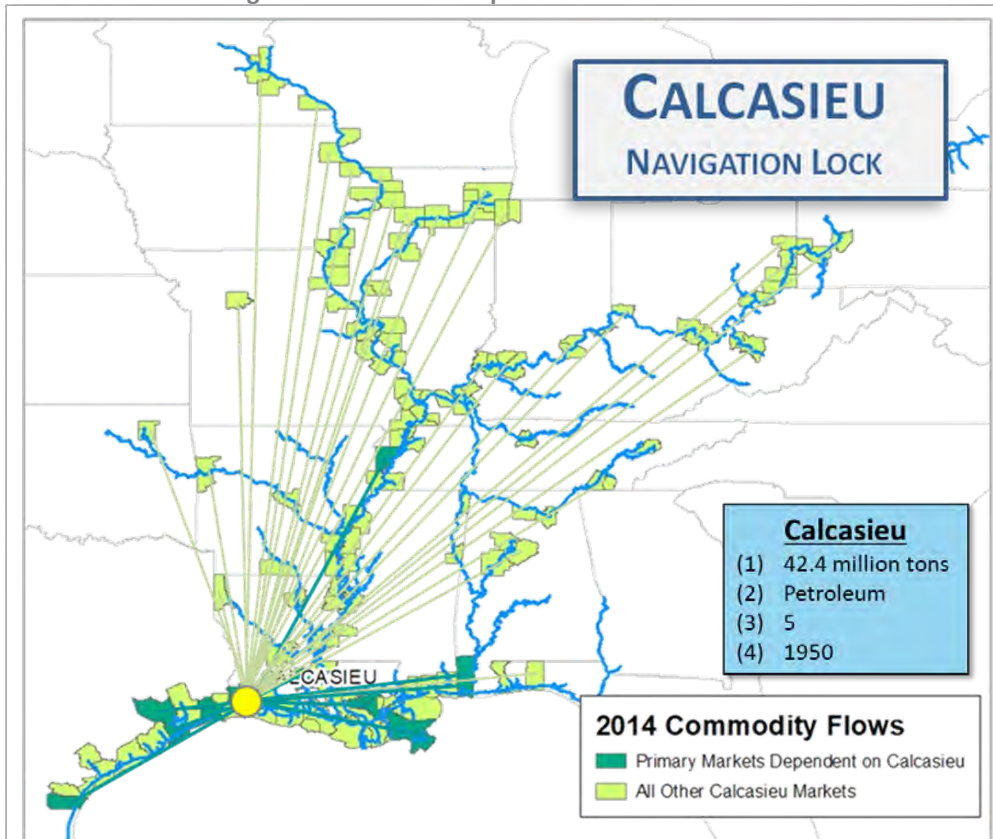


Figure E.3 – Markets Dependent on Calcasieu Lock



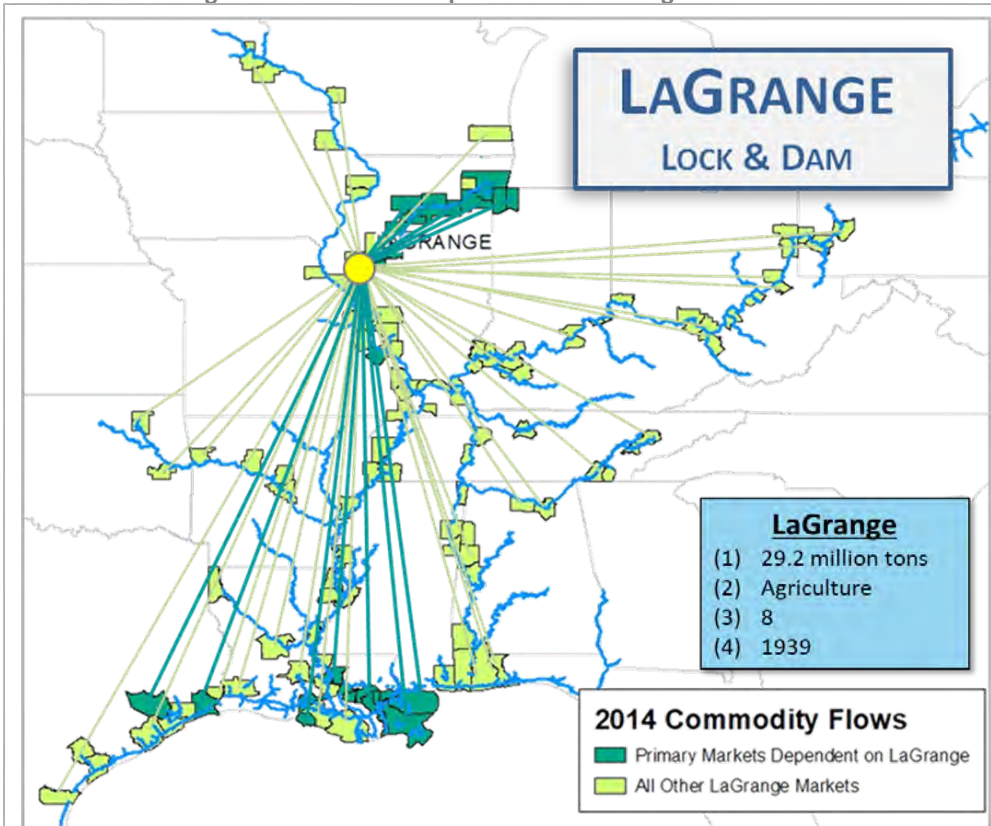
CALCASIEU LOCK & DAM

Calcasieu is a critical piece of the high-density waterway corridor that serves plastic and chemical producers and petroleum refiners throughout the Gulf region. Unseen to most, Calcasieu moves 40 million tons of freight through the Gulf each year. This facility, and the system it supports, are vital commercial links within America’s freight network that (1) are essential to affordable energy production, (2) efficiently connect the Gulf region to global trade, and (3) integrate the Gulf region’s vital production into the core U.S. economy.

AN UNPLANNED CLOSURE WOULD:

- Immediately affect commerce in 170 counties in 18 states.
- Cost the shipping public more than \$1.1 billion annually in additional transport charges.
- Require the availability and use of 10,000 additional rail cars and several hundred locomotives.
- Result in the loss of 17,000 full-time, highly-compensated jobs.

Figure E.4 – Markets Dependent on LaGrange Lock & Dam



LAGRANGE LOCK & DAM

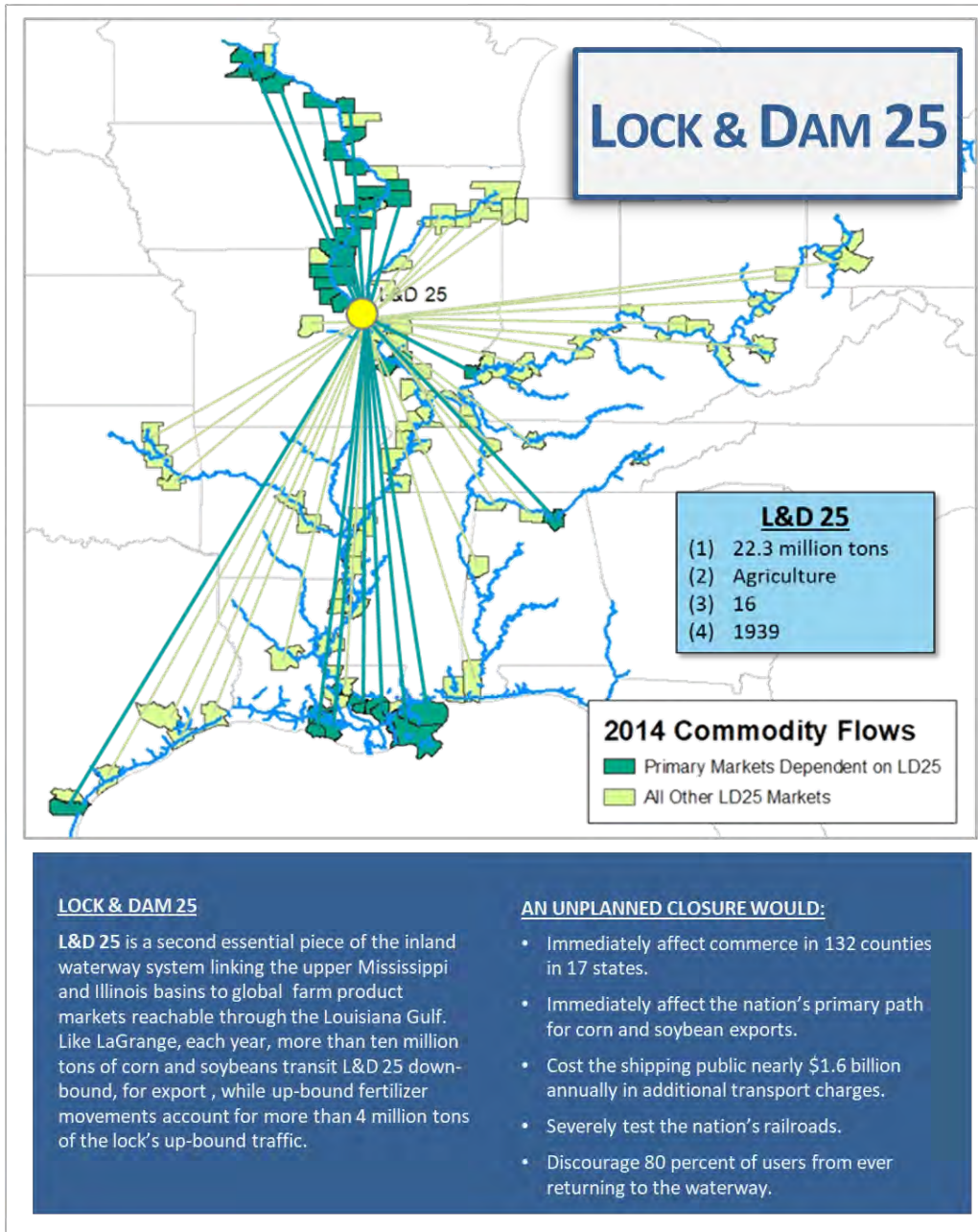
LaGrange is a critical piece of the marine highway that links the upper Mississippi and Illinois basin farmlands to export markets reachable through the Louisiana Gulf. Each year, more than ten million tons of corn and soybeans transit this lock down-bound, for export and the region's agriculture is equally served by up-bound fertilizer movements.

In addition to agricultural commerce LaGrange also is an integral component in the navigation system that links the Chicago Area Waterway System (CAWS) to the rest of the U.S.

AN UNPLANNED CLOSURE WOULD:

- Immediately affect commerce in 135 counties in 18 states
- Threaten the nation's primary path for corn and soybean exports.
- Cost the shipping public nearly \$1.7 billion annually in additional transport charges.
- Severely stress the nation's railroad infrastructure.
- Lead to a \$2.1 billion loss in farm-dependent incomes.

Figure E.5 – Markets Dependent on Lock & Dam 25



These figures point to the overall value of each lock. But, looking at traffic for individual commodities adds further to the story. Appendix 3 provides an expansive set of commodity-specific graphics. However, their value is worth demonstrating here. As described in Section 2, Ohio River traffic is being affected by two countervailing forces – a decreased reliance on coal and the increased ability to affordably produce chemical and plastics products. The commodity-specific graphics for Markland illustrate how related changes in transportation demands may affect the composition of traffic at Markland.

Figure E.6 – Distribution of Chemical Shipments Transiting Markland Locks & Dam

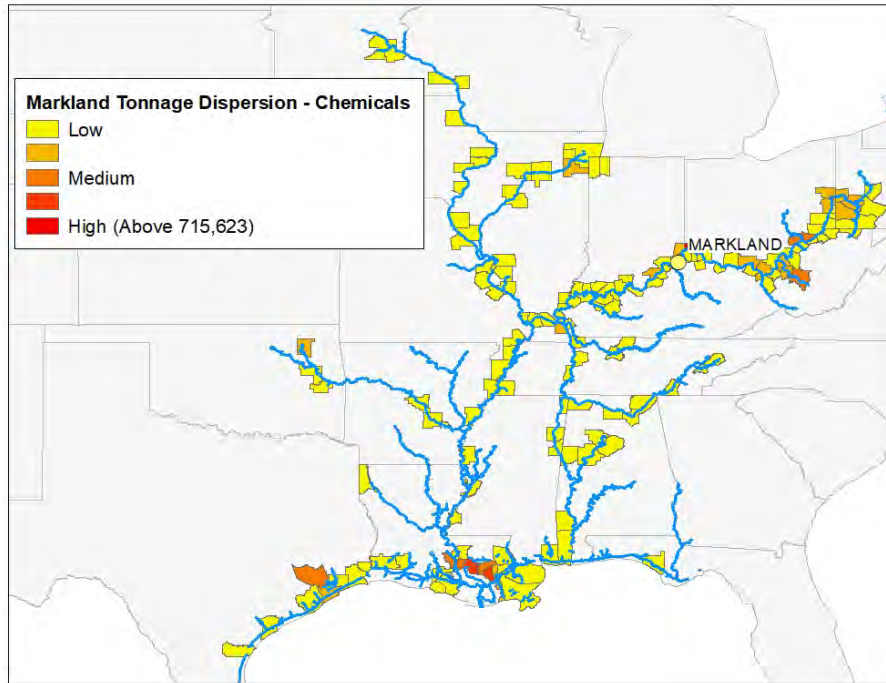
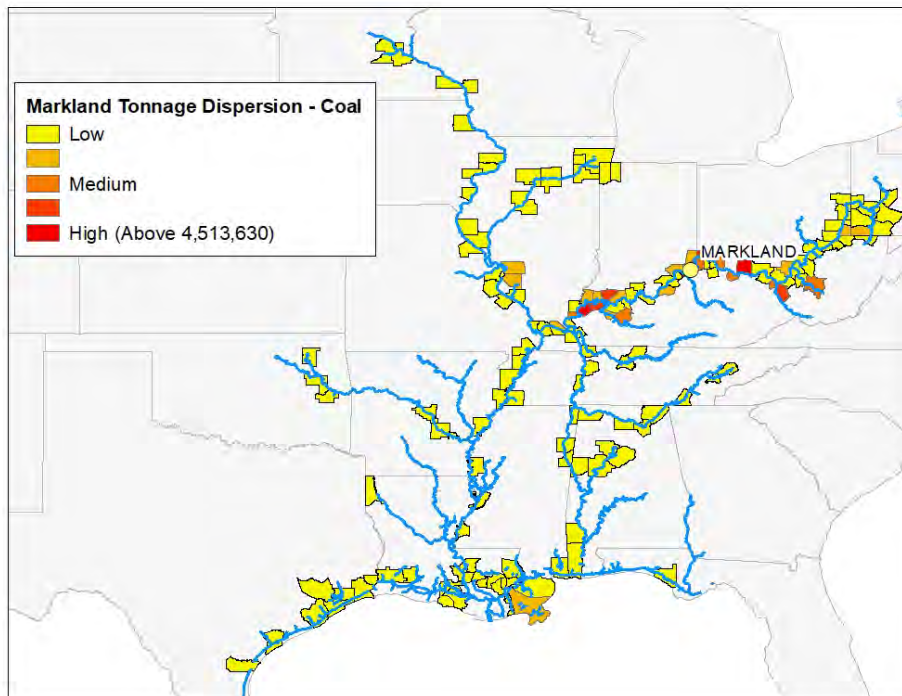


Figure E.7 – Distribution of Coal Shipments Transiting Markland Locks & Dam



Finally, the direct results described above were combined with a 2014 National Waterways Foundation analysis to estimate upper bounds for the regional

economic impacts associated with an unplanned lock closure. The regional impact – lost incomes and lost jobs –are summarized below.

Table E.2 – Estimated Regional Impacts

	Markland	Calcasieu	LaGrange	UM L&D 25
Regional Output	\$2,520,578,383	\$4,347,871,315	\$5,188,761,521	\$5,242,759,485
Regional Incomes	\$657,544,177	\$1,094,959,385	\$1,462,470,596	\$1,570,516,397
Regional Employment	13,210	17,487	24,447	24,250

Note: These impacts cannot be summed across the four locks.

SUMMARY AND FINDINGS

The historical importance of the inland navigation system to the United States has been tied to the network’s coverage of the heartland and its efficient connectivity covering over 12,000 miles. This comes from the standardization of system capabilities, and especially the minimum channel depth and “standardization” of the more than 170 lock and dam structures, that allows the same equipment to efficiently traverse the entire system and from which the success of the system has been derived.

Unfortunately, the connectivity of the system also creates vulnerability, and this study documents and illustrates the magnitude of the impact from the prolonged loss of any single lock and dam project. If an unscheduled and extended outage were to occur at any of the four locks analyzed here, the impact would reach across all of the states served by the system and cause billions of dollars in economic harm to shippers, the commerce that depends on those shippers, and the communities that rely on this substantial business activity.

A FEW KEY FINDINGS

- Each of the four locks considered within the study helps shippers avoid more than \$1 Billion in additional transportation costs each year.
- The important roles played by individual navigation projects span a broad range of both geographies and economic purposes, and in some cases provide freight mobility that could not be easily replaced by other transport modes.
- While every state that originates or terminates traffic supported by the four locks benefits from inland navigation’s availability, the results reflect the waterway’s *extraordinary* commercial value to 18 states, especially Louisiana, Texas, and Illinois.
- In the cases of LaGrange Lock & Dam and Lock & Dam 25, trucking to alternative waterway locations would mean an additional 500,000 loaded truck trips per year and an additional 150 million truck miles in the affected states. This is not tenable.

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1

Research Motivation, Context, and Approach

The National Waterways Foundation (NWF) has partnered with the U.S. Department of Transportation’s *Maritime Administration* (MARAD) to sponsor this research project which estimates the specific economic consequences resulting from the unscheduled and extended closure of four representative navigation locks. At each of the four locks selected, the impact on shippers currently using the locks, called the *Shipper Supply Chain Cost Burden* is estimated to exceed \$1 billion per year with very significant additional regional economic and employment impacts extending widely over the territory served by the inland waterway system.

Through this work the sponsors also seek to demonstrate an analytical framework that can be applied to additional locks and in some contexts, measurably reduce the resources needed to undertake robust waterway system project evaluations.

1.1 PROJECT OVERVIEW AND APPROACH

The more than 12,000 miles of navigable waterways in the U.S. are composed of segments with characteristics that vary considerably. On some segments of the system, like the lower Missouri and lower Mississippi Rivers, the combination of upstream water management and naturally occurring river flows allow for “open river” where barge traffic can move, unimpeded, from one end of the segment to the other. More commonly, however, maintaining dependable, year-long navigation requires the use of dams that help maintain acceptable channel depths within the pools they create. On these segments, passage around the necessary dams requires navigation locks that lift or lower vessels, including commercial towboats and barges, allowing them to pass from one pool to the next.

On waterway segments where dams and locks are necessary, any disruption in a lock’s operation can significantly inhibit barge transportation. In some cases, lock outages are scheduled to allow for necessary maintenance. These scheduled outages are announced months or even years in advance so that impacted waterway shippers can adjust commodity inventories or otherwise prepare for the service disruption. In other cases, however, weather, accidents, or mechanical failures lead to unscheduled lock closures of varying durations. Because carriers and shippers have no opportunity to prepare for unscheduled lock outages, these closures can be tremendously disruptive to water-dependent commerce. It is this latter type of outage on which the current work is focused.

The overall effort has been divided into four broad sets of tasks:

- The development of a methodology for selecting a small number of locks for careful analysis;
- The collection and analysis of the data necessary to defensibly estimate the direct economic costs of the subject lock closures;
- The extension of the direct closure-related costs to estimate the broader, economy-wide regional indirect impacts, and
- The documentation of the approach to allow use of the methodology in future analyses.

Additionally, the study team was charged with using visualization tools that enhance the interpretation of the team's analytical results. The sections that follow are organized around these goals.

Finally, while the topics and methods described here are anchored to rigorous economic and statistical principles, the research team has attempted to use a practical, applied approach suited for real-world practitioners.

1.2 REPORT STRUCTURE

Chapter 2 provides the primary results that have been generated by this research effort. For each of the four locks selected for detailed analysis, tables and graphical representation summarize Shipper Supply Chain Cost Burden and the resulting regional economic impact that would result from an unanticipated closure of the analyzed lock and dam project. Chapter 2 concludes with an assessment of how rail capacity may impact these shipper costs.

Beyond developing the results for these four selected locks, an additional goal of the work reported here is to demonstrate efficient methods that will facilitate future project analyses. To that end, we include fairly detailed and technical descriptions of both data and methodologies. Chapters 3, 4, and 5 fully describe application of the data and existing tools used to screen and select locks, calculate the costs averted by preventing unscheduled lock closures, and estimate the regional economic impacts. Additional supporting material is provided in three Appendices.

2

Study Methodology and Findings Lock Selection, Shipper Supply Chain Cost Burden Analysis, Regional Economic Impact Analysis

The analytical path summarized in the introduction produced three specific products – a screening tool that was used by project sponsors to select four individual locks for further analysis, estimates of the supply chain costs that would be imposed directly on waterway users when unplanned lock closures are not avoided, and estimates of subsequent regional impacts that extend the estimated closure costs to a broader set of economic effects. At the time that this project was begun in 2016, the most recent year for which complete data sets were available was 2014, and the reported findings are based on that year’s information. These findings and applications are summarized below.

2.1 LOCK SELECTION

The screening tool described is a cross-sectional framework that compares fully disaggregated lock and dam infrastructure and performance characteristics to isolate navigation projects based on analytical purpose. For each lock, specific screening tool elements reflect:

- Physical characteristics (e.g., age, number/dimensions of chambers);
- Performance (e.g., tonnage, number of lockages, processing times); and
- Network role (e.g., system ton-miles, and associated lockages at other locations).

The current work developed corresponding data for a population of 170 navigation locks. By design, the screening tool coalesces data that allow an array of cross-sectional comparisons of lock attributes, performance, and network functions. In the current application, the study team did not apply a weighting scheme that favors or reduces the importance of any particular lock characteristic. Instead, screening tool data were provided without any presupposed preferences.

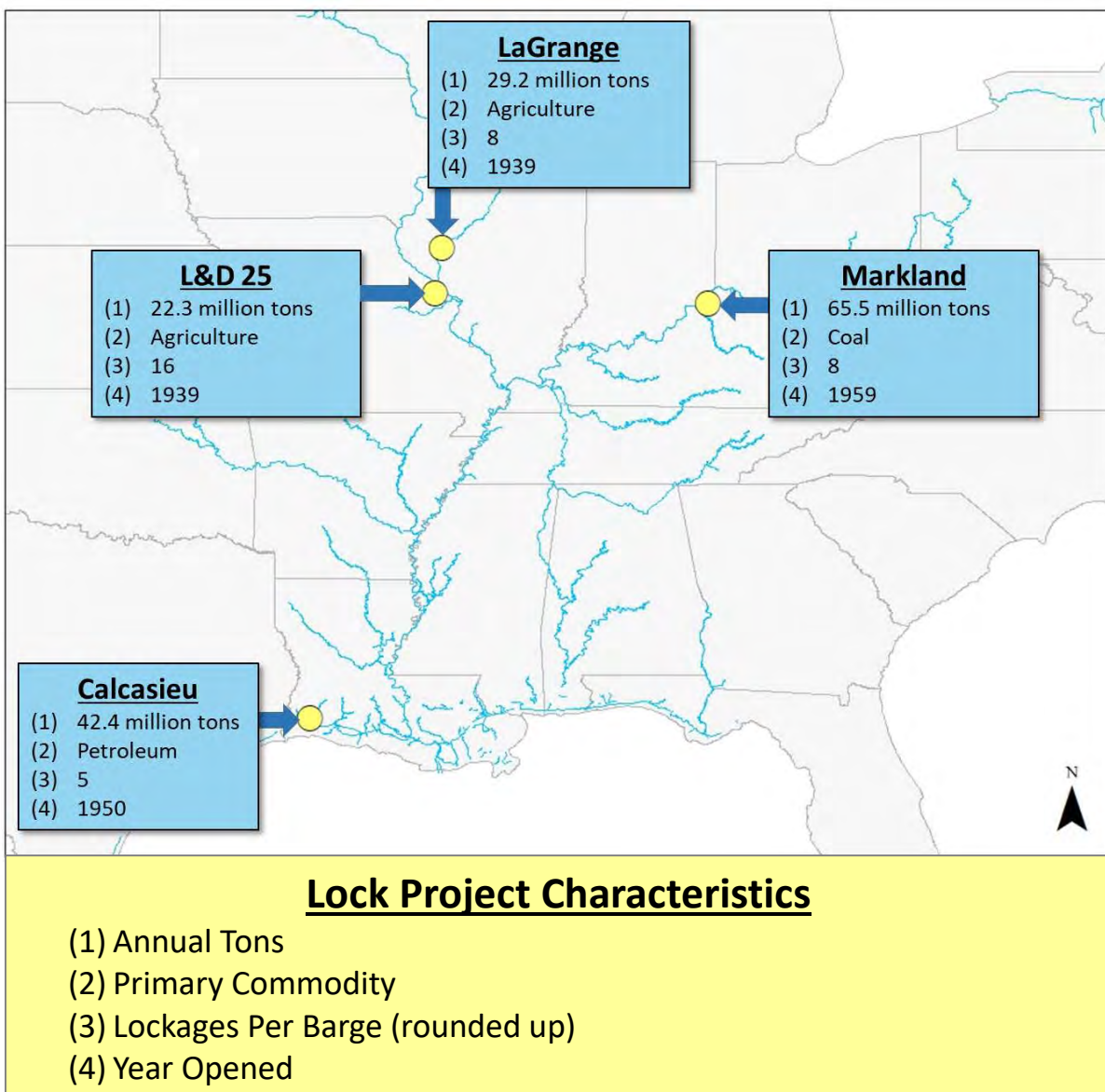
Based on these data, the project sponsor evaluated a subset of the whole universe of locks and ultimately selected four facilities for further analysis. These include Markland Locks & Dam on the Ohio River, near Cincinnati; Calcasieu Lock on the Gulf Intracoastal Waterway in Louisiana; LaGrange Lock & Dam, the southern-most of the navigation structures on the Illinois River; and Lock & Dam 25 (L&D25) on the Mississippi River, immediately north of St. Louis. These four locations are depicted graphically in Figure 2.1. Chapter 3 more fully describes the lock selection criteria and process. However, generally, these locks were selected to reflect a solid cross-section of geography, commodity mix, and network role. Table 2.1 provides sample screening tool data for the four locks selected for further study.

Table 2.1 – Screening Tool Results Summary

	CALCASIEU	LAGRANGE	L&D 25	MARKLAND
LOCK LOCATION INFORMATION				
River	GIWW	ILLINOIS	MISSISSIPPI	OHIO
River Mile	238.5	80.2	241.4	531.5
Bank	R	R	R	L
USACE Division	MVD	MVD	MVD	LRD
USACE District	MVN	MVR	MVS	LRL
State	LA	IL	MO	KY
Town	Lake Charles	Beardstown	Winfield	Warsaw
Latitude	30.088061	39.94507	39.003117	38.774413
Longitude	-93.293273	-90.53714	-90.689209	-84.966172
LOCK CHARACTERISTICS				
Lift	4	10	15	35
Length	1205	600	600	1200
Width	75	110	110	110
Year Opened	1950	1939	1939	1959
Gate Type	Sector	Miter	Miter	Miter
Mooring Cells	N	N	Y	Y
AGGREGATE LOCK ACTIVITY				
Lockages	3,987	3,659	3,172	4,071
LPMS Total Tons¹	42,240,214	27,199,448	21,673,519	52,753,624
COMMODITY INFORMATION				
WCSC Coal	245,836	443,288	660,624	30,788,869
WCSC Petroleum	24,988,887	5,623,494	320,411	7,440,371
WCSC Chemicals	9,078,337	4,888,770	4,171,737	3,898,264
WCSC Crude Materials	3,937,379	3,401,419	3,082,613	14,339,508
WCSC Primary Manufact. Prod.	2,744,157	3,344,289	1,667,149	4,896,902
WCSC Food and Farm Products	843,753	11,460,988	12,433,825	4,089,324
WCSC Machinery / Equipment	9,222	5,632	6,602	55,525
WCSC Waste Materials	626,896	-	-	-
WCSC Total Tons¹	42,474,467	29,167,880	22,342,961	65,508,763
SYSTEM FUNCTIONS				
System Ton-Miles Supported	2,330,362,699	35,764,883,159	29,499,570,937	48,278,194,662
Lockages per Barge	4.4	8.1	15.9	7.5
Total Tons - Pool Above	58,671	1,065,293	0	10,801,531
Total Tons - Pool Below	62,800	2,344,044	33,815	22,015,111

¹ Limitations in LPMS data collection methods (particularly pertaining to coal movements) often lead to deviations between LPMS and WCSC-based tonnage values. In such cases, the WCSC figures are generally considered more reliable

Figure 2.1 – Selected Lock Project Characteristics



2.2 SHIPPER SUPPLY CHAIN COST BURDEN (SSCCB) ANALYSIS

At its core, the current project is intended to simulate and measure the direct economic costs of unanticipated navigation lock closures using existing data and tools in ways that reduce the resources required to undertake this type of analysis. Meeting this goal required the execution of three primary task sets that included:

- Lock selection and data preparation;
- Scenario design and traffic diversion assessments; and
- The calculation of shipper supply chain costs both before and after an unanticipated lock closure.

As with all study elements and consistent with the *Project Proposal*, this work is designed to conform to the Principles & Guidelines (P&G) that govern the analysis of all federal inland navigation infrastructure projects by the United States Army Corps of Engineers (USACE).²

As noted, the study team estimated supply chain costs and navigation-related shipper cost burdens for unplanned outages at four individual locks. As expected, in terms of traffic and commercial function, LaGrange and L&D 25 are relatively similar. By contrast, Markland and Calcasieu differ from both each other and from the two upper Mississippi and Illinois River locks.

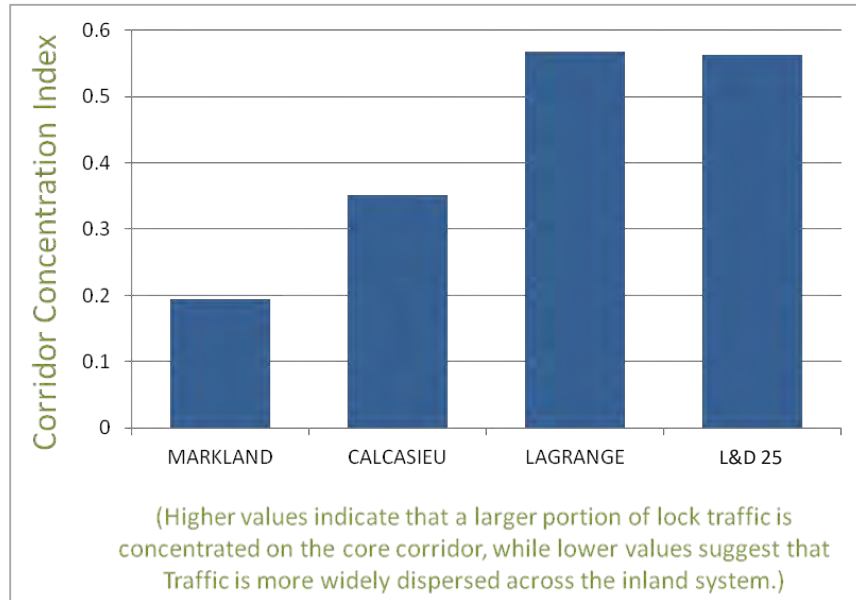
LaGrange and L&D 25 feature long-haul movements that consist mostly of down-bound corn and soybeans and up-bound fertilizer. Traffic at Markland is dominated by coal movements that are typically shorter in distance. However, the remaining Markland traffic is quite diverse, both in terms of commodities and shipment geographies. Finally, shipments through Calcasieu are somewhat shorter than Markland moves and often not even half the length of the shipments that transit LaGrange or Lock & Dam 25. Whereas, Markland is dominated by coal and LaGrange and L&D 25 are dominated by grain, Calcasieu traffic is primarily petroleum and chemical products.

These four locks support traffic on every segment of the Mississippi River system. Most of the traffic at LaGrange and L&D 25 flows the length of that main-stem and makes relatively lesser use of tributaries or intermediate terminal locations. By contrast, both the Ohio River coal traffic and, to a lesser degree, the traffic flows through Calcasieu routinely involve origins and destinations that are located along system tributaries or at intermediate spots between major terminal regions. To highlight this difference, the study team developed a *Corridor Concentration Metric* that combines data on traffic distributions with information describing shipment distances into a single measure called the *Corridor Concentration Index*. All else equal, a value closer to zero indicates that diverted shipments are less likely to face capacity constraints and a value closer to 1 signals the opposite, based both on the shipment distances and the limited number of available routes. The results of this calculation for the four subject locks are depicted in Figure 2.2. A shipper traversing a lock with a higher concentration metric score is more likely to face capacity issues in seeking to use alternative modes, especially rail, if lock operations are disrupted. This is more fully discussed in Section 2.4, and the data used and a discussion of the metric's calculation are provided in Appendix 1.

Finally, while nearly every state that originates or terminates traffic supported by the four locks clearly benefits from inland navigation's availability, analysis reflected the waterway's *extraordinary* commercial value in Louisiana, Texas, and Illinois.

² See *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, Washington, DC, March 10, 1983.

Figure 2.2 – Corridor Concentration Metrics



Markland Locks & Dam

The Shipper Supply Chain Cost Burden expected at Markland if an unscheduled closure of the lock were to occur is summarized in Table 2.2, and based on the 2014 data used in the study, the annual Cost Burden is estimated to exceed \$1.3 billion.

The geographical distribution of this outcome is depicted in Figure 2.3. What is very clearly shown by the figure is that the impact of even a single lock closure can be system-wide and will be felt across the entire midsection of the United States. Appendix 3 provides similar graphics based on commodity-specific flows.

As noted in Section 2.1 (Lock Selection), the Markland traffic includes a substantial number of relatively short-haul coal movements that generally serve markets that are rail-competitive. While coal is the primary source of traffic volumes, both chemicals and petroleum products generate larger aggregate averted costs. Given the uncertainty of future coal volumes and the projected growth in chemical and plastics, this distinction is important. The distributions of current coal and chemical traffic that transits Markland are depicted graphically in Figures 2.4 and 2.5. The contrast is fairly striking.

The study-estimated 2014 tonnage at Markland, based on Waterborne Commerce Statistics Center (WCSC) data, is 12.8 million tons greater than the traffic volumes reported through the Lock Performance Monitoring System (LPMS). An examination of the commodity-specific values reveals that this variation is almost entirely attributable to differing values for coal. This sort of reporting differential is common to coal movements throughout the Ohio basin and is well-known to both the USACE and other transportation practitioners. Because the LPMS data sometimes depend on estimates by lock personnel who necessarily are focused principally on

safe and expeditious vessel transits, the WCSC data more accurately capture instances of barge loadings to depths greater than 9 feet observed when river conditions allow.

Calcasieu Lock

Located roughly halfway between Houston and Baton Rouge and immediately south of Lake Charles, Louisiana, the Calcasieu Lock is a critical element in inland navigation between Texas and Louisiana. The Shipper Supply Chain Cost Burden for Calcasieu is reported in Table 2.3 and depicted in Figure 2.6. In total, the cost burden is estimated to exceed \$1.1 billion. Not surprisingly, traffic through the single-chamber lock is dominated by petroleum and chemical traffic that, together accounted for 80 percent of the project's 2014 tons. The shorter shipment distances impact the per-ton cost. However, on a ton-mile basis, these costs are consistent with the values attained elsewhere. Appendix 3 provides similar graphics based on commodities.

A forward-looking regional view suggests measurable traffic growth in coming decades. In, 2015, Texas and Louisiana, together, accounted for nearly two-thirds of all U.S. investment in “mobile” manufacturing capital. Much of this reflects what the *American Chemistry Council* estimates to be \$164 billion in new natural gas-related chemical and plastics investment.

LaGrange Lock & Dam and Lock & Dam 25

Volumes at LaGrange and at Lock & Dam 25 are dominated by Gulf-destined, down-bound flows of corn and soybeans. Ten million tons of farm products pass through each lock annually. The 20 million ton total is nearly six times greater than the volume of farm products moving by rail in the same corridor. In addition to down-bound corn and soybeans, both locks handle approximately four million tons of up-bound fertilizer annually. Finally, LaGrange tonnage also includes chemical, petroleum, and manufactured goods flows tied to commerce with origins and destinations along the Chicago Area Waterway System (CAWS).

The potential Shipper Supply Chain Cost Burden for grain passing through LaGrange and L&D 25 are large compared to corn and soybean movements elsewhere on the inland system. There are two reasons for this. First, below St. Louis, the Mississippi is open river, where tow sizes of 30 barges or more are common. Thus, total per ton barge charges are lower than elsewhere.

As important, both terminal capacity constraints and railroad line-haul capacities over relevant route segments suggest that, if forced from the river, most upper Mississippi and Illinois River basin corn and soybeans would divert to all-rail routings to locations in the Pacific Northwest (PNW).³ Railroad per-ton costs (to any location) are significantly higher than the cost of barge transportation to the Louisiana Gulf and the distance to the Pacific Northwest is generally twice the distance to Gulf export locations. Thus, even though cost estimates were offset to reflect ocean rate differentials to Pacific Rim destinations, the relatively high cost of rail diversions leads to high potential supply chain costs. The Shipper Supply Chain Cost Burden for a closure at LaGrange and Lock & Dam 25 is reported in Tables 2.4 and 2.5 and depicted in Figures 2.7 and 2.8. The total cost burden of an unplanned closure exceeds \$1.5 billion at either lock.

³ While Canadian ports are not necessarily excluded, for the most part, use here to the “PNW” refers to West Coast locations in Oregon and Washington.

Table 2.2 – Closure-Related Supply Chain Cost Burden, Markland Locks & Dam

	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	30,788,869	1,675	473	\$7.21	\$221,987,745
Petroleum Products	20	7,440,371	2,598	967	\$49.49	\$368,253,302
Chemicals	30	3,898,264	1,693	1,412	\$70.91	\$276,416,124
Crude Materials	40	14,339,508	1,673	757	\$16.93	\$242,729,791
Primary Manufactured Goods	50	4,896,902	1,658	1,294	\$32.75	\$160,394,481
Farm Products and Food	60	4,089,324	1,826	1,342	\$9.41	\$38,460,711
Equipment	70	55,525	1,586	1,216	\$32.75	\$1,818,681
TOTAL		65,508,763				\$1,310,060,835

Table 2.3 – Closure-Related Supply Chain Cost Burden, Calcasieu Lock

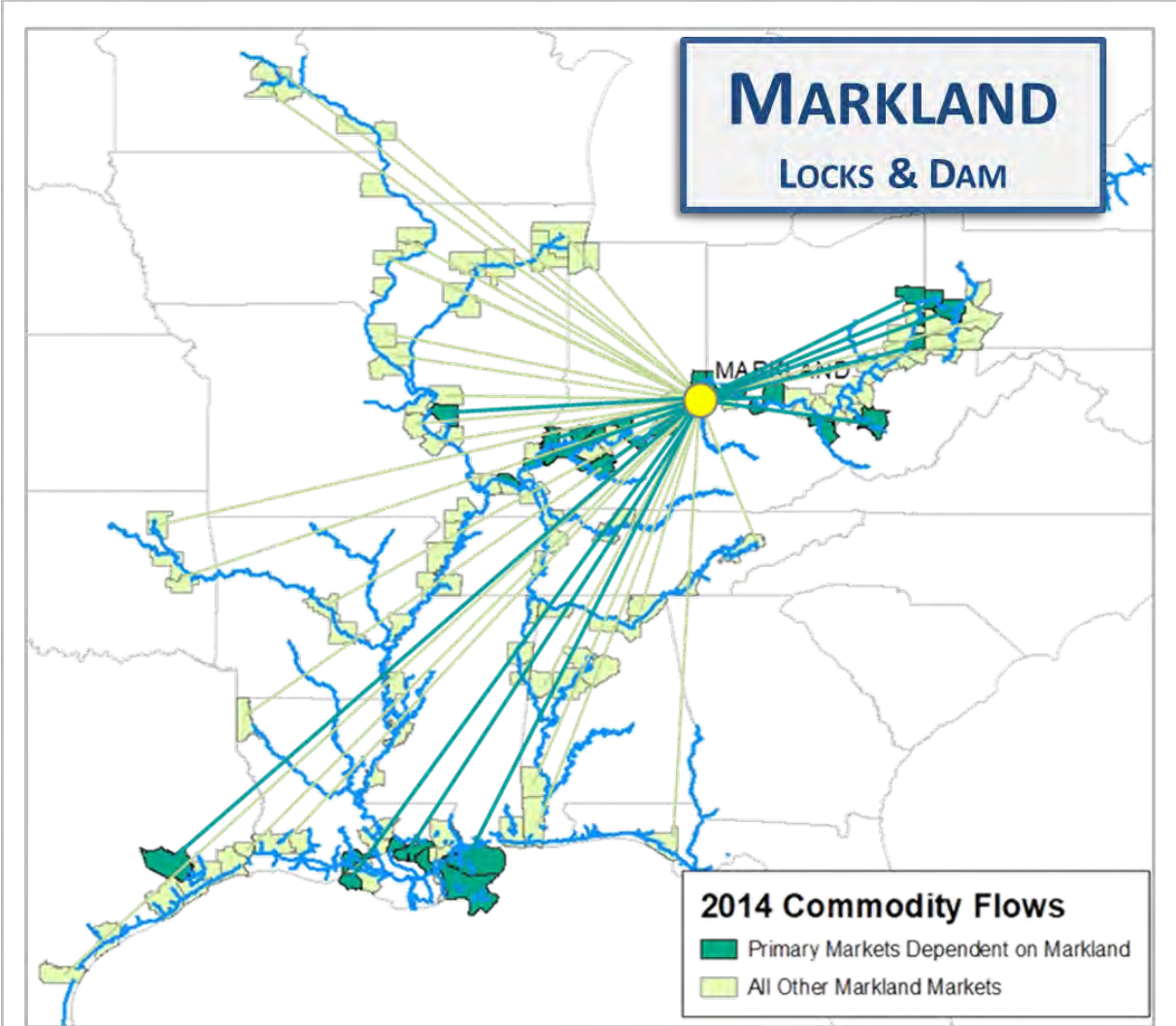
	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	245,836	1,617	1,268	\$26.97	\$6,629,552
Petroleum Products	20	24,988,887	2,859	542	\$21.70	\$542,287,348
Chemicals	30	9,078,337	2,022	846	\$25.44	\$230,953,087
Crude Materials	40	3,937,379	1,578	1,230	\$45.66	\$179,789,257
Primary Manufactured Goods	50	2,744,157	1,568	1,114	\$43.73	\$120,009,771
Farm Products and Food	60	843,753	1,769	1,021	\$26.97	\$22,753,806
Equipment	70	9,222	307	524	\$26.97	\$248,693
Scrap and Waste	80	626,896	1,537	259	\$26.97	\$16,905,741
TOTAL		42,474,467				\$1,119,577,255

Table 2.4 – Closure-Related Supply Chain Cost Burden, LaGrange Lock & Dam

	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	443,288	1,566	942	\$45.77	\$20,291,015
Petroleum Products	20	5,623,494	2,210	1,202	\$32.53	\$182,914,135
Chemicals	30	4,888,770	1,739	1,230	\$51.45	\$251,529,491
Crude Materials	40	3,401,419	1,552	1,270	\$61.22	\$208,236,345
Primary Manufactured Goods	50	3,344,289	1,513	1,056	\$30.96	\$103,524,351
Farm Products and Food	60	11,460,988	1,588	1,226	\$81.38	\$932,684,606
Equipment	70	5,632	704	1,416	\$84.87	\$477,986
TOTAL		29,167,880				\$1,699,657,929

Table 2.5 – Closure-Related Supply Chain Cost Burden, Lock & Dam 25

	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	660,624	1,547	713	\$38.90	\$25,696,959
Petroleum Products	20	320,411	1,732	1,518	\$47.14	\$15,103,646
Chemicals	30	4,171,737	1,612	1,430	\$59.66	\$248,899,601
Crude Materials	40	3,082,613	1,568	1,488	\$67.76	\$208,863,996
Primary Manufactured Goods	50	1,667,149	1,677	845	\$22.93	\$38,225,955
Farm Products and Food	60	12,433,825	1,598	1,323	\$83.16	\$1,033,977,564
Equipment	70	6,602	660	1,270	\$82.19	\$542,606
TOTAL		22,342,961				\$1,571,310,327



MARKLAND LOCK & DAM

Markland is a key element in the waterway thoroughfare that moves 60 million tons of freight through the Ohio River basin each year. Markland and the system it supports are a vital commercial conduit within the basin that:

- Is essential to affordable energy.
- Efficiently connects the upper Midwest to the resource-rich Gulf.
- Integrates the Midwest with wide-ranging domestic and global trade.

AN UNPLANNED CLOSURE WOULD:

- Immediately affect commerce in 175 counties in 18 states.
- Cost the shipping public more than \$1.3 billion annually in additional transport charges.
- Disrupt the affordable delivery of electric power throughout the eastern U.S.
- Require the availability and use of 40,000 additional rail carloads and 60,000 additional truckloads.
- Discourage 80 percent of users from ever returning to the waterway.

Figure 2.4 – Distribution of Chemical Shipments Transiting Markland Locks & Dam⁴

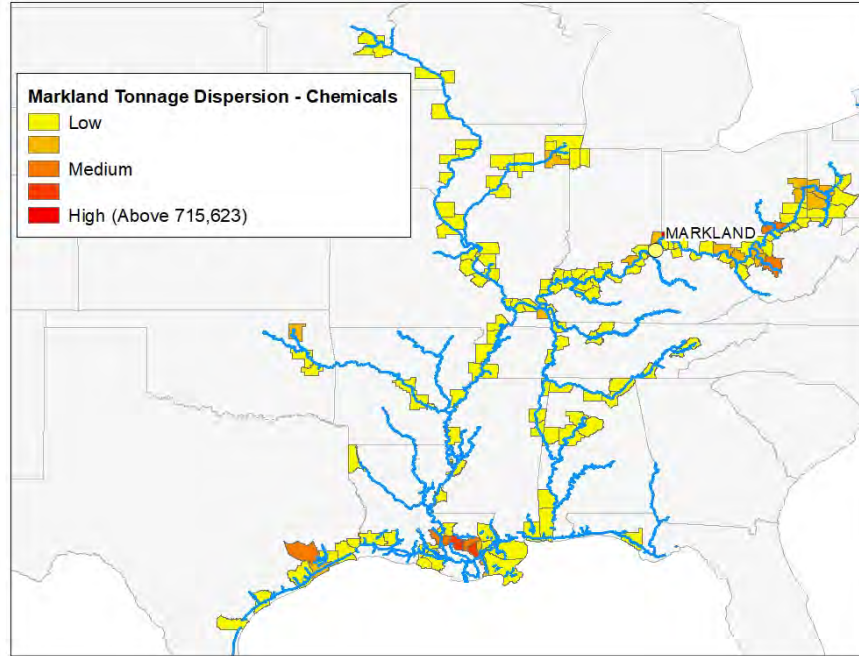
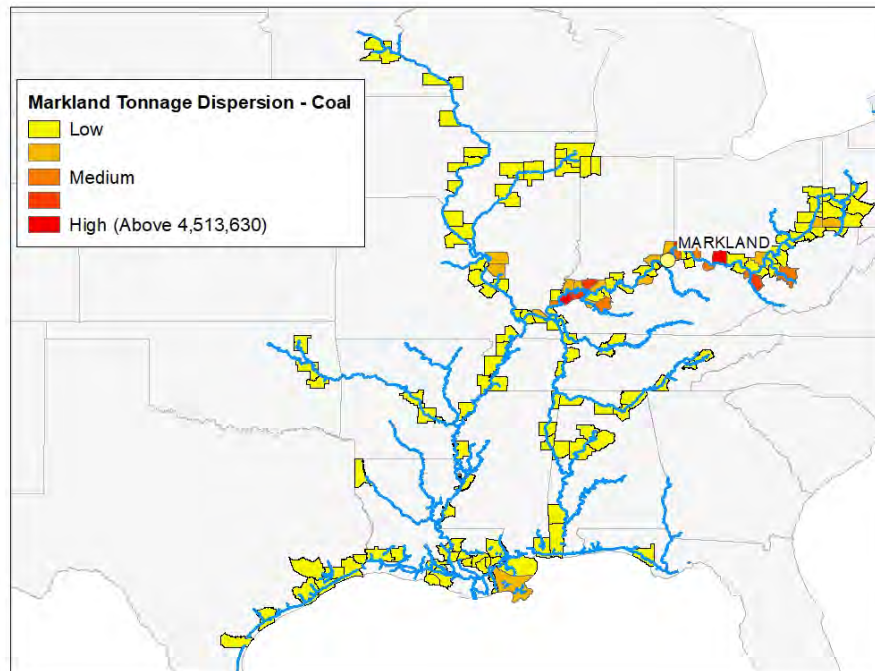
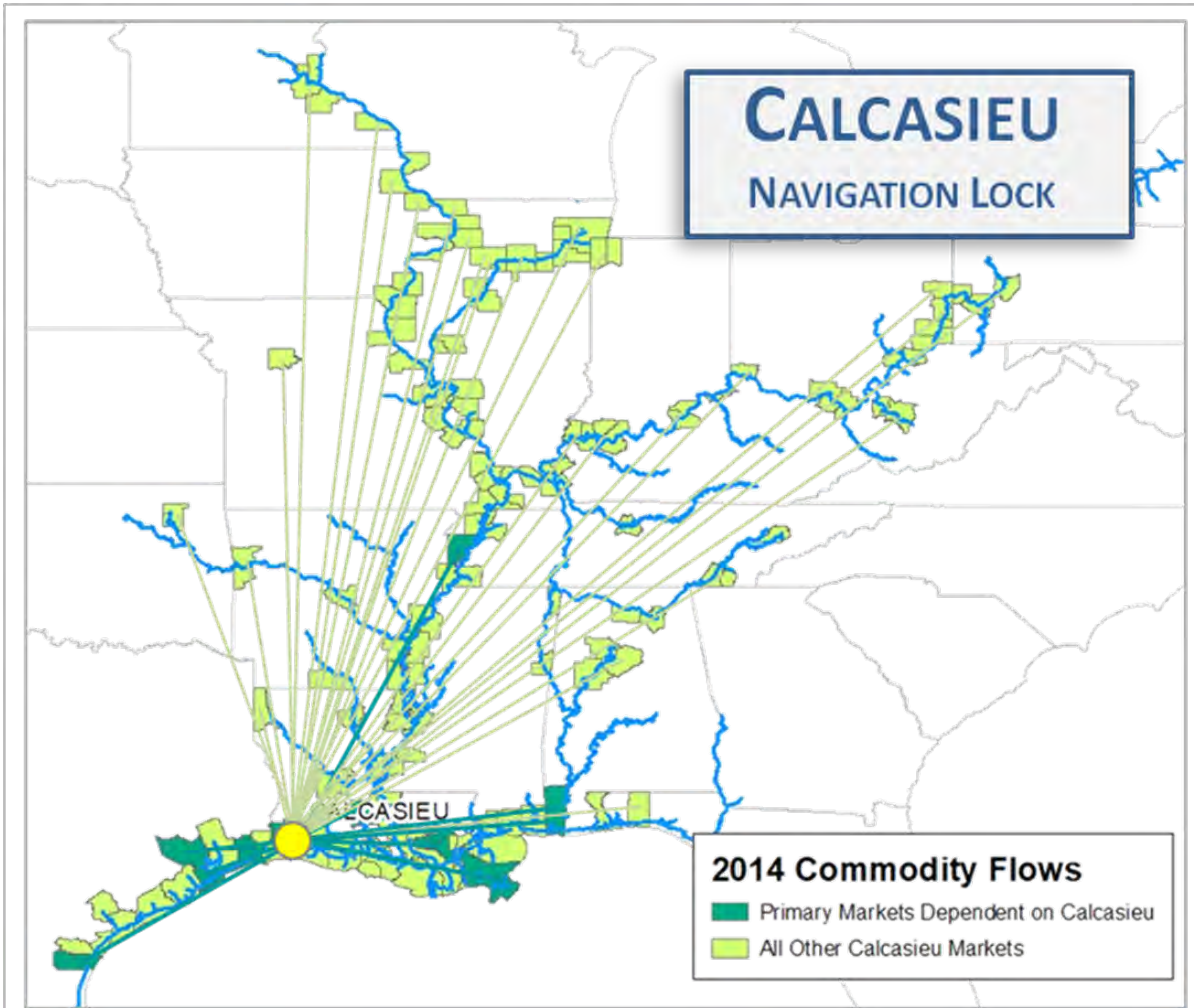


Figure 2.5 – Distribution of Coal Shipments Transiting Markland Locks & Dam



⁴ These graphics are provided to emphasize the potential change in Ohio River traffic composition. Similar depictions for an array of commodities and encompassing all four locks can be found in Appendix 3.

Figure 2.6 – Markets Dependent on Calcasieu Lock⁵



CALCASIEU LOCK & DAM

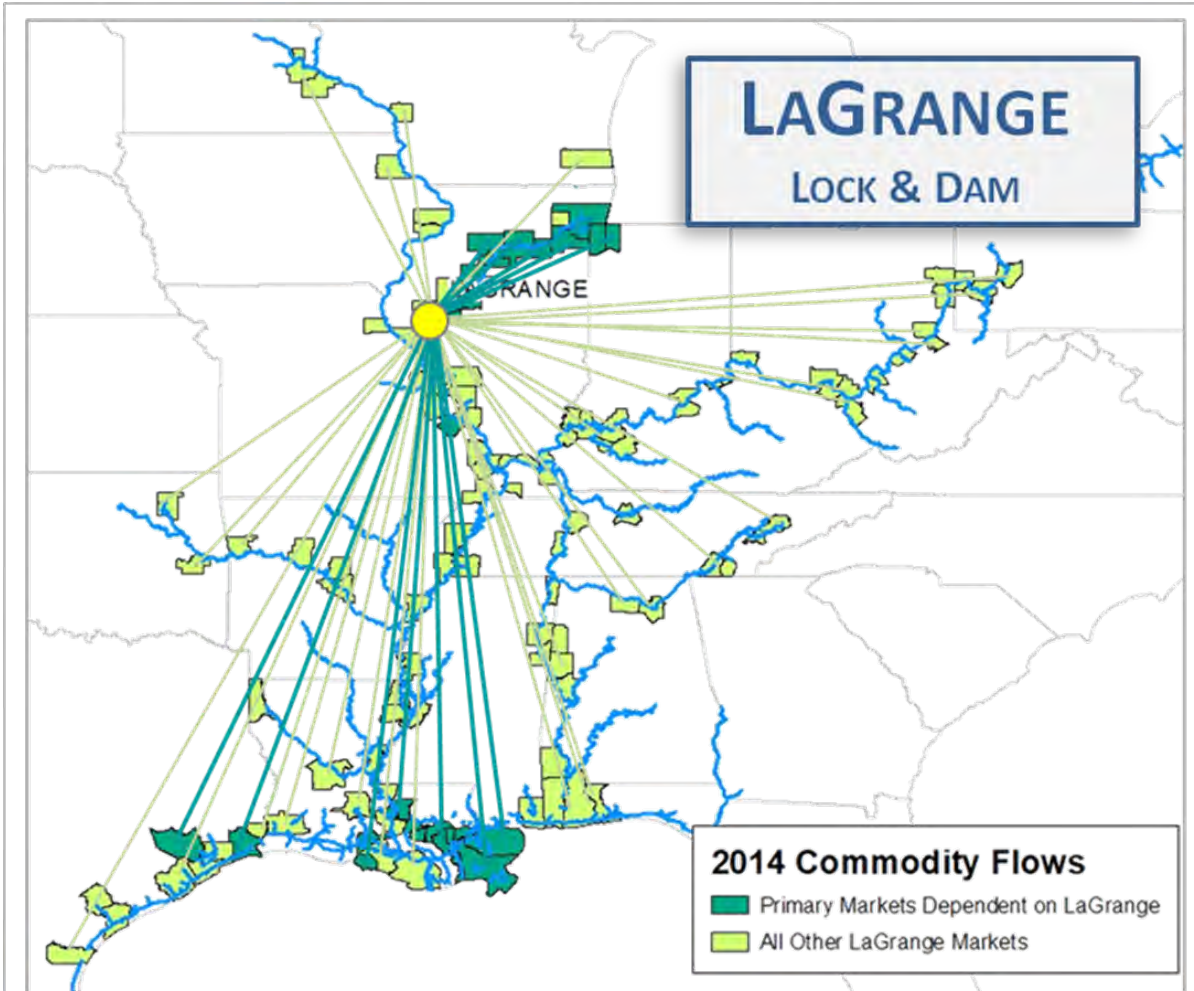
Calcasieu is a critical piece of the high-density waterway corridor that serves plastic and chemical producers and petroleum refiners throughout the Gulf region. Unseen to most, Calcasieu moves 40 million tons of freight through the Gulf each year. This facility, and the system it supports, are vital commercial links within America’s freight network that (1) are essential to affordable energy production, (2) efficiently connect the Gulf region to global trade, and (3) integrate the Gulf region’s vital production into the core U.S. economy.

AN UNPLANNED CLOSURE WOULD:

- Immediately affect commerce in 170 counties in 18 states.
- Cost the shipping public more than \$1.1 billion annually in additional transport charges.
- Require the availability and use of 10,000 additional rail cars and several hundred locomotives.
- Result in the loss of 17,000 full-time, highly-compensated jobs.

⁵ Depictions similar to that provided for Markland for Calcasieu commodities can be found in Appendix 3.

Figure 2.7 – Markets Dependent on LaGrange Lock & Dam⁶



LAGRANGE LOCK & DAM

LaGrange is a critical piece of the marine highway that links the upper Mississippi and Illinois basin farmlands to export markets reachable through the Louisiana Gulf. Each year, more than ten million tons of corn and soybeans transit this lock down-bound, for export and the region’s agriculture is equally served by up-bound fertilizer movements.

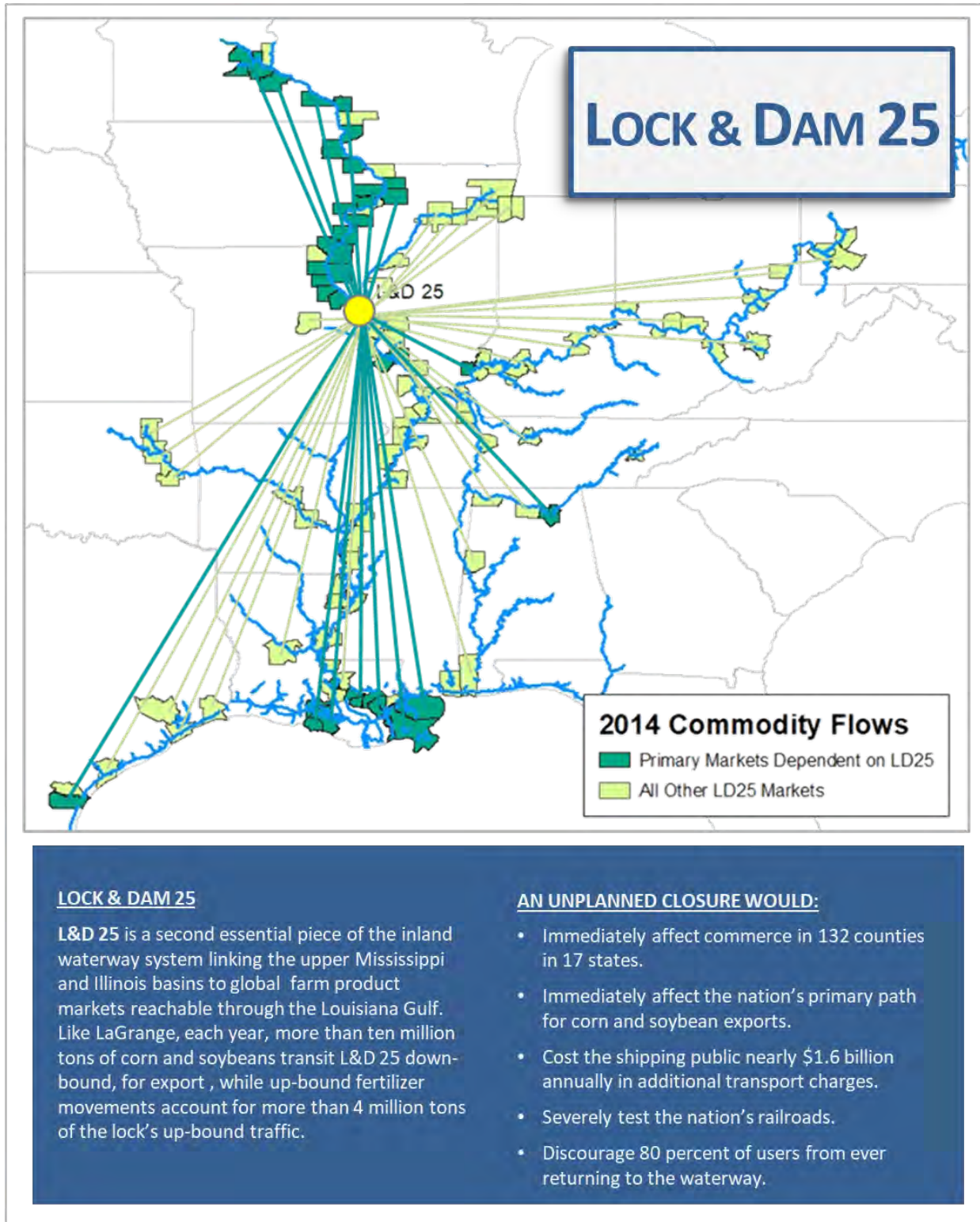
In addition to agricultural commerce LaGrange also is an integral component in the navigation system that links the Chicago Area Waterway System (CAWS) to the rest of the U.S.

AN UNPLANNED CLOSURE WOULD:

- Immediately affect commerce in 135 counties in 18 states
- Threaten the nation’s primary path for corn and soybean exports.
- Cost the shipping public nearly \$1.7 billion annually in additional transport charges.
- Severely stress the nation’s railroad infrastructure.
- Lead to a \$2.1 billion loss in farm-dependent incomes.

⁶ Depictions similar to that provided for Markland for LaGrange commodities can be found in Appendix 3.

Figure 2.8 – Markets Dependent on Lock & Dam 25⁷



⁷ Depictions similar to that provided for Markland for Lock & Dam 25 commodities can be found in Appendix 3.

2.3 REGIONAL ECONOMIC DEVELOPMENT (RED) ANALYSIS

Consistent with the overarching goal to use existing resources more efficiently, results from a prior National Waterways Foundation sponsored-study were used to expedite the estimation of regional economic impacts for the four subject locks.⁸ Section 5 describes the specific steps necessary to this application. The earlier NWF work involved converting lock-related efficiencies into production cost advantages that were used as drivers in economic simulations. Here, we combine the earlier study results with current estimates of avoided transportation costs to estimate upper bounds for regional economic impacts (output, incomes, and employment) attributable to the subject locks. Note “output” refers to the total value of all regional sales. These estimates are combined with an alternative methodology to estimate a corresponding lower bound for the same impacts. It is the midpoint or average for each estimated outcome that is reported here.

Before presenting the results of these estimations, it’s useful to consider three points. First, even though there is often an overlap, *economic benefits and economic impacts are not the same thing*. Economic benefits are the *net efficiency gains* for which there is no offset. In this case these gains are the transportation costs avoided by ensuring reliable navigation infrastructures. Economic impacts are different. While they do account for the improved efficiency (direct effects), regional impacts also capture the ways that an economic improvement affects production, jobs, and incomes within a specific study area. These additional impacts often reflect economic transfers from one region to another. Nonetheless, they are a very real economic result of improved transportation access.

Next, calculating economic impacts requires an understanding of where a direct stimulus is likely to have its effects. It’s easy to understand that a cost-constraining navigation project physically located in a remote rural location will not materially affect economic conditions in the region surrounding the lock. However, it’s more difficult to determine where the direct effects *will* be felt. In response, the current analysis (and the earlier NWF-sponsored work) makes a strong simplifying assumption. In estimating regional economic impacts, the analysis assumes that for all non-farm product commodities, the economic stimulus associated with avoided transportation costs is divided equally between the region where the waterway shipment originates and the region where it terminates. As further explained in Section 5, this assumption is not tenable for farm products. Consequently, in the case of this commodity group, all direct effects are assumed to occur in the originating region.

Finally, unlike large-scale feasibility studies, this study does not adopt a *systems* approach, but instead examines each subject lock in isolation. For the estimated regional economic impacts, this methodology means that the results are *not* additive. Any attempt to sum effects across locks would result in double-counting.

⁸ INLAND NAVIGATION IN THE UNITED STATES: An Evaluation of Economic Impacts and the Potential Effects of Infrastructure Investment, National Waterways Foundation, November 2014, <http://www.nationalwaterwaysfoundation.org/documents/INLANDNAVIGATIONINTHEUSDECEMBER2014.pdf>

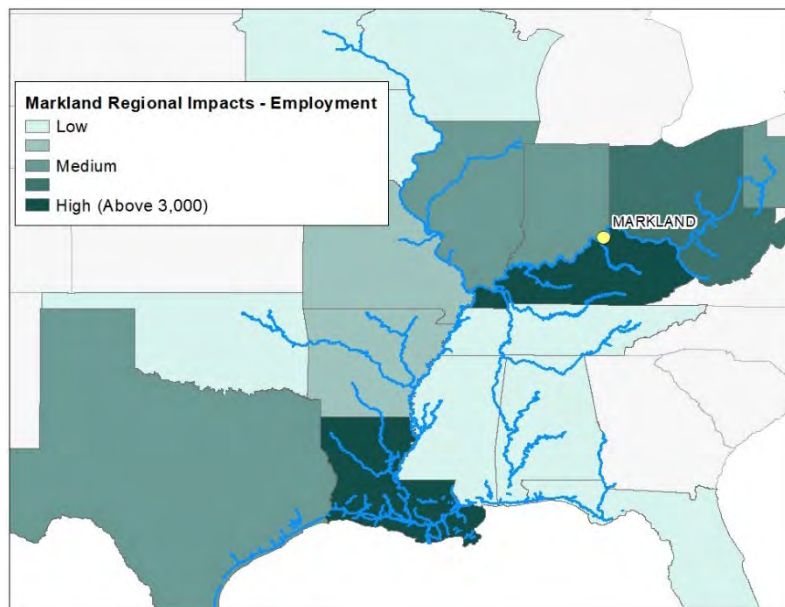
Markland Locks & Dam - Table 2.6 provides estimates of the economic impacts tied to the commercial use of Markland. These values reflect the importance of Markland as a means of shuttling Kentucky coal mid-Ohio basin power plants, but they also document economic activity generated in Louisiana by a lock so far upstream, due to the ability to affordably move chemicals and petroleum from manufacturing and refining facilities on the Gulf to the upper Ohio basin. Regional employment effects of Markland are shown in Figure 2.9.

Table 2.6 – Economic Impacts Attributable to Markland Locks & Dam

State	Total Avoided Costs	Total Attributable Output*	Total Attributable Incomes	Total Attributable Employment
AL	4,504,940	10,742,105	2,693,298	49
AR	6,474,484	16,184,170	5,185,339	81
FL	163,962	558,126	135,933	2
IA	814,055	2,033,786	650,840	10
IL	42,622,718	90,346,646	27,064,511	463
IN	78,141,984	115,728,190	31,296,844	719
KY	326,983,504	470,449,884	125,966,921	3,008
LA	257,103,456	853,703,317	206,841,402	3,240
MN	634,116	1,671,426	530,007	8
MO	14,157,717	36,993,878	11,669,365	177
MS	3,208,111	5,954,770	1,455,911	30
OH	264,459,882	401,523,540	109,226,097	2,433
OK	5,012,705	9,548,722	2,363,199	47
PA	65,205,206	98,410,103	26,584,599	600
TN	7,960,054	12,267,476	3,324,682	73
TX	37,597,321	131,395,819	31,967,086	474
WI	96,643	246,196	79,088	1
WV	194,919,978	262,820,230	70,509,053	1,793
TOTAL	\$1,310,060,836	\$2,520,578,383	\$657,544,177	13,210

* Output is the total value of all regional sales.

Figure 2.9 – Regional Employment Effects of Markland Locks & Dam



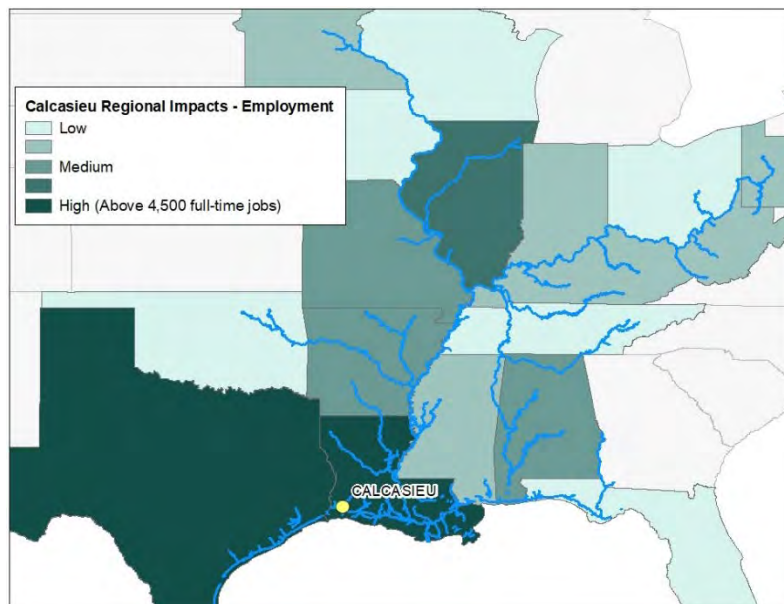
Calcasieu Lock - Calcasieu Lock is an essential component in a conduit that links oil refining and chemical manufacturing facilities in Texas with similar operations in Louisiana and other locations along the Gulf-Intracoastal Waterway. Thus, it is not surprising that Texas and Louisiana rank first and second in economic activity summarized in Table 2.7. Notably, however, Illinois ranks third in terms of Calcasieu's economic impacts. This importance, as it impacts regional employment, is depicted in Figure 2.10.

Table 2.7 – Economic Impacts Attributable to Calcasieu Lock

State	Total Avoided Costs	Total Attributable Output*	Total Attributable Incomes	Total Attributable Employment
AL	42,888,109	132,913,445	33,324,529	608
AR	33,118,475	107,593,798	34,472,595	515
FL	3,815,650	16,880,611	4,111,323	66
IA	764,635	2,482,772	794,522	12
IL	79,201,353	218,190,142	65,361,690	1,108
IN	33,631,545	64,734,109	17,506,308	394
KY	29,271,965	54,735,745	14,655,957	337
LA	283,789,119	1,224,690,717	296,726,908	4,554
MN	15,751,393	53,959,619	17,110,536	255
MO	26,871,911	91,257,134	28,786,190	436
MS	25,072,671	60,485,023	14,788,285	299
OH	12,189,517	24,053,005	6,543,118	151
OK	4,172,954	10,331,143	2,556,840	50
PA	15,370,275	30,148,846	8,144,438	180
TN	5,463,483	10,943,102	2,965,756	66
TX	486,123,401	2,208,018,996	537,185,533	8,236
WI	828,422	2,742,786	881,099	13
WV	19,236,622	33,710,319	9,043,758	209
TOTAL	\$1,117,561,501	\$4,347,871,315	\$1,094,959,385	17,487

* Output is the total value of all regional sales.

Figure 2.10 – Regional Employment Impacts Attributable to Calcasieu Lock



LaGrange Lock & Dam and Lock & Dam 25 - Tables 2.8 and 2.9 summarize the state-specific output, employment and income effects of LaGrange Lock & Dam and the Lock & Dam 25. Regional employment impacts are isolated in Figures 2.11 and 2.12. Together, these tables and figures point to the importance of available navigation to the agricultural regions defined by the upper Mississippi and Illinois River basins. There are several points worth noting.

Table 2.8 – Economic Impacts Attributable to LaGrange Lock & Dam

State	Total Avoided Costs	Total Attributable Output *	Total Attributable Incomes	Total Attributable Employment
AL	8,585,416	26,606,843	6,670,962	122
AR	5,472,911	17,780,146	5,696,683	85
FL	1,276,983	5,649,432	1,375,936	22
IA	226,791	736,392	235,656	4
IL	1,243,665,137	3,426,146,930	1,026,346,801	17,402
IN	43,902,241	84,503,180	22,852,538	514
KY	12,675,954	23,702,809	6,346,627	146
LA	270,539,494	1,167,512,015	282,873,239	4,341
MN	2,865,943	9,817,876	3,113,238	46
MO	6,600,766	22,416,232	7,070,986	107
MS	5,127,185	12,368,762	3,024,100	61
OH	11,597,985	22,885,763	6,225,594	143
OK	3,670,326	9,086,768	2,248,871	44
PA	4,905,791	9,622,725	2,599,492	57
TN	6,280,104	12,578,755	3,409,044	76
TX	72,471,408	329,172,070	80,083,765	1,228
WI	592,709	1,962,373	630,398	9
WV	3,545,102	6,212,449	1,666,667	38
TOTAL	\$1,704,002,248	\$5,188,761,521	\$1,462,470,596	24,447

* Output is the total value of all regional sales.

Figure 2.11 – Regional Employment Impacts of LaGrange Lock & Dam

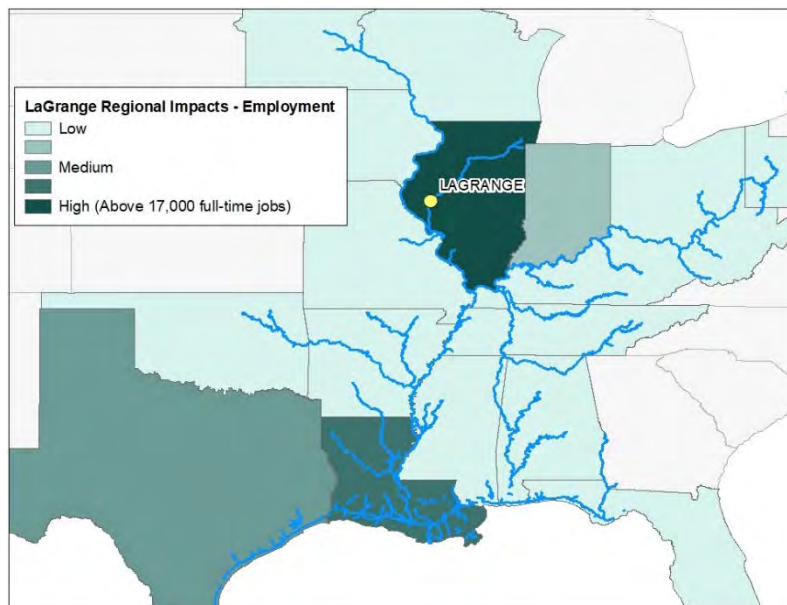
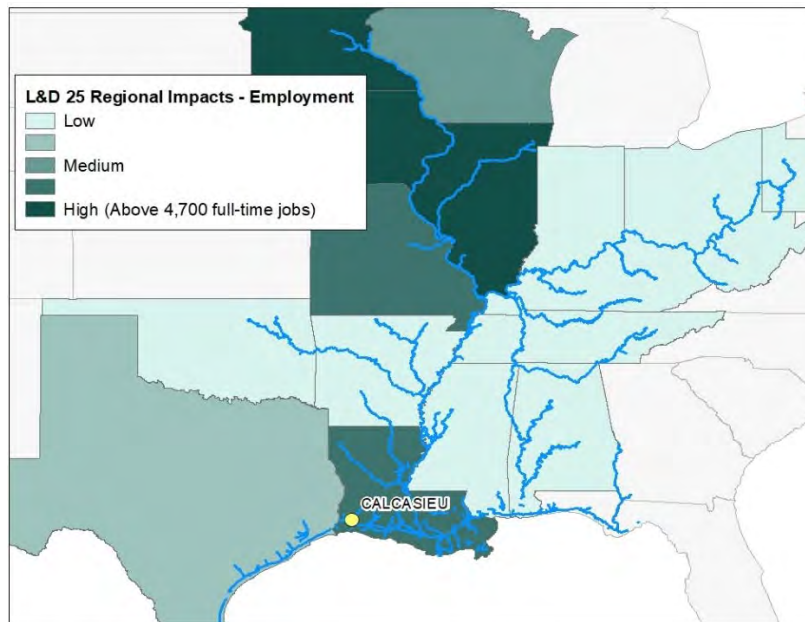


Table 2.9 – Economic Impacts Attributable to Lock & Dam 25

State	Total Avoided Costs	Total Attributable Output *	Total Attributable Incomes	Total Attributable Employment
AL	2,793,743	8,658,018	2,170,769	40
AR	6,801,464	22,096,288	7,079,557	106
FL	-	-	-	-
IA	369,628,309	1,200,184,825	384,076,031	5,763
IL	340,595,456	938,299,258	281,079,727	4,766
IN	2,812,857	5,414,196	1,464,183	33
KY	2,371,176	4,433,870	1,187,206	27
LA	211,309,773	911,906,412	220,943,268	3,391
MN	379,834,042	1,301,199,232	412,608,844	6,147
MO	130,893,626	444,515,357	140,218,116	2,123
MS	4,737,495	11,428,678	2,794,254	56
OH	2,182,266	4,306,163	1,171,402	27
OK	2,073,890	5,134,410	1,270,708	25
PA	848,134	1,663,618	449,411	10
TN	1,253,866	2,511,435	680,639	15
TX	24,780,404	112,554,967	27,383,324	420
WI	79,374,813	262,798,466	84,422,032	1,266
WV	3,226,594	5,654,293	1,516,926	35
TOTAL	\$1,565,517,907	\$5,242,759,485	\$1,570,516,397	24,250

* Output is the total value of all regional sales.

Figure 2.12 – The Regional Employment Impacts of Lock & Dam 25



First, as mentioned above, in the case of farm products, the whole of the economic impacts are assumed to reside in the origin regions. Also, as described in Section 2.4, the likely diversion of current waterborne shipments of corn and soybeans to the PNW would increase transportation costs significantly above present levels. Together, these combined influences predict a fairly dramatic decline in farm incomes within both river basins, with attendant indirect and induced impacts throughout the region.

However, even though down-bound grain is assumed to have no effect on the Louisiana Gulf economy, the effects of LaGrange and of L&D 25 are still pronounced in Louisiana (19 percent of the total for LaGrange, 14 percent of the total for L&D 25). Based on commodity disaggregations of the subject traffic, these impacts are almost exclusively attributable to the waterways' ability to constrain costs for up-bound movements of chemicals and petroleum products.

2.4 RAILROAD CAPACITY AND ITS IMPACT ON SHIPPER COSTS

There are several complexities that lie just below the surface of the navigation-attributable averted costs summarized in Section 2.2. Some of these are addressed by the P&G, but rarely treated in application. Other intricacies lie outside the P&G's normal bounds.

The basic questions are:

1. To the extent that railroads and rail-served terminals would be expected to absorb diverted waterway traffic, do they have the capacity to accommodate the additional demands?
2. If capacity is inadequate, would the railroads and terminal operators invest in new capacity to support the same routes currently used by waterway shippers?
3. If, instead of adding new capacity, traffic is diverted to alternative locations where transportation costs are higher, are those higher costs appropriately included in the calculation of navigation related benefits?
4. How do time horizons and uncertainty about modal availability affect the answers to the first three questions?

The P&G and Capacity

With regard to the issue of capacity, the P&G (2.6.3 (a) 4, p. 50) state:

In projecting traffic movements on other modes (railroad, highway, pipeline, or other), the without-project condition normally assumes that the alternative modes have sufficient capacity to move traffic at current rates unless there is specific evidence to the contrary.

Based on this guidance, USACE studies almost always assume that alternative modes or modal combinations have capacities that are sufficient to accommodate diverted traffic. When capacity has emerged as a potential issue, the assumption has been that it can be added without adversely affecting prevailing freight rates. In either case, this allows analysts to rely on currently observed values and relieves any need to estimate the cost of additional capacity or the extent to which those costs might affect project benefit calculations.

Where and Why Is Capacity an Issue?

As noted, unless there is evidence to the contrary, the methods used to estimate averted shipper costs presume that there is transport capacity available from the other primary freight modes – truck and rail – to absorb the additional volumes presented as a result of the individual lock closure.

After reviewing the mix of commodities, transportation alternatives, and the pattern of origins and destinations that determine corridor concentration and length of haul, rail capacity does not appear to be an issue for Markland or Calcasieu traffic. In the cases of LaGrange and L&D 25, however, it appears that the capacity assumption is inappropriate and, if left untreated, may lead to an understatement of the shipper costs that would result from an unplanned lock closure.

One useful way to illustrate why this concern is present at LaGrange and L&D 25 but less so at Markland and Calcasieu is to further examine the traffic concentration and length of haul. Figures 2.13 and 2.14 reflect the traffic concentration of the four locks and again illustrate that traffic flows through both L&D 25 and LaGrange are concentrated along north-south corridors and feature a line-haul that routinely extends more than a thousand miles.⁹ Alternatively, Calcasieu (to some degree) and Markland (in particular) serve traffic in many corridors, with trip distances that are only 60 percent as long for LaGrange and L&D 25. Where it exists, this concentration of waterway traffic into narrowly-defined, heavy-haul corridors has implications regarding the adequacy of both line-haul and terminal capacities.

Line-Haul Railroad Capacity Issues

Currently, LaGrange and L&D 25 support the movement of roughly 10 million tons each of corn and soybeans from the upper Mississippi and Illinois basins to export locations at or near New Orleans (the Louisiana Gulf). This grain is produced on farmland that has no meaningful alternative use. Even in the event of long-term decline in farm incomes and further restructuring to regional agriculture, there is no reason to suppose that a reduction in agricultural production would take place.

Table 2.10 summarizes current (2014) railroad movements from potentially affected upper basin states to the Louisiana Gulf. Figure 2.15 depicts the rail network serving those regions. Looking first at the data, it is clear that any attempt to substitute rail for barge toward the movement of 10 million additional down bound tons would represent a significant increase in north-south railroad traffic. LaGrange and L&D 25 both provide extreme evidence of potential congestion.

Virtually all waterway movements of corn and soybeans through LaGrange originate in Illinois, so that an unplanned lock outage would leave 10 million tons of corn and soybeans seeking a south bound routing along corridors that currently accommodate only 2.2 million tons of farm products annually.¹⁰

Grain movements through L&D 25 have more geographically dispersed origins that would allow a wider variety of potential line-haul routings. However, the percentage increase in southbound traffic would be even greater, with 10 million tons seeking movement along rail corridors that currently accommodate only 1.2 million tons of farm products annually.

⁹ The stylized (green) corridors are based on the study team's examination of the data used to generate the Corridor Concentration Index described in Section 2 and Appendix 1.

¹⁰ The 2.2 million ton total is the total volume of soybeans and corn railed from Illinois, Iowa, Minnesota, Missouri, and Wisconsin to export locations in Louisiana as indicated through the Surface Transportation Board's 2014 Annual *Carload Waybill Sample*.

Figure 2.13 – Corridors Served by Markland and Calcasieu

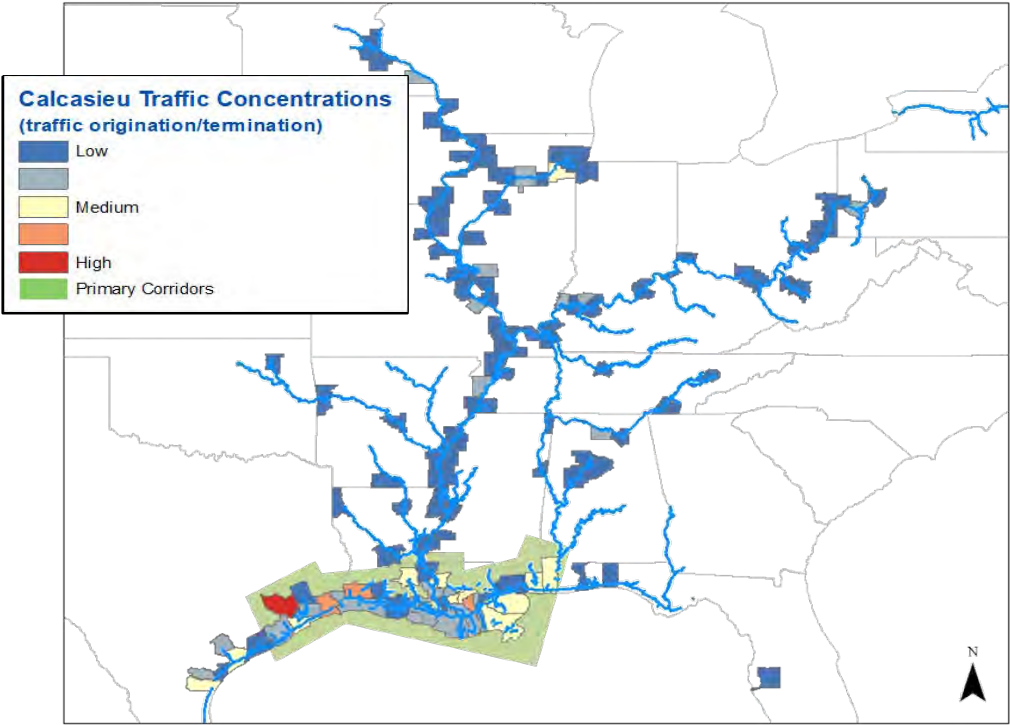
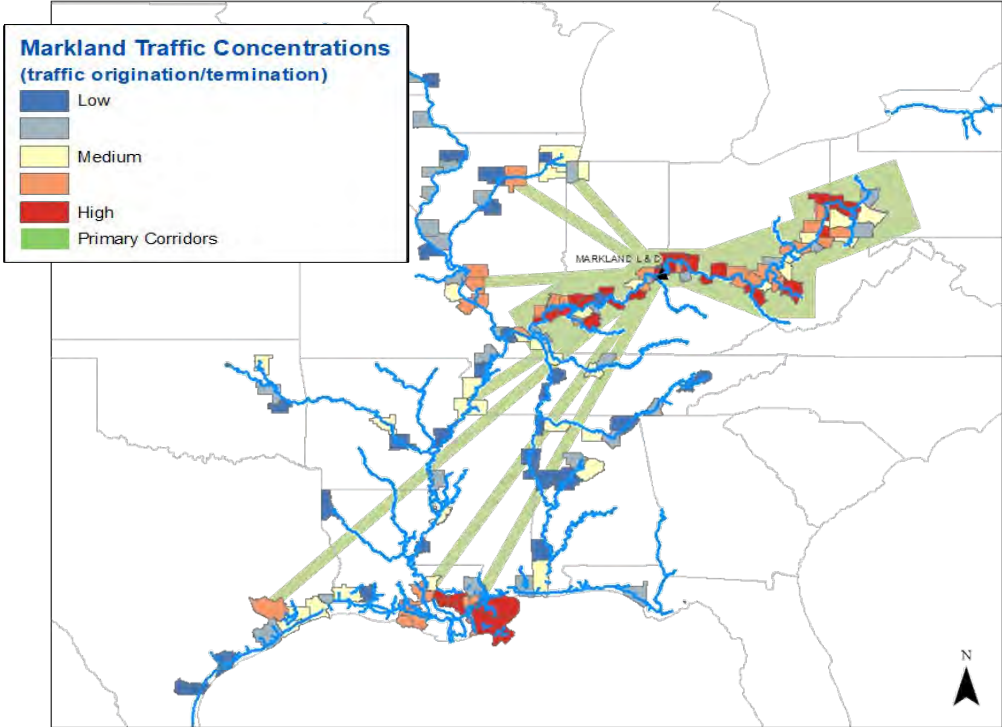


Figure 2.14 – Corridors Served by LaGrange and L&D 25

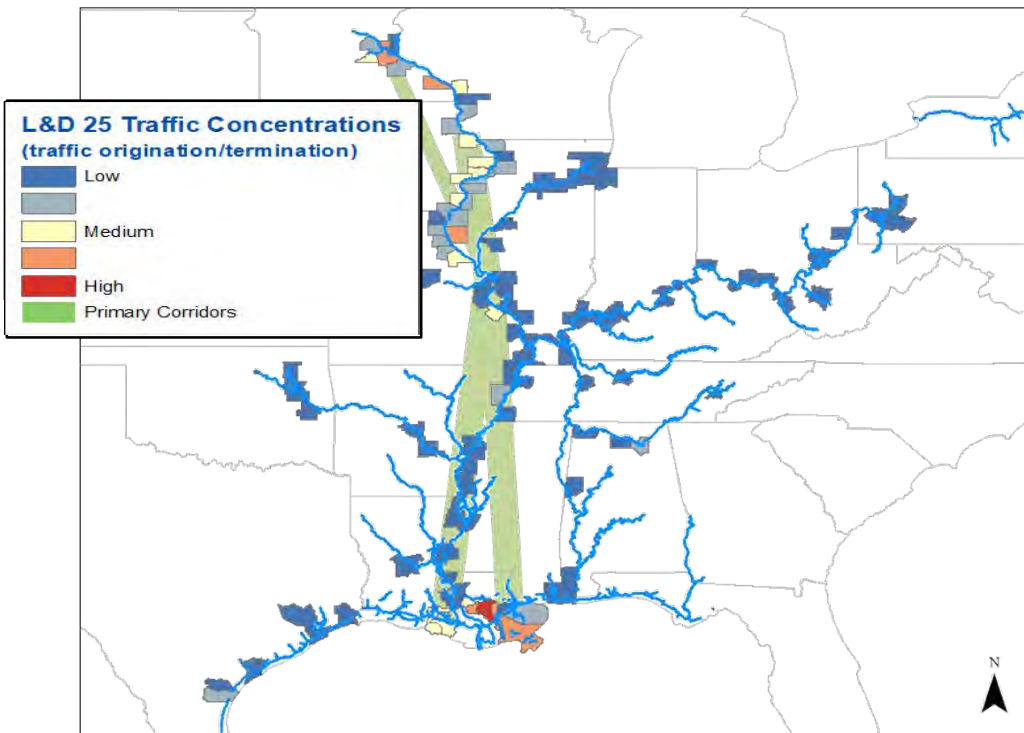
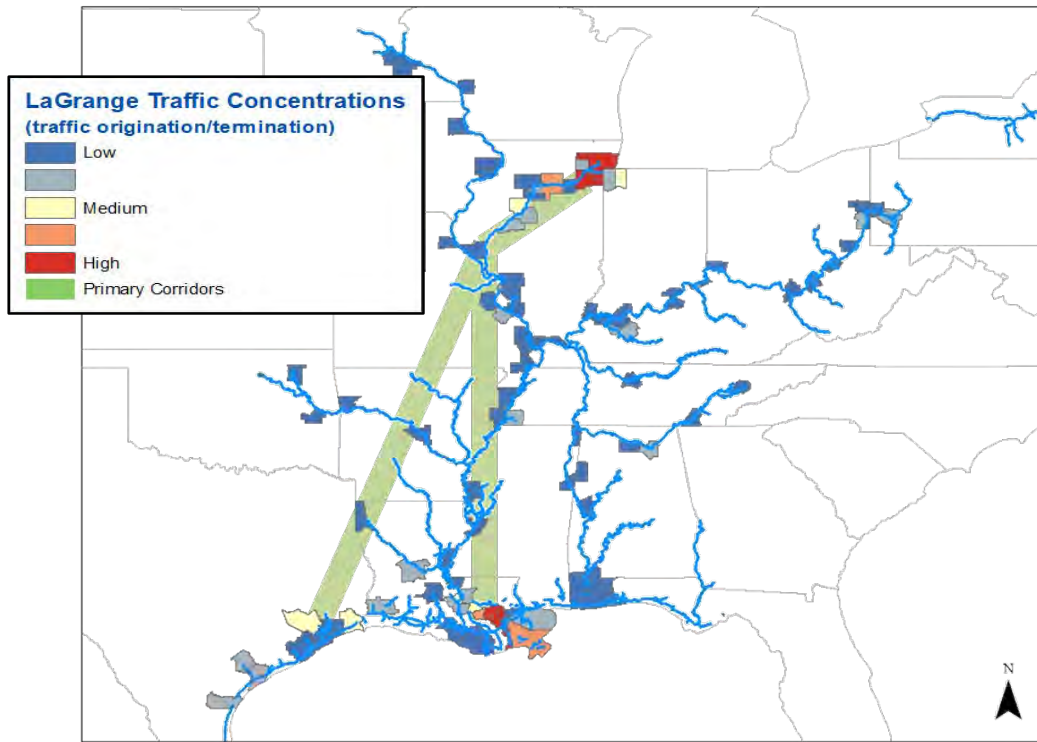
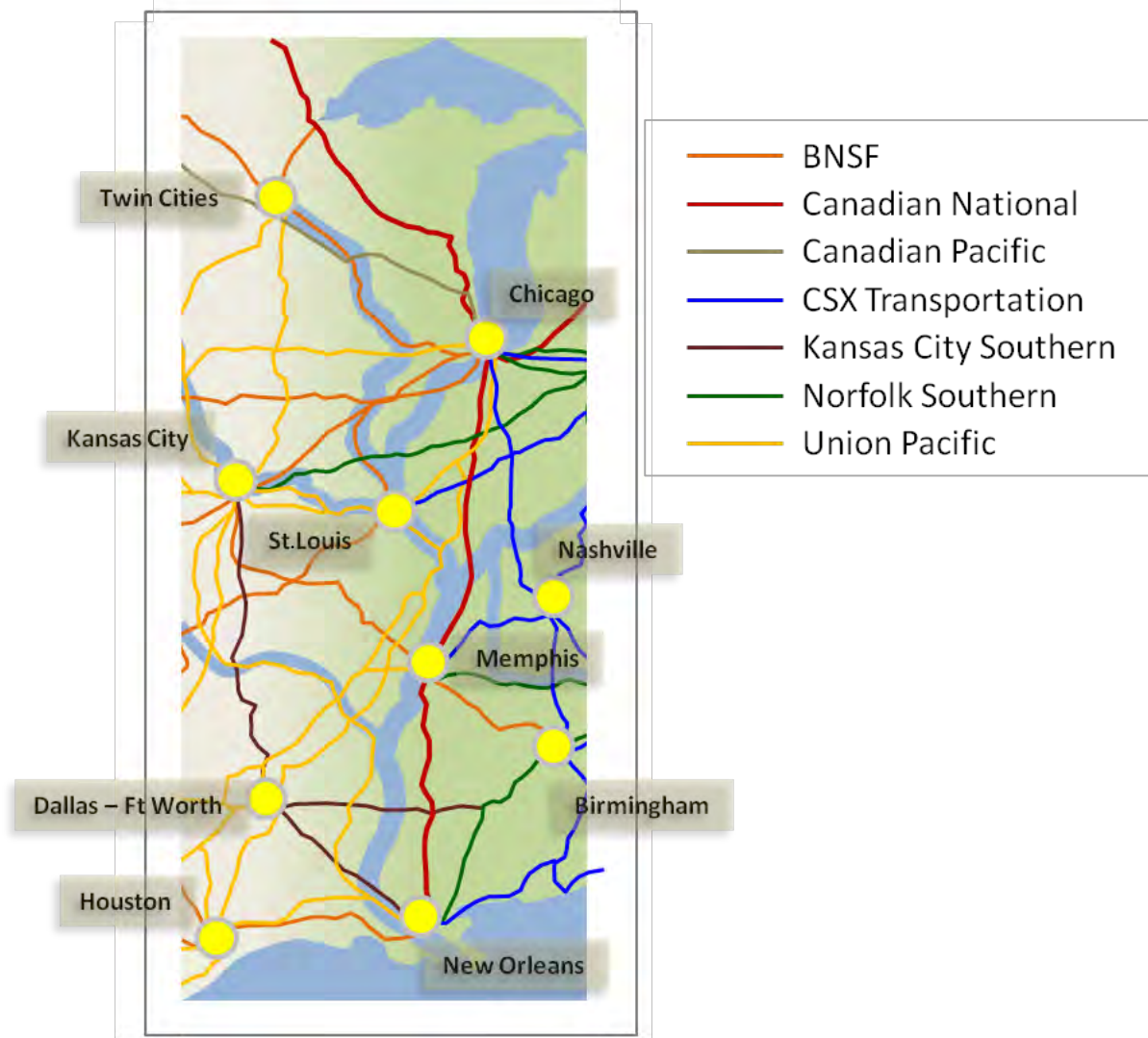


Table 2.10 – Summary of Railroad Traffic
(2014, Tons in Millions)

Originating State	Farm Products by Rail to Louisiana	All Rail Movements to Louisiana	Farm Products by Rail to all Destinations
Illinois	2.2	10.2	28.7
Iowa	0.7	1.4	7.6
Minnesota	0.2	0.4	13.1
Missouri	0.1	0.5	4.6
Wisconsin	0.2	0.6	2.8
TOTAL	3.4	13.1	56.8

Figure 2.15 – Core Regional Rail Network



Routing an additional 10 million tons to *any* location would require additional locomotives, covered hoppers, train crews, and track capacity. It would also require the use of nonexistent railroad capacity at many originating and destination terminal facilities. Setting aside the terminal issues for a moment, line-haul implications are relatively easy to explore.

Table 2.11 converts 10 million tons of additional annual demand for corn and soybean transport into line-haul railroad system characteristics based on an unplanned outage at LaGrange. Given *current* conditions, the equipment required to meet this additional demand is available. Data shows that presently there are more than 60,000 covered hoppers in storage. Similarly, both Union Pacific and BNSF have each stored hundreds of readily serviceable locomotives. Thus, under *current* conditions equipment is not an issue. However as recently as 2014, both locomotives and appropriate freight cars were much scarcer.

Again, almost without regard to export destination, the addition of the trains needed to accommodate a 10-million-ton increase would require between 200 and 300 additional qualified crew members. In some instances, displaced crews from unaffected locations could be expected to qualify and bid for jobs along affected routes. In other cases, it would be necessary to hire altogether new personnel to fill newly-created vacancies. Any attempt to accommodate the demands resulting from an unplanned lock closure through increased rail carriage could create at least temporary labor shortages.

In the case of LaGrange, both the Canadian National and Union Pacific could accommodate some of the incremental line-haul traffic. Doing so would require between three and four loaded trains originating toward the south each day and a corresponding number of originating north bound empties. Assuming that this traffic could be split between the two carriers, each affected segment of the railroad would see an additional three or four trains per day. Over the least active route segments, this would likely represent an immediate and unrelenting increase of train activity of roughly 25 percent.

In the end, any attempt to accommodate an unanticipated lock outage at LaGrange through the increased movement of corn and soybeans between Illinois and the Louisiana Gulf would place significant line-haul stresses on the Canadian National and Union Pacific Railroads. While it is likely that both carriers could adjust to accommodate the measurable increases in demand, doing so would not be accomplished quickly, easily, or without disruption to more general operations throughout the rail system.

An unanticipated outage at L&D 25 would present similar challenges with some important variations. On the positive side, the more westerly upstream origins for south bound corn and soybean movements would perhaps allow BNSF to play a larger role in addressing the sudden new demands. Unfortunately, the transit distance between most Iowa, Minnesota and Wisconsin origins are considerably longer than LaGrange-dependent traffic. Moreover, in some cases, traffic diverted to rail would necessarily transit Chicago, so that the car cycle times indicated for LaGrange would likely be much longer for L&D 25 movements.

Table 2.11 – Illustrative Rail System Impacts, LaGrange Outage

Railroad System Impacts	
Additional Annual Tons from LaGrange	10,000,000
Average Car Loading (Tons)	112
Additional Annual Carloads	89,286
Average Car Cycle Time (Days)	21
Annual Cycles	17
Additional Freight Cars (Continuous)	5,208
Train Length (Cars)	80
Additional Daily System Trains (Loads & MTYS)	65
Locomotives per Consist	2.5
Additional Locomotives	163
Average RR Distance (Miles)	1,000
Daily Trains per 100 Mile Track Length	7

LaGrange, L&D 25 and Terminal Capacity Issues

Potential line-haul congestion issues likely pale in magnitude compared to the constraints that exist at the terminal ends of diverted waterway movements. At least some Louisiana Gulf grain terminals have only modest rail access; some have no rail access at all; and a significant volume of corn and soybeans are loaded to ocean-going vessels via mid-stream transfer, thereby avoiding downstream terminals altogether.

There are also possible terminal constraints at the origination end of Gulf-bound shipments of corn and soybeans. However, these limitations may not be as severe as the constraints faced at Louisiana Gulf destinations. Table 2.12 provides the characteristics of Iowa’s water-served grain terminals. While these characteristics are not necessarily descriptive of off-river terminals, they suggest that rail car capacity is an issue.

Finally, if necessary, new export grain terminal capacity can be created in the upper Mississippi and Illinois basin, on the Louisiana Gulf, or anywhere else it is desired. However, creating this capacity would require substantial private sector investment. Within the current context, new investments in terminal track capacities at the basin states origins would only be predicted as a response to *extended* lock closures. Further, in the case of export terminals, new alternative rail-served capacity is only likely if there is a permanent closure of either LaGrange or L&D 25 or if there are significant and lasting changes in the global markets these terminals serve.

Table 2.12 – Iowa’s Water-Served Grain Terminals

Company	Iowa Location	Rail Car Storage	Dry Storage	Commodities
Cargill	Council Bluffs	104	2.2 mb	Soybeans, corn
Ag Processing	Sergeant Bluffs	250	3.5 mb	Soybeans, bean products
Colusa	Wever	0	3.5 mb	Corn, soybeans, wheat
ADM/Growmark	Burlington	54	0.5 mb	Corn, soybeans, wheat
AGRI	Burlington	0	0.6 mb	Corn, Soybeans
Grain Processing Corp.	Muscatine	0	na	Corn
Cargill AgHorizons	Muscatine	25	1.2 mb	Corn, Soybeans
Cargill AgHorizons	Buffalo	30	0.9 mb	Corn, Soybeans
CHS Inc.	Davenport	35	na	Corn, Soybeans, General
CHS Inc.	Davenport	25	na	Corn, Soybeans
River/Gulf Grain Co.	Bettendorf	0	na	Corn, Beans, General Commodities
ADM/Growmark	Clinton	0	0.7 mb	Corn, Soybeans
Cargill AgHorizons	Dubuque	40	60,000	Corn, Soybeans
Peavey	Dubuque	45	0.4 mb	Corn, Soybeans, Others
Agri-Bunge, LLC	McGregor	25	1.0 mb	Corn, Soybeans

Time Horizons and the Likelihood of New Capacity Investment

The P&G assumes that adequate alternative capacity is available *or* that additional capacity can be added with no adverse effect on costs. Clearly, the first part of this assumption is suspect in the cases of LaGrange and L&D 25. This leads to several additional questions – would railroads and terminal operators invest in new capacity? where would new (or modified) facilities be located? how much would additional capacity cost? and how would incremental capital costs be recovered?

Necessary improvements to railroad line-haul capacity can generally be made incrementally and at costs that do not adversely affect railroad costs or rates.¹¹ However, this is probably not true for terminal facilities. Estimating the cost of new or expanded rail-served grain terminals on the Louisiana Gulf is beyond the scope of our current work, but the magnitude of the necessary expenditures would be large.

Given this probability and the current dominance of barge transport in the movement of upper basin corn and soybeans to the Gulf, investors would likely be hesitant to build new, rail-served terminal capacity unless there is a *guarantee* that waterborne commerce would not be restored over a time horizon measured in several decades. This seems like an extraordinary hurdle. Moreover, even if investors were willing to build new soybean and corn export capacity, there is no reason to assume that it would be located on the Gulf as opposed to the Pacific Northwest or East Coast. Even in the long-run, the conclusion that alternative freight capacity for moving grain between the upper basin states and the Louisiana Gulf is or will be available is simply not supportable.

¹¹ See Mark L. Burton “Available Navigation and the Incremental Cost of Railroad Capacity: Preliminary Lessons from the Upper Mississippi Basin,” Proceedings of the Agricultural Outlook Forum 98, , D.C., pp. 431-437, Washington, 1998.

The Effect of a Lock Closure on Rail Charges for Export Soybeans and Corn

Using a short-run time horizon, a recent United States Department of Agriculture (USDA) study acts upon the same conclusions regarding capacity. The USDA analysis considered similar disruptions at LaGrange and L&D 25.¹² It concluded that roughly 60 percent of the waterway grain that currently is exported through the Louisiana Gulf would divert to rail carriage and be bound for alternative export destinations – primarily the Pacific Northwest. Moreover, in the USDA work, this diversion is bolstered by hypothetical rail rate increases to Gulf destinations of five and 15 percent. Based on our computations, the magnitudes of the USDA study’s diversions appear reasonable, though depending on terminal capacities, they may reflect a lower bound.

Based on this study’s analysis of railroad capacity, as well as findings provided in the USDA study, it appears that an unscheduled lock outage would divert a substantial portion of corn and soybeans from their current Louisiana Gulf export destinations to Pacific Northwest gateways. The estimated railroad charges associated with these PNW diversions are notably higher than existing rail charges to Gulf export locations. However, rates on the modest amount of corn and soybeans currently moving to the Louisiana Gulf by rail were not changed. These currently observed rail rates were also applied to the subset of currently waterborne corn and soybean shipments that were allowed Gulf coast diversions.

Non-Grain Waterway Diversions

Table 2.13 provides the 2015 LPMS statistics for LaGrange and L&D 25. The aggregations of Food and Farm Products and All Chemicals obscure an important similarity. Traffic through both locks is characterized by roughly 10 million tons of down-bound corn and soybeans and four million tons of up-bound fertilizer. Together, these commodities account for more than half of the traffic at each lock.

It’s possible that rail pricing for the movement of non-grain commodities – particularly fertilizer would be affected by a closure. However, the relatively smaller volume of these movements and their dispersed geography makes anything more than their traditional treatment impractical.

Table 2.13 – LPMS Statistics: LaGrange and L&D 25

LPMS Commodity Groupings	2015 Tons	
	LaGrange	2015 Tons L&D 25
00 - All Units (Ferried Autos, Passengers, Railway Cars)	-	-
10 - All Coal, Lignite, and Coal Coke	825,600	435,200
20 - All Petroleum and Petroleum Products	3,282,660	295,000
30 - All Chemicals and Related Products	5,220,730	4,222,345
40 - All Crude Materials, Inedible, Except Fuels	2,742,110	2,347,780
50 - All Primary Manufactured Goods	2,864,981	1,475,263
60 - All Food and Farm Products	9,157,172	16,066,195
70 - All Manufactured Equipment & Machinery	36,475	71,910
80 - All Waste Material	3,200	4,800
90 - All Unknown or Not Elsewhere Classified - 90	13,900	1,600
TOTAL	24,146,828	24,920,093

¹² See: Yu, T.E, B.C. English and R.J. Menard. Economic Impacts Analysis of Inland Waterway Disruption on the Transport of Corn and Soybeans. Staff Report #AE16-08. Department of Agricultural and Resource Economics, University of Tennessee. September 2016.

3

Screening Tool Development

The purpose of the screening tool was to select locks on the inland waterway system that represent a balanced, cross-section. Section 2.1 summarizes the results of the current study's screening tool construction and application and these results are more fully provided in Appendix 2..

3.1 FREIGHT DATA AND DATA ACCESS

Compared to other industries, freight transportation data is plentiful. While each data product has limitations, access to and the use of these data is critical in this study and will be equally important for others who replicate these methods. The three most important data elements are:

- Lock Performance Monitoring System (LMPS) data;
- Waterborne Commerce Statistical Center (WCSC) data; and
- The Surface Transportation Board's annual Carload Waybill (CWS) data¹³

Lock Performance Monitoring System (LPMS) Data

Each time a vessel transits a navigation lock, lock personnel log its passage and record a variety of data describing the specific lock operation, the vessel, and the vessel's contents. This information is collected, processed and made available by the USACE's National Data Center (NDC) as a part of its Lock Performance Monitoring System (LPMS).

The chief advantage of the LPMS data is that they are available quickly – usually with only a three-month lag. There are two primary limitations. First, LPMS data are only available for locations where the USACE operates navigation facilities. There is no corresponding set of information for reaches of open river. Second, tonnage information is estimated by the towboat operators transiting the locks and are not subject to verification.

The LPMS data are publicly released at a level of disaggregation that is sufficient for many analytical uses. Table 3.1 provides a sample of the publicly available summary for one navigation lock (Peoria Lock) for 2014-2016. As Table 3.2 illustrates, these same data are available on a monthly basis by direction (up-bound v. down-bound) from 1999 forward.

¹³ The screening tool development described here did not use data from the CWS. However, it was used extensively in the evaluation of shipper supply chain costs described in Section 4. Moreover, from an organizational standpoint it seemed more sensible to describe all three primary data sources within a single subsection. This screening tool can be used by others who may wish to study additional locks on the inland waterway system.

Table 3.1 – Sample Annual LPMS Data¹⁴

PEORIA LOCK & DAM Description	(Tons in Thousands)		
	CY2016	CY2015	CY2014
10 - All Coal, Lignite, and Coal Coke	3,705.2	3,605.6	4,299.8
20 - All Petroleum and Petroleum Products	5,259.4	5,057.9	4,865.5
30 - All Chemicals and Related Products	2,255.4	2,951.8	3,534.3
40 - All Crude Materials, Inedible, Except Fuels	2,153.4	2,668.6	2,861.3
50 - All Primary Manufactured Goods	8,161.6	7,056.7	7,558.7
60 - All Food and Farm Products	34.3	44.8	70.9
70 - All Manufactured Equipment & Machinery	9.5	1.4	27.0
80 - All Waste Material	-	-	-
TOTAL TONS	21,578.8	21,386.8	23,217.5

Table 3.2 – Sample Monthly LPMS Data¹⁵

PEORIA LOCK & DAM Description	JANUARY 2014 (Tons in Thousands)		
	Up-Bound	Down-Bound	Total
10 - Coal, Lignite And Coke	45.3	56.0	101.3
20 - Petroleum and Petroleum Products	87.8	173.4	261.2
30 - Chemicals and Related Products	168.7	157.3	326.0
40 - Crude Materials, Inedible, except Fuels	125.5	15.5	141.0
50 - Primary Manufactured Goods	72.9	14.1	87.0
60 - Food and Farm Products	22.4	459.1	481.5
70 - All Manufactured Equipment and Machinery	7.5	5.0	12.5
80 - Waste Material	3.2	-----	3.2
TOTAL TONS	533.3	880.4	1,413.7

Finally, the LPMS data include entries noting arrival times, processing times, corresponding delays, and delay cause. While these data are potentially valuable, undetectable variations in reporting (both cross-sectional and longitudinal) remains a notable limitation of this dataset.

Waterborne Commerce Statistics Center (WCSC) Data

All USACE data activities are organized under its National Data Center and all activities, but one are headquartered at offices in Alexandria, Virginia. The exception is the Waterborne Commerce Statistics Center (WCSC), located in New Orleans. The WCSC produces an array of valuable products describing waterborne activities on the inland system, in coastal waters, and at both deep-draft and inland ports.

Every vessel operator is required to report each commercial vessel movement to the WCSC on a quarterly basis. These data form the basis for the various WCSC products that are typically released annually. Like the LPMS data, public releases reflect a certain degree of aggregation. However, because this reporting is by waterway segment (as opposed to individual locks), the publicly available data support only limited applications. Table 3.3 provides a summary of often used WCSC data elements.

¹⁴ Available at <http://www.navigationdatacenter.us/lpms/lpms.htm>

¹⁵ Available at <http://www.navigationdatacenter.us/lpms/lpms.htm>

Table 3.3 – Base WCSC Data Record Contents

Field No.	Variable Name	Description	Variable Type
1	REFNO	Team-assigned reference number	N
2	OFIPS	Origin state/county FIPS code	N
3	OST	Origin state (alpha)	A
4	OLAT	Origin latitude	N
5	OLON	Origin Longitude	N
6	OZIP	Origin ZIP Code	N
7	TFIPS	Destination state/county FIPS code	N
8	TST	Destination state (alpha)	A
9	TLAT	Destination latitude	N
10	TLON	Destination longitude	N
11	TZIP	Destination ZIP Code	N
12	LPMS_GP	LPMS commodity group	N
13	LPMS2	Two-digit LPMS commodity (numeric)	N
14	LPMS2A	LPMS commodity group (alpha)	A
15	OWW	Origin waterway (numeric)	N
16	OLOC	Origin location (numeric)	N
17	ODOCK	Origin dock code (numeric)	N
18	ORRMILE	Origin river mile	N
19	ODRAFT	Origin draft	N
20	ONAME	Origin name (alpha)	A
21	OSNAME	Originating shipper name (alpha)	A
22	TWW	Destination waterway (numeric)	N
23	TLOC	Destination location (numeric)	N
24	TDOCK	Destination dock code (numeric)	N
25	TRRMILE	Destination river mile	N
26	TDRAFT	Destination draft	N
27	TNAME	Destination name (alpha)	A
28	TSNAME	Destination shipper name (alpha)	A
29	TONS	Tons per loaded barge	N
30	WWTRIPDIS	Total waterway segment distance	N
31	BRGTYPE	Barge type	A

The full population of disaggregated WCSC records can sometimes be obtained if project sponsors involve federal entities. However, the WCSC rules for the release of disaggregated confidential data are both strict and rigorously enforced.

The Carload Waybill Sample (CWS)

In the U.S., railroad shipments are accompanied by *waybills*, documents that describe the shipments characteristics, equipment used, network routing, and (if a revenue movement) shipper charges. By statute, the Surface Transportation Board (STB) samples the population of waybills to develop its annual Carload Waybill Sample (CWS) that, with proper care, can be expanded to replicate full population characteristics.

The CWS is available in three forms – (1) a public use sample that obscures origin and destination information as necessary to protect confidentiality, (2) a confidential (but *masked*)

version that contains complete shipment information, but wherein carriers can replace actual charges for contract rail movements with constructed rates, and (3) an *unmasked* version that contains actual charges for all movements. Most federal and state agencies can obtain access to the confidential CWS. However, access to the unmasked sample is heavily restricted.

From a use standpoint, the CWS is well-documented and easy to manipulate.¹⁶ However, like all data products, it has limitations. First, the sampling the CWS introduces imprecision. This is particularly true as it is applied in more limited geographic or product settings. Second, the CWS is compulsory for Class I railroads, but it does not regularly reflect short-line or regional railroad (Classes II and III) activities unless those activities are in conjunction with a larger railroad. Finally, like the WCSC, there is a lag of, at least, two years in the CWS's availability.

3.2 ELEMENTS AND ANALYTICS – LOCK CHARACTERISTICS

The following lock characteristics are publicly available from the USACE:

Lock Location

Although some lock data may include latitude and longitude information, the most common way to reference lock location is by river name and river-mile. However, it may also be useful to associate a lock facility with other jurisdictions (e.g., counties and states). Unfortunately, the use of waterways as jurisdictional boundaries sometimes makes these associations difficult.

Lock Age

Most locks are built over multiple year periods, so that age is dated from when the subject lock was opened to traffic rather than when it was constructed. Also, available data routinely include notations regarding whether / when a subject lock has undergone major rehabilitation. From a reliability standpoint, the reopening date of a rehabilitated lock is often more meaningful than its original opening date.

Chambers, Chamber Dimensions, and Other Chamber Characteristics

Most navigation facilities feature a single lock (main) chamber. However, some locations also have one or more auxiliary chambers. Tow configuration is often (but not universally) determined by lock dimensions. Therefore, information describing main chamber length and width is essential in evaluating lock capacity. Similarly, the availability and sizes of auxiliary

A NOTE ON GEOGRAPHY

Both the WCSC and LPMS records are geocoded, with associated latitudes and longitudes. Additionally, the project descriptions include town, county, and state names. However, if analysts desire to combine these data with additional, geographically indexed data elements from other sources, it will often be necessary to append the associated Federal Information Processing Standardization (FIPS) codes to the navigation data.

A data bridge for accomplishing this is available upon request from the study team.

¹⁶ For a full description of the CWS, See, Surface Transportation Board Carload Waybill Sample Reference Guide, October 18, 2013, available at: <https://www.stb.gov/stb/docs/Waybill/2012%20STB%20Waybill%20Reference%20Guide%20-%20FINAL.pdf>

chambers affect lock reliability. Therefore, information describing auxiliary chamber dimensions is also useful. Finally, data describing the lock lift at normal pool elevations can help analysts evaluate processing times and should be included where available.

Ancillary Navigation Structures

Lock processing times can be affected by the availability of ancillary navigation structures such as mooring cells. Thus, the availability of these structures should be noted.

3.3 ELEMENTS AND ANALYTICS – LOCK PERFORMANCE

In most cases, individual locks are evaluated within a system context. Nonetheless, it is essential to isolate, measure, and understand individual lock uses and performance in order to establish realistic system relationships. Most (but not all) of the metrics described below are based on confidential WCSC and LPMS data.

Tows, Vessels, and Lockages

The disaggregated LPMS data contain data describing the number of tows through a lock, the number of lockages, and the number of vessels. The number of lockages per tow is an important indicator of how carriers are using the subject lock and how well suited the lock is to those uses.

Commodity-Specific Tonnages

The LPMS data contain information describing the commodities and corresponding tonnages passing through each lock. However, these data often reflect only the best estimates of lock personnel and/or vessel crews. The WCSC data contain more reliable commodity and loading information, but they record neither the movement of empty barges nor passage through individual locks. The remedy is to route each WCSC record and append lockage information based on the record's internal route string and the river-mile of each subject lock. The resulting records can then be compared to the LPMS values as a means of validation and calibration. This process is not absolutely necessary to the derivation of lock tonnages. It is, however, necessary to the development of the above and below pool metrics described below.

Processing Times and Delays

The LPMS records contain information describing delay, and processing times. This information includes delay causes that can be used to make cross-sectional comparisons.

3.4 ELEMENTS AND ANALYTICS – NETWORK ROLE

As noted, most project evaluations are conducted in a network setting, so that the performance of one project both impacts and is impacted by the performance of other projects that are a part of that system. Capturing this interdependence leads to stronger analytics and better decision-making. Previously, however, the simple metrics available for the initial comparisons did not include measures that capture a project's network value. The current work addresses this by introducing three new measures. These are described below:

System Ton-Miles

If WCSC records are used to compute lock tonnages as described above, it is a doable exercise to flag each record that passes through a subject lock, calculate the ton-miles of transportation attributable to that record, and sum the number of freight ton-miles of traffic associated with the subject lock. When combined with other metrics, this value provides numerous insights regarding the relative burdens of any potentially displaced waterway traffic.

System Lockages

Assuming a reliance on the WCSC data, each record can be processed to include a total number of lockages. From this, it is possible to calculate the average number of lockages (both in aggregate or by commodity) for traffic passing through the lock. This results in a useful measure of the subject lock's interdependence with other system locks.

Above-Pool and Below-Pool Traffic

Navigation pools are created by dams that stabilize pool elevations. Navigation locks exist to allow vessel traffic to pass from one pool to another. Generally, locks and dams are combined at a single location. As a result, an event that leads to an unplanned lock closure could also disrupt up-stream and/or down-stream pools elevations. In this way, the possible disruption *could* affect commercial barge traffic that does not pass through the subject lock. This sort of scenario (See Figure 3.1) has not typically been considered within project analyses, but can often add valuable insight about possible disruption impacts. Again, using the WCSC records, shipments can be identified that originate or terminate in the pools above or below the subject structure.

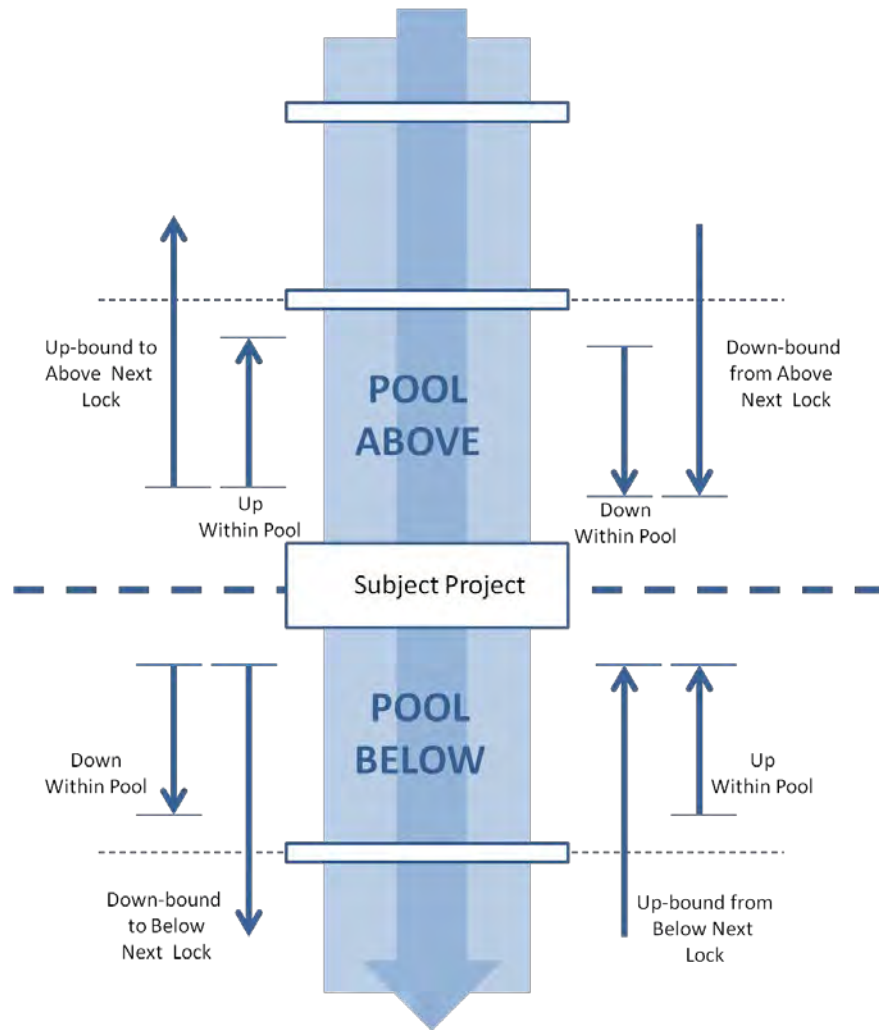
COMMODITY DEFINITIONS

Within the USACE's data, the Waterborne (WCSC) data and Lock Performance (LPMS) data aggregate across differently defined commodity groupings. Fortunately, the disaggregated WCSC records are labeled under both systems.

Further, if analysts elect to include railroad waybill data in the development of a screening tool, it will be necessary to bridge between USACE definitions and rail data that are organized under Standard Transportation Commodity Codes (STCCs).

Finally, the US Department of Commerce data are organized under the North American Industrial Classification System (NAICS).

Figure 3.1 – Above and Below Project Pool Traffic



4

Estimating Closure Related Shipper Supply Chain Cost Burdens

At the core of this project is the analysis of the direct economic effects of unanticipated navigation lock closures using existing data and tools in ways that measurably reduce the resources required to undertake this research. Accomplishing this aim requires the execution of three primary task sets including:

- Lock selection and data preparation;
- Scenario design and traffic diversion assessments; and
- The calculation of shipper supply chain costs before and after an unanticipated lock closure.

This work is designed to conform to the P&G that currently guide the analysis of all federal inland navigation USACE infrastructure projects.¹⁷

4.1 LOCK SELECTION, TRAFFIC SAMPLES, AND DATA PREPARATION

Section 3 describes the development and application of the screening tool used to identify four locks for inclusion in the current study. These locks included:

- Markland Locks & Dam on the Mid-Ohio, near Cincinnati;
- Calcasieu Lock on the Gulf Intracoastal Waterway, near Lake Charles, Louisiana;
- LaGrange Lock & Dam, the lowest of the navigation locks on the Illinois River; and
- Lock & Dam 25, north of St. Louis, near the Mississippi's confluence with the Illinois River.

The following process steps require the preparation of the navigation traffic data and other data resources necessary to identify and measure the effects of an unanticipated lock closure.

Sampling Lock Traffic

When the volume of annual traffic through a subject lock is sufficiently small, it is sometimes possible to work with the entire population of annual traffic movements. However, in most cases, to do so is not feasible. Consequently, it is necessary to sample the annual traffic in a way that yields a manageable number of observations that can subsequently be used to accurately estimate population-wide impacts. This study used a stratified sample based on commodity groupings and the reported two-digit WCSC tonnages (described in Section 3.1). This sampling

¹⁷ See *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*, Washington, DC, March 10, 1983.

pattern resulted in samples of between 900 and 1,400 records for each lock, representing 2-3 percent of all records and 10-12 percent of total 2014 tonnages.¹⁸

For each of the four subject locks, the result was a base sample dataset that included the data fields summarized in Table 4.1. Subsequent steps within the calculation of various supply chain cost components add many additional fields, but the initial WCSC record remains as the primary unit of observation throughout the analysis.

4.2 CLOSURE SCENARIOS, SHIPPER ALTERNATIVES, AND TRAFFIC DIVERSIONS

From a computation standpoint, the manipulation of the WCSC records is the most difficult task. However, in terms of analytical requirements, it is the identification of shipper alternatives and traffic diversions that poses the greatest challenge. Ultimately, meeting this challenge requires a variety of different approaches as described below.

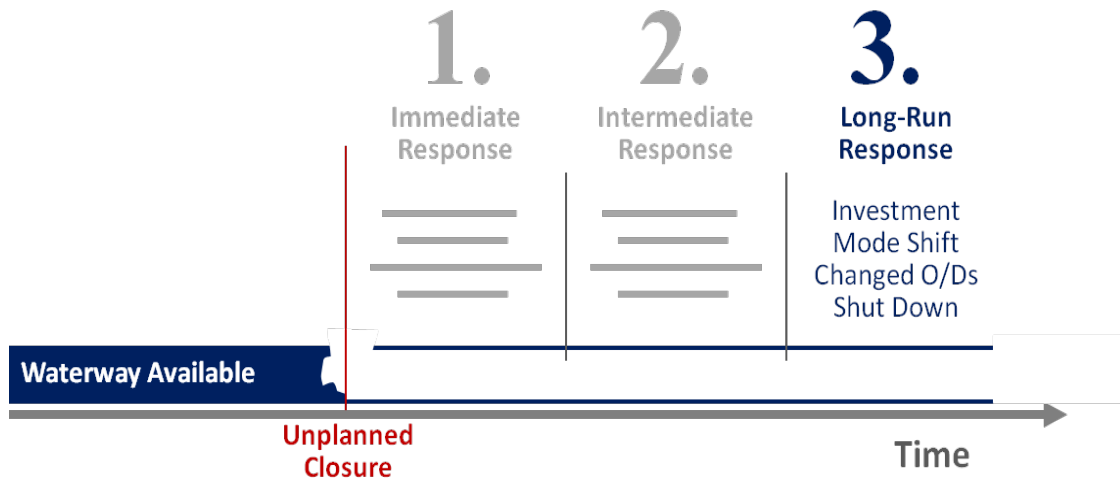
When shippers encounter an unplanned lock outage, they are immediately faced with difficult questions. Some of these include:

- Does the disruption affect more than one lock and does it affect *system* operations?
- Is there available and reliable information about the probable closure duration?
- Is some portion of the waterway still useful and, if so, can the usual carrier(s) continue to provide service over open waterway segments?
- How large are existing user commodity inventories and how long will these last?
- What are the costs, characteristics, and availabilities of transportation alternatives?
- What are the potential penalties for delayed commodity delivery?
- Are rivals similarly affected and how will *they* respond?

Depending on the answers to these questions, each shipper is likely to exhibit a variety of behaviors over time. Those with the luxury to do so may, in the short-run, cease shipping and rely on existing inventories. If that is not possible, but the duration is expected to be brief, some shippers may opt for relatively expensive stop-gap, short-run measures. Ultimately, however, if the unplanned outage is sufficiently long or if there is uncertainty about its duration, all affected shippers will be forced toward long-run strategies. These may involve re-sourcing inputs elsewhere, abandoning certain downstream markets, capital expenditures for new non-water freight transport facilities, or even shutting down a facility (i.e., worst case scenario). This sequence is depicted graphically in Figure 4.1.

¹⁸ In the late 1990s, study team members participated in a numerous USACE studies that experimented with a variety of different sampling methods. Then, as now, it appears that sampling techniques have little influence on analytical results.

Figure 4.1 – Shipper Responses to Unplanned Lock Closures



To capture these various shipper responses under uncertainty, past studies typically have relied heavily on shipper surveys that pose questions based on possible outage durations of between 15 and 180 days. Shippers are asked to outline their responses under each scenario. While the aim of this complex survey structure is important, it can also lead to considerable confusion, an equal amount of speculation, and poor survey response rates.

Ideally, the perfect study would evaluate every alternative available to every affected shipper, then let the least-cost alternative identify the diversion. Unfortunately, this is impractical. Comparative alternative costs were calculated to identify diversions when no other information was available. However, where at all possible, this analysis relied on information from six other sources to identify the most likely long-run shipper diversions. These are bulleted then discussed individually. Information included:

- Available Modal Alternatives
- Shipment Characteristics
- Ancillary Costs
- Railroad Pricing Practices and Rate Data
- Geographic Substitutes
- Shipper Surveys and Interviews

Available Modal Alternatives

Generally, it was assumed that highway access is ubiquitous. However, this is not the case for rail. In most cases, it was possible to identify whether or not shippers have existing railroad access and again, in most cases, the rail capacity that shipper access affords. The P & G that guide USACE studies suggest that new modal access can be added as necessary to create shipping alternatives.

Shipment Characteristics

Simple modal access does not necessarily guarantee that a modal alternative is viable. In some cases, shipment characteristics preclude an alternative even when that alternative is physically possible. For example, in our consideration of unscheduled outages at LaGrange or Lock and Dam 25, all affected grain shippers are served by truck as are alternative port locations on waterways that would be unaffected by the outage. However, both LaGrange and L&D 25 accommodate approximately 10 million tons of corn and soybeans each year. Thus, while the economies evidenced by a limited number of longer truck movements suggest that trucking to alternative waterway locations might be a viable option, doing so for the whole of the *diverted barge shipments would involve an additional 500,000 loaded truck trips per year and an additional 150 million truck miles in the affected states*, an untenable solution.

Ancillary Costs

As noted above, ancillary costs can be an important factor in shippers' supply chain decision-making. Accordingly, even when comparative line-haul rates suggest that a modal alternative is viable, requisite changes in loading, unloading, or storage costs make the alternative untenable.

Railroad Pricing Practices and Rail Data

Section 2.4 provides an extensive discussion of railroad issues and their effect on navigation project evaluations. In some settings, railroads have exercised the ability to influence traffic diversions through rate-setting. In the extreme, our analysis included this reality in the determination of least-cost alternatives.

Geographic Substitutes

For some waterway traffic, origins and/or destinations are unchangeable. In other cases, specific products can be sourced from multiple locations that provide multiple transportation alternatives to shippers who might be affected by an unplanned lock outage. For example, some fertilizer components can be shipped to the upper Mississippi and Illinois basins from a variety of locations that involve multiple carriers across differing freight modes. Where this sort of geographic substitution is possible, it was included in our treatment of potential diversions.

Shipper Surveys and Interviews

The study team developed a simple shipper survey and enlisted members of the National Waterways Foundation Study Oversight Team to distribute to shippers with traffic through Markland Locks. Unfortunately, the response rate was low and for this reason were not judged to be analytically useful. Fortunately, field notes from earlier studies existed. While these earlier interview results did not apply specifically to this study's population of shippers, it was possible to identify patterns applicable to specific industries or commodities without regard to shipper specifics.

4.3 ESTIMATING TRANSPORTATION COSTS FOR EACH ALTERNATIVE

This analysis compares economic outcomes under differing scenarios. In a freight setting, meeting this need generally requires a comparison of shipper costs with and without a proposed

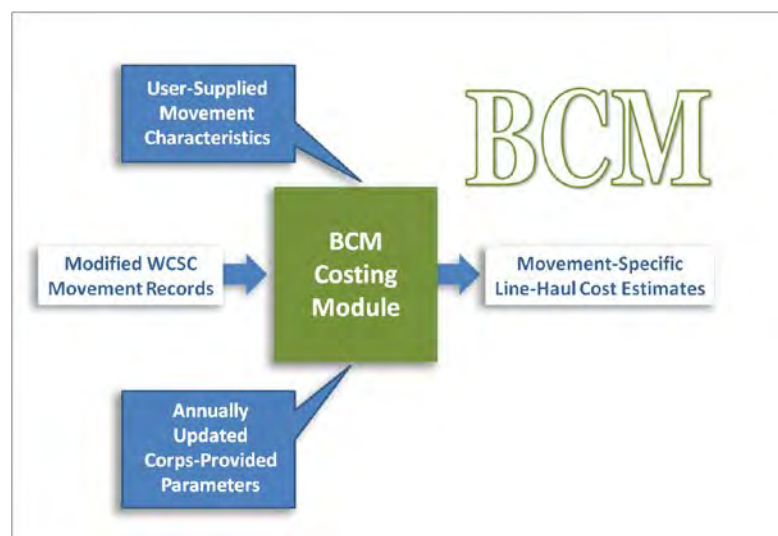
project or a proposed policy. The most essential the most essential tools are those used to estimate modal line-haul and terminal costs. In addition to the data elements described in Section 3.1, the current analysis relied on three such tools. These included:

- A Barge Costing Model (BCM) developed by the Tennessee Valley Authority and certified for USACE applications;
- Elements of STB's Uniform Rail Costing System (URCS) cost estimates for CWS movements, along with supplemental information needed to produce railroad rate estimates; and
- A motor carrier costing model made available through the American Transportation Research Institute (ATRI).

The Barge Costing Model (BCM)

The BCM is a deterministic waterway costing model originally developed by the Tennessee Valley Authority, but now formally approved for use by the USACE. Figure 4.2 depicts the BCM operation.

Figure 4.2 – Barge Costing Model



The model is most easily executed on a movement-by-movement basis. However, it also features a batch mode for the manipulation of multiple records. In either case, the basic inputs can be drawn from individual WCSC records and include origin dock, destination dock, tonnage, commodity, etc. Prescribing a specific barge type or dimensions can be done, users can allow the routine to select an appropriate barge based on tonnage and commodity. Users can also modify various parameters such as fuel price, empty-return ratios, carrier rates of return, and in some cases, shipment routings.

In addition to user supplied parameters, the model is updated periodically by the USACE to reflect changes in vessel horsepower, average vessel dimensions, average fuel costs, lock processing times, labor rates, etc. These parameters can also be manipulated by users, but only by those who are willing to explore the routine in areas beyond the typical user interface.

Railroad Movement Costing

Given the economics and often limited competition that governs rail carriage, there is often a significant difference between estimated line-haul costs and observed railroad rates. Nonetheless, estimating incremental (or variable) costs, at least, provides a useful starting point for a more careful analysis of actual railroad rates.

Third-party logistics providers offer rail cost estimation software that functions much like the BCM described above. However, for those wishing to forego the expense of proprietary software, the CWS provides movement-specific cost estimates of variable costs based on the STB's Uniform Rail Costing System (URCS). URCS has been routinely assailed by academic economists.¹⁹ Still, its use is mandated by the STB and its results govern the outcomes of regulatory proceedings, so that it is rarely successfully challenged.

Whether based on URCS or a proprietary product, any final rate estimates must scale variable costs so that the final rate estimates provide contributions toward the recovery of the fixed and common costs associated with network elements, as well as a competitive return on investment for rail carriers. In practice, railroads accomplish this by setting rates that reflect costs *and* the demand characteristics of rail shippers. Analysts can use observable shipment characteristics such as shipment size, distance, the number of competing railroads, the availability of modal substitutes, etc. as proxies for these demand characteristics.

Within the current analysis, URCS-based cost estimates were used and railroad rates for shipments with varying characteristics. The estimated rates and corresponding movements were submitted to third-party logistics providers who specialize in the subject commodities. Based on their feedback and insights, additional adjustments were made to obtain the rates used to reflect railroad costs.

Motor Carrier Costs

As confounding as rail rates may be, truck rates are relatively simple to estimate. Because motor carriers face minimal fixed and virtually no common costs, and because motor carriage competition is, in most cases, intense, truck rates tend to closely follow operating costs.

In reality, it would be possible to independently assemble information describing motor carrier capital costs, vehicle maintenance costs, labor costs, fuel use, and administrative costs to generate an acceptable estimate of motor carrier costs that does not rely on any underlying model. However, in the current setting, this work is based on a motor carrier cost model

¹⁹ For example, see Wesley Wilson and Frank Wolak in *Modernizing Freight Rail Regulation*, Transportation Research Board Special Report 318, June 2015. Available at: <http://www.trb.org/Publications/Blurbs/172736.aspx>

developed by ATRI.²⁰ With the ATRI model as a benchmark, commodity-specific information developed by the Minnesota Department of Transportation to simulate commodity-based rate variability was used. The resulting motor carrier cost parameters are summarized in Table 4.1.

Table 4.1 – Motor Carrier Costs (Per Mile)

Commodity Grouping	Total Truck Cost per Mile	
	Single Driver	Team Drivers
Overall	\$2.09	\$2.71
Rubbish	\$4.67	\$6.06
Dairy	\$3.12	\$4.05
Food Products	\$2.73	\$3.54
Paper	\$2.58	\$3.34
Petroleum	\$2.46	\$3.19
Timber	\$2.30	\$2.99
Aggregate	\$2.12	\$2.75
Industrial Supplies	\$2.06	\$2.67
Construction	\$2.03	\$2.63
Ag Chemicals	\$1.88	\$2.44
Agricultural	\$1.85	\$2.40
General Products	\$1.82	\$2.36
Beverages	\$1.52	\$1.97

Ancillary Supply Chain Costs

As transportation professionals, we tend to focus on the line-haul, fleeting, and switching activities that we're familiar with, but transportation decision-makers (shippers) are more inclined to focus on total supply chain costs when evaluating their choices. Therefore, it is important to represent these ancillary supply chain costs as accurately as possible when assessing a navigation project's value.

Ancillary costs include outlays necessary for loading, unloading, commodity storage, loss and damage, safety stocks, and administrative expenses. In some cases, these costs are invariant to decisions regarding line-haul mode, but in other cases, mode choice has significant impacts on the magnitude of ancillary costs. Since there are presently no readily available data sets describing these ancillary costs, other sources were relied upon, including past studies, shipper queries, and industry publications.²¹

²⁰ ATRI is a research organization supported directly by the American Trucking Association, See: *An Analysis of the Operational Cost of Trucking: 2016 Update, September 2016*. Available at: <http://atri-online.org/wp-content/uploads/2016/10/ATRI-Operational-Costs-of-Trucking-2016-09-2016.pdf>

²¹ The USACE's *Planning Center of Expertise for Inland Navigation (PCXIN)* has developed an ancillary cost model that is scheduled for external review during the fall of 2017 and which will hopefully be made publicly available soon afterward.

4.4 ESTIMATING THE SHIPPER SUPPLY CHAIN COST BURDEN

Calculating averted shipper costs involves combining the data and tools with the diversion considerations described above to estimate both existing supply chain costs and the costs that would be incurred under the alternative scenario(s).

Table 4.2 illustrates a small portion of the summary spreadsheet developed as a part of the Markland analysis. The selected cells depict the rate calculations for several coal movements. Because of uncertainty regarding the most likely diversion, some movements required the calculation of supply chain costs under both all-rail and a combined, barge-rail alternative. Note also, that, while not used for the coal movements, the spreadsheet allows for the calculation of an all-truck alternative. Where the combined barge-rail alternative is tenable, it in fact, yields the lower alternative supply chain cost.

The estimation results yield Shipper Supply Chain Cost Burden – the increased supply chain costs associated with loss of the navigation alternative through the particular lock in dollars-per-ton. This value, multiplied by the tonnage yields an estimate total cost burden for the subject shipment. It is also often useful to use shipment distances to calculate both rates and averted shipper costs on a per-ton-mile-basis to be sure that the traditional distance-rate relationship is evident in the estimated rates. Finally, there may be instances in which the estimated averted costs are negative. On its face, this suggests either irrational behavior on the part of shippers or an error in the calculation of supply chain costs. Certainly, either of these is possible. However, there are also more reasonable explanations. Individual shippers may not immediately react to changing conditions. This is particularly true when there are significant costs to switching from one modal alternative to another. In fact, if these switching costs are sufficiently high, perfectly rational, profit-maximizing shippers may opt to suffer losses rather than switch at all if they view those losses to be tied to transient market conditions (say, for example, low water).

If conditions allow and the number of annual movement is not overwhelming, it is possible to estimate averted costs for the entire population of traffic using a subject lock. In such cases, the work of estimating supply chain cost differentials is finished. If, however, as in this work, the number of records is large so that movements are sampled, it is necessary to expand the averted shipper costs estimated for sample movements to the entire traffic population.

In the four cases treated here, the expansion of the sample findings was accomplished through the estimation of simple quadratic regression equations, where averted shipper costs served as the dependent variable and shipment distance and distance squared formed the independent variables. In those instances where the quadratic term failed to attain statistical significance, a simple linear form was used in place of the quadratic.

Table 4.2 – Sample of Calculated Averted Supply Chain Costs

REF NO.	COMMODITY	TONS	WW ROUTE COST PER TON	ALL-RAIL ROUTING COST PER TON	SPLIT BARGE-RAIL ROUTE COST PER TON	ALL-TRUCK ROUTING COST PER TON	AG-TRUCK ROUTE COST PER TON	AVERAGE ALTERNATIVE COST PER TON	SHIPPER SAVINGS PER TON	SHIPPER SAVINGS PER TON-MILE
234	Coal	1755	\$ 16.45		\$ 23.33			\$ 23.33	\$ 6.88	\$ 0.0192
235	Coal	1550	\$ 16.45		\$ 23.33			\$ 23.33	\$ 6.88	\$ 0.0192
236	Coal	1589	\$ 12.56		\$ 15.60			\$ 15.60	\$ 3.04	\$ 0.0140
237	Coal	1817	\$ 8.07			\$ 9.31		\$ 9.31	\$ 1.24	\$ 0.0270
238	Coal	1555	\$ 8.07			\$ 9.31		\$ 9.31	\$ 1.24	\$ 0.0270
239	Coal	1592	\$ 8.07			\$ 9.31		\$ 9.31	\$ 1.24	\$ 0.0270
240	Coal	1917	\$ 8.07			\$ 9.31		\$ 9.31	\$ 1.24	\$ 0.0270
241	Coal	1411	\$ 8.07			\$ 9.31		\$ 9.31	\$ 1.24	\$ 0.0270
242	Coal	1719	\$ 8.07			\$ 9.31		\$ 9.31	\$ 1.24	\$ 0.0270
243	Coal	1436	\$ 32.18	\$ 53.40	\$ 44.55			\$ 48.97	\$ 16.80	\$ 0.0132
244	Coal	1413	\$ 32.18	\$ 53.40	\$ 44.55			\$ 48.97	\$ 16.80	\$ 0.0132
245	Coal	1814	\$ 31.80	\$ 35.16	\$ 34.85			\$ 35.01	\$ 3.21	\$ 0.0039
246	Coal	1532	\$ 31.80	\$ 35.16	\$ 34.85			\$ 35.01	\$ 3.21	\$ 0.0039
247	Coal	1526	\$ 31.80	\$ 35.16	\$ 34.85			\$ 35.01	\$ 3.21	\$ 0.0039
248	Coal	1674	\$ 48.46	\$ 35.16	\$ 43.18			\$ 39.17	\$ (9.29)	\$ (0.0114)
249	Coal	1875	\$ 47.47	\$ 35.16	\$ 42.68			\$ 38.92	\$ (8.55)	\$ (0.0105)
250	Coal	1643	\$ 38.79	\$ 60.69	\$ 59.83			\$ 60.26	\$ 21.47	\$ 0.0138
251	Coal Coke	1510	\$ 22.66	\$ 84.83	\$ 65.18			\$ 75.00	\$ 52.34	\$ 0.0237
252	Coal Coke	1504	\$ 22.72	\$ 52.65	\$ 43.76			\$ 48.20	\$ 25.48	\$ 0.0203
253	Coal	1510	\$ 22.57	\$ 36.39	\$ 35.44			\$ 35.92	\$ 13.35	\$ 0.0158
254	Coal	1732	\$ 33.17	\$ 36.55	\$ 35.56			\$ 36.06	\$ 2.89	\$ 0.0034
255	Coal	1744	\$ 22.94	\$ 36.39	\$ 35.47			\$ 35.93	\$ 12.99	\$ 0.0154
256	Coal	1832	\$ 22.63	\$ 36.39	\$ 35.47			\$ 35.93	\$ 13.30	\$ 0.0157
257	Coal	1891	\$ 27.12	\$ 36.55	\$ 35.59			\$ 36.07	\$ 8.95	\$ 0.0105
258	Coal	1966	\$ 33.17	\$ 36.55	\$ 35.56			\$ 36.06	\$ 2.89	\$ 0.0034
259	Coal	2027	\$ 22.63	\$ 36.55	\$ 35.59			\$ 36.07	\$ 13.44	\$ 0.0158

5

Estimating Regional Economic Development Impacts

5.1 THE DIFFERENCE BETWEEN BENEFITS AND IMPACTS

Discussions of public sector investments in transportation infrastructure involve a variety of economic concepts and terminology, including references to economic *benefits* and economic *impacts*. While functionally related, benefits and impacts are distinct concepts and their measures play decidedly different roles in the decision-making process.

Investments in transportation infrastructure are undertaken because they improve economic outcomes – they either provide additional capacity that can accommodate *more* economic total activity or they relieve congestion and, thereby, avoid increasing transportation costs. Either way, there is a net improvement in aggregate welfare measured across the whole of the jurisdiction. In cases of federal investments, this implies that a subject investment provides net benefits to the nation as a whole. As specified in the P&G, these gains are referred to as National Economic Development (NED) *benefits*.²²

Projects that improve economic efficiency usually attract economic activities from other regions. This attraction is a predictable response to the efficiency-enhancing investment, but rarely does it further increase the overall national benefits attributable to that investment. Instead, regional impacts represent a movement of economic activity in response to attainable efficiencies. Therefore, while these regional impacts may be important, they do not usually affect the national decision-making process. The P&G refer to these interregional transfers as Regional Economic Development (RED) benefits.²³ Federal-level decision-makers rarely compute these RED benefits. Instead, if they are estimated, it is usually by regional-level stakeholders who wish to explore the regional benefits associated with national-level investments. It is just this sort of regional impact analysis that provides the results described in Section 2.3.

5.2 THE GENERAL STRUCTURE OF REGIONAL MODELS

Typically, regional impact analyses are conducted in settings similar to the one depicted in Figure 5.1. A direct, exogenously imposed stimulus begins an iterative series of economic activities within a region. To begin with, those affected by the stimulus will often need to acquire additional goods and services from other sellers within the subject region. These are the *Indirect Effects* noted in the figure. Moreover, this iterative set of impacts changes incomes within the region which, in turn, leads to further changes in the magnitude of regional activity. These are represented by the *Induced Effects* depicted in Figure 5.2. These economic impacts are revealed

²² National Economic Development (NED) benefits are discussed throughout the P&G. However, the account definition is provided in Chapter 1 (1.7.1). Measurement issues are discussed in Chapter 2.

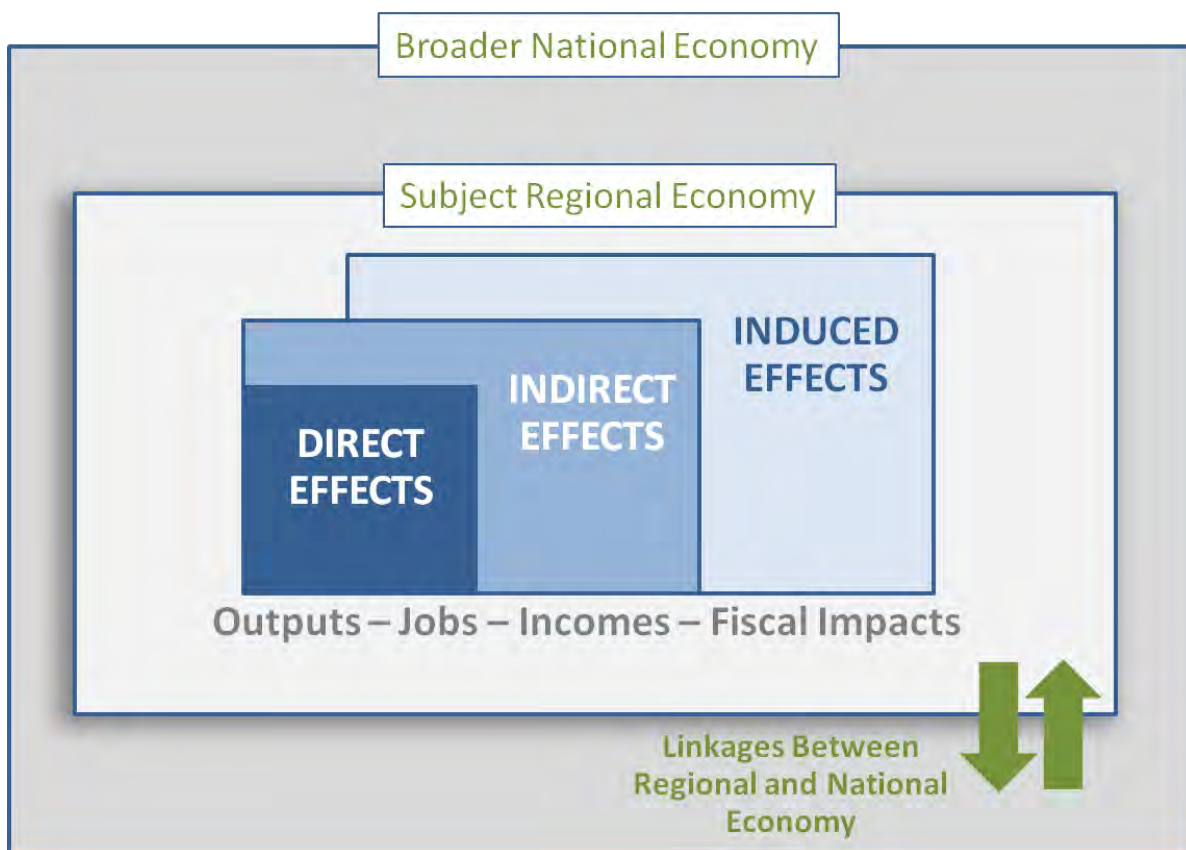
²³ Regional Economic Development (RED) benefits are defined in Chapter 1 (1.7.4).

in regional changes to output (sales), employment, incomes, and public sector fiscal effects. Finally, regional economies seldom exist in isolation, but instead, buy goods and services *from* and sell goods and services *to* other regions within the overall economy.

The magnitude of the regional impacts attributable to a stimulus depends on several things, including, the nature and magnitude of the stimulus, the size and economic composition of the regional economy, and the size and composition of the larger national economy, and the linkages between the regional and the national economy.

Figure 5.1 and the relationships it depicts describe the estimation of regional impacts for the four locks considered here.

Figure 5.1 – Representative Regional Economic Impact Construct



5.3 ESTIMATING BASIC ECONOMIC IMPACT BENCHMARKS

As with most forms of economic modeling, the level of approach in impact analyses ranges between the very basic and the very complex. The form used here combines two of the simpler alternatives to form hybrid estimates. Nonetheless, this approach (1) builds upon earlier NWF-sponsored work that was both theoretically and empirically sophisticated, (2) also incorporates standard impact techniques (3) is easily replicated, and (4) produces results that are robust and informative.

Economic Form of Direct Effects

The stimulus or Direct Effect depicted in Figure 5.1 can come in one of two forms. It can be a demand-side stimulus, where their exogenous force increase or decrease demands for goods or services produced in the subject region or the stimulus can be a supply shock, where there is an exogenous change in the cost of producing goods or services within the region. Changes in the availability or performance of transportation infrastructures are almost always among this latter group. Specifically, in this study, the stimulus (or shock) is the substantial increase in transportation cost that is predicted under an unscheduled lock closure. This form of stimulus is identical in nature to the overall system outage that was the basis for the 2014 NWF-sponsored study: *Inland Navigation in the United States: An Evaluation of Economic Impacts and the Potential Effects on Infrastructure Investment*.

Geography of Direct Effects and Consequent Impacts

The increased transportation costs attributable to a lock closure are tied to the locations of the producers who originate waterborne shipments and the subsequent users of the shipped commodities, not the location of the lock itself. In this analysis, the initial river origin and final river destination are used as proxies for the geographical distribution of impacts. In addition, the analysis estimates with one exception, that the increased cost of transportation owing to a lock outage would be split evenly between the waterway origin and destination locations. In the case of farm products, the stimulus (increased costs) is placed exclusively at the origin, reflecting that most are export shipments

There are two reasons for the asymmetric treatment of farm products, particularly in the current application. First, the vast majority of down-bound grain transiting LaGrange and L&D 25 is bound for export over the Louisiana Gulf. Thus, these shipments generate relatively little economic activity at their domestic destinations. As importantly, there is a widely held conclusion that level of corn and soybean production in the Illinois and upper Mississippi basins is unlikely to be impacted by increased transportation costs and that changes in the export availability of these goods would not affect final market prices in the global markets where they compete. This implies that basin producers would likely absorb the majority of transportation cost increases in the form of lost incomes.

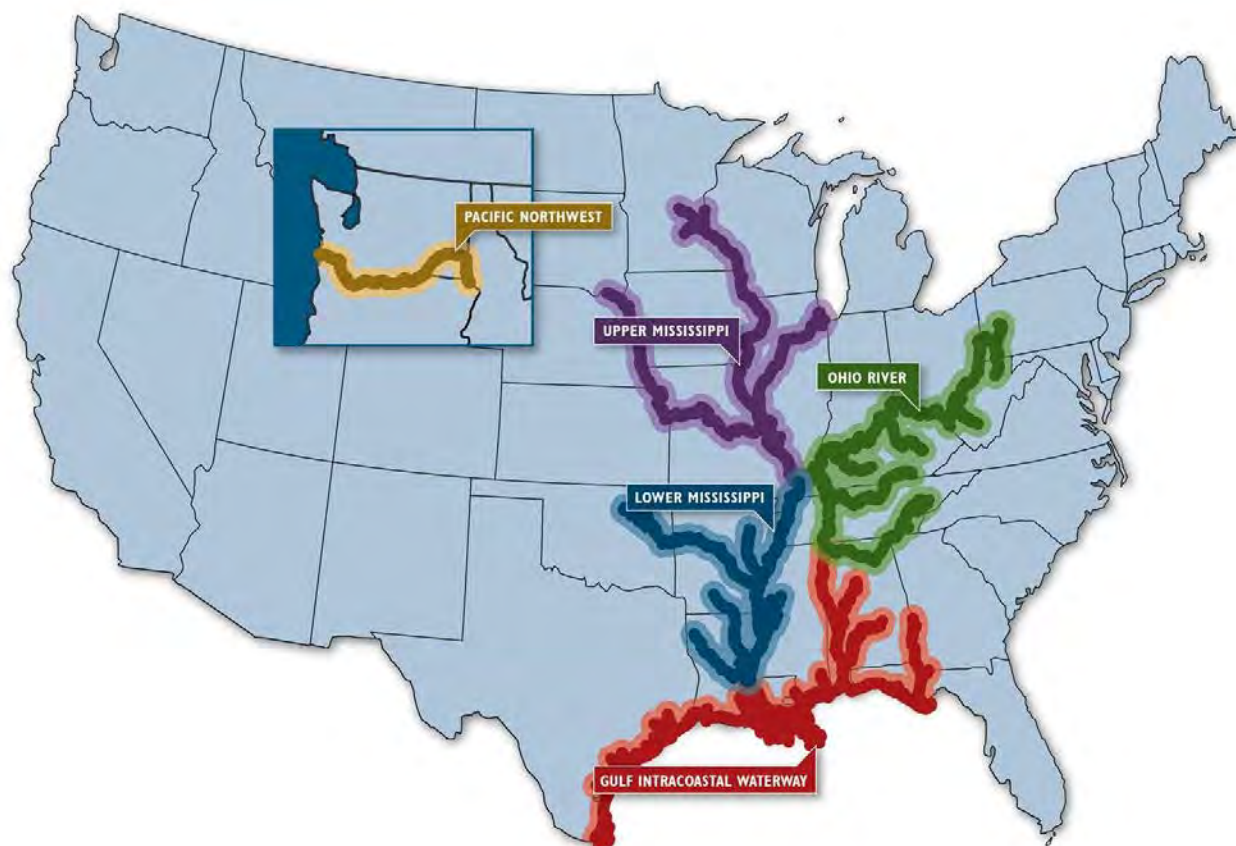
Determination and Effects of Study Regions

The extent of region or regions in which economic impacts are evaluated can be varied based on the purpose of the analysis and the availability of data. However, the scale of subject regions does affect the magnitude of the estimated effects. Referring again to Figure 5.1, there are linkages between the study region and the world beyond. Among other things, these linkages include leakages of economic consequences from the study region into the broader economy. The extent of these leakages depends on the extent to which regional demands can be satisfied internally. This, in turn, usually depends on the size of the study region. As a rule, larger regions are better able to self-supply economic resources, so that impacts are generally greater than would be generated by a similar shock in a geographically smaller region.

Figure 5.2 depicts the study regions used in the NWF's 2014 work. In the current application, the earlier empirical results are used to generate state-level predictions. On its face, this

application may seem tenuous. However, the study team judged that use of the 2014 results is, in fact, appropriate. Specifically, the amount of economic activity and resources available in any of the affected states is roughly analogous to the total economic activity evidence in the study region where that state is located. Moreover, the economic characteristics within a specific state tend to mirror those observed within the larger region.

Figure 5.2 – 2014 Study Region Geography



Current Study Impact Benchmark Estimation

For a variety of reasons, the methodology outlined above yields what may be interpreted as upper boundaries for output, income, and employment effects. Consequently, earlier reviewers of the current study suggested that these upper bound estimates be accompanied by corresponding estimates of what are likely to be lower boundaries for the same estimated outcomes. Following this suggestion, the study team produced high and low impact estimates for each affected state. It is the midpoint or average of these estimates that are reported in Section 2.

Upper-Bound Estimates Within the current study, the Direct Effects depicted in Figure 5.1 are the avoided increases in supply chain costs that would result from an unscheduled lock outage. Their analogue in the 2014 study is the increase in system-wide user costs that would occur from

a full system outage. Given this ready comparison it was relatively easy to derive transportation cost based multipliers and apply them to current study cost projections. Specifically, for each multiplier i , multipliers are calculated as:

$$\text{MULT}_i = \frac{\text{IMPACT}_{14_i}}{\text{COST}_{14_i}}$$

Based on this construct, the multipliers applied here are provided in Table 5.1.²⁴

Table 5.1 – Study-Derived Economic Impact Multipliers
(Based Against Navigation-Related Avoided Costs)

State	Output Multiplier per \$1 of Avoided Cost	Income Multiplier per \$1 of Avoided Cost	Employment Multiplier per \$10 Million of Avoided Cost
AL	5.125	1.229	18.3300
AR	5.549	1.793	22.5400
FL	7.597	1.767	22.7500
IA	5.549	1.793	22.5400
IL	4.101	1.242	18.2200
IN	2.654	0.691	13.9000
KY	2.654	0.691	13.9000
LA	5.718	1.326	18.6400
MN	5.549	1.793	22.5400
MO	5.549	1.793	22.5400
MS	3.246	0.788	14.2100
OH	2.654	0.691	13.9000
OK	3.839	0.885	14.5200
PA	2.654	0.691	13.9000
TN	2.654	0.691	13.9000
TX	5.718	1.767	22.7500
WI	5.549	1.793	22.5400
WV	2.654	0.691	13.9000

Lower-Bound Estimates There are numerous alternatives to the methodology described above. To estimate the lower bound of potential economic impacts, the study team applied multipliers made available by the U.S. Bureau of Economic Analysis as part of its RIMS II Regional Input-Output Modeling System.²⁵

²⁴ Some states are served by waterway segments that lie in more than one of the 2014 regions. In these cases, the multipliers were calculated as the simple mean of the corresponding regional average.

²⁵ For a full description of the RIMS II economic simulation products and their use see: *RIMS II, An Essential Tool for Regional Developers and Planners*, available at: https://www.bea.gov/regional/pdf/rims/RIMSII_User_Guide.pdf

Like most input-out packages, the RIMS II products are easily applied to simulate demand-side stimuli, but are more difficult to use in the case of a supply-side disturbance as is modeled here. Typically, in such cases, supply-side shocks are treated as overall changes to regional incomes. This tends to understate the magnitude of impacts or, as was desired here, produce a lower bound on probable output, income, and employment impacts. The correspond RIMS II multipliers are reproduced here in Table 5.2.

Finally, it is the average or blended results from these alternative methods that are reported in Section 2, Tables 2.6 – 2.9.

Table 5.2 – RIMS II Impact Multipliers (Household Incomes)
(Based On Navigation-Related Avoided Costs)

State	Output Multiplier per \$1 of Avoided Cost	Income Multiplier per \$1 of Avoided Cost	Employment Multiplier per \$10 Million of Avoided Cost
AL	1.0728	0.3250	10.0086
AR	0.9482	0.2884	8.5720
FL	1.2510	0.3876	11.6335
IA	0.9447	0.2848	8.6470
IL	1.4083	0.4085	9.7650
IN	1.1960	0.3504	9.5203
KY	1.0862	0.3107	9.0880
LA	1.0339	0.3238	9.3414
MN	1.3021	0.3792	9.8312
MO	1.2427	0.3491	9.9061
MS	0.9858	0.2950	9.3012
OH	1.2929	0.3829	10.8242
OK	1.1125	0.3408	9.6592
PA	1.2694	0.3691	9.4631
TN	1.3523	0.3950	10.3448
TX	1.4871	0.4427	11.1339
WI	1.0724	0.3338	9.3603
WV	0.8512	0.2496	7.8008

6 Final Thoughts

The objective of this analysis was to develop detailed information cataloging the economic effects of unplanned lock outages at four locations. However, a second important goal was to demonstrate that primary and secondary data can be combined with existing (or slightly modified) modeling platforms to estimate these navigation outcomes with less extensive, expensive, and time-consuming field work.

Within the course of this work, the study team developed two new metrics for measuring the nature and extent of inland navigation’s commercial influence. These include the *Corridor Concentration Metric* presented in Section 2 and further described in Appendix 1 and the *Above and Below Pool* traffic measures described in Sections 2 and 3.

Both measures provide easily calculable metrics that capture important aspects of commercial navigation. Both the corridor concentration metric and the above and below pool tonnage measures emerged in response to specific sponsor questions and both have potentially important implications in the future evaluation of inland navigation investments. Accordingly, we would strongly urge others to further develop both the calculation and use of these metrics and to explore additional ways to quantitatively address relevant system use and performance.

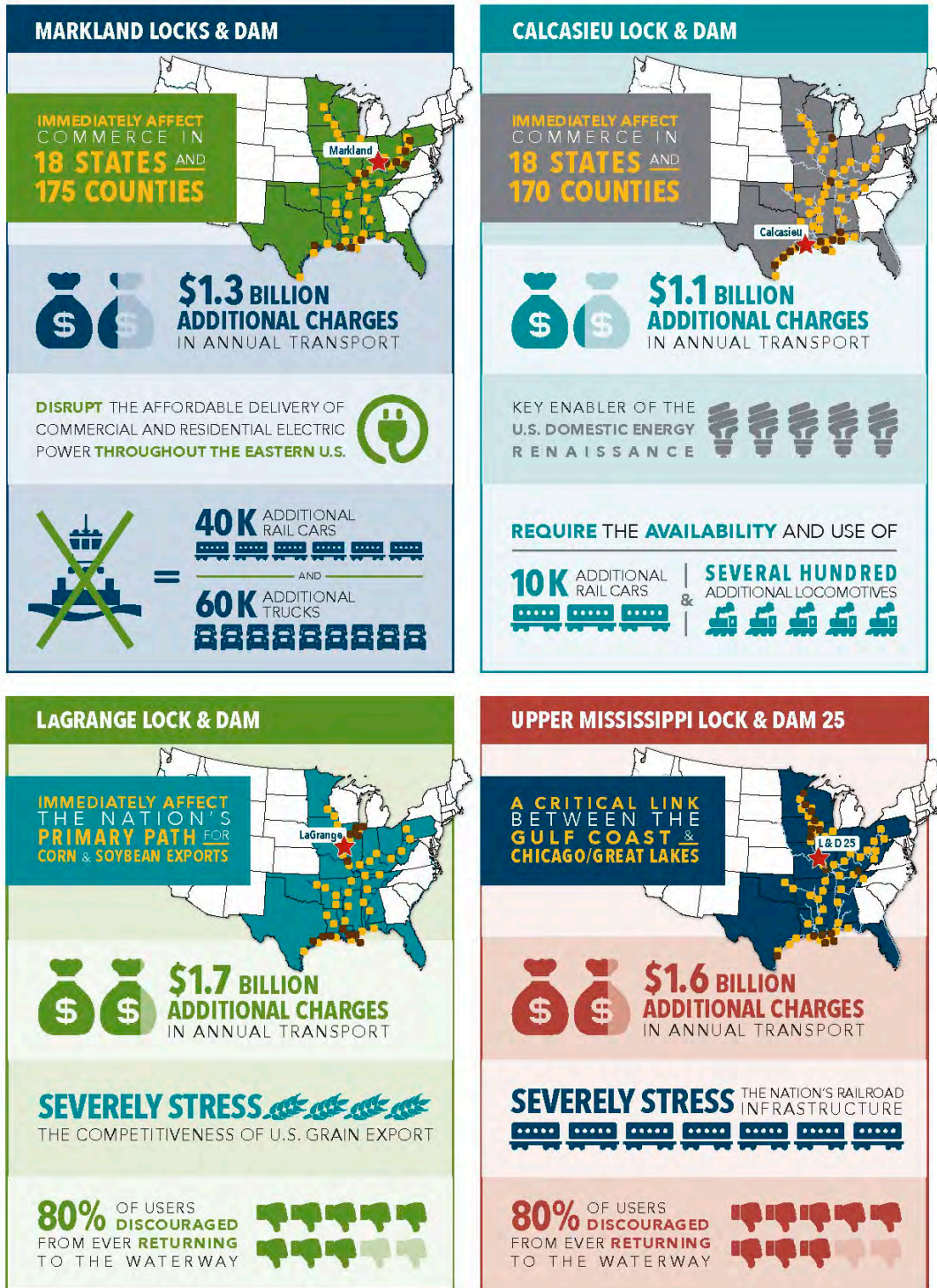
Finally, the study’s results confirm many long-held beliefs, but also offer new insights. A few (though not all) key findings are summarized in the Executive Summary. These are repeated here for emphasis and with the hope that readers will find it useful to carry these results forward in other uses. It is clear, to the study team at least, that the nation’s navigable waterways represent an important linkage that is essential in its long-run value to both domestic commerce and global trade. We hope this is a message that will be communicated effectively going forward.

A FEW KEY FINDINGS

- Each of the four locks considered within the study helps shippers to avoid more than \$1 Billion in additional transportation costs each year.
- The important roles played by individual navigation projects span a broad range of both geographies and economic purposes, and in some cases provide freight mobility that could not be easily replaced by other transport modes.
- While every state that originates or terminates traffic supported by the four locks benefits from inland navigation’s availability, the results reflect the waterway’s *extraordinary* commercial value to Louisiana, Texas, and Illinois.
- In the cases of LaGrange Lock & Dam and Lock & Dam 25, trucking to alternative waterway locations would mean an additional 500,000 loaded truck trips per year and an additional 150 million truck miles in the affected states. This is not tenable.

Figure 6.1 – Further Communication of Study Findings

Consequences the Nation will Face with Unscheduled Closures of our Locks and Dams



Appendix One

The Corridor Concentration Metric

The Corridor Concentration Metric (CCM) is a simple construct that combines the state-wise distribution of lock traffic measured in ton-miles with average shipment distances to derive a general measure of traffic concentration. Specifically, the CCM is defined as:

$$CCM_L = \frac{D_L}{\sum_{i=1}^n R_i \times 1,000}$$

where:

CCM_L = the Corridor Concentration Metric for a subject lock “L”

D_L = the tonnage weighted average shipment distance for traffic through lock “L”

R_i = The ratio of the total ton-miles to or from state i to the maximum number of ton miles to or from any individual state.

The table below uses the calculation of the CCM for Markland as an example:

State	Total Originating Ton Miles	Total Terminated Ton-Miles	Total All Ton-Miles	Ratio of Total Ton- Miles to the Maximum
LA	14,399,474,691	10,240,748,471	24,640,223,162	1.0000
OH	4,051,434,666	14,710,792,680	18,762,227,346	0.7614
KY	10,331,298,804	5,704,384,151	16,035,682,955	0.6508
WV	7,057,660,488	5,790,115,034	12,847,775,522	0.5214
PA	1,344,088,656	4,936,857,314	6,280,945,970	0.2549
IN	3,661,044,210	1,619,888,897	5,280,933,107	0.2143
IL	3,030,052,592	1,495,883,204	4,525,935,796	0.1837
TX	1,908,576,169	1,159,450,906	3,068,027,075	0.1245
MO	866,830,173	125,487,478	992,317,651	0.0403
AL	210,183,417	550,622,631	760,806,048	0.0309
AR	179,246,839	268,612,332	447,859,171	0.0182
TN	100,801,333	340,366,581	441,167,914	0.0179
OK	130,661,110	237,662,945	368,324,055	0.0149
MS	164,447,667	39,204,414	203,652,081	0.0083
IA	35,540,072	99,296,485	134,836,557	0.0055
MN	24,128,679	98,490,685	122,619,364	0.0050
FL	0	55,613,031	55,613,031	0.0023
WI	0	21,992,327	21,992,327	0.0009
TOTAL	47,495,469,566	47,495,469,566	94,990,939,132	3.8551
			Sum of R_i	3.8551
			Average Trip Distance	751
			CCM	0.1948

Appendix Two

Additional Screening Tool Results

No.	Lock	River	Year Open	Rehab	Status	Num Chambers	Bank	Lift	Chamber Length	Chamber Width	Mooring	State	Vessels
1	Claiborne	Alabama	1969	none	operational	1	L	30	600	84	N	AL	77
2	Millers Ferry	Alabama	1969	none	operational	1	L	45	600	84	N	AL	114
3	Robert F. Henry	Alabama	1972	none	operational	1	L	45	600	84	N	AL	62
4	Great Bridge	Albemarle and Chesap	1932	none	operational	1	L	3	600	72	N	VA	
5	L&D 2	Allegheny	1934	none	operational	1	L	11	360	56	Y	PA	5,501
6	L&D 3	Allegheny	1934	none	operational	1	L	14	360	56	Y	PA	
7	L&D 4	Allegheny	1927	none	operational	1	R	11	360	56	Y	PA	1701
8	L&D 5	Allegheny	1927	none	seasonal	1	R	12	360	56	N	PA	1121
9	L&D 6	Allegheny	1928	none	seasonal	1	R	12	360	56	N	PA	377
10	L&D 7	Allegheny	1930	none	seasonal	1	R	13	360	56	N	PA	14
11	L&D 8	Allegheny	1931	none	seasonal	1	L	18	360	56	N	PA	
12	L&D 9	Allegheny	1938	none	seasonal	1	L	22	360	56	Y	PA	
13	Jim Woodruff	Apalachicola	1954	none	operational	1	R	33	450	82	N	FL	
14	Arthur V. Ormond	Arkansas	1969	none	operational	1	R	19	600	110	Y	AR	875
15	Col Charles D. Maynard	Arkansas	1968	none	operational	1	L	17	600	110	Y	AR	1499
16	Dardanelle	Arkansas	1969	none	operational	1	L	55	600	110	Y	AR	898
17	David D. Terry	Arkansas	1968	none	operational	1	L	18	600	110	Y	AR	1250
18	Emmet Sanders	Arkansas	1968	none	operational	1	R	14	600	110	Y	AR	1402
19	James W. Trimble	Arkansas	1969	none	operational	1	R	20	600	110	Y	AR	2393
20	Joe Hardin	Arkansas	1868	none	operational	1	L	20	600	110	Y	AR	1284
21	Murray	Arkansas	1969	none	operational	1	R	18	600	110	Y	AR	1081
22	Norrell (Post Canal)	Arkansas	1967	none	operational	1	L	30	600	110	N	AR	1280
23	Ozark - Jetta Taylor	Arkansas	1969	none	operational	1	L	34	600	110	Y	AR	825
24	Robert S. Kerr	Arkansas	1970	none	operational	1	L	48	600	110	N	OK	1246
25	Toad Suck Ferry	Arkansas	1969	none	operational	1	L	16	600	110	Y	AR	878
26	W.D. Mayo	Arkansas	1971	none	operational	1	R	21	600	110	N	OK	1196
27	Webers falls	Arkansas	1970	none	operational	1	L	30	600	110	N	OK	1429
28	WILBUR D MILLS	Arkansas	1967	none	operational	1	L	20	600	110	N	AR	1350
29	Berwick	Atchafalaya	1950	none	operational	1	R	14	307	45	N	LA	3509
30	Jonesville	Black	1972	none	operational	1	R	30	600	84	N	LA	998
31	Black Rock	Black Rock Canal	1914	none	operational	1	R	5	650	70	N	NY	2069
32	Armistead I. Selden	Black Warrior	1957	none	operational	1	L	28	600	110	N	WA	1508
33	Hohn Hollis Bankhead	Black Warrior	1975	none	operational	1	L	22	600	110	N	AL	1193
34	Holt	Black Warrior	1966	none	operational	1	L	64	600	110	N	AL	1458
35	William Bacon Oliver	Black Warrior	1991	none	operational	1	L	68	600	110	N	AL	1341
36	Calcasieu	Calcasieu River	1968	none	operational	1	L	0	575	56	N	LA	13247
37	Moore Haven	Caloosahatchee	1953	none	operational	1	R	2	250	50	Y	FL	4281
38	W. P. Franklin	Caloosahatchee	1965	none	operational	1	L	3	400	56	Y	FL	7411
39	Thomas J. Obrien	Calumet	1960	none	operational	1	R	4	1000	110	Y	IL	10444
40		1 Cape Fear	1915	none	operational	1	R	11	200	40	Y	NC	
41		2 Cape Fear	1917	none	operational	1	R	9	200	40	Y	NC	
42	William O. Huske	Cape Fear	1935	none	operational	1	R	9	300	40	Y	NC	
43	George W. Andrews	Chattahoochee	1962	none	operational	1	L	25	450	82	N	GA	208
44	Walter F. George	Chattahoochee	1963	none	operational	1	L	88	450	82	N	GA	231
45	Chicago	Chicago River	1938	none	operational	1	R	4	600	80	N	IL	34979

No.	Lock	River	Year Open	Rehab	Status	Num Chambers	Bank	Lift	Chamber Length	Chamber Width	Mooring	State	Vessels
46	Melton Hill	Clinch River	1963	none	operational	1	R	58	400	75	N	TN	
47	Barkley	Cumberland	1964	none	operational	1	L	57	800	110	Y	KY	1367
48	Cheatham	Cumberland	1952	none	operational	1	R	26	800	110	Y	TN	2007
49	Cordell Hull	Cumberland	1973	none	replaced	1	L	59	400	84	N	TN	
50	Old Hickory	Cumberland	1954	none	operational	1	L	60	400	84	Y	TN	2134
51	Deep Creek	Dismal Swamp Canal	1940	none	operational	1	L	12	300	52	N	VA	1484
52	South Mills	Dismal Swamp Canal	1941	none	operational	1	L	12	300	52	N	NC	1433
53	Freshwater Bayou	Freshwater Bayou	1968	none	operational	1	R	4	600	84	N	LA	13511
54	Bayou Boeuf	GIWW	1954	none	operational	1	R	11	1156	75	N	LA	18251
55	Calcasieu	GIWW	1950	none	operational	1	R	4	1205	75	N	LA	14437
56	Leland Bowman	GIWW	1985	none	operational	1	R	5	1200	110	N	LA	14401
57	Algiers	GIWW Algiers Canal	1956	none	operational	1	R	18	797	75	N	LA	10915
58	Bayou Sorrel	GIWW Morgan City Port Al.	1952	none	operational	1	R	21	800	56	N	LA	7108
59	Port Allen	GIWW Morgan City Port Al.	1961	none	operational	1	R	45	1202	84	N	LA	7930
60	Brazos East	GIWW Texas	1943	none	operational	1	C	0	750	75	Y	TX	27755
61	Brazos West	GIWW Texas	1943	none	operational	1	C	0	750	75	Y	TX	25553
62	Colorado River East	GIWW Texas	1944	none	operational	1	L	12	1200	75	Y	TX	22069
63	Colorado River West	GIWW Texas	1944	none	operational	1	L	12	1200	75	Y	TX	22306
64	Harvey	GIWW West	1935	none	operational	1	R	20	425	75	N	LA	6003
65	GREEN RIVER - 1	Green	1956	none	operational	1	R	8	600	84	Y	KY	3495
66	GREEN RIVER - 2	Green	1956	none	operational	1	R	14	600	84	Y	KY	1431
67	Inner Harbor Nav Canl Lk	GWW East	1923	none	operational	1	L	17	640	75	N	LA	8500
68	Brandon road	Illinois	1933	1988	operational	1	R	34	600	110	N	IL	3446
69	Dresden island	Illinois	1933	1995	operational	1	L	22	600	110	Y	IL	3437
70	Lagrange	Illinois	1939	1988	operational	1	R	10	600	110	N	IL	3063
71	Lockport	Illinois	1933	1989	operational	1	L	39	600	110	N	IL	3342
72	Marseilles	Illinois	1933	1996	operational	1	L	24	600	110	Y	IL	3765
73	Peoria	Illinois	1938	1990	operational	1	L	11	600	110	N	IL	3316
74	Starved Rock	Illinois	1933	1996	operational	1	R	19	600	110	Y	IL	3886
75	London	Kanawha	1933	none	operational	2	R	24	360	56	N	WV	935
76	Marmet	Kanawha	2008	none	operational	3	R	24	360	56	Y	WV	2039
77	Winfield	Kanawha	1997	none	operational	3	R	28	360	56	Y	WV	1624
78	Kaskaskia	Kaskaskia	1973	none	operational	1	R	29	600	84	N	IL	1985
79	Catfish Point	Mermentau	1951	none	operational	1	R	0	500	56	N	LA	1087
80	CHAINS OF ROCKS L/D 27	Mississippi	1953	2009	operational	2	L	21	1200	110	N	IL	2343
81	LOCK & DAM 1	Mississippi	1930	1980	seasonal	2	R	38	400	56	Y	MN	2358
82	LOCK & DAM 10	Mississippi	1936	2006	seasonal	1	R	8	600	110	N	IA	3678
83	LOCK & DAM 11	Mississippi	1937	2012	operational	1	R	12	600	110	N	IA	5010
84	LOCK & DAM 12	Mississippi	1939	2000	operational	1	R	9	600	110	Y	IA	2831
85	LOCK & DAM 13	Mississippi	1938	1996	operational	1	L	11	600	110	Y	IL	2387
86	LOCK & DAM 14	Mississippi	1922	1996	operational	2	R	11	600	110	N	IA	2292
87	LOCK & DAM 15	Mississippi	1934	1993	operational	2	L	16	600	110	N	IA	2539
88	LOCK & DAM 16	Mississippi	1937	1991	operational	1	L	9	600	110	N	IL	2723
89	LOCK & DAM 17	Mississippi	1939	1988	operational	1	L	8	600	110	N	IL	2108
90	LOCK & DAM 18	Mississippi	1937	1990	operational	1	L	10	600	110	Y	IL	2424

No.	Lock	River	Year Open	Rehab	Status	Num Chambers	Bank	Lift	Chamber Length	Chamber Width	Mooring	State	Vessels
91	LOCK & DAM 19	Mississippi	1957	2008	operational	1	R	38	1200	110	Y	IA	2164
92	LOCK & DAM 2	Mississippi	1930	1995	seasonal	1	R	12	500	110	N	MN	3354
93	LOCK & DAM 20	Mississippi	1936	1994	operational	1	R	10	600	110	N	MO	2385
94	LOCK & DAM 21	Mississippi	1938	1990	operational	1	L	10	600	110	N	IL	2413
95	LOCK & DAM 22	Mississippi	1938	1990	operational	1	R	10	600	110	Y	MO	2041
96	LOCK & DAM 24	Mississippi	1940	2003	operational	1	R	15	600	110	Y	MO	2149
97	LOCK & DAM 25	Mississippi	1939	1999	operational	1	R	15	600	110	Y	MO	2192
98	LOCK & DAM 3	Mississippi	1938	1991	seasonal	1	R	8	600	110	N	MN	7749
99	LOCK & DAM 4	Mississippi	1935	1994	seasonal	1	L	7	600	110	N	WI	4973
100	LOCK & DAM 5	Mississippi	1935	1998	seasonal	1	R	9	600	110	Y	MN	3476
101	LOCK & DAM 6	Mississippi	1936	1999	seasonal	1	L	6	600	110	N	WI	3898
102	LOCK & DAM 7	Mississippi	1937	2002	seasonal	1	R	8	600	110	Y	MN	5286
103	LOCK & DAM 8	Mississippi	1937	2003	seasonal	1	L	11	600	110	N	WI	3086
104	LOCK & DAM 9	Mississippi	1938	2005	seasonal	1	L	9	600	110	N	WI	3946
105	Lower Saint Anthony Falls	Mississippi	1959	none	seasonal	1	R	25	400	56	Y	MN	2139
106	MEL PRICE LOCK & DAM	Mississippi	1990	none	operational	2	L	24	1200	110	N	IL	2343
107	Upper Saint Anathjony Fall	Mississippi	1963	none	seasonal	1	R	49	400	56	Y	MN	2040
108	Hildebrand	Monongahela	1959	none	operational	1	L	21	600	84	Y	WV	207
109	LOCK & DAM 2	Monongahela	1905	none	operational	2	R	9	720	110	Y	PA	3021
110	LOCK & DAM 3	Monongahela	1907	none	operational	2	R	8	720	56	Y	PA	4185
111	LOCK & DAM 4	Monongahela	1932	none	operational	2	R	17	720	56	Y	PA	6171
112	Maxwell	Monongahela	1963	none	operational	2	R	20	720	84	Y	PA	4095
113	Morgantown	Monongahela	1950	none	operational	1	L	17	600	84	Y	WV	400
114	Opekiska	Monongahela	1964	none	operational	1	R	22	600	84	N	WV	260
115	Point Marion	Monongahela	1994	none	operational	1	L	19	720	84	Y	PA	1474
116	L&D 52	Ohio	1969	none	operational	2	R	12	1200	110	Y	IL	7703
117	L&d 53	Ohio	1980	none	operational								7351
118	Belleville	Ohio	1969	none	operational	2	R	22	1200	110	Y	OH	3592
119	Cannelton	Ohio	1971	none	operational	2	R	25	1200	110	Y	IN	5740
120	Captain Anthony Meldahl	Ohio	1962		operational	2	R	30	1200	110	Y	OH	4130
121	Dashields	Ohio	1929	1980	operational	2	L	10	600	110	Y	PA	3113
122	Emsworth	Ohio	1921	1986	operational	2	R	18	600	110	Y	PA	3404
123	Greenup	Ohio	1959	none	operational	2	L	30	1200	110	Y	KY	3957
124	Hannibal	Ohio	1973	none	operational	2	R	21	1200	110	Y	OH	3774
125	John T. Myers	Ohio	1975	none	operational	2	R	18	1200	110	Y	IN	5166
126	Markland	Ohio	1959	2011	operational	2	L	35	1200	110	Y	KY	4368
127	McAlpine	Ohio	1961	none	operational	2	L	37	1200	110	Y	KY	3276
128	Montgomery	Ohio	1936	1990	operational	2	L	18	600	110	Y	PA	3573
129	New Cumberland	Ohio	1959	none	operational	2	R	21	1200	110	Y	OH	2845
130	NewBurgh	Ohio	1975	none	operational	2	R	16	1200	110	Y	IN	6379
131	Pike Island	Ohio	1965	none	operational	2	L	18	1200	110	Y	WV	3128
132	Racine	Ohio	1967	none	operational	2	L	22	1200	110	Y	WV	3622
133	Robert C. Byrd	Ohio	1993	2002	operational	2	L	23	1200	110	Y	WV	1945
134	Smithland	Ohio	1980	none	operational	2	R	22	1200	110	Y	IL	4184
135	Willow Island	Ohio	1972	none	operational	2	R	20	1200	110	Y	OH	3405

No.	Lock	River	Year Open	Rehab	Status	Num Chambers	Bank	Lift	Chamber Length	Chamber Width	Mooring	State	Vessels
136	Ortona	Okeechobee	1937	none	operational	1	R	11	250	50	Y	FL	5128
137	Old River	Old River	1963	none	operational	1	R	35	1200	75	N	LA	3376
138	Columbia	Ouachita	1972	none	operational	1	L	18	600	84	N	LA	393
139	Felsenthal	Ouachita	1984	none	operational	1	R	18	600	84	N	AR	263
140	H.K. Thatcher	Ouachita	1984	none	operational	1	R	12	600	84	N	AR	182
141	L&D 3	Red	1992	none	operational	1	L	31	785	84	N	LA	1330
142	Joe D. Waggoner	Red	1994	none	operational	1	L	25	785	84	N	LA	2158
143	John H. Overton	Red	1987	none	operational	1	L	24	785	84	N	LA	1416
144	Lindy Claiborne Boggs	Red	1984	none	operational	1	L	36	785	84	N	LA	1657
145	Port Mayaca	St. Lucie Canal	1977	none	operational	1	R	2	400	56	Y	FL	4394
146	St. Lucie	St. Lucie Canal	1941	none	operational	1	R	13	250	50	Y	FL	5129
147	Chickamauga	Tennessee	1937	none	operational	1	R	49	360	60	Y	TN	3623
148	Fort Loudoun	Tennessee	1943	none	operational	1	L	72	360	60	N	TN	1453
149	General Joseph Wheeler	Tennessee	1963	none	operational	2	R	48	600	110	Y	AL	2003
150	Guntersville	Tennessee	1965	none	operational	2	R	39	600	110	Y	AL	1497
151	Kentucky	Tennessee	1944	none	operational	1	R	57	600	110	Y	KY	2986
152	Nickajack	Tennessee	1967	none	operational	1	R	39	600	110	Y	TN	1640
153	Pickwick Landing	Tennessee	1984	none	operational	2	L	55	1000	110	Y	TN	2394
154	Watts Bar	Tennessee	1941	none	operational	1	L	58	360	60	Y	TN	1592
155	Wilson	Tennessee	1959	none	operational	3	R	94	600	110	N	AL	2661
156	Aberdeen	Tenn-Tombigbee	1985	none	operational	1	R	27	600	110	N	MS	1969
157	Amory	Tenn-Tombigbee	1985	none	operational	1	L	30	600	110	N	MS	2008
158	Fulton	Tenn-Tombigbee	1985	none	operational	1	L	25	600	110	N	MS	2025
159	G.V. Sonny Montgomery	Tenn-Tombigbee	1985	none	operational	1	L	30	600	110	N	MS	1991
160	Glover Wilkins	Tenn-Tombigbee	1985	none	operational	1	R	25	600	110	N	AL	2020
161	Howell Heflin	Tenn-Tombigbee	1978	none	operational	1	L	36	600	110	N	AL	2020
162	Jamie Whitten	Tenn-Tombigbee	1985	none	operational	1	L	84	600	110	N	MS	2312
163	John C. Stennis	Tenn-Tombigbee	1980	none	operational	1	R	27	600	110	N	MS	2289
164	John E. Rankin	Tenn-Tombigbee	1985	none	operational	1	R	30	600	110	N	MS	2053
165	Tom Bevill	Tenn-Tombigbee	1979	none	operational	1	L	27	600	110	N	AL	2090
166	Coffeerville	Tombigbee	1960	none	operational	1	R	34	600	110	N	AL	2490
167	Demopolis	Tombigbee	1954	none	operational	1	L	40	600	110	N	AL	2594

No.	Ktons	Lockages	WCSC Tons	LPMS Tons	WCSC Ton-Miles	System		Above Pool Tonnage	Below Pool Tonnage	Pool Above Total	Pool Below Total
						System Lockages	Lockages per Barge				
1		65						0	0	0	0
2		98						0	0	0	0
3		34						0	0	0	0
4			667896	941000	215389170	287	1	0	0	0	0
5	2148	3803	1732368	2148000	438768003	15628	10	0	0	0	0
6			1732368	2164000	438768003	15628	10	0	0	0	0
7	412	1117	294446	412000	173054654	2437	12.4	0	1,358,167	0	1,358,167
8	75	544	6593	75000	12183864	104	26	0	113,374	0	113,374
9	21	100	6593	21000	12183864	104	26	0	0	0	0
10	75	7.25	6593	14000	12183864	104	26	0	0	0	0
11								0	0	0	0
12								0	0	0	0
13								0	0	0	0
14	6759	1189	6865895	6759000	6300563711	74708	17.7	0	493,143	0	493,143
15	8638	1711	8829595	8638000	7622745294	83444	15.5	4,874	474,968	4,874	474,968
16	6723	1184	6807975	6723000	6252996277	74262	17.7	0	18,845	0	18,845
17	8441	1581	8834469	8441000	7622802803	83486	15.5	1,089,395	0	1,089,395	0
18	8800	1713	9312829	8800000	7879113329	84641	14.9	4,921	42,491	4,921	42,491
19	7303	2431	22227660	7303000	6414502087	73530	6.4	704,200	0	704,200	0
20	8756	1643	9355320	8756000	7901242586	84722	14.9	0	398,688	0	398,688
21	6851	1363	7173279	6851000	6357914368	75112	17.2	3,344	2,476,789	3,344	2,476,789
22	9105	1653	9760696	9105000	8106186465	85217	14.3	0	0	0	0
23	6137	1147	6690500	6137000	6198273127	73464	17.9	800,260	93,525	800,260	93,525
24	5794	1446	6247617	5794000	5839927519	69661	18.2	0	0	0	0
25	6789	1202	7176623	6789000	6357954334	75132	17.2	439,178	0	439,178	0
26	5793	1414	6247617	5793000	5839927519	69661	18.2	0	1,784,821	0	1,784,821
27	5416	1475	5908615	5416000	5571702408	66340	18.4	0	57,595	0	57,595
28	9140	1679	9760696	9140000	8106186465	85217	14.3	0	0	0	0
29	22	2939	27079187	22000	23529847909	143368	10.2	0	0	0	0
30	1076	1045	980457		310860181	1590	3.2	0	0	0	0
31	82	1532		82000				0	0	0	0
32	7693	1413	7496716	7693000	3094603079	31318	6.9	633,806	4,768,059	633,806	4,768,059
33	4505	1034	5776575	5941000	2181969077	25613	6.7	18,000	687,550	2,249,033	1,408,901
34	5941	1221	4385674	4505000	1681101232	20935	7.2	2,249,033	1,408,901	18,000	687,550
35	7071	1268	6748538	7071000	2479373640	28501	6.5	264,900	422,856	264,900	422,856
36	469	3987	6875951	469000	2330362699	14708	4.4	153,786	53,103,923	153,786	53,103,923
37	4	3511	1500	4000	216000	15	5	0	0	0	0
38	4	5598	1500	4000	216000	15	5	0	0	0	0
39	5916	4279	5742072	5916000	6164914723	39822	11	0	0	0	0
40								0	0	0	0
41								0	0	0	0
42								0	0	0	0
43		117				6		0	0	0	0
44		117						0	0	0	0
45	245	10959	5742072	245000	6164914723	39822	11	0	0	0	0

No.	Ktons	Lockages	WCSC Tons	LPMS Tons	WCSC Ton-Miles	System		Above Pool		Pool Above Total	Pool Below Total	
						System Lockages	Lockages per Barge	Tonnage	Below Pool Tonnage			
46									0	0	0	0
47	2848	1224	6486803	2843000	1666441011	10498	2.8	3,034	10,772,707	3,034	10,772,707	10,772,707
48	9103	1932	8393157	9103000	2676507498	19544	4.3	0	15,764,247	0	15,764,247	15,764,247
49				2000				0	6,422,021	0	6,422,021	6,422,021
50	3942	2340	3722409	3942000	910911877	8837	4	0	0	0	0	0
51		762						0	0	0	0	0
52		727						0	0	0	0	0
53	1767	10709	1932571	1767000	48649163	1210	1	0	0	0	0	0
54	27662	14410	27462258	27662000	17647599353	113798	9.3	6,894,997	2,446,334	6,894,997	2,446,334	2,446,334
55	42240	12662	42493113	42240000	29681602961	200403	10.4	58,671	62,800	58,671	62,800	62,800
56	41664	11943	42463776	41664000	29795802996	200802	10.5	203,675	1,227,654	203,675	1,227,654	1,227,654
57	26128	9160	25730654	26168000	16926752587	101171	9.1	0	0	0	0	0
58	20931	9123	25109528	20931000	14552636064	110247	7.4	248,162	650	248,162	650	650
59	22289	6238	42510954	22289000	29718256912	200534	10.4	0	350,007	0	350,007	350,007
60	26281	15723	42235018	26281000	29654587951	199893	10.5	0	5,920	0	5,920	5,920
61	26184	15653	42235018	26184000	29654587951	199893	10.5	0	5,920	0	5,920	5,920
62	26210	13818	42235018	26210000	29654587951	199893	10.5	0	0	0	0	0
63	24921	12577	49387493	24921000	31321763246	202261	9.1	2,136,995	0	2,136,995	0	0
64	1679	4988	2186522	1679000	1344642232	8693	7.3	10,822,601	0	10,822,601	0	0
65	7685	3072	7143955	7685000	3288738566	25678	5.7	0	0	0	0	0
66	6483	1384	5813336	6483000	2127604927	19130	5.2	0	0	0	0	0
67	15834	8431	16295127	15834000	8892738205	41423	5.6	457,815	0	457,815	0	0
68	12588	3384	11642182	12588000	11295143107	73149	10.4	0	4,011,986	0	4,011,986	4,011,986
69	16455	3692	15060210	16455000	16390111066	91425	10.7	944,703	1,802,965	944,703	1,802,965	1,802,965
70	27222	3659	29730341	27222000	35764883159	139837	8.1	1,065,293	2,344,044	1,065,293	2,344,044	2,344,044
71	12360	3264	11256415	12360000	11102816894	70946	10.5	0	393,134	0	393,134	393,134
72	17839	3892	16217395	17839000	18624286359	97485	10.5	535,134	1,932,045	535,134	1,932,045	1,932,045
73	25834	3889	25310546	25834000	29524869639	131837	9	625,092	4,431,271	625,092	4,431,271	4,431,271
74	19853	4081	18290793	19853000	21364870646	108591	10.3	1,650	7,726,854	1,650	7,726,854	7,726,854
75	1110	1186	1127521	1172000	320258774	3077	4.5	463,798	2,056,305	463,798	2,056,305	2,056,305
76	8310	1770	6328262	8310000	2533240087	24095	6.4	4,198,360	4,919,168	4,198,360	4,919,168	4,919,168
77	11285	1541	11463918	11319000	4832358078	41573	6	1,357,043	117,865	1,357,043	117,865	117,865
78	1366	1079	2038323	1366000	789234525	1126	1.2	0	0	0	0	0
79	123	970	91347	123000	6419736	314	2.8	0	0	0	0	0
80	25692	2302	62807436	61139000	75112819904	375344	10	0	0	0	0	0
81	713	1444	1361988	713000	274236910	4086	6.7	0	5,265,481	0	5,265,481	5,265,481
82	12506	2849	11524054	12506000	15216808424	167886	22.8	17,692	591,068	17,692	591,068	591,068
83	13154	3202	12115122	13154000	15236313668	169606	21.8	0	1,545,186	0	1,545,186	1,545,186
84	13904	2723	13124858	13904000	17085679764	183207	21.8	663,201	178,561	663,201	178,561	178,561
85	14133	2786	13306798	14133000	17327259882	184889	21.7	0	2,353,083	0	2,353,083	2,353,083
86	16100	2963	17054804	16103000	20005637897	202124	19.7	327,523	469,042	327,523	469,042	469,042
87	16433	2933	16478324	16453000	20443624506	203455	20.2	280,308	771,458	280,308	771,458	771,458
88	16832	3316	16789159	16832000	21405626625	204243	19.9	674,735	744,437	674,735	744,437	744,437
89	17652	2903	17775362	17652000	22349673753	211281	19.5	17,006	854,268	17,006	854,268	854,268
90	18584	3090	18674967	18584000	23392977411	216825	19	0	1,547,389	0	1,547,389	1,547,389

No.	Ktons	Lockages	WCSC Tons	LPMS Tons	WCSC Ton-Miles	System		Above Pool		Pool Above Total	Pool Below Total
						System Lockages	Lockages per Barge	Tonnage	Below Pool Tonnage		
91	18498	1932	19341938	19097000	24921165521	218523	18.5	919,500	414,383	919,500	414,383
92	6880	2452	6472877	6880000	8664991028	103859	25	2,042,902	0	2,042,902	0
93	19097	3272	19644803	19097000	25370303092	218870	18.3	124,136	1,654,891	124,136	1,654,891
94	20925	3358	21747261	20925000	27996972455	226968	17.1	193,085	699,192	193,085	699,192
95	21346	3158	21927735	21346000	28353386574	228495	16.6	255,763	1,010,250	255,763	1,010,250
96	21785	3190	23034787	21785000	29481889251	231220	16	17,887	0	17,887	0
97	21674	3172	23095753	21674000	29499570937	231348	15.9	0	33,815	0	33,815
98	6877	3775	6472877	6877000	8664991028	103859	25	0	369,221	0	369,221
99	7357	3077	6907949	7357000	9329578657	111152	25.1	19,570	0	19,570	0
100	7388	2542	6907949	7388000	9329578657	111152	25.1	0	1,629,210	0	0
101	9089	2726	8613564	9089000	12155104538	136811	24.8	7,828	0	7,828	0
102	9360	3577	8613564	9360000	12155104538	136811	24.8	0	342,226	0	342,226
103	9754	2395	9383024	9754000	13037758496	146631	24.4	0	795,258	0	795,258
104	11125	2948	10187441	11125000	13292571029	152382	23.4	0	1,314,816	0	1,314,816
105	716	1585	1361988	716000	274236910	4086	6.7	0	0	0	0
106	25692	2302	55234898	53661000	67665616432	368629	11	0	5,272,032	0	5,272,032
107	712	1207	1361988	712000	274236910	4086	6.7	0	0	0	0
108	5	61		5000				0	0	0	0
109	16071	3326	15603307	16235000	5309892425	130187	12.4	6,622,970	0	6,622,970	0
110	9794	4109	10151641	11216000	2928204921	88072	12.1	214,139	2,467,962	214,139	2,467,962
111	10235	5612	9554511	10235000	2673277896	83935	12.2	839,533	395,824	839,533	395,824
112	9884	3642	9547720	10147000	2302103863	80783	11.6	5,409,922	133,632	5,409,922	133,632
113	176	254	91340	176000	28224060	960	16	91,340	3,708,692	91,340	3,708,692
114	5	64		5000				0	0	0	0
115	3483	1274	3076966	3483000	550126040	32291	11.8	5,220,559	0	5,220,559	0
116	83238	7634	75636357	87931000	82094774301	328469	7.7	21,139		21,139	4,576,482
117	76478	7177	75636357	76478000	82094774301	328469	7.7	10,637,443		10,637,443	3,960,677
118	44486	3499	43515873	44813000	24233826273	191481	7.5	430,906		430,906	412,894
119	68642	5686	72978248	69895000	58140399748	323646	7.7	10,604,472		10,604,472	17,245,883
120	45270	4071	39888523	46181000	30322787757	199116	8.8	5,411,330	4,576,482	5,411,330	19,937,793
121	18073	3709	16408423	20309000	5678582399	143553	12.6	35,457	3,960,677	35,457	3,328,051
122	18171	3894	16408423	18615000	5678582399	143553	12.6	1,259,041	412,894	1,259,041	1,246,700
123	41345	3835	39888523	41704000	30322787757	199116	8.8	5,912,292	17,245,883	5,912,292	10,668,083
124	43435	3714	16408423	44241000	5678582399	143553	12.6	13,543,440	19,937,793	13,543,440	1,701,539
125	63670	5090	67676788	64174000	63097071542	311676	8.1	19,992,182	3,328,051	19,992,182	14,801,568
126	52314	4340	58789721	52754000	48278194662	253305	7.5	10,801,531	1,246,700	10,801,531	22,015,111
127	26011	3189	72978248	69930000	58140399748	323646	7.7	8,260,660	10,668,083	8,260,660	11,575,901
128	20296	4266	16408423	20966000	5678582399	143553	12.6	2,591,973	1,701,539	2,591,973	11,820,151
129	27956	2828	16408423	31208000	5678582399	143553	12.6	2,807,798	14,801,568	2,807,798	8,838,263
130	77055	6363	16408423	31208000	5678582399	143553	12.6	7,780,488	22,015,111	7,780,488	13,883,874
131	29082	3095	16408423	32238000	5678582399	143553	12.6	7,156,057	11,575,901	7,156,057	19,126,279
132	45889	3593	43515873	46287000	24233826273	191481	7.5	855,689	11,820,151	855,689	2,513,694
133	23832	1935	37087411	40833000	26555672336	194602	9.1	11,291,908	8,838,263	11,291,908	8,035,659
134	38754	3929	69018665	71042000	63809667860	312506	8	3,407,930	13,883,874	3,407,930	427,002
135	41127	3303	16408423	41886000	5678582399	143553	12.6	2,919,121	19,126,279	2,919,121	2,509,472

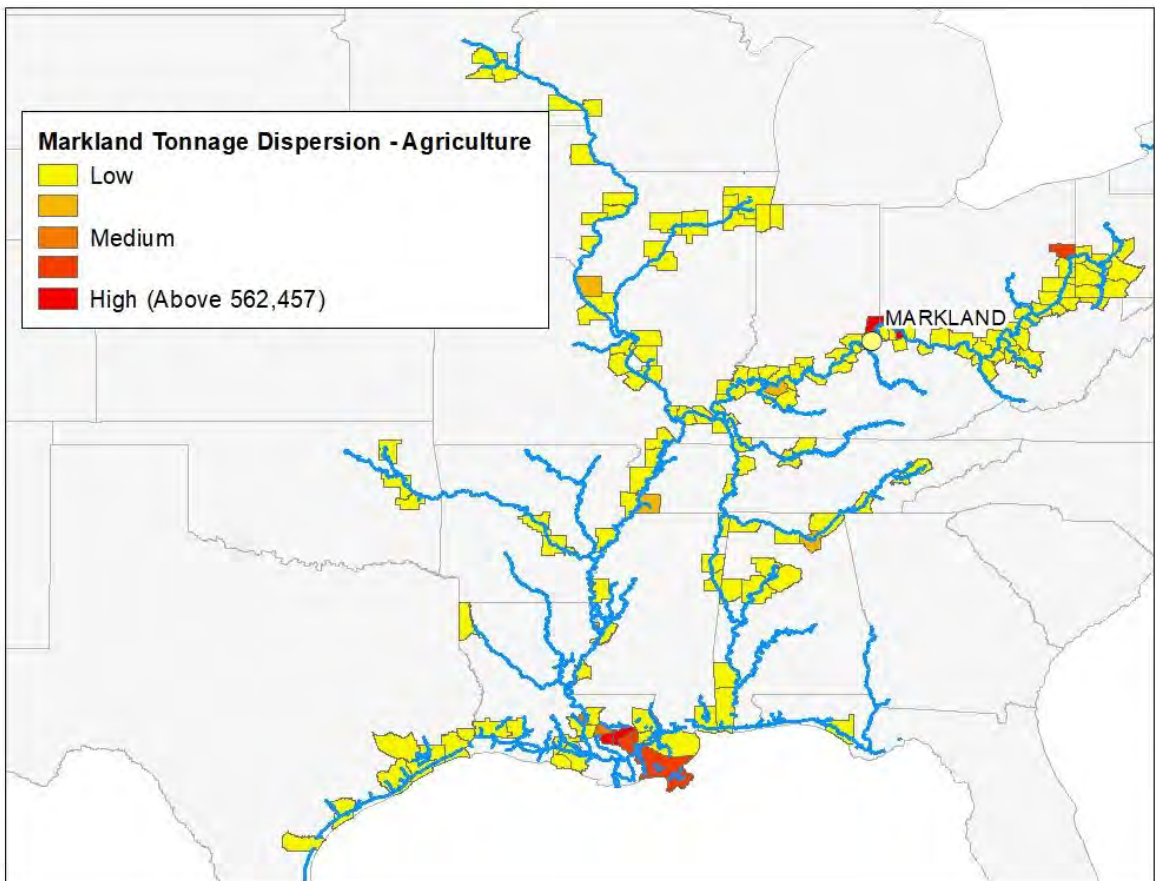
No.	Ktons	Lockages	WCSC Tons	LPMS Tons	WCSC Ton-Miles	System		Above Pool		Pool Above Total	Pool Below Total
						System Lockages	Lockages per Barge	Tonnage	Below Pool Tonnage		
136	4	4021	1500	4000	216000	15	5	0	2,513,694	0	0
137	7321	3142						0	8,035,659	0	0
138	544	474	502728	544000	171767632	896	4.1	0	427,002	0	12,007
139	67	251	60575	67000	38275490	400	9.3	0	2,509,472	0	341,295
140	6	126		6000				0	0	0	0
141	840	976	642970	840000	504037223	2004	5.8	0	0	0	3,231,362
142	695	1371	621380	695000	486575383	1920	5.7	0	12,007	0	0
143	3813	1313	4260574	3813000	2643987727	10387	4.1	0	341,295	0	6,125
144	3813	1569	3178822	3813000	2311689559	8738	4.5	0	0	0	0
145	3	3237	1500	3000	216000	15	5	0	0	0	0
146	6	3789	1500	6000	216000	15	5	0	6,125	0	0
147	831	2756	798482	831000	945065460	5363	11.1	0	0	0	2,983,967
148	459	1262	420489	459000	463077263	2486	10.5	1,320	3,231,362	1,320	133,025
149	8701	2183	8385549	9077000	8252933380	56484	12	596,107	0	596,107	300
150	4665	1362	3708313	4665000	3414826894	25760	11.2	14,807	0	14,807	6,685,001
151	29324	4748	22125836	29324000	14144444162	101665	7.9	1,624,541	0	1,624,541	12,008,713
152	2586	1242	2052613	2586000	2146049233	13672	10.8	1,449,158	2,983,967	1,449,158	2,049,281
153	12874	2346	12848401	13072000	10685848234	84840	11	8,055	133,025	8,055	4,783,509
154	623	1587	568212	623000	629658037	3606	10.9	3,180	300	3,180	1,400
155	9099	2559	8381699	9099000	8252393630	56432	12	300	6,685,001	300	2,926,413
156	5079	1708	5675570	5079000	3772566019	43572	15.1	553,196	12,008,713	553,196	371,869
157	5254	1796	5997641	5254000	4077779332	48525	15.6	0	2,049,281	0	177,345
158	5268	1814	5979703	5268000	4071088236	48431	15.6	0	4,783,509	0	0
159	5263	1806	5981203	5263000	4071302736	48436	15.6	310,760	1,400	310,760	0
160	5267	1810	5997641	5267000	4077779332	48525	15.6	0	2,926,413	0	0
161	6207	1850	6194409	6207000	3649069287	42483	13.6	52,854	371,869	52,854	574,200
162	5555	2042	6298947	5555000	4216896329	50152	15.2	214,211	177,345	214,211	3,000
163	5646	2080	5764165	5646000	3531862818	41801	14.4	81,486	0	81,486	102,900
164	5279	1813	5981203	5279000	4071302736	48436	15.6	0	0	0	0
165	5978	1917	6194409	5978000	3649069287	42483	13.6	25,800	0	25,800	178,800
166	10121	2286	9560008	10121000	4721385987	45708	8.3	129,769	574,200	129,769	4,446,210
167	10036	2318	9567952	10036000	4783812010	46208	8.5	5,662,515	3,000	5,662,515	104,889

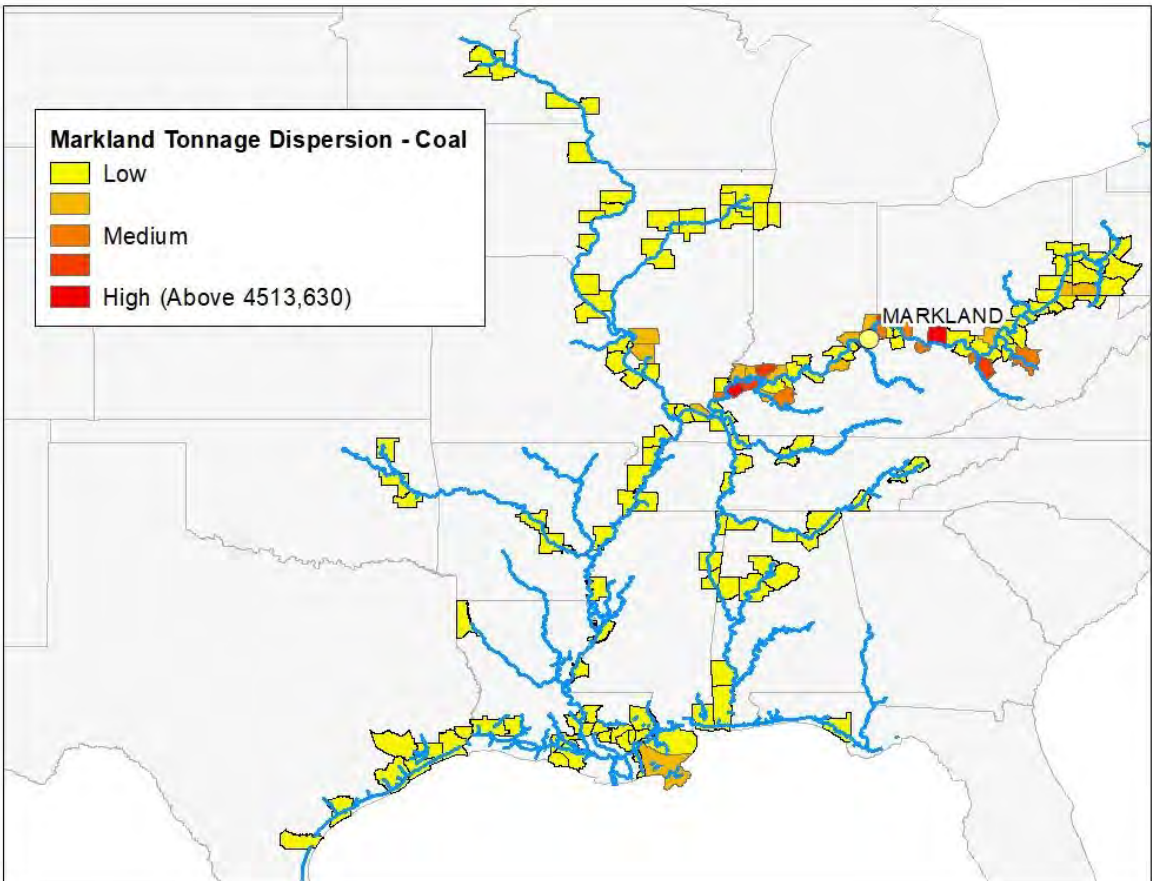
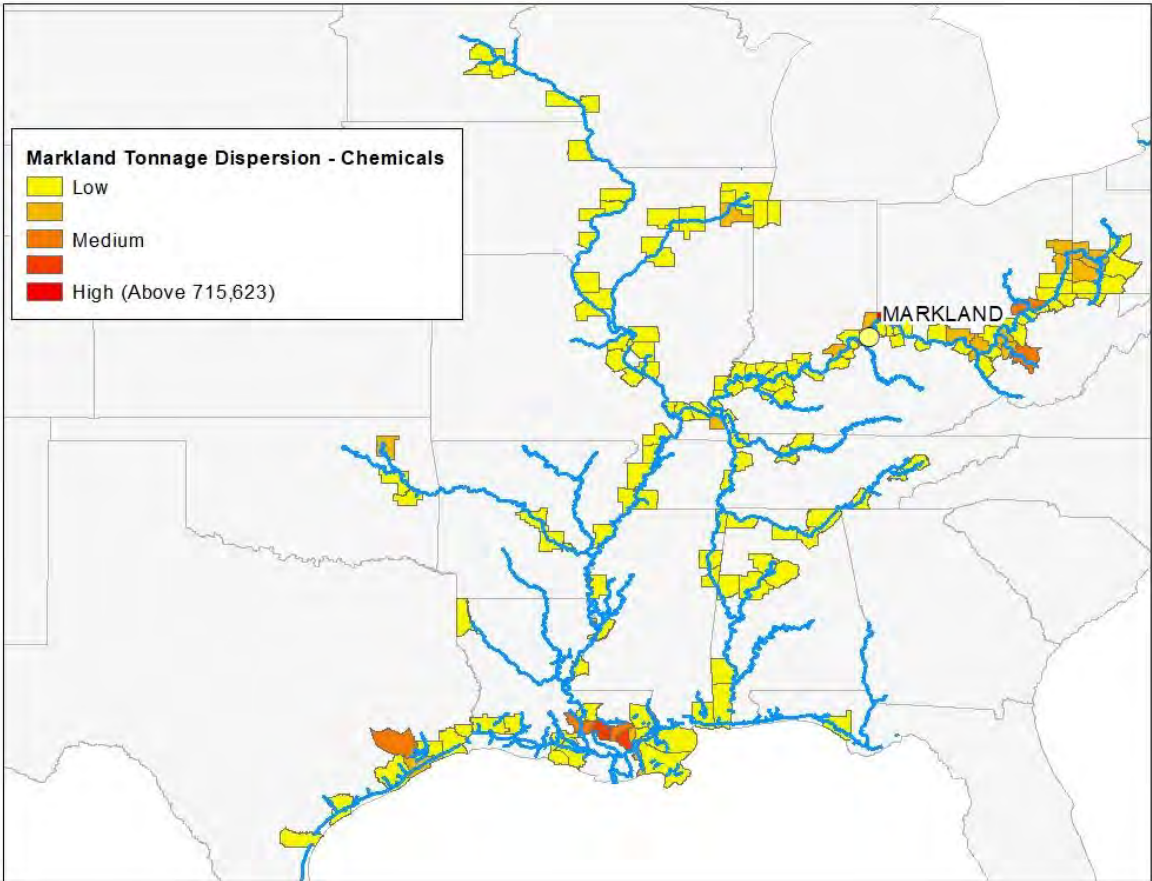
Appendix Three

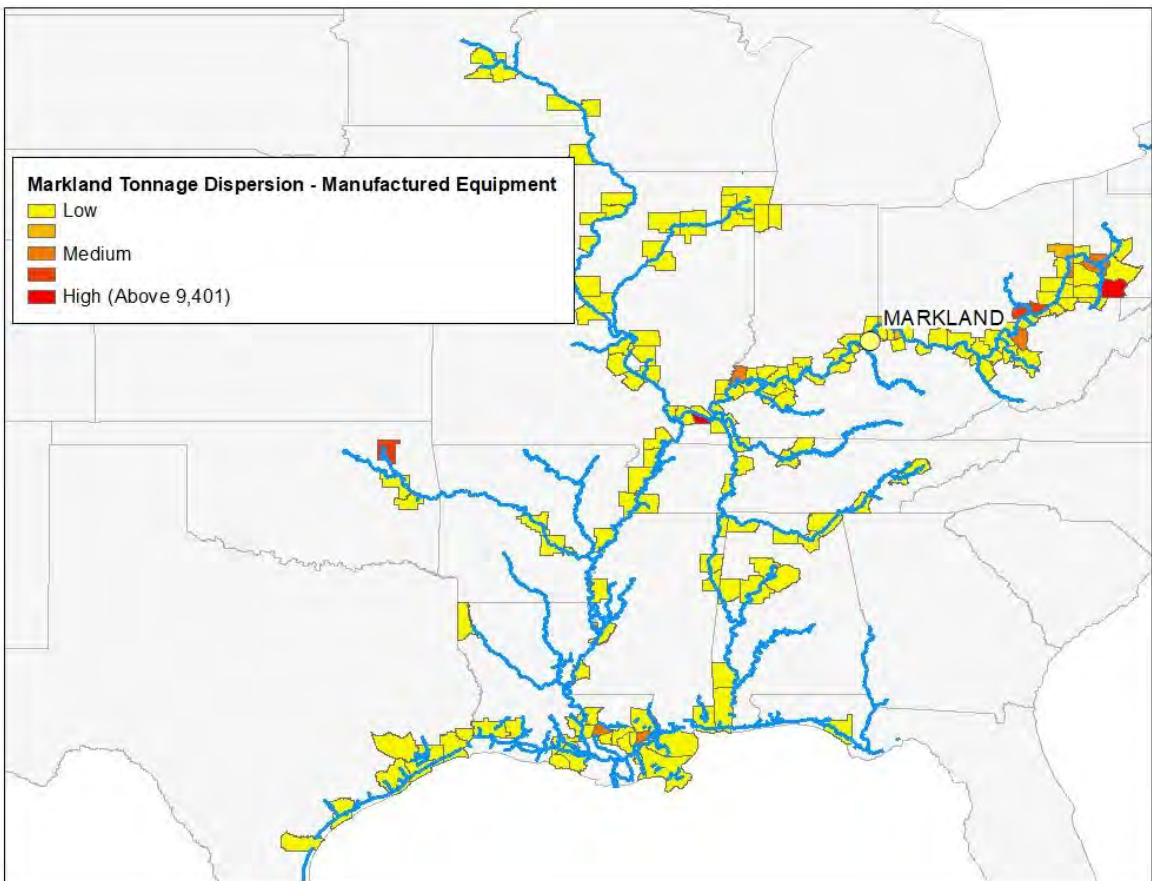
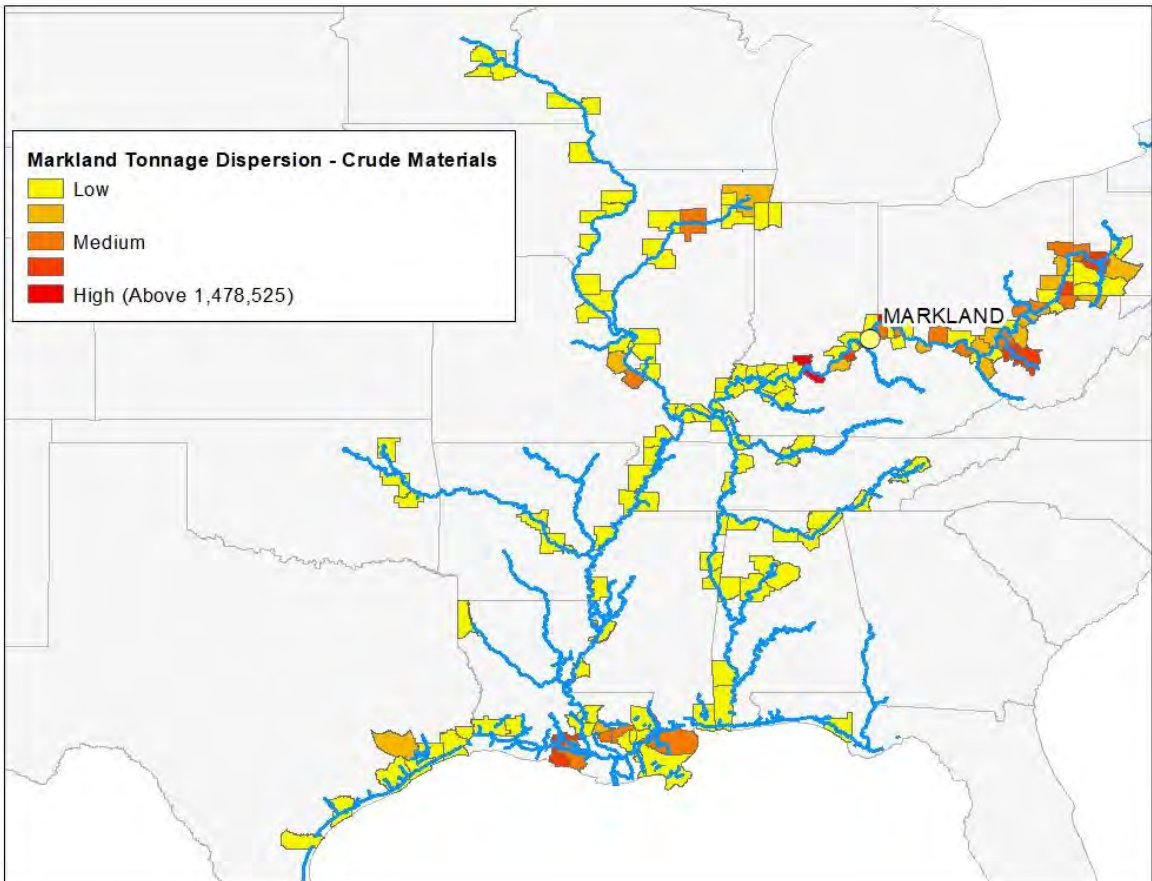
Commodity-Specific Lock Traffic

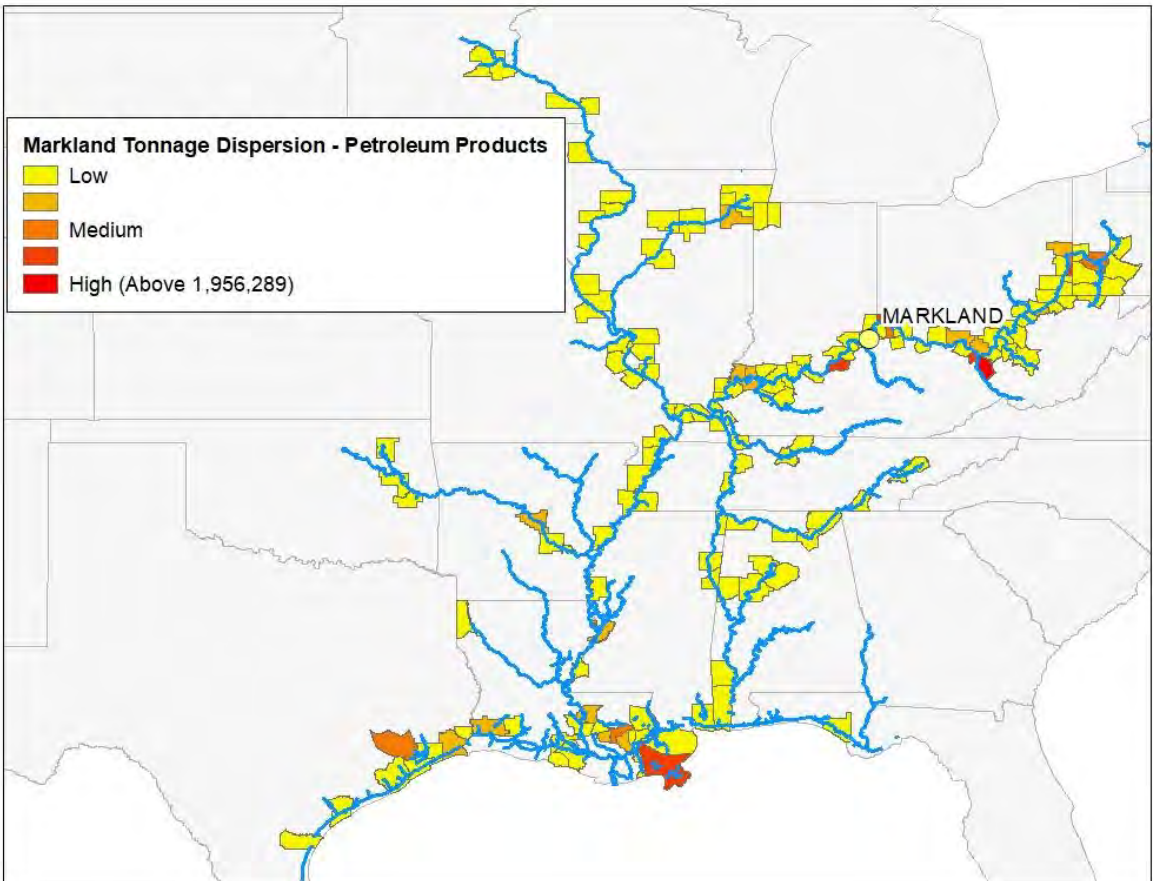
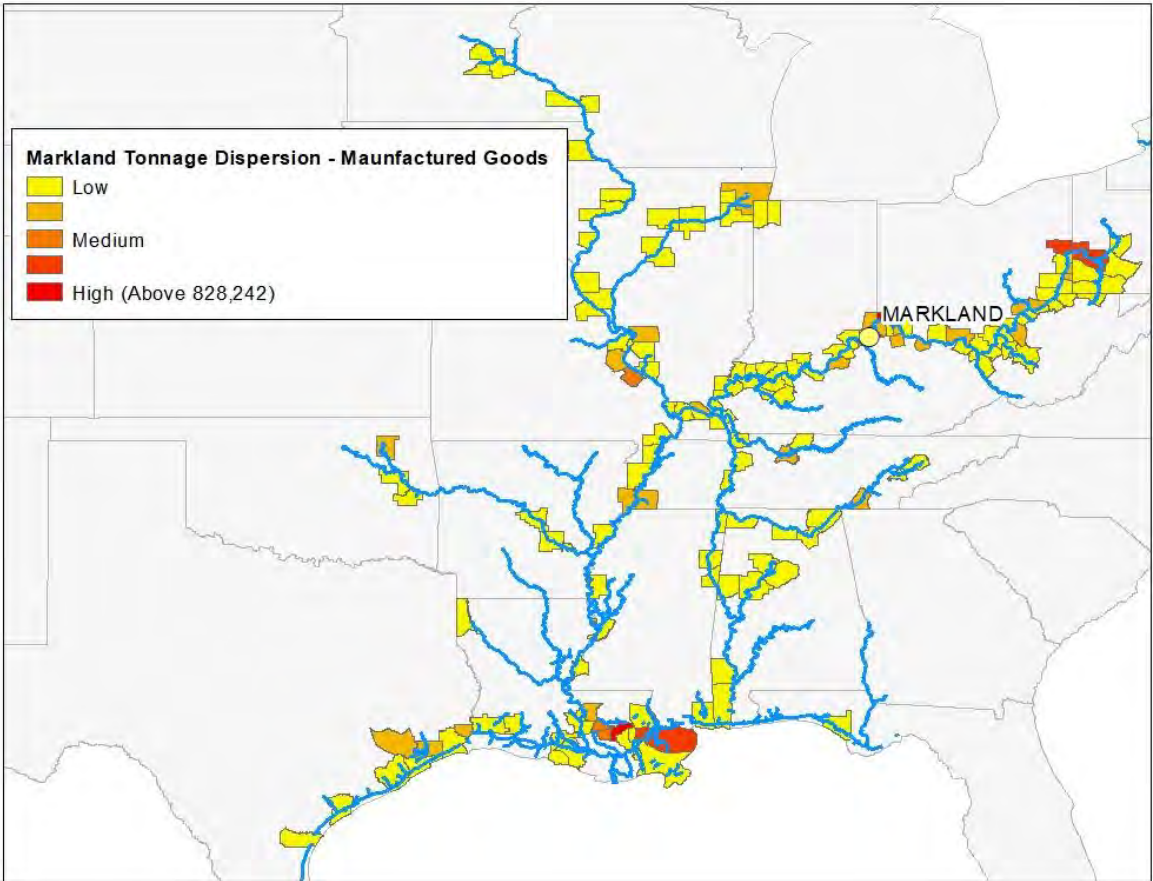
Markland Locks & Dam

	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	30,788,869	1,675	473	\$7.21	\$221,987,745
Petroleum Products	20	7,440,371	2,598	967	\$49.49	\$368,253,302
Chemicals	30	3,898,264	1,693	1,412	\$70.91	\$276,416,124
Crude Materials	40	14,339,508	1,673	757	\$16.93	\$242,729,791
Primary Manufactured Goods	50	4,896,902	1,658	1,294	\$32.75	\$160,394,481
Farm Products and Food	60	4,089,324	1,826	1,342	\$9.41	\$38,460,711
Equipment	70	55,525	1,586	1,216	\$32.75	\$1,818,681
TOTAL		65,508,763				\$1,310,060,835



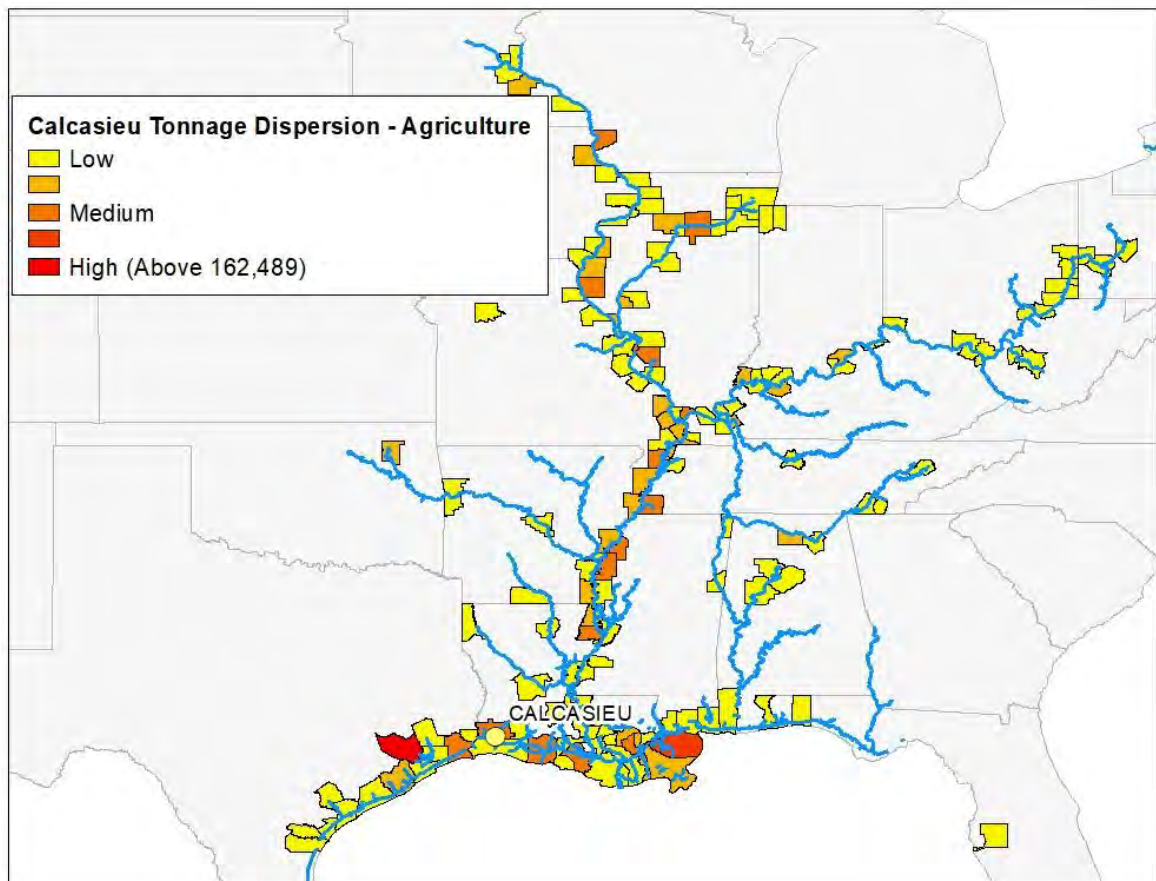


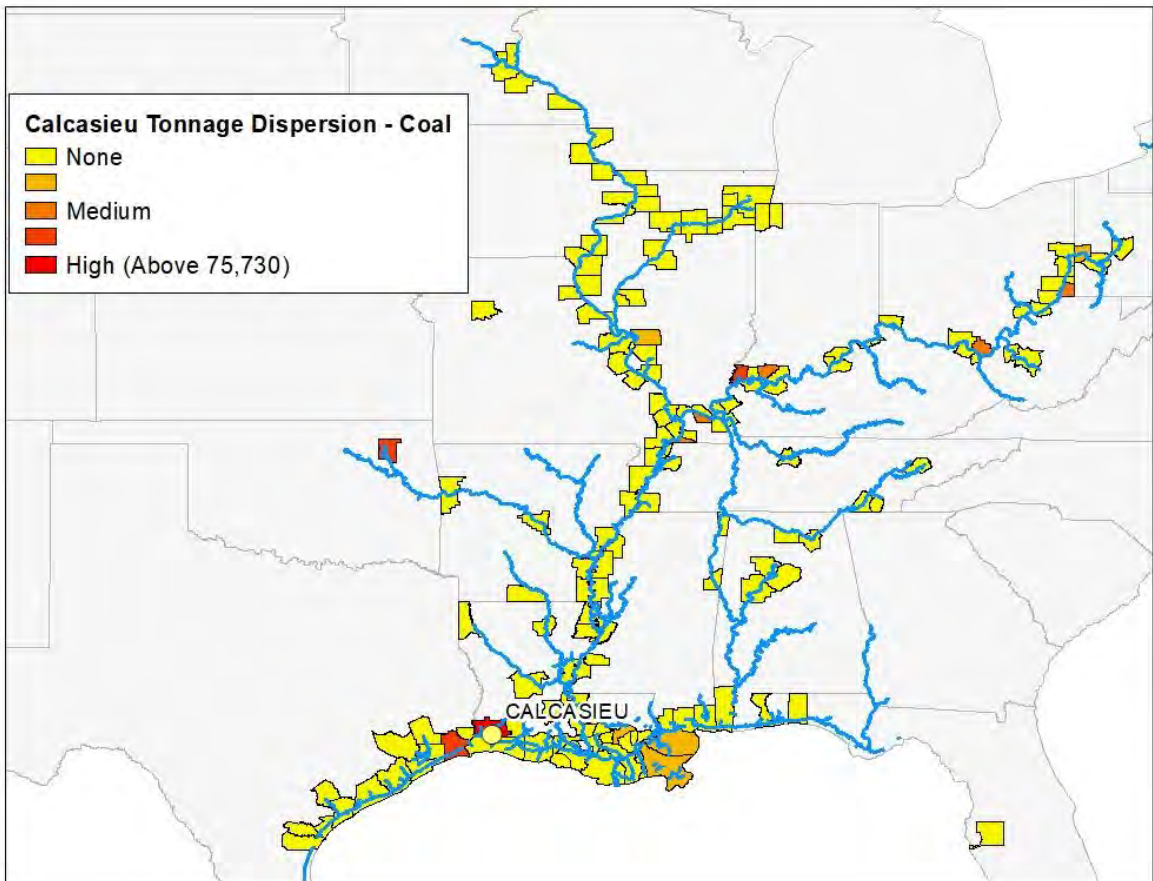
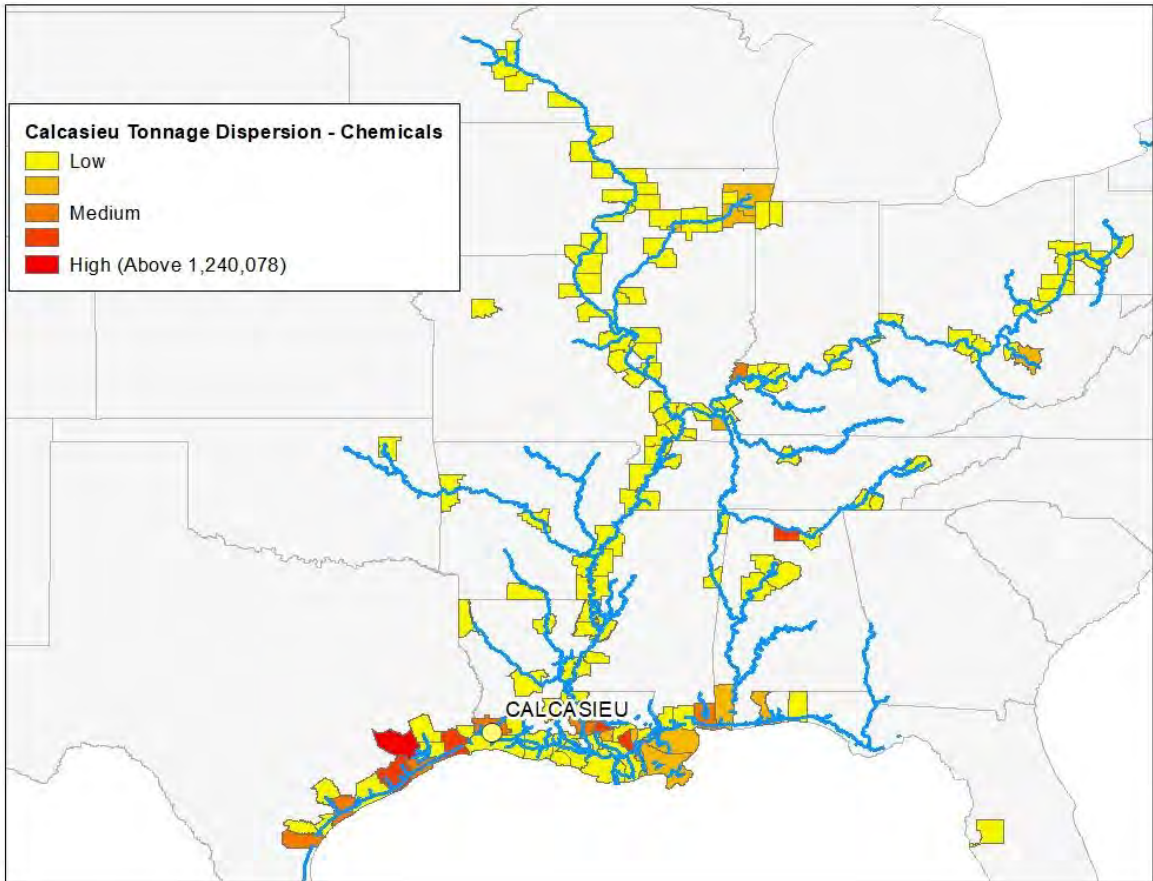


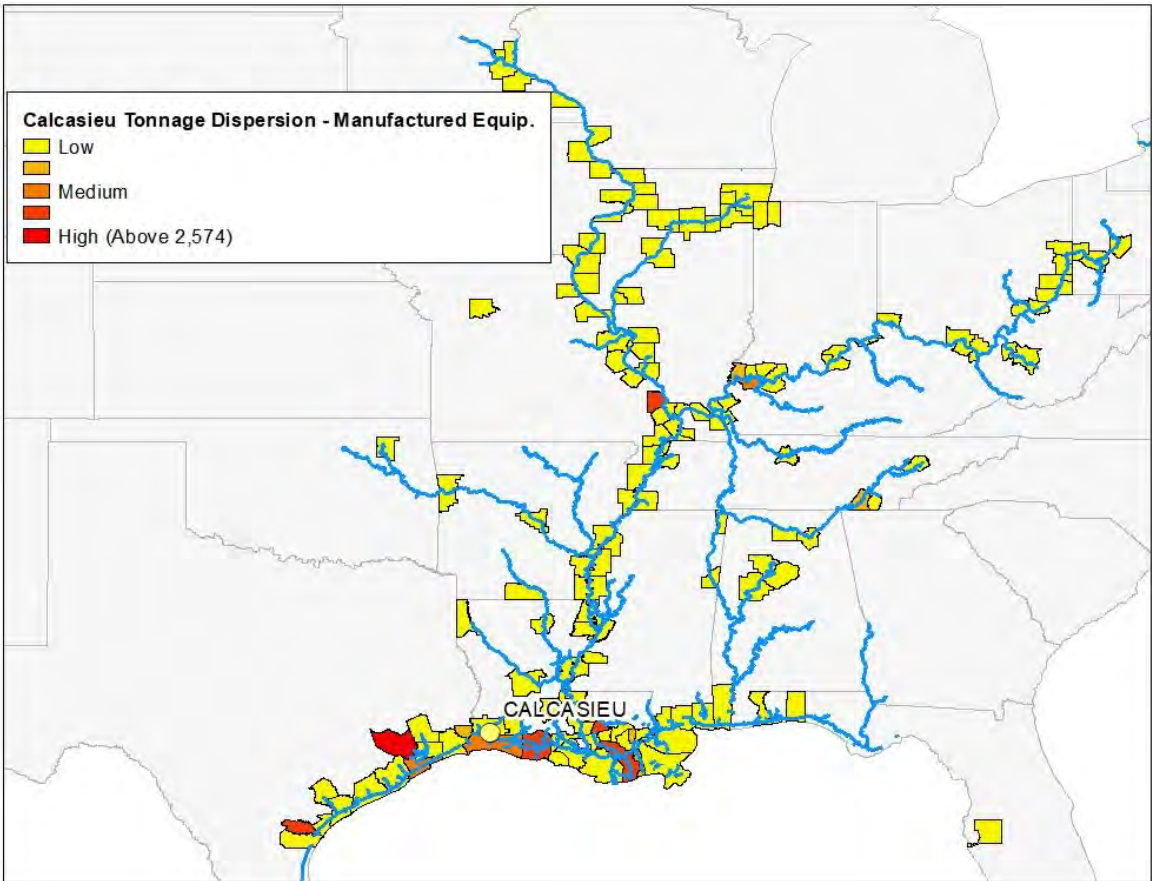
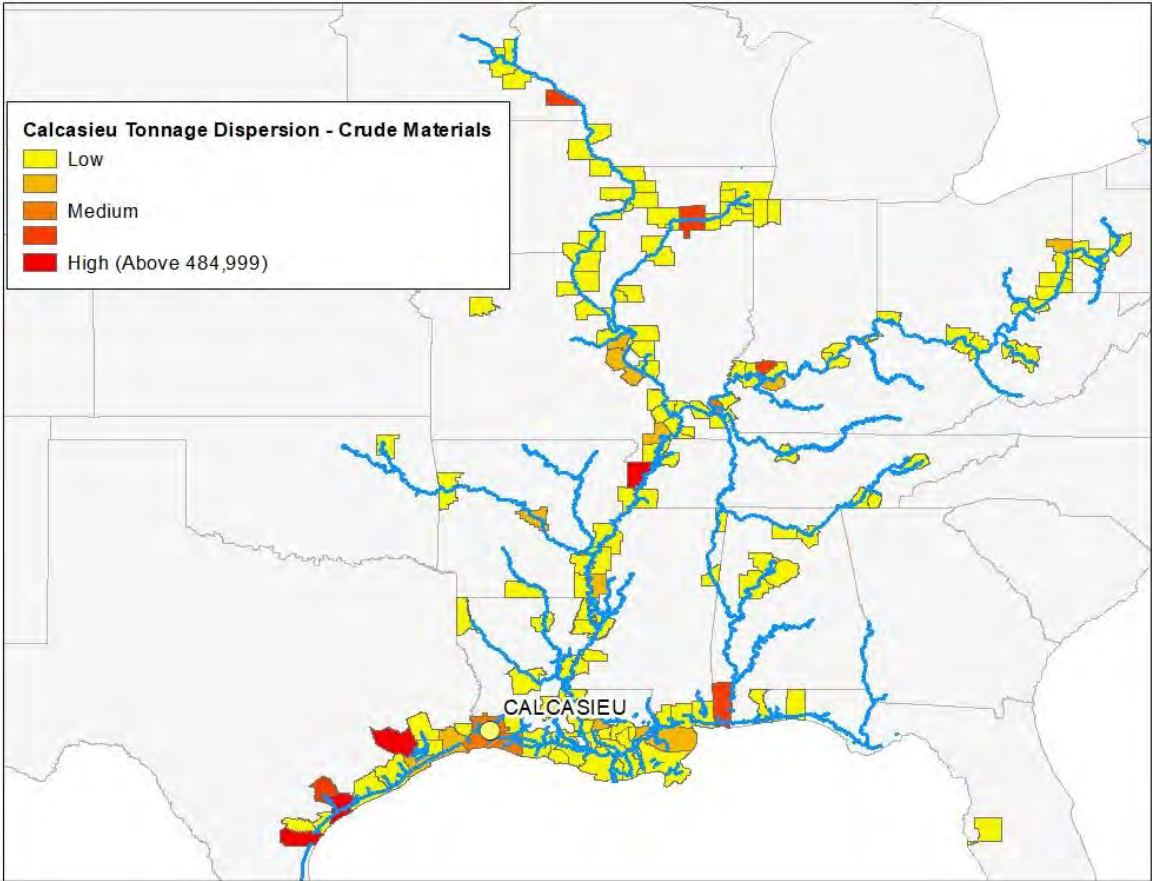


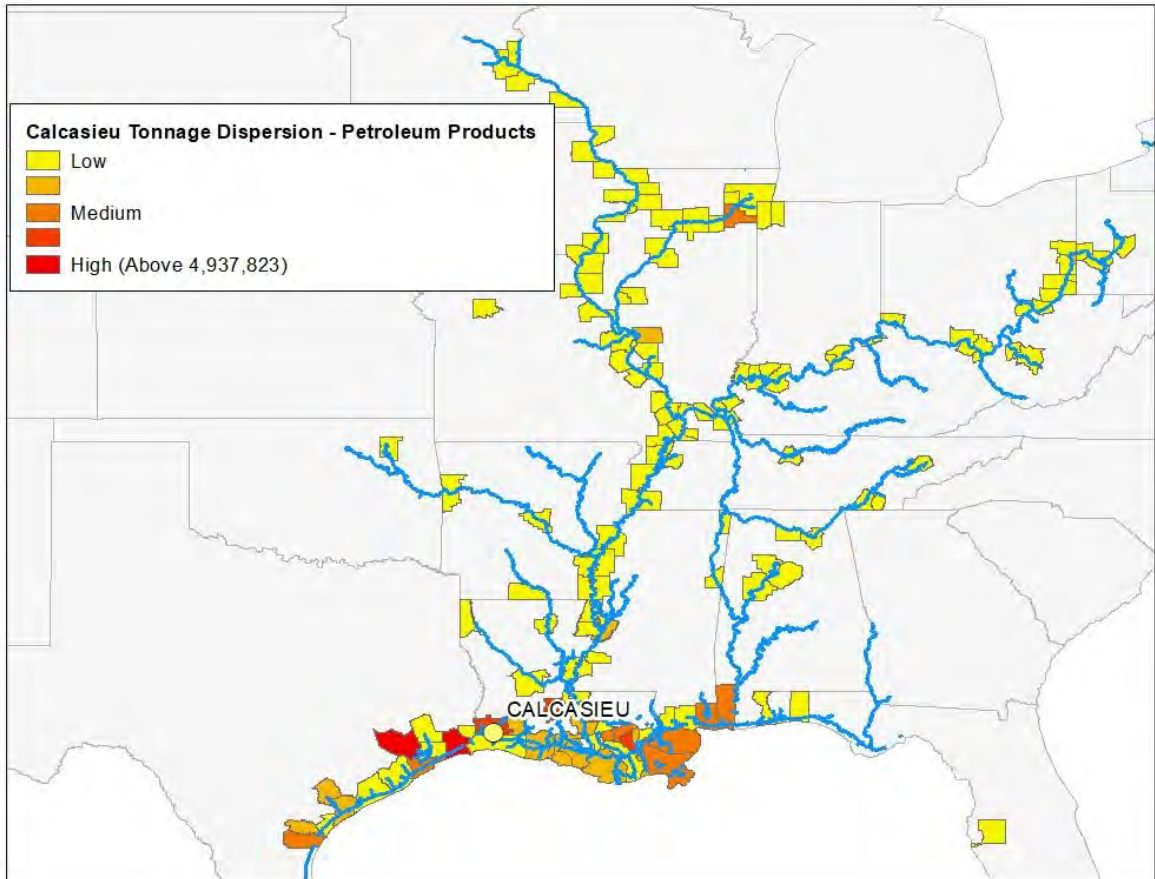
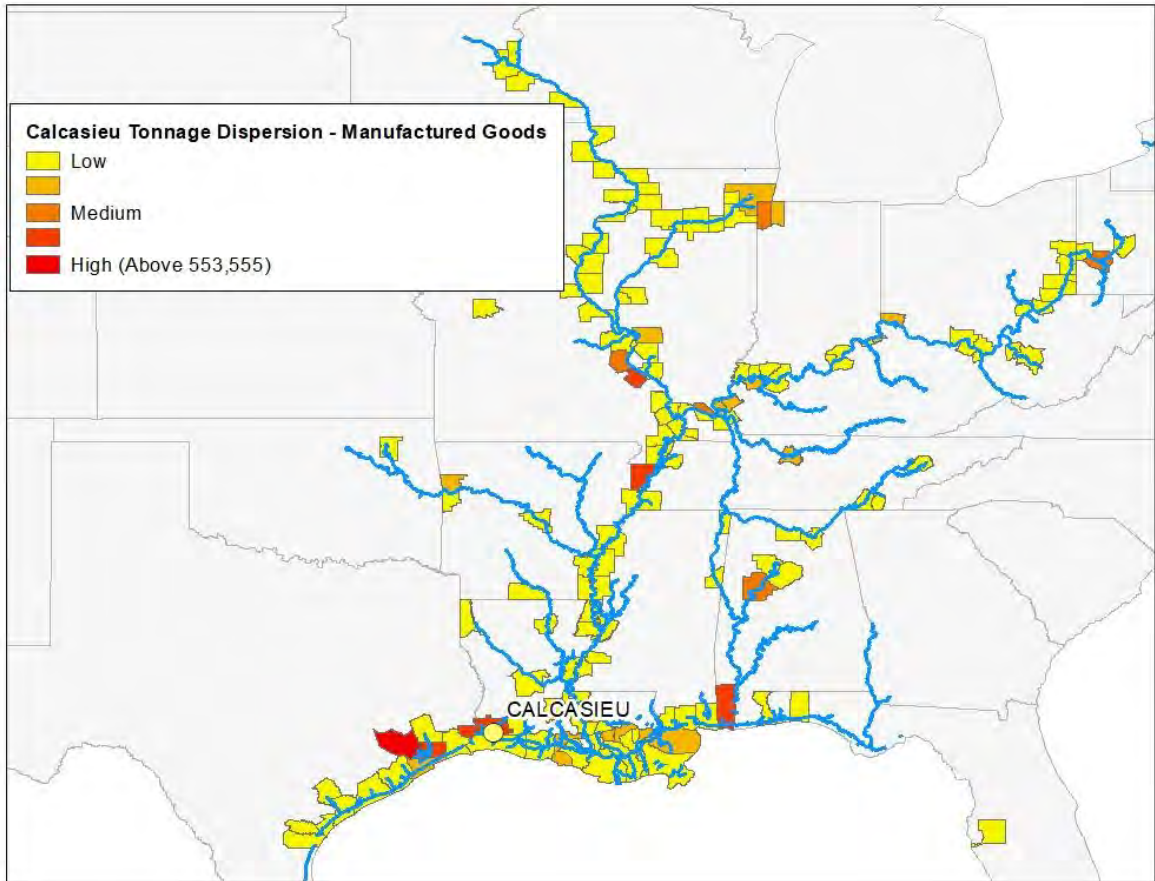
Calcasieu Lock

	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	245,836	1,617	1,268	\$26.97	\$6,629,552
Petroleum Products	20	24,988,887	2,859	542	\$21.70	\$542,287,348
Chemicals	30	9,078,337	2,022	846	\$25.44	\$230,953,087
Crude Materials	40	3,937,379	1,578	1,230	\$45.66	\$179,789,257
Primary Manufactured Goods	50	2,744,157	1,568	1,114	\$43.73	\$120,009,771
Farm Products and Food	60	843,753	1,769	1,021	\$26.97	\$22,753,806
Equipment	70	9,222	307	524	\$26.97	\$248,693
Scrap and Waste	80	626,896	1,537	259	\$26.97	\$16,905,741
TOTAL		42,474,467				\$1,119,577,255



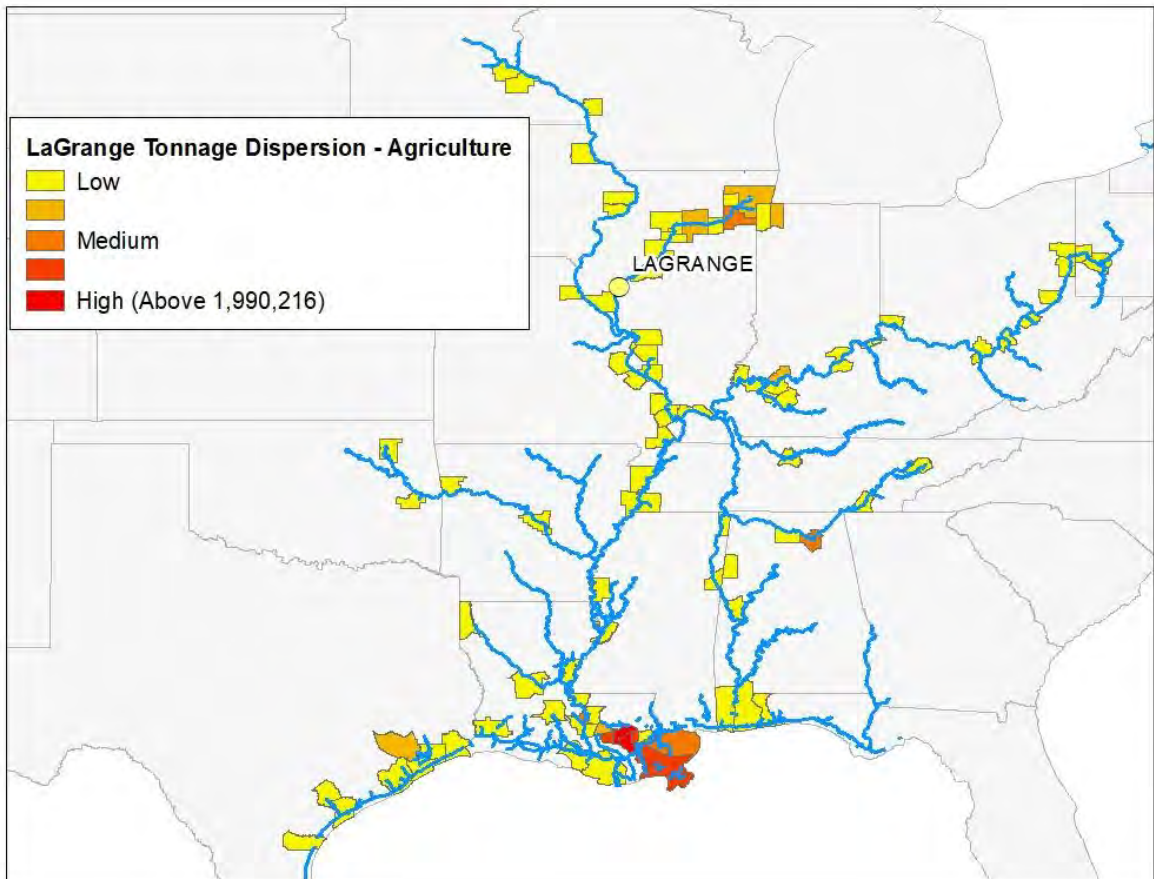


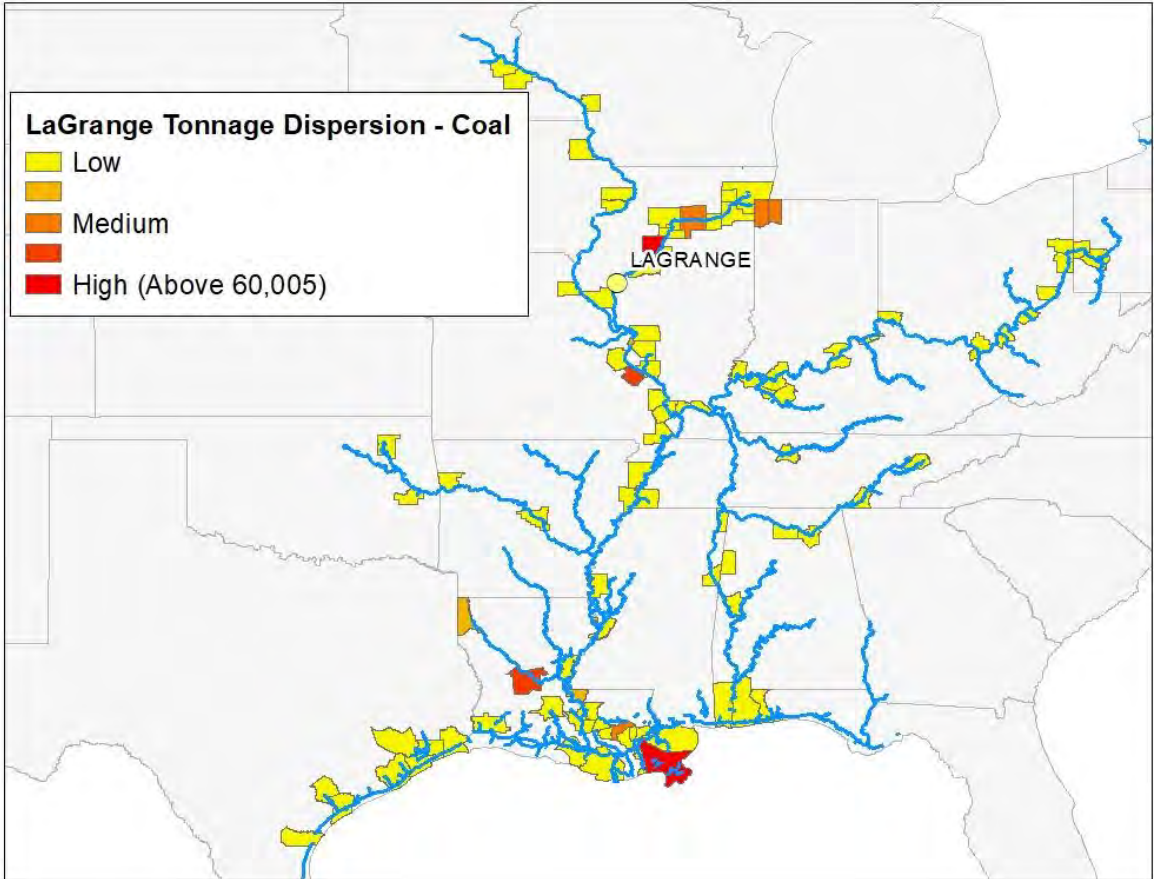
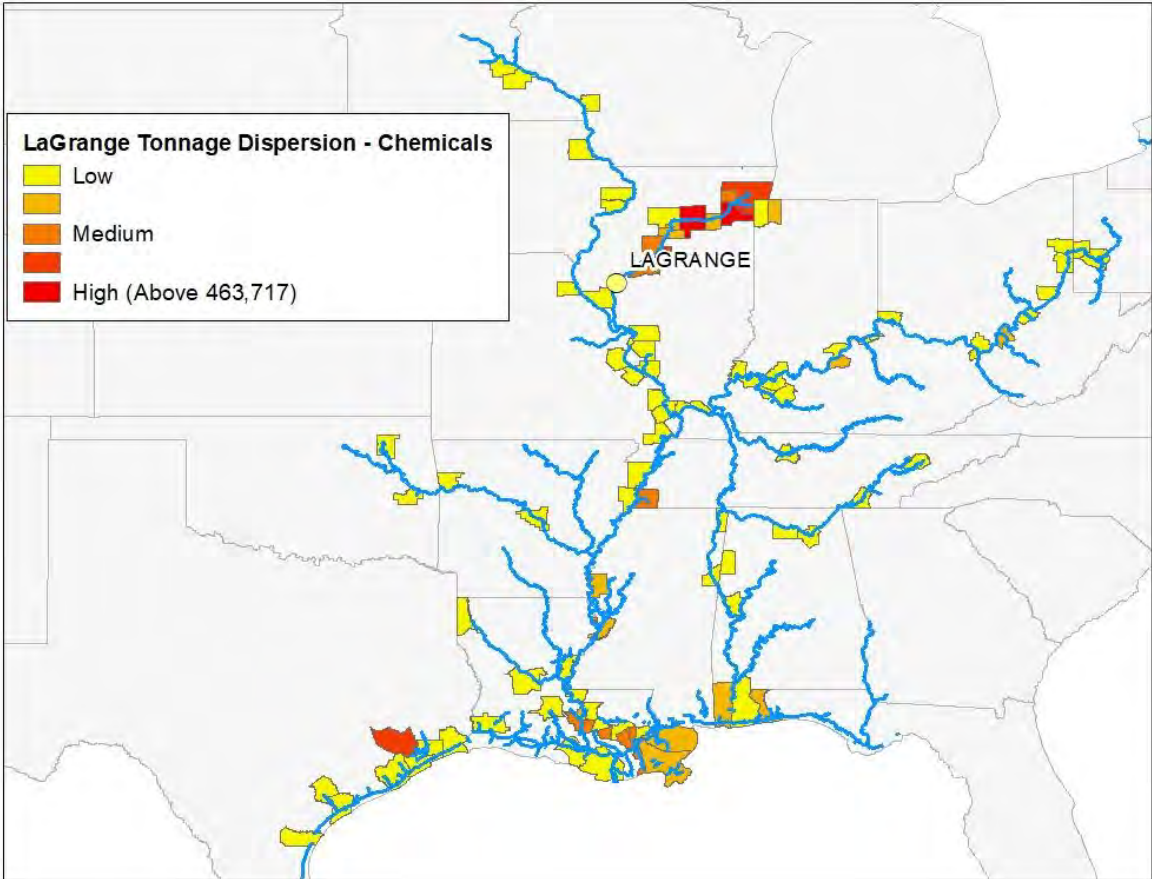


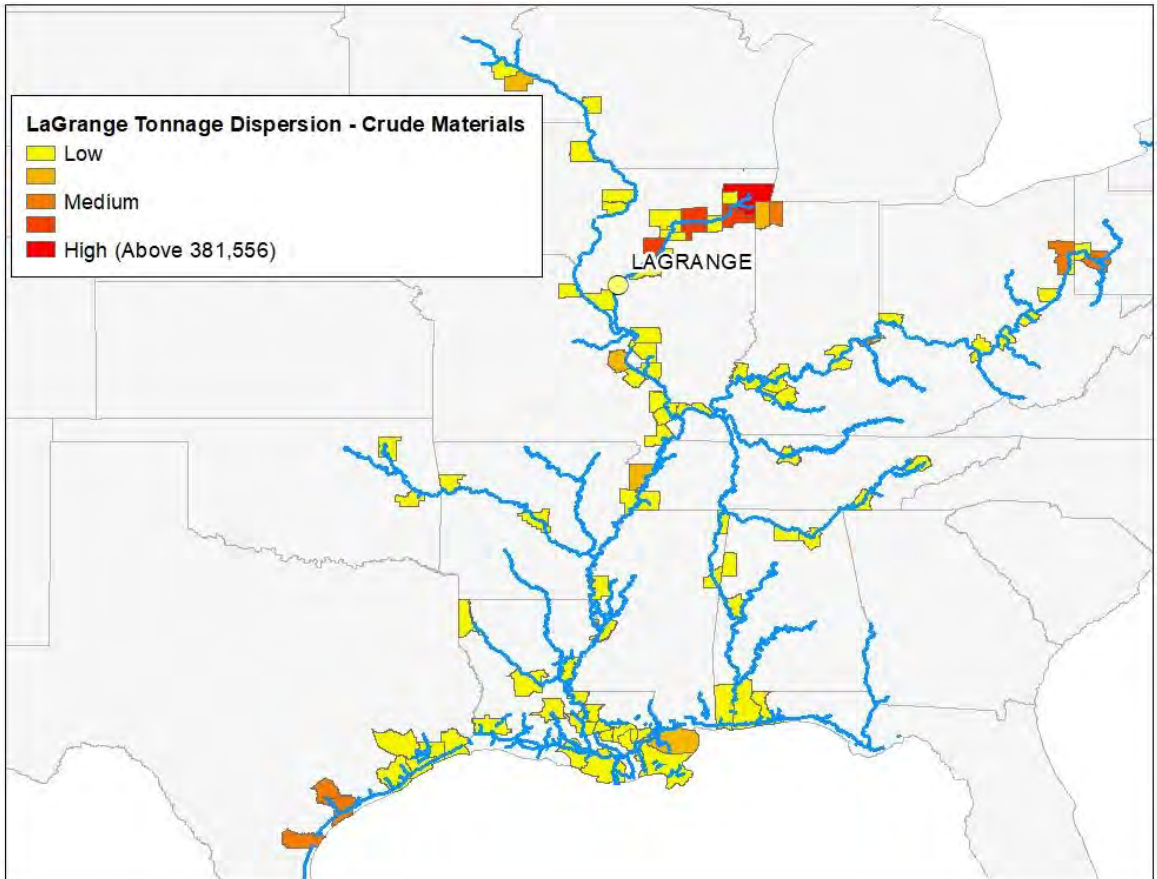
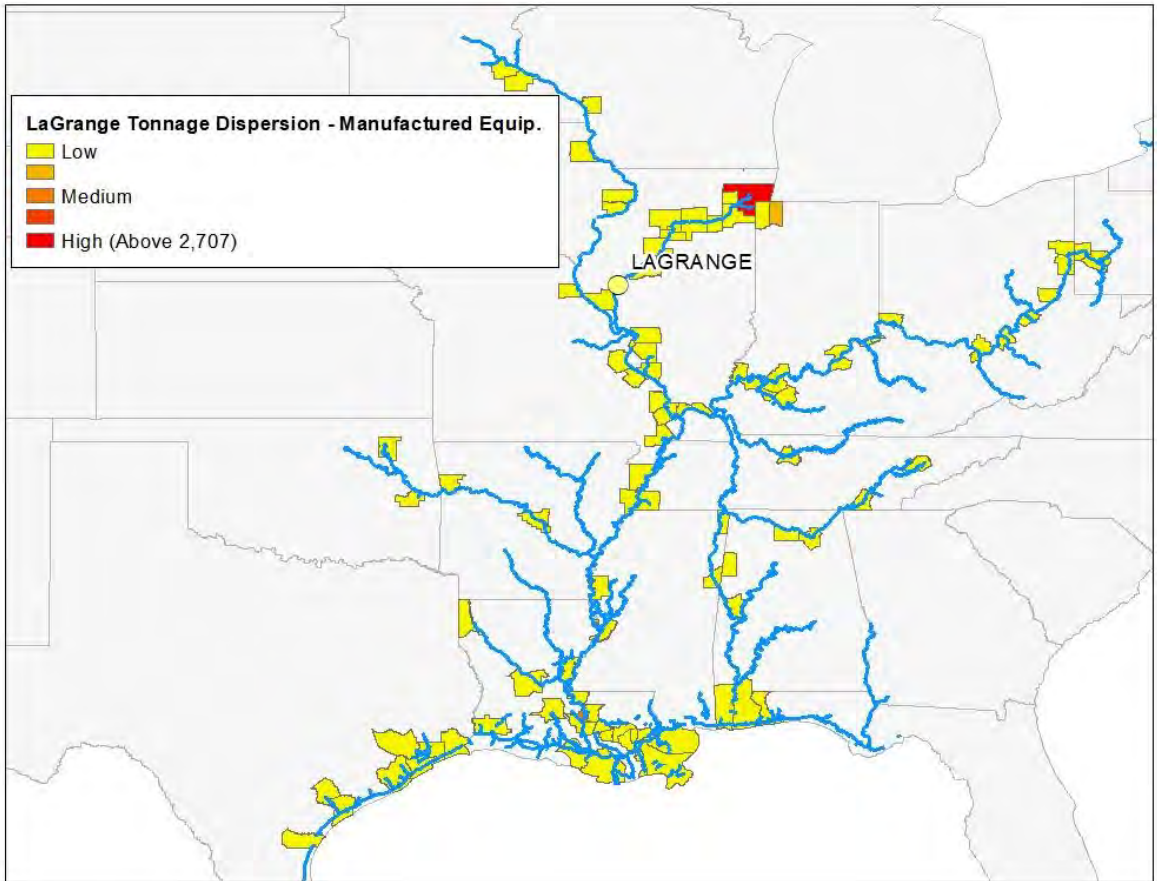


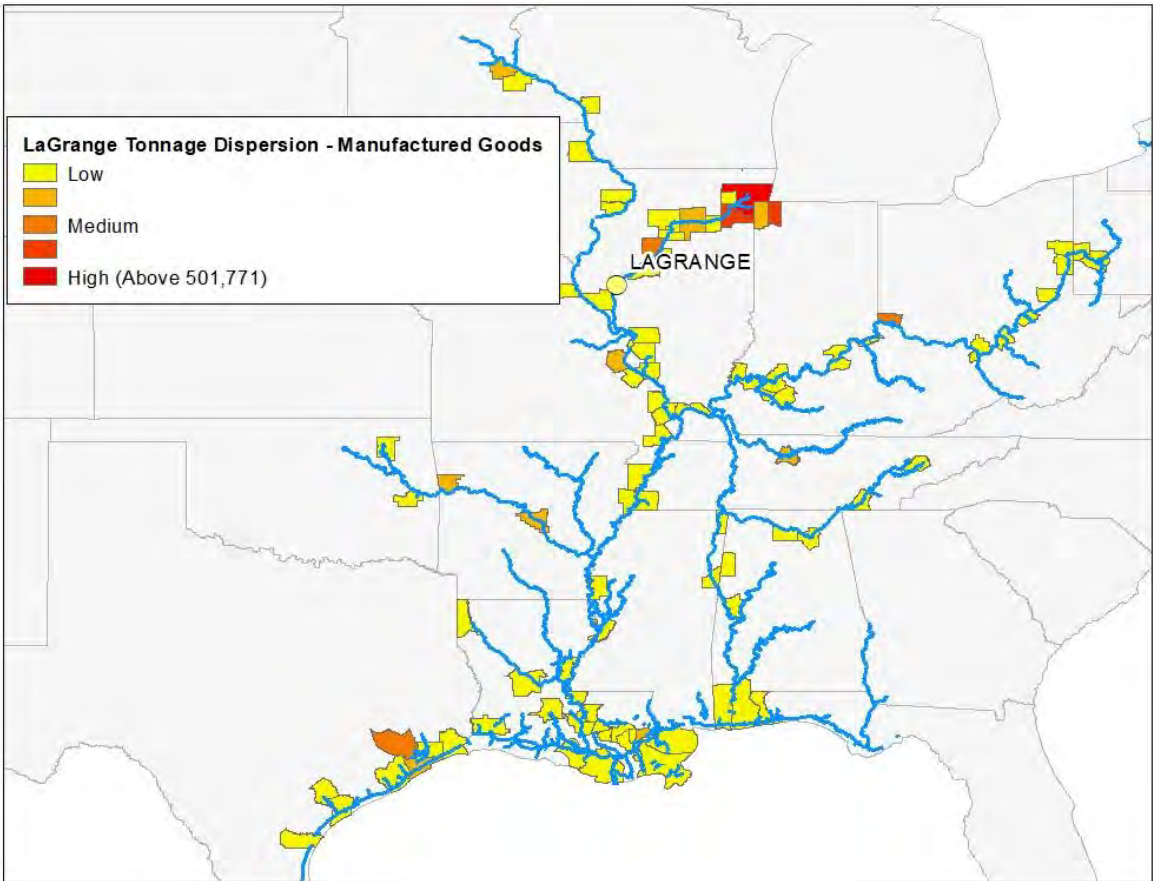
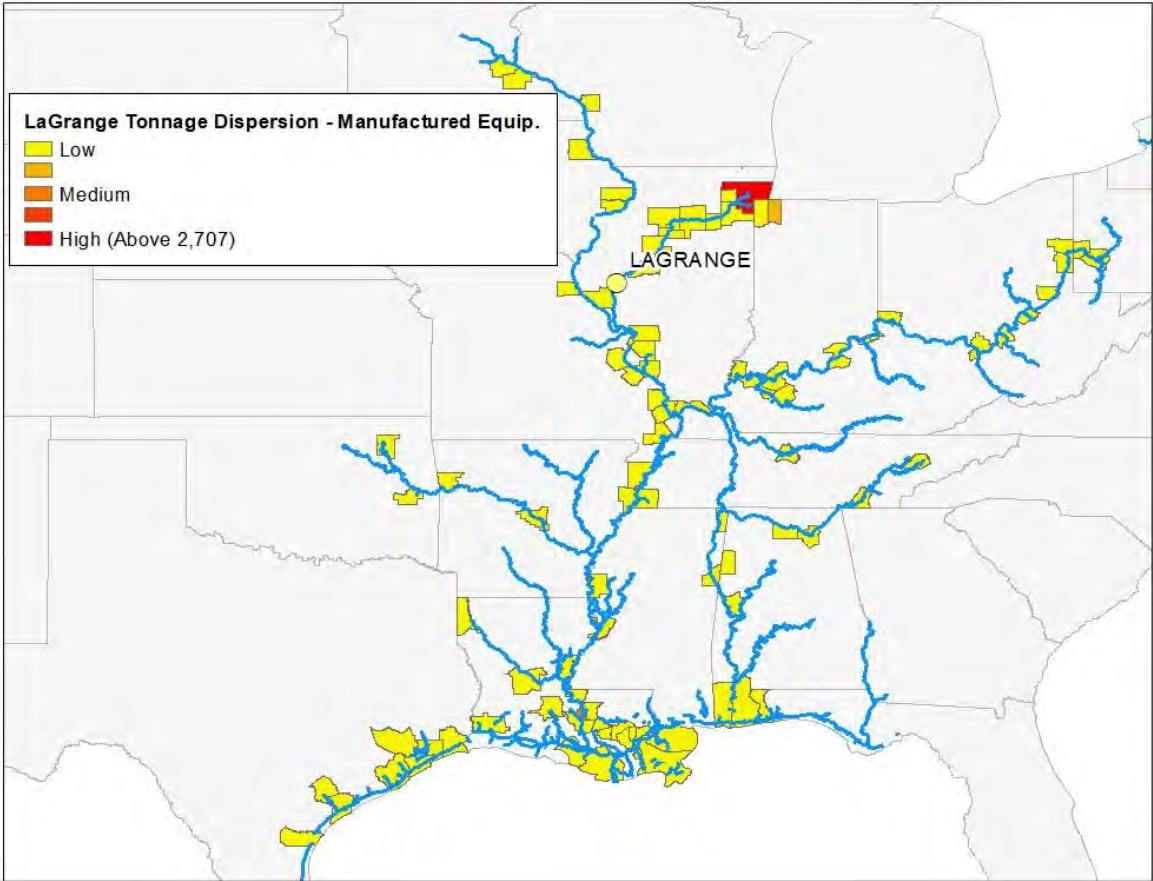
LaGrange Lock & Dam

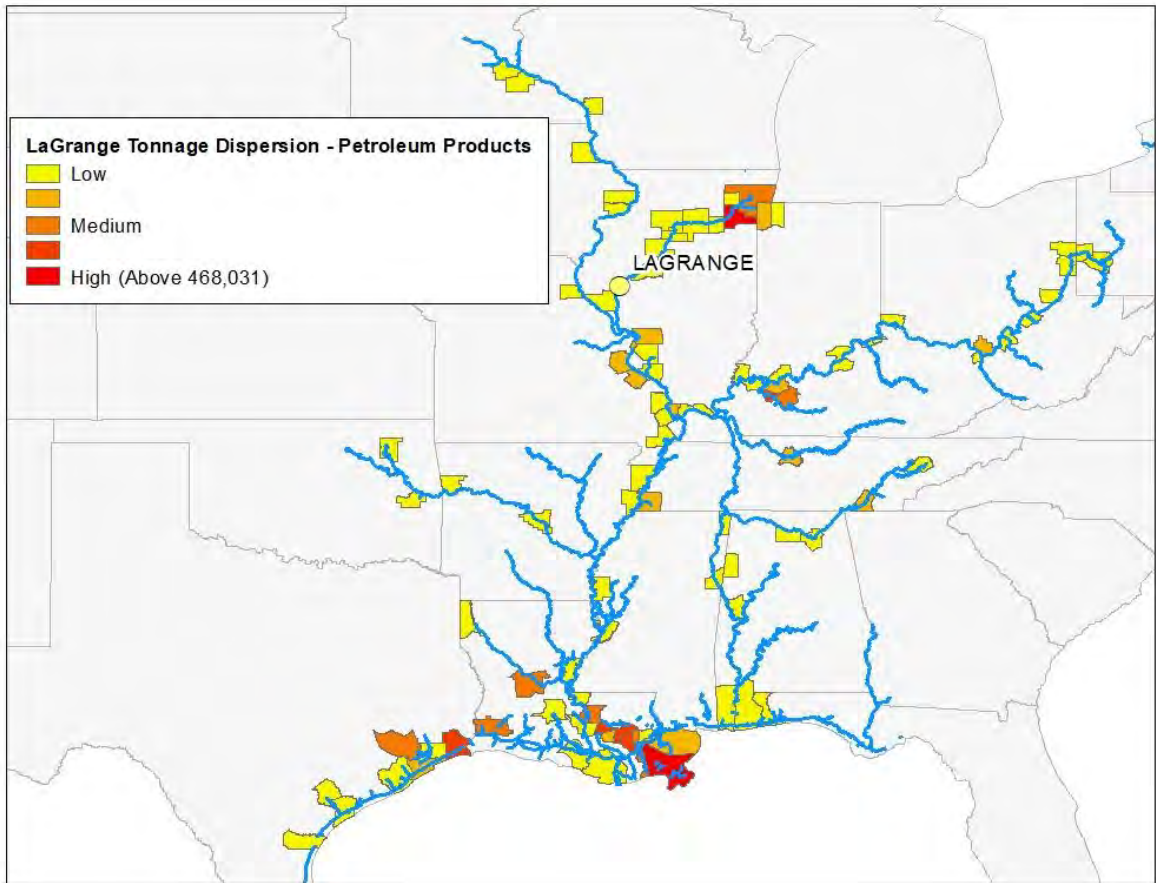
	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	443,288	1,566	942	\$45.77	\$20,291,015
Petroleum Products	20	5,623,494	2,210	1,202	\$32.53	\$182,914,135
Chemicals	30	4,888,770	1,739	1,230	\$51.45	\$251,529,491
Crude Materials	40	3,401,419	1,552	1,270	\$61.22	\$208,236,345
Primary Manufactured Goods	50	3,344,289	1,513	1,056	\$30.96	\$103,524,351
Farm Products and Food	60	11,460,988	1,588	1,226	\$81.38	\$932,684,606
Equipment	70	5,632	704	1,416	\$84.87	\$477,986
TOTAL		29,167,880				\$1,699,657,928











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	LPMS Group	Total 2014 Tons	Tons per Barge	Average Distance	Cost per Ton	Total Averted Costs
Coal	10	660,624	1,547	713	\$38.90	\$25,696,959
Petroleum Products	20	320,411	1,732	1,518	\$47.14	\$15,103,646
Chemicals	30	4,171,737	1,612	1,430	\$59.66	\$248,899,601
Crude Materials	40	3,082,613	1,568	1,488	\$67.76	\$208,863,996
Primary Manufactured Goods	50	1,667,149	1,677	845	\$22.93	\$38,225,955
Farm Products and Food	60	12,433,825	1,598	1,323	\$83.16	\$1,033,977,564
Equipment	70	6,602	660	1,270	\$82.19	\$542,606
TOTAL		22,342,961				\$1,571,310,327

