Transforming the Marine Transportation System through Multimodal Freight Analytics

5th Biennial Marine Transportation System Research & Development Conference

Measuring the Network Impacts of Local Disruptions: An Inland Waterways Case Study

Sponsored by

The National Waterways Foundation

The U.S. Maritime Administration

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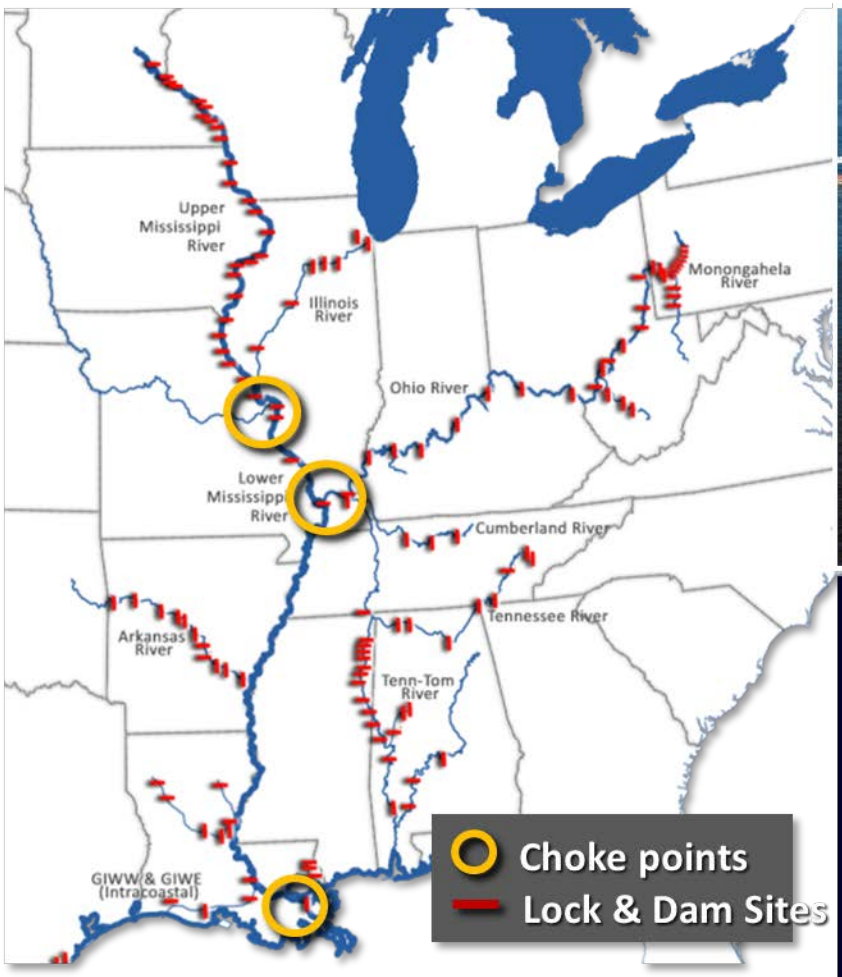
The University of Tennessee
Center for Transportation Research

Vanderbilt University
Vanderbilt Center for Transportation And Operational Resiliency (VECTOR)

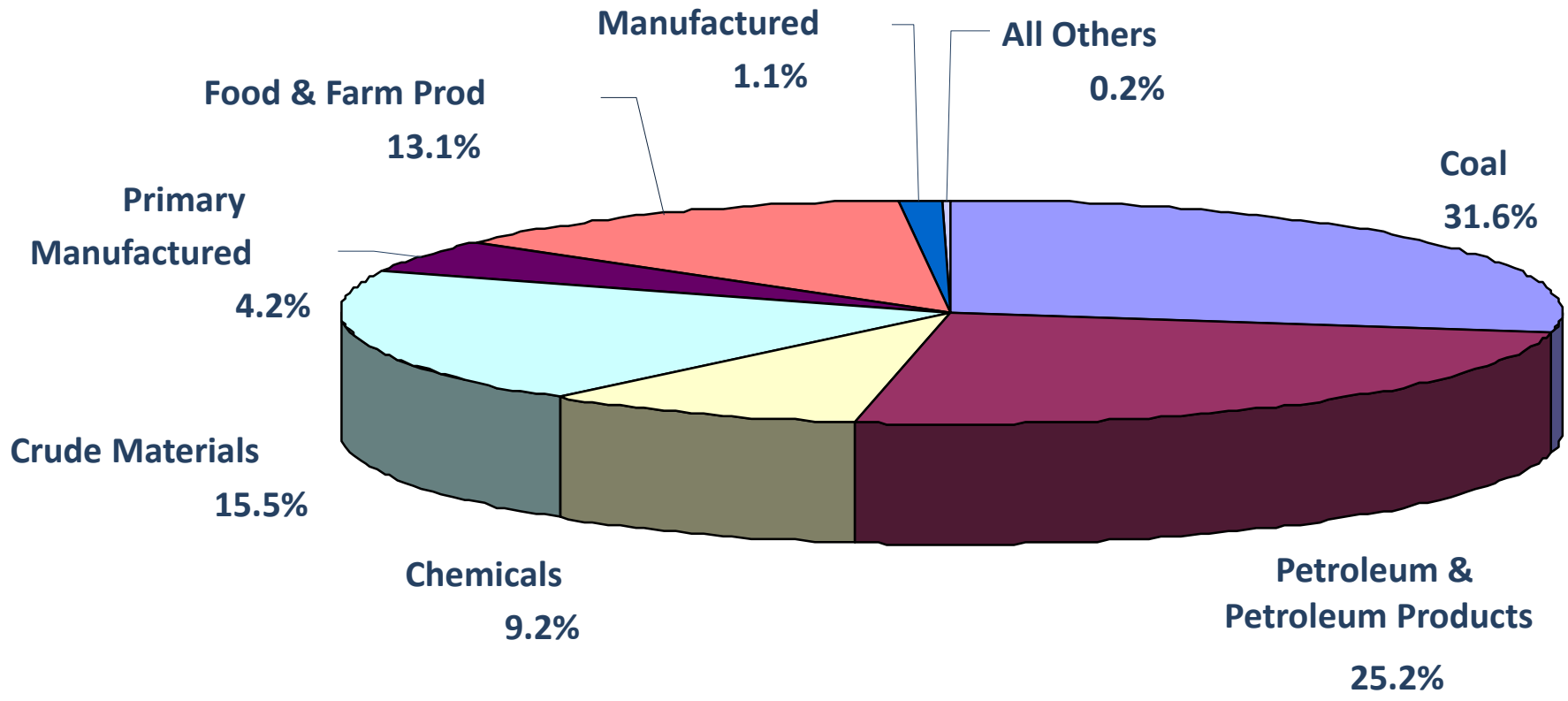
1. Motivation and Study Design
2. Lock Selection Process and Analysis
3. Supply-Chain Cost Burden Calculations
4. Railroad Capacity Exploration and Implications
5. Regional Economic Impacts
6. Implications, Lessons Learned and Next Steps

U.S. Inland Waterway System

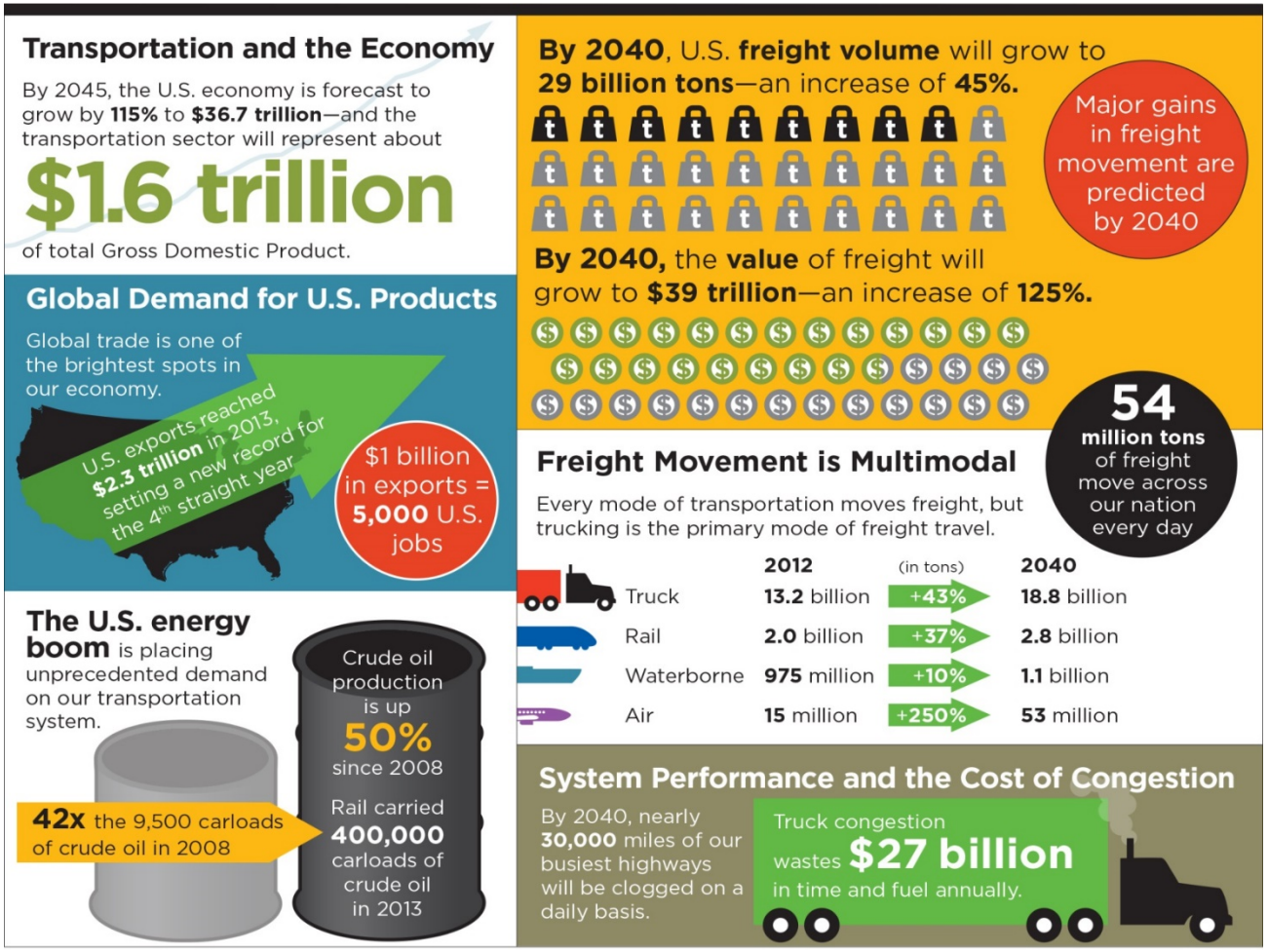


- Nearly 12,000 Miles 9 ft & Over
- 198 lock sites / 241 chambers
- Operated by Army Corps of Engineers
- Most locks and dams were built more than 30 years ago

What WAS Moving? Inland Waterways Commodities (2013)
566.7 Million Tons, $216 Billion Value



Trends: How We Move Things …



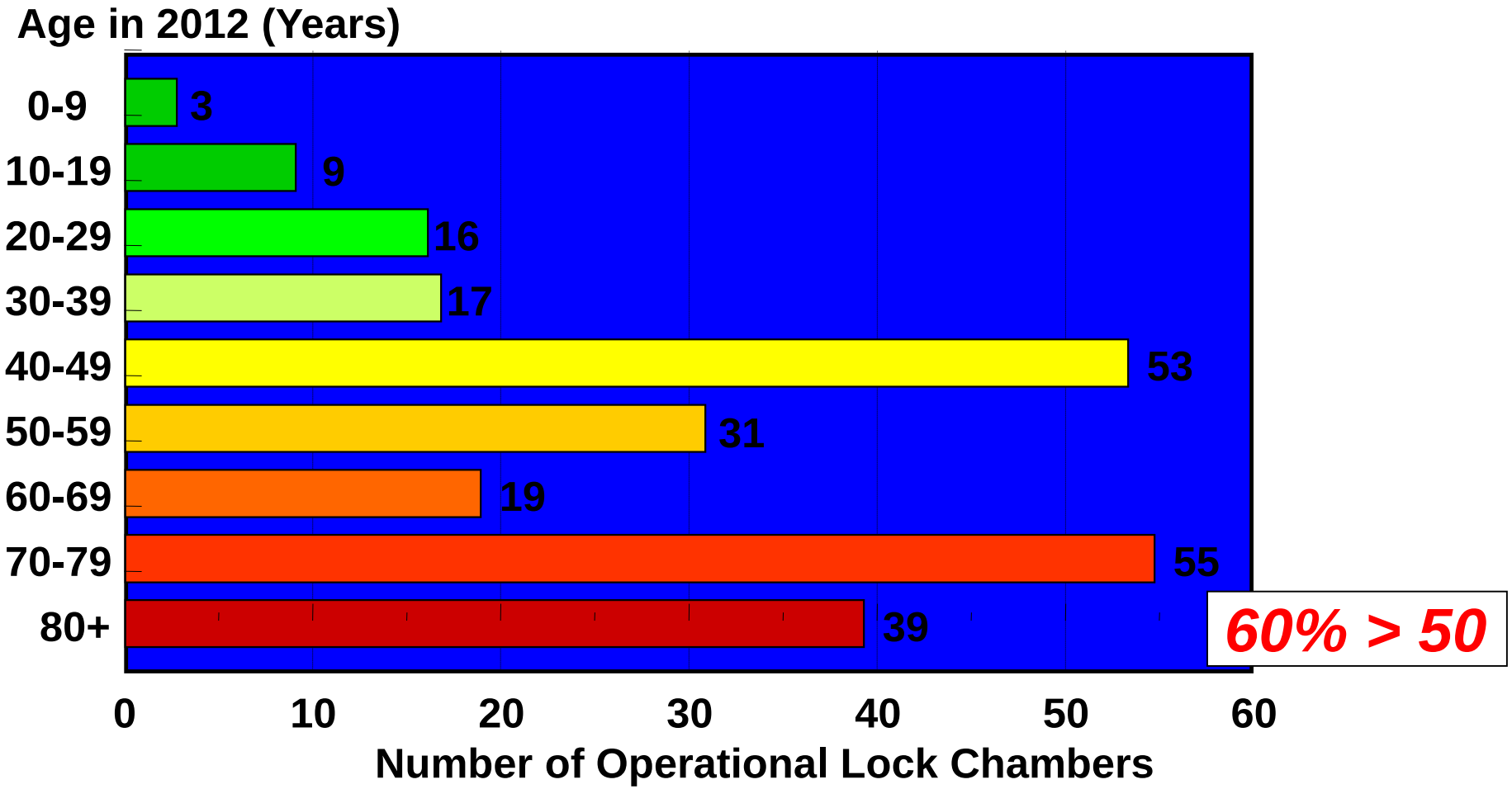
LOSS OF WATERWAYS EQUALS ECONOMIC DAMAGE

The Trouble with Aging

The 12,000 miles of our navigable inland waterways system touch 38 states and carry approximately 565 million tons of freight annually. The 242 locks and dams are maintained and operated by the U.S. Army Corps of Engineers. The oldest of these, the Elizabeth Lock and Dam (L/D#3) in Pittsburgh, opened to traffic in 1906, but most were built in the 1930s and ‘40s. The aging infrastructure as a whole is in critical need of modernization, without which the inland waterways system will cease to provide reliable freight transportation capacity.

NATIONAL WATERWAYS FOUNDATION

Our Challenge: Aging Infrastructure



*Includes all operational deep and shallow draft Corps and TVA navigation locks and control structures.

1 MOTIVATION AND STUDY DESIGN

Impact of Funding Shortfalls Magnified by Extreme Weather

"As of today (Oct 16,2017) the Ohio River is now OPEN at Lock and Dam 52. The river reopened on Saturday after it had been closed for nearly a week due to rising river stages that exceeded the maximum locking stage of 20.7 feet. Precipitation from Hurricane Nate prompted the rising river levels and closure, but L&D 52 was closed from September 6-14 due to an unscheduled maintenance outage at the 89 year-old facility. As of today there are 59 vessels with 658 barges waiting to transit L&D 52. This backup is over a 20-mile stretch of river."

- WATERWAYS COUNCIL UPDATE

1 MOTIVATION AND STUDY DESIGN

Unscheduled Lock Closures Will Become More Frequent

The U.S. Army Corps of Engineers (USACE) has worked hard to maintain and operate aging waterway infrastructures, but doing so is increasingly expensive. And even with dedicated maintenance efforts and larger budgets, unplanned, failure-related closures will become more frequent.

Demonstrate Use of Affordable, and Reliable Tools To Estimate Economic Effects

- Estimate both Shipper Cost Burden (NED) and Regional Economic Impacts
- Use Available Data, Existing Models, and Minimal Field Work
- Document Work, so It Could Be Replicated by Others
- Methods Reflect Economic Principles and Hard-Won (NETS) Advances
- To the Fullest Extent Possible, Methods Comply with the P&G

1 PREVIOUS WORK

Developing quick, affordable, and reliable methods imposed a need to lean heavily on our past work and on the past work of many others who have used often temperamental data to model freight transportation outcomes.

The Study Benefited Measurably from Past Work

- Past USACE Analyses
- Modeling Techniques that Emerged from the' NETS Program
- Past Work Performed by the Tennessee Valley Authority
- Past Work Also Sponsored by the National Waterways Foundation

2 LOCK SELECTION PROCESS AND ANALYTICS

Study Goal

Develop Information that Would Allow the Study Sponsors to Select Four System Locks for Extensive Analysis

Study Process Steps

1. Define Relevant Metrics that Allow Useful Comparisons
2. Assemble, Harmonize, and Modify Data Elements
3. Present Results in Ways that Facilitated Sponsor Lock Selections

2 DEFINING THE METRICS

1 Lock Characteristics

- Location
- Age and Rehab
- Chambers
- Physical Dimensions
- Related Structures
- Proximity of Other Modes

2 Lock Performance

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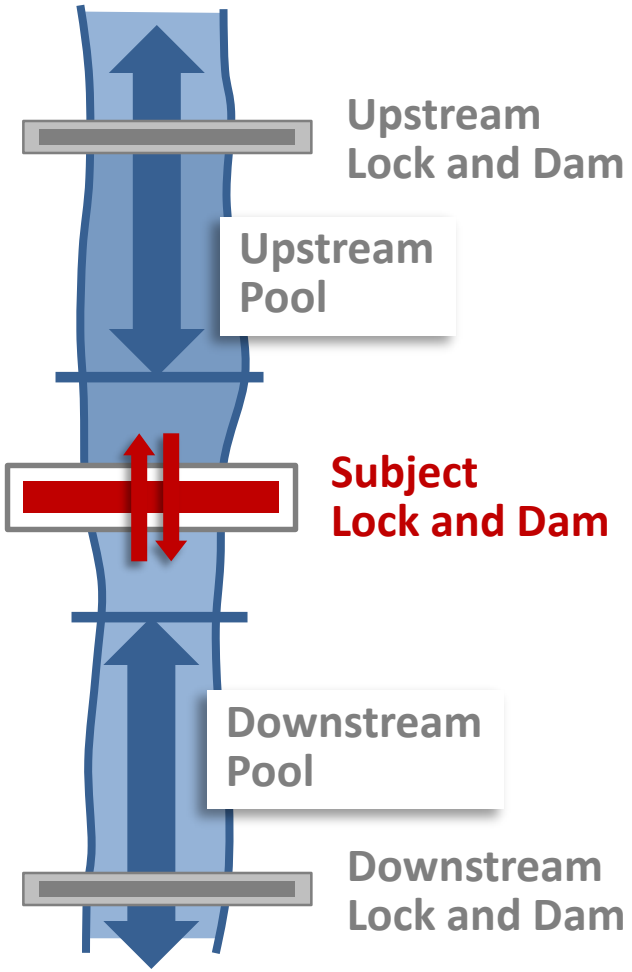
- Tows, Vessels, Lockages and Tons
- Tonnages by Commodity and Season
- Processing and Delay Times

3 Network Role

- System Ton-Miles
- Related Lockages Elsewhere
- Above and Below Pool Traffic
- Corridor Concentration Metric

2 DEFINING NEW METRICS – POOL TONNAGE



2 DATA ACQUISITION AND MANAGEMENT

1. USACE, WCSC (Movement) Data
2. USACE, LPMS (Lock) Data
3. STB, Carload Waybill (Rail Movement) Data
4. Geographic Information System (GIS) Data

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2 COMMUNICATING LOCK SELECTION INFORMATION

Initially, Analysis Included 170 Locks

Lock	chamber	river	YR_Open	Major_Rehab	Status	Age_Opening	vessels	ktons
Claiborne	main	Alabama	1969	none	operational	47	77	
Millers Ferry	main	Alabama	1969	none	operational	47	114	
Robert F. Henry	main	Alabama	1972	none	operational	44	62	
2	main	Allegheny	1934	none	operational	82	5,501	2148
3	main	Allegheny	1934	none	operational	82		
4	main	Allegheny	1927	none	operational	89	1701	412
5	main	Allegheny	1927	none	seasonal	89	1121	75
6	main	Allegheny	1928	none	seasonal	88	377	21
7	main	Allegheny	1930	none	seasonal	86	14	75
8	main	Allegheny	1931	none	seasonal	85		
9	main	Allegheny	1938	none	seasonal	78		
Jim Woodruff	main	Apalachicola	1954	none	operational	62		
Arthur V. Ormond	main	Arkansas	1969	none	operational	47	875	6759
[illegible]		[illegible]	[illegible]		[illegible]			

2 COMMUNICATING LOCK SELECTION INFORMATION

Heat Maps – To Rank and Compare Candidate Locks

River	Lock	River_Mile	Vessels	ktons	Lockages	SYS_LOCS	AV_SYS_LOCS
UMR	UMR 18	410	2424	18584	3090	216825	19
UMR	UMR 20	343	2385	19097	3272	218870	18
UMR	UMR 22	301	2041	21346	3158	228495	17
UMR	UMR 24	273	2149	21785	3190	231220	16
UMR	UMR 25	241	2192	21674	3172	231348	16
UMR	Melvin Price	201	6172	53661	7306	737258	22
Illinois	Thomas Obrien	326	10444	5916	4279	39822	11
Illinois	Lockport	291	3342	12360	3264	70946	11
Illinois	Brandon Road	286	3446	12588	3384	73149	10
Illinois	LaGrange	80	3063	27222	3659	139837	8
Ohio	Montgomery	32	4806	20966	5507	287106	13
Ohio	Willow Island	161	4767	41886	4243	287106	13
Ohio	Greenup	341	4547	41704	4310	398232	9
Ohio	Meldahl	436	5074	46181	4639	398232	9
Ohio	Markland	531	5858	52754	5177	506610	8
Ohio	JT Myers	846	6930	64174	6413	623352	8
Ohio	Smithland	918	7359	71042	6934	625012	8
Ohio	Lock 52	938	8668	87931	8639	656938	8
Tenn	Chickamauga	431	3623	831	2756	5363	11
Tenn	Kentucky	22	2986	29324	4748	101665	8
Ark	No 2 Wilbur Mills	13	1350	9140	1679	85217	14
Tenn-Tom	Tom Bevill	307	2090	5978	1917	42483	14
GIWW	Port Allen	228	7930	22289	6238	200534	10
GIWW	Harvey	98	6003	1679	4988	8693	7
GIWW	Inner Harbor Lk	93	8500	15834	8431	41423	6
GIWW	Algiers	88	10915	26128	9160	101171	9
GIWW	Bayou Sorrel	28	7108	20931	9123	110247	7
GIWW	Leland Bowman	162	14401	41664	11943	200802	11
GIWW	Calcasieu	237	14437	42240	12662	200403	10

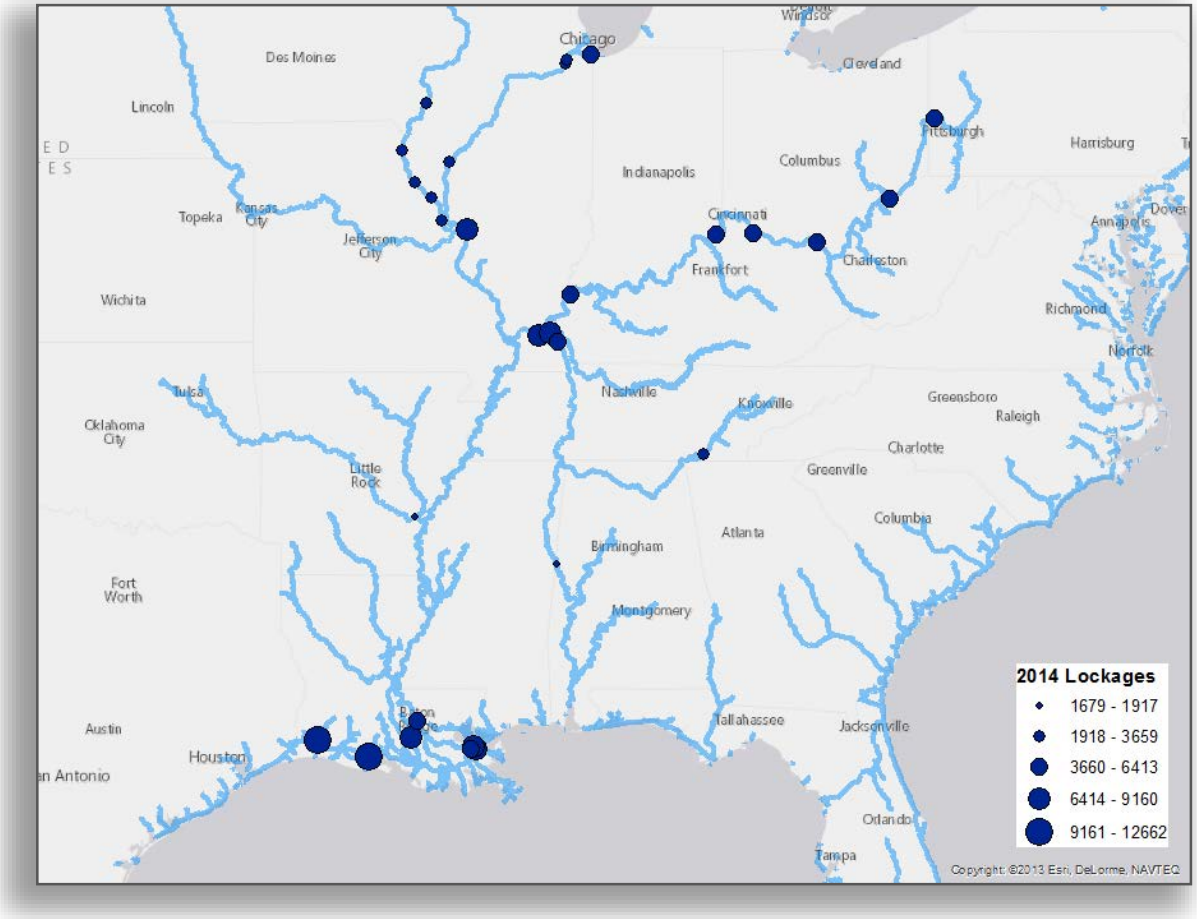
2 COMMUNICATING LOCK SELECTION INFORMATION

Heat Maps – To Rank and Compare Candidate Locks

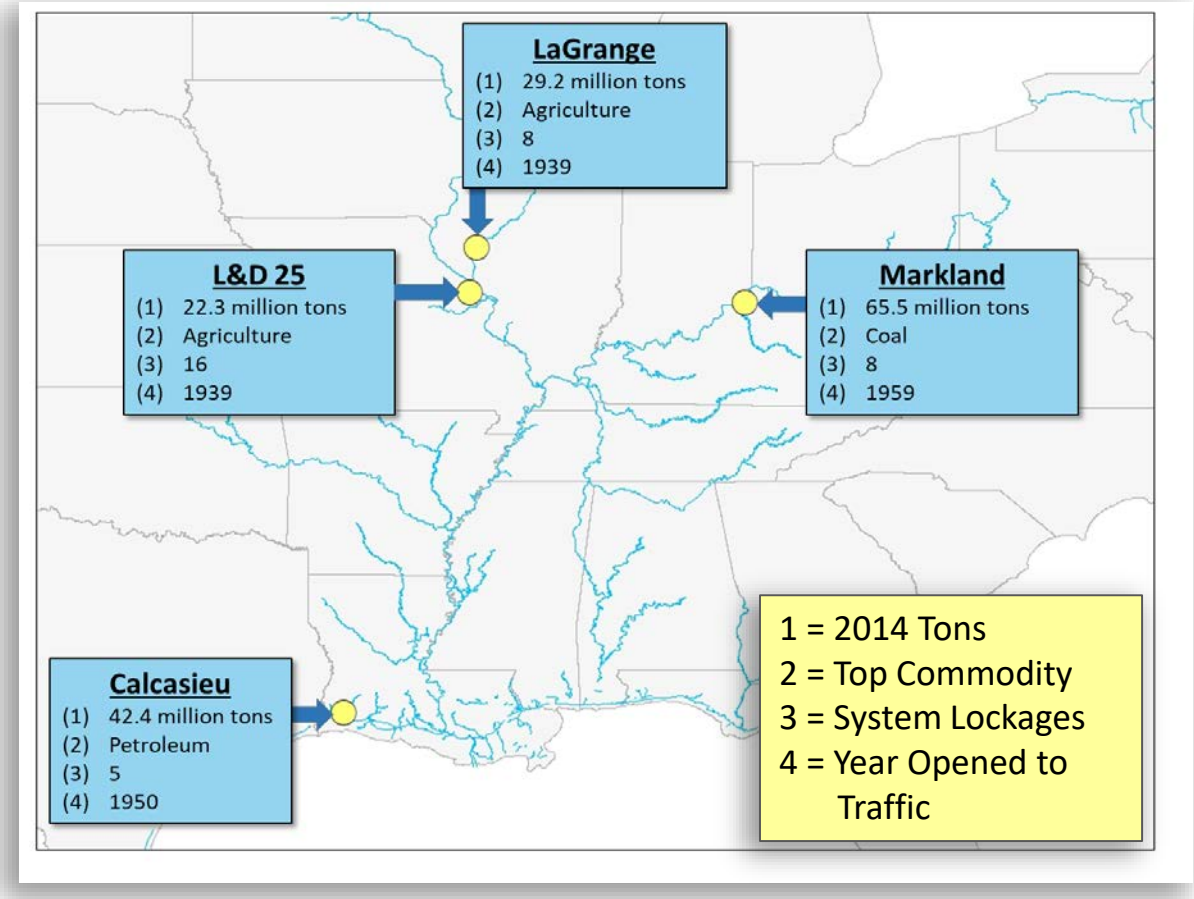
WtwyName	Mile Num	LockName	TOTAL ABOVE	TOTAL BELOW	TOTAL
MISSISSIPPI	201	MELVIN PRICE	0	5,475,696	5,475,696
MISSISSIPPI	241	MISSISSIPPI - 25	0	213,595	213,595
MISSISSIPPI	273	MISSISSIPPI - 24	17,887	2,860,048	2,877,935
MISSISSIPPI	301	MISSISSIPPI - 22	1,100,391	1,086,715	2,187,106
MISSISSIPPI	325	MISSISSIPPI - 21	193,085	1,201,284	1,394,369
MISSISSIPPI	343	MISSISSIPPI - 20	127,205	1,656,289	1,783,494
MISSISSIPPI	364	MISSISSIPPI - 19	919,500	411,314	1,330,814
MISSISSIPPI	410	MISSISSIPPI - 18	0	1,547,389	1,547,389
MISSISSIPPI	437	MISSISSIPPI - 17	194,500	854,268	1,048,768
MISSISSIPPI	457	MISSISSIPPI - 16	676,256	748,573	1,424,829
MISSISSIPPI	483	MISSISSIPPI - 15	1,888,608	848,660	2,737,268
MISSISSIPPI	493	MISSISSIPPI - 14	353,587	1,313,670	1,667,257
MISSISSIPPI	522	MISSISSIPPI - 13	0	3,971,113	3,971,113
MISSISSIPPI	557	MISSISSIPPI - 12	664,720	178,561	843,281
MISSISSIPPI	583	MISSISSIPPI - 11	0	1,543,667	1,543,667
MISSISSIPPI	615	MISSISSIPPI - 10	29,914	3,400,088	3,430,002
MISSISSIPPI	648	MISSISSIPPI - 09	14,571	1,304,084	1,318,655
MISSISSIPPI	679	MISSISSIPPI - 08	0	3,598,866	3,598,866
MISSISSIPPI	753	MISSISSIPPI - 04	19,570	2,809,020	2,828,590
MISSISSIPPI	797	MISSISSIPPI - 03	0	369,221	369,221
MISSISSIPPI	815	MISSISSIPPI - 02	8,394,600	2,809,020	11,203,620

2 COMMUNICATING LOCK SELECTION INFORMATION

Data Maps – To Understand the Geographies



2 LOCKS SELECTED



- Diverse Traffic
- Diverse Geography
- Diverse Infrastructure
- Diverse Commercial Function

3 SUPPLY-CHAIN COST BURDEN (SCCB) CALCULATIONS

Study Goal

To Estimate the Shipper Supply-Chain Burden (SSCB) of an Unscheduled Lock Outage of Indefinite Duration

Study Process Steps

1. Traffic Data Sampling and Preparation
2. Diversion Analysis and Costing
3. Extension of Results to the Population of 2014 Lock Traffic

3 DATA PREPARATION

Routing the WCSC Data

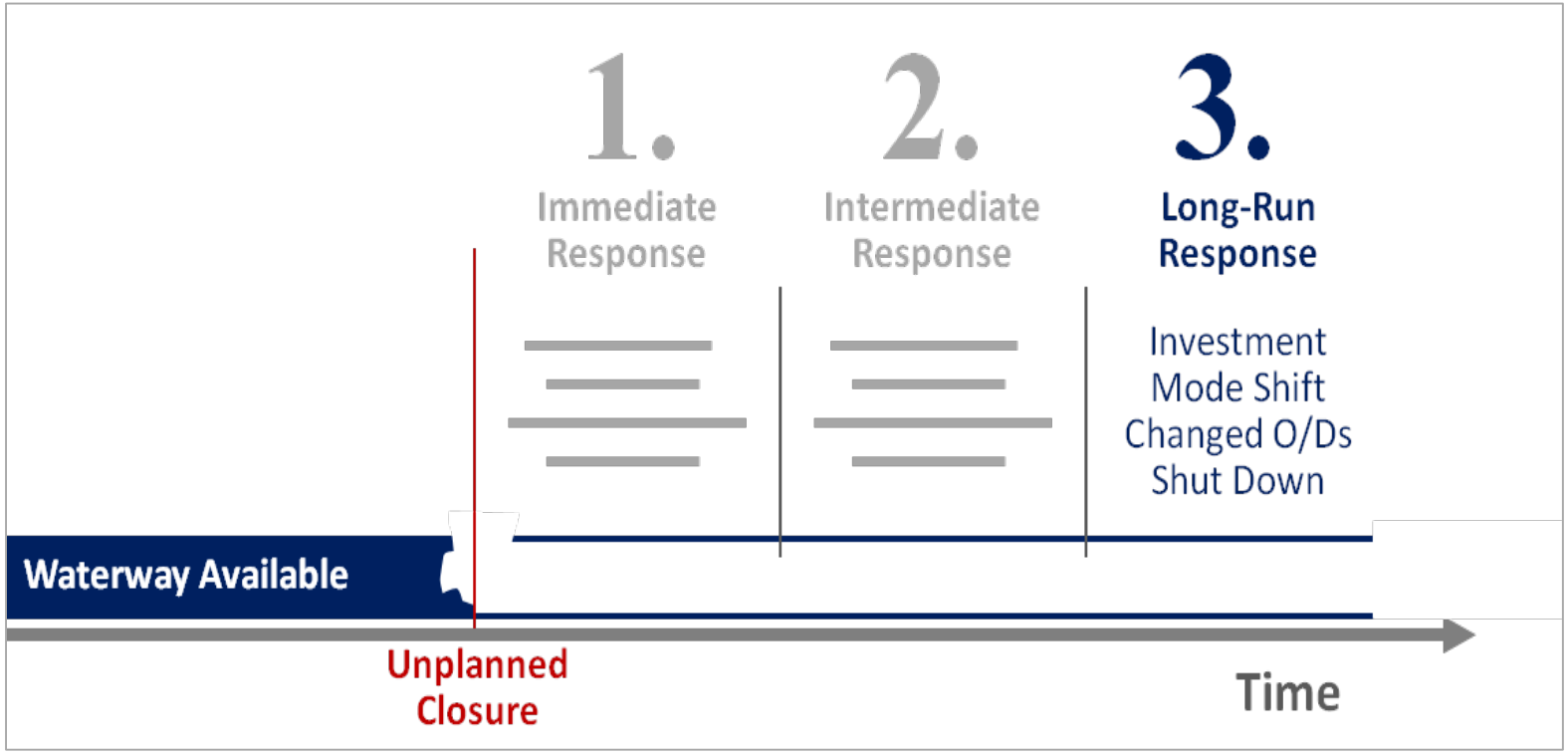
- The WCSC is a census of commercial waterway traffic, with hundreds of thousands of records – one for every vessel trip.
- These records contain "route strings," a series of codes that capture where the movement begins, where it ends and how it is routed between the two points.
- Each record is placed on the inland network and, based on that network and how the shipment is routed, the record is supplemented to indicate the locks it necessarily transited.
- The tonnages for all records passing through each lock are summed and those sums are compared to LPMS tonnages to ensure that the routing algorithm is working correctly.
- The WCSC records associated with a subject lock are then isolated for further analysis.

3 CALCULATING THE SCCB

1. Identifying Lock Traffic Populations
2. Sample Design and Execution
3. Scenario Development
4. Identifying the Optimal Shipper Alternative(s)
5. BCM Execution; Rail and Truck Rate Modeling; Determining Ancillary Costs
6. Combining Elements and Calculating Alternative Scenario Costs
7. Calibrating, Validating and Troubleshooting

3 DIVERSIION ANALYSIS AND COSTING

Closure Scenario and Diversion Analysis



3 DIVERSION ANALYSIS AND COSTING

Help in Identifying the "Least-Cost" Alternative

1. Available Modal Alternatives
2. Shipment Characteristics
3. Ancillary Costs
4. Railroad Pricing Practices and Rate Data
5. Shipper Surveys and Interviews

3 DIVERSION ANALYSIS AND COSTING

The Movement Costing Tool Kit

1. Barge Costing Model (BCM), originally developed by TVA and now approved for USACE applications
2. Rail Cost Model Similar to the Rail Components in FHWA's Intermodal Transportation and Inventory Cost (ITIC) Model
3. Motor Carrier Cost, based on Parameters Provided annually by the American Transportation Research Institute (ATRI)
4. Ancillary Costs based on Shipper Surveys, Interviews, and Trade Publications

3 DIVERSION ANALYSIS AND COSTING

A "Hypothetical" Example – The Setup

- An upriver firm ships a dry-bulk, non-hazardous commodity from a Louisiana origin to its location 1,100 river miles to the north. On average, it uses 36,000 tons of the material annually, receiving 1,500-ton shipments at regular intervals.
- The firm ships finished goods by rail, but cannot receive inbound rail shipments. The commodity in question is essential to the producer and the only source is Louisiana. The upriver firm is approximately 50 river miles above the subject lock and there is a transload facility immediately below the lock. The highway distance between the transload facility and the shipper is 40 miles.
- The only diversion alternative Is to barge from Louisiana to the transload location below the lock, transload from barge to truck and truck the material the 36 miles to its location. The associated charges are summarized in the table below.

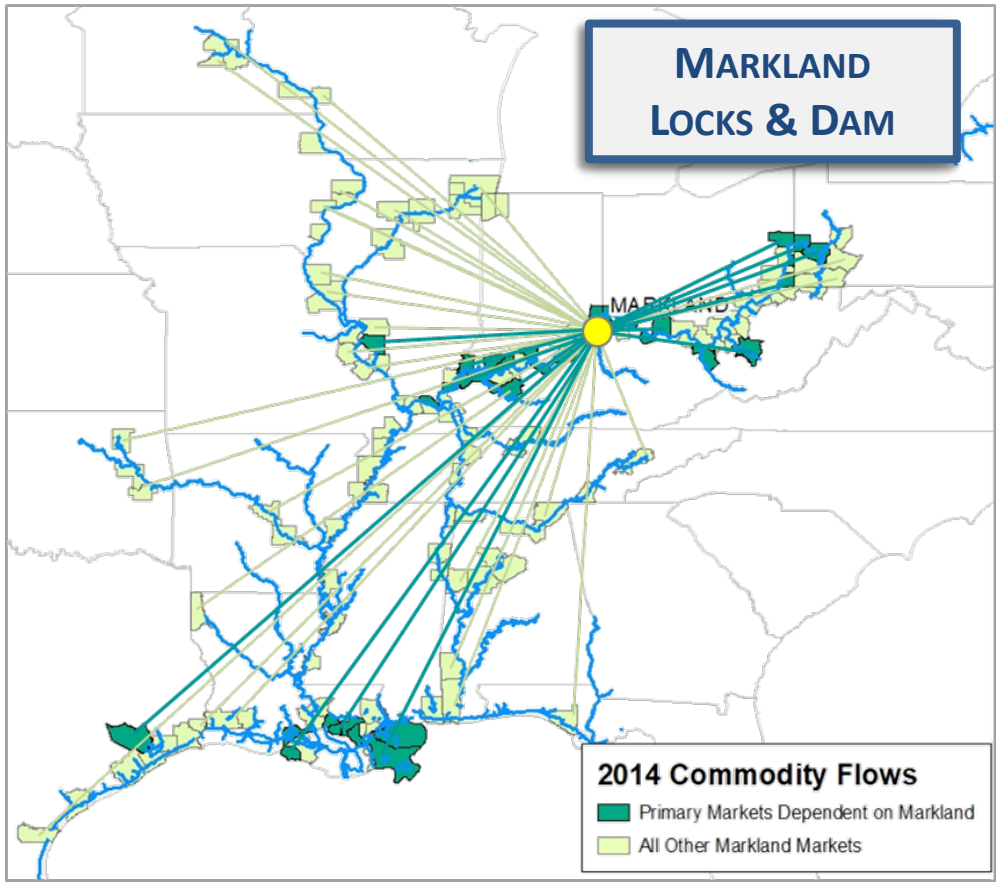
3 DIVERSION ANALYSIS AND COSTING

A "Hypothetical" Example – The Numbers

Parameters	With-Project Routing	Without Project Routing
Annual Tons	36,000	36,000
Shipment Tons	1,500	1,500
Barge Loading Cost ($/Ton)	$1.70	$1.70
WW Distance	1,050	1,000
Line-Haul Barge Charge ($/Ton)	$11.55	$11.00
Barge Unloading Cost ($/Ton)	$1.75	-
Truck Transoad Charge ($/Ton)	-	$3.00
Truck Distance	-	40
Truck Line-Haul Charge ($/Ton)	-	$4.05
Truck Unloading Charge ($/Ton)	-	$2.25
Total Per-Ton Charges	**$15.00**	**$22.00**
Total Shipment Charges	**$22,500**	**$33,000**
Total Annual Charges	**$540,000**	**$792,000**

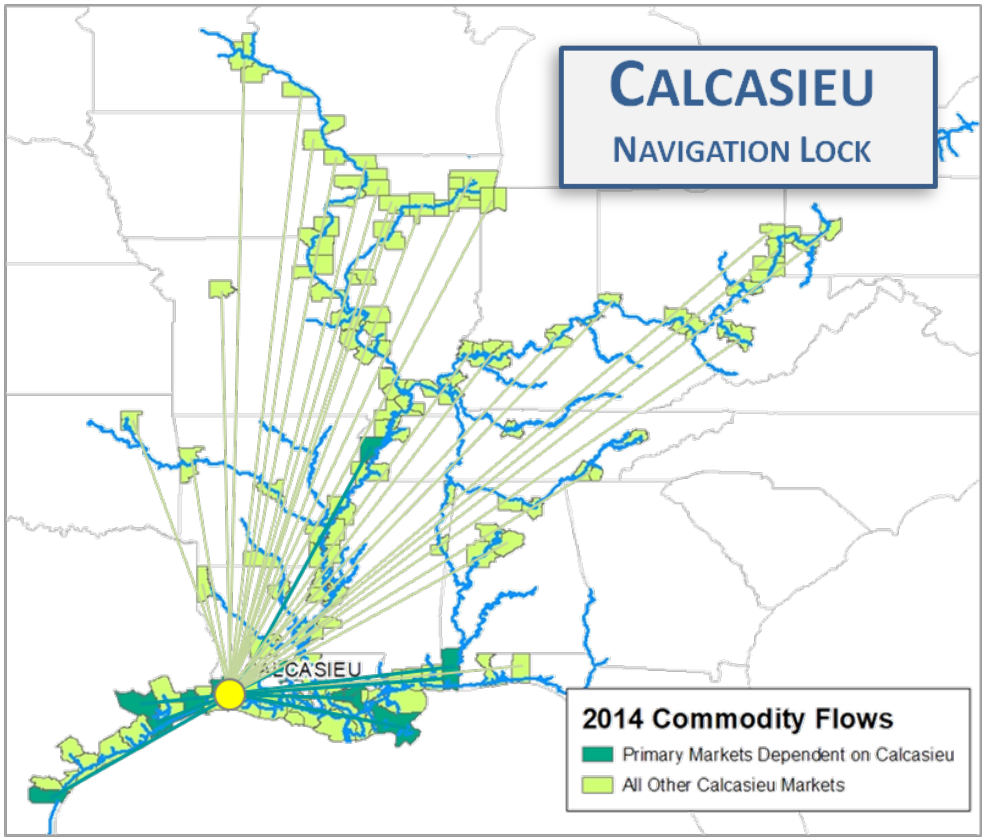
3 DIVERSION ANALYSIS AND COSTING

Closure-Related Shipper Cost Burden - MARKLAND



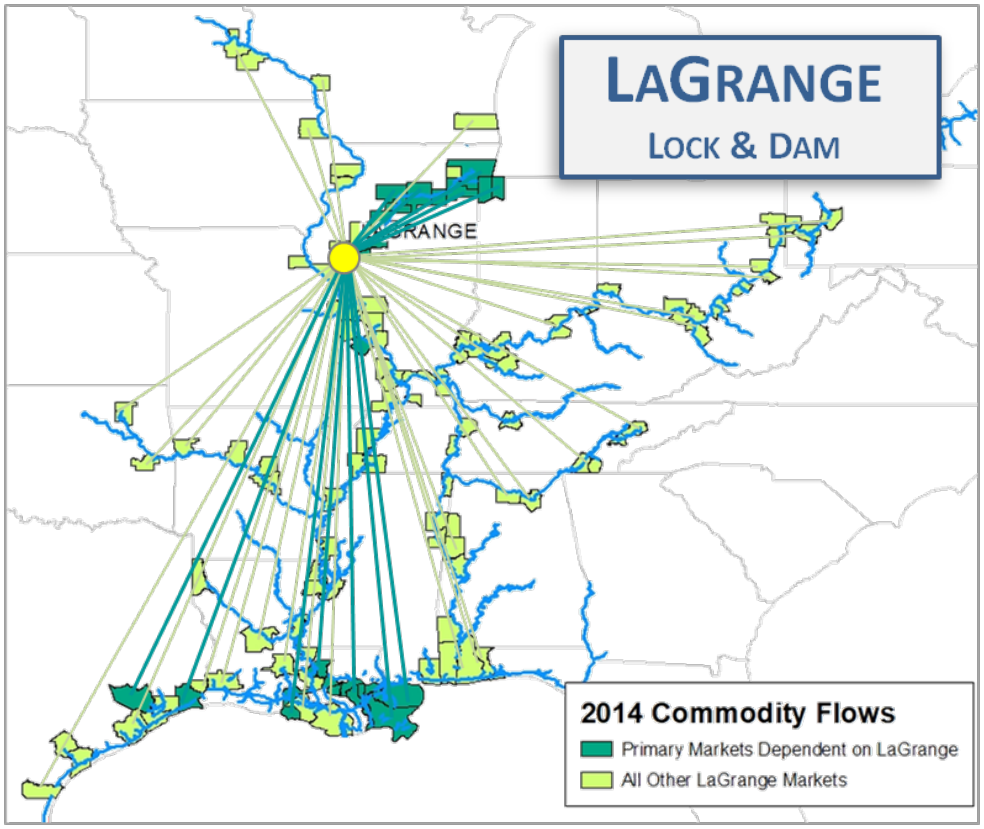
3 DIVERSION ANALYSIS AND COSTING

Closure-Related Shipper Cost Burden - CALCASIEU



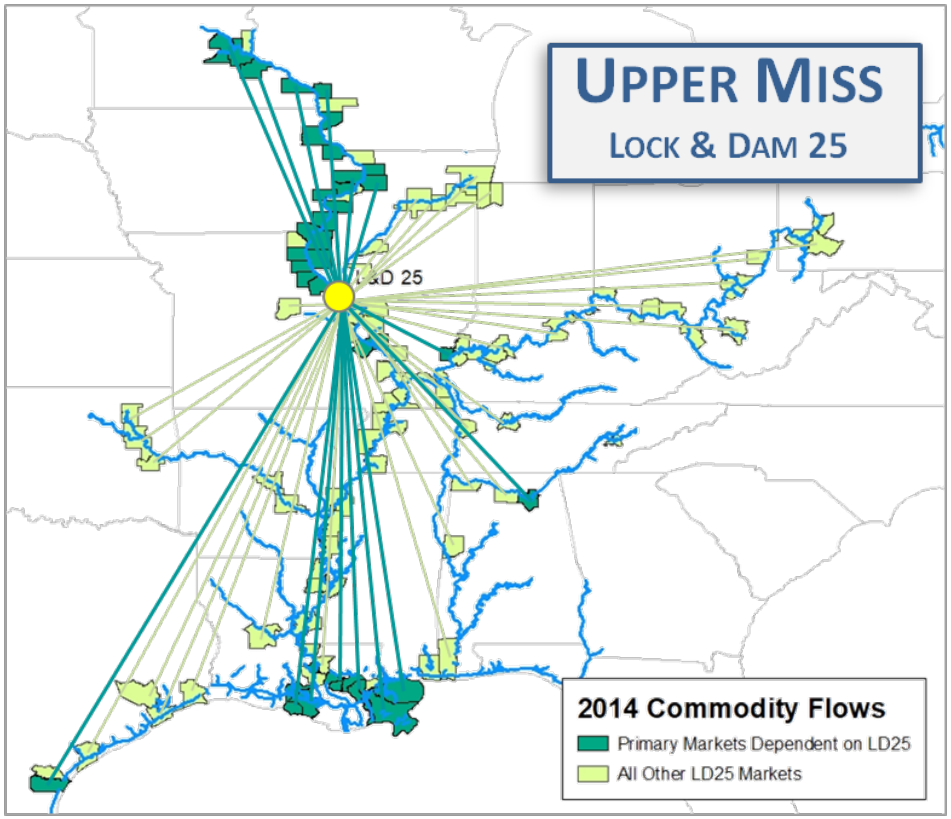
3 DIVERSION ANALYSIS AND COSTING

Closure-Related Shipper Cost Burden - LAGRANGE



3 DIVERSION ANALYSIS AND COSTING

Closure-Related Shipper Cost Burden – Lock & Dam 25



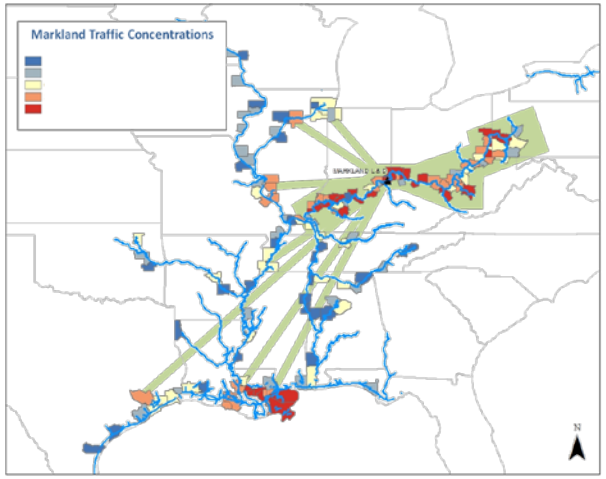
3 DIVERSION ANALYSIS AND COSTING

Closure-Related Shipper Cost Burden

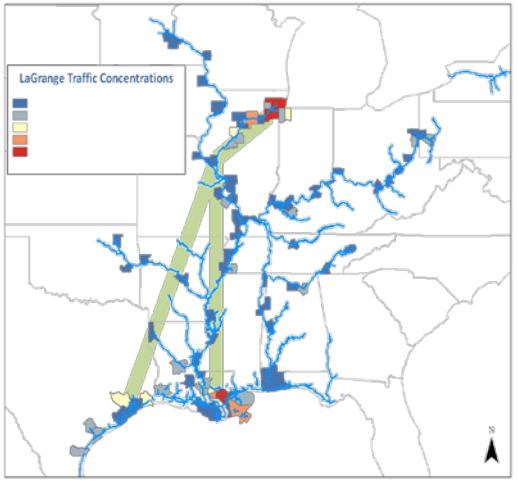
	MARKLAND		CALCASIEU		LAGRANGE		UM L&D 25	
Commodity Group	2014 Tons	Avoided Cost Burden ($ Millions)	2014 Tons	Avoided Cost Burden ($ Millions)	2014 Tons	Avoided Cost Burden ($ Millions)	2014 Tons	Avoided Cost Burden ($ Millions)
Coal	30,788,869	$221.99	245,836	$6.63	443,288	$20.29	660,624	$25.70
Petroleum Products	7,440,371	$368.25	24,988,887	$542.29	5,623,494	$182.91	320,411	$15.10
Chemicals	3,898,264	$276.42	9,078,337	$230.95	4,888,770	$251.53	4,171,737	$248.90
Crude Materials	14,339,508	$242.73	3,937,379	$179.79	3,401,419	$208.24	3,082,613	$208.86
Manufactrd Goods	4,896,902	$160.39	2,744,157	$120.01	3,344,289	$103.52	1,667,149	$38.23
Farm and Food Prod	4,089,324	$38.46	843,753	$22.75	11,460,988	$932.68	12,433,825	$1,033.98
Equipment	55,525	$1.82	9,222	$0.25	5,632	$0.48	6,602	$0.54
Scrap and Waste			626,896	$16.91				
TOTAL	**65,508,763**	**$1,310.1**	**42,474,467**	**$1,119.6**	**29,167,880**	**$1,699.7**	**22,342,961**	**$1,571.3**

4 RAILROAD CAPACITY

MARKLAND



LAGRANGE



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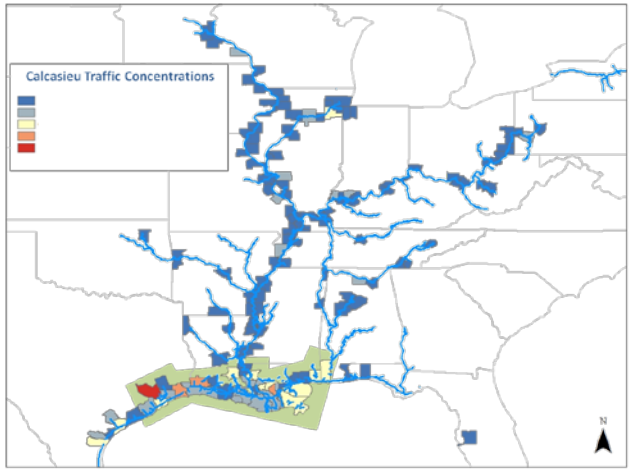
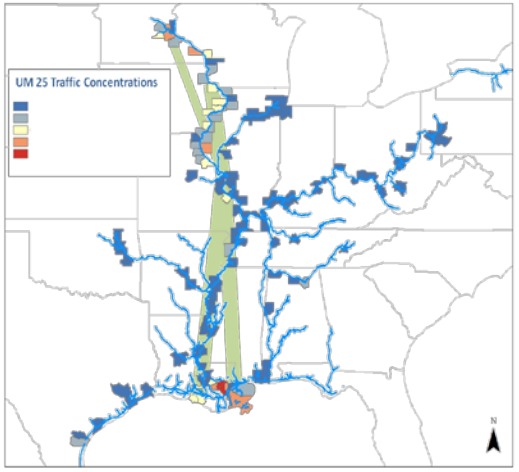
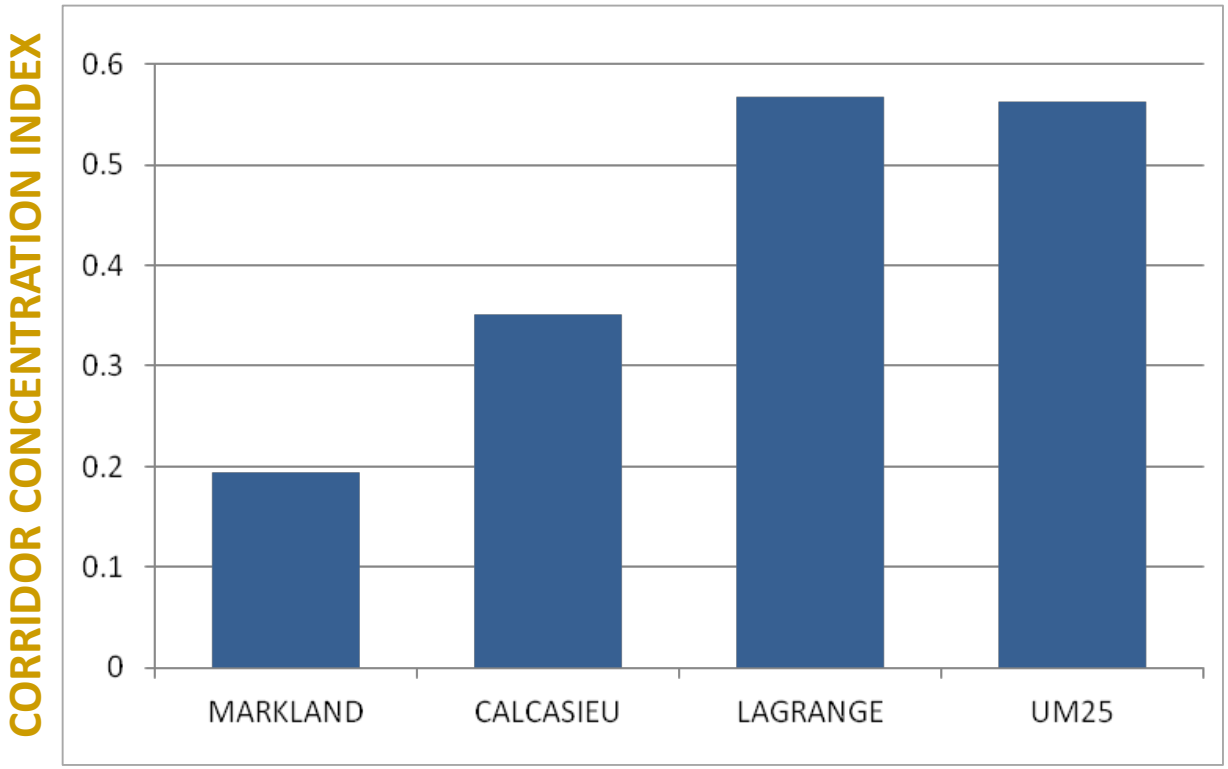


UM L&D 25



4 RAILROAD CAPACITY



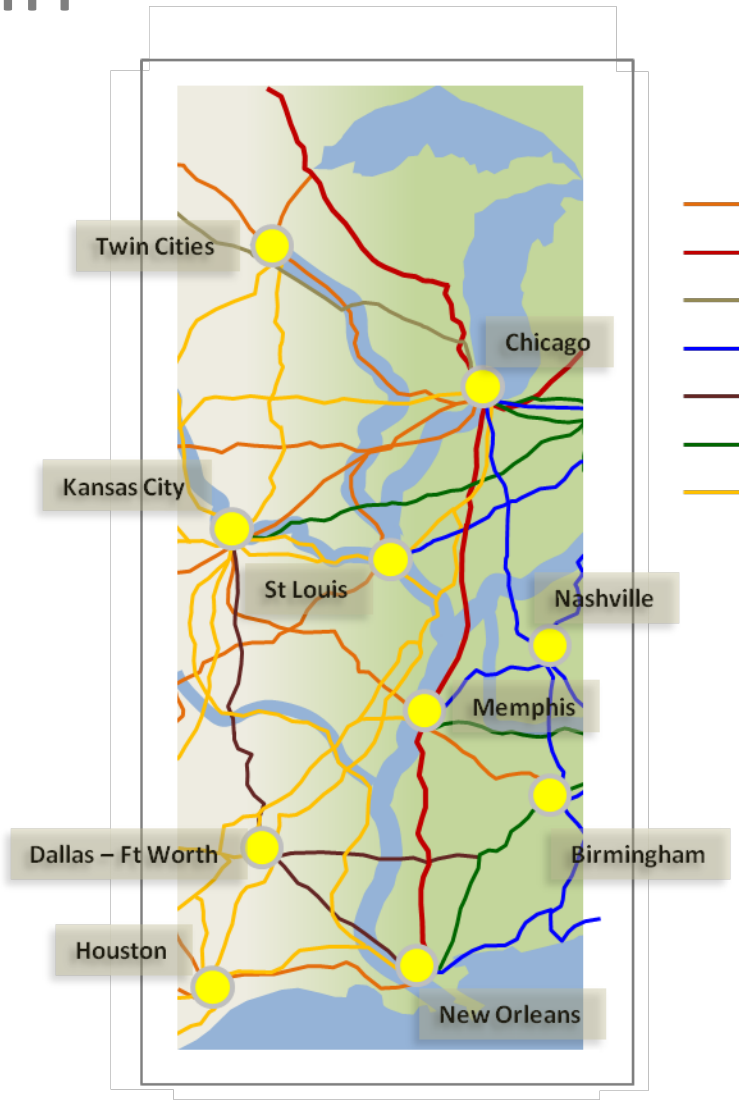
Higher values indicate a larger portion of lock traffic is Concentrated on the core corridor, while lower values suggest that Traffic is more widely dispersed across the inland system

4 RAILROAD CAPACITY

Origin Capacity Issues
(Rail Car Capacity)

Line-Haul Capacity Issues
(Track Capacity)

Destination Capacity Issues
(Rail Access / Car Capacity)



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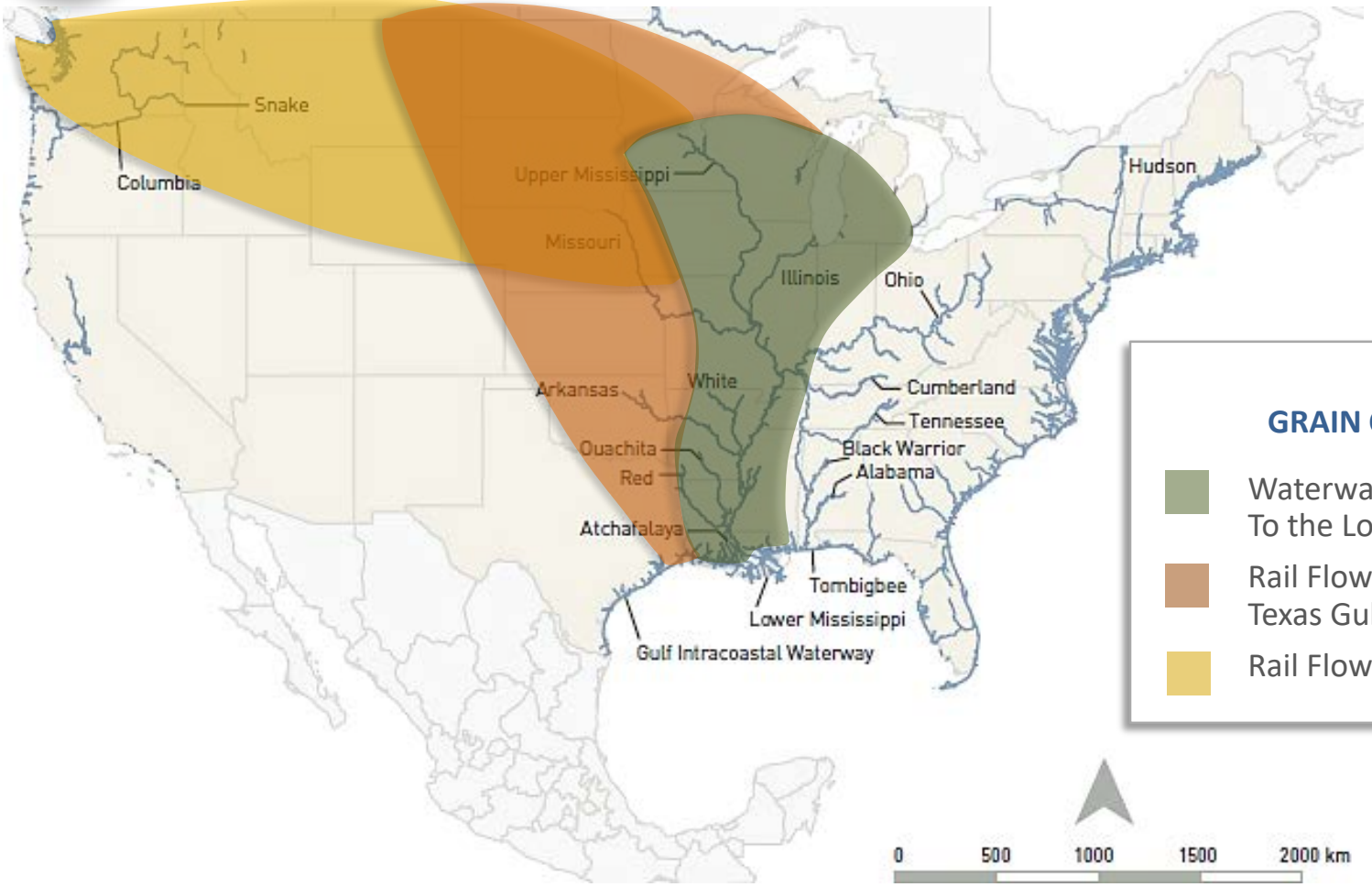


4 RAILROAD CAPACITY

2014 Rail Traffic to the Louisiana Gulf

Originating State	Farm Products by Rail to Louisiana (Tons X1M)	All Rail Movements to Louisiana (Tons X1M)	Farm Products by Rail to all Destinations (Tons X1M)
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**

4 RAIL CAPACITY

The Bottom Line

1. Rail Capacity in the Louisiana Gulf Corridor is Insufficient to Accommodate Closure-Diverted Grain Traffic
2. Fixing What Can Be Fixed (Equipment, Crews, Lind-Haul Trackage) Would Take A Year and Still Not Create the Needed Capacity
3. Terminal Constraints, Particularly On the Louisiana Gulf May Not Be Fixable
4. Diverted Grain Would Mostly Be Pushed Over the PNW at Significantly Higher Costs to Farmers

5 REGIONAL ECONOMIC IMPACTS (RED)

Study Goal

To Estimate the Regional Burden Faced in the Event of an Unplanned Lock Outage of Indefinite Duration

Study Process Steps

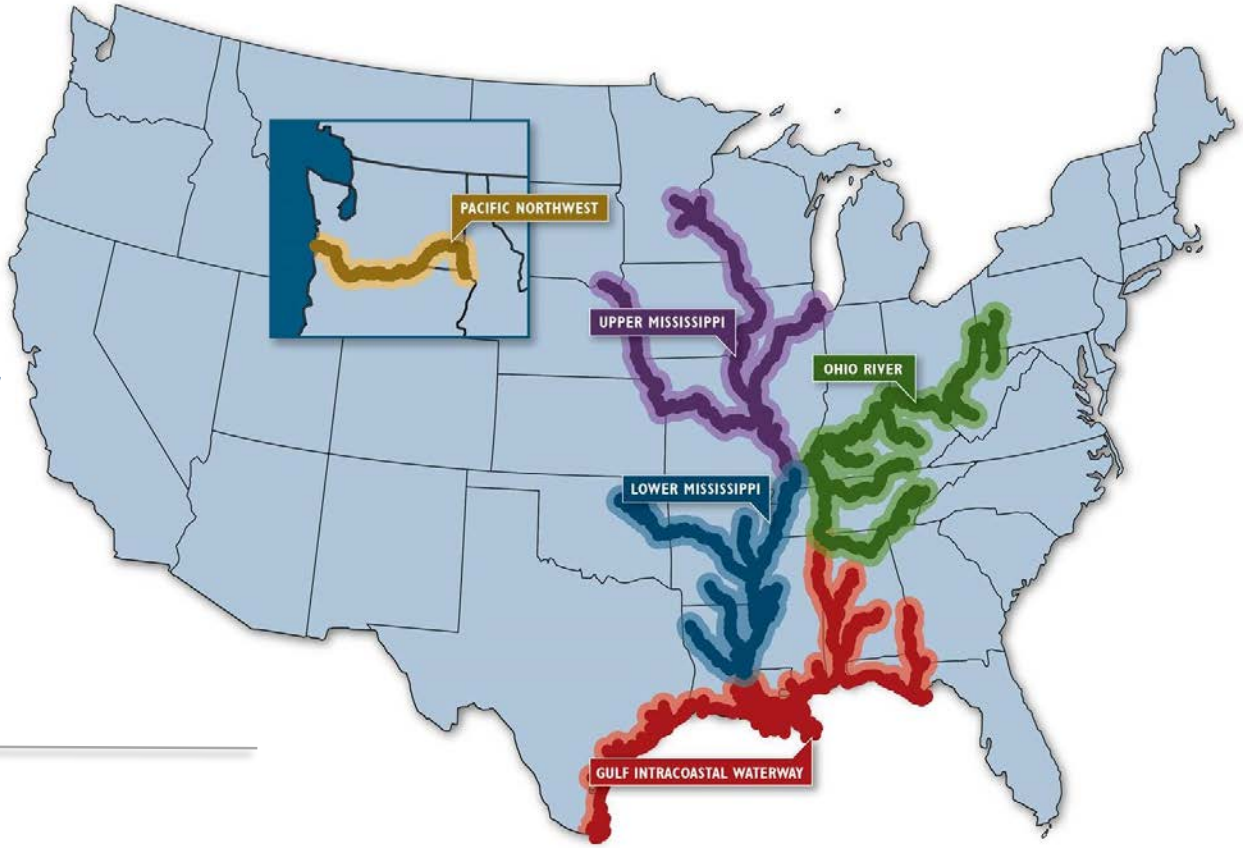
1. Convert Shipper Cost Increases Into Direct Regional Simulation Impacts
2. Modify Existing Modeling Platforms to Reflect Current Study Needs
3. Estimate, Validate, and Communicate Regional Results

5 REGIONAL ECONOMIC IMPACTS

Past NWF-Sponsored Research

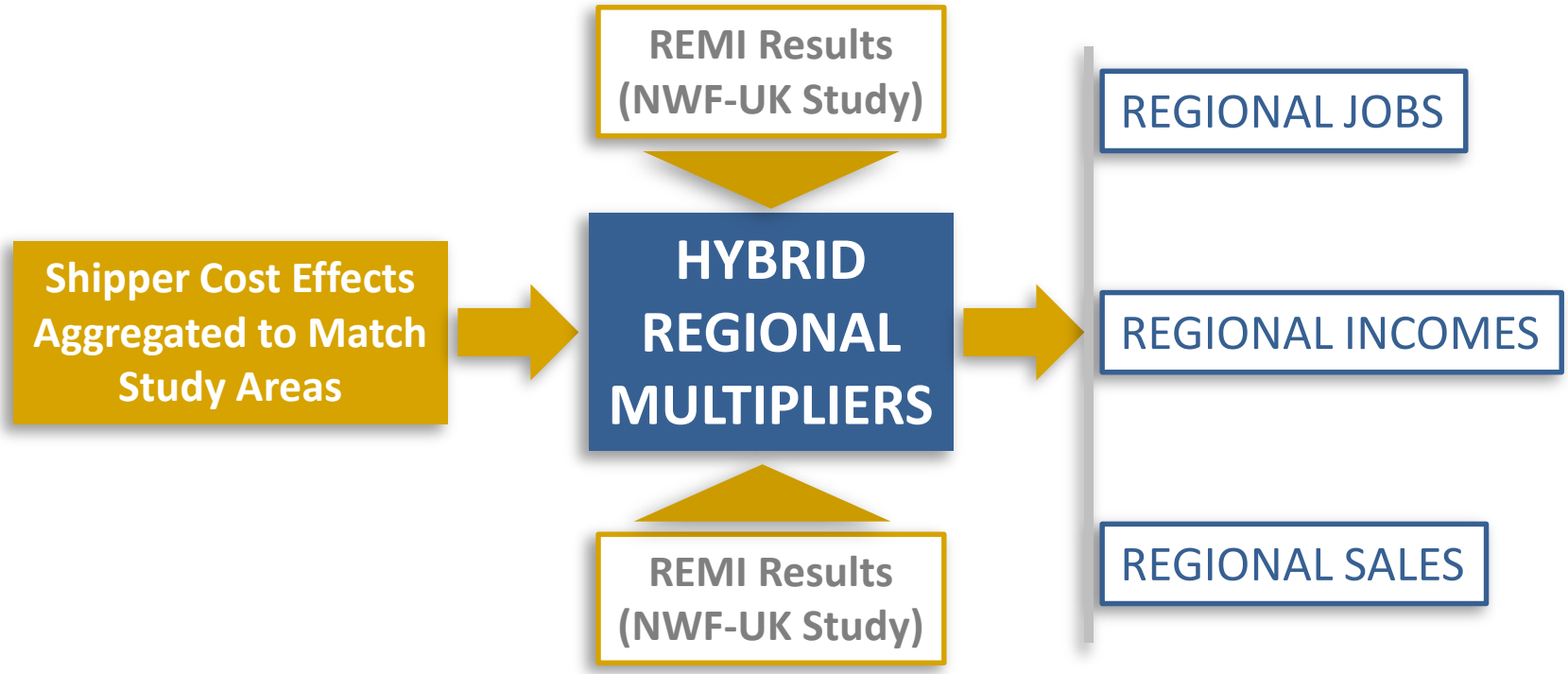
University of Kentucky 2014 Analysis

REMI-Based Analysis of Full System Closure



5 REGIONAL ECONOMIC IMPACTS (RED)

Regional Modeling Platform and Process



5 REGIONAL ECONOMIC IMPACTS (RED)

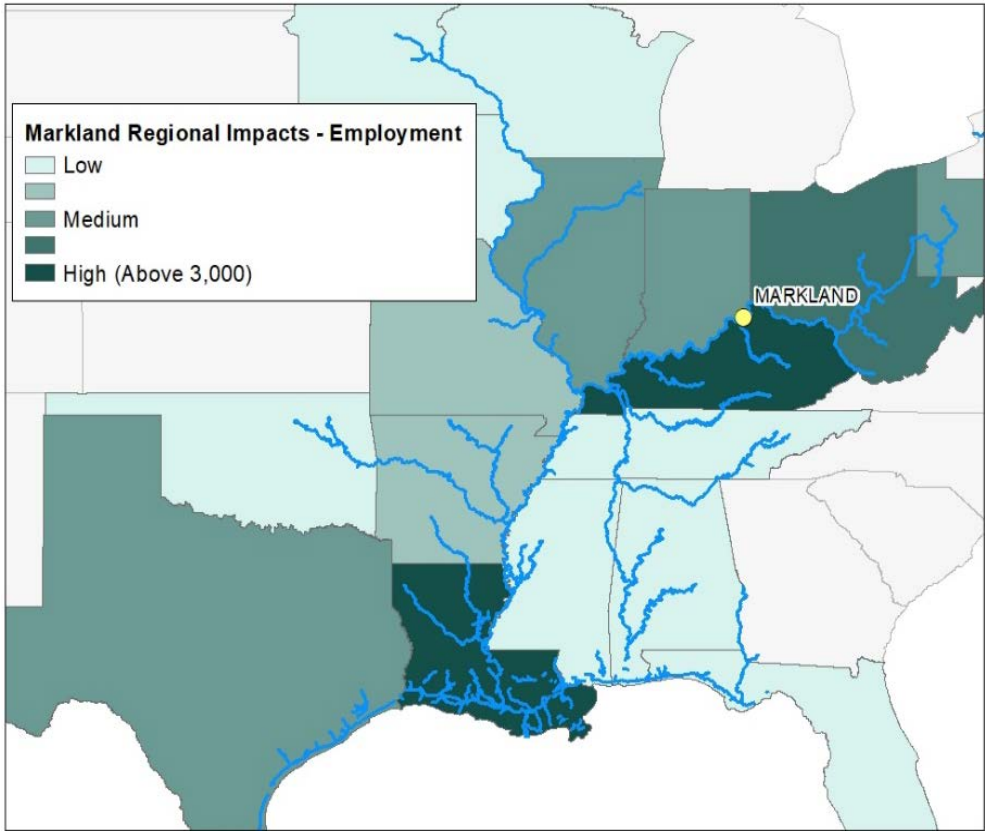
Regional Modeling Results - MARKLAND

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	$1,310,060,835	$2,520,578,383	$657,544,177	13,210

Results for individual locks are not additive.

5 REGIONAL ECONOMIC IMPACTS (RED)

Regional Modeling Results - MARKLAND



5 REGIONAL ECONOMIC IMPACTS (RED)

	Output ($ Millions)	Incomes ($ Millions	Jobs
MARKLAND	$2,250	$657	13,210
CALCASIEU	$1,117	$4,348	17,487
LAGRANGE	$1,704	$5,188	24,447
L&D 25	$1,565	$4,243	24,250

6 IMPLICATIONS, LESSONS LEARNED & NEXT STEPS

1. What Did the Study Confirm and What Did It Tell Us that We Didn't Know?

2. What Are the Logical Next Steps in Improving Our Ability to Evaluate the Economic Value of Inland Navigation Infrastructure?

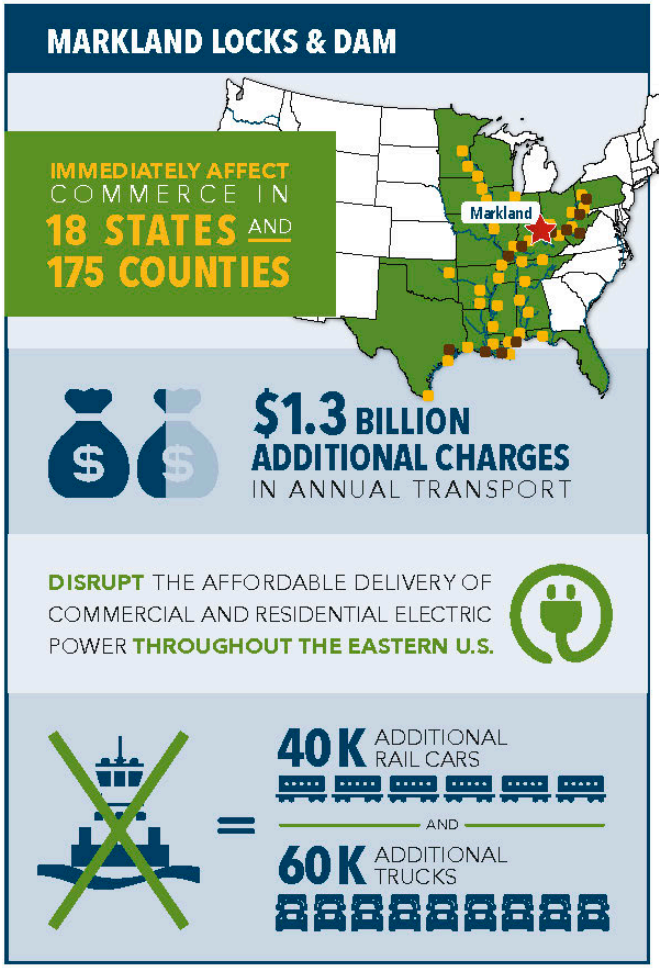
6 IMPLICATIONS, LESSONS LEARNED & NEXT STEPS

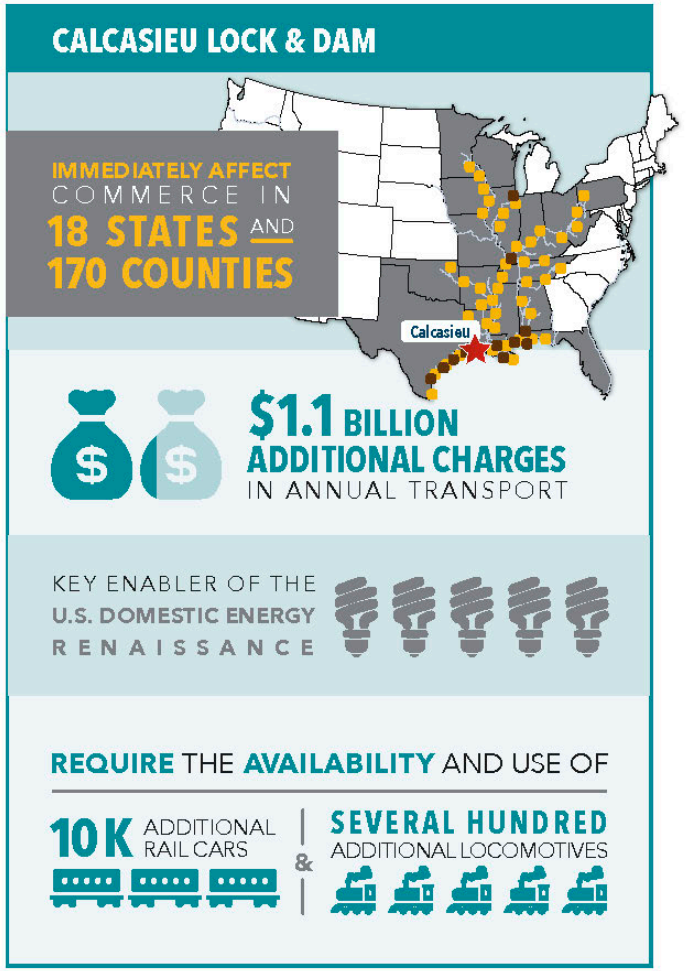
1. Direct impact on Shippers at all four locks from an extended unscheduled closure will exceed $1 billion annually.

2. Direct and Regional Impact extend to 18 states and especially Louisiana, Texas and Illinois.

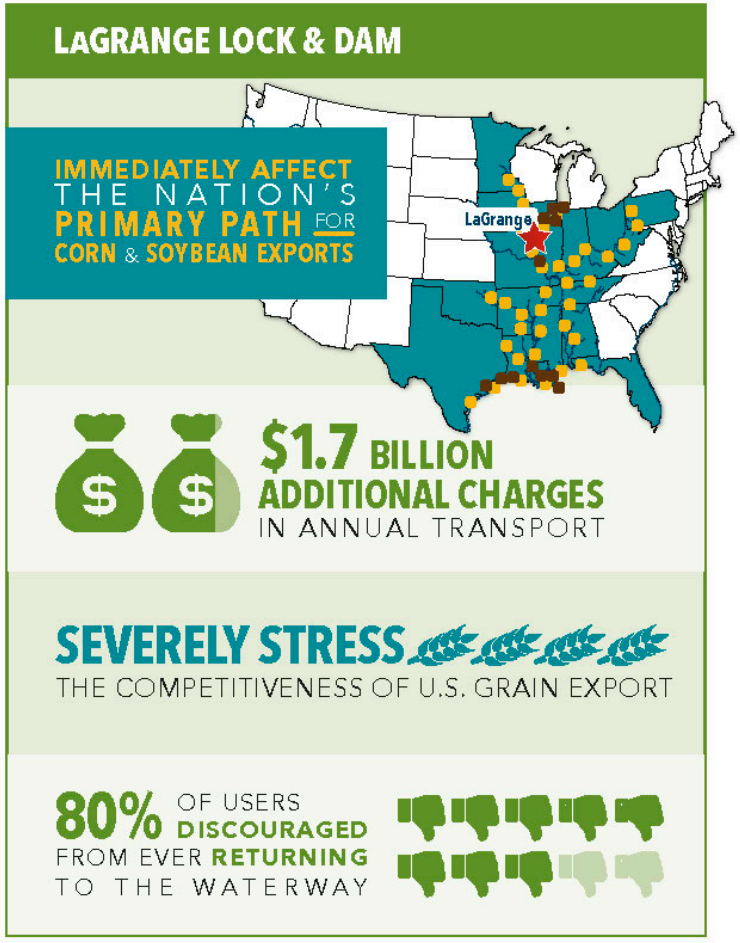
3. Rail capacity limitations will be especially pronounced in the long haul corridors to/from the Gulf Coast.

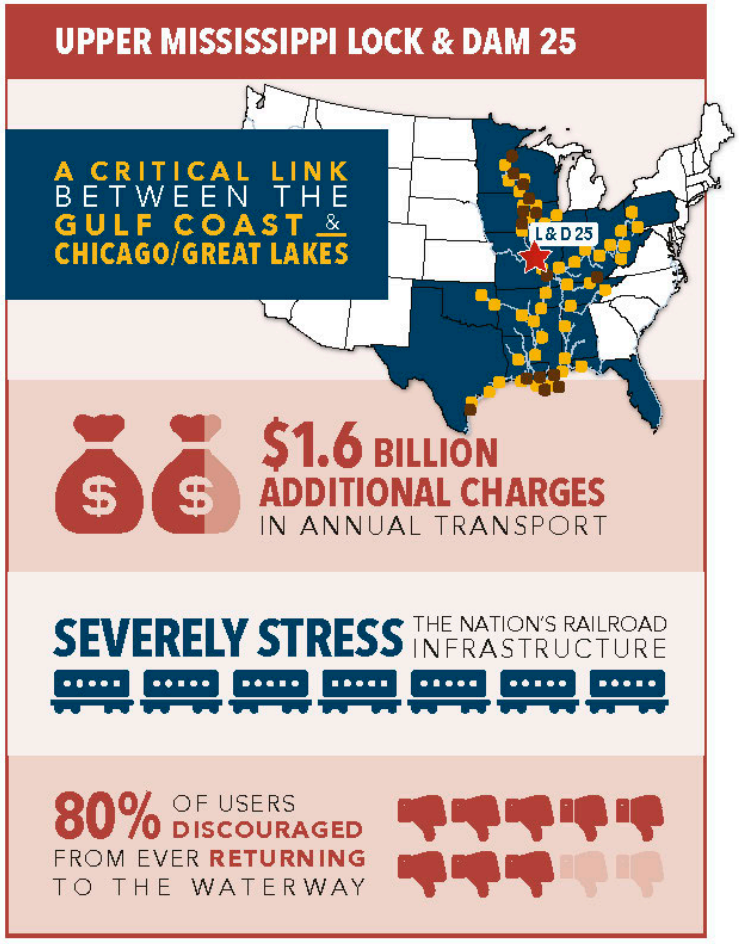
6 IMPLICATIONS, LESSONS LEARNED & NEXT STEPS





6 IMPLICATIONS, LESSONS LEARNED & NEXT STEPS





6 IMPLICATIONS & LESSONS LEARNED

1. The methods currently used by the USACE conform to sound economic principles and the P&G.
2. Alternative modal capacity is not as assured as we might think, particularly in corridors where waterways are already dominant.
3. Even outside a system simulation setting measures of system importance (related ton-miles, related locakages can greatly clarify the system value of individual facilities.
4. Measures of above and below pool traffic may prove hugely important in some settings.
5. Inputs and other ancillary data need to be updated thoroughly and frequently. And the nnderlying “Bid Data” are far to fragile.

6 NEXT STEPS

1. Further discriminate results and gather and respond to observations and criticisms.
2. Further explore the implications of above and below pool traffic in the calculation of project benefits.
3. Further explore the implication of corridor concentration, particularly as it relates to tributary traffic.
4. Develop and promote thoughtful (realistic) avenues for improving data resources.
5. Convene with like-minded researchers to avoid unnecessary duplications and to assure timely, coordinated methodological advances.

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