CASE STUDY:

CUMBERLAND/TENNESSEE RIVER INLAND WATERWAY RESILIENCE ANALYSIS

IN SUPPORT OF THE DHS/USACE PORT RESILIENCE GUIDE

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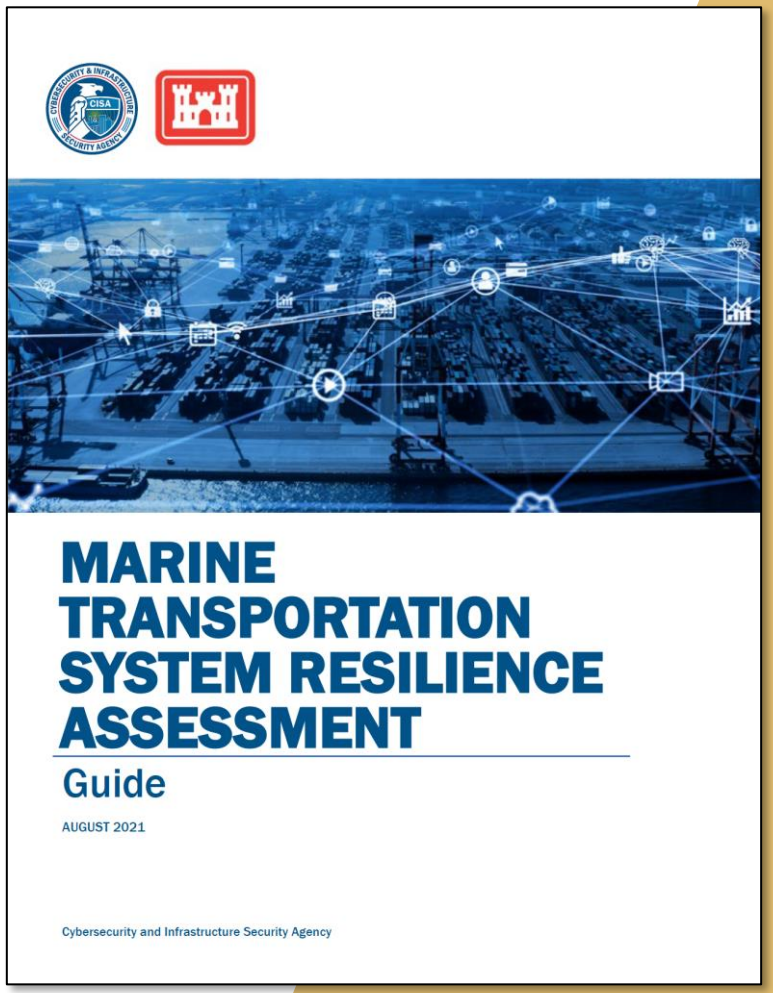
PORT RESILIENCE GUIDE

- The MTS resilience guide advocates for a functional approach to characterization
- The MTS provides two major functions--the transport of people and cargo—and relies upon several sub-functions to enable them:
  - Navigation, cargo transfer, storage, cargo tracking/monitoring, ship services, etc.
- Systems can be characterized by understanding which infrastructure supports which functions throughout the MTS being assessed



PORT RESILIENCE GUIDE - OBJECTIVES

Pre-Assessment	• Help set assessment direction • Support consensus building/buy-in
Design Assessment	• Support scoping, planning, and data collection strategy
Connect with Resources	• Drive method selection
Conduct Assessment	• Form basis of assessment • Inform REO development/evaluation
Implement Findings	• Help articulate findings and build buy in for selected alternatives

CASE STUDIES TO VALIDATE GUIDE PROCESS

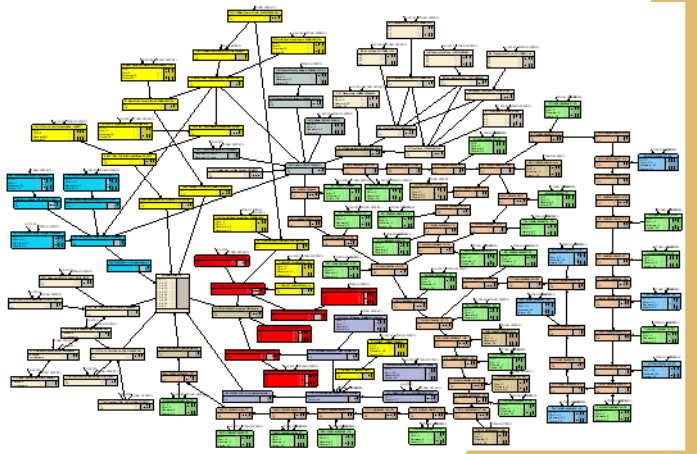
1. Bayesian Network Analysis of Earthquake Resilience at the Port of Portland
Lead: Dr. Martin Schultz, EL

2. Inland Waterway Petroleum Supply Chain
Leads: Drs. Janey Camp and Craig Phillip, Vanderbilt

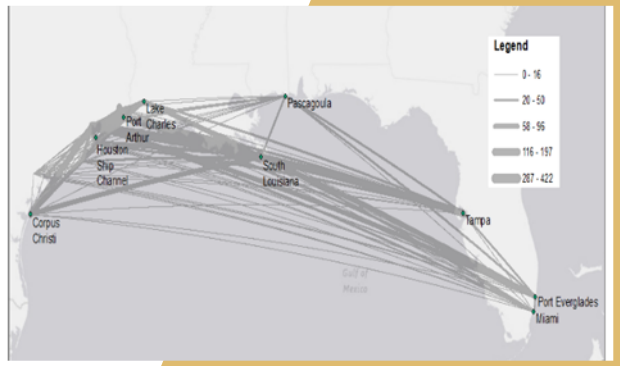
3. National MTS Network Analysis
Lead: Dr. Brandan Scully, CHL

4. Caribbean Critical Supply Chains RRAP Project
Leads: CISA HQ, Dr. Paul Lewis and James Butler, Argonne National Lab

5. Institutionalizing Resilience: Insights From Resilience Assessment Initiatives at Sea Ports
Leads: Austin Becker and Ellis Kalaidjian

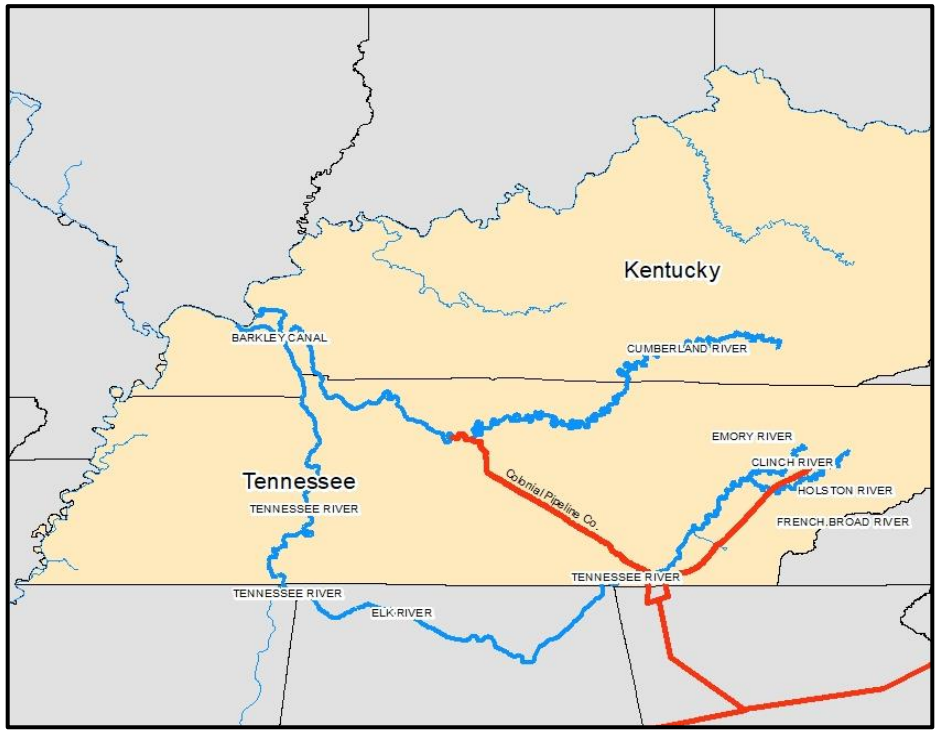


Bayesian Network of Critical Infrastructure Systems
Source: Schultz et al 2016



Network of Gulf Port Connectivity. Source: Scully and Chambers 2019.

TN/CUMBERLAND RIVER SYSTEM REGION OVERVIEW



INLAND WATERWAYS SUPPORT TENNESSEE'S KEY INDUSTRIES

Industry Sub-Category	Percent of Goods Shipped by Water (Tons)	Direct Tennessee Jobs
Crop production	**34.2%** of inbound **15.0%** of outbound	1,860*
Utilities	**12.0%** of inbound	3,560
Transportation** & Warehousing	**8.3%** of inbound	38,560

*Total for Agriculture, Forestry, Fishing, and Hunting sector (NAICS 11)

**Related to water transportation

TOP INLAND WATERWAYS COMMODITIES BY WEIGHT

(comprising 62% of total tonnage)

- Sand, gravel, shells, clay, salt, and slag — **9.4 million tons**
- Coal, ligite, and coal coke — **6.2 million tons**
- Petroleum products — **3.4 million tons**

TOP INLAND WATERWAYS COMMODITIES BY VALUE

(comprising 65% of total value)

- Gasoline — **$1.3 billion**
- Fuel Oils — **$1.2 billion**
- Transportation equipment, including railcars, aircraft, and commercial ships — **$857.7 million**

TENNESSEE'S INLAND WATERWAY ASSETS AT A GLANCE

Tennessee, Mississippi, and **Cumberland** Rivers

5 public ports

In 2018,

30.8M tons of freight

valued at

$5.2 BILLION

moved on Tennessee's inland waterways, which is equivalent to

770,000 TRUCKS

Avoided trucks translates into **reduced congestion, emissions, and crashes,** lessening impacts on highway infrastructure

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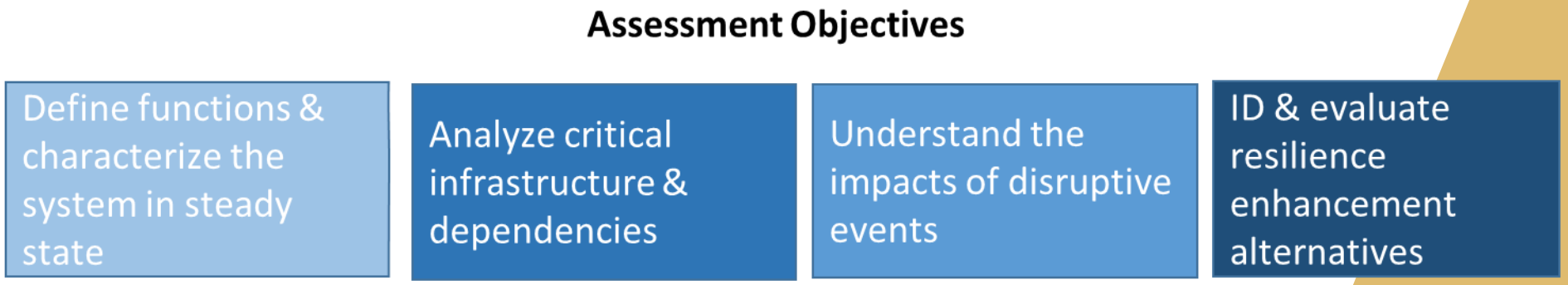
KEY RESEARCH QUESTIONS

- Can we ID Ports/Docks/Terminals that can transfer cargos to/from other modes to provide redundancy in the face of disruption and provide system redundancy?
- What are the impacts of natural hazard events on the IW System Operation and Delivery of Commodities?
- Can the Inland Waterway System ensure petroleum product supply to Middle & East Tenn if Colonial Pipeline is disrupted?

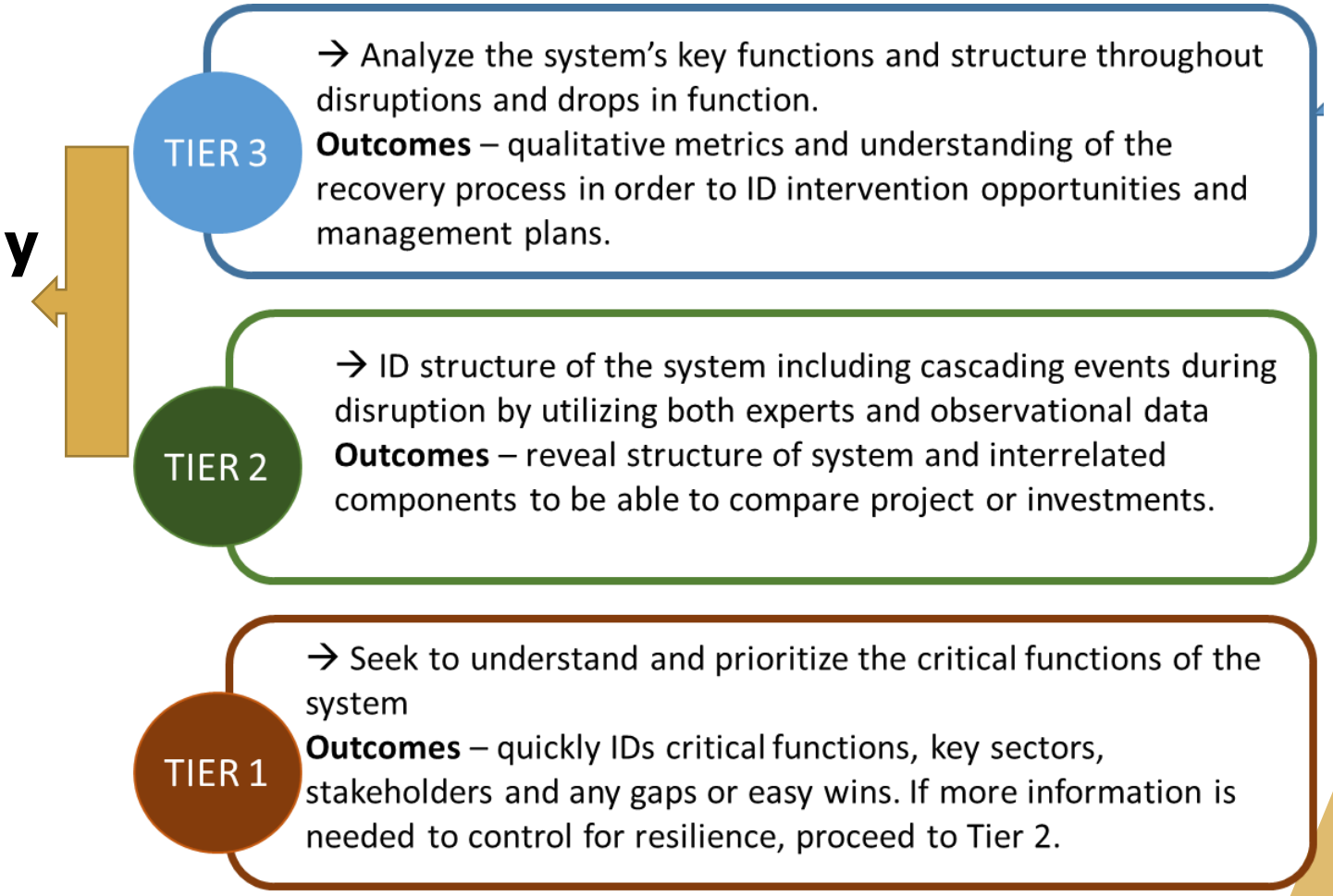
PROJECT ACTIVITIES/TASKS

1. Plan and Convene **2 Stakeholder Roundtable Sessions**
2. Prepare summary of **Priorities and Takeaways** from the Stakeholder roundtables
3. Identify and secure necessary data to **Characterize the System**
4. **Apply *Guide* methodology**/approach and/or RRAP approaches to characterize/evaluate region
5. **Identify and evaluate 3 disruption scenarios**
6. **Estimate impacts for each scenario** on the case study area & the petroleum supply chain
7. **Identify potential operational resilience strategies** including operational variability and recovery time, etc.



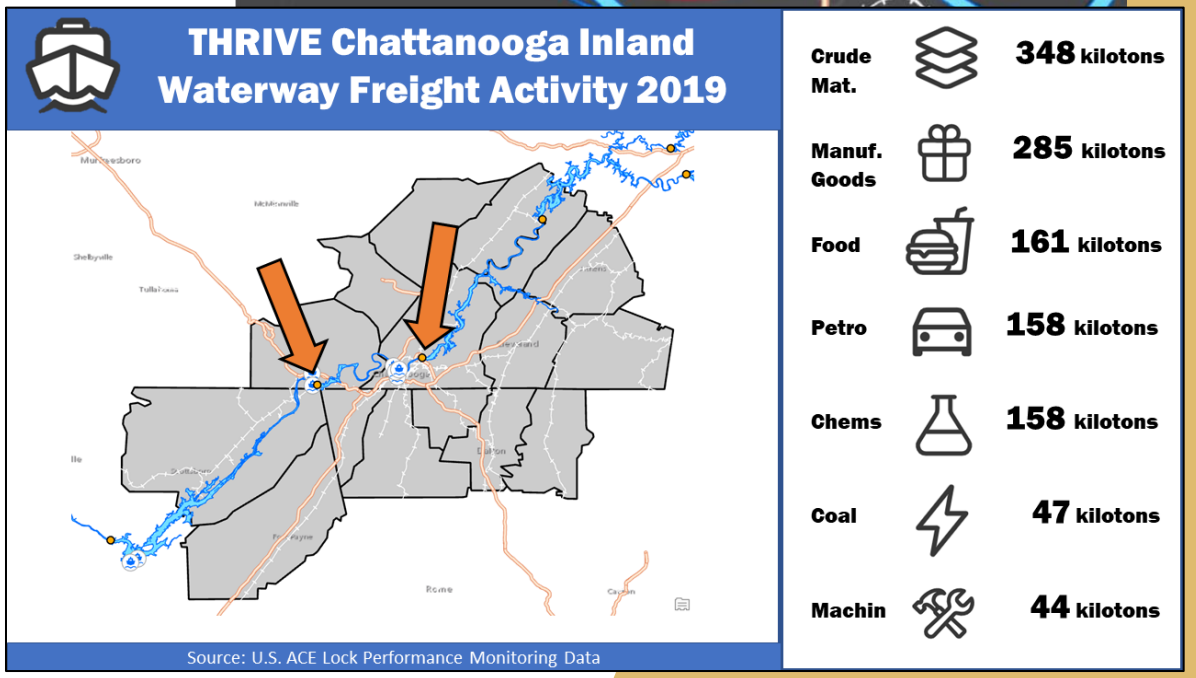
ALIGNMENT WITH GUIDE TIERS

Inland Waterway Case Study



CHARACTERIZING THE REGION

- Considering key assets and infrastructure
- Evaluating connectivity and opportunities for multi-modal transfers
- Reviewing historical commodity flows (including during times of disruption)
- Identifying disruptions and potential impacts



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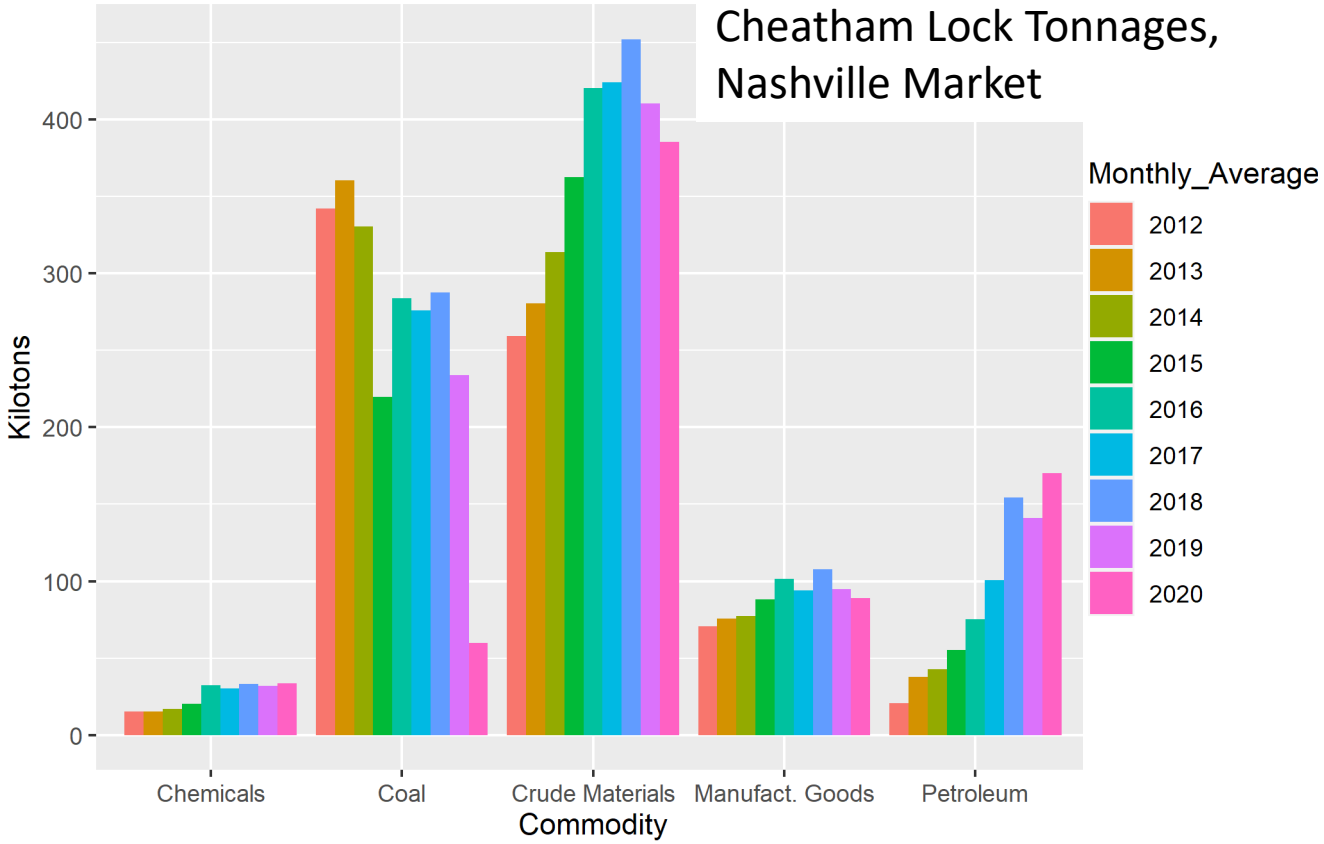
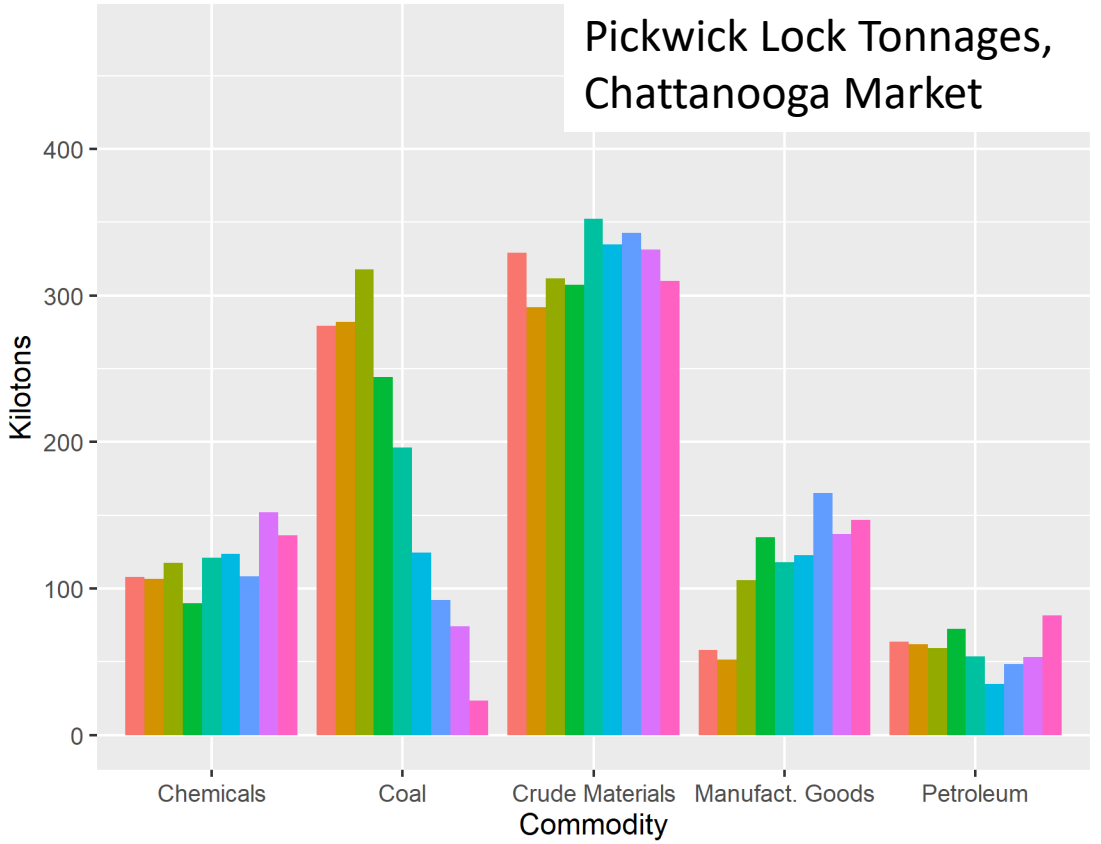
CHARACTERIZING THE REGION

Cheatham Lock Tonnages, Nashville Market



Pickwick Lock Tonnages, Chattanooga Market



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STAKEHOLDER INVOLVEMENT - MTG 1

Marine/Barge Carriers
AWO
Tenn-Cumberland Waterways Council
HF Lines
Ingram Barge Company

Shippers
TVA
Pine Bluff Aggregates
Waterways Council

State Government
TDOT
KY Transp. Cabinet
TEMA
KY EMA
AL DOT

Infrastructure Owners/Operators
US Army Corps of Engineers– Nashville District
TVA
Columbia Pipeline

Terminal/Port Operators
Pine Bluff Aggregates
HF Lines
Grand Rivers Terminal (Watco)
Port of Decatur
Jasper Industrial Park

NGO's
Cumberland River Compact
TRVA

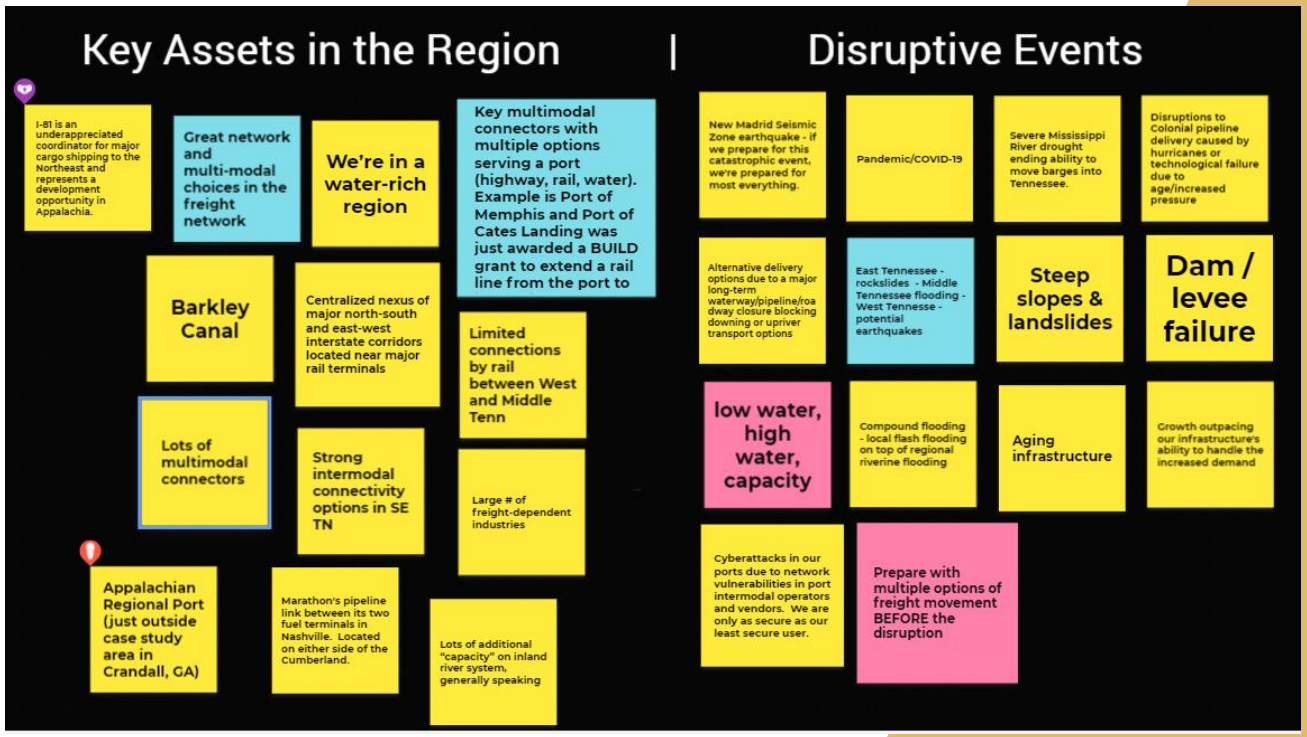
Research
TRB Inland Waterway Committee
TRB Resilience Section
Marine Board

Planning Agencies
Greater Nashville Regional Council
Chattanooga TRHIVE

Others
DHS CISA
US Army Corps of Engineers - ERDC
PHMSA
US DOT / CMTS

STAKEHOLDER INVOLVEMENT – MTG 1

- Key Assets Identified
  - Port of Memphis Intermodal Hub
  - Barkley Canal
  - Tennessee–Tombigbee Waterway
- Disruptions Outlined
  - Seismic, Waterway Outage, and Pipeline Disruption
  - Lack of Redundancy in Petro and other supply chains
  - Resilience Actions



SELECT DISRUPTION SCENARIOS

1. **Multimodal Impact Event**
   - Colonial Pipeline Spur to Tennessee
2. **Lock Outage**
   - Cheatham Lock and Dam Maintenance
3. **Waterway Navigability Impacted by Earthquake**
   - New Madrid Fault Event Impacting Tennessee/Cumberland/Ohio River Confluence and Bridge Crossings

DISRUPTION SCENARIO:

COLONIAL PIPELINE SPUR TO TENNESSEE, SERVICE INTERRUPTION

CONTINGENCY PLANS, IMPACTS, LESSONS LEARNED, RECOVERY AND RESILIENCE

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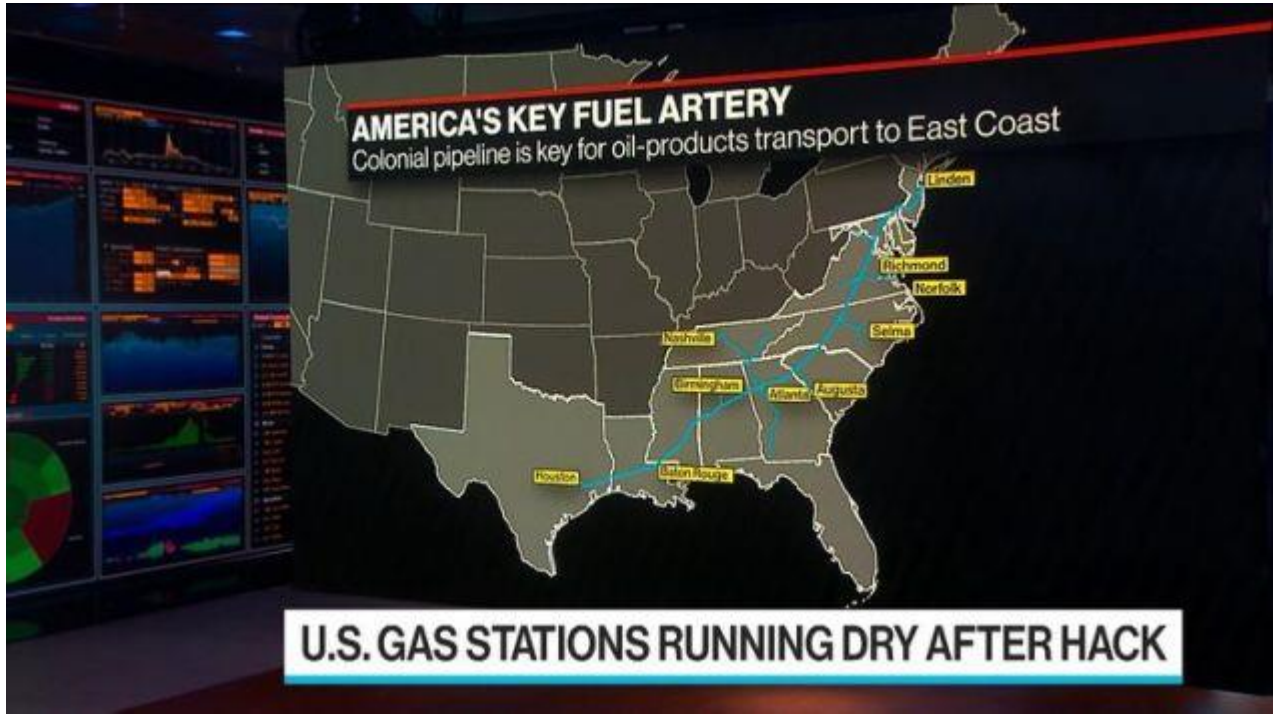
HISTORICAL DISRUPTIONS OF COLONIAL PIPELINE

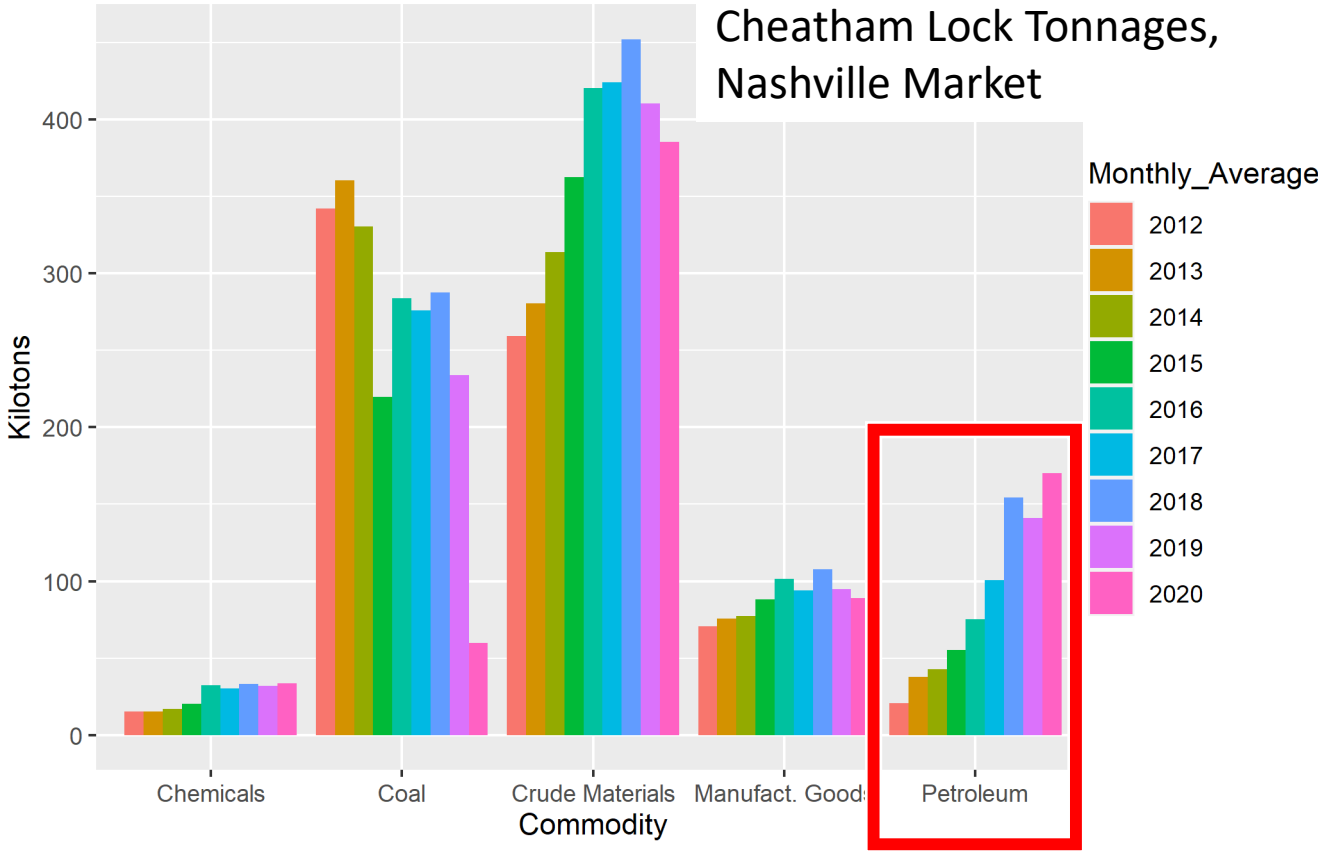
2021 Ransomware Cyberattack

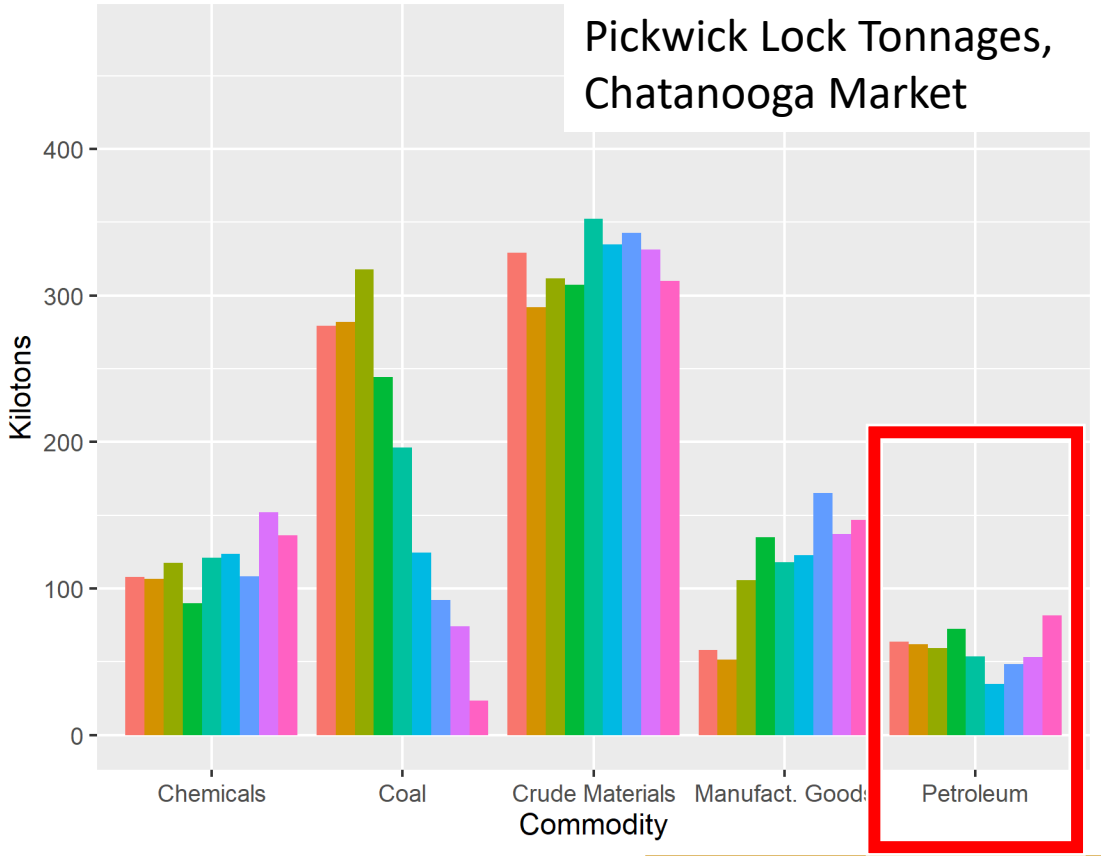


- 2017 Hurricane Harvey Closure
- 2016 Explosion Closure

Photo courtesy of Bloomberg

SINCE 2012 RIVER DELIVERED REFINED PETROLEUM HAS SUPPLEMENTED THE COLONIAL PIPELINE INTO THE NASHVILLE MARKET





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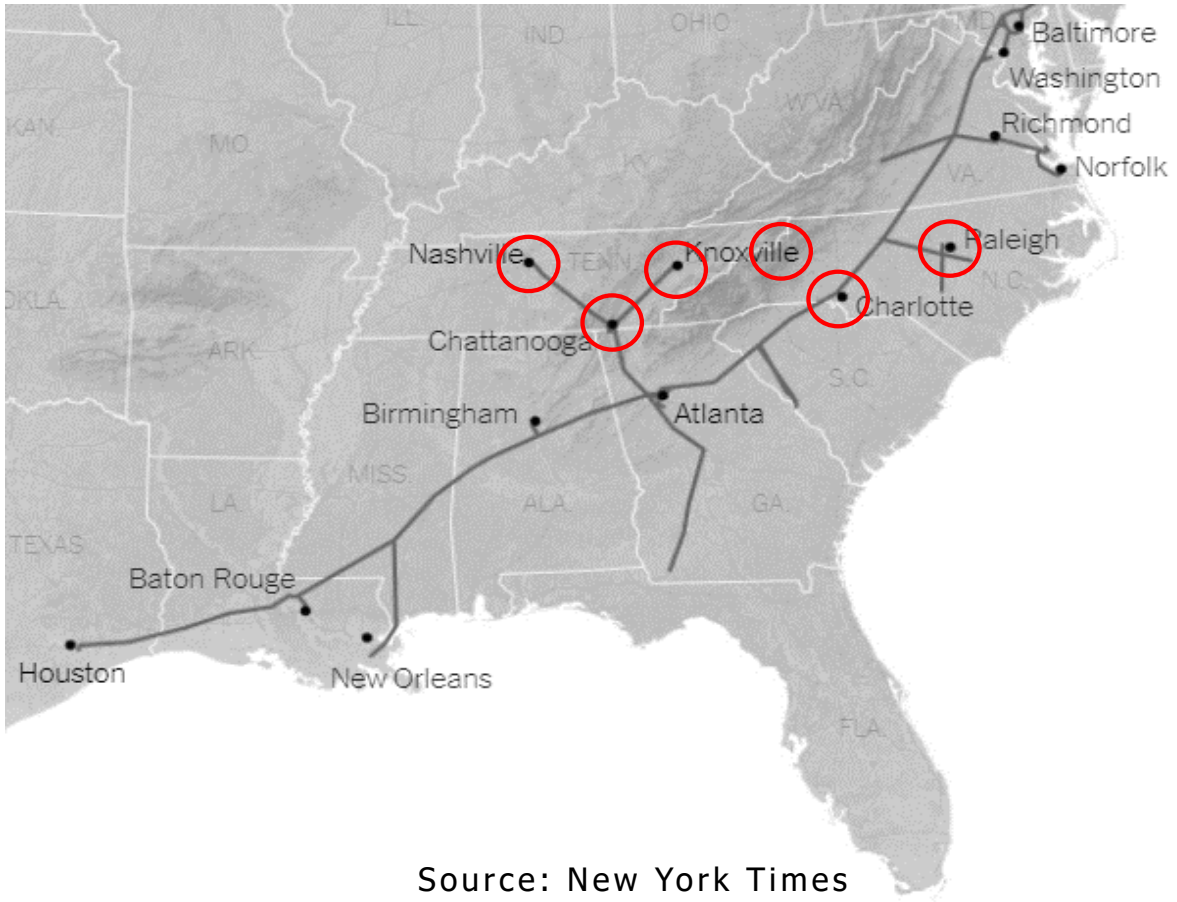
MAJOR SE MARKETS SERVED BY THE COLONIAL PIPELINE

City	Population
Nashville, TN	692,587
Chattanooga, TN	179,690
Knoxville, TN	186,173
Raleigh, NC	464,485
Charlotte, NC	857,425
Asheville, NC	91,560

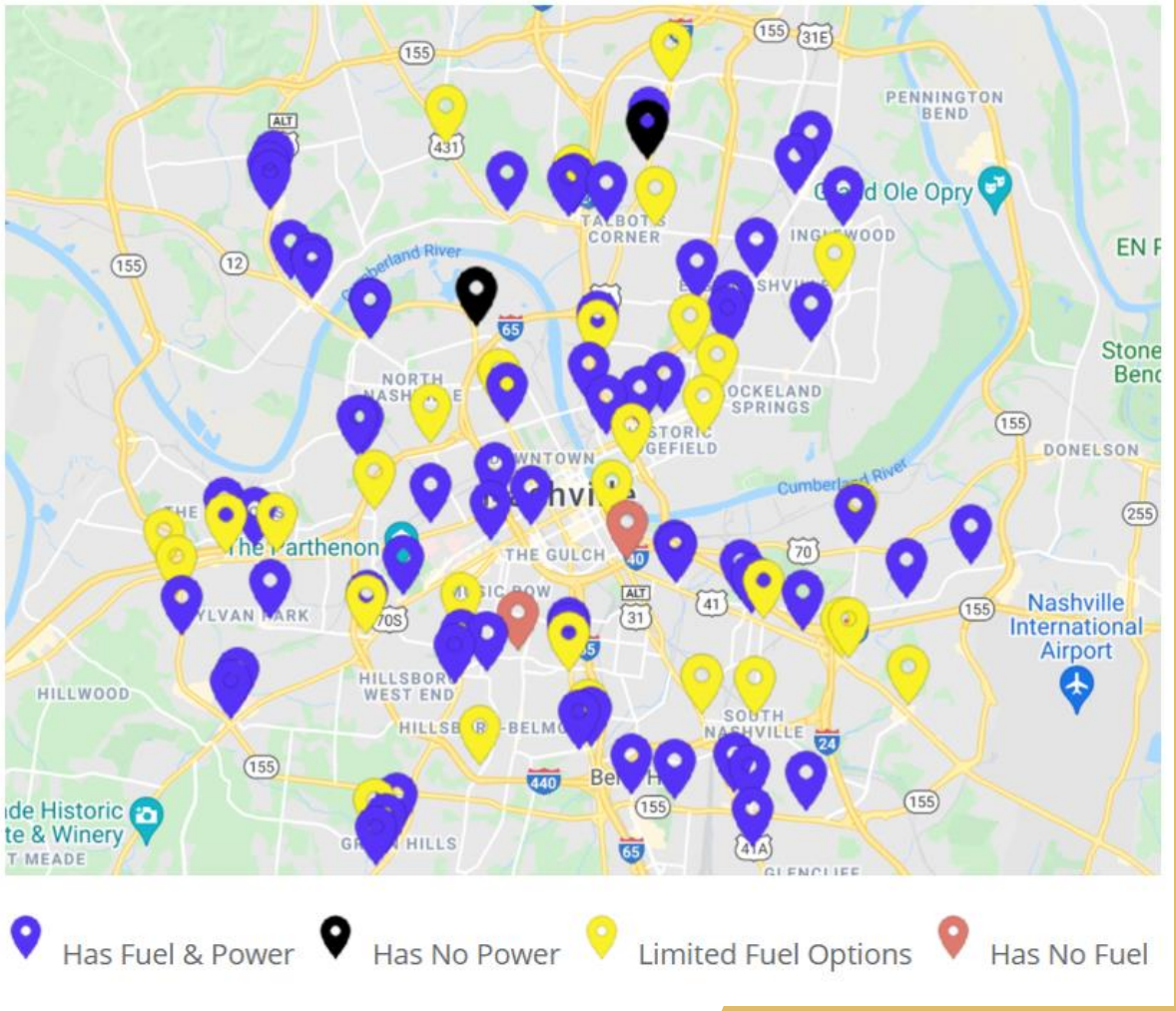


Source: New York Times

WHAT HAPPENED DURING LAST MONTH'S PIPELINE DISRUPTION?

GasBuddy

- Source: GasBuddy
  - Quoted by NPR, WSJ, the Tennessean
  - Daily Gas Station Outages by city, daily
  - Largest gas price discovery platform in North America
  - Caveat: crowdsourced



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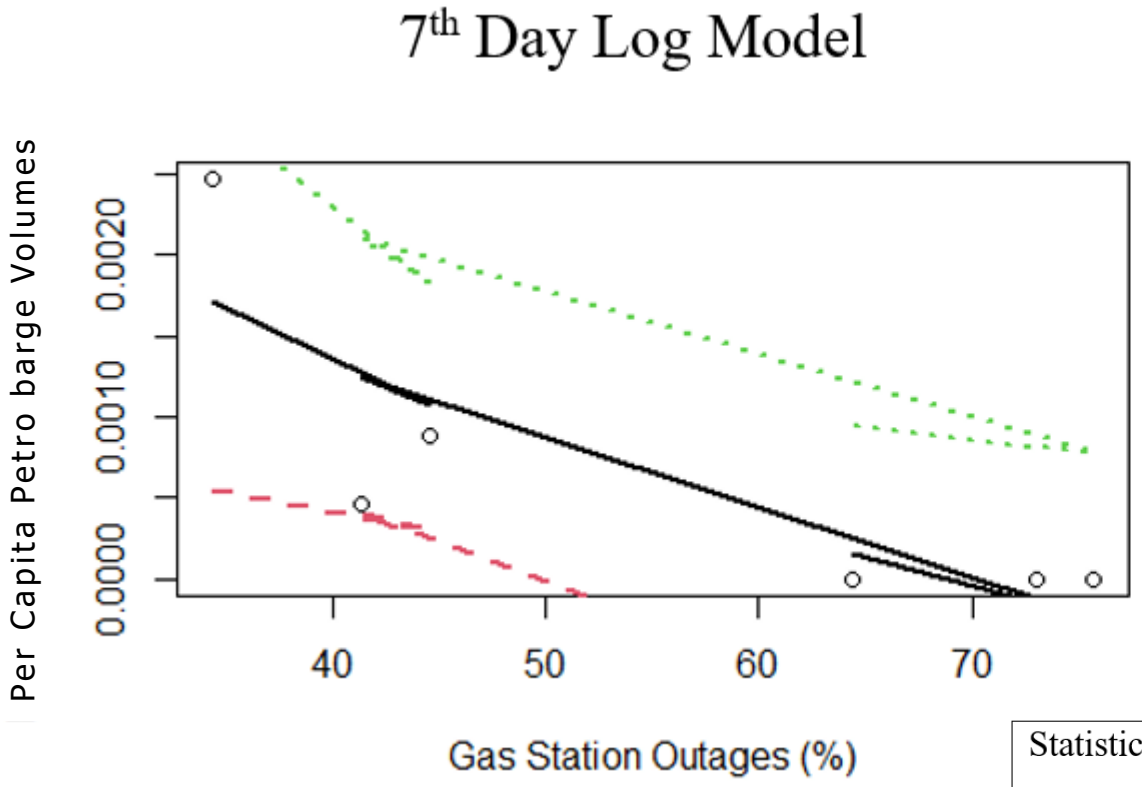
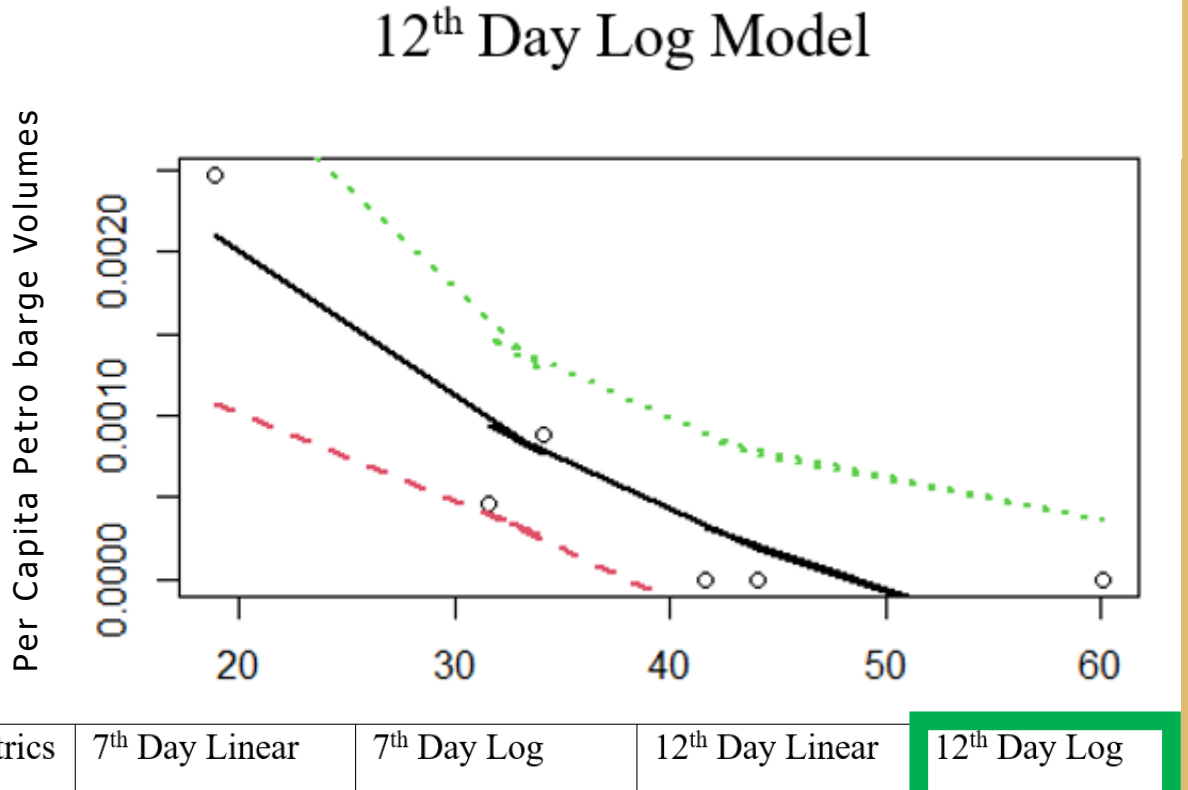
GAS BUDDY DATA CAN MEASURE THE DISRUPTION IMPACT AT THE LOCAL LEVEL

City	7th Day Station Outages (%)	12th Day Station Outages (%)	Annual Petro Vol (kt)	Population [43]	Per Capita Petro barge Volumes (kt/person)
Nashville, TN	34.4	18.9	1715	692,587	0.002476
Chattanooga, TN	44.6	34.1	158	179,690	0.000879
Knoxville, TN	41.4	31.6	85.83	186,173	0.000461
Raleigh, NC	75.7	44.1	0	464,485	0
Charlotte, NC	66.4	41.6	0	857,425	0
Asheville, NC	73	60.1	0	91,560	0

WATERBORNE PETRO VOLUMES & GAS STATION OUTAGE ANALYSIS





Statistical Metrics	7th Day Linear Model	7th Day Log Model	12th Day Linear Model	12th Day Log Model
P-Value	0.05409	0.03488	0.04407	**0.01105**
Adjusted R^2	0.5571	0.6391	0.5973	**0.7917**
Std. Error	.00001634	0.000788	.00001985	0.000507

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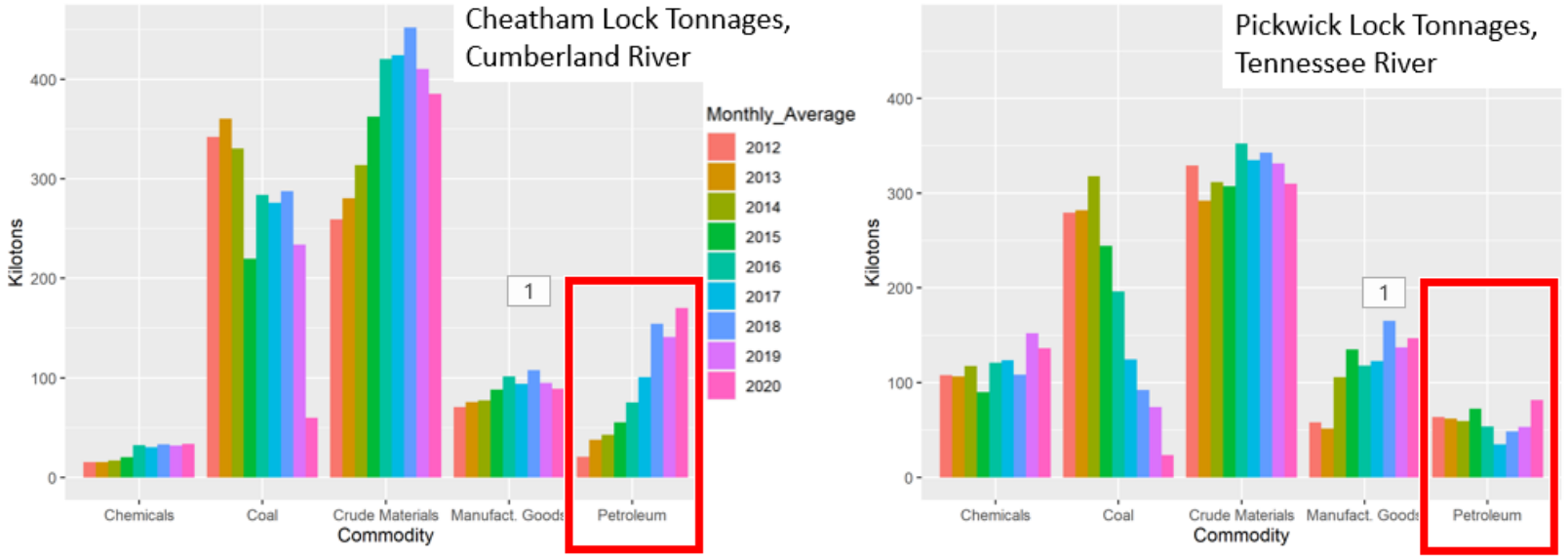
Q: To what extent can the inland waterway system **ensure supply of petroleum products** to the Middle and East Tennessee regions during a disruption of the Colonial Pipeline?



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Raleigh, NC	75.7	44.1	0	464,485	0
Charlotte, NC	66.4	41.6	0	857,425	0
Asheville, NC	73	60.1	0	91,560	0

A: Supply disruption in Nashville was *much lower* than reported in other markets.

RESILIENCE ENHANCEMENT OPTIONS (REOs) IDENTIFIED IN PREVIOUS DHS MARINE RELATED PROJECTS

- **Compile and Document Information**
  - Infrastructure vulnerabilities and priority list for repair
  - Critical infrastructure lists
  - Roles/responsibilities during disaster scenarios
  - Standard and alternate operating procedures
- **Collaborate and Coordinate**
  - Host a series of planning workshops to familiarize partners with risk
  - Inform public and private entities of relevant vulnerabilities to systems and provide support for enhancing resiliency
  - Work collaboratively with local, state, and federal emergency management organizations
- **Improve existing infrastructure**
  - Address aging infrastructure (bridges, locks, dams)
  - Undertake soil liquefaction mitigation efforts in earthquake prone areas
  - Share results of natural hazard modeling on facility specific basis to encourage owner/operator hazard mitigation planning
- **Incorporate Additional Tools**
  - Vessel Queue Prioritization and Sorting Tool (USCG)
  - Cyber Security Evaluation Tool (CSET) and Cyber Resilience Review (CRR)

STAKEHOLDER MEETING 2

Disruption Scenario 1 – Multimodal Impacts

- Colonial Pipeline Spur to Tennessee, Service Interruption
  - Megan Simpson – USACE Nashville District
  - Ben Bolton – TDEC Office of Energy Program's (OEP)
  - Barry Gipson - James Companies, former Pipeline Company Executive
  - Moderator: Miguel Moravec – Vanderbilt University

Takeaways

  - Develop additional liquid bulk waterway terminal capacity
  - Identify mothballed terminals, especially near multimodal assets
  - Continue strong industry / government collaboration

STAKEHOLDER MEETING 2

Disruption Scenario 2 – Lock Outage

- Cheatham Lock and Dam Maintenance
  - Megan Simpson – USACE Nashville District
  - Gene Whelan - Pine Bluff Materials, Operator of Largest Multicommodity Marine Terminal on the Cumberland River
  - Steve Southern - Ingram Barge Company, Activation of Waterway Action Plans to Improve Stakeholder Coordination
  - Moderator: Craig Philip – Vanderbilt University

Takeaways:

- Update Building Codes
- Continue strong industry / government collaboration

STAKEHOLDER MEETING 2

Disruption Scenario 3 – Waterway Navigability Impacted by Earthquake

- New Madrid Fault Event Impacting Tennessee/Cumberland/Ohio River Confluence and Bridge Crossings
  - James M. Wilkinson, Jr. – Executive Director, CUSEC (Central US Earthquake Consortium)
  - Ben Bolton – TDEC Office of Energy Program's (OEP)
  - Moderator: Janey Camp - Vanderbilt University

Takeaways:

- Increase Traffic on Tombigbee River
- Update Building Codes
- Rely on resilient, alternate energy sources / vehicles

RESILIENCY ENHANCEMENT OPTIONS FOR REGION

- **Expand Chattanooga and Knoxville terminals to accept fuel barges**
  - Theme: Improve existing infrastructure
  - Note: Colonial pipeline purchased one of the fuel terminals in Chattanooga, so when their services went offline it impacted that terminal as well
- **Increase Traffic on Tombigbee River**
  - Theme: Collaborate and Coordinate
  - Scenarios: Earthquake impacting Mississippi river, shutdown of colonial pipeline
  - Note: TennTom much more narrow than Cumberland, Tennessee
- **Update Building Codes**
  - Theme: Improve existing infrastructure
  - Scenarios: All
  - Proactive building codes are among best mitigation techniques

SUMMARY

- Applied *Port Resilience Guide* approach to an inland system
- Involved stakeholders through process
- Identified key disruption scenarios and considered impacts
  - Unique disruption provided additional study benefit
- Key resilience enhancement options identified

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