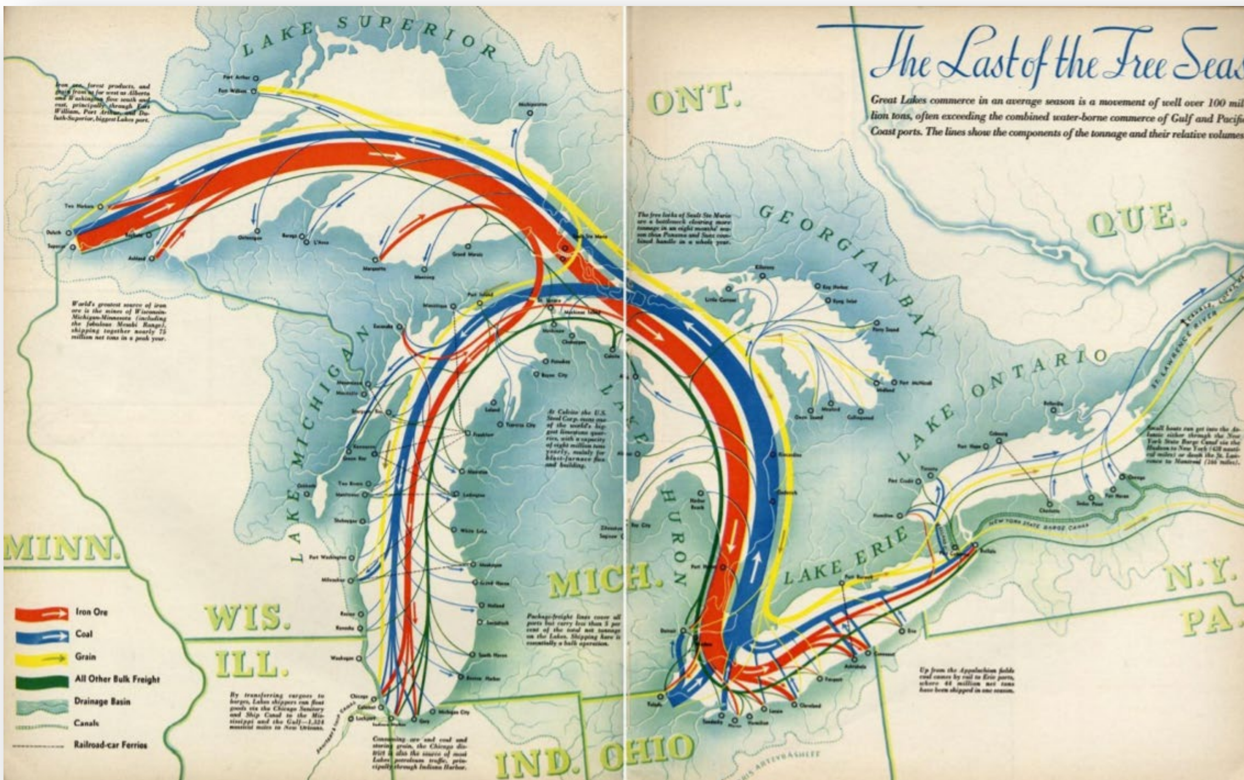
Oil Spill Economics: Estimates of the Economic Damages of an Oil Spill in the Straits of Mackinac in Michigan

Addendum A | Multibillion-dollar Economic Impact to Great Lakes Shipping, Steel Production, and Jobs



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Executive Summary

The waterways of the Great Lakes basin provide the basis for a regional shipping industry dominated by steel that supports millions of U.S. jobs in manufacturing and associated value chains. Enbridge Line 5, an aging oil pipeline, transports Canadian sweet crude oil through Michigan's Straits of Mackinac on its way from the Alberta tar sands to refineries in Ontario. This report is an addendum to our May 2017 estimate[1] of $6.3 billion in potential economic and ecological impacts of a significant spill from this pipeline, and it extends the findings of the original study to include estimated impacts on the shipping industry and associated value chains.

Simulations of a 25,000-barrel oil spill[2] from Line 5 revealed off-shore impacts extending beyond the Straits of Mackinac and into Lake Michigan, Lake Huron, Georgian Bay, and the St. Marys River, which is adjacent to the Soo Locks, where freighters, barges, tugboats, and other watercraft traverse the 21-foot drop between Lake Superior and Lake Huron. An oil spill from Line 5 likely would likely lead to the closure of shipping traffic across the Straits of Mackinac, as well as a closure of the Soo Locks. According to the U.S. Department of Homeland Security, closure of one of the two operational locks, the Poe, could send North America into a prolonged recession and precipitate the loss of more than 10 million U.S. jobs.

Estimates suggest a two-week closure of the Soo Locks during the early shipping season would halt U.S. steel production and curtail production along steel-dependent value chains, including the automotive industry. We estimate the economic impact of a temporary closure of routes through the Soo Locks and St. Marys River for 12 days and the Straits of Mackinac for 15 days, which would be necessary to avoid vessel interference during oil cleanup operations and to prevent the transport of oil to unaffected areas.

We conducted interviews with experts and other key informants, and used the data collected to develop a causal loop diagram, which allowed for the development of a system dynamics model of the shipping industry. Scenarios revealed that impacts would increase rapidly because of bottlenecking of shipping vessel traffic, and the effects would slow as the industry recovers.

We estimate lost economic output resulting from a 15-day closure to be $45.8 billion. Additional scenarios of longer closure periods revealed economic impacts of over $1.1 trillion for a 180-day closure (which is consistent with estimates generated by the U.S. Department of Homeland Security and the U.S. Army Corps of Engineers). The Independent Risk Analysis (2018) on Line 5 conducted for the State of Michigan included an estimate of economic impacts of a worst-case oil spill to the shipping sector based on a closure of the Straits of Mackinac for five days, and their estimate was only $42 million. However, that estimate was based on daily operational costs for the ships only, rather than the impacts to the broader value chain linked to the steel and other commodities being shipped. The report acknowledges that a stoppage of five days "will likely result in bottleneck delays in vessels along the Straits as well as at the Soo Locks, but these costs are not considered" (p.293). The estimates provided in

[1] See "Oil Spill Economics: Estimates of the Economic Damages of an Oil Spill in the Straits of Mackinac in Michigan," Robert B. Richardson, Ph.D., and Nathan Brugnone, M.S., Department of Community Sustainability, Michigan State University, May 2018, commissioned by FLOW (For Love of Water), available at http://flowforwater.org/wp-content/uploads/2018/05/FLOW_Report_Line-5_Final-release-1.pdf.

[2] Simulations conducted by University of Michigan Water Center research scientist Dave Schwab.

this Addendum are significantly greater primarily due to the consideration of the costs of bottleneck delays, lost business revenue, and the associated effects on steel mills, automobile manufacturing facilities, and related sectors. These estimates are likely conservative in that they extended independent estimates based only on closure of the Poe Lock, and not the open waters of the Great Lakes and the Straits of Mackinac.

Introduction

The Great Lakes comprise the largest body of surface freshwater in the world. This precious resource forms the basis for the unique economy of this region, which is the third largest economy in the world, with an estimated Gross Domestic Product (GDP) exceeding $6 trillion dollars (Homeland Security, 2015b; Martin Associates, 2018). This success owes to the transportation efficiencies and resulting competitive edge conferred by Great Lakes waterways to the regional shipping industry, as depicted in Figure 1, which supports more than 1.5 million (with some estimates exceeding 10 million) U.S. jobs in manufacturing and associated value chains (Homeland Security, 2014; Homeland Security, 2015b; Martin Associates, 2018; USACE, 2018). The U.S. Department of Homeland Security (2015a; 2015b), however, has deemed “[o]ne of the Nation’s most economically vital systems … potentially the least resilient” and “the Achilles heel of the North American industrial economy.”

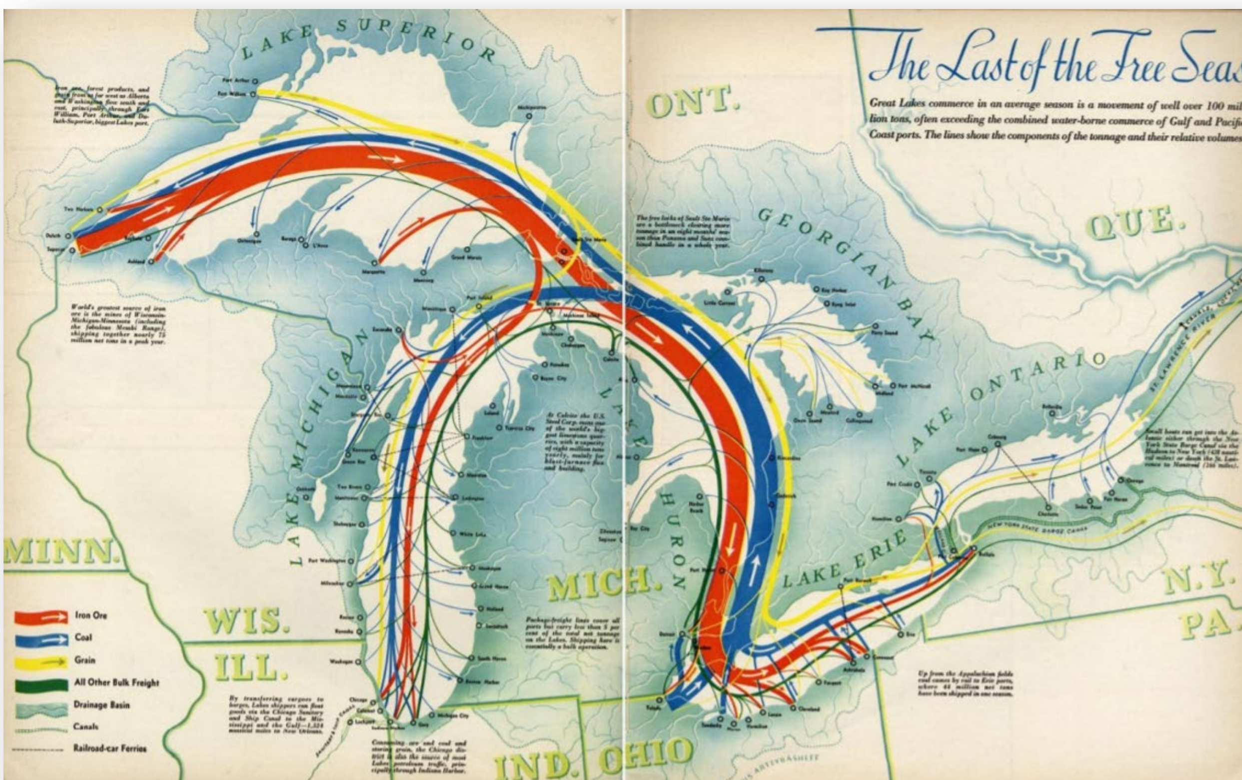

Figure 1: Map of 1940s iron ore, coal, grain, and other bulk commodity shipping routes (Homeland Security, 2015b)

As North American oil pipelines have become central to broader debates about the environment and Indigenous peoples' rights, the potential threat to the Great Lakes of one pipeline, in particular, has captured the awareness of Midwestern constituencies and lawmakers. Enbridge Line 5, an aging oil pipeline, traverses Michigan's Straits of Mackinac, through which it transports Canadian sweet crude oil on its way from the Alberta Tar Sands back to refineries in Canada.

The potential economic impacts of a significant oil spill from this pipeline into the turbulent waters of the Mackinac Straits were detailed in the main portion of this report. The present addendum extends the findings of the original study to include estimated impacts of a Line 5 spill on the shipping industry and associated value chains.

Background: Great Lakes Shipping

Each year, as for the last 200, the ice-free months of approximately March through December on the Great Lakes are alive with commerce. Lake Freighters, or "Lakers" (and some of the smaller 'Salties'), transport dry bulk commodities within and between states, as well as internationally. Today, more than 70 - 80% of all iron ore mined in the United States must traverse the Great Lakes (Homeland Security, 2014; Miller, 2018). Most of this iron ore, in the form of taconite, makes its way from ports along western Lake Superior to refineries throughout the Great Lakes (Miller, 2018; USACE, 2018); see Figure 2 for locations of mines and shipping ports. Along with taconite, bulk commodities like coal, limestone, and grain (10% of U.S. exports of the latter) make their way through one or more narrow water elevators called locks (Homeland Security, 2015b; Martin Associates, 2018). Recent reports from Martin Associates, the United States Army Corps of Engineers (USACE), and Homeland Security underlie the economic and industrial importance of the maritime shipping industry of the Great Lakes. Martin Associates (2018) estimates the economic impacts of a fully functioning shipping industry on the Great Lakes at $35 billion U.S. (in annualized revenue). The USACE (2018) and the Department of Homeland Security (2015a; 2015b) reports, on the other hand, reemphasize generation-old concerns about the Soo Locks. During World War II, the Soo was heavily fortified against aerial attack, due to the United States' acute awareness of the vulnerability of the locks in their role as a major artery of North American industry (Warner, 2014). Today, a closure of one of the two operational locks, the Poe, according to the Department of Homeland Security, could send North America into prolonged recession and precipitate the loss of more than 10 million U.S. jobs (mainly in California, Texas, and the Midwest) and 2 to 5 million Canadian and Mexican jobs (Homeland Security, 2014; Homeland Security, 2015b; Todd, 2016). Industries, from automotive to construction to agricultural, are predicted to be negatively impacted by such a closure (Homeland Security, 2015b; USACE, 2018). Even the case of a vessel grounding along the St. Marys River—the waterway connecting Lake Superior to Lake Huron and containing the Soo Locks—could, and occasionally does, disrupt manufacturing markets over the course of mere days via bottlenecking and cascading effects of multi-vessel traffic delays (Homeland Security, 2015b; USCG, 2017). The USACE (2018) and Homeland Security (2015b) estimates suggest a two-week closure of the Soo during the early shipping season could halt U.S. steel production and curtail production along steel-dependent value chains including the automotive industry.

Figure 2: Taconite mines and ports in Northern Minnesota (Homeland Security, 2015b)

Cascading economic impacts arising from vessel delays are intrinsic to the Great Lakes Navigation System (GLNS) (USCG, 2017; USACE, 2018). There are few physical boundaries congruent with those erected for geopolitical ends. Hence, effective governance of the GLNS waters is predicated upon a shared sense of place and reciprocity. The GLNS "is a [nonlinear] system of… locks, ports, harbors, navigation channels, dredged material disposal facilities and navigation structures," whose economic dynamism is characterized not by competition, but by interdependence (USACE, 2013a). This means a delay at one port, even a small port, may translate to significant impacts down the supply chain as delays compound each other (USACE, 2013a). The GLNS, then, is conceived of as a system not unlike a river ecosystem with many inflowing streams, where a change in the volume of a few major tributaries or keystone agents can alter the output of the entire system, and where a high degree of unpredictability suffers the most dependent and vulnerable first. Consider, in this context, tightly coupled, Great Lakes waterway-dependent industries like the taconite mining, steel refining, automotive manufacturing, sales, and repair industry nexus, as depicted in Figure 3. Consider also the capital-intensive nature of this resource-based value chain with substitutes for neither capital (steel) nor shipping (Miller, 2018; USACE, 2018), and the system vulnerability to large perturbations, like an oil spill event, becomes apparent. See Miller (2018), USACE (2018), and Homeland Security (2015b) for further discussion regarding the characteristics generating vulnerability in steel-dependent industries.

Figure 3: Ports, Mills, Rails, & Shipping Routes (Homeland Security, 2015b)

Methods

In preparation of this addendum, we interviewed civilian and military personnel, domain experts and researchers, community organizations, and other interested stakeholders. We then identified a foundational set of contacts through literature and discussion and conducted sampling via convenience. Interviewees subsequently recommended additional contacts to expand our stakeholder network, a method known as snowball sampling. We maintained cognizance of the potential for self-selection given the contentious nature of the topic. Considering this last point, we extend thanks to those who were willing to discuss the topic.

Stakeholder interviews were aggregated and cross-referenced with literature to identify consistent narrative themes. The key thematic elements were then extracted and arranged into a Concept Map, a diagram representing ideas and their linkages. Next, we added arrows between model elements to represent causal relations. This representation is known as a Causal Loop Diagram. We iteratively generated refinements of the Causal Loop Diagram until arriving at the simplest diagram that sufficiently captured relevant elements and their causal relationships. Finally, we developed a System Dynamics Model based on the Causal Loop Diagram.

This addendum follows the same formula as the main study. The results represent the synthesis of diverse narratives in the context of a credible oil spill scenario. Credible, in this case, means a nonzero probability of occurrence and most worthy of consideration according to approximate stakeholder consensus. To remind the reader: We assume the same hypothetical scenario involving a major spill of approximately 2,500,000 gallons of crude oil (about 59,500 barrels). The scenario is based on assumptions related to (i) the vulnerability of the pipelines to damage from events such as an anchor strike, (ii) a failure of the automatic response valves, and (iii) a delay in human response of up to two hours. We draw upon Schwab (2016) to help estimate spill extent. Given that our spill scenario is 2,500,000 gallons, we assume that the spill extent exceeds that of the 1,000,000-gallon-spill scenario presented in Schwab (2016). Specifically, we assume that oil spreads far enough to necessitate the temporary closure of routes through the St. Marys River and, hence, by proxy, the Soo Locks. Based upon USACE (2018), we assume that 95% of the traffic in the GLNS represents inter- and intra-lake trade (i.e., non-international). Furthermore, we assume the spill event occurs during the early part of the shipping season when supply chain reserves are strained. Given that extreme winter weather drives steel reserve depletion, we assume an earlier-than-average end to the prior shipping season and a later-than-average beginning to the subsequent.

Additionally, we assume United States Coast Guard closure of shipping routes through the Straits of Mackinac for 15 days and the Soo Locks for 12 days. Were an oil spill to occur in the Straits, closure of these shipping routes would be necessary to (i) avoid vessel collision during booming and related oil cleanup operations, and (ii) to prevent the transport of oil to unaffected areas. It is important to note, however, that vessel captains often behave more conservatively than USCG orders; this speaks to the adage that, "there are old sailors, and there are bold sailors, but there are no old, bold sailors." On the other hand, it is during the last approximately 10% of the shipping season that profits are generated. Hence, the behaviors of vessel operators during this time of year can be more aggressive. As these two pieces of information are contradictory, we shall take the average traffic as a reasonable estimate.

We reemphasize that the composition of total GLNS traffic attributed to bulk commodities like steel, combined with the interdependent port structure of the GLNS (see USACE, 2018), indicates that cascades and feedback loops generate most of the economic impacts in a malfunctioning GLNS and, therefore, our scenario. Thus, in fine-tuning our shipping impact scenario, we draw upon the Meadows et al. (2018) Independent Risk Analysis produced for State of Michigan. In particular, they highlight the potential for compounded impacts arising from bottlenecked vessel, yet their shipping estimates employ a simple summation and, thus, do not include feedback effects. The State of Michigan directed this report to represent a *worst-case spill event*, yet Meadows et al. (2018) assume only a 5-day delay to Straits of Mackinac shipping routes. A 5-day delay within the Meadows et al. framework is assumed short enough to not trigger these feedbacks. Yet their report also states the potential for significantly longer impacts than 5 days. Interview data agree. This assumption, then, is insufficient for an assessment of worst-case economic impacts resulting from a *force majeure*. Thus, while we do not endeavor to approximate a worst case, we assume a slightly longer delay of 15 days and apply reasoning from Meadows et al. (2018), USACE (2018), and Homeland Security (2015b), as well as interview data, to justify parameterization of a gradual return to full industrial capacity. The last assumption is founded upon compounded shipping vessel delays, the resulting halt of taconite mines, capital depletion at refineries and factories, the reduction of inventory at retail outlets, and the subsequent gradual return to full capacity of each of these interlinked operations. For instance, it took two months for a U.S. Steel mill to return to full capacity following a crane accident (Platts, 2014). We also note, as in Homeland Security (2015b), that a single missing part will stall manufacturing, and the on-demand manufacturing paradigm exacerbates potential cascading of such effects (Homeland Security, 2015b). Figure 4 is supplied to illustrate the interdependencies that underscore our assumptions. More explicitly, Gary Works (U.S. Steel), one of the largest steel mills in the U.S., halted production during April of 2014 due to weather-induced iron ore delay (Homeland Security, 2015b). At least one more steelmaker curtailed production, and "[s]teel that had been ordered was not made… Some powerplants were extremely low on coal," while, "[t]he limestone trade did not resume in earnest until well into April" (Lake Carriers' Association, 2015). Furthermore, more than *50% of total steel production in the United States occurs at three facilities (including Gary Works) located at the southern end of Lake Michigan* (Homeland Security, 2015b).

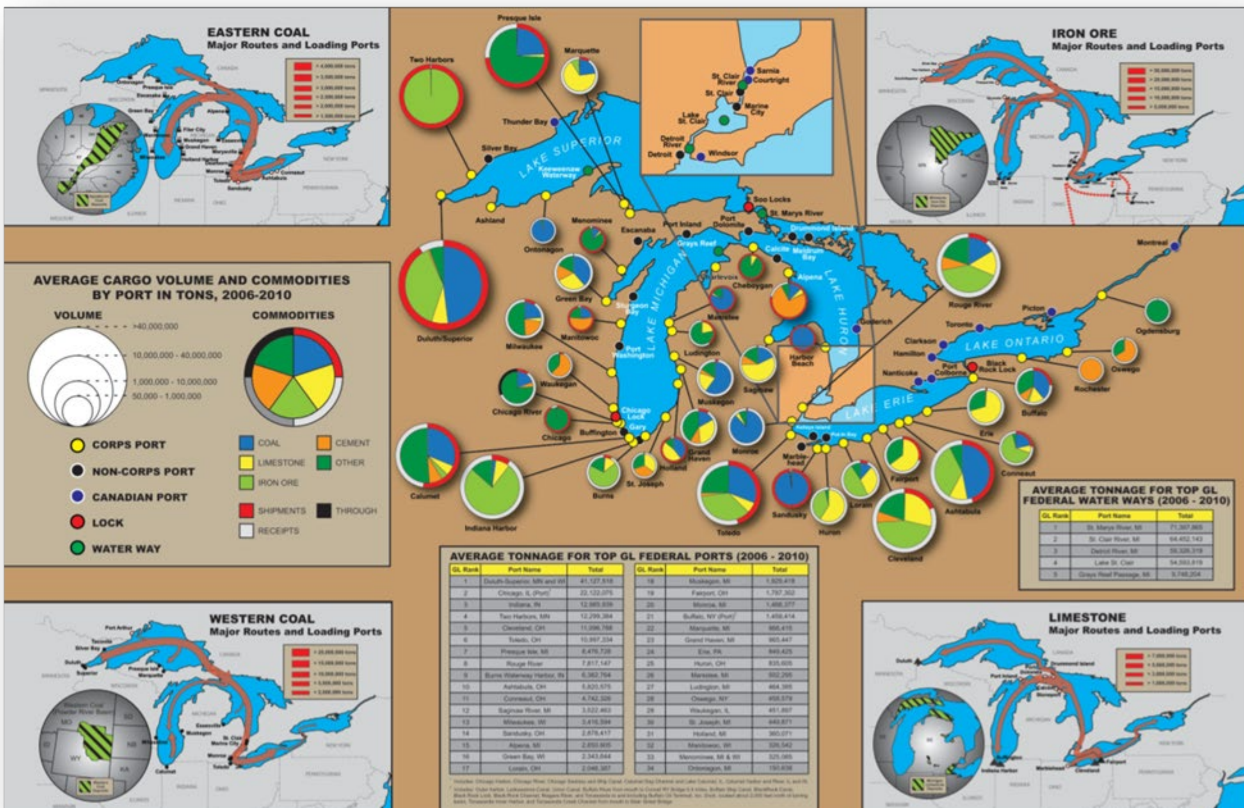

Figure 4: Interdependency of Great Lakes shipping (USACE, 2013b)

Finally, we note that parameter estimates are based upon estimates of delays at the Soo Locks. This is useful and appropriate for at least two reasons: (i) We assume both the Straits of Mackinac and the Soo Locks are affected, and (ii) the best literature available examines failure of the Soo Locks. Given the vessel traffic overlap among the Soo Locks and the Straits of Mackinac (see Figure 4), as well as the assumption of a simultaneous closure of both, the Soo Locks makes a useful and powerful proxy.

Results

The Causal Loop Diagram of our System Dynamics Model is displayed below in Figure 5. Green components represent aspects of the economy, blue are vessel movement, and red are oil spill related.

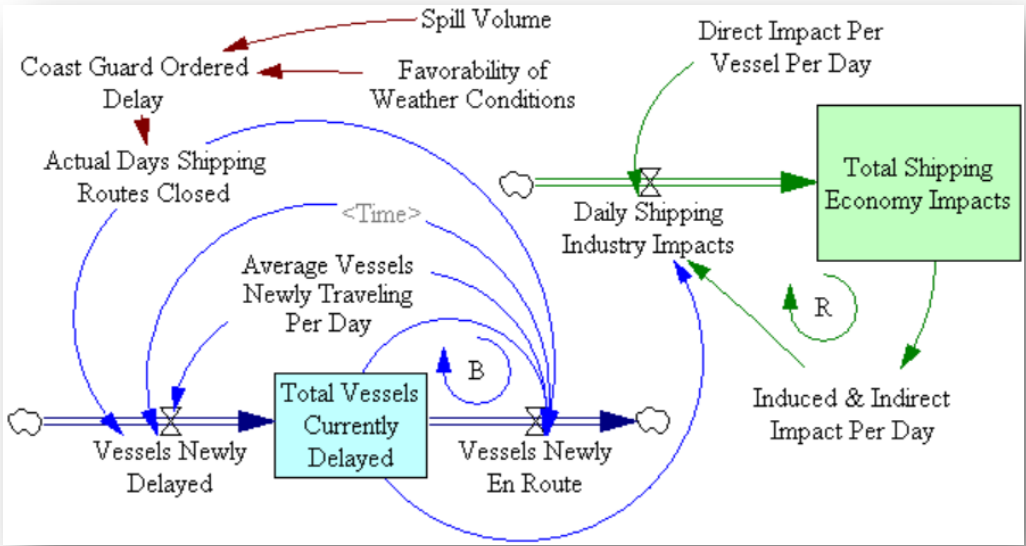

Figure 5: System Dynamics Model of Oil Spill Impacts to Shipping Industry

Of particular interest are (i) the reinforcing feedback loop (**R**) between *Total Shipping Economy Impacts* and *Indirect & Induced Economic Impacts Per Vessel Per Day*, and (ii) the balancing feedback loop (**B**) between *Total Vessels Currently Delayed* and *Vessels Newly En Route*. The (**R**) feedback loop generates secondary economic impacts dependent upon total impacts to the economy. This is consistent with the definition of secondary economic impacts. The (**B**) feedback loop quantifies the compounding effects of bottlenecking vessel traffic and cascading delays within steel-associated value chains as producers shutdown following waterway closures and subsequently restart.

Figure 6 demonstrates the expected: The initially gradual buildup of effects immediately following the oil spill grows rapidly as impacts cascade throughout the system and compound. Impacts eventually level off following the period of rapid expansion as industry recovers. Figure 7 is provided for scenario comparison and model validation: Note increasing lengths of waterway closure generate similar, but stretched, behavioral patterns with larger impacts. Plotting the scenarios on longer timescales (e.g., a year) produces leveling-off like that in Figure 6.

Figure 6: Economic impacts of 15-day closure

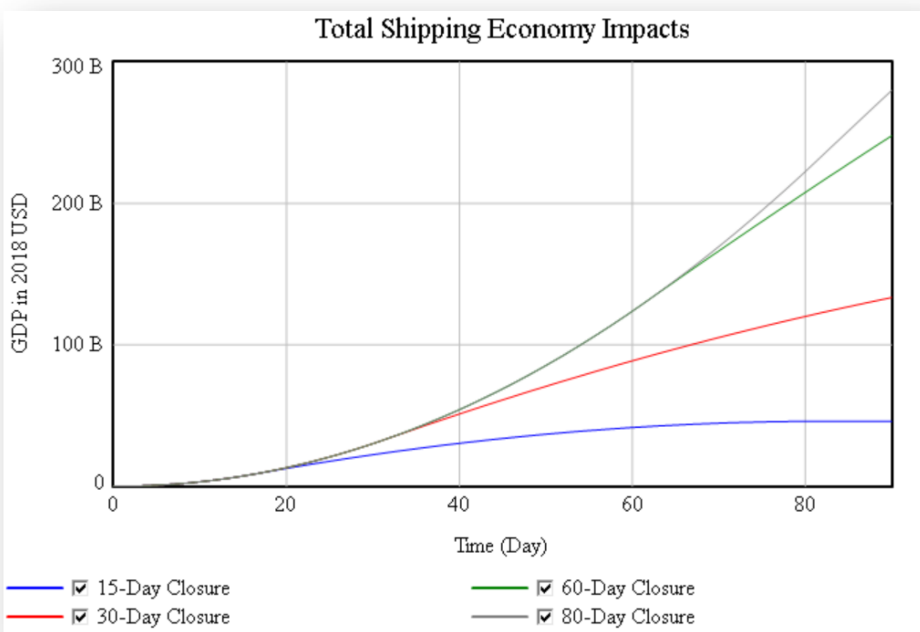

Figure 7: Comparison of economic impacts of 15-, 30-, 60-, and 80-day closure

Numerical estimates of this study are provided in Table 1 below. Note the 180-day closure scenario is consistent with Homeland Security (2015b) and the USACE (2018) 6-month-plus scenario.

Table 1: Economic impacts to Great Lakes shipping industry as GDP in 2018 USD quantified on day 90 (except where noted)

Length of Straits Closure	**Economic Impacts (*in terms of forgone GDP*)**
15-Day Closure	$ 45,837,000,000
30-Day Closure	$ 133,401,000,000
60-Day Closure	$ 247,855,000,000
80-Day Closure	$ 279,890,000,000
180-Day Closure (*quantified at day 180*)	$ 1,174,480,000,000

Discussion and Conclusions

First, let us note the estimates in Figures 6 and 7 as well as Table 1 are computed as total impacts to the steel industry value chain as a function of shipping delays at the Soo Locks and the Straits of Mackinac. Potential economic impacts to the second-, third-, and fourth-largest shipping-dependent industries—coal, grain export, and limestone—are implicitly included via raw material dependencies and secondary economic effects. Hence, impacts to smaller industrial nexuses are only implicitly accounted for as well. This implies that overall impacts could be far greater. And though we are primarily focused on the 15-day scenario, additional scenarios are provided for both validation and consideration.

We suggest study findings be interpreted within the following context: Shipping impacts are not recoverable. A quote describing the impact of delays imposed by the severe winter of 2014 illustrates this potential: "Make no mistake about it, some economic activity was lost forever because of the difficulties in keeping the shipping lanes open," (Lake Carriers' Association, 2015b). Thus, a rush to offset incurred impacts may futile. The findings of Homeland Security (2015b) support this analysis and show that even a 2-week delay solely to the Poe Lock would drive business shutdowns and increased unemployment following a shutdown of 75% or more of the steel industry. These are among the key insights of the study.

Critics of this study may be tempted to cite the estimated total size of the Great Lakes shipping economy as presented by Martin Associates (2018)—$35 billion USD. This figure, however, represents a *functioning*, as opposed to *malfunctioning*, shipping industry. Another course of critical reasoning might attempt to draw upon studies predating USACE (2018) and Homeland Security (2015b) that produced much smaller estimates, such as the outdated USACE study concluding impacts of $160 million U.S. for a 30-day closure. As argued, however, in Homeland Security (2015b), "[t]he impacts described here are more severe than those predicted in prior studies because this analysis took a *comprehensive view of the supply chain and its relationship to the National economy* [emphasis added]." However, this estimate is derived from the Martin Associates study (Garret, 2015), which produced estimates one-and-a-half orders of magnitude lower than those of USACE (2018) and Homeland Security (2015a, 2015b). Adjusting for this discrepancy, we recover economic impacts of approximately $50.5 billion U.S., which is slightly greater than our estimate of $45.8 billion. We may, hence, interpret this as verification of our estimate.

Implicit in our estimate are regional dependencies upon the steel industry. If we recall that the last 10% - 15% of the shipping year is dedicated to profit generation, we may understand the underlying narrative communicated by our estimate. Given a long enough delay at the right (or, in this case, wrong) time of year, each point along the steel industry supply chain nexus will lack adequate capital reserves. There are no backup mines. Refineries and manufacturers cannot substitute rail or truck transport without incurring significant impacts due to (i) a lack of necessary infrastructure, and (ii) a significantly increased shipping premium associated with the alternatives (Homeland Security, 2015b; Miller, 2018; USACE, 2018). Miller (2018) also cautions the lack of historical precedent implies much uncertainty regarding how businesses would behave given a catastrophe of this nature. A number of businesses may be forced to under-employ or simply shutdown to survive (Miller, 2018; USACE, 2018).

Consistent with the authors of USACE (2018) and Miller (2018), we emphasize that this estimate is potentially conservative given the adaptation of data from a scenario that considered closure of only the Poe Lock and not the Straits of Mackinac. Yet, given the relative size of the steel industry nexus and economy, we are confident in the usefulness of the proxy data. Furthermore, the most common destinations for Soo Locks' vessel traffic are ports along Lake Michigan (Homeland Security, 2015b). A more telling fact may be that, "The ***three largest steel mills***, which ***account for about half of the domestic integrated steel capacity***, are ***located at the southern tip of Lake Michigan***, around Gary, Indiana: Indiana Harbor (ArcelorMittal), Gary Works (U.S. Steel), and Burns Harbor (ArcelorMittal) [emphasis added]," (Homeland Security, 2015b); see Figure 4 for a detailed map. Given (i) the scenario assumption that the spill radius is large enough to result in the closure of the Soo Locks for most of time the Straits of Mackinac are closed; (ii) given that closure of the Soo Locks prevents Lake Superior-bound traffic; and (iii) given delays in restarting (a) vessel traffic, (b) mining, (c) refinement, (d) and manufacture, we are confident in the applicability of the model as a conservative estimate of total scenario-relevant economic impacts.

References

Garret, E. 2015. New Great Lakes heavy icebreaker facing stiff winds in Congress. MLive. Available at: https://www.mlive.com/news/grandrapids/index.ssf/2015/08/peters_great_lakes_icebreaker.html.

Homeland Security. 2014. Great Lakes Shipping Study. National Protection and Programs Directorate. Integrated Analysis Task Force. Homeland Infrastructure Threat and Risk Analysis Center.

Homeland Security. 2015a. Unanticipated Closure of the Poe Lock. National Protection and Programs Directorate. Office of Cyber and Infrastructure Analysis (OCIA). Available at: https://www.csgmidwest.org/GLLC/documents/DHSSooLocksCongressionalHandout.pdf.

Homeland Security. 2015b. The Perils of Efficiency: An Analysis of an Unexpected Closure of the Poe Lock and Its Impact. Office of Cyber and Infrastructure Analysis. Available at: http://www.greatlakesports.org/wp-content/uploads/2016/03/OCIA-The-Perils-of-Efficiency-An-Analysis-of-an-Unexpected-Closure-of-the-Poe-Lock-and-Its-Impact.pdf.

Lake Carriers' Association. 2015. Lakes Deep Freeze Cost Economy $705 Million and 3,800 Jobs. Available at: http://www.lcaships.com/2015/01/06/lakes-deep-freeze-cost-economy-705-million-and-3800-jobs/.

Martin Associates. 2018. Economic Impacts of Maritime Shipping in the Great Lakes-St. Lawrence Region. Saint Lawrence Seaway Development Corporation, et al. Available at: http://greatlakesseaway.org/downloads/2018-glsls-study-en-hr.pdf.

Meadows, G. et al. 2018. Independent Risk Analysis for the Straits Pipelines: Final Report. Michigan Technological University. Available at: https://mipetroleumpipelines.com/document/independent-risk-analysis-straits-pipelines-final-report.

Miller, S. 2018. A Regional and National Economic Assessment of the Soo Locks at Sault Ste. Marie, Michigan. Michigan State University. Available at: https://www.lre.usace.army.mil/Portals/69/soolocks/NewSooEconomicStudy/New%20Soo%20Lock%20Appendix%20B%20Attachments.pdf?ver=2018-07-24-101553-383.

Platts. 2014. Force Majeure Events at US Steel's Great Lakes Works Could Disrupt Supply." Available at: http://www.platts.com/latestnews/metals/pittsburgh/force-majeure-events-at-us-steels-great-lakes-21470889.

Schwab, D. 2016. Statistical Analysis of Straits of Mackinac Line 5: Worst Case Spill Scenarios. Water Center, University of Michigan, Ann Arbor, MI: University of Michigan. Available at: http://graham.umich.edu/media/pubs/Mackinac-Line-5-Worst-Case-Spill-Scenarios.pdf.

Todd, S. 2016. Report: U.S., Michigan Face Dire Consequences if Soo Locks Fail. Detroit Free Press. Available at: https://www.freep.com/story/news/politics/2016/03/03/us-michigan-face-dire-consequences-if-soo-locks-fail/81261608.

United States Army Corps of Engineers. 2013a. Great Lakes Navigation System: Economic Strength to the Nation. Available at: https://www.lre.usace.army.mil/Portals/69/docs/Navigation/GLN_Strength%20to%20the%20Nation%20Booklet2013v2_final2w.pdf.

United States Army Corps of Engineers. 2013b. The Great Lakes Navigation System. Available at: https://www.lre.usace.army.mil/Portals/69/docs/Navigation/GrtLaksNavSysBro_REV%2011%20Feb%202013.pdf.

United States Army Corps of Engineers. 2018. Soo Locks, St. Marys River Sault Ste. Marie, Michigan: New Soo Lock Economic Validation Study. Available at: https://www.lre.usace.army.mil/Portals/69/soolocks/NewSooEconomicStudy/New%20Soo%20Lock%20Econ%20Validation%20Study%20Main%20Report.pdf?ver=2018-07-19-082558-967.

United States Coast Guard. 2017. VTS St. Marys River Fact Sheet. Available at: https://homeport.uscg.mil/Lists/Content/Attachments/854/VTS%20Facts.pdf.

Warner, D. 2014. Northern Michigan History: When the Soo Locks Readied for World War II. Available at: https://mynorth.com/2014/02/northern-michigan-history-when-the-soo-locks-readied-for-world-war-ii.

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