

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

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Executive Summary

The Straits of Mackinac is a roughly five-mile (eight-kilometer) long section of waterway that joins Lakes Michigan and Huron into a single hydraulic system. The Mackinac Bridge connects Michigan's Upper and Lower peninsulas at their narrowest distance, and a submerged section of Enbridge Energy's Pipeline 5 (Line 5) spans the Straits of Mackinac just west of the Mackinac Bridge. The objective of this report is to provide an estimate of regional economic damages resulting from a potential breach of Line 5 at or near its crossing at the bottom of the Straits of Mackinac.

The framework for this estimation of the economic damages of a rupture of Line 5 in the Straits of Mackinac is based on a hypothetical scenario involving a major spill of approximately 2,500,000 gallons of crude oil (about 59,500 barrels). The scenario would involve damages to approximately 900 miles of shoreline across five Tier I counties (i.e., Charlevoix, Cheboygan, Emmet, Mackinac, and Presque Isle), for which impacts are expected to be greater, and ten Tier II counties (i.e., Alcona, Alpena, Antrim, Benzie, Chippewa, Delta, Grand Traverse, Iosco, Leelanau, and Schoolcraft Counties). 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. The basis for these assumptions was derived primarily from a document review and interviews with experts. It is important to note that this oil spill scenario does not necessarily reflect, nor is it intended to be interpreted as the worst-case scenario; rather, it is a reasonable case that is informed by expert knowledge. The scenario reflects the real possibility of technological failure and delay in human response. In the context of Line 5, the worst-case scenario may be far greater in terms of scale, scope, and the magnitude of impacts.

Estimates of economic damages of an oil spill under this scenario were developed based on information gathered from key informant interviews and a review of public documents and references listed at the end of this report. We include estimates of two categories of economic damages from an oil spill: (i) the costs of natural resource damages and restoration, and (ii) the economic impacts to the private sector and to municipalities in the region. The economic costs of natural resource damages and restoration from an oil spill are estimated to be \$697.5 million. These estimates are potentially conservative, given the sensitivity of the freshwater ecosystem and the presence of numerous endangered species.

A breach of the pipeline would have significant impacts to several economic sectors in the region, including tourism, commercial fishing, municipal drinking water and sewer operations, and real estate. The present value of economic damages to the tourism sector from an oil spill under the scenario are estimated to be \$4.8 billion. The present value of economic impacts to the commercial fishing sector is estimated to be \$61.0 million under the scenario. Estimates of the economic damages to municipal water systems related to drinking water provision and wastewater treatment facilities are related to the potential

costs of facility repair and replacement, and the economic damages to municipal water systems are estimated to be more than \$233 million. Finally, we estimated the economic damages to coastal property based on losses of annualized benefits, based on 2017 county equalized values of real and personal property. The present value of economic damages to coastal properties under the scenario is more than \$485 million. The total estimate of potential economic damages from this scenario is more than \$5.6 billion. An overview of the estimates of natural resource damages and economic impacts by sector is presented below in Table 1.

Table 1: Overview of estimates of natural resource damages and economic impacts of an oil spill from Line 5 in the Straits of Mackinac

Category	Economic Damages
Natural resource damages and restoration	\$697,500,000
Economic impacts	
• Tourism	\$ 4,823,082,926
• Commercial fishing	61,050,000
• Municipal water systems	233,090,000
• Coastal property	485,811,163
Total economic impacts	\$5,603,034,089

While the assumptions upon which these estimates are based are admittedly coarse, reflecting the high levels of uncertainty regarding the scope of an oil spill, the estimates themselves demonstrate that the potential economic damages of a release of oil from Line 5 at or near its crossing at the Straits of Mackinac are high. We believe that these estimates are conservative and likely underestimate economic impacts, as they do not take into account the consequences for public health, the challenges related to containment, or the possibility of an oil spill of greater geographic scale. Previous oil spills in open waters have involved tens of billions of dollars in economic damages, and there are reasons to believe that a rupture of Line 5 has the potential to inflict damages of a similar or greater magnitude.

The findings and conclusions expressed in this report are those of the authors, who are responsible for any errors or omissions.

Introduction

The Great Lakes are the largest surface freshwater system on Earth. Only the polar ice caps contain more fresh water. The Great Lakes and their connecting channels contain 84 percent (%) of North America's surface fresh water, and about 21% of the world's supply of fresh surface water, and they are among the most ecologically diverse ecosystems on the planet (EPA, 2017). They provide drinking water to tens of millions of Canadians and Americans and are important to the economies of both Canada and the United States, supporting manufacturing, transportation, farming, tourism, recreation, energy production, and other forms of economic growth (Environment Canada and EPA, 2017).

The Straits of Mackinac is a roughly five-mile (8 kilometer [km]) long section of waterway that joins Lakes Michigan and Huron into a single hydraulic system (Schwab, 2016). The Mackinac Bridge connects Michigan's Upper and Lower peninsulas at its narrowest point, between Mackinaw City and St. Ignace (Adie, 2012). Travelers driving over the Mackinac Bridge in Northern Michigan are treated to one of the most spectacular vistas in the entire Great Lakes region (Alexander and Wallace, 2012). A submerged section of Enbridge Pipeline 5 (Line 5) spans the Straits of Mackinac just ¼-mile west of the Mackinac Bridge. The objective of this report is to provide an estimate of regional economic damages resulting from a potential breach of Line 5 at or near its crossing at the bottom of the Straits of Mackinac. For purposes of this report, the terms breach, spill, and leak will be used synonymously.

Line 5 was built in 1953 by the Lakehead Pipe Line Company (later rebranded as Enbridge Energy Partners, L.P.) and was engineered by the Bechtel Corporation, four years before the Mackinac Bridge was constructed. Line 5 is owned and operated by Enbridge Energy Partners, L.P., a Calgary, Alberta, Canada-based energy company. It is a 645-mile, 30-inch-diameter pipeline that originates in Superior, Wisconsin, travels through Michigan's Upper and Lower Peninsulas, and terminates in Sarnia, Ontario, Canada (Enbridge, 2017). As it travels under the Straits of Mackinac, Line 5 splits into two 20-inch-diameter, parallel pipelines that are buried onshore and taper off to deep levels underwater, crossing the Straits west of the Mackinac Bridge for a distance of 4.5 miles (about 7.2 km). The twin pipelines of Line 5 run about 1,000 feet apart at depths ranging between 100 and 270 feet and have existed at the bottom of the Straits for more than six decades (Groundwork Center for Resilient Communities, 2017). Line 5 occupies the State-owned lakebed of the Straits of Mackinac per an easement authorized by the Michigan Department of Conservation (now Department of Environmental Quality) in 1953 (MPPTF, 2015). In order for this pipeline to be built on state-owned lands and waters, the Michigan Legislature enacted a new public trust law, 1953 PA 10, that authorized certain limited private use of public trust waters for public utilities. Thus, Line 5 occupies public waters and is subject to the public trust, of which the State of Michigan acts as trustee in perpetuity.

Line 5 transports approximately 22.7 million gallons—or up to 540,000 barrels (bbl) per day of light crude oil, light synthetic crude, and natural gas liquids, the latter of which are refined into propane (Alexander and Wallace, 2012; Enbridge, 2017). It is part of the Enbridge Lakehead System, one of the largest networks of pipelines in the world. The pipeline is operated by Canadian-based Enbridge Energy Partners, L.P., and it was originally constructed to transport Canadian oil products to Canadian refineries via the shortest available route. The Lakehead System serves major refining centers in the Great Lakes, the Midwest, and Ontario, Canada, and through connections with affiliated pipelines, the System has access to refineries in the Mid-Continent and Gulf Coast regions. These interstate pipeline networks are regulated by the Pipeline and Hazardous Materials Safety Administration (PHMSA), a federal agency under the U.S. Department of Transportation that enforces pipeline safety rules and regulations. A map of the Lakehead System is presented in Figure 1, and a map of Line 5 is presented in Figure 2.

The focus of this report is on the portion of Line 5 that are the dual pipelines located on the bottomlands of the Straits of Mackinac. However, this represents just a small portion of Line 5—less than 5 miles out of a total 645 miles of the length of the pipeline. It is important to note that the onshore portions of Line 5 pose also pose a significant risk to Michigan's waters. In the Upper Peninsula, Line 5 crosses 16 tributaries within 9 miles of Lake Michigan, and 11 of those are less than 4 miles from the Lake (TMWC, 2017). An oil spill in this area would have a high likelihood of reaching Lake Michigan. In the Northern Lower Peninsula, Line 5 crosses the Indian River, Little Sturgeon River, Pigeon River, and Upper Black River, and passes near many inland lakes, including Burt, Douglas, Mullet, and Paradise Lakes. These water resources are ecologically and economically important, and they are also vulnerable to exposure to risks from Line 5.

This report provides an estimate of the potential economic damages of an oil spill from Line 5 at or near its crossing of the Straits of Mackinac. Estimating the economic damages from such an event involves confronting a number of challenges related to the uncertainty of the scope and extent of the impacts from an oil spill in an open freshwater environment. Using data collected from key informant interviews and a review of relevant reports, publicly-available data, and other documents, potential economic damages were estimated based on a hypothetical spill scenario involving the release of 2.5 million gallons of crude oil, or approximately 59,500 barrels. This scenario is based on an assumption a failure of the automatic response system and a delay in human response.



Figure 1: Map of the Lakehead System (Source: Pipeline and Hazardous Materials Safety Administration)

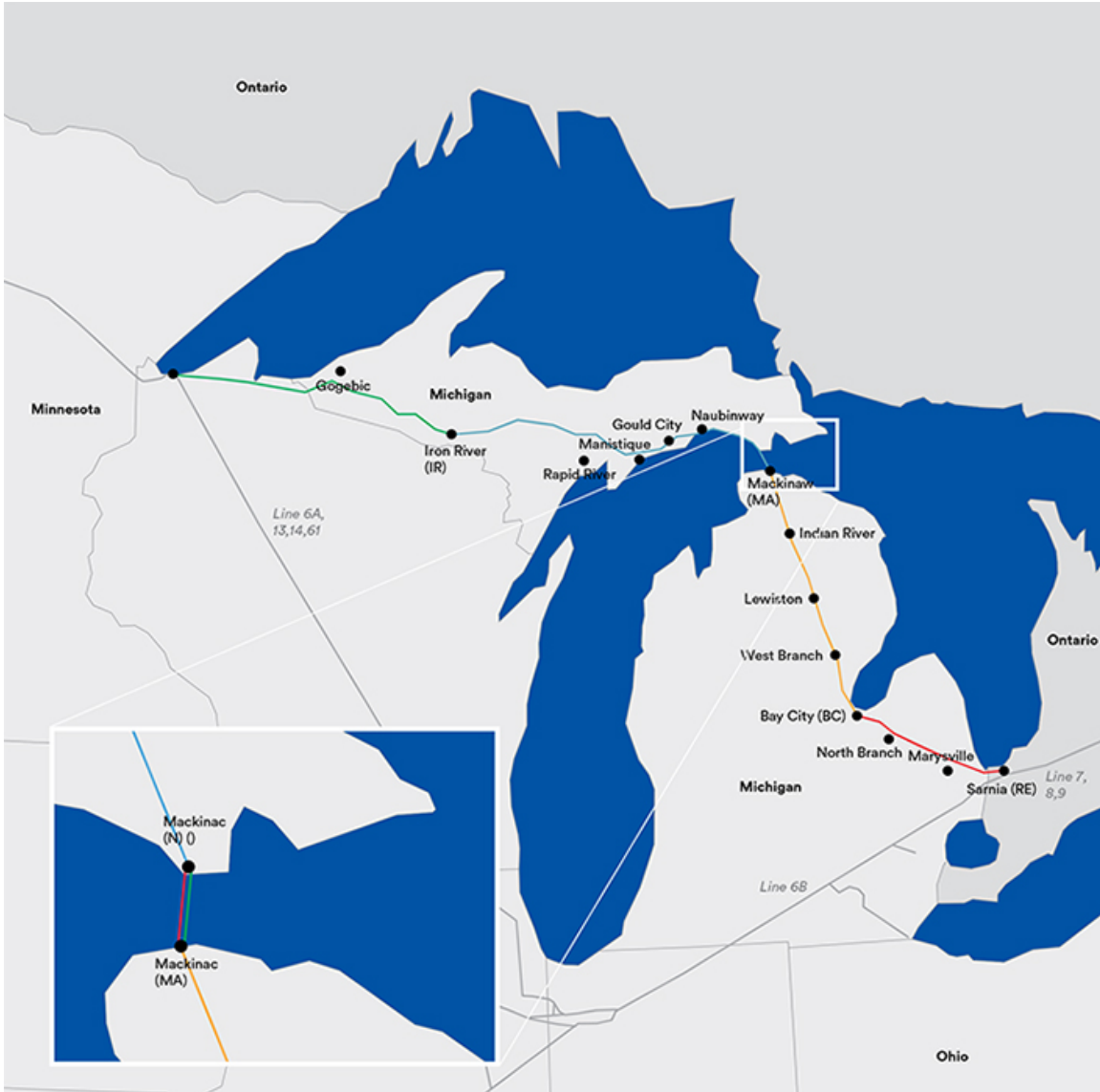


Figure 2: Map of Line 5; inset: crossing at the Straits of Mackinac (Source: Enbridge Energy Partners, L.P.)

There is broad uncertainty about the effects of the release of oil under this scenario, including the location of a possible spill along the pipeline, the time of year, and the extent of affected shoreline. For purposes of this report, we assume that a spill occurs when the waters are ice-free, and we assume that the breach would affect approximately 900 miles of shoreline, primarily near the Straits of Mackinac and extending farther into Lake Huron and Lake Michigan. It is important to emphasize the high levels of uncertainty related to this scenario. If a rupture were to occur, it is possible that automatic response valves would be triggered, and a release of oil could be of a lesser magnitude. However, it is also possible that a failure of those valves and an extended delay in response, such as those experienced in pipeline ruptures, could lead to a release of oil of a far greater magnitude than this scenario, with economic damages well in excess of the estimates in this report. The estimates provided in this report are associated with one

scenario of an oil spill, and they demonstrate the potential economic damages from such a scenario. It is important to note that this oil spill scenario does not reflect a worst-case scenario; rather, it is a reasonable case that is informed by expert knowledge. The scenario also does not consider lost non-market values, including passive use values, such as existence value (Carson et al., 2003). The scenario reflects the real possibility of technological failure and delay in human response. We believe that these estimates are conservative and likely underestimate economic impacts, as they do not take into account the consequences for public health, the challenges related to containment, or the possibility of an oil spill of greater geographic scale. In the context of Line 5, the worst-case scenario may be far greater in terms of scale, scope, and the magnitude of impacts.

Background

Enbridge Energy Partners, L.P. (Enbridge) claims that it is “committed to safe operations, environmental stewardship and social responsibility” (Enbridge, 2013). However, Enbridge is the same firm responsible for the largest (by surface area affected) and most costly inland oil spill in American history (Alexander and Wallace, 2012). An Enbridge pipeline ruptured near Marshall, Michigan in July 2010, and according to the company, it released more than 840,000 gallons of tar sands oil into the Kalamazoo River system (FWS, 2015a). Despite warnings of trouble, oil flowed for 17 hours before Enbridge shut down the pipeline, after being alerted by an outside caller (Ellison, 2017a). From 2010 to 2014, more than 1.2 million gallons of oil have been recovered from the river (EPA, 2016a). The delay in human response with this event raises serious concerns regarding the response to a rupture of Line 5.

In March 1991, the Enbridge Line 3 pipeline ruptured near Grand Rapids, Minnesota, spilling over 1.7 million gallons of oil, much of which flowed into the Prairie River, a tributary of the Mississippi, amounting to the largest inland oil spill in history, in terms of amount of oil released (Shaffer, 2014). In 2014, Enbridge applied for approval of a Line 3 replacement, which would cross 337 miles of Minnesota carrying 760,000 barrels of crude oil per day on its route from Alberta to the Enbridge terminal in Superior, Wisconsin. Across the Enbridge pipeline system, there have been more than 1,000 spills in North America between 1999 and 2014, totaling more than 7 million gallons of oil (Young, 2012; TMWC, 2017).

Although the Enbridge pipeline sections that cross the Straits of Mackinac have never spilled oil into the conjoined waters of Lakes Michigan and Huron, Line 5 has ruptured at least 29 times over the past 50 years and has spilled at least 1.13 million gallons of oil (Ellison, 2017a). Many of these events were relatively small in scope, such as a 2015 spill of just 8 gallons near Marenisco in 2015, and a release of approximately 20 gallons in 2013 near Mackinaw City, perilously close to the Straits area. A larger spill involved the release of 222,600 gallons of oil and natural gas near Crystal Falls, Michigan, in 1999. The rupture was caused by the line lying on a rock, and the spill forced the evacuation of about 500 people after responders ignited a vapor cloud that sparked a 36-hour long fire

(Alexander and Wallace, 2012; Ellison, 2017a). In 1976, a pipe failure on Line 5 caused a release of 210,000 gallons of oil near Lake Gogebic. Four years earlier, 252,000 gallons were released near Iron River because of a longitudinal weld failure. A similar weld failure caused a spill of 285,600 gallons near Lake Gogebic in 1968. Although the pipeline is 65 years old, 1968 is the earliest year of data available. A map of the locations of oil spills from the Line 5 pipeline system since 1968 is presented in Figure 3.

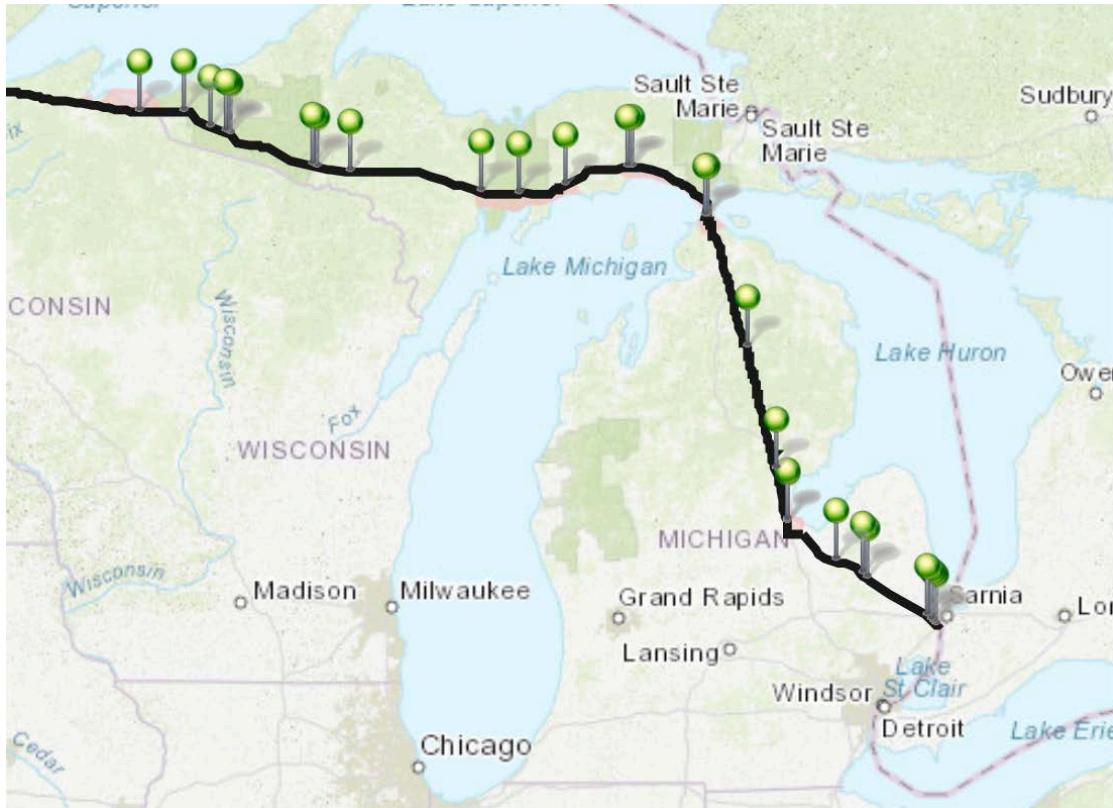


Figure 3: Map of locations of oil spills along Enbridge Line 5, 1968-2017 (Source: Ellison, 2017a)

Recent events have demonstrated that the Straits of Mackinac are at risk of contamination, and that Line 5 is vulnerable to a rupture. In August 2017, Enbridge disclosed that there were a few areas of exposed bare metal on the underwater pipeline at the bottom of the Straits of Mackinac; it was later determined that there were dozens of areas where the protective coating had been damaged. Enbridge was aware of the damages as early as 2014 but did not disclose their existence for three years (Ellison, 2017b). Of the 48 anchor support locations inspected by Enbridge on the pipeline, the vast majority were found to have missing coating, and 42 supports were found to have had some issue of concern (Tower, 2017). On April 1, 2018, about 600 gallons of petroleum-based dielectric fluid leaked into the Straits of Mackinac and Lake Michigan after two power cables owned by Wisconsin-based American Transmission Company were damaged (Tower, 2018). The fluid was used for insulation for the cables, and was composed primarily of alkyl derivatives of benzene, a hydrocarbon present in oil, which is considered toxic to both humans and aquatic life. The leak was not reported to the U.S. Coast Guard until late the following day. The State of Michigan alleges that the damage

was caused by the anchor of the Clyde S. VanEnkevort, a tug and barge vessel passing through the Straits of Mackinac, which are a no-anchor zone (Oosting & Burke, 2018). An anchor strike by that same vessel was also determined to have dented Line 5 in three places (Lawler, 2018; Oosting & Burke, 2018).

A spill from Enbridge Line 5 in the Straits of Mackinac could contaminate nearby municipal drinking water intakes, devastate some of the commercial, recreational, and tribal fisheries of the Great Lakes, kill aquatic and terrestrial wildlife, impair critical ecosystem services, diminish coastal property values, and tarnish the image of the State of Michigan and perceptions of its high levels of ecological integrity. Pollution from a spill would almost certainly impose negative impacts on the State's multibillion-dollar tourism industry (Tourism Economics, 2017), particularly the iconic and historic tourist destinations of Mackinac Island, Bois Blanc Island, and Mackinaw City. In 2016, tourism in Michigan yielded \$23.7 billion in visitor spending alone, generating an estimated \$40.7 billion in total sales (Tourism Economics, 2017). Yet, of even greater concern, if volatile organic compounds (VOCs) found in oil were to enter municipal water and wastewater treatment plants, there would be significant costs for repair and replacement of important equipment. More damaging still, during periods when plants are inoperable, there would potentially be catastrophic public health crises resulting from untreated sewage and a lack of fresh drinking water.

Michigan Pipeline Safety Advisory Board

In 2014, Governor Rick Snyder created the Michigan Petroleum Pipeline Task Force by executive order. The goal of the Michigan Petroleum Pipeline Task Force was to identify and recommend actions within State government to protect the public health, safety and welfare of Michigan citizens and the environment related to the transportation of liquid petroleum products through major pipelines within the State (MPPTF, 2015). The Task Force made four recommendations for Line 5:

1. Ban heavy crude transport
2. Conduct an independent risk analysis
3. Conduct an independent pipeline alternatives analysis
4. Collect additional information from Enbridge

On September 3, 2015, Governor Rick Snyder created the Michigan Pipeline Safety Advisory Board (MPSAB) to implement the recommendations in the Michigan Petroleum Pipeline Task Force Report. The 15-member MPSAB, comprised of regulated stakeholders, government agencies, and non-governmental organizations, acts in an advisory capacity to the Governor.

Two years after its formation, however, the MPSAB had only produced one report—the pipeline alternatives report. This report, authored by Dynamic Risk, Ltd., an oil pipeline industry consultant, was criticized by State agencies and the public for both a failure to examine existing pipeline infrastructure and bias towards the construction of a tunnel to enclose the pipeline. The accompanying economic risk analysis was left unfinished. The

State canceled its contract with Det Norske Veritas (DNV) due to conflict of interest. As a result, the nearly-complete report was never released. The risk and decision-making burden was, thus, shifted to the public without adequate information regarding a worst-case scenario.

In January 2018, the State of Michigan entered into a contract agreement with Michigan Technological University to have a team led by Dr. Guy Meadows, formerly of the MPSAB, perform a risk analysis on Enbridge's Line 5 in the Straits of Mackinac. Dr. Meadows is Director of the Great Lakes Research Center at Michigan Tech, and he and a team of researchers are expected to release their study of the risk analysis in September 2018. While a broader understanding of risks of a breach of Line 5 in the Straits of Mackinac is anticipated to be informed by the research underway by this team, others cite the precautionary principle (Ackerman, 2017) and the legal duties of the public trust doctrine as ample evidence of the need to consider the worst-case scenario and to make an informed decision regarding the future of the pipeline.

Potential Economic Damages and Uncertainty

This report was commissioned by FLOW (For Love of Water), a Great Lakes water law and policy organization based in Traverse City, to address the public need and desire for transparent information regarding the potential impacts of a breach of Enbridge Line 5. The objective of this report is to provide reasonable estimates of the economic damages related to an oil spill from Line 5 in the Straits of Mackinac. To this end, we focus on natural resources, tourism, commercial fishing, municipalities, coastal real estate, and ecosystem services. The United States Environmental Protection Agency (EPA) has identified these areas as useful in understanding impacts of aquatic pollutants, particularly agricultural runoff and other contaminants. Therefore, we believe these sectors to be useful proxies of the economic impacts of an oil spill in this unique, sensitive environment. However, this report is not an exhaustive analysis of potentially affected sectors, but rather represents the several economic sectors that are likely to be affected by an oil spill, and they may serve as proxy measures of potential damages. There is a great deal of uncertainty associated with an oil spill, and this was confirmed among experts in every field we queried. This uncertainty reflects the uniqueness and complexity of the situation.

Never has such a large, freshwater ecosystem experienced an oil spill of the magnitude possible here. Most large aquatic oil spills have taken place in saltwater environments, with the Kalamazoo River oil spill being a notable exception. Also known as the Enbridge Line 6B spill, this pipeline purportedly released nearly one million gallons of oil-rich bitumen, a highly-viscous, semi-liquid form of petroleum into Talmadge Creek and the Kalamazoo River when it ruptured in 2010, although in the years that followed, more than 1.2 million gallons of oil have been recovered from the river (EPA, 2016a). Bitumen is a product of tar sands (also referred to as oil sands), which are a combination of clay, sand, water, and bitumen. Tar sands can be mined and processed to extract bitumen, which can then be refined into oil. Owing to human error and the lengthy delay by Enbridge in responding to the rupture, the magnitude of this spill far exceeded worst-

case projection. For this reason, our oil spill scenario does not represent the most commonly-occurring scenario from the Schwab (2016) simulations, nor is it a worst-case scenario; rather, it is a reasonable case that is informed by expert knowledge. The scenario reflects the real possibility of an anchor strike by marine vessels, a technological failure of automatic response valves, and a delay in human response of up to two hours. In the context of Line 5, the worst-case scenario may be far greater in terms of scale, scope, and the magnitude of impacts.

Throughout the report, we note the high levels of uncertainty in terms of the scale and scope of possible impacts of an oil spill, and we describe the assumptions associated with the estimation of potential economic damages. We note all sources of information where applicable, and we acknowledge each of these sources also operate on approximations and uncertainty. We do not make assertions regarding risk, or the probability of a spill and its potential impacts, as the variables necessary for calculation of probability are too numerous to fully consider. This report provides an estimate of potential economic damages under an oil spill scenario, and the assumptions that provide the basis for these estimates are based on published reports and the perspectives of key informants.

Economic Impact and Value

Aquatic ecosystems such as the Great Lakes Basin and the Straits of Mackinac provide an array of economic benefits, including recreation uses, community impacts, and the values of ecosystem services, such as water provision for irrigation, municipal drinking water, and wastewater treatment systems. Numerous other services are also reliant on these ecosystems, such as food production (i.e., commercial and subsistence fishing) and refugia and habitat (i.e., for resident and migratory fish and wildlife populations), and protection of these ecosystems is necessary to ensure that these benefits will be provided in the future. Degradation of these ecosystems with an oil spill would have negative economic consequences.

This report focuses on the regional economic costs from a potential breach of Line 5 at or near its crossing at the bottom of the Straits of Mackinac, and these should be interpreted as economic impacts, which are reductions in expenditures and the costs associated with restoring any environmental damages. The report does not speculate on the risks of such a breach of the pipeline, as the probability of such an event is uncertain. Nevertheless, there is a non-zero probability of a breach of the Line 5 pipelines, and as such, the economic consequences of such an event are worth consideration.

In this context, it is important to distinguish between economic value and economic impacts. Economic value refers to the maximum amount a consumer is willing to pay for a good or service in a market economy, where the value accrues to the consumers. For example, visitors to a beach for recreation may incur expenditures for their trips, but some would be willing to pay more. The difference between willingness to pay and actual spending is considered to be value that accrues to the visitor. In the context of

environmental benefits, many economic values are not considered in markets and are often ignored in policy decisions. Such market failures require the use of non-market valuation methods to estimate the economic value of changes in environmental quality. This report does not involve the use of these methods or the estimations of such values.

The regional economic impacts of changes in environmental quality would be conceptualized as the effect of an increase (decrease) in private and public expenditures that result from the changes. For example, suppose visitors to a beach spend money locally, for food purchases or fuel. If a pollution incident contaminates water quality at a particular beach, potential visitors to that beach may choose to travel elsewhere for recreation, thereby reducing local spending by recreation visitors to the affected beach. The reduction in local spending by recreation visitors would involve negative economic impacts to the region.

In this report, we focus only on economic impacts, and we distinguish between natural resources damages and restoration—the costs of which would be borne by federal and state agencies who would seek compensation from Enbridge in a legal settlement—and economic costs that would be borne by companies, landowners, and municipalities in the form of lost revenue or added costs of repair and alternative provision of services.

The economic impacts of technological disasters such as oil spills and similar events such as toxic leaching, chemical plant explosions, and radiological emissions have been well documented in numerous reviews (Flynn & Chalmers, 1980; Nelson, 1981; Cohen, 1995). Technological disasters tend to result from a combination of human error and mechanical malfunction, and depending on the scope, magnitude, and location, they can have significant impacts for human health, natural resources, and ecosystem services—all of which have social and economic consequences.

Coastal oil spills are of particular economic concern because the impacts of such events are greatest in terms of biological resources and other forms of natural capital (Cohen, 1995). Estimates of economic impacts after such events occur (*ex post*) can illuminate the magnitude, scope, and distribution of their social and economic costs, and even then, such analyses are often constrained by insufficient data. The challenges are amplified when economic damages are difficult to quantify, such as when long-run environmental impacts are unknown, tourism declines because of perceptions of a contaminated coastline, or residential property values decline as a result of the stigma of a polluted environment (Larkin et al., 2013).

The numerous oil spills in recent decades have generated an extensive body of literature on the economic dimensions of such events and their economic impacts (Meade and Sorensen, 1970; Burrows et al., 1974; Grigalunas et al., 1986; Assaf et al., 1986; Cohen, 1995; Larkin et al., 2013). This literature distinguishes between direct and indirect effects of oil spills. Direct effects would include economic damages that stem from physical injury to property (Epley, 2012; Winkler & Gordon, 2013) and natural resources (Cohen, 1995). Indirect effects are sometimes referred to as “pure economic losses,” or the lost earnings resulting from oil spills, such as damages to a region’s reputation that lead to

losses in the tourism sector, or to coastal restaurants unable to sell local fish (Larkin et al., 2013). There are also numerous other non-market losses associated with passive use values, whose estimation issues have been summarized in relation to past oil spills (Assaf et al., 1986; Grigalunas et al., 1986).

In March 1989, the oil tanker Exxon Valdez struck the submerged rocks of a reef and spilled roughly 11 million gallons of crude oil into Prince William Sound, off the coast of southern Alaska. The spill contaminated nearly 1,300 miles of shoreline and is considered one of the major environmental disasters in U.S. history (Carson et al., 2003). The spill had profoundly negative impacts on the fisheries of Prince William Sound, Lower Cook Inlet, and Kodiak Island. The social costs of the oil spill on south-central Alaska's fisheries during 1989 were estimated to be \$108.1 million (Cohen, 1995), or \$209.3 million in 2016 dollars. The economic effects persisted into 1990, where the social costs were estimated to be \$47.0 million, or \$86.3 million in 2016 dollars. Ecological effects have persisted for decades, as exposure to sequestered oil has continued to cause animal deaths (Graham, 2003). Salmon, for example, had increased mortality for four years after the spill because incubating eggs had been exposed to oil. Researchers estimated that shoreline habitats such as mussel beds affected by the spill would take up to 30 years to recover fully.

The contingent valuation method was used to estimate the passive use losses related to Exxon Valdez oil spill, and early estimates amounted to \$2.8 billion as the lower bound on aggregate passive use losses (or \$5.14 billion, in 2016 dollars) (Carson et al., 2003), which the authors acknowledge as conservative. Subsequent developments in econometric applications have advanced the estimation of non-parametric models and more flexible parametric models of the distribution of willingness-to-pay in contingent valuation. Estimates using these approaches have amounted to passive use losses up to \$7.19 billion dollars (or \$13.2 billion, in 2016 dollars).

In April 2010, an explosion at the Deepwater Horizon oil rig operated by British Petroleum (BP) at the Macondo exploration well in the Gulf of Mexico resulted in the deaths of 11 rig workers and the release of 134 million gallons of oil until the well was capped in July of 2010, approximately three months later. This incident became the worst offshore environmental disaster in U.S. history and was over 12 times greater in magnitude than the 1989 Exxon Valdez oil spill. Oil washed ashore and contaminated the coastlines of four U.S. states, Louisiana, Mississippi, Alabama, and Florida.

The spill had a negative impact on the fisheries of the Gulf of Mexico. Following the spill, recreational and commercial fishing activities were closed in affected federal waters between the mouth of the Mississippi River and Pensacola Bay, Florida (Morgan et al., 2016). Years after the event, many of the effects on natural resources and ecosystem services continue to linger. Federal government studies revealed that dolphins showed signs of oil poisoning, and dolphin deaths continued long after the spill at a higher rate than normal (Venn-Watson et al., 2015).

Economic estimates suggest that the BP spill significantly reduced demand for oysters in Louisiana in the months following the spill. The spill also had a negative impact on the recreation and tourism sector. Estimates of the economic impacts of cancelled recreational trips to coastal counties were developed for legal claims by the State of Florida (Court et al., 2017). A survey of households in 13 states indicated that 1.88 million planned visitor-trips to the region were cancelled up to a year after the incident, resulting in a loss of \$1.30 billion in visitor spending. Total regional economic losses were estimated at \$2.04 billion in industry output, \$1.37 billion in value added, and an employment loss of 20,486 job-years. As of January 2018, total costs of the spill to BP were estimated at approximately \$65 billion, including court fees, penalties, and cleanup costs (Bouso, 2018).

In May 2015, a pipeline operated by Plains All American Pipeline, L.P. ruptured and discharged approximately 105,000 gallons (2,500 barrels) of heavy crude onto land, beaches, and the Pacific Ocean coast of Santa Barbara, California, resulting in the largest coast spill in California in more than 25 years (MPPTF, 2015). Field teams documented dead fish, invertebrates, and other wildlife in the oiled areas following the spill. As part of the Natural Resource Damage Assessment and Restoration process, state and federal natural resource co-trustees are still investigating the extent to which the incident may have caused harm to birds (e.g., brown pelicans, common murre, Pacific loons, snowy plovers), marine mammals (e.g., California sea lions), fish (e.g., surf perch and grunion), and marine invertebrates and their habitats (NOAA, 2015). The spill also shut down fisheries, closed numerous beaches, and negatively affected recreational uses such as camping, non-commercial fishing, and beach visits.

As previously mentioned, in July 2010, a rupture of Enbridge's Line 6B pipeline released bitumen, a refined and viscous form of crude oil into Talmadge Creek and the Kalamazoo River, near Marshall, Michigan. Nearly one million gallons of oil were discharged in total, and the spill harmed wildlife, damaged the watershed, displaced 150 families from their homes, and cost Enbridge more than \$1.2 billion in cleanup expenses (FWS et al., 2015a). In a filing with the Securities and Exchange Commission, the \$1.2 billion figure included \$551.6 million spent on response personnel and equipment, \$227 million on environmental consultants and \$429.4 million on professional, regulatory, and other costs (Enbridge, 2014). Enbridge estimates it has \$219 million in spill costs yet-to-be-paid, and additional costs from ongoing restoration initiatives continue to mount.

In May 2015, the State of Michigan reached a \$75 million settlement with Enbridge, under which the company would pay for additional remediation and monitoring, the costs of construction and restoration of wetlands, removal of a dam, and improvements to recreation and boating sites along the River. In June of 2016, the United States, the State of Michigan, the Nottawaseppi Huron Band of the Potawatomi Tribe, and the Match-E-Be-Nash-She-Wish Band of the Pottawatomi Indians (Gun Lake Tribe), reached a settlement for natural resources damages that required Enbridge to pay an additional almost \$4 million for restoration projects and assessment costs. This was in addition to the cost of completing certain projects and monitoring under the May 2015 settlement with the State (comprising approximately \$58 million of the \$75 million settlement), for a

total estimated cost of \$62 million specifically related to natural resource damages. In addition, in July 2016, the U.S. Environmental Protection Agency and the Department of Justice reached a settlement with Enbridge, whereby the company would spend at least \$110 million on measures to prevent spills and improve operations across its pipeline system in the Great Lakes region, in addition to paying civil penalties totaling \$61 million for Clean Water Act violations resulting from the discharge (EPA, 2016a). Settlements with private landowners, businesses, or natural resource damage to their property, use, enjoyment, and natural features on their property are not available.

Methods

The framework for this estimation of the economic damages of a rupture of Line 5 in the Straits of Mackinac is based on a hypothetical scenario involving a major spill of approximately 2,500,000 gallons of crude oil (approximately 59,500 barrels). The scenario would involve damages to approximately 900 miles of shoreline across 15 counties in the Upper and Lower Peninsulas resulting from technological failure and delay in human response.

It is assumed that five Tier I counties (i.e., Charlevoix, Cheboygan, Emmet, Mackinac, and Presque Isle) will suffer the greatest damages because of closer proximity to the Straits and to the pipeline. It is further assumed that ten Tier II counties (i.e., Alcona, Alpena, Antrim, Benzie, Chippewa, Delta, Grand Traverse, Iosco, Leelanau, and Schoolcraft Counties) would also be affected, but to a lesser extent.

The impacts associated with this scenario are informed by a report of simulations of oil spills in the Straits of Mackinac by the Water Center at the University of Michigan (Schwab, 2016). The simulations were developed using a hydrodynamic model of discrete particle motion in the context of the currents in the Straits of Mackinac, using a statistical analysis of worst case spill scenarios. The simulations considered three different oil spill volumes: i) 5,000 barrels (bbl), ii) 10,000 bbl, and iii) 25,000 bbl (or approximately 210,000, 420,000, and 1,050,000 gallons, respectively¹).

The study simulated oil spills for 840 overlapping 60-day periods between May and October, when the lakes are free of ice cover. The report acknowledges that its assumptions and results presented in the report are conservative (Schwab, 2016). The simulation results found that over 15% of Lake Michigan's open water (9,141 km²) and almost 60% of Lake Huron's open water (35,264 km²) could be affected by visible oil from a spill in the Straits of Mackinac (see Table 2). At least 60% of the cases affected an area of 207 km² in Lake Michigan and 1,953 km² in Lake Huron.

¹ Based on 42 gallons per barrel.

Table 2: Offshore area affected by any case, by percentage range of cases (Schwab, 2016)

Percent of cases	Total area (km²)	Lake Michigan area (km²)	Lake Huron area (km²)
> 0%	44,405	9,141	35,264
> 20%	12,931	1,688	11,243
> 40%	5,684	518	5,166
> 60%	2,160	207	1,953
> 80%	635	64	571

A summary of the length of impacted shoreline for three different initial release volumes is provided below in Table 3. Estimates are provided in terms of (i) the length of shoreline that could be impacted by any spill, (ii) the maximum length of impacted shoreline in a single case, and (iii) the median length of impacted shoreline from all cases.

Table 3: Length (km) of impacted shoreline for three initial release volumes (Schwab, 2016)

Initial release volume (barrels)	All cases	Single case	Median
5,000	709	115	60
10,000	835	170	85
25,000	1,162	245	120

A graphical representation of the offshore area affected by any case in the simulations is presented in Figure 4.

The worst-case scenario modeled by Schwab (2016) is a spill of a magnitude of 25,000 bbl (approximately 1 million gallons) that is equivalent to the size of the spill that occurred in Line 6B in the Kalamazoo River in 2010 over a 17-hour period (the time period that oil flowed before Enbridge shut down the pipeline). However, that pipeline was 30 inches in diameter, and at the time, had a capacity of 10.1 million gallons (240,000 barrels) per day (Martell, 2014). While the terrestrial portion of Line 5 is 30 inches in diameter, the submerged portion of Line 5 consists of two pipelines, each measuring 20 inches in diameter, and they collectively have a capacity of up to 22.7 million gallons per day. If similar delays in management responses were employed in the event of an oil spill along Line 5 near the Straits of Mackinac, the total spill volume could conceivably be far greater than 1 million gallons. Furthermore, due to modeling assumptions, Schwab (2016) acknowledges that results presented in the report can be considered conservative, in terms of the extent of the oil spill simulations, and the associated scope and magnitude.

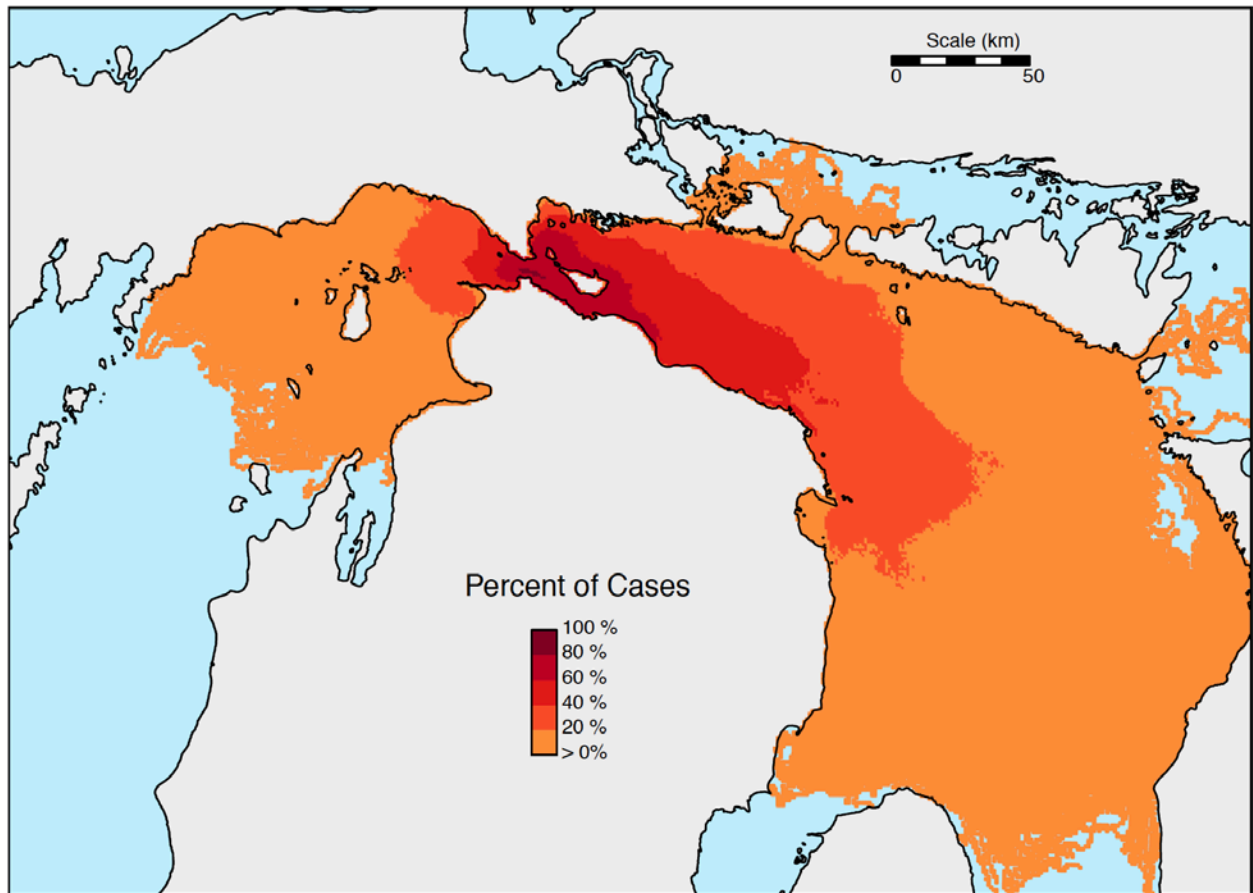


Figure 4: Percent of cases in which oil is present at any time after initial release (Schwab, 2016)

In at least one case from the simulations, 70% of the initial release volume of oil would be beached in less than 24 hours (Schwab, 2016). Other cases involved extensive beaching of oil within 6-12 hours of a rupture, which is short of the 17-hour delay before the company took action in the case of the rupture of Line 6B. Given the geographic scale of the potentially affected area of an underwater rupture of Line 5, and the limited equipment available to respond, containment of the spill could take months. Furthermore, given the strong currents in that location, the affected shorelines could conceivably reach even farther south in Lake Michigan, potentially to southern Lake Huron, or worse, into Georgian Bay and farther throughout the Great Lakes Basin. In fact, Canadian coastline impacts are forecasted in some of Schwab's (2016) simulations. And, although potentially significant, the present report does not consider economic implications of international shoreline oiling.

The oil spill scenario used in this estimate of economic damages is 2.5 million gallons, which may be conservative in light of discussions of the need for contingency planning to avoid a truly worst-case scenario. 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. It is worth noting that the oil spill scenario in this report does not reflect the

challenges of containment, which could potentially prolong the leak and magnify the geographic scale and scope of impacts. This scenario also does not consider the worst case, which could involve a prolonged spill of greater magnitude and broader geographic range (i.e., Georgian Bay, Saginaw Bay, Lake St. Clair, Lake Erie, Lake Ontario, etc.).

The framework of the estimation of the economic impacts in this study focuses on five categories of ecosystem services that are likely to be directly affected by an oil spill in the Straits of Mackinac: (i) refugia and habitat (natural resources), (ii) cultural services (recreation and tourism), (iii) food provision (fisheries), (iv) water supply (municipal water provision and treatment), and (v) shelter (personal property). This study does not consider the possibility of a rupture of Line 5 during the winter season when the Straits of Mackinac may be covered with ice, as the economic impacts would be difficult to estimate when containment may not be possible. This study also does not consider a rupture of Line 5 in the context of a spill of natural gas liquids, as there are few studies of the impacts of such an event. To that end, the estimates of economic damages in this report reflect the release of crude oil in the months when the waters of the Straits and adjacent lakes are free of ice cover. This report did not consider direct impacts to the Great Lakes shipping industry or the downstream effects that would be induced via import-export delays. In addition, this report did not consider the costs of evacuation of particular areas that could be exposed to air contamination from a release of oil. Finally, this report did not consider the potential impacts to economic sectors in Canada in areas affected by a release of oil from Line 5 because of limited availability of data. The exact location of a hypothetical spill along the pipeline is not considered, but it is assumed to be at or near its crossing at the Straits of Mackinac.

Data collection and analysis

The method for estimation involved (i) the collection of baseline data for the annual economic output for each of these categories of ecosystem services, (ii) the development of impact estimates, based on previously published reports, publicly-available data, and data collected from expert interviews, and (iii) the calculation of estimates of economic impacts for each scenario, across all five categories of ecosystem services, for three years immediately following a break of Line 5 in the Straits of Mackinac. The estimation of the economic impacts of an oil spill in the Straits of Mackinac involved the use of two methods of data collection:

1. Primary data: Key informant interviews
2. Secondary data: Document review

Primary data: Key informant interviews

The authors conducted a total of 30 interviews with key informants, including civil engineers, conservationists, fisheries biologists, hydrologists, legal experts, administrators of municipal water systems, real estate professionals, tourism professionals, and other experts. Recruitment of key informants was conducted through (i) purposive sampling (i.e., inquiries with individuals with specific responsibilities of

interest to the study), and (ii) snowball sampling (i.e., inquiries with new informants based on acquaintances and recommendations of initial informants).

Secondary data: Document review

The authors reviewed numerous reports, websites, and data sets, including:

- About Line 5, 2017. Enbridge Energy Partners, L.P.
- Alternatives Analysis for the Straits Pipelines, 2017. Dynamic Risk Systems, Inc.
- An Investigation into the Effect of Near Bottom Currents on the Structural Stability of Enbridge Line 5 in the Straits of Mackinac: Technical Report, 2017. Edward E. Timm.
- County economic profiles, 2017. National Association of Counties.
- EPA Response to Enbridge Spill in Michigan, 2016. U.S. Environmental Protection Agency.
- Enbridge Energy Line 5, 2017. Tip of the Mitt Watershed Council.
- Exhibit 5: Declaration of Mark P. Ebner. Tribes' Motion and Brief to Intervene as Parties-Plaintiff. National Wildlife Federation v. Administrator of the Pipeline and Hazardous Materials Administration, Case No. 16-cv-11727, 2016.
- Final Damage Assessment and Restoration Plan/ Environmental Assessment for the July 25-26, 2010 Enbridge Line 6B Oil Discharges near Marshall, MI.
- Leading the Way in Responsible Energy Delivery, 2013. Enbridge Energy, L.P., Superior Region Office.
- Statistical Analysis of Straits of Mackinac Line 5: Worst Case Spill Scenarios, 2016. Schwab, D. J., Water Center, University of Michigan.
- Sunken Hazard: Aging oil pipelines beneath the Straits of Mackinac an ever-present threat to the Great Lakes, 2012. National Wildlife Federation.

Literature from numerous studies of the impacts of previous oil spills was also reviewed, and their findings informed this study. A full list of resources can be found at the end of this document.

Estimates of Economic Damages

Estimates of potential economic damages of an oil spill from Line 5 near the Straits of Mackinac are presented below, including natural resource damages, impacts to tourism, impacts to the commercial fishing sector, losses in coastal property values, and potential costs borne by coastal municipalities.

Natural Resources and Ecosystem Services

The shorelines of Lake Michigan and Lake Huron near the Straits of Mackinac and beyond are endowed with an abundance of natural resources that are of vast ecological

and economic value, including fresh water, fish, wildlife, beaches, coastal sand dunes, and a variety of aquatic and terrestrial plants. Northern Michigan is home to vast stretches of diverse and undisturbed Great Lakes shorelines, including coastal wetlands, marshes, and limestone cobble shorelines, and these ecosystems provide habitat for a variety of plant and animal life. All types of freshwater organisms are susceptible to the harmful effects of exposure to oil, including mammals, aquatic birds, fish, insects, microorganisms, and vegetation. In addition, the effects of spilled oil on freshwater microorganisms, invertebrates, and algae also affect other species throughout the food web (EPA, 2016a). In particular, oil spills can lead to losses at the base of the food web that reduce food availability for other species.

Ecosystem services are the functions of an ecosystem that generate benefits or value to humans; they are the conditions and processes through which natural ecosystems sustain and fulfill human life. Ecosystems provide a range of benefits to all people, including the benefits of provisioning, regulating, cultural, and supporting services. Costanza et al. (1997) estimated the value of 17 ecosystem services for 16 biomes and an aggregate global value expressed in monetary units. The value of global ecosystem services was estimated to be around US\$ 33 trillion per year (in 1995 US dollars), a figure significantly larger than global gross domestic product (GDP) at the time. This estimate was based on the benefit transfer method, which assumes a constant unit value per hectare of ecosystem type and multiplies that value by the area of each type to arrive at aggregate totals. This can be improved somewhat by adjusting values using expert opinion of local conditions. Benefit transfer is analogous to the approach taken in GDP accounting, which aggregates value by multiplying price times quantity for each sector of the economy.

Estimating the natural resource damages from an oil spill from Line 5 near its crossing at the Straits of Mackinac involves confronting the challenges related to the uncertainty of the scope of an oil spill and the extent of its impacts in an open freshwater environment. The Schwab (2016) simulations involved quantitative analysis of 840 oil spill cases from a discharge from Line 5 and concluded that more than 44,000 km² (more than 27,000 square miles) of open water in Lakes Michigan and Huron, and more than 1,000 km (more than 620 miles) of shoreline of Lake Michigan, Lake Huron, and nearby islands are potentially vulnerable to the impacts of a spill.

Natural Resource Damage Assessment (NRDA) is the legal process that federal agencies use to evaluate the impacts of oil spills on natural resources along the nation's coast and throughout its interior (NOAA, 2017). The responsibilities of federal agencies in an NRDA include assessment, planning, and restoration. Federal and state agencies, and Indian tribes, referred to collectively as natural resource trustees, work together to identify the extent of natural resource injuries, the best methods for restoring them, and the type and extent of restoration required. In addition to examining environmental impacts, the NRDA process includes assessing and restoring the public's lost use of damaged natural resources (e.g., recreational fishing or swimming). An NRDA involves collecting, compiling and analyzing information, statistics, or data to determine the extent

of injuries to natural resources from hazardous substance releases or oil discharges, and to determine appropriate ways of restoring and compensating for those injuries.

There are few estimates of damages to natural resources from oil spills in freshwater ecosystems. One prominent example is the Natural Resource Damage Assessment and Restoration (NRDAR) from the oil spill from Enbridge Line 6B in the Kalamazoo River near Marshall, Michigan (FWS et al., 2015a). Although Enbridge reported a total release of more than 840,000 gallons from the 2010 rupture (FWS et al., 2015a), more than 1.2 million gallons of oil were recovered from the river in the four years that followed (EPA, 2016a).

There have been two settlements against Enbridge related to natural resource damages from that oil spill. Federal, State and tribal officials, acting as natural resource trustees, announced a natural resource damage settlement with Enbridge that will result in multiple resource restoration projects along the Kalamazoo River and a payment for restoration of nearly \$4 million. The State of Michigan filed a separate claim against Enbridge for compliance with State law requirements for cleanup, mitigation, compensation, and restoration in which the natural resource damages components of the resulting settlement were estimated to cost at least \$58 million. The two settlements combined result in at least \$62 million in natural resource damages resulting from that event (FWS, 2015b).

The rupture of Enbridge Line 6B released oil into Talmadge Creek and along approximately 38 miles of the Kalamazoo River. The oil impacted over 1,560 acres of stream and river habitat as well as floodplain and upland areas, injuring birds, mammals, reptiles, and other wildlife (FWS et al., 2015a). While the aquatic and terrestrial ecosystems of the Kalamazoo River are quite different from those of the Straits of Mackinac, Lake Michigan, Lake Huron, and nearby islands, it is possible to extrapolate the extent of potential natural resource damages of an oil spill from Line 5 based on the NRDAR of the rupture of Line 6B. Dividing the total costs for natural resource damages from the release from Line 6B (\$62 million) by the length of the affected shoreline (80 miles, based on 40 miles affected with two shorelines per mile of river) provides an estimate of natural resource damages of approximately \$775,000 per mile of shoreline.

The oil spill scenario in this report would involve the release of 2.5 million gallons of oil and damages to approximately 900 miles of shoreline across the Tier I and Tier II counties. Application of the estimate of natural resource damages per mile of affected shoreline to the oil spill scenario developed in this report would yield an estimate of natural resource damages from a rupture of Line 5 of approximately \$697.5 million. While estimation of natural resource damages through extrapolation is admittedly coarse, the calculations provide an estimate of the potential damages and associated costs of cleanup and restoration. These estimates may be conservative, given the sensitivity of the freshwater ecosystems of the Straits of Mackinac, the threatened and endangered species of the region, and the scale of the affected area.

Tourism

Tourism represents an important economic sector in Michigan and has been a high priority for private and public investment in the State. Michigan hosted 119 million person-trips in 2016, and visitor spending grew 3.0% to reach \$23.7 billion (Tourism Economics, 2017). Visitor spending generated \$40.7 billion in total business sales in 2016, as visitor dollars flowed through the State's economy to other sectors, such as business services, finance, and insurance, among others. (These are known as indirect and induced impacts.) Spending grew by \$670 million in 2016, with 75% of the increase stemming from the categories of food, beverage, and lodging expenditures. Direct spending by tourists supports approximately 221,420 jobs in Michigan, and the total tourism economy in 2016, including direct, indirect, and induced impacts, supported 337,490 jobs, or approximately 6.1% of total employment in the state. Including indirect and induced impacts, travel in Michigan generated nearly \$2.6 billion in state and local taxes and \$2.7 billion in federal taxes in 2016. In the absence of the state and local taxes generated by travelers, each Michigan household would have had to pay an additional \$685 to fill the gap (Tourism Economics, 2017).

Coastal areas feature prominently in the State's award-winning tourism promotion campaign, "Pure Michigan." Coastal areas of Northern Michigan attract millions of tourists each year who come to visit beaches, swim, sail, kayak, fish, view wildlife, and enjoy other activities that depend on clean water, clean air, abundant fish and wildlife, and overall environmental quality. For many households, beaches are the ultimate vacation destination. Mackinac Island alone hosts more than 1 million visitors per year and Sleeping Bear Dunes National Lakeshore receives more than 1.5 million visitors per year. Visitor spending in the fifteen counties considered in this study represent 7.34% of total tourism expenditures in the State.

There have been previous studies of recreation visitation at coastal tourist attractions in Michigan. A visitor study conducted at Sleeping Bear Dunes National Lakeshore in 2009 involved the distribution of questionnaires to visitors at 11 different locations (Holmes et al., 2010). Approximately 47% of visitors were visiting the park for the first time in their lifetime and 25% had visited six or more times (out of a total sample of 696 respondents, or n=696). Visitors were asked about their perceived importance of protecting several resources and attributes, and the attributes that were most commonly considered "extremely important" or "very important" were clean water (96%) and clean air (95%). Approximately 95% of respondents rated protection of scenic views as "extremely important" or "very important", and other highly-rated attributes included protection of sand dunes (94%), natural areas (93%), native wildlife (92%), and native plants (87%). All of these attributes would be damaged in the event of an oil spill, and these findings underscore the importance of high environmental quality to the tourism sector.

In an online survey of visitors to coastal sand dune areas in Michigan, respondents indicated that the activities of beach-going (20.1%) and scenic enjoyment (19.7%) were the top *primary* reasons for visiting these areas (n=7,062). In terms of all activities in which respondents participated, beach-going ranked highest (66.5%), followed by scenic

enjoyment (54.1%). Other highly-ranked activities included swimming, kayaking, and watching birds and wildlife from the shoreline (Arbogast et al., 2018). These findings also demonstrate the importance of the quality of coastal amenities for recreation and tourism.

Estimates of the economic impact of direct visitor spending and the total impact of visitor spending (including indirect and induced effects), are presented in Table 4. They are based on the calculations of the multiplier effects estimated in statewide estimates of the total economic impact of visitor spending in Michigan (Tourism Economics, 2017). Estimates indicate that Tier I counties generate \$1.7 billion in total economic impact of visitor spending, and Tier II counties generate \$1.2 billion in total economic impact of visitor spending, for an estimated total economic impact of visitor spending in the region of nearly \$3 billion.

Table 4: Economic impact of tourism in Michigan, 2016

Tier I Counties	Visitor spending	Total impact of visitor spending
Charlevoix	\$ 313,260,000	\$ 537,220,000
Cheboygan	89,910,000	154,190,000
Emmet	363,390,000	623,190,000
Mackinac	219,980,000	377,250,000
Presque Isle	35,920,000	61,600,000
Tier I sub-total	\$ 1,022,460,000	\$ 1,753,460,000
Tier II Counties		
Alcona	46,470,000	79,690,000
Alpena	42,010,000	72,040,000
Antrim	89,900,000	154,170,000
Benzie	115,680,000	198,380,000
Chippewa	159,830,000	274,100,000
Delta	67,750,000	116,190,000
Grand Traverse	426,850,000	732,020,000
Iosco	66,200,000	113,530,000
Leelanau	116,030,000	198,980,000
Schoolcraft	43,140,000	73,980,000
Tier II sub-total	\$ 719,970,000	\$ 1,234,710,000
Total: Tier I + II Counties	\$ 1,742,430,000	\$ 2,988,170,000

Visitor spending also supported \$11.6 billion in business and personal income, and sustained 337,490 jobs, or approximately 6.1% of total employment in the State. Tourism is particularly important to tribal economies throughout the region, and the sector is a major source of employment for tribal members. Travel in Michigan generated nearly \$2.6 billion in state and local taxes, and \$2.7 billion in federal taxes in 2016, including indirect and induced impacts. The year 2016 marked the 7th consecutive year of growth in visitation and visitor spending.

The impact of an oil spill on the tourism sector is largely based on the perception and preferences of tourist visitors. Negative perceptions about environmental amenities can persist long after containment and remediation. Previous studies confirm that tourism significantly declines after an oil spill. In Louisiana, leisure visitors spent much less following the Deepwater Horizon oil spill in the Gulf of Mexico. Leisure visitor spending in 2010 dropped by \$247 million, with an estimated total loss of \$422 million over three years, from 2011 through 2013 (Tourism Economics, 2011). There is also evidence that regional tourism declined, even in areas that did not experience oil pollution. These findings imply that perceptions of environmental quality matter in tourism decision-making, even where environmental quality is not compromised.

The duration of the impacts of oil spills on tourism has been found to extend well beyond the spill event (see Figure 5).

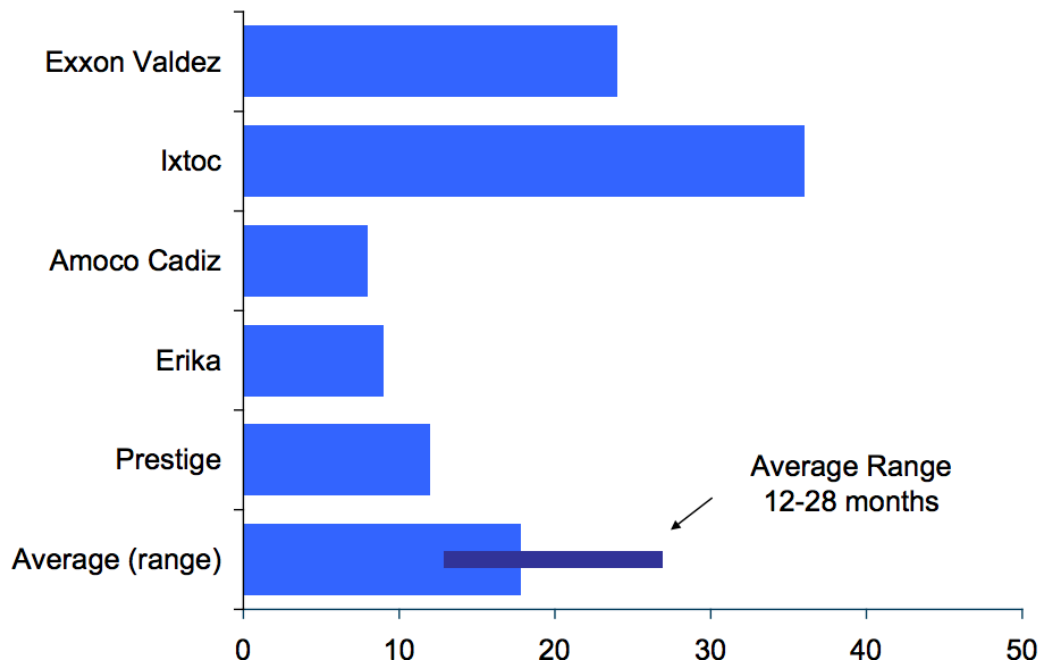


Figure 5: Months after initial disruption from oil spills for visitor spending to return to baseline (Tourism Economics, 2011)

Tourism Economics (2011) estimated the number of months after initial disruption for visitor spending to return to baseline, based on five previous oil spills, and found that the average duration of impacts for tourism is 12-28 months. They projected more enduring impacts in the Gulf of Mexico. It is worth noting that several of these oil spills did not occur near coastal shorelines, yet they still had immediate and enduring effects on tourism in their respective regions. Given the proximity of Line 5 to the shorelines of both the Lower and Upper Peninsulas of Michigan, a release of oil from in the Straits of Mackinac would likely have greater impacts than these examples, in terms of both the scope of impacts and their duration.

Estimates of the economic damages to the tourism sector of an oil spill from Line 5 in the Straits of Mackinac were developed based on the following assumptions:

- Tier I counties experience a loss of visitor spending and associated total economic impact of 60% in Year 1, 50% in Year 2, 40% in Year 3, 20% in Year 4, and 10% in Year 5.
- Tier II counties experience a loss of visitor spending associated total economic impact of 40% in Year 1, 35% in Year 2, 25% in Year 3, 15% in Year 4, and 10% in Year 5.

The present value of estimated economic damages to the tourism sector of an oil spill from Line 5 in the Straits of Mackinac was estimated based on a discount rate of 3%, which is appropriate for the estimate of economic impacts of environmental damages. Based on these assumptions, estimates of the total economic impact of an oil spill at or near the Straits of Mackinac on the tourism sector are presented in Table 5. The present value of economic damages to the tourism sector is estimated to reach more than \$4.8 billion.

Table 5: Present value of potential economic damages to the tourism sector from an oil spill from Line 5 in the Straits of Mackinac

Affected Area	Economic Impact
Tier I counties	\$ 3,156,228,245
Tier II counties	\$ 1,666,854,681
Total economic impact	\$ 4,823,082,926

Commercial fishing

From tournament anglers and charter boat captains to tribal and subsistence fisherwomen and men, fishing comprises a central aspect of the identity, spiritual life, and cultural heritage of many Michiganders (O’Keefe & Miller, 2011a). Among U.S. boaters, one in three lives in the Great Lakes Basin, and commercial fishing adds approximately \$1 billion to the Great Lakes regional economy (GLERL/NOAA, n.d.). The fishery is also an important aspect of Michigan’s economy. Commercial, tribal, and recreational fishing together generate an estimated \$5 billion to \$8.5 billion per year (Gillies, 2010). Of Michigan’s nearly 200 commercial fishing operations, about 75% are affiliated with the Chippewa-Ottawa Resource Authority (CORA) and the Great Lakes Indian Fish and Wildlife Commission (GLIFWC), which accounts for about half of the total commercial catch (Michigan Sea Grant, 2013). Coastal economies brought in \$23 million from charter fishing trips alone in 2016, and 90% of these voyages disembarked from communities along Lakes Michigan (78%) and Huron (12%) (O’Keefe & Miller, 2011b; O’Keefe, 2017).

We use average dockside value of commercial catches—approximately \$10 to \$12 million per year—for the direct effect baseline estimate (Michigan DNR, 2013; Michigan DNR, 2016). These figures, however, are undergirded by the fact that the majority of

economic impact in this sector is indirect and, sometimes, unquantifiable. For instance, charter captains are driven to their trade not by dreams of financial gain, but by the desire to help people enjoy fishing; in fact, the average charter captain operates at a financial loss (O’Keefe, 2015). These examples highlight the challenges encountered in estimating effects of a spill on the Michigan commercial fishing industry.

A report from the Michigan Department of Natural Resources (Gonia, 2014) estimates average annual indirect effects from commercial fishing to be four to five times the dockside value, and a commercial operation may be able to quintuple its gross dockside value by operating its own retail outlet. On the other hand, the task of estimating impacts to the fishery is fraught with uncertainty related to the timing and location of such an event. How should damages be modeled if a spill were to occur during spawning season? How would fish behave in the presence of oil? An event like this is unprecedented in this ecosystem and with this form of oil. Hence, we adopt a conservative point of view and wholly acknowledge the uncertainty in these estimates. This section considers neither recreational nor tournament fishing, but average annual dockside value of commercial fishing only. This is comprised of less than 51 State-licensed commercial operations (less than this engage in fishing during a given year, but many operations maintain their licenses due to irreplaceability) and about 150 tribal operations (Gonia, 2014).

Based upon information gathered from experts and other key informants, as well as data presented in Figures 6, 7, 8, and 9, it is clear that the tribes, bear a disproportionate amount of the risk with respect to the commercial fishing economy. This is not to discount the risk borne by *all* commercial fishing operations in the region; tribes and State-licensed bear about 50% each (GLMRIS, 2012). A map of fish harvests reported by the Chippewa Ottawa Resource Authority (CORA) is presented in Figure 6.

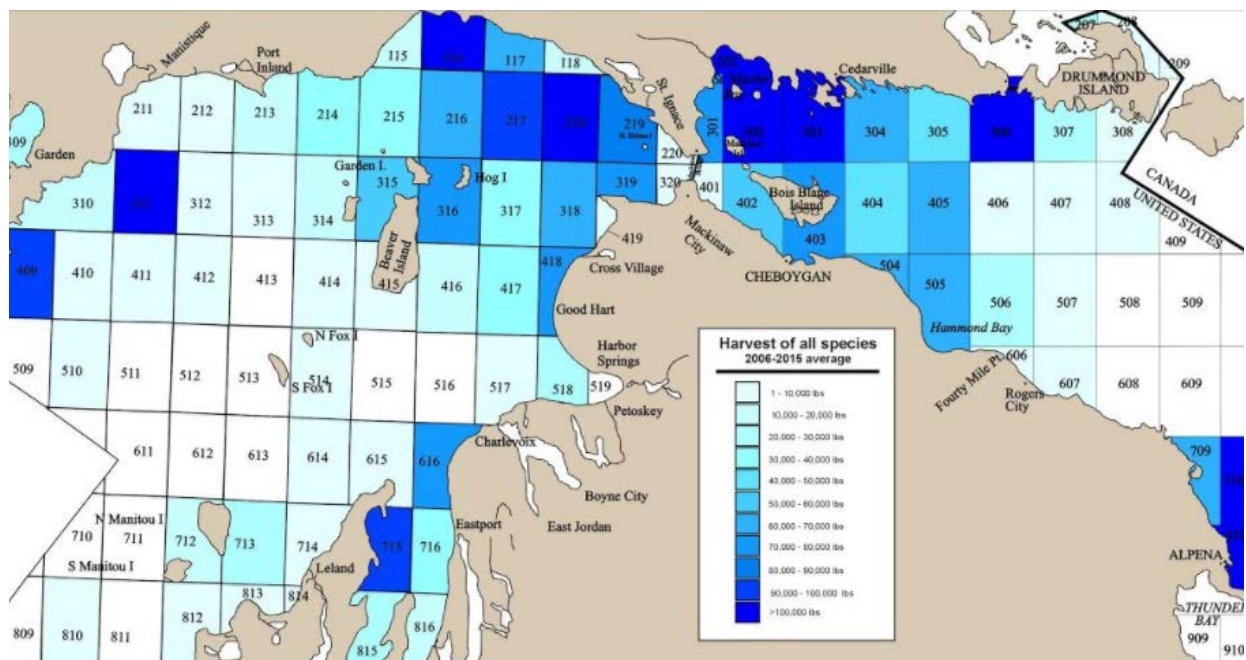


Figure 6: Fish harvest reported by CORA commercial fishers, summarized by grid, 2006 – 2015 average (Ebner, 2016)

Maps of commercial fishing locations in Lake Michigan and Lake Huron are presented in Figures 7 and 8.

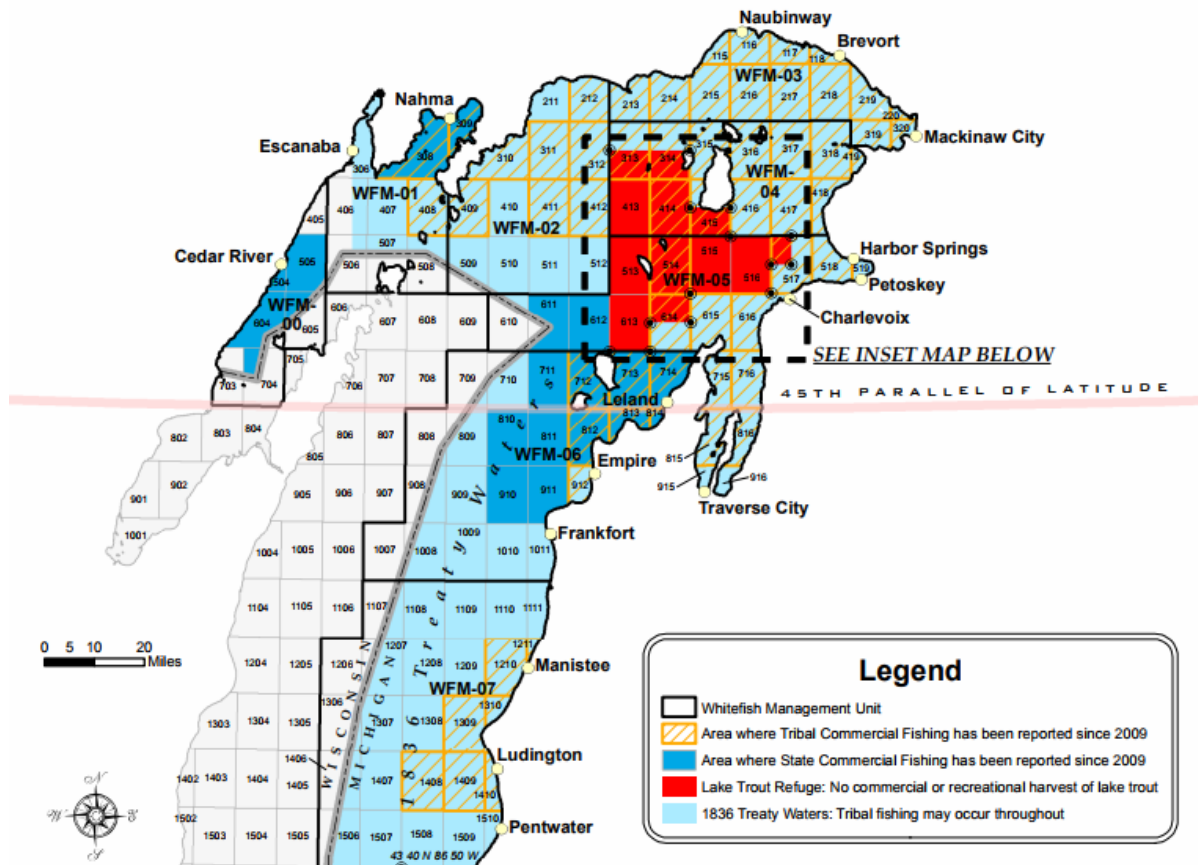


Figure 7: Commercial fishing locations map for Lake Michigan (DNR, 2013)

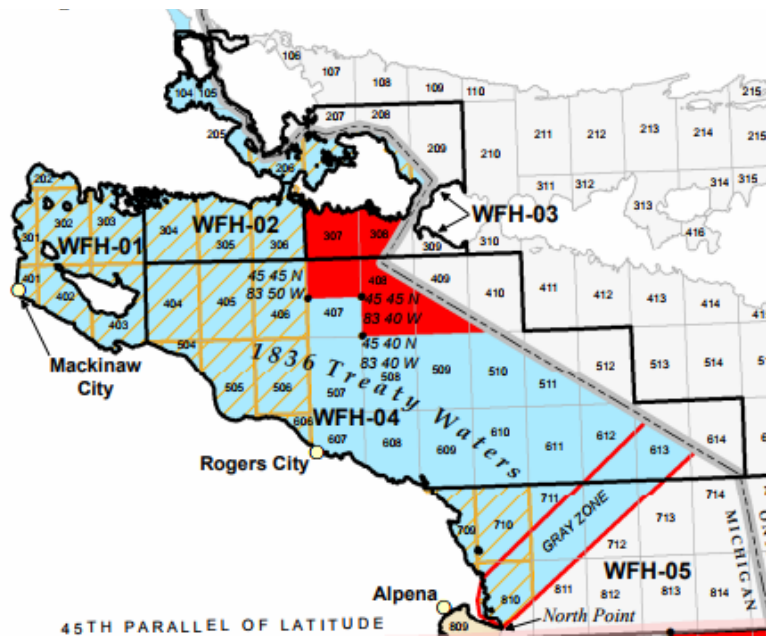


Figure 8: Commercial fishing locations map for Lake Huron (DNR, 2015)

Total fish harvest by the Little Traverse Bay Bands of Ottawa Indians in statistical grids of Northern Lakes Michigan and Huron between 2005 and 2015 is presented in Figure 9 (Ebner, 2016).

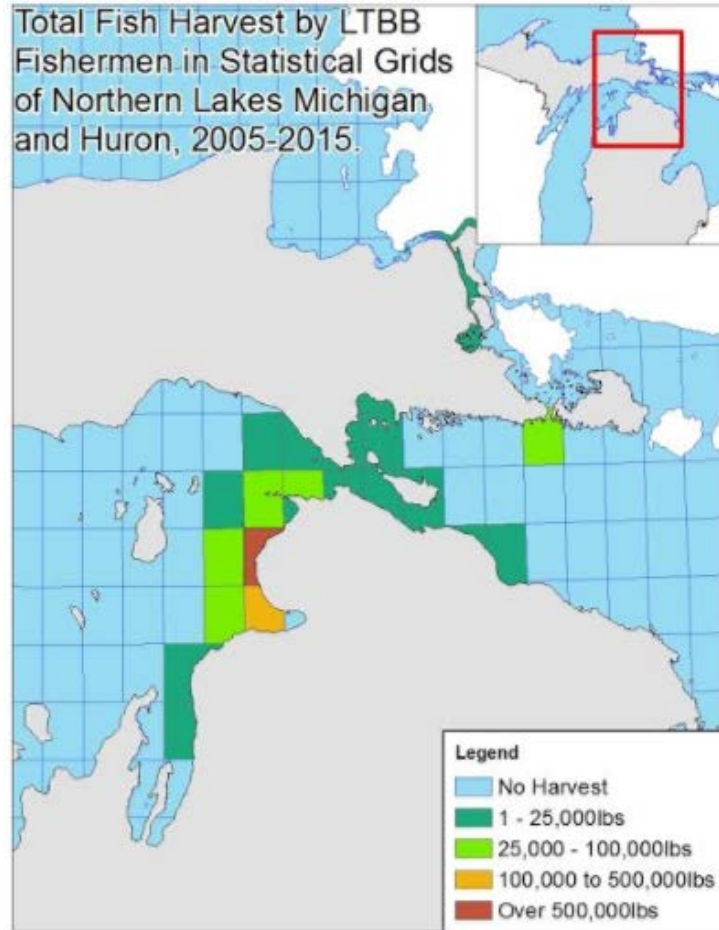


Figure 9: Total fish harvest by Little Traverse Bay Bands of Ottawa Indians in statistical grids of Northern Lakes Michigan and Huron, 2005-2015 (Ebner, 2016)

Estimates of the economic damages to the commercial fishing sector from an oil spill from Line 5 are presented in Table 6. Economic damages under the oil spill scenario are estimated at \$32 million for the first year following an oil spill event. Across the three years following an oil spill event, economic damages to commercial fishing are estimated to be \$62 million under the assumptions of the oil spill scenario developed for this report. While the presented time horizon is three years, it is worth noting that ecosystem effects from a spill—as well as negative consumer perceptions—could last for years or decades, and biological impacts may be observed in other Great Lakes. Lakes Michigan and Huron comprise the majority of Michigan’s commercial fishery. These ecosystems are highly sensitive to invasive species, and it is difficult to predict the extent to which an oil spill would exacerbate extant pressures on whitefish and other commercial species, as well as

the aquatic ecosystems they inhabit. Based on a discount rate of 3%, the present value of these estimates of economic damages to the commercial fishing sector is \$62.0 million.

Table 6: Present value of potential economic damages to the commercial fishing sector from an oil spill from Line 5 in the Straits of Mackinac

Time horizon	Economic Impact
Year 1	\$ 32,000,000
Year 2	\$ 20,000,000
Year 3	\$ 10,000,000
Total economic impact	\$ 62,000,000

Municipal Water Systems

From changes in tourist populations to reduced numbers of new business openings, Straits-area municipalities have the potential to be impacted in a variety of ways by an oil spill. These impacts may come in the form of emergency evacuation costs (for Mackinac Island and surrounding areas), tax revenue interruptions, and costs associated with provisioning alternative sources of clean drinking water. As confirmed through numerous interviews, the viability of townships, cities, and counties from Cheboygan to Charlevoix is closely tied to the health, unspoiled beauty, and perceived safety of the Great Lakes. Thus, while a complete analysis of potential oil spill impacts on municipalities would be wider in scope, our report conservatively focuses on wastewater treatment plants and provisioning of water resources to municipalities. This section includes some of the most surprising findings that we encountered through our research.

The ability to draw drinking water from just below the lake surface is a convenience that many coastal municipalities leverage. Water treatment facilities draw in surface or ground water and then filter, treat, and provide it to residential and commercial customers who then drink it, utilize it in food preparation, wash with it, and use it to irrigate lawns and crops. In a minority of Straits-area municipalities, water treatment is conducted in the same facility that conducts wastewater treatment. In most Straits-area municipalities, however, these functions are divided among separate facilities. Mackinac Island, for instance, has a relatively small residential population and yet has separate water and wastewater plants, whereas St. Ignace has a single facility. These two locales, along with Alpena, Traverse City, and East Tawas among others, draw from just below the lake surface for water processing and provisioning. Municipalities that do not draw surface water instead pump water from underground aquifers using wells. Mackinaw City, which pulls its water from wells, treats right at each source.

The other half of the municipal water role is dealing with the wastewater outflows of homes and businesses. Wastewater treatment plants are designed to maximum specific capacities based upon the service area population and composition. On rainless days, these facilities typically operate under their maximum capacity. However, Michigan's weather variability and frequent precipitation events lead wastewater facilities to regularly intake storm water that carries with it whatever it picks up along the way.

Before continuing with the analysis of municipal impacts, it is important to note that a true worst-case scenario is essentially inconceivable. Each time one attempts to paint a more-inclusive picture by reflecting expert opinion, one also comes up against the fact an issue this polarizing makes everyone susceptible to bias. What we are attempting to balance is fact, opinion, and possibilities. With the Kalamazoo River oil spill still in recent history, we are reminded that the impacts of aquatic oil spills are difficult to estimate with precision. Therefore, we draw attention to the context and acknowledge that the following estimates reflect high levels of uncertainty. This is what is known in sustainability literature as a “wicked problem,” with no single best solution (Rittel and Webber, 1973). The problem is ill-defined, with high levels of value conflict. With this caveat, we have developed the fairest estimates of economic damages, based on available information and reasonable assumptions.

Our estimates of economic damages to municipal water systems are based on two assumptions. First, we assume that spill management is impacted by rough water conditions. In the oil spill scenario, this means that VOCs are drawn into Straits-area water treatment plants. We assume this results in damage to biotic and abiotic treatment mechanisms, and leaves municipalities without water provisioning for 8,600 homes and businesses for up to six months. Cost estimates of residential and business water provisioning are computed using figures from the Flint water crisis, including \$293.75 per home per week for bottled water delivery (Livengood, 2016). Second, we assume stormy conditions that cause VOCs to be carried into three Straits-area wastewater treatment plants. Under this assumption, the VOC concentration in the air of each of three wastewater plants would potentially lead to ignition and destruction, which would imply the costs of replacement of municipal wastewater facilities.

Estimates of potential economic damages to municipal water systems from a release of oil from Line 5 are presented in Table 7. Costs to municipalities in the region are estimated to be more than \$233 million. It is worth noting the potential public health effects in the scenario associated with the lack of ability to process sewage. The buildup of sewage in homes and businesses would be exacerbated by a reduction in clean water availability. Expert interviews suggest the costs associated with a public health crisis of this magnitude would greatly exceed estimates of material costs in Table 7.

Table 7: Potential economic damages to municipalities from an oil spill from Line 5 in the Straits of Mackinac

Category	Economic Damages
Residences and businesses impacted	55,600
Months impacted	12
Bottled-water provisioning	\$ 196,000,000
Water plant repairs	\$ 1,100,000
Wastewater facility replacement	\$ 36,000,000
Total costs	\$ 233,100,000

Coastal property

Residential and commercial properties along the shoreline of northern Michigan include some of the most valuable real estate in the Great Lakes region, in part because of the scenic views and other environmental amenities that attract residents, second-home owners, and tourists to the area. A breach of Line 5 that released oil into the Straits of Mackinac could have significant negative impacts on the value of coastal properties, particularly on Mackinac Island and other nearby areas that are popular tourist destinations.

Estimates of the economic damages to coastal property for this study were constrained by a lack of readily-available data on real estate values in the region. However, several studies have estimated the impact on property values from previous oil spills. A study of the impact of a pipeline rupture in southern Maryland in 2000 found that property values declined approximately 11% (Simons et al., 2001). In that study, losses to the value of waterfront properties were approximately \$28,400, and the value of interior properties declined by an average of \$14,390.

Numerous studies have estimated the effects of the Deepwater Horizon oil spill on real estate prices in the Gulf of Mexico. In one study, the values of residential condominiums and single-family homes in coastal Alabama were initially impacted by up to 14%, but some of this loss was recovered after the well was capped (Epley, 2012). Vacant residential land suffered more significant losses in the aftermath of the spill (up to 42%), and losses of up to 16% persisted long after the event. Another study noted an average loss of approximately \$56,000 per home in affected areas (Myers, 2013). Using data on condominium prices in Orange Beach and Gulf Shores, Alabama, a before-and-after econometric test found that there was a 12.1% decline in condominium sale prices after the oil spill, while additional tests indicate a decline of 10.1% to 13.5% in sale prices over the first 100 days after the spill (Siegel et al., 2013). However, any significant negative price effects due to the spill were found to have dissipated by approximately 3.5 months after the spill.

It is worth noting that a rupture of Line 5 could occur in closer proximity to the shoreline than the Deepwater Horizon oil spill. The release of oil from Enbridge Line 6B in the Kalamazoo River led to the temporary evacuation of dozens of households, primarily because of exposure to contamination. In addition to the negative effects on water quality and aquatic ecosystems, releases of crude oil also negatively impact air quality through contamination from a wide range of chemicals, including VOCs. These same chemicals are also emitted by many other sources such as motor vehicles, industries, paints, and cleaning solvents.

Depending on the location of the release of oil from a breach of Line 5, the risk of exposure to contamination could potentially require the evacuation of some areas, and the relocation of households and businesses in the affected area. The economic damages of such an event are uncertain and context-dependent but given the high value of real estate

in the area and the scale of use during the summer season, the effects on property values could be highly significant.

More than 80% of the University of Michigan simulation analyses of worst-case spill scenarios involved direct impacts to northern Lake Michigan, Mackinac Island, and other parts of Lake Huron adjacent to the Straits of Mackinac (Schwab, 2016). Acknowledging the uncertainty associated with the location and scope of a possible rupture of Line 5, the economic damages to coastal property were estimated using the market value of coastal property, based on 2017 county equalized values of real and personal property (Charlevoix County, 2017; Cheboygan County, 2017; Emmet County, 2017; Mackinac County, 2017). Coastal property values were estimated based on the equalized values in coastal townships and cities in Tier I and Tier II counties. Maps were used to estimate the share of coastal properties as a percentage of total township/city area.

Estimates of the economic damages to coastal property of an oil spill from Line 5 in the Straits of Mackinac were developed based on the following assumptions:

- Tier I counties experience a loss of annualized benefits of coastal property of 80% in Year 1, 60% in Year 2, 40% in Year 3, 30% in Year 4, and 20% in Year 5.
- Tier II counties experience a loss of annualized benefits of coastal property of 50% in Year 1, 30% in Year 2, 15% in Year 3, 10% in Year 4, and 5% in Year 5.

Annualized benefits were calculated based on an estimate of a 50-year useful life. The present value of estimated economic damages to coastal property values from an oil spill from Line 5 in the Straits of Mackinac was estimated based on a discount rate of 3%, which is appropriate for the estimate of economic impacts of environmental damages. Based on these assumptions, estimates of the total economic impact of an oil spill at or near the Straits of Mackinac on coastal property values are presented in Table 8. Estimates of total economic damages are nearly \$500 million.

Table 8: Present value of potential economic damages to coastal property values from an oil spill from Line 5 in the Straits of Mackinac

Affected Area	Economic Damages
Tier I counties	\$ 235,774,960
Tier II counties	\$ 250,036,203
Total economic impact	\$ 485,811,163

Conclusions

Oil spills occurring in freshwater bodies receive less publicity than spills into oceans, even though freshwater oil spills are more frequent and often more destructive to the environment (EPA, 2016b). Freshwater bodies are important to human health and the environment, and they are highly sensitive to contamination from oil spills and other pollution. Both standing water and flowing water bodies are often used for drinking water

and frequently serve as nesting grounds and food sources for various freshwater animals. All types of freshwater organisms are susceptible to the harmful effects of oil spills, including mammals, aquatic birds, fish, insects, microorganisms, and vegetation. In addition, the effects of spilled oil on freshwater microorganisms, invertebrates, and algae tend to move up the food chain and affect other species (EPA, 2016b).

This report provides estimates of the economic damages from an oil spill from Line 5 at or near its crossing in the Straits of Mackinac. The estimates were based on an oil spill scenario involving a release of 2.5 million gallons of crude oil and affected shoreline of 900 miles across fifteen counties in Michigan. 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. The basis for these assumptions was derived primarily from a document review and interviews with experts. It is important to note that this oil spill scenario does not necessarily reflect, nor is it intended to be interpreted as, *the* worst-case scenario; rather, it is a reasonable case that is informed by expert knowledge. The scenario reflects the real possibility of technological failure and delay in human response. In the context of Line 5, the worst-case scenario may be far greater in terms of scale, scope, and the magnitude of impacts.

Natural Resource Damage Assessment is the legal process that federal agencies use to evaluate the impacts of oil spills on natural resources. The damages to natural resources and ecosystems from oil spills must be assessed, monitored, and restored, and their related injuries must be compensated, according to federal law. Estimates of natural resource damages in the event of a breach of Enbridge Line 5 at or near its crossing at the Straits of Mackinac could reach more than \$697 million for the oil spill scenario developed for this report, even under conservative estimates.

These damages also have negative impacts to numerous economic sectors that depend on the aquatic and terrestrial ecosystems that are affected, including coastal tourism, commercial fishing, municipal water treatment systems, and coastal real estate, among others. This study involved the estimation of potential economic damages to these economic sectors, based on assumptions and data collected from key informant interviews and a review of relevant documents and published research articles. Estimates of these economic impacts reach nearly \$5.6 billion under the oil spill scenario developed for this report. This estimate is also conservative, given the high levels of uncertainty regarding the location, scale, and scope of an oil spill near the Straits of Mackinac, and the potential for a worst-case scenario involving a rupture that affects a wider geographical range, or that involves a greater amount of oil released. A summary of the estimates of natural resource damages and economic impacts of an oil spill from Line 5 in the Straits of Mackinac is presented below in Table 9.

Table 9: Summary of estimates of natural resource damages and economic impacts of an oil spill from Line 5 in the Straits of Mackinac

Category	Economic Damages
Natural resource damages and restoration	\$697,500,000
Economic impacts	
• Tourism	\$ 4,823,082,926
• Commercial fishing	61,050,000
• Municipal water systems	233,090,000
• Coastal property	485,811,163
Total economic impacts	\$5,603,034,089

This report did not investigate potential direct impacts to the Great Lakes shipping industry or the downstream effects that would be induced via import/export delays. As a vital aspect of the U.S. economy, the Great Lakes Navigation System (GLNS) connects the Great Lakes regional economy, the 5th largest in the world, with trade partners around the region and globe (U.S. Army Corps of Engineers, 2013). The 60 ports on the Great Lakes support more than 128,000 U.S. jobs and collectively generate \$18.1 billion in annual revenue (U.S. Army Corps of Engineers, 2013). Delays to this system could have massive impacts on the economy. Furthermore, this report did not investigate the costs of evacuation of particular areas that would be intensely affected by a release of oil from Line 5 because of air contamination. Finally, because of limited availability of data, this report did not consider the potential impacts to economic sectors in Canada. The Schwab (2016) simulations demonstrated, however, that the shorelines of Ontario are vulnerable to impacts of an oil spill from Line 5.

This report is provided to demonstrate the potential economic damages from a release of crude oil in the highly sensitive freshwater environment of the Great Lakes, and as such, it does not reflect any analysis of the risk or probability of such an event. Nevertheless, given the age of the dual pipelines of Line 5 in the Straits of Mackinac, the company's track record with previous oil spills, and the documented history of economic impacts of previous oil spills, a rupture of this pipeline is possible, and has the potential to inflict economic damages that are significant, if not catastrophic.

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