Issue Brief 3
02/20/2015

Great Lakes Commission des Grands Lacs

Crude Oil Transport: Risks and Impacts

Introduction

Since 2010, the use of land and water transport networks to connect the oil and gas fields in the western United States and Canada with refineries and ports on the east, west and Gulf coasts has grown exponentially. Transport of two types of crude oil (Bakken shale oil and Alberta oil sands crude) has been increasing in the Great Lakes-St. Lawrence River states and provinces. It is expected that light crude oil from U.S. shale deposits and heavy crude from Alberta will play a prominent role in overall bulk commodity transport in the Great Lakes states and provinces well into the 2020s.[1]

The rise in crude oil shipments poses environmental and safety risks from accidents that may occur along pipelines, rail lines, waterways and at transshipment sites. All of these modes pose certain risks and each has certain advantages compared with the other modes. Therefore, decisions surrounding the transportation routes and mode of transport are foundational to the protection of the air, land and water resources of the region. For instance, while some risks of oil transport to the Great Lakes-St. Lawrence River region might be mitigated by construction of west-to-east and north-to-south pipelines (which would bypass the region), oil pipelines are long-term projects, expensive to construct and have fixed routes. Railroads, vessels, barges and trucks have less carrying capacity than pipelines, but their routes are more flexible, allowing oil industry shippers to respond more quickly to changing production locations and volumes and changes in demand from coastal refineries. Although pipelines have historically been the preferred choice of oil companies, these more flexible transport options can be practical and cost-effective alternatives.[2] [3]

All the modes of crude oil transport pose potential risks to the environment, public health and safety. This policy brief describes the range of risks and impacts associated with each mode of transport and the associated transshipment points. The intent of the brief is to provide local, state and provincial officials in the Great Lakes-St. Lawrence River region with an overview of what is known about the range of risks and associated impacts so that steps can be taken to ameliorate risks and prepare for potential spill incidents.

The Context: Defining Risks and Impacts

Risk is typically defined in relative terms, as a ratio describing the probability of an event with negative consequences. In the case of oil transport in the Great Lakes-St. Lawrence River region, the concept is complicated by numerous variables, including the variety of landscapes potentially affected by an oil spill-related incident, the vulnerability of those landscapes to damaging impacts, and the type and extent of the incident. An "incident" may range from a modest spill on isolated rural land in the winter (limiting ground contamination) to a major catastrophic spill in one of the Great Lakes or a derailment-produced spill and fire in a major urban area. Moreover, the risks can be further complicated by the properties of the oil being transported. For instance, research shows that Bakken crude oil is more volatile and has a lower flashpoint than conventional crude oil. [4] However, there is a need to better understand the properties of the different types of oil and how these properties influence the mode or modes of transportation chosen and the risks associated with those choices. For a detailed description of the types of crude oil being transported, please refer to *Issue Brief 1: Developments in Crude Oil Extraction and Movement.*

Because of the diverse nature of oil spills, it is difficult to predict the extent and duration of impacts on the Great Lakes-St. Lawrence River ecosystem, human health and the regional economy. As the Deepwater Horizon incident in the Gulf of Mexico in April 2010 demonstrated, impacts on fisheries, local businesses and tourism may persist until long after the oil has been removed.[5] [6] In the Great Lakes-St. Lawrence River region, there are more than 43 million people – approximately 8 percent of the U.S. population and 50 percent of the Canadian population – who depend on the Great Lakes and the St. Lawrence River for their drinking water supply.[7] Industries such as agriculture, tourism, and sport and commercial fishing are potentially at risk from impacts if an oil spill were to occur. In addition, manufacturing industries in the region rely both on oil for their operations and water for their industrial processes and could be impacted by oil spills.[8] Moreover, the region is home to pristine natural environments and ecologically sensitive areas and the Great Lakes, along with the St. Lawrence River, are central to the physical and cultural heritage of North America. A spill in such an important and sensitive region can have far-reaching consequences, including both the damage done by the oil itself and the impact of intensive cleanup efforts, which can compound the environmental impacts in ecologically sensitive areas.

All modes of crude oil transport have advantages and disadvantages based on a range of operational, economic and environmental factors and considerations. If states and provinces are to respond effectively to reduce risks and prepare for potential accidents, public officials need to understand the risks associated with each mode and their potential impacts on the environment in order to protect the health and safety of communities. The following section will discuss the special risks of crude oil spills for each mode of transportation and the impacts with respect to the Great Lakes-St. Lawrence River region. For details on advantages and disadvantages of each mode of transport on the region, please refer to *Issue Brief 2: Advantages, Disadvantages, and Economic Benefits Associated with Crude Oil Transportation.*

Associated Risks

Pipelines

The U.S. and Canadian pipeline infrastructure has been a component of domestic and international transportation of oil for more than a century. The 44,117 mile network of Canadian crude oil pipelines, regulated by the National Energy Board (NEB), stretches from Vancouver, British Columbia, into the Great Lakes-St. Lawrence River region as far as Montreal, Québec.[9] The Canadian pipelines are highly integrated with the U.S. crude oil pipeline infrastructure, which spans more than 57,348 miles including a portion of all of the Great Lakes states.[10] Within the Great Lakes-St. Lawrence River region, active crude oil pipelines extend over 9,122 miles.[11] [12] Studies show that pipelines have a lower spill incident and fatality rate per billion ton-miles of oil transported when compared with other modes of transport. However, a pipeline oil spill, when one occurs, can have severe and long lasting impacts on public health, the environment and regional economy. [13]

The age and quality of the pipeline infrastructure are important factors in assessing oil spill risk from this mode in the Great Lakes-St. Lawrence River region. According to the U.S. Department of Transportation's (DOT) Pipeline and Hazardous Material Safety Administration (PHMSA) Office of Pipeline Safety, much of the pipeline infrastructure has been in place for decades.[14] In the Great Lakes states, 55 percent of the pipelines were installed prior to 1970.[15] In the Canadian provinces, the NEB statistics from July 2011 show that approximately 48 percent of Canadian pipelines carrying hazardous liquids were installed more than 30 years ago.[16] Additionally, incident data collected by PHMSA show that the most common cause of spill incidents involving pipelines is pipeline infrastructure failure.[17]

The pipeline safety statistics from 2000-09 show 411 spill incidents from Canadian pipelines and 3,318 spill incidents from U.S. pipelines.[18] Within the eight Great Lakes states, 559 hazardous liquid spill incidents occurred between 2004-2010, resulting in property damages of over $1.1 billion.[19] Although data from Canada's NEB and the U.S. DOT show that pipelines result in fewer oil spill incidents and personal injuries than road and rail, this is a high-volume transmission mode and large spills in the recent past have demonstrated that the cumulative impact of a spill on the environment, economy and human health can be serious.

Pipeline Integrity: Over time the quality of pipeline performance declines due to structural degradation, cracks caused by corrosion, defective welding or incidental damage from third-party activities. The Enbridge pipeline spill near Marshall, Mich., on July 25, 2010, for example, was caused in part by a structural failure in a section of pipeline where cracks had formed due to corrosion and then coalesced to the point where the pipeline ruptured.[20]

Natural Hazards and Extreme Weather Conditions: Pipelines in the Great Lakes-St. Lawrence River region traverse diverse geographic areas and are subject to damage from the freeze-thaw cycle, ice, floods, subsidence, and shoreline and lakebed erosion. These potential damages to pipeline infrastructure may contribute to increased risks of a pipeline spill. Outdated information about potential hazards can also lead to increased risk. For example, flood maps and information provided by FEMA's Flood Insurance Rate Maps often date back to the 1970s.[21] Outdated information such as this can lead to increased risk in the event of a spill and also creates uncertainties regarding the effects of proposed pipeline infrastructure expansion.

Monitoring: Studies show that more efficient external sensors would improve the performance of current sensors, which some reports indicate have detected only five percent of pipeline spills in the United States in the last 10 years.[22] However, the existing regulatory framework has yet to require improved monitoring standards. Moreover, U.S. pipeline regulations do not require pipeline companies to publicly disclose what type of oil is transported, which would aid state and provincial officials in preparing for spills. Sporadic monitoring lapses and the inability to provide up-to-date data may exacerbate the risks from pipeline spills. While studies show that upgrading pipeline infrastructure with automatic shut-off valves can reduce potential risks, the current regulations do not require such upgrades.[23] [24] Pipeline companies may discourage the installation of remote shut-off systems due to installation costs.[25]

Location and Environment: Pipelines run through diverse ecological areas that may be home to endangered species and are sensitive to environmental degradation. Spill response planning resources developed by the U.S. Environmental Protection Agency (U.S. EPA) identify many areas of great ecological sensitivity throughout the U.S. Spill response atlases developed by Environment Canada show sensitive shoreline areas throughout the Canadian Great Lakes and St. Lawrence River. Location itself can be an important risk factor since there is a risk of delayed emergency response in remote areas. Both of these conditions must be considered when evaluating the potential risks of pipeline spills.

Human Error: Pipelines require regular maintenance inspections and constant monitoring during operation. Accidents may result from undetected structural or mechanical failures and made worse by insufficient or delayed monitoring. For example, the initial rupture of the Enbridge pipeline near Marshall, Mich. in 2010 was largely due to the physical condition of the pipeline, but the volume of crude oil released was at least partially the result of deficient integrity management procedures and inadequate training of control center personnel.[26]

Ships and Barges

About 70 percent of the oil sands crude currently being extracted in Alberta, Canada is sent to refineries in the United States.[27] The rise in production of Alberta oil sands increased the total quantity of oil transported to refineries in the United States by 53 percent between 2011 and 2012. [28] On the St. Lawrence River, crude oil has been imported for decades as a raw material for refineries in Montreal and Québec. Since September 2014, heavy oil sands crude is being exported via the river as well. Although crude oil is not currently transported on the Great Lakes, it has long been moved by barge to Midwestern and East Coast refineries via such inland waterways as the Mississippi, Ohio and Hudson rivers. In places such as Hennepin, Ill., and Albany, N.Y., barges are used to transport small quantities of crude oil as an alternative to rail transport.[29] Studies show that ships and barges pose fewer risks in transporting hazardous liquids than trains and trucks, and have economic advantages over these modes of transport, as well.[30,31,32] Given these advantages of transportation by vessel and the proximity of several oil refineries to major ports in the region, the Great Lakes-St. Lawrence Seaway deep-draft navigation system has predictably been receiving increased scrutiny as a potential routing alternative. In the absence of crude oil shipments on the Great Lakes, an analysis of spill data from commercial vessels transporting other hazardous liquids on the Great Lakes could provide some insight into the risk of a crude oil spill. But it should be noted that an oil spill in open water or inland-restricted waters, particularly involving oil sands crude oil, poses a much greater array of risks, including potential long-lasting impacts on the environment and the economy.[33]

Severe Weather: Weather conditions, especially on open waters, are a much greater risk factor for water transportation than for truck, rail or pipeline. Severe weather on the Great Lakes-St. Lawrence River system, in the form of high winds and waves, ice and reduced visibility – particularly when combined with equipment failure and/or human error – can substantially increase the risk of catastrophic events. Even with access to several high end weather forecasting tools and services, changing weather and extreme weather events can increase the risk of an accident and should not be ignored.

Spill Response Challenges in Streams, Rivers and Connecting Channels: Many of the refineries, oil storage facilities and ports in the region lie along the connecting channels and major tributaries of Great Lakes and the St. Lawrence River.[34] If a spill were to occur in these areas, there is a risk of spreading into adjacent waterways, which can complicate the response. A good example is the 2010 Enbridge spill. The original source was located alongside a small creek, but the oil ended up flowing down the creek to reach the Kalamazoo River and traveled some 30 miles downstream before it was contained. In the Lac-Mégantic spill, oil travelled from the derailment site in the village to Lac Mégantic itself and ultimately reached the Chaudière River, a tributary of the St. Lawrence River.

Human Factors: There is also greater responsibility placed on a single human operator for ship and barge operations than in surface transportation modes. While commercial shipping lanes linking cargo ports on the Great Lakes are well-established in open waters and tightly regulated in restricted and high-traffic areas, ultimate navigation routing decisions and ship handling maneuvers are still controlled by the vessel master on U.S. and Canadian flag vessels, or by a licensed pilot on foreign flag vessels operating in the Great Lakes via the St. Lawrence Seaway. There are portions of the St. Lawrence River that are very narrow and even the best pilots can make mistakes resulting in a spill.

Collisions, Allisions and Groundings: A barge or tanker ship containing crude oil can suffer severe structural damage and spill cargo as the result of a collision with another ship, an allision with a fixed structure such as a seawall, pier or bridge, or a grounding. The latest regulations by Transport Canada require all tankers, small and large, to be double-hulled by 2015.[35] Similarly, under the U.S. Oil Pollution Act (OPA) of 1990, double-hulled tankers will replace the double-bottom and double-side vessels by 2015.[36] For more details on OPA's legal framework, please refer to *Issue Brief 4: Regulations, Policies and Programs Governing Transport of Crude Oil.* Depending on the type of oil in the vessel, the impact resulting from a collision, allision or grounding may cause fire and a risk of explosion.[37]

Railroad Transport

According to the Association of American Railroads, 434,000 carloads of crude oil moved by rail across the U.S. in 2013, roughly 45 times the amount shipped in 2008, with the volumes expected to continue to rise.[38] The immense increase in the volume of oil shipped by rail is due to the rail industry's ability to quickly respond to increased production in the oil fields by modifying routes, adding cars and scheduling additional trains. However, the increased volume of rail transport has also led to a rise in oil spill incidents involving trains. Rail has historically been a safe and efficient way for suppliers to transport oil. Over the period 1996-2007, railroads statistically spilled less crude oil per ton-mile than either trucks or pipelines. However, in 2013 alone, the total volume of oil spilled by rail was more than the combined total from 1975-2012.[39] [40] Recent disastrous events – Lac-Mégantic, Québec (July 6, 2013); Casselton, N.D. (December 30, 2013); Aliceville, Ala. (November 7, 2013); and Lynchburg, Va. (April 30, 2014) – coupled with projections of the continued growth in volume of oil transported by rail have elevated the importance of understanding the safety and environmental risks associated with this mode. [41] Owing to the increasing number of incidents, rail transportation of crude oil has been receiving more public and regulatory scrutiny in the United States and Canada. Please refer to Issue Brief 4 for more details on the regulatory changes that have been made in the past year.

Infrastructure: Studies of Federal Railroad Administration (FRA) data show that 60 percent of freight train accidents are caused by derailments.[42] The major causes of derailments are broken rails or welds, buckled track, obstructions, and main-line brake operation. [43] Other factors include train speed, weather conditions and human error

Tank Car Design: The Class 111 tank car is most frequently used to ship crude oil in the U.S. and Canada. Several problems have been identified with this tank car model. These tank cars are prone to structural failure and rupture upon impact. Studies from the Transportation Safety Board (TSB – Canada) and the National Transportation Safety Board (NTSB – United States) show that the Class 111 car's wall thickness (7/16 inch) may not be sufficient to withstand impact during an accident. [44] The top-fittings, used for loading content, may burst open in a derailment or rollover. The head shields at the front of the cars are prone to puncture in a collision. The three bottom valves, facilitating quick unloading at the terminals, can break on impact and release oil. Out of the 63 oil-filled tanker cars that derailed in Lac-Mégantic, 60 cars (95%) spilled oil due to tank car damage – puncture of shell and front/rear heads were identified as the major structural points of failure.[45]

Mixed and Unit Trains: Mixed trains carry various types of cargo to and from multiple destinations. The combination of cars and cargos varies depending upon demand and may change. Unit trains are high-volume trains carrying one commodity from a single point of origin to a single destination. Unit trains carrying crude oil may contain as many as 120 to 140 tank cars and be over a mile long. Oil carried in unit trains poses risks because of the volume involved and because a derailment may result in fire and explosion that can spread to coupled tank cars. Mixed trains may carry a smaller volume of oil, but they, too, come with risks. Tank cars can be used to carry a variety of liquids, including hazardous materials other than oil; information about the commodity carried in any given tank car may be incomplete, leaving responders uncertain about appropriate response protocols in the event of an accident; and operators change the sequencing of cars during the rail journey based on the car's destination and other loads that are picked up.[46,47]

Regulatory: In the U.S., regulations require that railroads have either a 'basic' response plan or a more 'comprehensive' response plan, depending on the capacity of individual rail cars transporting the oil. In 1996 the Federal Railroad Administration (FRA) set the threshold differentiating the response plans at 1,000 barrels. This means that the more stringent requirements applied to comprehensive response plans do not apply to Class 111 tank cars, which carry around 700 barrels.[48] Mixed trains may haul sets of several Class 111 tank cars and unit trains usually contain more than 100 of them, but under existing regulations, operators of either type of train, regardless of the volume of oil being carried, are not required to develop and implement comprehensive response plans.

Human Capital Planning: In the quickly changing scenario of oil transportation, agencies at all levels might find it difficult to recruit, train and allocate employees to meet regulatory and inspection needs created by dramatically increased volumes of crude oil being transported. The FRA is facing strategic human capital planning challenges to cope with increased traffic flow, new technologies and new regulations – a risk factor that is actually applicable to regulatory agencies for all the modes of transport listed in this issue brief.[49] States are also facing challenges regarding inspection capacity. Some states, like New York, have started to hire additional inspectors,[50] but this process can be difficult because of lack of funding and lack of qualified candidates.

Crossings: Unmonitored crossing points are special risk zones where accidents with automobiles, vans, trucks and buses can increase the risk of an oil spill or explosion. With the advent of unit trains, which are frequently over a mile in length, automobile drivers may be tempted to run through closed crossings. Monitoring of crossings, including illegal trespassing, and installation of proper infrastructure are the responsibility of local law enforcement officials who do not always have the manpower to monitor crossings in densely trafficked urban areas. For example, an accident between a truck and an empty oil tanker in West Nyack, NY, in December 2013, that led to a fire and explosion took place at a location where there was a lack of infrastructure (safety gate system) and lack of monitoring.[51]

Train Assembly: Research shows that improperly assembled trains are more susceptible to derailment.[52] The distribution of cars that are empty or loaded and the length of the train affects its ability to negotiate track routes while subjected to 'stretching' and 'compressive' forces and may result in derailment. In addition to train assembly, other factors like track grades and turning radius affect train maneuverability, which may result in derailment.

Tanker Trucks

Tanker trucks provide flexibility, linking extraction sites and refineries to pipelines and rail terminals. Unlike other modes of transport, trucks are primarily used to transport oil for relatively short distances because long distance transport by truck is not ordinarily an economical option.[53] Although trucks transport only a small percentage of the oil being moved in the U.S. and Canada overall and an even smaller percentage in the Great Lakes-St. Lawrence River region, there has been a recent increase in truck oil shipments, which may be a cause of concern. Shipments of oil by truck from shale formations in North Dakota and oil sands in Canada to U.S.

refineries increased by 38 percent between 2011 and 2012.[54] The existing studies on truck transport indicate that trucks are not a favored mode of transport due to high incident rates per billion ton-miles when compared to rail, ship/barge and pipeline.[55] [56]However, the rise in production may change transportation trends.

Infrastructure: Since trucks are often used to transport oil to and from railway transshipment facilities and pipelines, poorly maintained and monitored infrastructure at delivery points and fuel loading terminals could contribute to accidents, including fire and explosion.[57]

Regulatory: A significant risk emerges from lack of information. For example, the U.S. DOT does not track the total number of cargo tank trucks operating within the United States.[58]

En route collision: As compared to other modes of transport, tanker trucks operate in close proximity to the general public and share the same infrastructure (i.e., highways, roads, neighborhoods). Trucks can also operate in densely populated areas. This increases the risk of accidents, including collisions and accidents at crossings. Collisions may involve multiple vehicles and can occur at high speeds, which may increase the risk of fire and explosion. [59]

Truck Design: Tanker trucks are typically loaded through bottom lines, which do not drain completely into the tank because they are at the lowest point on the container. The structurally fragile bottom lines can contain more than 50 gallons of the oil, referred to as 'wetlines,' and may contribute to an event leading to fire and explosion.[60]

Transshipment Facilities

The rise in crude oil production from United States and Canada is changing the ways in which oil is moved in both countries and the geography of oil transport lines, networks and nodes. Transshipment facilities are being expanded in some instances and new ones are being planned and created. These include truck transfer sites at the point of extraction to connect with pipelines; loading and off-loading sites at rail spurs and in rail yards; and transfer and storage sites along pipelines and at refineries and ports. The Port of Superior, Wisconsin, is facing this situation.[61]A proposal to facilitate the transport of crude oil on Lake Superior was recently put on hold. There are also proposals for new facilities such as the one being considered in Cacouna, Québec, which are also a outcome of this increase in production.[62]

While some Great Lakes-St. Lawrence River transshipment facilities are becoming more important because of their proximity to booming oil fields or have other geographic advantages, some transshipment facilities are less economically viable because they are linked to older and now declining sources of oil. This is an inherent problem of the boom-bust cycle of resource extraction-based economies. To cope with uncertainties, oil companies use multiple modes of transport to link key production sites and refineries. They also utilize makeshift facilities, as is happening in North Dakota, to provide immediate services. These temporary facilities are likely to create more risks than those that have been planned carefully and fully vetted by regulators.[63]

As Bakken shale oil production and Alberta oil sands production intensify, so may the transshipment and trans-loading infrastructure in the Great Lakes-St. Lawrence River states and provinces. In the Great Lakes states, recent information suggests that Canadian Pacific railway has five crude oil trans-loading facilities and the BNSF railway has nine.[64] [65] These could potentially increase their operating capacity to meet the rising demand of crude oil transportation. Any receiving facilities for crude oil on the Great Lakes would have to be new, purpose-built installations, presumably at major deep-draft ports near existing refineries in the region, since there is no current shipment of crude oil on the Great Lakes. On the St. Lawrence, there are already terminals in Montreal and Québec city, but there are plans to build new ones along the river. Smaller inland ports may also pose indirect risks to the Great Lakes, should they choose to ship oil as a commodity. The port at Wood River, Ill., for example, off-loads 40,000 barrels per day of heavy Canadian crude from pipelines onto barges, which creates the risk of a spill incident. [66]

The existing literature on crude oil transportation focuses almost exclusively on the modes of transportation and overlooks the substantial risks of transshipment points in the United States and Canada. A comprehensive understanding of risks and impacts of transshipment ports can help to manage these critical points and reduce the possibility of catastrophic accidents.

Infrastructure: The most common risk associated with transshipment points are the technical failure and defects of equipment such as an oil loader at a barge and truck-loading terminal that can cause oil to spill. [67] Cargo shipments may also be held for days at transshipment points before being transferred to other modes of transport and they may not be monitored for leakage and/or accidental damages. A case in point is the incident at the Port of Albany in June 2014, where 100 gallons of oil was spilled from a stored rail car because of a pressure release valve. [68] To respond to the increasing supply of oil, transshipment facilities have begun to increase their oil storage capacity, which further increases the risk.[69]

Regulatory: Regulatory oversight of Great Lakes-St. Lawrence River ports involves multiple jurisdictions and can vary widely based on port governance structures, of which there are many. On the U.S side, each of the 13 major ports of the Great Lakes-St. Lawrence Seaway System is governed by a public agency: a state, a county, a municipality or a legislatively enabled port authority. Individual docks in these ports are operated by private companies as tenants. In smaller U.S. Great Lakes ports, most docks are privately owned and operated. All U.S. Great Lakes commercial ports are accessed by federally maintained (U.S. Army Corps of Engineers) and federally regulated (U.S. Coast Guard) navigation channels. Additional federal regulatory oversight regarding liquid bulk transportation is wielded by the U.S. EPA and the U.S.DOT. States also play regulatory roles through their respective environmental protection and transportation agencies. In Canada, federal port authorities, provincial governments and municipal governments manage the ports and private companies own and operate the docks.[70] Federal commercial navigation oversight is provided by Transport Canada. Collectively, the sheer number of regulatory players involved in waterborne oil transportation on the Great Lakes complicates the risk management process. As with other transport risk "arenas," transshipment facilities are affected by the absence of current information on the potential risks they pose; risks that may be exacerbated by an increase in the volume of oil they are handling. For example, outdated coastal flood maps may underestimate a variety of dangers to Great Lakes carriers. The Great Lakes-St. Lawrence River region experiences lake level changes, coastal flooding, streambank and shoreline erosion, and storm surges among other hazards.[71] These hazards can potentially cause physical damage to the port infrastructure that can then lead to a catastrophic event.

Human Error: Past studies attribute the majority of failures to human errors while operating loading equipment at a terminal.[72] At transshipment sites, risks can also come from unmonitored docked cargos that can turn a small oil spill into a catastrophic event. Furthermore, unclear accountability for the docked cargo between docking and unloading can complicate or delay an oil spill response.

Impacts

As history has shown, oil spills can have major impacts on human health, the environment and the economy, regardless of which mode of transportation is used. When spilled, oil can infiltrate into the ground and contaminate groundwater. If spilled in open water or in a river, oil can spread rapidly. A spill on land can jeopardize commercial, industrial and residential areas in suburban/urban settings and recreational, agricultural and forest lands in rural settings A spill on water can impact aquatic ecosystems, fish and wildlife habitat including nesting and spawning areas and have water quality impacts that detrimentally affect recreation and public health. Because of their different natures, oil sands and shale oil can have different impacts when spilled, especially in open water, where the former will have the tendency to sink while the latter will mostly float.

Human health

A spill that occurs on a lake or a river where cities get their drinking water can be catastrophic if the spill is not contained in time and oil flows into municipal or industrial water intakes. Such a spill could cost cities, businesses and industry millions of dollars or more in damages in addition to public health impacts if communities are not immediately notified of the danger. Oil from a spill can penetrate into the ground and reach underground aquifers, which in many areas of the Great Lakes-St. Lawrence River region also serve as drinking water supplies. If ingested, water contaminated with oil can have detrimental impact on the nervous, digestive, respiratory and immune systems.

In case of a spill, several chemical components from the oil itself or from diluents can be released in the air, causing additional serious health problems. In a report published in 2010 evaluating the impact of the Enbridge spill, the Michigan Department of Community Health showed that over 50% of the people located in or near the spill site had at least one symptom of exposure to hazardous compounds in the air, and at least 40% had two symptoms. These were mostly headaches, respiratory symptoms and gastrointestinal problems.[73]

Another threat to public safety is the fires and explosions that can result from an oil spill or an accident involving crude oil. In Lac-Mégantic, for example, the fires and explosions following the derailment were the primary cause of the death of the 47 people of lost their life.[74] Any accident that occurs in a populated area places lives at stake.

Ecological impacts

Spilled oil impacts the environment sometimes severely. Oil spilled in water or on land near waterbodies can move quickly and spread rapidly in rivers, lakes and streams. Oil spilled on land may also contaminate groundwater aquifers.

Spilled oil can impair or destroy fish and wildlife habitat. It also directly impacts organisms that come in contact with it, including humans and aquatic or semi-aquatic flora and fauna. Detrimental effects may span the entire local ecosystem, including plants, fish, birds, mammals, amphibians, reptiles and invertebrates. Direct mortality of animals can occur from ingestion of oil or contaminated food and inhalation of toxic fumes. Indirect mortality can be the result of physical contact with oil. Birds whose feathers get covered by a layer of oil can lose their ability to fly. Their buoyancy and thermal protection can also be affected. The same is true with mammals that rely on their fur for thermal protection. Contact with and/or ingestion of oil can also result in reproductive and developmental problems, like abnormalities leading to malfunction of organs. Finally, an oil spill can destroy habitat, feeding and spawning sites.

As important as they are, cleanup efforts can have their own negative impact on the environment. Apart from the floating oil, crude oil that spreads along shorelines and sinks to the bottom in nearshore areas also has to be removed. Access to remote locations and the creation of staging areas can disrupt the local area and have negative impacts. Dredging of the waterbed is often deemed necessary after a spill, but also brings with it detrimental effects.[75] The Enbridge spill cleanup in the Kalamazoo River, for example, required dredging of the streambed, scraping oil from the shore, vegetation and debris removal, and construction of access to cleanup sites (boat launches, mat roads, dredge pads). Even though the impact of these activities has been kept as minimal as possible and there were important efforts to restore the sites afterwards, there were impacts nonetheless.

Economic impacts

Apart from impacts on human health and the environment, an oil spill can have major repercussions on the economy. Local businesses can see their revenue dramatically decrease because of loss of clientele. Local industries and agriculture may be impacted by lack of access to raw materials, inaccessible manufacturing resources such as power or water, and the inability to transport products. Property values for homes and commercial buildings may fall significantly. High quality agricultural or forest lands can be contaminated by oil, rendered inaccessible or damaged during cleanup efforts. Even after cleanup is completed, communities often face additional expenses to restore local tourism, build their business and win back lost clientele.[76]

After the 2010 Enbridge spill in Marshall, Mich., the local economy struggled and even four years later, local businesses continue to be affected by loss of clientele. A recent report[77] showed that the estimated cost of the 2010 Enbridge pipeline spill in Michigan was $1.35 billion.[78] In Lac-Mégantic, the train derailment destroyed the heart of the municipality and contaminated the soil. For months, the area was not accessible. One year later, some businesses are slowly starting to grow back close to downtown, but it will take years for the local economy to recover to pre-spill levels. An economic analysis of the impact of the spill there shows a 2.1% decrease in revenue for local businesses, 153 jobs lost, an important decrease of property taxes, and a 52% decrease in tourism activities for that summer.[79]

Great Lakes-St. Lawrence River communities rely heavily on coastal tourism and recreation. A crude oil spill near almost any community in the region would impact this economic sector. Beaches contaminated by crude oil wouldn't be accessible, swimming would be banned for a period, and aquatic sports – canoeing, kayaking, water-skiing or kite surfing, for example – would be restricted or possibly eliminated for a season. In locations like state parks or nature reserves, where there is high biodiversity or the presence of rare species, a spill would have not only environmental impacts, but major economic impacts with the loss of tourists, bird watchers and other nature enthusiasts. An open water spill could also have a major impact on fishing. The Great Lakes-St. Lawrence River region relies heavily on commercial fishing to supply the local population and for export. Sport fishing is even more important to the region's economy. Together, these two industries are worth more than $7 billion annually in the Great Lakes region.[80]Fishing excursions with professional guides, fishing trip with friends, or one-day fishing on the shore are common in the region. Amateur anglers are an important part of the economy[81] and a spill would have repercussions.

A spill significant enough to result in the closing of major roads and highways can have a major impact on local and regional economies and travel. In the same way, a railroad that is not accessible for days – like in the case of Lac-Mégantic – can prevent the shipment of raw material to industries, finished products to customers, and goods to population centers. Railroad tracks are often shared between passenger and freight trains and the closure of a route would impact passenger rail services as well. An incident at a transshipment point can render it dysfunctional for days, again impacting commercial freight traffic and possibly the passenger rail and tourism industries.

The negative economic impacts of a spill are also related to the direct cost of cleanup. The recent spills have cost billions of dollars. In some cases, the companies involved have paid cleanup costs. In others, such as the Lac-Mégantic accident, federal, state, provincial and local governments cover many of the cleanup costs as they are being incurred and it can take time and legal actions for the governments to get paid back.

Finally, a significant crude oil spill in Great Lakes waters could also reduce public acceptance of oil transportation, threatening capital investments, employment opportunities and existing industries.

Discussion: Gaps in Knowledge of Risks and Impacts

This brief summarizes the ways in which all the modes of crude oil transport through the binational Great Lakes-St. Lawrence River region pose certain risks that depend on a number of factors – the type of crude oil being transported, the mode of transport, the route and destination, population density of areas to which and through which oil is being transported, environmental protection concerns, ecological variability and vulnerability, the state of emergency preparedness and response capabilities in the region, climate and weather conditions. The resulting impacts may have complex and poorly understood consequences for the environment, human health, public safety and economy of the region. Assessments of risks and impacts are informed by what is known from spills and accidents that have happened thus far. Although some of the literature reviewed in this issue brief recommends one mode of transport over another, the conclusions are based on partial data and incomplete analysis that doesn't fully reflect the rapidly changing circumstances surrounding crude oil transport in the Great Lakes-St. Lawrence River region. With the rise in crude oil transportation, there are important issues that need to be properly understood in order to develop a more comprehensive regional approach to reduce the risks of spills. Most importantly, to avert catastrophic accidents, a more effective and informed disaster mitigation strategy needs to be developed.

Relative Risk Study: There is no complete study currently available of relative risks and impacts associated with oil transportation that systematically considers all the factors for each mode of transport – economic consequences, incident rates, fatality rates, long-term environmental damages, etc. A study of relative risks is necessary and should include risk assessments using scenario-based research and focusing on the distinctive risks and impacts for each mode of transport are needed.

Regulatory Gaps and Risk Governance: The role of government in regulating oil transportation and the broader issue of jurisdictional authority can affect the way that risks are identified and managed and how impacts are ultimately mitigated. Some gaps in the regulatory regime have already been identified, but others may exist and few have been fully addressed. For instance, the issue of liability is not fully addressed by the market or by regulators. In the case of rail transport, the shipping companies are often under-insured and the costs of accident remediation clearly exceed the insurance coverage available in the commercial market. [82] Although shared liabilities where the government bears the costs over and above the cap limit provided by insurance companies seems a possible solution, the use of public money to cover the costs of a spill cleanup has increasingly attracted public scrutiny. The issue is further complicated by the issue of liability when the oil is in transit. The information that underpins the regulatory regimes of the Great Lakes-St. Lawrence River states and provinces may not be up to the task to meet the current and growing challenges of crude oil transportation. Existing regulatory regimes governing other forms of transportation, such as those governing airline safety, may offer working models that can be used to evaluate the safety and response mechanisms for the various modes of transport that ship crude oil. For more information on regulatory gaps, please refer to Issue Brief 4: Regulations, Policies and Programs Governing Transport of Crude Oil.

Emergency Preparedness: Emergency preparedness as it is currently implemented may not provide adequate preparation for major spill incidents that may have catastrophic consequences; that is, low probability, high impact incidents. Preparedness programs have been complicated by lack of communication between shippers, carriers, and state emergency responders.[83] The Oil Pollution Act (OPA) created a framework for assessing risk through the National Preparedness for Response Exercise Program (PREP). This is a good model for building relationships between agency and industry partners to improve preparedness programs and ensure readiness in the event of a spill. PREP guides spill response exercises at regulated oil handling facilities. The exercises are intended as opportunities for industry and agencies to validate and/or refine spill response plans; to build, clarify and strengthen relationships; to confirm available resources and capabilities; and to provide participants with on-the-job training in their roles and responsibilities. Industry is responsible for the costs of PREP exercises, but the exercises themselves are overseen by the U.S. Coast Guard, U.S. EPA, PHMSA and/or the Department of Interior’s Bureau of Safety and Environmental Enforcement. PREP exercises can take place at the national, regional or state/local level and come in three scales including exercises to address large-scale catastrophic spills. These full-scale (“area”) exercises are based on a scenario built around a theoretical large spill and include participation at all levels of industry and government, including the deployment of equipment by field personnel. Due to their size and complexity, area PREP exercises are held around the country on a rotating basis set by representatives of each of the PREP agencies. Standard practice has long been to schedule these exercises so that each U.S. EPA Region and each U.S. Coast Guard Captain of the Port Zone holds at least one exercise every three years.

Oil Characteristics: One point of contention even among experts relates to concerns about different oil characteristics and the implications for transportation mode choices. For instance, while some research indicates that raw oil sands products have higher sulphur content than medium and light crude oils and can contribute to corrosivity, other research suggests that oil sands products in their transported state are not more corrosive than standard crude oil.[84] Similarly, there has been conflicting research regarding the explosivity and flammability of Bakken crude oil and its impact on transportation modes.[85] Studies of oil characteristics, particular with respect to the mode of transport being used, can help inform the decision-making and regulatory process.

Land Use Planning in the Great Lakes Region: Land use planning in the region happens at the local level of government (i.e., town, city, county) so the federal government cannot effectively control this aspect of development.[86] Local land use plans often do not consider broader impacts on the surrounding areas and nearby communities. In the wake of increasing oil transportation and commensurate increases in infrastructure there is a risk that unplanned (or poorly planned) development could negatively affect public health and safety and the environment of the Great Lakes-St. Lawrence River region.

This policy brief summarizes the key risks and impacts of crude oil transportation for the Great Lakes-St. Lawrence River states and provinces, particularly in light of the dramatic increase in demand for transportation capacity. With rapid expansion of crude oil production in Canada and the U.S., oil shippers are utilizing the region’s transportation infrastructure to get their product to east coast refineries and into global markets. All segments of this critical transport infrastructure, including rail, tanker ships and pipelines, are affected, along with the ports and sites where the oil is moved from one type of transport to another. The rising demand for crude oil transportation has challenged the response mechanisms and governance frameworks of public and private institutions that provide monitoring, safety regulations and emergency preparedness. The ability to address the risks created by crude oil transport in the region has also been affected by fragmented regulatory responsibility and limited enforcement capacity. The risks and impacts information in this brief is intended to contribute to discussions of how monitoring, safety regulation and emergency preparedness can be improved to insure public safety and the protection of critical environmental resources in the Great Lakes-St. Lawrence River region.

---

[1] Lyman Welch, et al., *Oil and Water: Tar Sands Crude Shipping Meets the Great Lakes?* (Alliance for the Great Lakes, 2013), 1-3.

[2] John Frittelli et al., *US Rail Transportation of Crude Oil: Background and Issues for Congress*, (Congressional Research Service, 2014), 4.

[3] Pick You Poison For Crude – Pipeline, Rail, Truck or Boat, Forbes 2014, accessed July 27, 2014, http://www.forbes.com/sites/jamesconca/2014/04/26/pick-your-poison-for-crude-pipeline-rail-truck-or-boat/

[4] *Operation Safe Delivery Update* (PHMSA, 2014), 16.

[5] America's Gulf Coast: A Long Term Recovery Plan after the Deepwater Horizon Oil Spill (Restore Gulf Coast, 2010), 1.

[6] Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in Gulf of Mexico (Maritime Mammal Commission, 2011), 10. The report states that Exxon Valdez oil spill's (1989) long-terms effects were felt 15 years or more after the spill.

[7] Great Lakes Basic Information, U.S Environmental Protection Agency, accessed August 19, 2014, http://www.epa.gov/greatlakes/basicinfo.html

[8] Consumptive Water Use in the Great Lakes Basin, U.S. Geology Survey 2008, accessed July 24, 2014, http://pubs.usgs.gov/fs/2008/3032/pdf/fs2008-3032.pdf

[9] "How extensive is Canada's pipeline system?", National Resource Canada, 2013, accessed July 21, 2014, http://www.nrcan.gc.ca/energy/infrastructure/5893#h-1-3.

[10] "Annual Report Mileage For Hazardous Liquid or Carbon Dioxide System 2014", Pipeline and Hazard Materials Safety Administration, accessed July 21, 2014, http://www.phmsa.dot.gov/portal/site/PHMSA/menuitem.6f23687cf7b00b0f22e4c6962d9c8789/?vgnextoid=d731f5448a359310VgnVCM1000001ecb7898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print.

[11] EIA GIS database, accessed July 20, 2014, http://www.eia.gov/state/notes-sources.cfm.

[12] Data and Statistics for each individual U.S. states can be found at Pipeline and Hazard Materials Safety Administration, accessed July 21, 2014, http://primis.phmsa.dot.gov/comm/reports/safety/WI_detail1.html?nocache=2566#_OuterPanel_tab_5.

[13] Diana Furchtgott-Roth and Kenneth Green, *Intermodal Safety in the Transport of Oil.* Studies In Energy Transportation. (Fraser Institute, 2013).

[14] Office of Pipeline Safety, *Building Safe Communities: Pipeline Risk and its Application to Local Development Decisions* (U.S. Department of Transportation, 2010), 5. The article states that at least 55% of currently operating hazardous liquid pipelines in the U.S were installed before 1970 and at least 71% were installed before 1980.

[15] Data on age of pipelines for U.S. states can be found at Pipeline and Hazard Materials Safety Administration database, accessed July 21, 2014, http://opsweb.phmsa.dot.gov/pipeline_replacement/by_decade_installation.asp

[16] *2011 December Report of the Commissioner and the Environment and Sustainable Development* (Officer of Auditor General of Canada, 2011), Exhibit 1.5, accessed August 15, 2014, http://www.oag-bvg.gc.ca/internet/English/parl_cesd_201112_01_e_36029.html#ex5.

[17] *The State of The National Pipeline Infrastructure,* Secretary's Infrastructure Report (U.S. Department of Transportation, 2011), 3.

[18] Focus on Safety and Environment: A Comparative Analysis of Pipeline Performance – 2000-2009 (Nation Energy Board, 2011), accessed July 24, 2014, http://www.neb-one.gc.ca/clf-nsi/rsftyndthnvrnmnt/sfty/sftyprfrmncndctr/fcsnsfty/2011/fcsnsfty2000_2009-eng.html#s2_5

[19] Data and Statistics for hazard liquid incidents for each individual U.S. states can be found at Pipeline and Hazard Materials Safety Administration database, accessed July 23, 2014, http://primis.phmsa.dot.gov/comm/reports/safety/NY_detail1.html?nocache=5332#_AllPanelliquid

[20] *"Enbridge Incorporated Hazardous Liquid Pipeline Rupture and Release, Marshall, MI, July 25, 2010"* (National Transportation Safety Board 2012), Pipeline Accident Report NTSB/PAR-12/01.

[21] "Great Lakes Coastal Flood Study", Great Lakes Coast, accessed July 23, 2014, http://www.greatlakescoast.org/great-lakes-coastal-analysis-and-mapping/.

[22] "Keystone XL Would Not Use most Advanced Spill Protection Technology", Inside Climate News 2012, accessed September 5, 2014, http://insideclimatenews.org/news/20121217/keystone-xl-longhorn-pipeline-safety-ogallala-edwards-aquifer-nebraska-texas-austin-tar-sands

[23] Paul Parfomak, *Keeping America's Pipelines Safe and Secure: Key Issues for Congress* (Congressional Research Service, 2013), 21. Although the report points at natural gas transmission pipelines, similar technology can also be installed for oil pipelines that can reduce the risks.

[24] *Studies for the Requirements of Automatic and Remotely Controlled Shutoff Valves on Hazardous Liquids and Natural Gas Pipelines with Respect t Public and Environmental Safety* (Oak Ridge National Laboratory, 2012), 182-185.

[25] "Safety Valve Was Skipped", The Wall Street Journal, accessed August 16, 2014, http://online.wsj.com/news/articles/SB10001424052748704506004576174322210513228

[26] According to the National Transportation Board investigation report http://www.ntsb.gov/doclib/reports/2012/PAR1201.pdf

[27] Lyman Welch, et al., *Oil and Water: Tar Sands Crude Shipping Meets the Great Lakes?* (Alliance For The Great Lakes, 2013), 2.

[28] Maude Barlow, *Liquid Pipeline: Extreme energy's threat to the Great lakes and the St. Lawrence River* (The council of Canadians, 2014), 10.

[29] Frittelli et al., *US Rail Transportation of Crude Oil,* 7.

[30] Welch, et al., *Oil and Water,*7-8. According to Coast Guard data, the average annual spill for commercial vessels from 2003-07 was approximately 3,157 gallons (60 events), and the average annual spill from 2008-12 was approximately 10 gallons (50 events).

[31] "With Production on the rise, oil by barge traffic sets off greater safety concerns", Alberta Oil Magazine 2014, accessed July 25, 2014, http://www.albertaoilmagazine.com/2014/06/athabasca-mississippi-oil-by-barge/. The cost of transporting crude oil through barge is $0.72 per ton-mile, as compared to $2.24 per ton-mile for equivalent rail capacity. Truck transportation, for the same capacity, is 37 times more expensive

[32] *Environmental and Social Impacts of Maritime Transport in the Great Lakes – St. Lawrence Seaway Region* (Research Traffic Group, 2013), 7

[33] Welch, et al., *Oil and Water*,7-8. According to Coast Guard data, the average annual spill for commercial vessels from 2003-07 was approximately 3,157 gallons (60 events), and the average annual spill from 2008-12 was approximately 10 gallons (50 events).

[34] *Emergency Preparedness And Response Programs For Oil and Hazardous Materials Spill: Challenges and Priorities For The Great Lakes – St. Lawrence River* (Great Lakes Commission, 2012), 21.

[35]*Moving Energy Safely: A Study of the Safe Transport of Hydrocarbons by Pipelines, Tankers and Railcars in Canada* (Standing Senate Committee on Energy, the Environment and Natural Resource, 2013), 24.

[36] Oil Pollution Act of 1990, (U.S DOT 1990), accessed July 29, 2014, https://www.federalregister.gov/articles/2000/06/23/00-15955/oil-pollution-act-of-1990-phase-out-requirements-for-single-hull-tank-vessels

[37] Welch, et al., *Oil and Water*,7-8. In January 2005, a large explosion aboard Egan Marine Corporation's tank barge, EMC-423, discharged about 84,000 gallons of crude oil into the Chicago Sanitary and Ship canal.

[38] Frittelli et al., *US Rail Transportation of Crude Oil,* 1.

[39] "More oil spilled from trains in 2013 than in previous 4 decades, federal data show", McClatchy Washington Bureau, accessed July 4, 2014, http://www.mcclatchydc.com/2014/01/20/215143/more-oil-spilled-from-trains-in.html. Oil spilled in 2013 was 1.1 million gallon as opposed to 792,600 gallons between 1975-2012.

[40] Frittelli et al., *US Rail Transportation of Crude Oil,* 14.

[41] Furchtgott-Roth and Green, *Intermodal Safety*, 2. The study states that while Canada shipped 20,000 barrels per day (bbl/d) by rail in 2011, the United States ships 115,000 barrels of oil per day, as of 2013 with a projected trend showing an increase to 300,000 barrels shipped per day by rail by 2015.

[42] Xiang Liu, et al., "Analysis of causes of major train derailment and their effect on accident rates", Journal of Transportation Research Board, No. 2289 (Transportation Research Board of the National Academies: Washington, 2012)

[43] Frittelli et al., *US Rail Transportation of Crude Oil,* 12.

[44] Presentation on "DOT-111 Tank Car Design", Office of Railroad, Pipeline and Hazardous Materials Safety, National Transportation Safety Board, 2012, accessed July 5, 2014, http://www.ntsb.gov/news/events/2012/cherry_valley/presentations/hazardous%20materials%20board%20presentation%20508%20completed.pdf.

[45] Railway Investigation Report R13D0054. Transportation Safety board of Canada., accessed August 20, 2014, http://www.tsb.gc.ca/eng/rapports-reports/rail/2013/r13d0054/r13d0054.asp

[46] Frittelli et al., *US Rail Transportation of Crude Oil,* 22.

[47] David Pumphrey, et al., *Safety of Crude Oil by Rail* (Center for Strategic and International Studies, 2014), 3.

[48] Frittelli et al., *US Rail Transportation of Crude Oil,* 16.

[49] Rail Safety: Improved Human Capital Planing Could Address Emerging Safety Oversight Challenges (U.S Government Accountability Office, 2013), 24.

[50] New York State. *Transporting Crude Oil in New York State: A Review of Incident Response and Prevention Capacity – Status Update*. (New York State, 2014)

[51] Bill Demarest, "Train Accident in West Nyack", Nyack Free Press, December 6, 2013, accessed Aug 16, 2014, http://nyackfreepress.blogspot.com/2013/12/train-accident-in-west-nyack.html

[52] *Safe Placement of Train Cars: A Report* (U.S. Department of Transportation and Federal Railroad Administration, 2005), 5-10.

[53] Refer footnote 39 in this article.

[54] "Oil Shipment by rail, truck, and barge up substantially", Institute For Energy Research, accessed June 24, 2014, http://instituteforenergyresearch.org/analysis/oil-shipments-by-rail-truck-and-barge-up-substantially/

[55] U.S. Rail Transportation of Crude Oil: Background and Issues for Congress, (Congressional Research Service, 2014), Figure 3, 4.

[56] CSX Transportation claims that "For every billion ton-miles of hazardous materials transported, trucks are involved in more than 10 times as many accidents as the railroads." Union Pacific Railroad claims that trucks are "16 times more likely thank train to have hazmat incident.".

[57] *Cargo Tank Trucks* (U.S. Government Accountability Office,2013), 6. Figure 2A points out the possible risks associated during loading-unloading process at delivery points and fuel loading terminals.

[58] *Cargo Tank Trucks: Improved Incident Data and Regulatory Analysis Would Better Inform Decisions about Safety Risks*, (U.S Government Accountability Office, 2013), 3.

[59] "Portion of I-69 remains closed due to tanker explosion", ABC12 News, accessed July 6, 2014, http://www.abc12.com/story/24347559/portion-of-i-69-remains-closed-following-tanker-explosion. In Genesee County, Michigan, a tanker carrying crude oil slipped, crashed and exploded on January 2, 2014. Hydro carbons were released in the air and there was a temporary evacuation.

[60] *Cargo Tank Trucks* (U.S. Government Accountability Office,2013), 1-7.

[61] For details on this project, see Issue Brief 1

[62] idem

[63] New Town, North Dakota has a make shift facility where trucks transfer the Bakken oil from well heads to Central Pacific rail cars . he Central Pacific Rail branch line terminates at New Town, ND. The Google image shows the make shift facility where tank trucks load oil onto railcars. At the bottom of the image, a more permanent loop track construction can be seen. http://goo.gl/maps/uBRR5

[64] For details on BNSF Crude Oil trans-load facilities, see https://www.bnsf.com/customers/oil-gas/interactive-map/pdfs/BNSF-OG-Overview-Map.pdf.

[65] For details on Canadian Pacific intermodal terminals, see http://www.cpr.ca/en/our-network-and-facilities/Pages/default.aspx

[66] Barlow, *Liquid Pipeline*, 10.

[67] For a detailed understanding of associated risks during loading and unloading processes that can cause a catastrophic accident, please see http://www2.uwstout.edu/content/lib/thesis/2000/2000trianag.pdf

[68] "100 gallons of oil spiked from rail car at Port of Albany", Times Union, accessed July 3, 2014, http://www.timesunion.com/local/article/100-gallons-of-oil-spills-from-Port-of-Albany-5588442.php.

[69] "Crude Loves Rock 'n' Rail – Bakken Oil Express, Dakota Plains, Bakken Link, & Savage", RBN Energy 2013, accessed July 30, 2014, https://rbnenergy.com/bakken-oil-express-dakota-plains-bakken-link-and-trenton-railport. The article says that both the transshipment points, Bakken Oil Express and Dakota Plains have increased their infrastructure and oil storing capacity since 2011.

[70] "Manual of Best Management Practices for Port Operations And Model Environmental Management System", Great Lakes Maritime Research Institute, accessed July 30, 2014, http://greatlakesports.org/pp/uploads/CorsonStudyFinal.pdf.

[71] For more information on Great Lakes natural hazards, see http://www.greatlakesresilience.org/climate-environment/coastal-hazards-risks. For more information on Great Lakes Coastal Analysis and Mapping, see http://www.greatlakescoast.org/great-lakes-coastal-analysis-and-mapping/.

[72] Curt Hart and John Bernhardt, Department of Ecology Spill Management Program: Prevention and Response Activities: 1994 Annual Report (Washing State Department of Ecology, 1994).

[73] Martha Stanbury *at al*. *Acute Health Effects of the Enbridge Oil Spill.* (Michigan Deparrtment of Community Health, 2010)

[74] The 47 Coroner's reports (one per victim) were published on October 8, 2014.

[75] Welch, et al., *Oil and Water*,4. Based on the lessons learnt from Kalamazoo River spill in 2010, the authors claim that extracting of one barrel of tar sands oil removes four tons of sand and soil and three barrels of water in the process.

[76] "Discussion on Oil Spill Impact", Planete-Energies, accessed June 14,2014, http://www.black-tides.com/index.php?chapitre=chap_3&menu=c2

[77] Coucil of Canadian and Equiterre. *Doubling Down on Disaster: Transporting Tar Sands Bitumen Threatens Lac Saint-Pierre and the St. Lawrence River*. (Council of Canadians, 2015)

[78] This was realized using the BOSCEM model that was developed to provide the US EPA Oil program a method to estimate oil spill costs. See http://www.epa.gov/oem/docs/oil/fss/fss04/etkin2_04.pdf for more information.

[79] Raymond Chabot Grant Thornton. *Analyse des impacts économiques à la suite des événements du 6 juillet 2013 à Lac-Megantic* (2014)

[80] See *A Joint Strategic Plan for Management of Great Lakes Fisheries* (Great Lakes fishery Commission, 2014). Available at http://www.glfc.org/factsheets/FACT%206_14-0913.pdf

[81] Consumptive Water Use in the Great Lakes Basin, U.S. Geology Survey 2008, accessed July 24, 2014, http://pubs.usgs.gov/fs/2008/3032/pdf/fs2008-3032.pdf

[82] "Risk Assessment for Railroads", Sightline Daily, accessed July 3, 2014, http://daily.sightline.org/2014/05/19/risk-assessment-for-railroads/. James Beardly, as quoted in Eric De Place's article. The maximum possible coverage is $1.5 billion in liability insurance for Class 1 railroads. Considering that the Lac Megantic impact alone was more than $2 billion, the coverage seems insufficient especially when the impacts can be severe in a more dense urban area.

[83] On May 7, 2014, Anthony Foxx (Secretary of Transportation, U.S. DOT) signed an order that requires all operating trains containing 1,000,000 gallons or larger amount of crude oil to provide the appropriate SERC – State Emergency Response Commission – with notification regarding their movement through the state's counties. However, such a step is yet to be amended and requires huge logistical planning of the current human capital with the FRA.

[84] Shanese Crosby et al., *Transporting Alberta Oil Sands Products*, 6.

[85] *A Survey of Bakken Crude Oil Characteristics Assembled For the U.S. Department of Transportation,* Submitted by American Fuel & Petrochemical Manufacturers (Dangerous Goods Transport Consulting, 2014), 4.

[86] For more information on land use planning in Great Lakes, see http://www.great-lakes.net/teach/pollution/sprawl/sprawl_2.html