Ottawa River Site-Specific Risk Assessment

Prepared for:
Energy East Pipeline Ltd.

Prepared by:
Stantec Consulting Ltd.
RPS Group plc

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Sign-off Sheet

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Prepared by ______________________________
(signature)

Nicole Lynass

Prepared by ______________________________
(signature)

Erik Page

Reviewed by ______________________________
(signature)

Heidi Tillquist

Approved by ______________________________
(signature)

Jim Howell

Stantec

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Abbreviations

°C	degrees Celsius
API	American Petroleum Institute
bbl	barrels
BTEX	benzene, toluene, ethylbenzene and xylene
CEPA	Canadian Energy Pipeline Association
Energy East	Energy East Pipeline Ltd.
EOC	Emergency Operations Centre
ERP	Emergency Response Plan
GRP	Geographic Response Plan
km	kilometre
m	metre
m/s	metre per second
MEAA	Mutual Emergency Assistance Agreement
NEB	National Energy Board
NEB OPR	NEB Onshore Pipeline Regulations
NOAA	National Oceanographic and Atmospheric Administration
OCC	Operations Control Centre
PAH	polycyclic aromatic hydrocarbons
PHMSA	Pipeline and Hazardous Materials Safety Administration
Project	Energy East Pipeline Project
PVC	polyvinyl chloride
ROW	right-of-way
RPS ASA	RPS Applied Science Associates
SCADA	supervisory control and data acquisition
Stantec	Stantec Consulting Ltd.
TransCanada	TransCanada PipeLines Ltd.
US	United States
WCD	worst case discharge

1.0 INTRODUCTION

Energy East Pipeline Ltd. (Energy East) proposes to re-purpose an existing natural gas pipeline currently operating in Saskatchewan, Manitoba and Ontario to crude oil service and construct new pipeline in Alberta, Saskatchewan, Manitoba, Ontario, Québec and New Brunswick to tie into the re-purposed pipeline. The resulting pipeline, called the Energy East Pipeline Project (Project), will be capable of transporting up to 1,100,000 barrels (bbl) of oil per day from Alberta and Saskatchewan to refineries in Eastern Canada. The Project involves a portion of new pipeline that crosses under the Ottawa River near Montréal, Québec.

1.1 OBJECTIVES

Energy East has requested that Stantec Consulting Ltd. (Stantec) and RPS Applied Science Associates (RPS ASA) identify the theoretical probability of a release and the probable size of such a release, and evaluate whether water quality at Montréal-area municipal water intakes would be affected if such a release were to occur at the Ottawa River crossing. Furthermore, it has been requested that Stantec review and analyze a report written by Savaria Experts-Conseils Inc. entitled *Mise en service de l'oléoduc Énergie Est de TransCanada: Impacts d'un déversement sur le territoire de la Communauté métropolitaine de Montréal*, henceforth referred to as the Savaria Report.

1.2 BACKGROUND

The Project's crossing of the Ottawa River is located 33 kilometres (km) northwest of the western tip of the Island of Montréal, Québec. A number of sensitive resources exist in this area of the river, including municipal drinking water intakes for the City of Montréal, municipal drinking water wells, ecologically sensitive areas, high population areas and other populated areas.

The width of the Ottawa River where the pipeline crossing is proposed is approximately 470 metres (m). At the Ottawa River crossing, proposed pipeline specifications include heavy walled pipe with fusion-bonded epoxy (FBE) coating for additional pipeline protection. Energy East is actively pursuing a trenchless design option through geotechnical, seismic and site assessments. Energy East continues to coordinate with local authorities for approval to complete the remaining seismic investigations at the river crossing, as well as provide an update to the National Energy Board (NEB). The feasibility assessment to evaluate alternative trenchless crossing and contingency crossing methods is expected to be completed in 2016.

2.0 SPILL FREQUENCY AND VOLUME ANALYSIS

2.1 SPILL VOLUMES

Examination of more than a decade of recent pipeline incident data (Pipeline and Hazardous Materials Safety Administration [PHMSA] 2014) indicates that the majority of pipeline releases are relatively small, with 50% of the spills consisting of 4 bbl or less (**Table 2-1**). Spill volumes were 50 bbl or less in almost 80% of the cases; less than 1,000 bbl over 95% of the time; and releases of 10,000 bbl or greater occurred in only 0.5% of cases. These data demonstrate that most pipeline spills are relatively small and large releases of 10,000 bbl or more are extremely uncommon.

Table 2-1 Distribution of Pipeline Spill Volumes

Spill Volume (bbl)	% of Spills Smaller[1]
4	50%
50	80%
1,000	95%
10,000	99.5%

[1] Values derived from PHMSA historical incident data (2002 to 2013).

2.2 SITE-SPECIFIC SPILL FREQUENCY

The NEB and PHMSA incident databases[1] were considered as sources for incident frequency data for this assessment. Other databases exist for other regions of the world, but were not considered applicable to this assessment.

While the exclusive use of the NEB incident database was considered, the dataset consists of only 37,000 km of liquid pipelines. In comparison, the PHMSA incident database contains over 320,000 km of liquid pipelines, providing greater statistical reliability. Additionally, the PHMSA dataset is more comprehensive in the types of data collected and thus allows for a more detailed analysis of causal factors.

For the purpose of this analysis, it is assumed that Canadian and United States (US) pipelines would have similar failure frequencies due to comparable regulations and industry standards. Thus, the NEB's statistics were incorporated into the PHMSA database to create a larger, but still applicable, pipeline incident database (henceforth referred to as the Combined Incident Database).

[1] Incident databases downloaded in April 2014.

Many pipelines built in the 1930s and earlier are still in operation today. Because the majority of pipelines in the US were constructed in the pre-modern era, these frequencies reflect incident rates associated with earlier pipeline design and construction methods that often do not meet current regulatory requirements or best management practices. Therefore, calculating spill frequency based upon the inclusion of older pipelines is conservative and expected to overestimate the probability of a release for the Project.

The Project incident frequency statistic is 0.00034 incidents/km*year. Based on that statistic, the Ottawa River crossing was evaluated to determine spill frequencies for a variety of spill volumes. Results are presented in **Table 2-2**.

Table 2-2 Occurrence Interval by Spill Volume

Segment Description	Distance (km)[1]	Occurrence Interval (years) by Spill Size			
		4 bbl	50 bbl	1,000 bbl	10,000 bbl
Ottawa River Crossing	0.802	7,375	18,475	73,745	737,475

[1] Crossing length includes the river width (472 m) plus an additional buffer to account for overland flow.

As discussed in Section 2.1, Spill Volumes, the majority of spills are 4 bbl or less. The occurrence interval for a spill of this size occurring at the Ottawa River crossing is approximately once every 7,375 years. The probability of a large spill (10,000 bbl) occurring within these areas is extremely small, with an estimated occurrence interval of 737,475 years. These spill volumes encompass more than 99.5% of pipeline incidents and therefore provide a reasonable range of potential spill volumes.

3.0 CRUDE OIL PROPERTIES AND CHARACTERISTICS

A variety of crude oils would be transported by the Project. These can be categorized into three general categories: conventional light crude oil, synthetic crude oil and diluted bitumen. Based on preliminary information from potential shippers, Energy East has identified three crude oils that are representative of these crude oil types: Bakken crude oil, Husky Synthetic Blend and Western Canadian Select, respectively.

3.1 LIGHT CONVENTIONAL CRUDE (BAKKEN CRUDE OIL)

Crude oil from the Bakken region is characterized by its high proportion of lightweight hydrocarbons, with few heavy constituents. Bakken crude oil also has low sulphur content, and therefore, is classified as a sweet crude oil. It is the lightest of the representative crude oils that might be transported by the Project.

Bakken crude oil has a American Petroleum Institute (API) gravity of 42.1, indicating that the crude oil will float on water (Royal Society of Canada 2015). It contains a much smaller fraction of heavy molecular weight compounds than lower value API crudes. Low viscosity oils, such as Bakken crude, form a very thin sheen across the surface of water that provides more exposure to the environment, thus enhancing weathering processes such as evaporation, dispersion and photodegradation. Bakken crude oil will form emulsions with water like other crude oils, but the emulsions will be less stable than heavy crudes. Thus, emulsions would be transitory and would release back to the water's surface soon after forming.

Compared with the other representative crude oils, Bakken crude oil contains a high proportion of straight-chained alkanes and benzene, toluene, ethylbenzene and xylene (BTEX) compounds, which are desirable for producing petroleum fuels, but can cause deleterious effects on the environment in the case of a release.

3.2 SYNTHETIC CRUDE (HUSKY SYNTHETIC BLEND)

Bitumen can be partially refined (i.e., upgraded) to create synthetic crude oil, a process that removes many of the high molecular weight compounds present in the bitumen (e.g., asphaltenes). Synthetic crude is comparable to mid-weight conventional crude oils. The representative synthetic crude oil, Husky Synthetic Blend, has an API gravity of 31.7, indicating that it will float on water (Crude Monitor 2016).

Environmental processes (e.g., spreading, evaporation and emulsification) will be intermediate in comparison to Bakken crude oil and Western Canadian Select. As a result of its intermediate characteristics, environmental effects from synthetic crude also will be intermediate in comparison with the other two representative crude oils.

3.3 DILUTED BITUMEN (WESTERN CANADIAN SELECT)

The oil extracted from the Alberta oil sands is called bitumen, which is highly viscous and has the consistency of peanut butter. In order for the bitumen to be transported by pipeline, it is blended with a diluent[2] (i.e., a lighter petroleum hydrocarbon product, such as condensate or synthetic crude) and transported as a blended heavy crude oil called diluted bitumen. While the precise composition of diluted bitumen will be determined by shippers and is considered proprietary information, there are publically available databases that provide information on key characteristics of these oils (e.g., Crude Monitor 2016; Environment Canada 2008). Comparison of physical and chemical properties demonstrates that diluted bitumen is similar to other naturally occurring heavy crude oils derived from various locations throughout the world, such as portions of California, Venezuela, Nigeria and Russia.

Compared with lighter crude oils, Western Canadian Select has a higher proportion of heavy molecular weight compounds, such as asphaltenes. Benzene, toluene, ethylbenzene and xylenes are lightweight petroleum hydrocarbons that are highly volatile and relatively water soluble. Heavy molecular weight petroleum hydrocarbons are much less soluble and are more environmentally persistent.

Like other crude oils, Western Canadian Select[3] has an API gravity of 20.9, indicating that it will float on the surface of water. Because it is more viscous than either synthetic or conventional light crude oils, it will spread over land and across the water's surface at a slower rate, reducing the area of effect in a given period of time. Because of their high viscosity, heavy crude oils do not disperse in the environment as much or as quickly as light crude oils. Like other crude oils, diluted bitumen can form emulsions (i.e., water-in-oil mixtures). Because of the greater proportion of heavy molecular weight compounds, Western Canadian Select emulsions tend to be more stable and have longer environmental persistence than emulsions formed by lighter crude oils. Toxicological effects attributable to BTEX compounds would be less than those observed for Bakken crude oil per unit volume. Western Canadian Select would have a greater environmental persistence than Bakken crude oil or Husky Synthetic Blend due to a larger fraction of heavier molecular weight petroleum hydrocarbons, though these compounds have low bioavailability.

3.4 SUMMARY OF CRUDE OIL CHARACTERISTICS

A summary of physical and chemical properties utilized in the Ottawa River fate and transport model are provided in **Table 3-1**.

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[2] Diluent is made up of a variety of light hydrocarbons that have relatively high percentages of BTEX by volume. This is the primary source of BTEX and other light constituents in diluted bitumen.

[3] Western Canadian Select has an API gravity of approximately 20.9. In general, crude oils with API gravity greater than 10 will float on water, whereas those oils with API gravity lower than 10 are more likely to sink in aquatic environments.

Table 3-1 Physical and Chemical Properties for Representative Crude Oils

Physical Parameter	Bakken Crude Oil	Husky Synthetic Blend	Western Canadian Select
Crude Oil Type	Light Conventional Crude	Synthetic Crude	Diluted Bitumen
Surface Tension (dyne/cm)	27.3	27.7	30.1
Pour Point (degrees Celsius [°C])	-55.0	-42.0	-33.0
API Gravity	42.1	31.7	20.9
Density (g/cm^3)	0.8165 at 16°C	0.8691 at 15°C	0.9258 at 15°C
Viscosity (cP)	2.7 @ 15°C	4.5 at 38°C	63.0 at 38°C
BTEX (% of whole oil)	1.01	0.31	0. 49

Hydrocarbon contaminant chemistry typically is reported as the total concentration of BTEX. For the purposes of this study, BTEX were considered together, as a single component of oil.

4.0 ENVIRONMENTAL FATE AND BEHAVIOUR IN WATER

The environmental fate of crude oil is controlled by many factors and persistence that vary with site-specific conditions. The environmental processes that affect the fate and behavior of crude oil described in the following sections assume no emergency response. The speed and efficacy of cleanup would reduce the duration and volume of oil in the environment, substantially affecting environmental fate and behavior. In the absence of emergency response intervention, major factors affecting the environmental fate of crude oil include:

- spill volume
- type of crude oil
- dispersal rate of the crude oil
- terrain
- receiving media
- weather

Once released, the physical environment largely dictates the environmental fate and persistence of the spilled material. Fate, transport and primary degradation processes of crude oil released to water are discussed below.

4.1 ENVIRONMENTAL FATE PROCESSES

If released into water, crude oil will float to the water's surface. If crude oil is left on the water's surface over an extended period of time, some constituents within the oil will evaporate, other fractions will dissolve, and eventually, some material may descend to the bottom as sedimentation. The following is a summary of the major processes that occur during crude oil dispersion and degradation.

- Physical Factors. Crude oil mobility in water increases with wind, stream velocity and increasing temperature. Most crude oils move across surface waters at a rate of 100 to 300 m per hour (Ramade 1978). If present, surface ice will greatly reduce the spreading rate of oil across a waterbody. Effects of crude oil in flowing waterbodies tend to be transitory, as opposed to contained waterbodies where crude oil would have a longer residence time, disregarding the benefits of cleanup. While thinning, spreading, and downstream transport will reduce in intensity at a specific site, crude oil spilled into flowing waters tends to move over a much larger area. Spreading and thinning of spilled crude oil in water also increases the surface area of the slick, thus enhancing surface dependent fate processes such as evaporation, degradation and dissolution.
- Dissolution. Dissolution of crude oil in water is not a substantive process controlling the crude oil's fate in the environment because most components of oils are relatively

insoluble (Neff and Anderson 1981). Moreover, evaporation tends to dominate the reduction of crude oil, with dissolution slowly occurring with time. Overall solubility of crude oils tends to be less than their constituents because solubility is limited to the partitioning between the oil and water interface and individual compounds are often more soluble in oil than in water, thus preferentially remaining in the oil. Dissolution increases with decreasing molecular weight, increasing temperature, decreasing salinity and increasing concentrations of dissolved organic matter. Greater photodegradation also tends to enhance the solubility of crude oil in water.

- Sorption. In water, heavy molecular weight hydrocarbons will bind to suspended particulates. This process can be especially significant in highly turbid or eutrophic waters. Organic particles (e.g., biogenic material) in soils or suspended in water tend to be more effective at adsorbing oils than inorganic particles (e.g., clays). Sorption processes and sedimentation reduce the quantity of heavy hydrocarbons present in the water column and available to aquatic organisms. However, these processes also render hydrocarbons less susceptible to degradation. Sedimented oil tends to be persistent and can cause effects to shorelines and benthic sediments.
- Evaporation. Over time, evaporation is the primary mechanism of loss of low molecular weight constituents and light oil products. As lighter components evaporate, remaining crude oil becomes denser and more viscous. Evaporation tends to reduce crude oil toxicity, but enhances crude oil persistence. In field trials, bulk evaporation of crude oil accounted for an almost 50% reduction in volume over a 12-day period, while the remaining oil still was sufficiently buoyant to float on the water's surface (Shiu et al. 1988). Evaporation increases with increased spreading of a slick, increased temperature and increased wind and wave action. Evaporation also is a significant environmental fate process for BTEX constituents within the water column.
- Photodegradation. Photodegradation of crude oil in aquatic systems increases with greater solar intensity. It can be a substantive factor controlling the reduction of a slick, especially of lighter oil constituents, but it will be less important during cloudy days and winter months. Photodegraded crude oil constituents can vary in toxicity and solubility as photodegradation processes alter the chemical structure of hydrocarbon compounds. Extensive photodegradation, like dissolution, may increase the biological effects of a spill event.
- Biodegradation. In the immediate aftermath of a crude oil spill, natural biodegradation of crude oil will not tend to be a substantive process controlling the fate of spilled crude oil in environments previously unexposed to oil. Furthermore, elevated concentrations nearest the source may cause localized toxicity to the micro-organisms that are responsible for biodegradation. Over time, naturally occurring microbial populations will re-establish and increase using the hydrocarbons as an energy source. Once established, biodegradation can proceed at appreciable rates. High molecular weight constituents tend to be resistant to biodegradation. Biodegradation is nutrient and oxygen demanding and may be precluded in nutrient-poor aquatic systems. It also may

deplete oxygen reserves in closed waterbodies, causing adverse secondary effects to aquatic organisms.

4.2 ENVIRONMENTAL BEHAVIOUR OF CRUDE OIL

4.2.1 Dispersion of Crude Oil

While crude oil does not dissolve in water the same way that, for example, salt dissolves in water, turbulent water is able to drive small droplets of the oil into the water column. Experimental data suggest that the maximum size of these droplets is approximately 70 microns (Delvigne and Sweeney 1988). If the droplets are small enough, natural turbulence in the water will prevent the oil from resurfacing, just as turbulence in the air keeps small dust particles afloat (National Oceanographic and Atmospheric Administration [NOAA] 2013). This process is called dispersion. Environmental conditions dictate the importance of dispersion. For oil spills on water during storm events, dispersion can be the chief removal mechanism of the slick. During storms, the majority of the oil can be dispersed into the water column. For spills under more normal weather conditions, dispersion generally is nominal and evaporation is the primary environmental fate process (NOAA 2013).

Chemically induced dispersion may be considered an appropriate method to clean up high volume crude oil spills, particularly those that occur in large bodies of water. In some cases, chemical dispersants are used as part of clean up to enhance dispersion because it facilitates natural weathering processes such as biodegradation and oxidation, thus reducing exposure of aquatic organisms to elevated oil concentrations. The decision to use chemical dispersants must be coordinated with applicable agencies.

4.2.2 Submersion of Crude Oil

Diluted bitumen, synthetic crude oil and other crude oils that would be transported by the Project all have API gravities greater than 10 and therefore initially will float on the surface of water. All crude oils weather (i.e., light end hydrocarbons evaporate) when exposed to the environment. With time, the remaining crude oil becomes denser as the proportion of light hydrocarbons decreases. Eventually, this process, particularly when combined with turbulent water, can result in remaining weathered oil sinking. This weathering process is not unique to diluted bitumen and occurs with all types of crude oils, regardless of their origin (Rymell 2009).

Environmental conditions, including water temperature and salinity, also can influence the behaviour of crude oil in an aquatic environment. The viscosity of the crude oil increases with decreasing temperature, so at lower temperatures, the crude oil is more likely to form solid globules and be limited in its dispersal. Temperature fluctuations also affect density as higher temperatures are associated with lower crude oil densities. Several spills have shown that temperature fluctuations can have substantive effects on crude oil behaviour. In the Morris J. Berman spill, which occurred in 1994 off the coast of Puerto Rico, crude oil was reported to sink when temperatures lowered and refloat again during the afternoons when sunlight increased the temperature of released crude oil (Rymell 2009).

Recent spills resulting in a substantive amount of submerged crude oil, for instance the 2010 Enbridge Line 6b spill in the Kalamazoo River, have given emergency response teams the opportunity to test and refine sunken and submerged oil recovery techniques. Many conventional and unconventional techniques have proven to be quite effective, including:

- Nets: specialized nets can be utilized to contain submerged globules of weathered crude oil as they migrate downstream or with a current.
- Bottom booms: have a heavy ballast to create a seal against the bottom of a waterbody and a float chamber that extends toward the surface of the water. These booms have the potential to be very effective in containing submerged oil.
- Dams: watergates, underflow weir dams and other dams can be set up on the bottom of a waterbody to contain oil as it migrates downstream or with a current. Underflow weir dams can be built using standard spill response equipment (i.e., sandbags, shovels, polyvinyl chloride [PVC] piping, etc.).
- Dredging: well established dredging techniques can be extremely effective in recovering sunken and submerged oils and have been used effectively following spills of high density crude oils.
- Manual Recovery: sunken oil has the tendency to collect in depressions and areas of low flow, where it can often be manually recovered. Techniques for manual recovery (e.g., vacuuming) are well established and can be executed using only standard spill response materials.
- Air Injection: submerged oil can be floated and recovered using injection of air similar to soil vapour extraction techniques used in remediation of contaminated soil.

A summary of transport and fate processes considered in this report is presented in **Figures 4-1** and **4-2**.

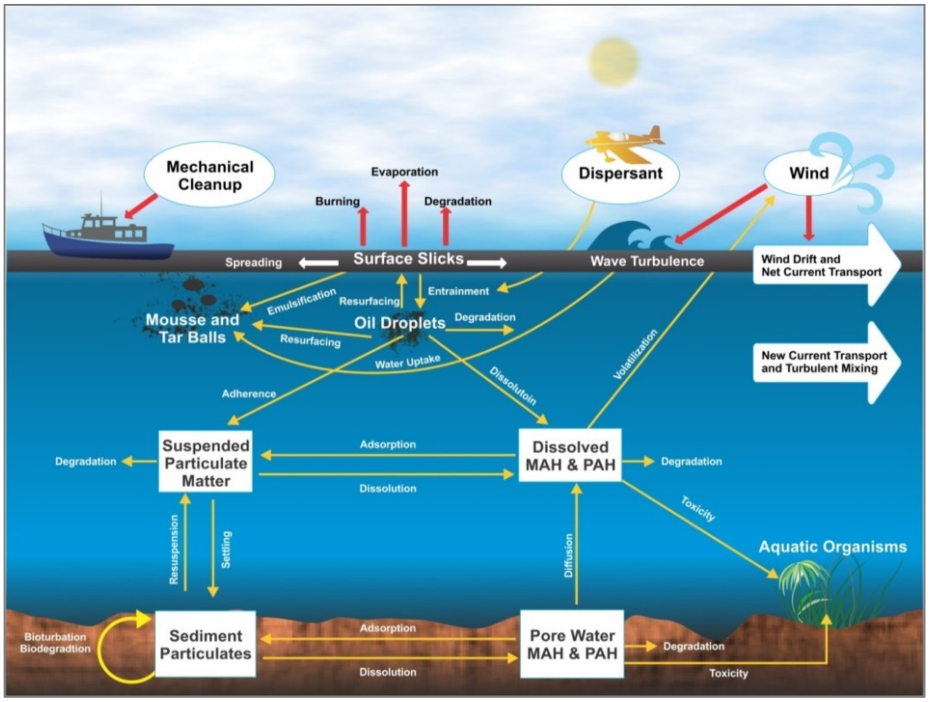

Figure 4-1 Oil Fate Processes in Open Water

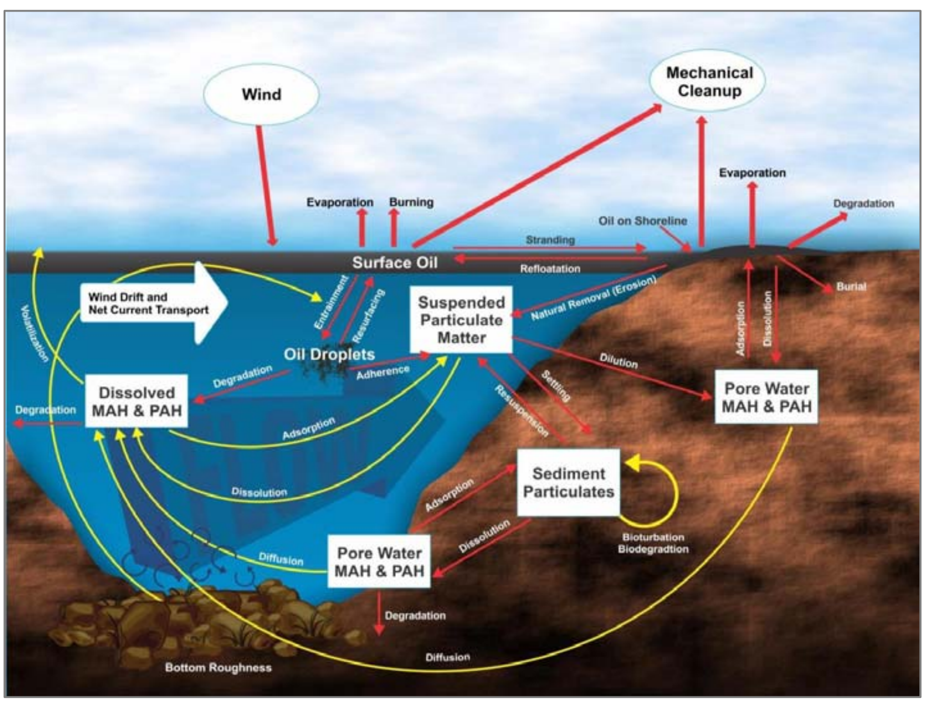

Figure 4-2 Oil Fate Processes near Shorelines

4.3 ENVIRONMENTAL FATE AND BEHAVIOUR DURING WINTER

During the winter, waterbodies may become covered with ice and possibly snow, and the land surface may be partially to completely covered with snow. Dispersal of oil spilled to the land generally would be slowed, although not necessarily stopped, by the snow cover. Depending on the depth of snow cover, as well as the temperature and volume of spilled material, the spill may reach the underlying dormant vegetation or wetlands, ponds and lakes. Similarly, surface spills to flowing rivers and creeks generally would be restricted in area by the snow and ice covering the waterbody, compared to seasons with little or no snow and ice cover. Spills under the ice to creeks, rivers and lakes are expected to disperse slowly as the currents generally are slow in winter and depressions and cracks in surface ice act as natural containment points (Dickens 2011). However, because of snow and ice, winter spills may be harder to detect and, when found, can be more difficult to contain and clean up.

During the winter, the Ottawa River freezes over with a thick layer of ice. This layer of ice would trap oil released below the river's surface and substantively reduce or eliminate the evaporation of benzene and other light hydrocarbons. Therefore, during ice cover, evaporative loss will be nominal and will allow a longer contact between the crude oil and the water column. However, natural undulations at the water-ice interface will trap the material and decrease its spreading rate, limiting the downstream movement of the oil. Where oil is in contact with water for substantial periods of time (e.g., days to weeks), there is the potential for localized effects to organisms in prolonged contact with the near-surface water (e.g., phytoplankton).

An oil spill affecting the Ottawa River during either freeze-up[4] or breakup may be difficult to contain, remove and cleanup. The ice may not be strong enough to support people or equipment. In rivers, the oil may be transported several kilometres under the ice or in broken ice before it can be contained. However, winter conditions can slow the transport of crude oil and, in certain circumstances, aid in emergency response, as covered in detail in Section 6.2.3.2, Winter Conditions.

[4] Freeze-up is the transition time in the fall when the lakes and rivers begin to freeze over.

5.0 DOWNSTREAM TRANSPORT MODELLING

Model simulations of the trajectory and fate of crude oil discharged from a pipeline crossing the Ottawa River were conducted to provide predictions of minimum time of first arrival for crude oil and oil constituents (i.e., BTEX) at 21 downstream locations. The RPS ASA's SIMAP trajectory and fate model was used to simulate spills of varying sizes (4, 50, 1,000, and 10,000 bbls) and representative crude oil types (Bakken Crude Oil, Husky Synthetic Blend, and Western Canadian Select).

SIMAP is a physical fate model that calculates the downstream transport of whole oil and oil components. The SIMAP model tracks the lower molecular weight aromatic components of the oil by dividing them into chemical groups based on volatility, solubility and hydrophobicity. The evaporation calculation in the SIMAP model is specific to each oil component. The modelled chemical groups are:

- Monocyclic aromatic hydrocarbons: BTEX and substituted benzenes;
- 2-ring polycyclic aromatic hydrocarbons (PAHs; naphthalenes);
- 3-ring PAHs;
- Volatile aliphatics;
- Semi-volatile aliphatics;
- Low volatility aliphatics; and
- Residual fraction (both aromatics and aliphatics).

The residual fraction in the model is composed of non-volatile and insoluble compounds that remain in the “whole oil” that spreads and can be transported on the water surface, stranded on shorelines, and dispersed into the water column as oil droplets or become submerged or remain on the surface as tar balls depending on their density. This is the fraction that composes black oil, water-in-oil emulsions and sheen.

5.1 TRANSECT LOCATIONS

Predictions of minimum time of first arrival for crude oil and BTEX compounds were provided at 21 transects along the Ottawa River, Rivière des Mille Îles, Rivière des Prairies and St. Lawrence River, as summarized in **Figure 5-1**.

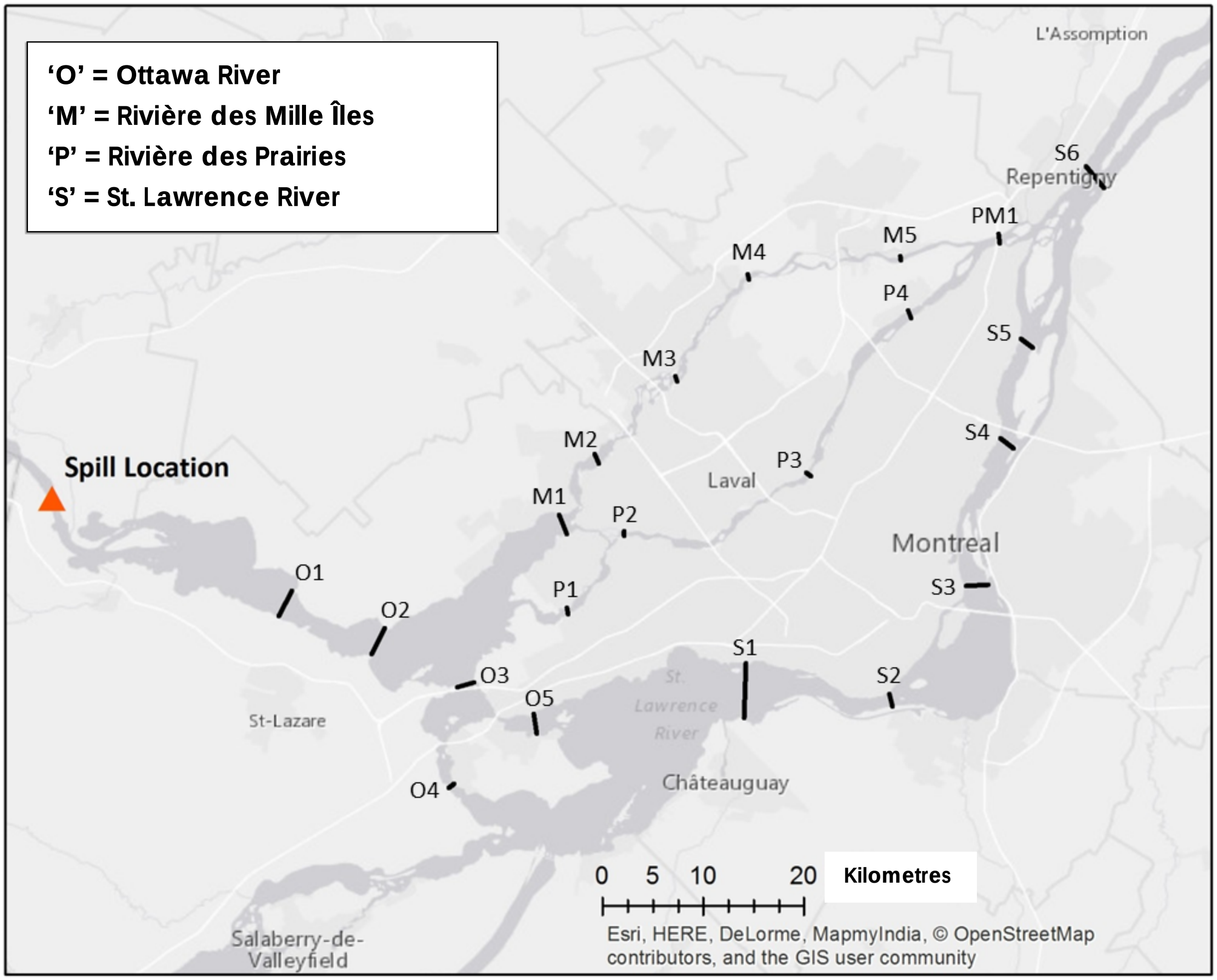

Figure 5-1 Transect Locations

5.2 SPILL SCENARIOS

The spill scenarios modelled incorporated the three crude oil types and four release volumes specified in order to cover the reasonable range of theoretically possible spill events at the Ottawa River crossing. In addition, the variability in river flow that occurs throughout the year requires that a range of flow conditions be incorporated to capture the range of possible downstream transport of the spilled oil. The combination of three oil types, four release volumes and three river flow conditions result in 36 possible spill scenarios. In order to capture the potential range of arrival times, a subset of the 36 was selected and subsequently modelled. Spills of Bakken Crude Oil were included in the modelled scenarios across the range of volumes and discharge conditions. The other two crude oils are similar to one another, but different from Bakken Crude Oil in that they have a higher density and viscosity and have a tendency to form thick surface slicks and more readily adhere to the shoreline and, thus, would be transported more slowly, with less volume expected to arrive at each of the transect locations than Bakken Crude Oil.

A total of 22 spill scenarios were chosen in order to assess the full range of possible transport times, including small spills during low flow conditions through to high volume spills during spring runoff. **Table 5-1** lists the 22 spill scenarios modelled.

Table 5-1 Spill Scenarios Modelled

River Discharge Condition	Oil Type	4 bbl	50 bbl	1,000 bbl	10,000 bbl
Low Discharge (September)	Bakken	x	x	X	x
	HSB	x	x		
	WCS			X	x
Average Discharge (June)	Bakken			X	x
	HSB			X	x
	WCS	x	x		
High Discharge (April)	Bakken	x	x	X	x
	HSB	x	x		
	WCS			X	x

Bakken = Bakken Crude Oil; HSB = Husky Synthetic Blend; WCS = Western Canadian Select.

5.3 MODELLING APPROACH

5.3.1 Hydrodynamic Model

The SIMAP oil spill model system was used to determine the transport and fate of spills entering the Ottawa River at the site of the pipeline crossing to determine the minimum time of transport to the downstream transect locations in the Montréal region. Results of the analysis provide the time of first oil arrival.

5.3.1.1 Oil Transport Processes

Winds

Winds blowing over the water surface combine with currents to transport surface slicks. Surface oil is transported by wind in the downwind direction at a rate of 3.5% of wind speed (Sajjadi et al. 1999). Wind forcing causes oil to accumulate along shorelines and in some cases, persistent wind can pin oil to the shoreline for long periods. Wind speed and direction are highly variable in the Montréal region and spills may occur during no-wind conditions or during storm events with high winds that may overwhelm surface oil transport driven by river currents. In order to calculate in-water hydrocarbon concentrations that result from maximum downstream transport of the spills, no winds were applied in the spill scenarios simulated.

Hydrodynamics

Hydrodynamic data defining current speed and direction within the oil spill domain were required inputs to the oil spill model. A hydrodynamic model (BFHYDRO) was used to predict the currents. The hydrodynamic model included the Ottawa River starting upstream from the spill site, the St. Lawrence River north of Lac Saint-Francois, the Rivière des Mille Îles and the Rivière des Prairies. The currents in this region are dominated by freshwater inflow, elevation changes along the river channels and channel cross sectional area. The system is a series of river channels and lakes and includes many areas of rapids, falls and hydroelectric facilities. River flows into the Montréal region from both the Ottawa River from the west and the St. Lawrence River from the southwest. The volume in the St. Lawrence River is between 2 and 6 times that of the Ottawa River at the confluence of these two rivers, depending on the season. River volume in the St. Lawrence River is controlled by the regulated water levels in Lake Ontario. This regulated discharge results in a relatively constant volume in the St. Lawrence River throughout the year. The Ottawa River varies in volume in response to seasonal changes, more like a natural (uncontrolled) river. The Ottawa River flows into the Lac des Deux Montagnes, where current velocity is low. From the Lac des Deux Montagnes, part of the Ottawa River flows east in to Lac Saint Louis, another slow moving waterbody, and the remainder of the Ottawa River flows through the Rivière des Prairies and the Rivière des Mille Îles.

A hydrodynamic model grid was established to encompass river reaches from the pipeline crossing through the downstream channels surrounding Montréal where a number of drinking water intakes are located. The model grid was generated to reflect the channel geometry and was designed with mean river discharge. River discharge data were obtained from the following Environment Canada gauge sites (Environment Canada 2012):

- St. Lawrence River at Cornwall (02MC002)
- Ottawa River at Barrage de Carillon (02LB024)
- Ottawa River at Terrasse-Vaudreuil (02OA107)
- Ottawa River at the Marina of Sainte-Anne-de-Bellvue (02OA033)
- Rivière des Mille Îles at Bois-des-Filion (02OA003)

Monthly average river discharge at each gauge location is summarized in **Table 5-2**. Note that station 020A003 was not used to design the model, but rather was assessed to understand the flow division amongst the rivers in the region. The model was established with river discharge inputs in the Ottawa River just upstream of the pipeline crossing and the St. Lawrence River upstream of Montréal. The model also was designed with appropriate discharge out of the Lac des Deux Montagnes to the St. Lawrence River through the two branches on either side of Ile Perrot.

Table 5-2 Summary of Monthly Average River Discharge

Month	Ottawa River at Barrage de Carillon (02LB024)	St. Lawrence River at Cornwall (02MC002)	Rivière des Mille Îles at Bois-des-Filion (02OA003)	Ottawa River at Terrasse-Vaudreuil (02OA107)	Ottawa River at the Marina of Sainte-Anne-de-Bellvue (02OA033)
Monthly Average Discharge (m^3/s)					
January	1,756	6,539	176	437	629
February	1,759	6,876	167	417	584
March	2,022	7,198	207	475	655
April	3,510	7,405	482	836	1,026
May	3,141	7,713	462	707	865
June	2,004	7,858	264	346	558
July	1,425	7,740	149	180	288
August	1,201	7,627	88	142	217
September	1,144	7,528	75	137	239
October	1,460	7,376	119	230	364
November	1,846	7,266	178	374	562
December	1,897	7,068	187	391	586
Average	1,938	7,370	214	451	629

Three different hydrodynamic modelling scenarios were simulated representing mean, high and low river discharge conditions. These scenarios capture a reasonable range of discharge conditions. The mean discharge scenario was based on the average annual discharge and the low and high discharges were based on representative months that exhibited relatively low (September) or high (April) flow. Note that given the lack of discharge variability in the St. Lawrence River, the representative low and high months were chosen based on the seasonality of the Ottawa River. Snapshots of the current speeds associated with the mean, low and high discharge conditions are shown in **Figures 5-2**, **5-3** and **5-4**, respectively. The current velocities vary significantly throughout the area, with peak speeds (>1 m per second [m/s]) near the pipeline crossing and in the narrow portions of the St. Lawrence River. The relative change of velocities in the St. Lawrence River for the different ‘seasons’ is low because the river exhibits little variation in discharge through the year. Discharge rates and current velocities in the other rivers exhibit more significant changes throughout the year.

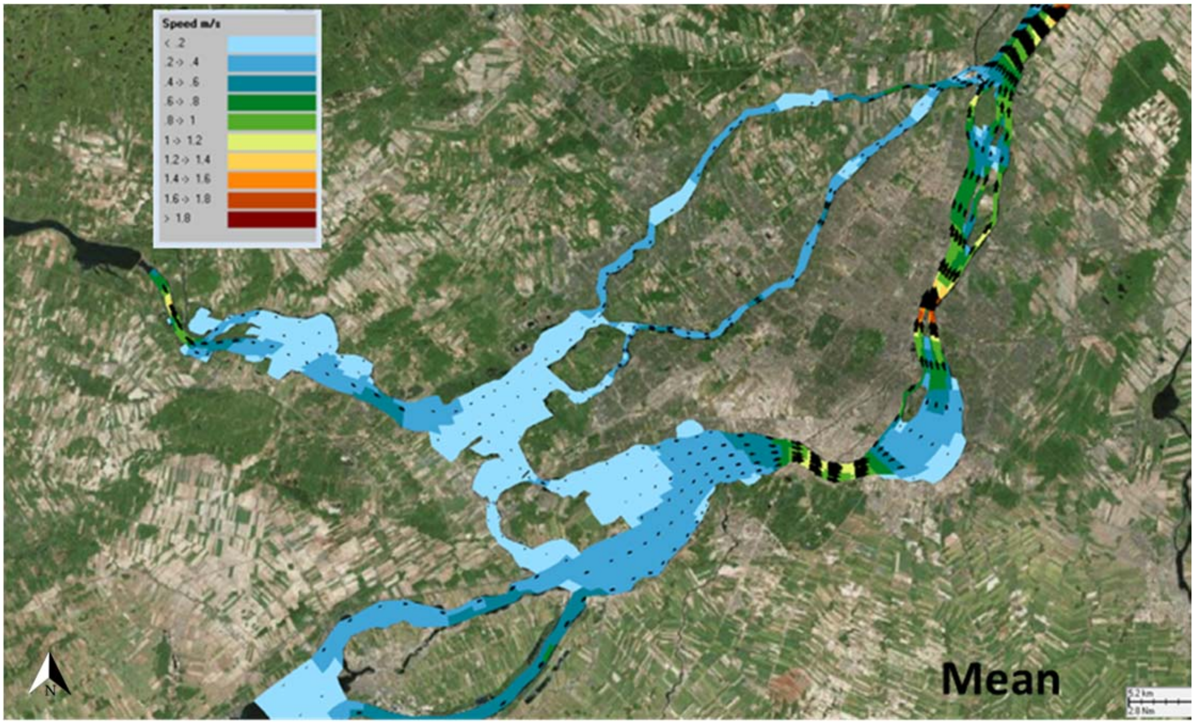

Figure 5-2 Mean Discharge Current Speeds

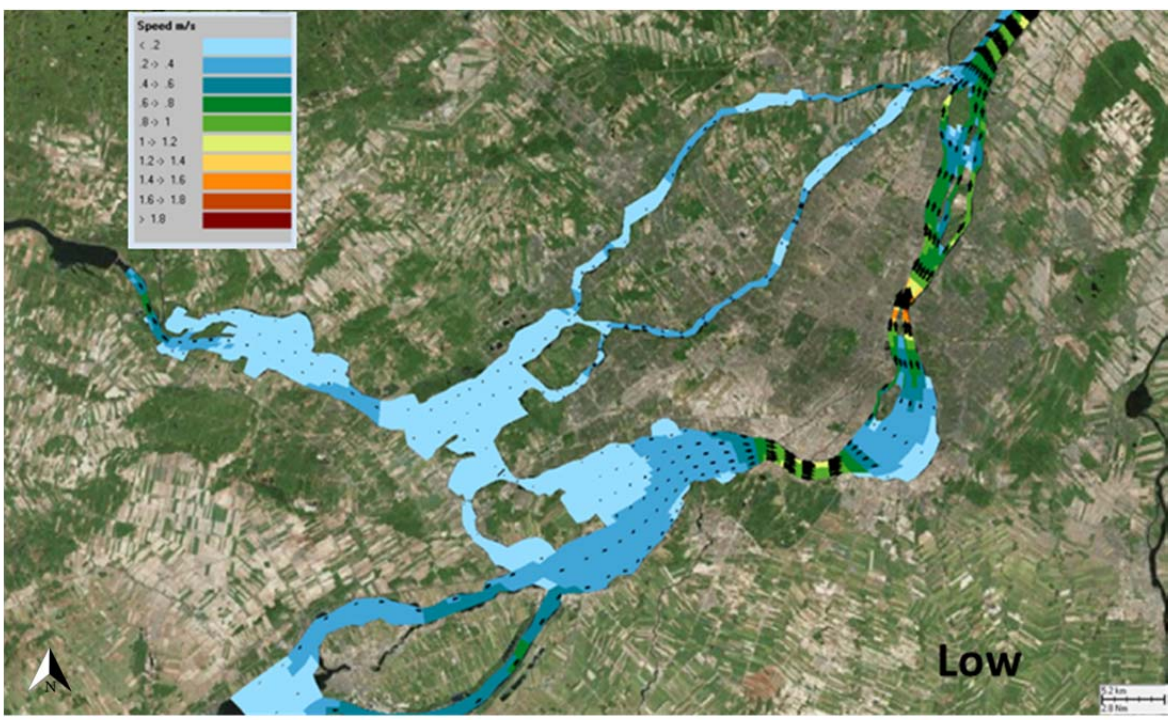

Figure 5-3 Low Discharge Current Speeds

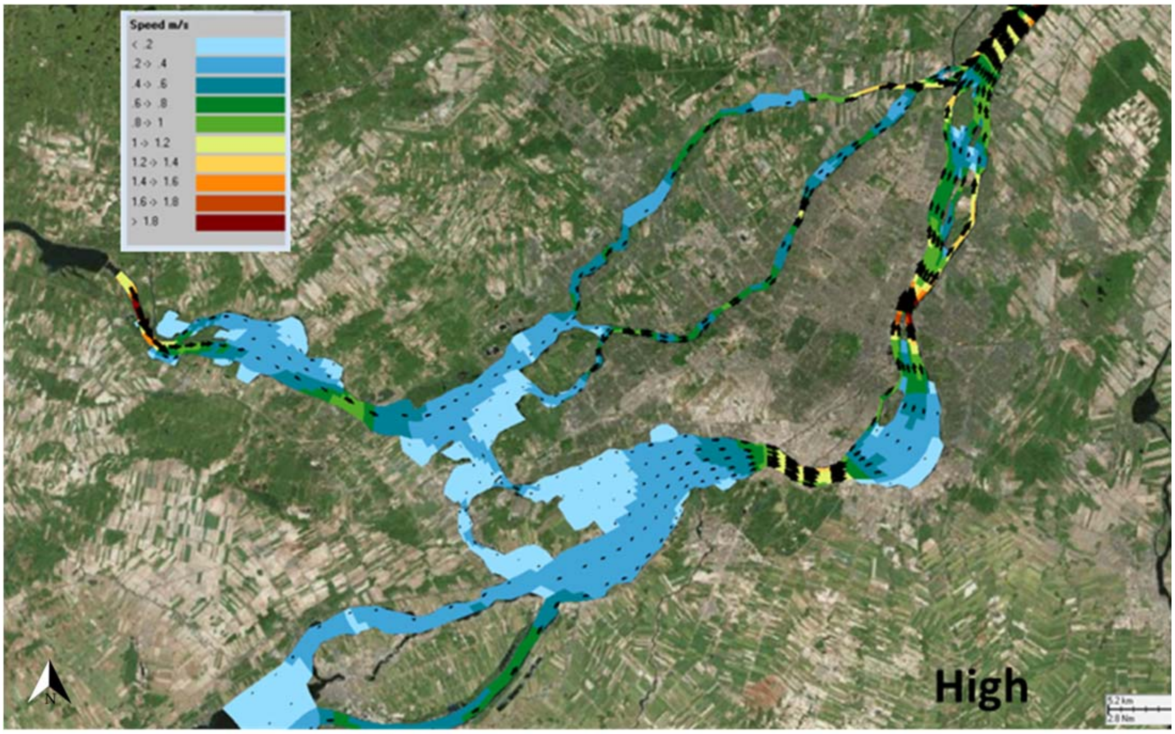

Figure 5-4 High Discharge Current Speeds

5.4 MODELLING RESULTS

Output from the SIMAP model consists of downstream trajectories of oil for each of the 22 spill scenarios modelled. The model calculates the time of first arrival for each of the 21 transects outlined in Section 5.1, Transect Locations. The values for time of first oil arrival are provided in table form with one table for each of the three rivers. Each row in the tables contains arrival time for a single scenario, and reading across the row, one can see the values change with increasing distance downstream. Reading the values down each column, one can see the values at a single transect across all spill scenarios. First oil arrival is given in hours after the spill. **Table 5-3** lists the model outputs for the St. Lawrence River, **Table 5-4** contains the results for the Rivière des Prairies and **Table 5-5** lists outputs for the Rivière des Mille Îles.

In some cases, crude oil is not predicted to reach the most distant transects or quantities are predicted to be trace or unmeasurable (less than 5 parts per billion). This can be seen by the empty fields in **Tables 5-3** through **5-5**. This can occur for a number of reasons including the presence of upstream turbulence, which can increase solubilization into the water column, and channel morphology, which can affect concentrations in the water column based on stream width and cross sectional area. An estimate of the time of first arrival of oil at any point downstream can be determined by interpolating between adjacent transects.

Table 5-3 Minimum Time of First Arrival – St. Lawrence River

Flow	Vol	Oil	O1 Arrival Time (hours)	O2 Arrival Time (hours)	O3 Arrival Time (hours)	O4 Arrival Time (hours)	O5 Arrival Time (hours)	S1 Arrival Time (hours)	S2 Arrival Time (hours)	S3 Arrival Time (hours)	S4 Arrival Time (hours)	S5 Arrival Time (hours)	S6 Arrival Time (hours)
Low	4	Bakken											
	50	Bakken											
	1,000	Bakken			89.2								
	10,000	Bakken	34.8	47.7	86.5								245.5
	4	HSB											
	50	HSB											
	1,000	WCS			92.5								
	10,000	WCS	34.3	47.3	88.2	241.8	163.7						246.8
Mean	1,000	Bakken			43.8								
	10,000	Bakken	18.5	24.8	42	89.8	63.7	148.5	153				
	1,000	HSB											
	10,000	HSB			42.3	82.3	69.3		182.3				
	4	WCS											
	50	WCS											
High	4	Bakken											
	50	Bakken											
	1,000	Bakken			22.2								
	10,000	Bakken	9.8	12.8	23.2		35	94.5	99.5				
	4	HSB											
	50	HSB											
	1,000	WCS			23.8								
	10,000	WCS	9.7	12.8	22.8		35.5		89				

Note: Green highlighted cells indicate that measurable contamination did not reach the transect

Table 5-4 Minimum Time of First Arrival – Rivière des Prairies

Flow	Volume	Oil	O1 Arrival Time (hours)	O2 Arrival Time (hours)	P1 Arrival Time (hours)	P2 Arrival Time (hours)	P3 Arrival Time (hours)	P4 Arrival Time (hours)	PM1 Arrival Time (hours)	S6 Arrival Time (hours)
Low	4	Bakken								
	50	Bakken								
	1,000	Bakken				156.2				
	10,000	Bakken	34.8	47.7	141.8	164.7	209.2	242.2	238.8	245.5
	4	HSB								
	50	HSB								
	1,000	WCS				156.2				
	10,000	WCS	34.3	47.3	144.3	140.5	194.2	221.3	240	246.8
Mean	1,000	Bakken				95		143		
	10,000	Bakken	18.5	24.8	87.8	88.7	106.7	126.2	132.7	
	1,000	HSB						141.8		
	10,000	HSB			83.5	92.7	111.2	127.8	141.5	
	4	WCS								
	50	WCS								
High	4	Bakken								
	50	Bakken								
	1,000	Bakken			37.5	42.2				
	10,000	Bakken	9.8	12.8	38.5	42.5	48.5	55.8	61.3	
	4	HSB		15.2						
	50	HSB		13.5						
	1,000	WCS			40.8	45.8				
	10,000	WCS	9.7	12.8	37	43.8	47.8	57	62.2	

Note: Green highlighted cells indicate that measurable contamination did not reach the transect

Table 5-5 Minimum Time of First Arrival – Rivière des Mille Îles

Flow	Volume	Oil	O1 Arrival Time (hours)	O2 Arrival Time (hours)	M1 Arrival Time (hours)	M2 Arrival Time (hours)	M3 Arrival Time (hours)	M4 Arrival Time (hours)	M5 Arrival Time (hours)	PM1 Arrival Time (hours)	S6 Arrival Time (hours)
Low	4	Bakken									
	50	Bakken									
	1,000	Bakken			122.3						
	10,000	Bakken	34.8	47.7	119.3	137.7	173.2	189.3	233.5	238.8	245.5
	4	HSB									
	50	HSB									
	1,000	WCS			123						
	10,000	WCS	34.3	47.3	119.7	137.8	187.8	211.7	233.5	240	246.8
Mean	1,000	Bakken									
	10,000	Bakken	18.5	24.8	70.5	89	105.2	113.5	129	132.7	
	1,000	HSB									
	10,000	HSB			73.8		111.2	120.7	138	141.5	
	4	WCS									
	50	WCS									
High	4	Bakken									
	50	Bakken									
	1,000	Bakken			33.5						
	10,000	Bakken	9.8	12.8	33.5		49.7	53.8		61.3	
	4	HSB									
	50	HSB									
	1,000	WCS			33.5						
	10,000	WCS	9.7	12.8	34.2		49.8	53.7	60.5	62.2	

Note: Green highlighted cells indicate that measurable contamination did not reach the transect

In general, the model suggests a fraction of the oil from each spill scenario may enter all three rivers; however, a larger fraction of the total spilled volume is predicted to travel east into the Rivière des Prairies and the Rivière des Mille Îles. In all spill scenarios, oil entering the Rivière des Prairies is predicted to travel downstream and into the St. Lawrence River east of Montréal. Oil reaching the St. Lawrence River downstream from the confluence of the rivers east of Montréal may reach that point by following any of the three rivers.

The hydrodynamic models used for this analysis are sophisticated representations of a highly complex river system. As with any model, the results should be used with caution as there are uncertainties in the currents generated by the hydrodynamic model. Velocity through the river channels in the Montréal region is highly variable in response to the changes in river channels that occur over short distances. There are narrow and relatively deep channels followed by broad shallow "lakes" followed by rapids, and consequently the current velocities rise and fall frequently. While oil is passing through rapids, it can be mixed in the water column; however, when it transits through quiescent lakes, the oil may rise towards the surface. Capturing this degree of variability is difficult and the lack of current observations in the river channels in this area makes validating the hydrodynamic model difficult. Despite these uncertainties, the results presented in this report represent best available science and available data.

5.5 POTENTIAL EFFECTS

5.5.1 Magnitude of Effects

In general, as the leading edge of the spill moves downstream, a given location will experience an elevated BTEX concentration that increases rapidly and then more slowly declines as the contaminant plume moves downstream.

Generally, BTEX concentrations would decrease as a plume moves downstream due to dilution and evaporation. However, in some circumstances, BTEX concentrations in the water column may drop to trace levels in places where the oil mass is dispersed across a large of volume of water in the channel, and farther downstream, may increase as the oil mass accumulates in areas with smaller channel cross sections. Larger spill volumes generally would result in higher concentrations traveling farther downstream than the small volume releases.

While a release of crude oil directly into the Ottawa River from the Project might be transported to downstream locations over time, the possibility of such an event would be very low, as demonstrated in Chapter 2.0, Spill Frequency and Volume Analysis. Assuming such a spill was to occur, Energy East would presume that downstream drinking water intakes could be temporarily affected. Energy East would immediately notify downstream municipalities in the event of a spill to allow for intakes to be preemptively shut down until the spill was contained and water quality was deemed safe for consumption. Water quality would be tested and water intakes would not be reopened until officials determined that the water was safe for human use and consumption.

5.5.2 Duration of Effects

Effects to drinking water quality tend to be transitory as crude oil moves downstream past a specific location, as shown by the Bridger Pipeline spill on the Yellowstone River spill (Section 5.5.3). Furthermore, although the BTEX compounds are relatively soluble, they have short half lives in water, ranging from approximately 3 to 6 hours (Mackay and Leinonen 1975; Thomas 1982). Therefore, although water quality could be affected in the event of a spill, effects would be transitory.

5.5.3 Case Studies

A number of recent high profile spills have provided important information on the fate and behaviour of crude oil releases into large rivers. Each spill is unique and it is prudent to avoid drawing broad generalizations from a single event. However, these spills provide significant data and, in combination with existing information and other case studies, industry and regulators gain a more comprehensive understanding of the fate, behaviour and consequences of oil spills.

Enbridge Line 6B, Kalamazoo River Spill, 2010

On July 26, 2010, the Enbridge Line 6B pipeline failed due to pipe integrity issues during a major flood event and released approximately 20,000 bbl of diluted bitumen into Talmadge Creek, a tributary to the Kalamazoo River near the town of Marshall, Michigan. This release provides important information regarding the fate, behaviour and downstream transport of a worst case scenario spill event with a heavy crude oil (Cold Lake diluted bitumen).

Within approximately 2 weeks of the spill, a large quantity of crude oil began to sink as the light hydrocarbons evaporated from the surface slick (US Environmental Protection Agency 2015). The conditions of the river at the time of the spill also played a critical role in this behaviour as turbulence caused by the flooding introduced sediment, rocks and debris into the oil and contributed to the formation of water-in-oil emulsions. This behaviour is not unique to diluted bitumen as all crude oils become denser and more viscous as weathering occurs, increasing the probability of some material sinking. A recent report by the Royal Society of Canada (2015) analyzing the physical and chemical properties of diluted bitumen and other crude oils concluded the following:

> *"The Panel found that the dozens of crude oil types transported in Canada exist along a chemical continuum, from light oils to bitumen and heavy fuels, and the unique properties of each of these oil types (their chemical 'fingerprints') determine how readily spilled oil spreads, sinks, disperses, impacts aquatic organisms, including wildlife, and what proportion ultimately degrades in the environment. Despite the importance of oil type, the Panel concluded that the overall impact of an oil spill, including the effectiveness of an oil spill response,*

> *depends mainly on the environment and conditions (weather, waves, etc.) where the spill takes place and the time lost before remedial operations.*"

This finding demonstrates that the most important factors in limiting the effects of a crude oil spill are an understanding of the environmental conditions at the time and location of the spill and organizing a rapid, effective emergency response.

Bridger's Poplar Pipeline, Yellowstone River, 2015

On January 17, 2015, the Poplar Pipeline was breached following a major flood event. This spill occurred in the Yellowstone River approximately 9.6 km upstream of the town of Glendive, Montana, and involved the release of approximately 700 bbl of Bakken Crude Oil, which entered the river via a split along the circumference of the pipe. At the time of the spill, the Yellowstone River was frozen over with a patchy layer of ice, which limited evaporation of light hydrocarbons such as BTEX and introduced turbulence into the water. Because of the turbulence caused by broken ice, Bakken Crude Oil's low viscosity and the lack of evaporation as a major fate process, the oil dispersed throughout the water column, resulting in higher than expected benzene levels.

In the days following the release, benzene was detected at the city of Glendive's water supply approximately 8 km downstream of the pipeline crossing. This was unexpected as the intake is located at a depth of 4.2 m, whereas crude oil and dissolved constituents typically are found on the water's surface or within the uppermost water layer. This was attributed to the greater than expected dispersion caused by the presence of ice on the Yellowstone River. Despite these effects, water samples were tested and the Glendive water supply was deemed fit for consumption approximately 72 hours after initial detection.

6.0 SPILL RESPONSE

6.1 OVERVIEW

6.1.1 TransCanada Pipeline Safety Program

Safety and environmental protection measures will be incorporated in the design, construction, and operation of the pipeline to reduce the potential for accidents and malfunctions. Energy East will use industry standards, specifications and best practices for the Project. The Project will comply with federal government regulations, primarily under the authority of the NEB. Also, Energy East will follow regulations of other federal, provincial or municipal bodies, including Environment Canada, Fisheries and Oceans Canada and Transport Canada.

6.1.1.1 Design

The Project will be designed in a way that meets or exceeds industry standards. Pipeline safety starts with careful route selection and design. Safeguards have been implemented during design and will be implemented during construction and operation. Steel suppliers, mills and coating plants are prequalified using a formal qualification process consistent with the International Organization for Standards. The pipe is engineered with stringent composition requirements for compounds such as carbon to ensure weldability during construction. Each batch of pipe is mechanically tested to prove strength, fracture control and fracture propagation. The new pipe is hydrostatically tested. Each pipe joint is traceable to the steel supplier and pipe mill shift during production. A formal quality surveillance program is in place at the steel mill and coating plant. The pipe is inspected in the plant with stringent tolerances on roundness and nominal wall thickness. The pipe is also inspected for surface preparation prior to coating. The coating process is carefully monitored to control quality. A final check of film thickness is completed as a final inspection. For further detail, refer to the NEB Application, Engineering Assessment.

The best way to minimize environmental effects is to carefully select the Project’s route; for further details on routing selection, refer to the NEB Application, Volume 4, Section 2.2. For pipeline construction and routing, Energy East considered factors like native topography, land use, rare and endangered species habitat, historical resources and population centres.

6.1.1.2 Construction

The Project will be constructed in a way that meets or exceeds industry standards. The pipeline field welds will be x-ray or ultrasonically tested. The pipeline will be hydrostatically tested to 125% of MAOP.

To mitigate the potential for effects of corrosion on the new pipeline, Energy East will use FBE coating—a protective coating that is applied to the external surface of the pipe to prevent corrosion. An impressed current cathodic protection system will be installed. This system will apply a low voltage direct current to protect the pipeline from corrosion. The specification of 1% sediment and water by volume is the industry standard to minimize the potential for internal corrosion. A tariff specification of 0.5% is contained in Energy East's transportation agreement with its shippers and is lower than the industry standard. The pipeline is designed to operate in turbulent flow to minimize water dropout, which is a potential cause of internal corrosion.

Historically, one of the most important risks associated with operating a crude oil pipeline is the potential for third-party excavation damage. To minimize the risk of third-party damage, the pipeline will be built in an approved right-of-way (RoW) and markers will be installed at regular intervals and at road, railway and water crossings. In addition, the depth of cover will meet or exceed federal regulations.

6.1.1.3 Operation and Maintenance

The Project will be operated and maintained in a way that meets or exceeds industry standards. During operation, the pipeline will undergo regular inspections, maintenance, and monitoring to ensure correct operation. Energy East would complete regular visual inspections (ground or aerial) of the RoW. Energy East will also monitor activity in the area to prevent unauthorized trespass or access.

During operation, the pipeline will be cleaned using ILI tools. The pipeline will be inspected with smart ILI tools, which measure and record Stress Corrosion Cracking (SCC); internal and external metal loss, and dents. This allows Energy East the ability to proactively manage cracking and corrosion, as well as, any damage caused by third party excavation.

The pipeline will be monitored 24 hours a day, 365 days a year from TransCanada's operations control centre (OCC) using a sophisticated supervisory control and data acquisition (SCADA) system. Energy East will implement a leak detection strategy utilizing multiple real-time and non-real-time leak detection methods. This strategy uses a spectrum of methods to ensure redundant detection capabilities in all operating conditions and includes criteria for leak detection thresholds and pipeline shutdown. The leak detection strategy includes:

- Real-Time Transient Model (RTTM) and Modified Volume Balance (MVB) model-based leak detection systems will be used to partition the pipeline into smaller segments and monitor each on a mass balance basis. These systems are capable of detecting leaks as small as 1.5% to 2% of pipeline flow within 2 hours.
- These systems will be complemented by a Pressure-Flow Monitoring (PFM) system that will provide an additional monitoring layer by quickly alerting the operators to large unexpected deviations in a combination of interrelated pressures and flows that could indicate sudden changes in pipeline operations. The PFM system will be implemented and tuned to reliably identify these deviations based on an analysis of historical operational data.
- The systems described will be configured to alert the OCC controllers of potential issues through the SCADA system, which provides a comprehensive information display for incident

analysis and investigation, including key flows, pressures and other sensor data to facilitate continuous monitoring of pipeline conditions.

- These real-time systems are supplement by the following non-real-time methods:
  - Software-based line balance checks will be used to monitor receipt and delivery volumes, and detect leaks smaller than 1.5% of the pipeline flow volume.
  - In-line inspections conducted as part of the pipeline integrity process provide the capability to detect pinhole sized pipeline leaks.
  - Aerial and ground patrols provide periodic monitoring of facilities, pipeline RoW and surrounding areas for indications of potential leaks and potential threats.
  - Third-party observations of oil or odours are reported to TransCanada through the PA Program and provide additional Project monitoring.

In the event that an alarm (such as one from the leak detection system) is annunciated, indicating a potential leak, the OCC controller has a maximum of 10 minutes to conclusively explain the cause of the alarm as a non-leak using established procedures. If a leak cannot be ruled out by the controller, a safe pipeline shutdown is immediately initiated. If multiple leak triggers are noted at any point during those 10 minutes, the pipeline shutdown is immediately initiated (the 10 minute period for diagnosis is skipped).

It is anticipated that pipeline shutdown, including pump shutdown and valve closure to isolate sections, will be completed within 12 minutes based on current design information. Emergency response, including dispatch of field personnel to site, would be immediately initiated through TransCanada's Emergency Management system. Pipeline control valves used to isolate sections will be located at pump stations and at regular intervals along the pipeline, as well as on either side of major water crossings or near sensitive resources.

The leak detection system will alarm the OCC operators through the SCADA system and also will provide the OCC operators with information on incident analysis and investigation. In addition, there will be a redundant, stand-by OCC to be used in case of emergency.

Energy East will have a maintenance, inspection and repair program that will meet or exceed regulatory requirements and ensure the integrity of the pipeline during operation. TransCanada's annual pipeline maintenance program (PMP) will be designed to maintain the safe and reliable operation of the pipeline. The PMP is underpinned by a company-wide goal to ensure facilities are reliable and in-service. Data collected each year will be used to help develop the following year's program.

Energy East will mitigate third-party excavation risk by implementing comprehensive public awareness and damage prevention programs focused on education and awareness. Energy East will participate in national and local call centres such as Call Before You Dig, One Call Centres programs where they are present. For further detail on these and other operation and maintenance measures, refer to the NEB Application, Engineering Assessment.

Lastly, Energy East will have an Emergency Response Plan (ERP) in place to respond to incidents. The ERP contains comprehensive manuals, detailed training plans, equipment requirements, resource plans, auditing, change management and continuous improvement processes. TransCanada's Capital Planning management System and Asset Management System and ERP will help TransCanada operate the pipeline in an environmentally responsible manner.

6.2 EMERGENCY RESPONSE

The NEB Onshore Pipeline Regulations (NEB OPR) describe the requirements of ERPs.

In accordance with NEB OPR, Energy East would be required to immediately notify the Transportation Safety Board in the event of a release of crude oil of any volume. In addition to the Transportation Safety Board, Energy East would make timely notifications to other agencies, including the appropriate local emergency agencies, first responders, applicable provincial departments and Aboriginal communities. In many cases, oil spill responses could be handled by Energy East; however, some spills may require supplemental support from response contractors, or other pipeline companies through mutual aid agreements and co-ops. The NEB is the lead federal response agency for oil spills occurring on land and in inland waters. Energy East would be responsible for cleaning up the spilled crude oil to meet or exceed regulatory requirements. In accordance with applicable regulations, Energy East would be responsible for oil spill cleanup and would be required to meet applicable cleanup levels.

Federal regulations require pipeline operators to have ERPs prepared and in place to respond to emergency incidents that may occur. ERPs are prepared to assemble a comprehensive plan that can be followed in the event of an emergency. Per applicable regulations, the objectives of Energy East's ERP would be to: 1) establish guidelines and procedures to be followed in emergencies to protect the health and safety of the public and responders, 2) minimize hazards resulting from pipeline emergencies, 3) establish procedures for training employees on emergency procedures, and 4) establish guidelines for continuing educational and liaison programs designed to inform community first responders and the public of the procedures to follow in recognizing, reporting and responding to an emergency condition.

Effective January 1, 2014, TransCanada has entered into a Mutual Emergency Assistance Agreement (MEAA) amongst all other member companies of the Canadian Energy Pipeline Association (CEPA), which includes Kinder Morgan-Canada, Alliance Pipeline Ltd., Enbridge Pipelines Inc., Spectra Energy Transmission, and numerous others. The MEAA between CEPA members strengthens the emergency response process. This agreement formalizes the current industry practice of mutual assistance during an emergency, where by member companies share staff, equipment, and other resources, which increases each individual company's existing emergency response capabilities. This mutual assistance agreement facilitates a quicker response to protecting people, the environment and property.

This section will describe how the response effort generally is administered during the emergency phase of the spill response. For a more detailed analysis, see ESA Volume 6, Section 7.3, Emergency Response. Energy East's ERP will outline the specific steps and measures they will implement along the pipeline route. In addition, an overview of available remediation alternatives will be presented.

6.2.1 Emergency Response Stages

Emergency response activities take place in stages. A release begins with an initiator (i.e., cause) and initial loss of crude oil from the pipeline system. Once the leak is detected, the emergency response is conducted as follows: 1) pump station shutdown; 2) valve closure to conduct leak isolation; 3) stoppage of flow the pipe; and 4) initiate containment and recovery, which can be conducted concurrently to the cessation of oil releasing from the pipeline infrastructure.

The duration of each stage 1 – 3 determines the quantity of crude oil released. The fourth stage limits migration of possible crude oil released and possible impacts. Pipeline flow would not resume until the cause of the leak is identified, the infrastructure has been repaired and approval received from regulatory agencies and senior company personnel.

6.2.2 Emergency Notifications

Emergency notification procedures are started immediately after a release event has been discovered. Typically, regulatory agencies and local emergency services are notified immediately following discovery of a release event. Concurrently, Energy East internal notifications are conducted to activate an emergency response and the relevant departments in accordance with pre-established emergency notification procedures.

Once a spill was detected, Energy East responders would be mobilized immediately.

6.2.3 Crude Oil Containment and Recovery

Energy East will prepare a Geographic Response Plan (GRP), specific for the Ottawa River. The GRP includes detailed information related to trained personnel, pre-positioned equipment available, additional response resources, and deployment tactics specific for the Ottawa River. The GRP allows emergency responders to quickly and effectively deploy response equipment based on a detailed site-specific deployment plan. The GRP ensures that sufficient equipment and resources are available to address the worst-case discharge at the Ottawa River.

First response cleanup options typically used to address crude oil spills include various containment methods combined with recovery procedures, such as mechanical and vacuum pumping, use of absorption products (i.e., pads) and soil excavation. Application of biologic surfactants, chemical oxidizers and burning of liquid crude oil may be used only if permitted by the regulatory authorities with jurisdiction.

Containment efforts will begin as soon as initial assessment activities are complete and the spill scene is cleared for entry. Containment technologies typically are applied near the pipeline release point and further downstream along identified drainage basins and ditches. If surface water has been affected, containment actions will be implemented to stop additional crude oil movement within the effected surface water body. Basic containment equipment and materials that typically are used include:

- Floating containment booms for application to surface water bodies ranging from small drainage ditches and streams to rivers and lakes.
- Floating absorbent booms and pads that absorb free oil, retard water absorption (i.e., hydrophobic) and recover oil.
- Earth moving equipment, sand bags and PVC pipe to quickly construct earthen containment and underflow dams.

To facilitate prompt emergency response on the Ottawa River, Energy East will stage emergency response equipment near the city of Montréal, in accordance to the Ottawa River GRP.

6.2.3.1 Flowing Waters

There are a number of specific containment techniques that can be employed on flowing waters such as the Ottawa River. These include:

- Inverted Weir Dams: On higher-flow creeks and rivers, angled pipes will be placed in sand bag or earthen dams to allow clean water to flow from the bottom (allowing floating oil to be blocked at the surface).
- Deflection Booming: On fast-flowing rivers (exceeding 0.5 m/s), booms would be angled in order to deflect floating oil towards shore. In some cases, it might be necessary to use multiple booms. Efforts will be made to utilize local knowledge in order to take advantage of natural eddies and collection points.

The Ottawa River GRP will identify specific tactics that are likely to be deployed in the event of a release. In general, the preferred recovery process is mechanical removal of oil from the environment, using sorbents and/or oil skimmers wherever safe and possible.

On small spills, sorbent pads would be deployed into the thickest areas of the collected slicks. Once pads are oil-soaked, they would be removed using pitch forks, pike poles or debris scoops. Sorbent booms also would be used, either to sweep oil within the contained area to increase the oil thickness or positioned, as a liner, inside skirted booms. Recovered sorbent booms and pads will be double-bagged, placed in lined bins to avoid secondary contamination and properly disposed of.

6.2.3.2 Winter Conditions

Cold weather will have an effect on the emergency response and can facilitate response and recovery operations. Loss of light ends (weathering) slows down at lower temperatures, which can offset some of the temperature effect on viscosity. The evaporation rate at 5°C is approximately one-third of the evaporation rate at 30°C. As a result, oils may remain amenable to treatment by recovery for a longer period at colder temperatures. Additionally, when water is at or near its maximum density in near-freezing temperatures, heavier oils are less likely to sink. Cold, viscous oil will spread more slowly providing additional time for response.

The frozen conditions can create a solid working platform over the oil and create natural barriers that are used to contain and immobilize oil. Additionally, oil can be quickly encapsulated under ice as there may be many under-ice pockets where oil can accumulate in natural depressions, facilitating under-ice recovery.

The traditional strategy for dealing with oil under the ice in a river is to cut slots in the ice to aid in recovery. Ice slots can be cut using chain saws, handsaws, ice augers or some form of trencher. Another effective variation of this technique is the diversionary plywood barrier. This method uses plywood to help divert oil beneath the ice to an area in which a skimmer or suction equipment can be located to remove the oil. The Ottawa River GRP will identify specific tactics and locations for deploying these tactics based on ice conditions and pre-staged equipment.

During work on the ice, Energy East would rigorously conduct on-going vapour monitoring. Because the oil would be isolated under the ice and vapours would not be exposed to the atmosphere, they could build up and pose a substantive hazard to those working on the ice and conducting ice slotting.

6.2.3.3 Oil in Sediment

In the event of a spill, oil could contact shorelines and, under certain conditions such as severe flood events with strong turbulence, might become submerged (Section 4.2.2).sediments If crude oil remains in the environment at high concentrations for extended periods of time, there is potential for long-term effects. However, the potential for these effects would be minimized by cleanup, which reduces the amount of oil in the environment. With effective and prompt cleanup, shorelines would be protected from contamination and crude oil would remain buoyant through the recovery process, limiting the amount of oil that would sink and bind with sediments.

In the event of oil becoming entrained in sediments, a number of recovery and remediation techniques exist, including removal of contaminated soils with vacuum trucks or through dredging.

6.2.3.4 Crude Oil Recovery Strategies

Timely recovery of liquid crude oil at the ground surface is essential to limit the extent and magnitude of effects on the subsurface. Crude oil recovery efforts will begin concurrent with containment activities. Initial recovery efforts would be conducted where crude oil is pooled at the point of the release and at downstream containment areas where crude oil might be accumulating.

Residual crude oil within the isolated section of pipeline will be removed and, depending on its condition, transported to an off-site facility for recycling, treatment or disposal.

Typical recovery equipment and materials used to respond to spills are:

- containment and adsorbent boom
- tanker trucks equipped with vacuum pumps (e.g., vacuum trucks)
- mechanical pumps (e.g., centrifugal, impeller, diaphragm)
- earth-moving equipment (e.g., backhoes, front end loaders, tandem dump trucks, hand shovels)
- floating oil skimmers of various types
- portable storage, including frac tanks or transport tanker trucks, or both
- boats

7.0 CLEANUP AND REMEDIATION

For a spill into the Ottawa River, initial emergency response actions would focus on protection of public safety and sensitive resources.

Corrective remedial actions are enforced by applicable regulatory agencies. Required remedial actions might include active remediation (i.e., excavation, installation and operation of systems that recover oil located below ground, and on and within the water column) to allowing the contaminated soil and water to recover through natural environmental fate processes. Decisions concerning remedial methods and extent of the cleanup will be governed by applicable regulations and spill site conditions. Additional information on remediation strategies is available in ESA Volume 6, Section 7.4, Remediation.

7.1 TIMING

During and after a cleanup, the the response team, regulatory agencies, and stakeholders would review remediation endpoints for the cleanup proposed by Energy East. Endpoints are characteristics of the environment that are considered acceptable in terms of residual hydrocarbons (e.g., amount of weathered oil along a riverbank, amount of hydrocarbon remaining in soils) and potential chronic effects. At a certain point, the environmental benefits gained in further removal of residual hydrocarbons are outweighed by potential damage caused by the cleanup or treatment activities. For example, removal of relatively low levels of weathered hydrocarbons could require extensive disturbance of riverbanks or wetlands, which, if too intrusive, could delay rather than accelerate recovery (Baker 1995, 1997; Owens and Sergy 2003, 2007).

An analysis of the environmental effects of the spill is required to assess the various recommended endpoints that promote natural recovery. Once the defined endpoint for a specific habitat (or substrate) is attained through cleanup and remediation measures, the residual hydrocarbons would be allowed to continue weathering through natural attenuation processes (biological degradation by microorganisms), which would reduce their levels over time. The affected site would be monitored regularly to confirm that rehabilitation and recovery of the affected areas are successful. The need for and scope of monitoring would be determined in consultation with government agencies and stakeholders, as appropriate.

8.0 COMPARISON WITH SAVARIA REPORT

In comparison to the Savaria report, this site-specific risk assessment (using Stantec and RPS ASA analyses) focused on the Ottawa River spill scenario as this crossing has the highest potential to affect Montréal-area surface water intakes in the event of a spill. The Savaria report estimated the trajectory and fate of crude oil discharged from the Project for the following three river crossings: Ottawa River, Rivière des Mille Îles, and Rivière L'Assomption. The trajectory analysis assumed a worst case spill scenario occurred at each crossing.

While the Savaria report represents an alternative approach, the Savaria report oversimplified several critical assumptions and calculations, such as worst case discharge (WCD) calculations and site-specific river hydrodynamics, resulting in substantial overestimations of oil movement and spill volumes. While simplifying assumptions can be used as a preliminary screening tool, results should be carefully interpreted with more complexity and realism added to the analysis before definitive conclusions are drawn. Some of the conclusions reached by the Savaria report are not appropriate given the oversimplifications within the analysis.

8.1 WORST CASE DISCHARGE CALCULATION

The WCD calculation used by Savaria gave no consideration to critical factors that substantially affect WCD, such as draindown properties, actual valve locations, and topography. Studies have concluded that spills rarely approach WCD volumes due to these and other factors (California State Fire Marshal 1993). The oversimplification resulted in volumes up to 103,000 bbl, substantially larger than the largest historical North American onshore pipeline spill (e.g., 33,000 bbl onshore; PHMSA 2014).

The analysis conducted by Stantec and RPS ASA elected to use an alternative approach that focused on a reasonable range of spill volumes based on actual spills. As discussed in Section 2.1, Stantec and RPS ASA analyses used a range of volumes between 4 and 10,000 bbl that accounts for 99.5% of pipeline spills since 2002 (PHMSA 2014).

While the use of WCD is critically important for emergency planning purposes, use of WCD volumes overestimates a reasonable expectation of probable spill volume. The Savaria report does not acknowledge the low probability of such an event, which may mislead a reader to believe that the worst case spill volume is a reasonable expectation for a spill release.

8.2 DOWNSTREAM TRANSPORT

The interconnecting rivers within the Montréal area are hydrologically complex systems that range from river runs and rapids through constricted waterways to expansive lake-like areas. As a result of the complexity, river velocities and currents vary widely throughout this area. The Savaria report did not account for this complexity when travel times were calculated. Rather, the Savaria report used a single velocity, which was based on the flood-stage river discharge and the wetted width of the Ottawa River at the location of the crossing. This location is relatively narrow and, therefore, velocities at this location would be substantially higher than at most other locations.

Use of a single velocity can be a suitable approximation for a screening-level assessment for rivers with relatively constant widths and cross-sectional areas. However, it is not an accurate or reasonable approximation for the highly complex river systems surrounding Montréal that are characterized by narrow and relatively deep channels followed by broad shallow "lakes," resulting in current speeds that rise and fall frequently and dramatically. Therefore, transport rates calculated from a single velocity, identified at the narrow crossing of the Ottawa River, substantially overestimate velocity throughout the system and results in much shorter travel times than would actually occur.

In contrast, Stantec utilized RPS ASA's SIMAP to model hydrodynamics within the river systems, which involves a variety of representative current speeds at different river locations resulting in substantially more realistic estimates of travel times to downstream locations.

Using a single velocity, the Savaria report concluded that a spill from the Ottawa River would reach the first downstream surface water intake in approximately 4 hours. The more realistic model used within this report that accounts for complex river hydrology concludes that, depending on the spill volume, river conditions, and crude oil type released, it would take between approximately 10 and 40 hours for a spill to reach transect O1, the same location as the drinking water intake referenced in the Savaria report. These realistic transit times provide sufficient time for emergency responders to detect, isolate, contain and begin cleaning up a potential release.

9.0 CONCLUSION

Despite the low probability of a crude oil release into the Ottawa River, this report evaluated the fate and behaviour of several crude oils; used a hydrodynamic model to estimate time of transit to downstream municipal drinking water intakes; and summarized design, operational and emergency response procedures to reduce the potential for effects on municipal drinking water intakes located downstream of the Ottawa River crossing. Lastly, the report compared and contrasted findings of this report with those of the Savaria report, illustrating concerns with the Savaria report that may have led to inappropriate conclusions.

Key Findings

A release from the Project at the Ottawa River crossing is unlikely to affect surface water intakes near Montréal because the probability of a release of 4 bbl or less occurring at the crossing is estimated to be less than approximately once every 7,375 years and the probability of a release of 10,000 bbl or more is estimated to be less than approximately once every 737,470 years.

In the unlikely event that a spill did enter the Ottawa River, effects to water quality at Montréal area surface water intakes are improbable because:

1) The majority of spills likely would be 4 bbl or less and approximately 80% of the spills would be 50 bbl or less.
2) Depending on the spill volume, river conditions and crude oil type released, it would take between approximately 10 and 40 hours for crude oil to reach the first downstream surface water intake (transect O1). Depending on these same variables, crude oil would take days to reach municipal intakes close to Montréal.
3) Both the crude oil and benzene dissolved from the crude oil are extremely buoyant.

Emergency response tactics would further reduce the potential for effects to water quality.

1) Energy East's ERP requires that emergency response equipment be staged near Montréal, thus facilitating a prompt response to any potential spills.
2) The significant travel times predicted would provide time for detection of the leak, isolation of the affected pipeline segment with remotely operated valves and check valves and initiation of Energy East's ERP.
3) If a leak into the Ottawa River was detected, Energy East's ERP requires operators to immediately notify regional operators who could close municipal water intakes as a preventative measure.
4) Emergency crews would deploy pre-positioned containment and absorbent booms to contain the spill as close to the release site as practical. The ERP will identify the location

of Montréal area intake structures and additional booms will be deployed around the locations, if appropriate.

Cleanup and remediation would reduce further effects to water quality.

1) Water samples will be collected during containment and cleanup to monitor water quality and determine the areal extent of contamination.

The Savaria report contains several assumptions and methodologies that lead to inappropriate conclusions, including:

1) Calculation of WCD volumes without considering important factors such as draindown properties, actual valve locations or topography.

2) Use of a single velocity calculated based on a narrow portion of the Ottawa River, resulting in much shorter travel times than would be expected to occur under more representative conditions.

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