Statoil

Statoil Canada Ltd. - East Coast Operations
Newfoundland and Labrador Offshore Area
Validation of 2008 Oil Spill Trajectory Modelling Results and Effects Assessment of Accidental Events

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1 Introduction

The following information was prepared in response to the following comment from the Canada-Newfoundland and Labrador Offshore Petroleum Board (C-NLOPB):

> *Please confirm, in light of the information you provided to us this week concerning maximum credible oil blowout rates resulting from Statoil's recent analysis of Flemish Pass reservoir properties, that the results of the "Hypothetical Spill Trajectory Probabilities from the StatoilHydro 2008 Mizzen Drilling Program" (S.L. Ross Environmental Research Ltd. Ottawa, ON January 2008) and the resultant conclusions of the EA, are still valid.*

The 2008 Drilling EA included modelling based on a 5,000 m^3/day accidental release (subsurface and topsides scenarios). Modelling for flow rates, different than those presented in the original 2008 EA, was undertaken and the results of this modelling is used to provide an update to the environmental assessment of potential environmental effects that could occur should a major accidental event occur in the Flemish Pass. This report includes additional spill trajectory modelling results and updated information regarding the environmental effects assessment of accidental events, particularly Section 8 of the original 2008 Drilling EA.

Results of a stochastic modelling exercise are included to inform the environmental assessment. The probability of a spill remains consistent with that detailed in the original 2008 Drilling EA. Statoil's Oil Spill Response Plan currently on file with the C-NLOPB is applicable to this update.

2 Oil Spill Fate/Behaviour and Trajectory Modelling

2.1 Introduction

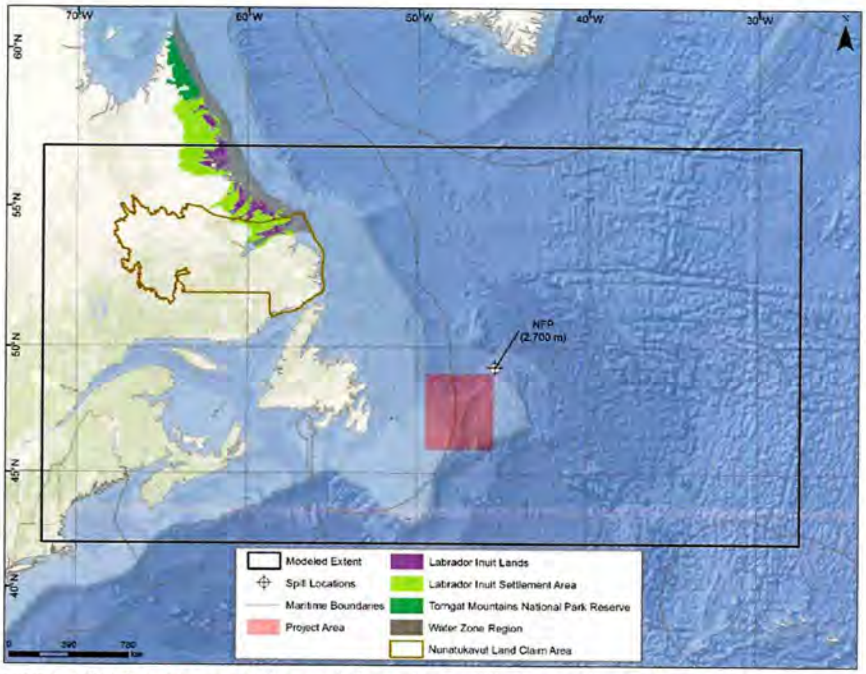
RPS (dba Applied Science Associates, Inc.) conducted trajectory and fate modelling in support of Statoil's Flemish Pass area drilling environmental assessment. The modelling report provides trajectory and fate results for unmitigated subsurface blowouts and topside releases, with comparisons to results presented previously in the original environmental assessment (LGL 2008). The modelling reported herein involves hypothetical releases of Bay du Nord crude oil at a site located in the Northern Flemish Pass (NFP) area, located approximately 500 km east of the Newfoundland coast, northeast of the Grand Banks, and north of the Flemish Cap (Figure 1). The water depth at the NFP release location is 2,700 m. Major currents, including the Labrador Current and the Gulf Stream, influence the circulation and biological productivity in this region.

This modelling was conducted to evaluate possible release events associated with exploration drilling, including a subsurface blowout and a topside release. Three-dimensional oil spill trajectory and fate modelling and analyses were performed to support evaluation of the potential effects that releases of oil may have in the Atlantic Ocean near Newfoundland. RPS's nearfield OILMAPDeep blowout model and the farfield Spill Impact Model Application Package (SIMAP) trajectory, fate, and effects models were used. This report provides a brief description of the study area, modelled scenarios, an overview of the modelling approach, details about the model input data used, and a discussion of the model results. Detailed information on the model and spill trajectory results can be found in Appendix 1.

2.2 Study Area, Scenarios, and Modelling Approach

2.2.1 Study Area and Scenarios

Newfoundland comprises a series of islands off the east coast of Canada, and along with Labrador forms the easternmost Canadian province. The relatively shallow waters of the continental shelf extend eastward up to 500 km from the Newfoundland coast. Known as the Grand Banks, this area contains substantial petroleum resources. The project study area (46-49°N, 45.5-49.5°W) encompasses the Grand Banks and Flemish Cap, which are located in the northwest sector of the Jeanne d'Arc sedimentary rift basin, east of Newfoundland in the Atlantic Ocean. These biologically productive regions sit atop the Hibernia, White Rose, and Tera Nova oil fields. The model domain (i.e., extent of study area) extends as far west as 72°W and east to 28°W, encompassing Canadian, US, and International waters (Figure 1).



Note: The black bounding box represents the modelling extent, while the smaller box represents the Statoil study area.

Figure 1 Study Area, including the Hypothetical Release Location (NFP) and Water Depth

A single release location was chosen for modelling at the NFP site (Table 1). Subsurface blowouts near the sea floor and topside releases were modelled separately in a stochastic analysis, which investigated the effects of environmental variability, throughout the year over multiple years, on trajectory and fate.

Table 1 Hypothetical NFP Release Location and Stochastic Scenario Information

NFP Scenario Parameters	Subsurface Blowout	Topside Release
Block	EL1140	
Latitude	49° 13' 43.764"	
Longitude	45° 25' 5.054"	
Product	Bay du Nord crude oil	
Release Duration	36 d	
Model Duration	160 d	
Number of Stochastic Runs	119 annual (55 winter & 64 summer)	
Water Depth of Release	2,700 m	Surface (0 m)
Gas to Oil Ratio	45.9 m^3/m^3	N/A
Pipe Diameter	31.1 cm	N/A
Oil Discharge Temperature	80°C	N/A
Release Rate	4,980 Sm^3/d	15,900 Sm^3/d
Total Release Volume	179,280 Sm^3	572,400 Sm^3

2.2.2 *Overall Modelling Approach*

This modelling study employed a stochastic approach to determine the potential trajectory and fate of hypothetical hydrocarbon releases. Stochastic modelling provides a probabilistic view of the likelihood that a given region might experience effects from released hydrocarbons over many possible environmental conditions occurring within and across multiple years.

Hypothetical release scenarios were simulated using the OILMAPDeep and SIMAP modelling packages, two three-dimensional trajectory and fate models developed by RPS. OILMAPDeep was used to define the near-field dynamics of the subsurface blowout plume which was then used as the initial conditions for the far-field modelling conducted in SIMAP. These near-field plume dynamics include the location and size of the subsurface plume at the termination (i.e., trap) height and the characterization of the oil droplet size distribution. Typically, the near-field model is on the timescale of seconds and length scale of hundreds of metres, whereas the far-field model is on the scales of hours/days and many kilometres. These models are described in Appendix 1.

A stochastic approach was used in SIMAP to determine the potential footprint of areas that may be affected by a release of oil based upon variability in meteorological and hydrodynamic conditions. A stochastic scenario is a statistical analysis of tens to hundreds of individual trajectories resulting from the same release event, with each trajectory starting at a randomized time from a relatively long-term window. The stochastic approach analyzes the same type of release under varying environmental conditions to provide the anticipated variability in probable movement and behaviour of the release. In order to reproduce the natural variability of winds and currents, the model requires both spatially- and temporally-varying datasets (e.g. hourly to daily time scales) spanning at least five years. A sufficient number of model runs will adequately sample the variability in wind and current speed and direction in the region of interest, and will result in a prediction of the many possible oil pathways for a release at the prescribed location.

In a stochastic analysis, multiple model runs (tens to hundreds of releases) are laid upon one another to create a cumulative footprint of releases. Further analyses provide two types of information for specific thresholds of interest including: 1) the probability that a given area may experience contamination, and 2) the shortest amount of time required for oil to reach any point within the predicted area. To analyze the probability or likelihood of potential effects, specific thresholds for surface oil thickness and shoreline oiling are used (Table 1). Figures and further analyses in this study include the lower socio-economic thresholds of concern calculated from stochastic results.

Table 2 Stochastic Thresholds Used to Define Regions with Potential Effects

Stochastic Threshold	Cut-off Threshold	Rationale
Surface Oil Thickness	*0.04 µm	Visible threshold used to determine impacts on socioeconomic resources (e.g., possibility of fisheries closure). This minimum thickness would relate to a slick being barely visible as a colourless or silver sheen (Lewis 2007; Bonn Agreement).
	10 µm	Biological threshold for ecological impacts to organisms using the water surface (e.g., birds) (French et al. 1996; French McCay 2009). Oil appears dark brown.
Shoreline Oil Mass	*1 g/m^2	The threshold for potential effects on socio-economic resource uses, as this amount of oil would conservatively trigger the need for shoreline cleanup on amenity beaches. Oil would appear as a dull brown sheen (Lewis 2007; Bonn Agreement).
	100 g/m^2	A conservative screening threshold for potential ecological effects to shoreline habitats, which has typically been 100 g/m^2, based on a literature synthesis showing shoreline effects at this degree of oiling (French et al. 1996; French McCay 2009). The oil appears as a dark brown coat or opaque/black oil.

*Thresholds used in supporting figures. For comparison, a bacterium is 1-10 µm, a strand of spider web silk is 3-8 µm, and paper is 70-80 µm. 1 g/m^2 is roughly equivalent to 1 µm.

2.2.3 *Model Uncertainty and Validation*

The SIMAP model has been developed over many years to include as much information as possible to simulate the trajectory, fate, and effects of oil spills. However, there are limits to the complexity of processes that can be modelled, as well as gaps in knowledge regarding the affected environment. Assumptions based on available scientific information and professional judgment were made in the development of the model, which represent a best assessment of the processes and potential mechanisms for effects that could result from oil spills.

The major sources of uncertainty in the oil fates effects models are:

- Oil contains thousands of chemicals with differing physical and chemical properties that determine their fate in the environment. The model must of necessity treat the oil as a mixture of a limited number of components, grouping chemicals by physical and chemical properties.
- The fates model contains a series of algorithms that are simplifications of complex physical-chemical processes. These processes are understood to varying degrees.
- The model treats each spill as an isolated, singular event and does not account for any potential cumulative effects.
- A number of physical parameters including but not limited to hydrodynamics, water depth, total suspended solids concentration, and wind speed were not sampled extensively throughout the entire modelled domain. However, the data that did exist was sufficient for this type of modelling. When data was lacking, professional judgment and previous experience was used to refine the model inputs.

In the unlikely event of an actual oil spill, the trajectory, fate, and effects will be strongly determined by the specific environmental conditions, the precise locations and types of organisms present, and a myriad of details related to the event and specific timeframe. Modelled results are a function of the scenarios simulated and the accuracy of the input data used. The goal of this study was not to forecast every detail that could potentially occur, but to describe a range of possible consequences and effects of oil spills under various representative scenarios.

2.3 Model Input Data

2.3.1 Oil Characterization

A Bay du Nord (BdN) crude oil was modelled in this study. BdN is a light crude oil with low viscosity and a high aromatic content (Tables 3 and 4). The low viscosity and high aromatic content of the BdN oil provides a conservative approximation of anticipated effects within the water column, as a larger proportion of constituents has the potential to dissolve. The physical and chemical data used to specify this oil was provided by Statoil, with additional assays and measurements by SL Ross and Intertek (SL Ross 2016; Intertek 2016). The physical and chemical parameters of BdN oil are similar to those of Hibernia crude oil, which was used in previous studies (SL Ross 2016; ESTC 2001), as confirmed by Statoil (Statoil 2016). These two oils would likely behave similarly in a release event. The "pseudo-component" approach is used to simplify oils for use in SIMAP. Chemicals in the oil mixture are grouped by physical-chemical properties, and the resulting component category behaves as if it were a single chemical with characteristics typical of the chemical group. In this component breakdown, aromatic groups are both soluble (i.e. dissolve into the water column) and volatile (i.e. evaporate to the atmosphere), while the aliphatic groups are only volatile. The total hydrocarbon concentration within a boiling range is the sum of aromatic and aliphatic. Residual oil is considered relatively inert, but will decay over time.

Table 3 Physical Properties for the Oil Product Used in Modelling

Physical Property	Bay du Nord crude oil
Density (g/cm^3)	0.84553 @16°C 0.85800 @0°C
Viscosity (cP)	5.0 @20°C 53.0 @0°C
API Gravity	35.850
Pour Point (°C)	-9
Interface Tension (dyne/cm)	15.5
Emulsion Maximum Water Content (%)	72

Table 4 Fraction of the Whole Oil Comprised of Different Distillation Cuts for Bay du Nord Crude Oil

Distillation Cut	Boiling Point (°C)	Description	Fraction of Bay du Nord Crude Oil
AR1	< 180	highly volatile and soluble monoaromatic hydrocarbons (BTEX and MAHs; C9-C10)	0.023739
AR2	180 – 264	semi-volatile and soluble 2-ring aromatics (MAHs and PAHs; C11-C12)	0.004166
AR3	265 – 380	low volatility and solubility 3-ring aromatics (PAHs; C13-C16)	0.066998
AL1	< 180	highly volatile aliphatics (C4-C10)	0.206261
AL2	180 – 264	semi-volatile aliphatics (C10-C15)	0.160834
AL3	265 – 380	low volatility aliphatics (C15-C20)	0.168002
Residuals	> 380	aromatics ≥ 4 rings and aliphatics > C20 that are neither volatile nor soluble	0.37000

2.3.2 Environmental Data

Environmental data inputs include the following, and are further described in Appendix 1:

- Habitat, shoreline and bathymetry
- Currents and winds
- Water temperature and salinity
- Ice cover

2.4 Model Results

The results from both the subsurface blowouts and topside releases from the NFP release location presented below illustrate the spatial extent of the water surface and shoreline oil contamination. Stochastic results include:

- The probability footprints for surface oil in excess of 0.04 µm;
- The corresponding minimum time for surface oil to exceed a threshold of 0.04 µm;
- The probability footprints of shoreline oil in excess of 1 g/m²; and
- The corresponding minimum time for surface oil to exceed a threshold of 1 g/m².

The probabilities of oiling were based on a statistical analysis of the ensemble of individual trajectories modelled for each release scenario. Stochastic figures do not imply that the entire contoured area would be covered with oil in the event of a release, nor do they provide any information on the quantity of oil in a given area. Rather, these figures denote the probability of oil exceeding socioeconomic effects thresholds over all stochastic runs (119 individual releases for the annual scenario), at all modelled time steps (over 160 days), and for each point within the modelled domain. Note that only probabilities of ≥1% were included in the map output.

The minimum time footprints correspond with the associated probability of oiling map. Each figure illustrates the shortest amount of time required (from the initial release) for each point within the footprint to exceed the defined threshold. The time reported is the minimum value for each point from the entire ensemble of trajectories. Together, probability and minimum time figures can be interpreted together to read: "There is X% probability that oil will exceed the identified threshold at a specific location, and this exceedance can occur in as little as Y days". The stochastic figures below do not imply that the entire contoured area would be covered with oil in the event of a single release, nor do they provide any information on the quantity of oil in a given area. The Exclusive Economic Zone (EEZ) for Canada and the U.S., as well as the international border, are depicted on each map to provide context in regards to the spatial extent and potentially affected territorial waters from any potential release (VLIZ, 2014). Probability contours for subsurface blowouts and topside releases are provided in Figures 2 to 5 and are available in greater detail in Appendix 1 (Sections 4.1 and 4.2, respectively).

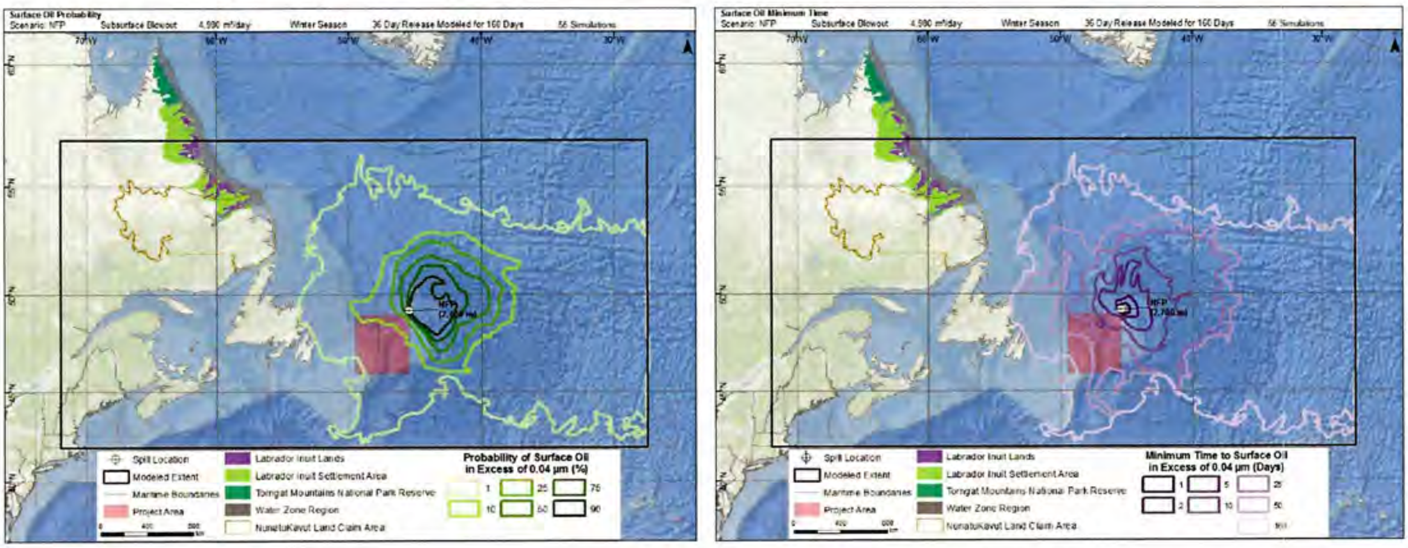


Figure 2Subsurface release (winter) surface oiling probabilities above 0.04 µm (left) and minimum time to surface oiling in days for threshold exceedance (right)

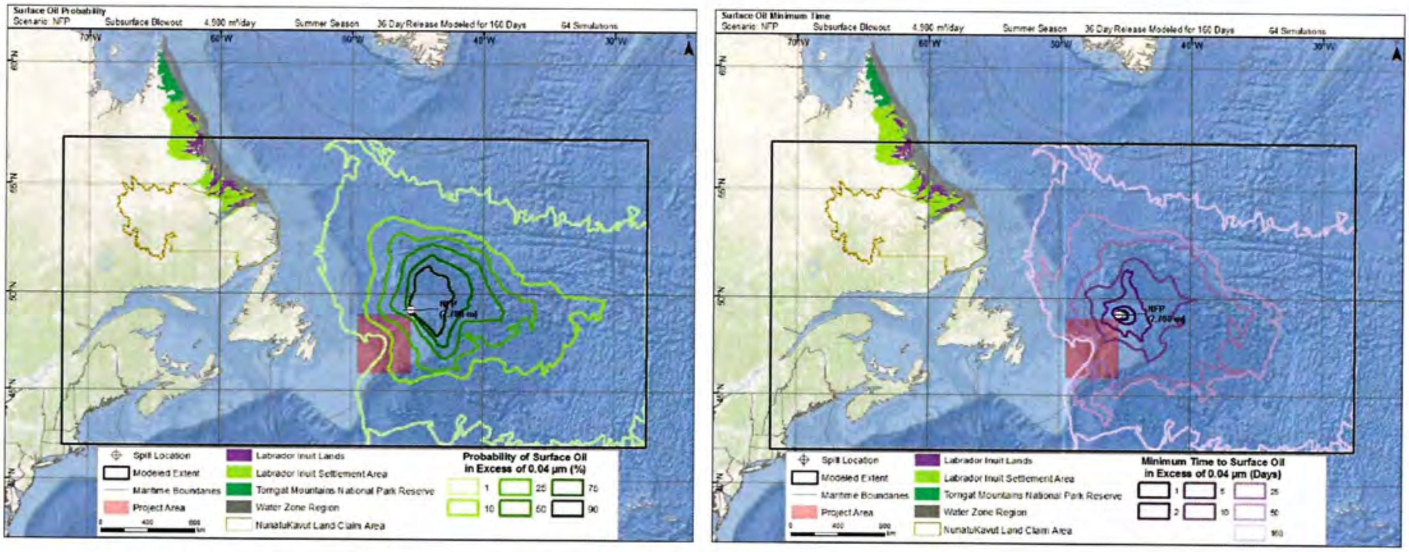


Figure 3Subsurface release (summer) surface oiling probabilities above 0.04 µm (left) and minimum time to surface oiling in days for threshold exceedance (right)

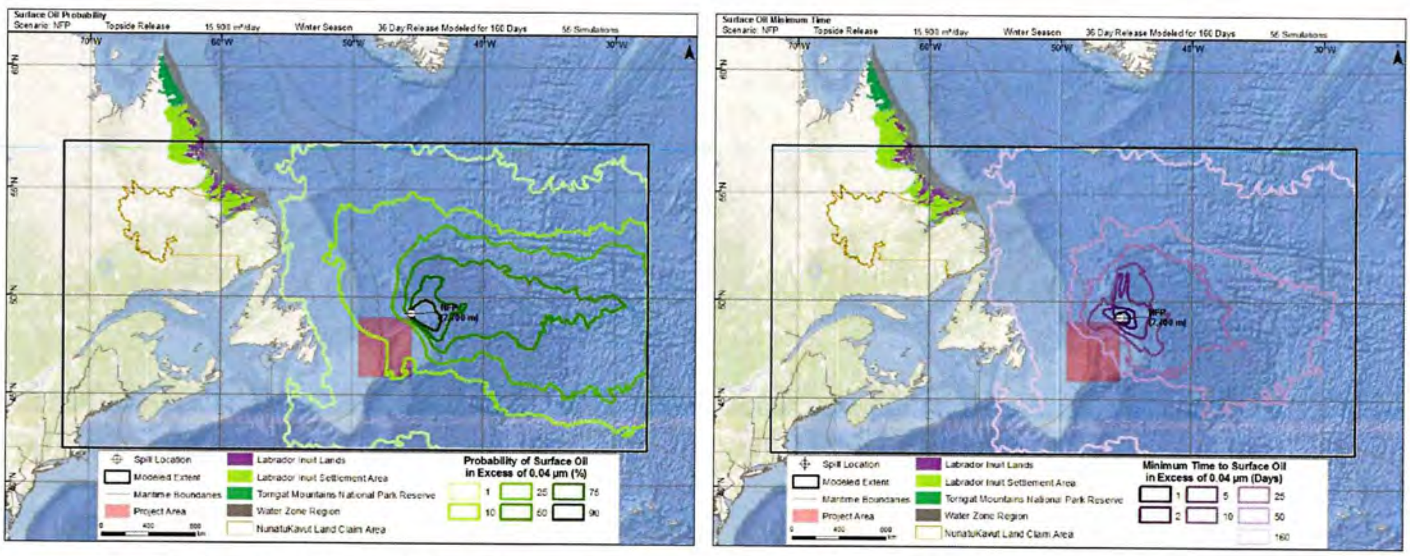


Figure 4Topside release (winter) surface oiling probabilities above 0.04 µm (left) and minimum time to surface oiling in days for threshold exceedance (right)

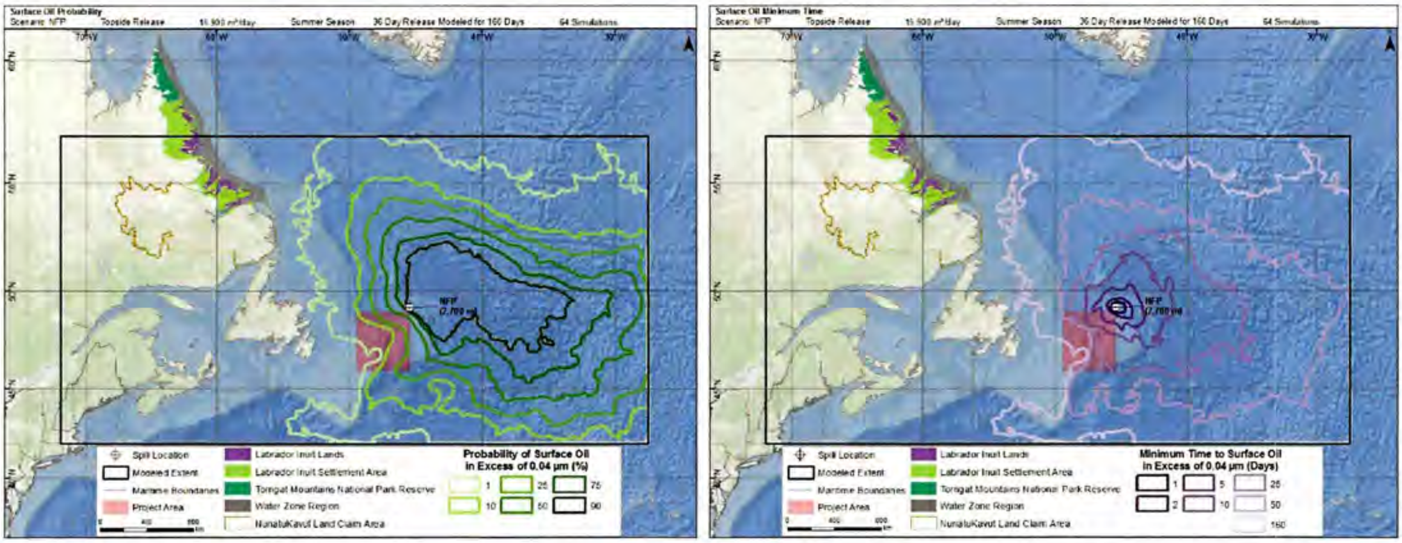


Figure 5Topside release (summer) surface oiling probabilities above 0.04 µm (left) and minimum time to surface oiling in days for threshold exceedance (right)

Two mass balance plots have been provided for a single representative 36-day topside release scenario to depict the general weathering trends (focusing on evaporation) of BdN crude oil (see Appendix 1, Figure 4-1). Results are presented over two time scales including 0-30 days and 0-160 days within the simulation to illustrate the amount of time over which the lighter fractions of BdN crude oil on the water surface evaporate into the atmosphere. Approximately 37% of surface oil evaporates in the first 2 days and evaporation rates rapidly decline after that point. By 48 days, only 12 days following the modelled end of flow rate, approximately 45% of the total released mass of BdN crude oil is predicted to evaporate. Two oil mass balances illustrate the time history of oil at 30 days and at the end of the 160-day simulation demonstrating a consistent amount of evaporation (42% to 46%), a decrease in water column contamination, an increase in the amount decayed, and approximately 11% of the oil leaving the modelled domain (Table 5).

Table 5 Oil mass Balance, Given in Percent of the Total Release Volume at 30 days and at the End of the 160-day Simulation

Timeframe	Surface	Evaporated	Water column	Ashore	Decayed	Outside Grid
30 days	17%	42%	27%	0%	13%	0%
160 days	0%	46%	2%	0%	41%	11%

2.5 Discussion and Conclusions

In general, the majority of surface oil from both a topside release and subsurface blowout is predicted to move to the east of the hypothetical release location (see Appendix 1, Section 4). Threshold exceedance is generally predicted to be greater at each location within the grid for topside releases, when compared to the subsurface scenario, due to the total volume of the topside release being over threefold higher than the subsurface release. In other words, larger volumes of released oil typically result in higher predicted probabilities of oil exceeding the threshold within the defined footprint.

Seasonal investigation yields different predicted surface results for summer and winter scenarios. During the topside summer release scenario, a much larger 90% probability surface oil footprint is predicted. Lower wind speeds during summertime conditions reduce the likelihood of entrainment (i.e., surface oil forced into the water column), resulting in oil on the surface being transported great distances by wind and currents, thereby increasing the size of that probability footprint. Under stormier wintertime conditions, wind induced waves result in greater amounts of entrainment, thereby reducing the amount of oil on the surface and reducing the likelihood that oil will be found on the surface. For the subsurface blowouts, winter and summer scenario, contour lines are smaller in overall area than topside releases due to the lower release volume. However, the same trend in summer vs. winter is observed in the subsurface blowout scenario, with smaller surface area footprints during wintertime conditions.

In general, only annual and winter release scenarios were predicted to have surface oil reaching the coastline (threshold of $1g/m^2$) at a probability of 1-3% (see Appendix 1). The oil that is predicted to make it to shoreline is expected to be highly weathered, as minimum time estimates to make contact with the shoreline ranged from approximately 50 to 160 days. Any oil that would make its way to shore is expected to be patchy and discontinuous. The small amount of oil that could make contact with the shoreline, as predicted from a subsurface release, would be stranded on the northeast coast of the island of Newfoundland (Figure 4-7). Similarly, for the topside release, a small amount of oil is predicted to make contact with the shoreline at a few points along the northeast coast of the island of Newfoundland and on the south coast of Labrador (Figure 4-12).

Oil spill trajectory modelling was undertaken for the original 2008 EA. No shoreline oiling was predicted by the 2008 study. In this study, release volumes were similar in the subsurface blowouts (4,890 m^3/day), but threefold higher for surface releases (15,900 m^3/day), the duration of flow was similar (36 days verses 30 days), and the threshold of concern was identical to this study (0.04 µm, which is equivalent to 1 gram per 25 m^2). The larger amount of oil modelled here has a higher likelihood of exceeding the very conservative surface oil threshold. Additionally, because the modelling was conducted over a 160-day period in this study, over five times the duration of the previous study, oil was transported much further distances. Because of this increased time, this most recent study does predict that some regions of Newfoundland and a very small portion of Labrador may have up to 3% probability of being oiled, however most cases are closer to 1% or lower. subsurface

While it is understood that the hypothetical releases modelled in spill trajectory modelling studies are in no way intended to predict a specific future event, rather they are used as a planning tool for use in environmental assessments and spill contingency planning. The results presented in this document demonstrate that there are a range of potential trajectories and fates that may result following a release of crude oil based upon the environmental variability that may occur over the course of a year or many years. If there were an event such as a subsurface blowout or topside release, it is likely that a different volume of oil may be released from a different location than modelled here.

While it is impossible to know the exact trajectory and fate of an oil release in the future, inferences may be made from this study.

3 Potential Effects of Accidental Events

The following sections provide updated information regarding effects assessment presented in the original 2008 EA report, namely:

- literature review regarding the effects of crude oil on each VEC (fish and fish habitat, commercial fisheries, seabirds, marine mammals and sea turtles, special/sensitive areas; species at risk).
- effects assessment of potential topside and subsurface release scenarios based on amended flow-rates
- additional mitigation that may be required

It should be noted that the scenarios modelled are low-probability worse-case events (see Section 2.4 of this report and Appendix 1, Section 4.1 and 4.2). The flow-rates are based on known reservoir properties in the Flemish Pass area. The flow duration of 36-days is based on best-estimates of the ability to shut in the well (stop the flow).

The effects of surface oiling were described in the original EA Report (LGL 2008). However, because of higher flowrates for the topside scenario (similar for the subsea scenario) and because the modelling was conducted over a 160-day period in this study, oil was transported much further distances than that modelled in the original 2008 EA Report. With an increased spill rate (15,000 m^3/day) and extended model run (160 days), there is also a potential for interaction with the shoreline or nearshore environment in winter. For the subsurface scenario (winter), the modelling predicts, that without implementation of mitigation, there is a very low probability (1%) of highly weathered oil reaching the nearshore / shoreline environment within 50-100 days (subsurface scenario) and 100-160 days (topside scenario) after release where oil exposure is above a 1.0 g/m^2 threshold. The flow rates modelled (above) show that the

3.1 Fish and Fish Habitat

Potential interactions of an accidental event with fish and fish habitat are identified in Table 6.

Table 6 Potential Interactions of Accidental Events and Fish and Fish Habitat VEC

Valued Ecosystem Component: Fish and Fish Habitat								
Accidental Event Scenario	Fish Habitat Components				Fish Life Stage			
	Water	Sediment	Plankton	Benthos	Eggs / Larvae	Juvenile [a]	Adult Pelagic	Adult Demersal
Topside crude blowout (15,900 m^3 oil/day)	X	X	X	X	X		X	
Subsurface crude blowout (4,980 m^3 oil/day)	X	X	X	X	X	X	X	X
Notes: [a] Often closely associated with the substrate								

Benthic habitat (and its invertebrate community) may be affected by an oil spill as oil has been found to persist in marine sediments for several years if not disturbed and sublethal effects can occur from even low levels of hydrocarbons. Deep-water coral communities in the Gulf of Mexico were examined three to four months after the well was capped following the Deepwater Horizon spill (White et al. 2012). All sites greater than 20 km from the spill site had healthy coral communities and 7 of the 11 surveyed sites appeared to be unchanged from September 2009, when they had been previously visited previously (White et al. 2012). There was one site 11 km southwest of the spill site that had coral that exhibited signs of physiological stress, including tissue loss, sclerite enlargement, excess mucous production and bleached ophiuroids (commensal species), and were covered by brown flocculent material (White et al. 2012).

Filter feeding organisms that prey on plankton can ingest naturally- or chemically-dispersed oil droplets when they are of a similar size to some plankton (IPIECA and IOGP 2015). Relatively simple organisms, such as bivalves, cannot biochemically process the higher molecular weight PAHs in the oil; therefore, PAHs can bioaccumulate in some organs (Neff and Burns 1996). Predators that consume oil-contaminated bivalves may therefore be exposed to elevated concentrations of the higher molecular PAHs by this ingestion route.

Plankton are a source of food for larvae and some adult fish and zooplankton could be affected by a blowout or spill through mortality, sublethal effects, or hydrocarbon accumulation if oil concentrations are high enough. Potential effects on plankton vary by species and can include a change in phytoplankton community structure due to contamination and an increase in biomass due to decreased zooplankton predation (Abbriano et al. 2011).

Limited or inhibited air-sea gas exchange and light penetration and may also result in reduced phytoplankton productivity and growth (González et al. 2009; Abbriano et al. 2011). The phytoplankton community structure can also be altered as different phytoplankton taxa have varying responses to crude oil (Gilde and Pinckney 2012). Zooplankton species may also vary in their responses to hydrocarbons, with exposure time a more important component to mortality than oil concentration at the site (Abbriano et al. 2011). Zooplankton communities are expected to fully recover soon after a spill as a result of their ability to avoid oil patches, short generation time, and high fecundity (Seuront 2010).

Eggs and larvae exposed to high concentrations of oil generally exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. Fish embryos exposed to oil (either naturally or chemically dispersed) following a spill has the potential to affect the development, structure, and function of the cardiac system, resulting in impaired swimming stamina (Lee et al. 2015).

The drilling for this Project will occur in open water at intermediate to deep depths (1,000 to 2,700 m). Oil released from an offshore blowout is predicted to rise to the surface on time scales of hours to days. Because of the depths involved in these releases and the low total suspended solid load in the water column this far offshore, there will be limited amounts oil adhering to suspended sediments and therefore a low potential for significant amounts of oil to be deposited on the bottom. Oil interactions with the benthos in the proposed Project Area are anticipated to be low, with little of the total amount of released oil predicted to settle to the benthos.

Both the subsurface and topside release scenarios have the potential to interact with fish and fish habitat, and have potential to result in negative effects. Only the subsurface release scenario have potential to interact with juvenile and adult demersal invertebrates and fish, assuming that the juvenile stage occurs mostly near bottom.

There is a very low probability (1%) of highly weathered oil reaching the nearshore / shoreline environment (50-100 days subsurface scenario; 100-160 days topside scenario) where oil exposure is above a 1.0 g/m² threshold. In consideration of the potential for shoreline oiling from an accidental event, if a spill were to occur, Statoil would undertake real-time monitoring of surface oil movement and real-time modelling to provide additional information of potential areas where shoreline oiling may occur. This real-time information will assist in deploying spill response measures (e.g. shoreline protection, containment, and recovery) to those areas where there is a potential for shoreline oiling. With the implementation of shoreline protection measures, and containment and recovery operations, and the low probability (one percent) and long-time to shore (greater than 50 days) the potential for environmental interactions with fish and fish habitat are not likely.

Spill prevention is paramount in all of Statoil activities. In the unlikely event of an oil spill, the implementation of spill response measures, would reduce the reversible effects. Mitigation measures are identified in Table 7.

Table 7 Accidental Event Effects Assessment for the Fish and Fish Habitat VEC

Valued Ecological Component: Fish and Fish Habitat								
			Evaluation Criteria for Assessing Environmental Effects					
Accidental Event Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation Options**	**Magnitude [a]**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Topside crude blowout (15,900 m^3 oil/day)	Contamination (N); Health effects (N); Tainting (N)	Prevention; Contingency plan; Spill response protocols	0-1	6	1	2	R	2
Subsurface crude blowout (4,980 m^3 oil/day)	Contamination (N); Health effects (N); Tainting (N)	Prevention; Contingency plan; Spill response protocols	0-1	6	1	2	R	2

Magnitude
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent
1 = < 1 km^2
2 = 1-10 km^2
3 = 11-100 km^2
4 = 101-1,000 km^2
5 = 1,001-10,000 km^2
6 = > 10,000 km^2

Frequency
1 = < 11 events/year
2 = 11-50 events/year
3 = 51-100 events/year
4 = 101-200 events/year
5 = > 200 events/year
6 = continuous

Duration
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility (population level)
R = Reversible
I = Irreversible

Ecological/Socio-Cultural and Economic Context
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative anthropogenic effects

The absolute geographic extent varied by season for each scenario but both described by same criterion rating
a The definitions of magnitude ratings remain the same as presented in LGL 2008

The residual effects of an accidental event on the fish and fish habitat VEC is predicted to have negligible to low magnitude, regardless of the spill scenario. Geographic extent and duration for both the topside and subsurface blowout scenarios are predicted to be >10,000 km^2, and 1 to 12 months.

Based on these criteria ratings, the residual effects of an accidental event on the fish and fish habitat VEC is predicted to be not significant (Table 8). The likelihood of a major accidental event is low.

Table 8 Significance of Predicted Residual Environmental Effects of Accidental Events on the Fish and Fish Habitat VEC

Valued Ecological Component: Fish and Fish Habitat				
Project Phase/Activity	Significance of Predicted Residual Environmental Effects		Likelihood [a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Topside crude blowout (15,900 m^3 oil/day)	NS	3		
Subsurface crude blowout (4,980 m^3 oil/day)	NS	3		

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥ 4 rating)

S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

3.2 Commercial Fisheries

3.2.1 Updated Information on Commercial Species

Figure 6 illustrates the pattern of fishing activity in 2015 for all commercial species, based on Canadian catch data as obtained from Fisheries and Oceans Canada (DFO) with respect to the Study and Project Areas. Fishing activities in the Study Area have not changed substantially since the environmental assessment reports were accepted and the overall program approved. Fishing activity maps for cod, redfish, and American plaice are provided in Appendix 2.

As per the probability plots illustrated in Figures 2-5, the predominant direction of an oil slick on the surface is eastward. Based on the commercial catch data, commercial fishing effort is focused within the western half of the 2008 EA Project Area and further westward. The closest aggregation of fishing occurs in an area predicted to have between 1% and 50% surface oiling probability (summer) and between 1% and 25% of surface oiling (winter) from a subsurface and/or topside release.

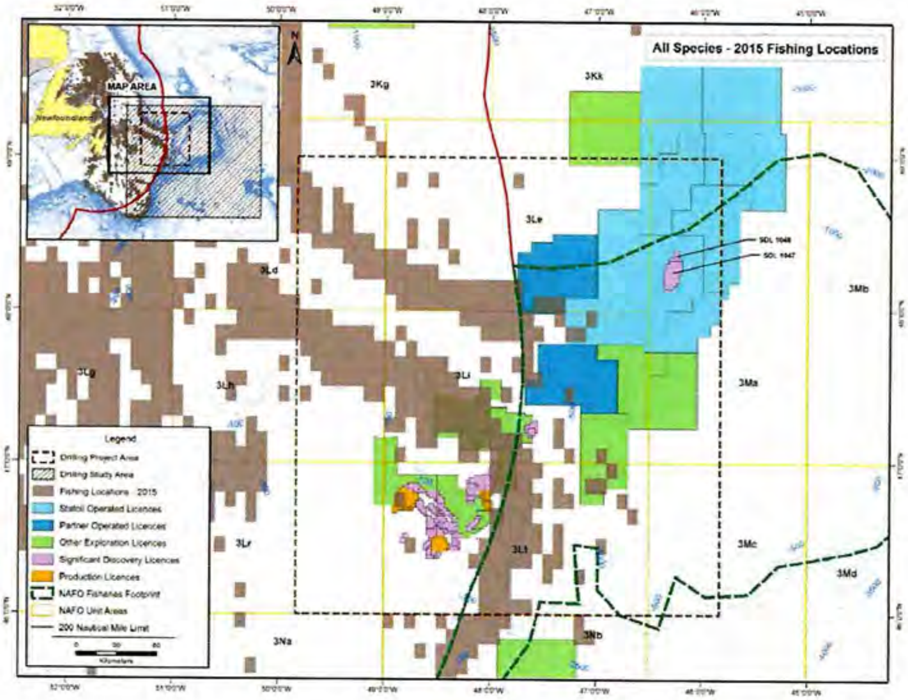


Figure 6 Pattern of Canadian Fishing Activity for 2015 for All Commercial Species in Relation to the Drilling EA Project Area (Canadian data only)

From the perspective of the commercially important domestic fisheries – snow crab (Figure 7), shrimp (Figure 8) and Greenland Halibut (Figure 9) – these species are harvested within the Project Area and within the area of potential surface oiling (10% to 25% probability for snow crab and Greenland halibut, 1% to 10% probability for northern shrimp).

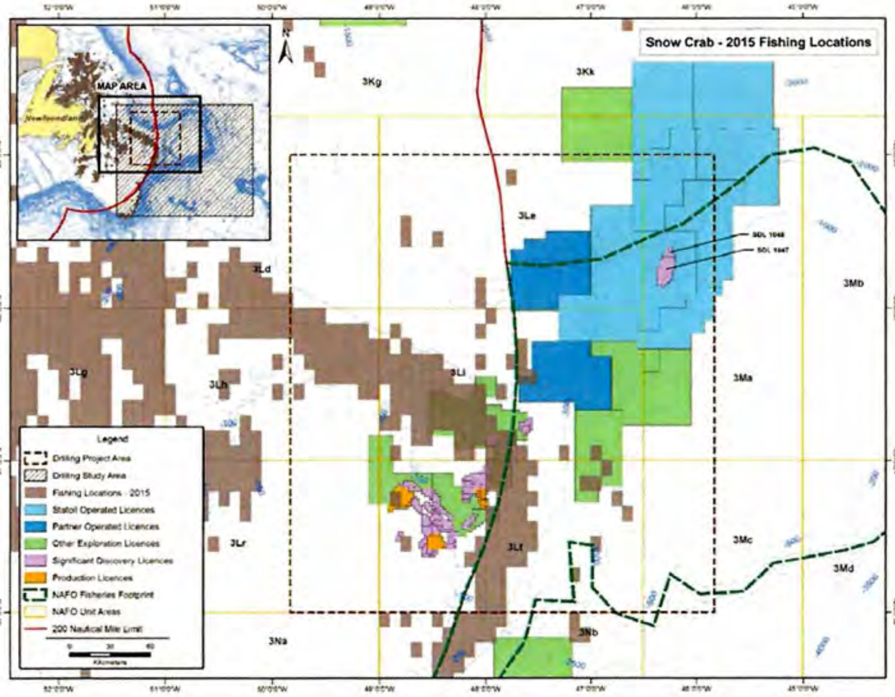


Figure 7 Pattern of Snow Crab Fishery in 2015 (Canadian data only)

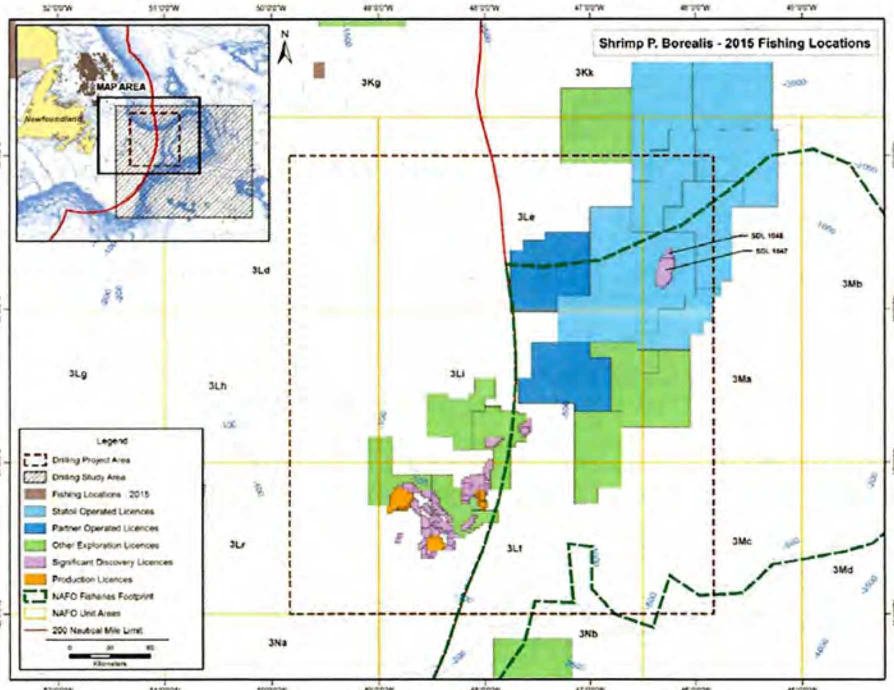


Figure 8 Pattern of Northern Shrimp Fishery in 2015 (Canadian data only)

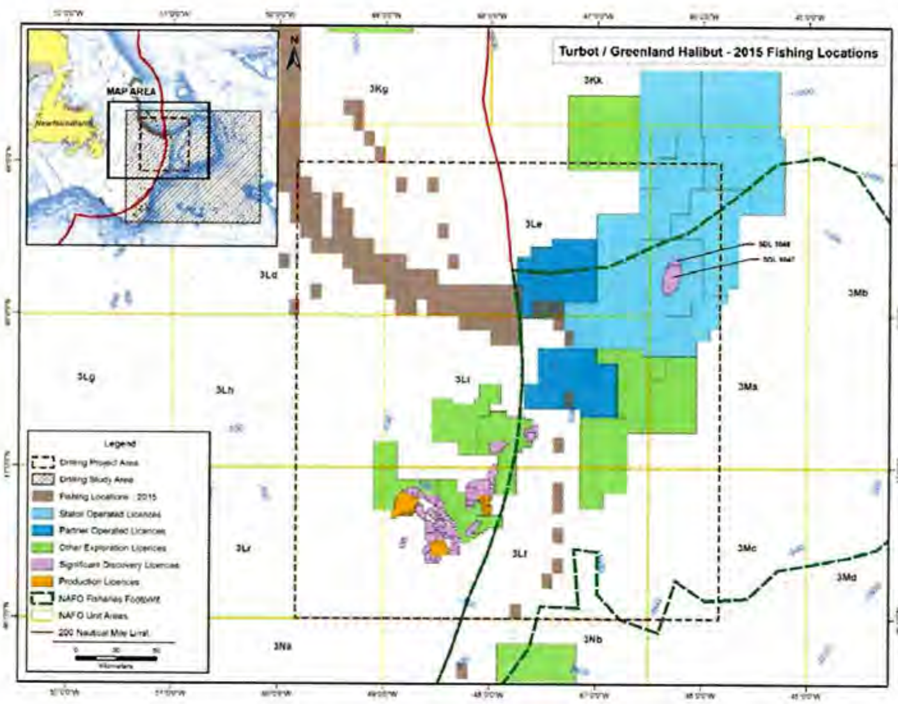


Figure 9 **Pattern of Greenland Halibut Fishery in 2015 (Canadian data only)**

3.2.2 *Accidental Event Environmental Effects Prediction*

While physical effects of a spill on fish are assessed as not significant (Section 3.1.2), economic impacts might still have potential to occur if a spill prevented or impeded a harvester's ability to access fishing grounds (areas closed to fishing, or areas temporarily excluded during the spill or spill clean-up), caused damage to fishing gear (through oiling) or resulted in a negative effect on the marketability of fish products (because of market perception resulting in lower prices, even without organic or organoleptic evidence of tainting).

Within the Project Area, there are areas where both intensive and limited fishing activity are typically recorded. Thus, the extent of the impact from a spill is very much dependent on the location of the release site vis-à-vis the nearest fishing activity at the time of the release.

If surface oil were to reach an area when fisheries were active, it is likely that fishing activity would be halted, owing to the possibility of fouling gear if raised through the slick. If the release site was some distance from the commercial fishing grounds, and with knowledge of the potential track of the oil based on real-time monitoring and modelling, there would be time to notify fishers to prevent the setting or hauling of gear and thus prevent or reduce gear damage.

Exclusion from the spill area would be expected to be short-term, as spill direction, spill response methods and sea and wind conditions in the Project Area would promote fairly rapid evaporation and weathering of the oil. Modelling indicates that 45% of oil will evaporate within 12 days after the flow has stopped. Nevertheless, if fishers were required to cease fishing, harvesting might be disrupted (though, depending on the extent of the slick, alternative fishing grounds might be available in a nearby area). An interruption could result in an economic impact because of reduced catches, or extra costs associated with having to relocate fishing effort. However, with implementation of spill containment and recovery mitigations, and the predicted evaporation rate, any closure should be temporary and short-term.

Effects due to market perceptions of poor product quality (e.g., no buyers or reduced prices) are more difficult to predict, since the actual (physical) impacts of the spill might have little to do with these perceptions. It would only be possible to quantify these effects by monitoring the situation if a spill were to occur and if it were to reach active fish harvesting areas.

Fish exposed to an oil spill may ingest oil (including PAHs) and could potentially pose a health threat to human consumers, thus affecting the marketability of catches. Market perceptions of poor product quality (e.g., tainting) can persist even when testing indicates that safe levels are safe for consumption. The hydrocarbon concentrations at which tainting (i.e., when a food product has an unusual odour or flavour) may occur are very low (although no reliable chemical threshold has been established); taint is determined by sensory testing (ITOPF 2011). Depressed market prices may be the result of reduced demand for seafood that is perceived to be tainted, as was demonstrated following the Deepwater Horizon oil spill. Even after federal and state testing showed Gulf seafood to be safe to eat, sales remained depressed due to lack of consumer confidence (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011).

Spill location, seasonal timing, and how much oil reaches the fisheries resource can vary; this makes assessing the effects of an oil spill for the commercial fishery difficult. A change in availability of fisheries resources can be affected by of other factors such as the natural fluctuations in species levels, variation in fishing effort, contamination from other sources, or climatic effects (ITOPF 2011).

With the application of mitigation measures (e.g., spill containment and recovery, economic compensation) the effects are likely to be not significant.

In the event of a spill, Statoil will implement a compensation program in accordance with the "Compensation Guidelines Respecting Damages Relating to Offshore Petroleum Activity (C-NLOPB and C-NSLOPB, 2002 and as amended) and with Canadian East Coast Offshore Operators Non-attributable Fisheries Damage Compensation Program established by the Canadian Association of Petroleum Producers (2007). The compensation program includes measures and mechanisms to address attributable and non-attributable economic loss associated with accidental events. Their purpose is to provide fair and timely compensation to commercial fish harvesters and processors who sustain actual loss because of the accidental release of petroleum (spills), with the aim of leaving them in no worse position, or in a better position, than before the incident occurred.

These principles will be an important component of SCL's response if a spill results in economic consequences, and will ensure that any actual loss to the fisheries industry resulting from any oil spill is fully and equitably addressed.

Potential interactions of an accidental event with commercial fisheries are identified in Table 9.

Table 9 Potential Interactions of Accidental Events and Commercial Fisheries VEC

Valued Environmental Component: Commercial Fisheries			
Accidental Event Scenario	**Damage to Fishing Gear and Vessels**	**Access to Fishing Grounds**	**Catchability**
Topside crude blowout (15,900 m³ oil/day)	X	X	X
Subsurface crude blowout (4,980 m³ oil/day)	X	X	X

The residual effects of an accidental event on the commercial fisheries VEC is predicted to have negligible to low magnitude, regardless of the spill scenario. Geographic extent and duration for both the topside and subsurface blowout scenarios are predicted to be >10,000 km², and 1 to 12 months, as identified in Table 10.

Table 10 Accidental Event Effects Assessment for the Commercial Fisheries VEC

Valued Ecological Component: Fish									
			Evaluation Criteria for Assessing Environmental Effects						
Accidental Event Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation Options**	**Magnitude [a]**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Topside crude blowout (15,900 m³ oil/day)	Health effects (N); Tainting (N)	Prevention; Contingency plan; Spill response protocols, Compensation Plan	0-1	6	1	2	R	2
Subsurface crude blowout (4,980 m³ oil/day)	Health effects (N); Tainting (N)	Prevention; Contingency plan; Spill response protocols, Compensation Plan	0-1	6	1	2	R	2

Magnitude
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent
1 = < 1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1,000 km²
5 = 1,001-10,000 km²
6 = > 10,000 km²

Frequency
1 = < 11 events/year
2 = 11-50 events/year
3 = 51-100 events/year
4 = 101-200 events/year
5 = > 200 events/year
6 = continuous

Duration
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility (population level)
R = Reversible
I = Irreversible

Ecological/Socio-Cultural and Economic Context
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative anthropogenic effects

The absolute geographic extent varied by season for each scenario but both described by same criterion rating
a The definitions of magnitude ratings remain the same as presented in LGL 2008

Based on these criteria ratings, and the low probability of a worse-case spill occurring, the residual effects of an accidental event on the commercial fisheries VEC during the Project is predicted to be not significant (Table 11).

Table 11 Significance of Predicted Residual Environmental Effects of Accidental Events on the Commercial Fisheries VEC

Valued Ecological Component: Fish				
Project Phase/Activity	Significance of Predicted Residual Environmental Effects		Likelihood [a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Topside crude blowout (15,900 m³ oil/day)	NS	3		
Subsurface crude blowout (4,980 m³ oil/day)	NS	3		

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km² (≥ 4 rating)

S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

3.3 Seabirds

Potential interactions of an accidental event with marine birds are identified in Table 12.

Table 12 Potential Interactions of Accidental Events and Seabirds

Accidental Event Scenario	Seabirds
Topside crude blowout (15,900 m³ oil/day)	X
Subsurface crude blowout (4,980 m³ oil/day)	X

French-McCay (2009) developed a combined oil encounter and mortality rate, when exposed to floating oil with a thickness of 10 g/m², of 99% for surface divers, 35% for nearshore aerial divers, 5% for aerial seabirds, and 35% for wetland birds based on their behaviour patterns. Studies conducted following the 1989 *Exxon Valdez* oil spill have tried to determine if marine bird populations have recovered in the Prince William Sound area in Alaska. Iverson and Esler (2010) suggested a population recovery time of 24 years for harlequin duck after the *Exxon Valdez* spill based on modelling.

The residual effects of an accidental event on the seabird VEC is predicted to have low to high magnitude, regardless of the spill scenario. As indicated in Table 13, geographic extent and duration for both the topside and subsurface blowout scenarios are predicted to be > 10,000 km², and 1 to 12 months.

There is a very low probability (1%) of highly weathered oil will reach the nearshore / shoreline environment (50-100 days (subsurface scenario); 100-160 days (topside scenario)) where oil exposure is above a 1.0 g/m² threshold. With the implementation of spill containment and recovery operations and shoreline protection measures, the likelihood of marine birds interaction with oil above the 100 g/m² biological threshold (French et al., 1996; French McCay 2009) in the nearshore and shoreline environment is not likely.

Table 13 Accidental Event Effects Assessment for the Seabird VEC

Valued Ecological Component: Seabirds									
			Evaluation Criteria for Assessing Environmental Effects						
Accidental Event Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation Options**	**Magnitude [b]**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Topside crude blowout (15,900 m³ oil/day)	Mortality (N)	Prevention; Contingency plan; Spill response protocols	1-3	6	1	2	I [a]	2
Subsurface crude blowout (4,980 m³ oil/day)	Mortality (N)	Prevention; Contingency plan; Spill response protocols	1-3	6	1	2	I [a]	2

Magnitude	Geographic Extent	Frequency	Duration	Reversibility (population level)
0 = Negligible	1 = < 1 km²	1 = < 11 events/year	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km²	2 = 11-50 events/year	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km²	3 = 51-100 events/year	3 = 13-36 months	
3 = High	4 = 101-1,000 km²	4 = 101-200 events/year	4 = 37-72 months	
	5 = 1,001-10,000 km²	5 = > 200 events/year	5 = > 72 months	
	6 = > 10,000 km²	6 = continuous		

Ecological/Socio-Cultural and Economic Context
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative anthropogenic effects

The absolute geographic extent varied by season for each scenario but both described by same criterion rating

a Effects on individuals irreversible but any population effects are likely reversible
b The definitions of magnitude ratings remain the same as presented in LGL 2008

Based on these criteria ratings, the residual effects of an accidental event on the seabird VEC during the Project is predicted to be significant (Table 14) but of low probability of occurring. Because the significant negative effect is irreversible at the individual level but reversible at the population level, the population of seabirds, a renewable resource, will be able to meet future needs of resource users.

Table 14 Significance of Predicted Residual Environmental Effects of Accidental Events on the Seabird VEC

Valued Ecological Component: Seabirds				
Project Phase/Activity	Significance of Predicted Residual Environmental Effects		Likelihood [a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Topside crude blowout ($15,900\ m^3$ oil/day)	S	3	1	2-3
Subsurface crude blowout ($4,980\ m^3$ oil/day)	S	3	1	2-3

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥4 rating)

S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

3.4 Marine Mammals and Sea Turtles

Potential interactions of an accidental event with marine mammals and sea turtles are identified in Table 15.

Table 15 Potential Interactions of Accidental Events and Marine Mammal and Sea Turtles

Valued Environmental Components: Marine Mammals, Sea Turtles		
Accidental Event Scenario	Marine Mammals	Sea Turtles
Topside crude blowout ($15,900\ m^3$ oil/day)	X	X
Subsurface crude blowout ($4,980\ m^3$ oil/day)	X	X

Most marine mammals, with the exception of fur seals, polar bears, and sea otters, are not very susceptible to oiling effects. There have been several studies on the ability of marine mammals to detect and/or avoid oil-contaminated waters, with varying results (Ackleh et al. 2012).

Seals may interact with spilled oil but are not considered to be at high risk from the effects of oil exposure. However, some evidence implicates oil spills with seal mortality, particularly young seals. As previously discussed, seals are present on or near portions of the Project Area for at least part of the year. The majority of the Project Area falls outside of the area where pack ice typically occurs. The pack ice that occurs in the proposed drilling area is distant from the primary harp seal breeding area known as the Front. It is unlikely that oil accidentally released at proposed drilling sites will reach the pack ice where harp seals breed. There is a possibility that aged oil could contact the southern edge of loose pack ice for a few weeks during years of very heavy ice conditions, but seals are much less common on the deteriorating southern extremities of the pack ice than they are farther north. Few seals are expected to be exposed to oil from an accidental release at the drilling and production sites and most seals do not exhibit large behavioural or physiological reactions to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil.

Monitoring studies of marine mammals following oil spill events in different parts of the world have demonstrated evidence implicating oil spills with the mortality of cetaceans. Following the Exxon Valdez oil spill, sea otters, harbour seals, Stellar sea lions, killer whales, and humpback whales were most affected by the spill (Lee et al. 2015). There was a low (2%) estimated carcass recovery rates of cetaceans following the Deepwater Horizon oil spill (Williams et al. 2011). This low recovery rate limits the statistical validity of proposed cause-effect relationships and illustrates the challenge to link oil exposure to acute and chronic effects in marine mammals (Lee et al. 2015).

After the Deepwater Horizon spill, 609 dead sea turtles were documented in 2010, with at least 18 of the dead turtles visibly oiled (NMFS 2011). Sea turtles are likely uncommon in the Study Area and are even less likely to occur in the proposed Project Area. Sea turtles could interact with spilled oil but there is a very low likelihood that sea turtles will be exposed to oil from an accidental release near the drilling area. Effects of oil on sea turtles will be reversible, but there is a possibility that foraging abilities may be inhibited by exposure to oil.

Effects on marine mammals and sea turtles would be low and reversible. Based on available marine mammal data and the biology of marine mammals known to occur in the area, the Project Area is not likely an exclusive feeding area or breeding area. Some species are likely present in the area year-round, but most species likely just occur there during summer months. However, there are limited available data for winter time. For marine mammals, it is likely that only small proportions of populations are at risk at any time. Population-level effects are unlikely, as no significant long-term and lethal effects from external exposure, ingestion, or bioaccumulation of oil have been demonstrated.

The residual effects of an accidental event on the marine mammal and sea turtle VEC is predicted to have negligible to low magnitude, regardless of the spill scenario. Geographic extent and duration for both the topside and subsurface blowout scenarios are predicted to be >10,000 km², and 1 to 12 months as shown in Table 16.

Table 16 Accidental Event Effects Assessment for the Marine Mammals and Sea Turtles VEC

Valued Ecological Component: Marine Mammals and Sea Turtles								
			Evaluation Criteria for Assessing Environmental Effects					
Accidental Event Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation Options**	**Magnitude [a]**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Topside crude blowout (15,900 m^3 oil/day)	Health effects (N)	Prevention; Contingency plan; Spill response protocols	0-1	6	1	2	R	2
Subsurface crude blowout (4,980 m^3 oil/day)	Health effects (N)	Prevention; Contingency plan; Spill response protocols	0-1	6	1	2	R	2

Magnitude	Geographic Extent	Frequency	Duration	Reversibility (population level)
0 = Negligible	1 = < 1 km^2	1 = < 11 events/year	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km^2	2 = 11-50 events/year	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km^2	3 = 51-100 events/year	3 = 13-36 months	
3 = High	4 = 101-1,000 km^2	4 = 101-200 events/year	4 = 37-72 months	
	5 = 1,001-10,000 km^2	5 = > 200 events/year	5 = > 72 months	
	6 = > 10,000 km^2	6 = continuous		

Ecological/Socio-Cultural and Economic Context
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative anthropogenic effects

The absolute geographic extent varied by season for each scenario but both described by same criterion rating
a The definitions of magnitude ratings remain the same as presented in LGL 2008

Based on these criteria ratings, the residual effects of an accidental event on the marine mammals and sea turtles VEC is predicted to be not significant (Table 17). The likelihood of spill event, as modelled, is very low.

Table 17 Significance of Predicted Residual Environmental Effects of Accidental Events on the Marine Mammal and Seabird VEC

Valued Ecological Component: Marine Mammals and Seabirds				
Project Phase/Activity	Significance of Predicted Residual Environmental Effects		Likelihood [a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Topside crude blowout (15,900 m^3 oil/day)	NS	3		
Subsurface crude blowout (4,980 m^3 oil/day)	NS	3		

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥3 rating) and geographic extent > 100 km^2 (≥ 4 rating)

S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

3.5 Species at Risk

3.5.1 Updated Information on Species at Risk

An updated listing of Species at Risk Act (SARA) and Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listed species for the Grand Banks area of relevance to this assessment is provided in Appendix 3.

The draft 2015 "Recovery Strategy for the Northern Wolffish and Spotted Wolffish and Management Plan for the Atlantic Wolffish" (DFO 2015) identifies critical habitat for the northern and spotted wolffish. The critical habitat identified falls within the area showing 1% to 10% probability of surface oiling where oil exposure is above a 1.0 g/m^2 threshold from a subsurface blowout and 1% to 25% probability of surface oiling at the same threshold from a topside release.

It is noted that the North Atlantic right whale does have a critical habitat statement pursuant to SARA. However, based on sightings to date, it is an infrequent visitor to the Study Area. Furthermore, the critical habitat designated for this species is located in the Grand Manan Basin in the Bay of Fundy. Similarly, the leatherback sea turtle, which can occur in the Study Area, has had potential but not formally designated critical habitat areas identified in recent years (DFO 2013). Again, these areas do not occur within the Study Area.

There is a proposed recovery strategy and management plan for the red knot, a medium-sized shorebird with a typical sandpiper profile (Environment and Climate Change Canada 2016). Newfoundland and Labrador is a stopover in the fall for the rufa subspecies, as it migrates between its breeding grounds in Arctic Canada and wintering grounds in South America.

3.5.2 Accidental Event Environmental Effects Prediction

Potential interactions of an accidental event with species at risk[1] are identified in Table 18. Species are not listed individually unless they are the only representative of a specific biota group.

Table 18 Potential Interactions of Accidental Events and Species-at-Risk that Could Occur in the Study Area

Valued Ecosystem Component: Species at Risk				
Accidental Event Scenario	**Species/Biota Group**			
	Fish	**Birds**	**Whales**	**Leatherback Sea Turtle**
Topside crude blowout (15,900 m^3 oil/day)	X	X	X	X
Subsurface crude blowout (4,980 m^3 oil/day)	X	X	X	X

Accidental events associated with the proposed exploration and appraisal / delineation drilling Project have the potential to interact with fish (white shark and three species of wolffish), seabirds (Ivory Gull), marine mammals (blue whale (Atlantic population), fin whale (Atlantic population), North Atlantic right whale, northern bottlenose whale (Scotian Shelf population) and Sowerby's beaked whale) and the leatherback sea turtle currently listed on Schedule 1 of SARA. The potential contamination effects of accidental events on the not at-risk species are described in Sections 3.1 (fish/fish habitat), 3.3 (seabirds) and 3.4 (marine mammals and sea turtles) and are relevant to species at risk.

In the unlikely event of an oil spill, species at risk could potentially interact with the spilled oil. Potential effects include a decrease in habitat quality or potential mortality through reduction of water and/or sediment quality, lethal and sub-lethal effects from acute or chronic exposure to water-soluble fractions of hydrocarbons, physical and physiological functions that may be adversely affected through direct contact, ingestion, or respiratory inhalation, and risk of mortality or physical injury to seabird species at risk through oiling of feathers.

In consideration of the present knowledge of the Jeanne d'Arc Basin and Flemish Pass, the modelling exercises, and on past monitoring experience with large spills (e.g., Exxon Valdez, Arrow, DWH, and others), as well as implementation of spill response measures, the residual environmental effects from an oil spill on marine fish species at risk and marine mammal and sea turtle species at risk are predicted to be not significant. A precautionary conclusion is drawn that the residual adverse

[1] All Species at Risk are considered and discussed together in this section, given the clear inter-relationships between these components of the environment.

environmental effect of a blowout incident is predicted to be significant for seabird species at risk, but not likely to occur.

Prevention of accidental events is the primary mitigation measure (Table 19). However, in the case of an accidental event, spill response measures will be implemented. SCL's plans for spill response are discussed in detail in its Oil Spill Response Plan- Offshore Newfoundland (OSRP-ONL), which is on file at the C-NLOPB.

The worst-case geographic extent and duration of the reversible residual effects of the accidental event scenarios on species at risk are >10,000 km² and 1 to 12 months (Table 19). With the exception of seabirds, the worst-case magnitude is negligible to low. The worst-case magnitude for seabirds is low to high. There is a very low probability (1%) of highly weathered oil reaching the nearshore / shoreline environment (50-100 days (subsurface scenario) and 100-160 days (topside scenario)) where oil exposure is above a 1.0 g/m² threshold. With the implementation of spill containment and recovery operations and shoreline protection measures, the likelihood of oil interacting with species at risk in the nearshore and shoreline environment is not likely.

Table 19 Accidental Event Effects Assessment for Species at Risk VEC

Valued Ecological Component: Species at Risk								
Accidental Event Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation Options**	**Evaluation Criteria for Assessing Environmental Effects**					
			Magnitude [a]	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Topside crude blowout (15,900 m³ oil/day)	Health effects (N); Tainting (N)	Prevention; Contingency plan; Spill response protocols	0-1 1-3 (seabirds)	6	1	2	R I [b]	2
Subsurface crude blowout (4,980 m³ oil/day)	Health effects (N); Tainting (N)	Prevention; Contingency plan; Spill response protocols	0-1 1-3 (seabirds)	6	1	2	R I [b]	2

Magnitude
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent
1 = < 1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1,000 km²
5 = 1,001-10,000 km²
6 = > 10,000 km²

Frequency
1 = < 11 events/year
2 = 11-50 events/year
3 = 51-100 events/year
4 = 101-200 events/year
5 = > 200 events/year
6 = continuous

Duration
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility (population level)
R = Reversible
I = Irreversible

Ecological/Socio-Cultural and Economic Context
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative anthropogenic effects

a The definitions of magnitude ratings remain the same as presented in LGL 2008
b Effects on seabird individuals irreversible but population effects are likely reversible

The absolute geographic extent varied by season for each scenario but both described by same criterion rating

Based on these evaluation criteria and a high level of confidence in professional judgement, the residual effects of each of the accidental event scenarios on the species at risk VEC are predicted to be not significant (Table 20).

Table 20 Significance of Predicted Residual Environmental Effects of Accidental Events on the Species at Risk VEC

Valued Ecological Component: Species at Risk				
Project Phase/Activity	Significance of Predicted Residual Environmental Effects		Likelihood [a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Topside crude blowout (15,900 m^3 oil/day)	NS (fish, marine mammals and sea turtles) S (seabirds)	3	1 (seabird)	2-3 (seabird)
Subsurface crude blowout (4,980 m^3 oil/day)	NS (fish, marine mammals and sea turtles) S (seabirds)	3	1 (seabird)	2-3 (seabird)

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥ 4 rating)

S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
1 = Low probability of occurrence
2 = Medium probability of occurrence
3 = High probability of occurrence

Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

3.6 Sensitive and Special Areas

The sensitive and special areas within the modelled extent of the oil spill scenarios and the Project Area are identified in Figure 10. Additional information on these areas is provided for in Appendix 4 and includes national, provincial and international designations. Potential interactions of an accidental event with sensitive and special areas are identified in Table 21.

Table 21 Potential Interactions of Accidental Events and Sensitive and Special Areas that Could Occur in the Study Area

Accidental Event Scenario	Sensitive and Special Areas
Topside crude blowout (15,900 m^3 oil/day)	X
Subsurface crude blowout (4,980 m^3 oil/day)	X

Several sensitive and special areas have been designated primarily for their benthic habitat types (Appendix 4). Although there may be an interaction between benthic habitat and an oil spill, the likelihood is low. As discussed in Section 3.1, in the unlikely event of an accidental spill, interactions with the benthos are anticipated to be low, with little of the total amount of released oil predicted to settle to the benthos.

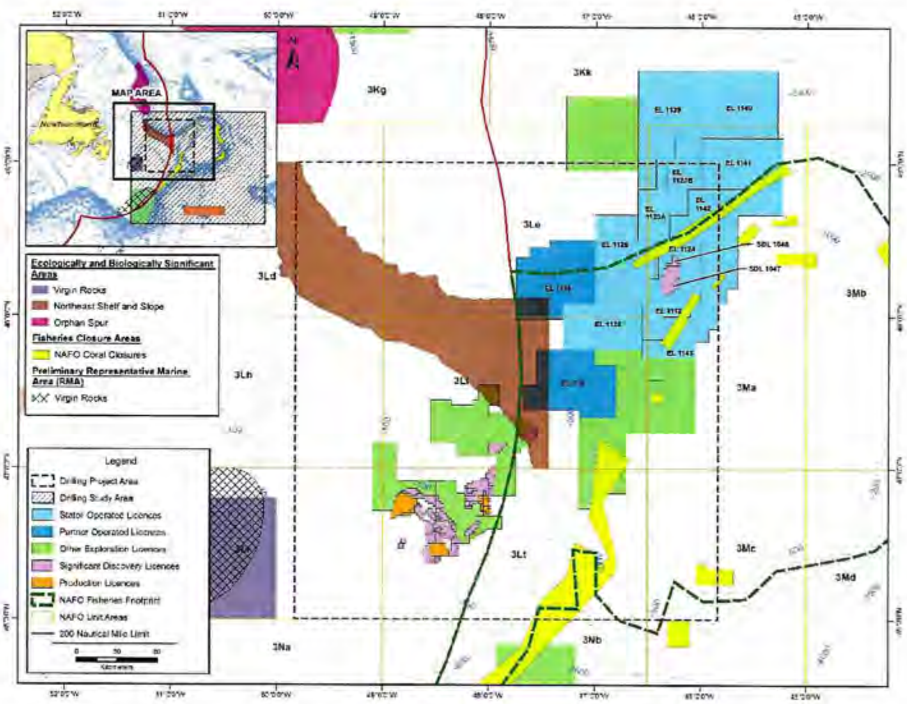


Figure 10 Sensitive Areas and Special Places in 2008 EA Project Area

Prevention of accidental events is the primary mitigation measure (Table 22). However, in the case of an accidental event, spill response measures (e.g., containment, recovery, etc.) will be implemented. SCL's plans for spill response are discussed in detail in its Oil Spill Response Plan- Offshore Newfoundland (OSRP-ONL), which is on file at the C-NLOPB.

Significant environmental effects for the Sensitive and Special Areas VC are defined as those that would cause an adverse change in one or more of the important and defining ecological and socio-cultural characteristics of such an area, resulting in a permanent decrease in its overall integrity, value or use. Updated descriptions of the potential effects of a spill on the ecological and socio-cultural characteristics of the sensitive and special areas (fish and fish habitat, commercial fisheries, seabirds, and marine mammals and sea turtles), are assessed in Sections 3.1, 3.2.2, 3.3, and 3.4, respectively. Based on the locations of the special areas, the very low probability (1%) of highly weathered oil reaching the nearshore / shoreline environment (50-100 days (subsurface scenario); 100-160 days (topside scenario)) where oil exposure is above a 1.0 g/m² threshold, and the potential effects of a spill on the ecological and socio-cultural characteristics of the sensitive and special areas, the worst-case magnitude, geographic extent, and duration of the reversible residual effects of the accidental event scenarios on special and sensitive areas are negligible to low, >10,000 km², and 1 to 12 months (Table 22). With the implementation of spill containment and recovery operations and shoreline protection measures, the likelihood of oil interacting with sensitive and special areas in the nearshore and shoreline environment is not likely.

Table 22 Accidental Event Effects Assessment for Sensitive and Special Areas

Valued Ecological Component: Sensitive and Special Areas								
			Evaluation Criteria for Assessing Environmental Effects					
Accidental Event Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Mitigation Options**	**Magnitude [a]**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Topside crude blowout (15,900 m³ oil/day)	Change in habitat (N)	Prevention; Contingency plan; Spill response protocols	0-1	6	1	2	R	2
Subsurface crude blowout (4,980 m³ oil/day)	Change in habitat (N)	Prevention; Contingency plan; Spill response protocols	0-1	6	1	2	R	2

Magnitude
0 = Negligible
1 = Low
2 = Medium
3 = High

Geographic Extent
1 = < 1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1,000 km²
5 = 1,001-10,000 km²
6 = > 10,000 km²

Frequency
1 = < 11 events/year
2 = 11-50 events/year
3 = 51-100 events/year
4 = 101-200 events/year
5 = > 200 events/year
6 = continuous

Duration
1 = < 1 month
2 = 1-12 months
3 = 13-36 months
4 = 37-72 months
5 = > 72 months

Reversibility (population level)
R = Reversible
I = Irreversible

Ecological/Socio-Cultural and Economic Context
1 = Relatively pristine area or area not negatively affected by human activity
2 = Evidence of existing negative anthropogenic effects

a The definitions of magnitude ratings remain the same as presented in LGL 2008

The absolute geographic extent varied by season for each scenario but both described by same criterion rating

Based on these evaluation criteria and a high level of confidence in professional judgement, the residual effects of each of the accidental event scenarios on the sensitive and special areas VEC are predicted to be not significant (Table 23).

Table 23 Significance of Predicted Residual Environmental Effects of Accidental Events on the Sensitive and Special Areas VEC

Valued Ecological Component: Sensitive and Special Areas				
Project Phase/Activity	Significance of Predicted Residual Environmental Effects		Likelihood [a]	
	Significance Rating	Level of Confidence	Probability of Occurrence	Scientific Certainty
Topside crude blowout (15,900 m^3 oil/day)	NS	3		
Subsurface crude blowout (4,980 m^3 oil/day)	NS	3		

Significance Rating (significance is defined as a medium or high magnitude (2 or 3 rating) and duration > 1 year (≥ 3 rating) and geographic extent > 100 km^2 (≥ 4 rating)

S = Significant negative environmental effect
NS = Not significant negative environmental effect
P = Positive environmental effect

Level of Confidence (professional judgement)
1 = Low level of confidence
2 = Medium level of confidence
3 = High level of confidence

Probability of Occurrence (professional judgement)
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Level of Scientific Certainty (based on scientific information and statistical analysis or professional judgement)
1 = Low level of scientific certainty
2 = Medium level of scientific certainty
3 = High level of scientific certainty

[a] Only considered in the event of significant (S) residual effect

Based on these evaluation criteria and a high level of confidence in professional judgement, the residual effects of each of the accidental event scenarios on the sensitive and special areas VEC are predicted to be not significant (Table 23).

4 Concluding Statement

The releases modelled in this study are considered representative of other potential releases in the Project Area. Potential releases from shallower locations may result in more rapid surfacing of released subsurface oil, slightly more evaporation and less dissolution. While the NFP release location is slightly outside of the 2008 EA Project Area, the currents and winds that occur at this location are similar to those found within. In general, the boundary set up by the Labrador Current and the Gulf Stream has the potential to result in dynamic currents, however general flow would be towards the east. Due to the proximity of land, should there be a release in the western-most region of the Project Area, there may be a higher potential for surface oil to make contact with the shoreline. However, the overall probability would likely still be considered low, as was predicted in the previous modelling (SL Ross 2008).

With the assessment of additional spill trajectory modelling results, the environmental effects predicted in the previously approved environmental assessment for accidental events remain valid.

SCL reaffirms its commitment to implement the mitigation measures proposed in the original 2008 EA Report, and in the 2008 C-NLOPB Environmental Assessment Screening Decision.

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APPENDICES

Appendix 1 – RPS ASA Trajectory Modelling in Support of Statoil Exploration Drilling at the Northern Flemish Pass Site

Trajectory Modelling in Support of Statoil Exploration Drilling at the Northern Flemish Pass Site

Prepared for: Statoil

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Draft	Statoil - RPS ASA Technical Report_NFP_20170331.docx	3/31/2017	Partial DRAFT version of report for Statoil review
Draft	Statoil - RPS ASA Technical Report_NFP_20170330.docx	3/30/2017	Partial DRAFT version of report
Draft	Statoil – RPS ASA Technical Report_NFP_20170329.docx	3/29/2017	Partial DRAFT version of report

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List of Acronyms and Abbreviations

AL: Aliphatic portion of the total hydrocarbon, which is modelled as a volatile fraction within the SIMAP model and can therefore evaporate.
AR: Aromatic portion of the total hydrocarbon, which is modelled as a volatile and soluble fraction within the SIMAP model and can therefore evaporate and dissolve.
BTEX: Benzene, toluene, ethylbenzene, and xylene
CERC: Coastal Engineering Research Center
CERCLA: The U.S. Superfund or Comprehensive Environmental Response, Compensation, and Liability Act of 1980
ESI: NOAA Environmental Sensitivity Index
ESMF: Earth System Modelling Framework
ESTC: Environment Canada Environment Science and Technology Center
EVI: Maine Department of Environmental Protection Environmental Vulnerability Index
GEBCO: The General Bathymetric Chart of the Oceans operated by the International Hydrographic Organization (IHO) and Intergovernmental Oceanographic Commission (IOC) of UNESCO.
GOR: Gas to Oil Ratio
HYCOM: The U.S. Navy HYbrid Coordinate Ocean Model used for currents
MAH: Monocyclic aromatic hydrocarbons (monoaromatic), with only one six carbon ring
NBDNR: Canada's New Brunswick Department of Natural Resources
NOAA: U.S. National Oceanic and Atmospheric Administration
NODC: U.S. National Ocean Data Collection Center of NOAA
NOGAPS: U.S. Navy Operational Global Atmospheric Prediction System for winds
NRC: U.S. National Research Council
NRDA: The U.S. Natural Resource Damage Assessment
NRDAM/CME: Natural Resource Damage Assessment Model for Coastal and Marine Environments
NRL: U.S. Naval Research Laboratory
NSDNR: Canada's Nova Scotia Department of Natural Resources
PAH: Polycyclic (polyaromatic) aromatic hydrocarbons, with two or more six carbon rings
SIMAP: Spill Impact Model Application Package, a 3D trajectory and fate model
THC: Total hydrocarbons
UNESCO: United Nations Educational, Scientific, and Cultural Organization
WOA: World Ocean Atlas, a database from NODC NOAA containing observational data of physical and chemical parameters of seawater from many thousands of cruises.

1 Introduction

RPS (dba Applied Science Associates, Inc.) conducted trajectory and fate modelling in support of Statoil Canada Ltd.'s Flemish Pass area drilling environmental assessment. This report provides trajectory and fate results for unmitigated subsurface blowouts and topside releases, with comparisons to results presented previously in the original environmental assessment (LGL 2008). The modelling reported herein involves hypothetical releases of Bay du Nord (BdN) crude oil at a site located in the Northern Flemish Pass (NFP), located approximately 500 km east of the Newfoundland coast, northeast of the Grand Banks, and north of the Flemish Cap (Figure 2-1). The water depth at the NFP release location is 2,700 m. Major currents, including the Labrador Current and the Gulf Stream, influence the circulation and biological productivity in this region.

This modelling was conducted to evaluate possible release events associated with exploration drilling, including a subsurface blowout and a topside release. Three-dimensional oil spill trajectory and fate modelling and analyses were performed to support evaluation of the potential effects that releases of oil may have in the Atlantic Ocean near Newfoundland. RPS's nearfield OILMAPDeep blowout model and the farfield Spill Impact Model Application Package (SIMAP) trajectory, fate, and effects models were used. This report provides a brief description of the study area and modelled scenarios, an overview of the modelling approach, details about the model input data used, and a presentation and discussion of the modelled results.

2 Background and Modelling

2.1 Study Area and Scenarios

Newfoundland comprises a series of islands off the east coast of Canada, and along with Labrador forms the easternmost Canadian province. The relatively shallow waters of the continental shelf extend eastward up to 500 km from the Newfoundland coast. Known as the Grand Banks, this area contains substantial petroleum resources. The project study area (46-49 °N, 45.5-49.5 °W) encompasses the Grand Banks and Flemish Cap, which are located in the northwest sector of the Jeanne d'Arc sedimentary rift basin, east of Newfoundland in the Atlantic Ocean. These biologically productive regions sit atop the Hibernia, White Rose, and Terra Nova oil fields. The model domain (i.e., extent of study area) extends as far west as 72° W and east to 28°W, encompassing Canadian, U.S., and International waters (Figure 2-1).

A single release location was chosen for modelling at the NFP site (Table 2-1). Subsurface blowouts near the sea floor and topside releases were modelled separately in a stochastic analysis, which investigated the effects of environmental variability, throughout the year over multiple years, on trajectory and fate.

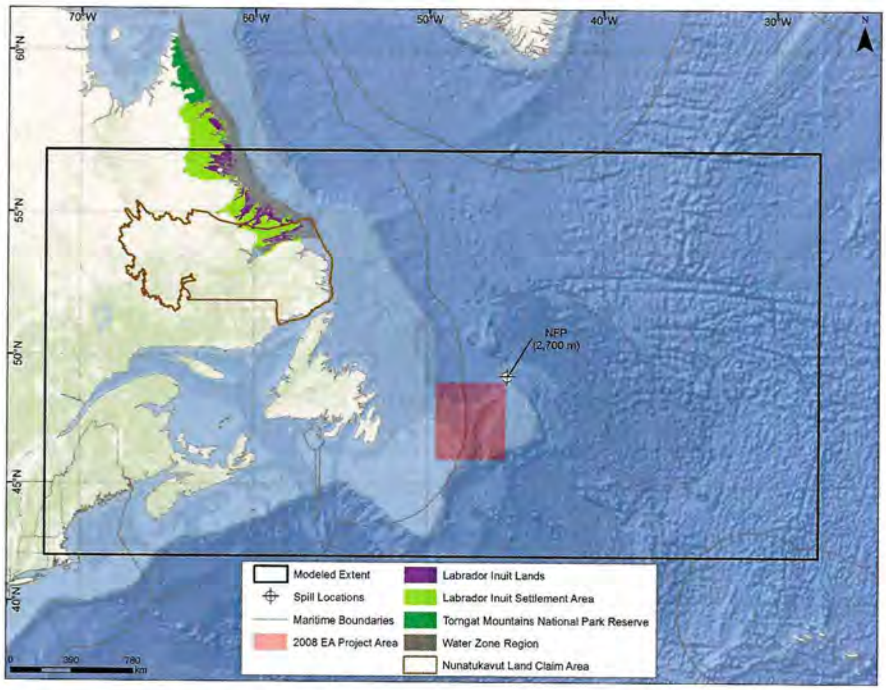


Figure 2-1: Study area, including the hypothetical release location (NFP) and water depth. The black bounding box represents the modelling extent, while the smaller box represents the Statoil Project Area.

Table 2-1: Hypothetical NFP release location and stochastic scenario information.

NFP Scenario Parameters	Subsurface Blowout	Topside Blowout
Block	EL1140	
Latitude	49° 13' 43.764"	
Longitude	45° 25' 5.054"	
Product	Bay du Nord crude oil	
Release Duration	36 d	
Model Duration	160 d	
Number of Stochastic Runs	119 annual (55 winter & 64 summer)	
Water Depth of Release	2,700 m	Surface (0 m)
Gas to Oil Ratio	45.9 m^3/m^3	N/A
Pipe Diameter	31.1 cm	N/A
Oil Discharge Temperature	80°C	N/A
Release Rate	4,980 Sm^3/d	15,900 Sm^3/d
Total Release Volume	179,280 Sm^3	572,400 Sm^3

2.2 Overall Modelling Approach

This modelling study employed a stochastic approach to determine the potential trajectory and fate of hypothetical hydrocarbon releases. Stochastic modelling provides a probabilistic view of the likelihood that a given region might experience effects from released hydrocarbons over many possible environmental conditions occurring within and across multiple years.

2.2.1 Modelling Tools

Hypothetical release scenarios were simulated using the OILMAPDeep and SIMAP modelling packages, two three-dimensional trajectory and fate models developed by RPS. OILMAPDeep was used to define the near-field dynamics of the subsurface blowout plume, which was then used as the initial conditions for the far-field modelling conducted in SIMAP. These near-field plume dynamics include the location and size of the subsurface plume at the termination (i.e., trap) height and the characterization of the oil droplet size distribution. Typically, the near-field model is on the timescale of seconds and length scale of hundreds of meters, whereas the far-field model is on the scales of hours/days and many kilometers.

OILMAPDeep Model

The OILMAPDeep model incorporates the basic dynamics of a subsurface oil and gas plume and the complexities of increased hydrostatic pressure at depths deeper than 200 m. It contains two sub-models, a plume model and a droplet size model. The plume model predicts the evolution of plume position, geometry, centerline velocity, and oil and gas concentrations until the plume either surfaces or reaches a terminal height, at which point the plume is trapped. The jet created by the blowout is modelled by considering the momentum of the oil discharge, the density difference between the expanding gas bubbles in the plume and the receiving water, the entrainment of water into the plume, the mixing by turbulence within the plume, hydrate formation, and transport by local ambient currents. The droplet model predicts the size and volume (mass) distribution of the oil droplets in the release, which influences fates processes such as oil rise velocity and dissolution (i.e., droplet size distribution).

For oil discharged during a deep-water blowout, the oil droplet size distribution has a profound effect on how oil is transported after the initial release as a buoyant plume. The size of the individual droplets dictates buoyancy, which controls the length of time that oil will remain within the water column. Large droplets surface faster than small ones, thus large droplets more quickly generate a floating oil slick transported by winds and surface currents. Small droplets remain in the water column longer than large droplets and are subjected to subsurface advection-diffusion and transport for a longer period of time. As oil is transported by subsurface currents away from the release location, natural dispersion of the oil droplets quickly reduces concentrations in the water column. However, the lower rise velocities of the smaller oil droplets correspond to longer residence times of oil suspended in the water column, which can increase dissolution of soluble components and result in larger volumes of water being affected.

SIMAP Model

The SIMAP modelling system originated from the oil fates and biological effects sub-models within the Natural Resource Damage Assessment Models for Coastal and Marine Environments (NRDAM/CME). RPS developed the NRDAM/CME in the early 1990s for the U.S. Department of the Interior for use in "type A" Natural Resource Damage Assessment (NRDA) regulations under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). The most recent version of the type A models, the NRDAM/CME (Version 2.4, April 1996) was published as part of the CERCLA type A NRDA Final Rule (Federal Register, May 7, 1996, Vol. 61, No. 89, p. 20559-20614). The technical documentation for the NRDAM/CME is in French et al. (1996). While the NRDAM/CME was developed for simplified NRDAs of small spills in the U.S., SIMAP was further developed to evaluate fate and effects of both real and hypothetical spills in marine, estuarine, and freshwater environments worldwide. Additions and modifications to SIMAP include increasing model resolution, allowing site-specific input data, incorporating spatially and temporally varying current data, evaluating subsurface releases and movements of subsurface oil, tracking multiple chemical components of the oil, enabling stochastic modelling, and facilitating analysis of results.

The three-dimensional physical fates model estimates the distribution of whole oil and oil components on the water surface, on shorelines, in the water column, and in sediments as both mass and concentration. Because oil contains many chemicals with varying physical and chemical properties, and the environment is spatially and temporally variable, the oil rapidly separates into different environmental compartments through multiple fates processes. Oil fate processes included in SIMAP are oil spreading (gravitational and by shearing), evaporation, transport, randomized dispersion, emulsification, entrainment (natural and facilitated by dispersant), dissolution, volatilization of dissolved hydrocarbons from the surface water, adherence of oil droplets to suspended sediments, adsorption of soluble and sparingly-soluble aromatics to suspended sediments, sedimentation, and degradation. Oil trajectory and weathering endpoints include surface oil, emulsified oil (mouse), tar balls, suspended oil droplets, oil adhered to particulate matter, dissolved lower molecular weight compounds in the water column and pore water, and oil on and in bottom sediments and shoreline surfaces.

2.2.2 Stochastic Approach

A stochastic approach was used in SIMAP to determine the potential footprint of areas that may be affected by a release of oil based upon variability in meteorological and hydrodynamic conditions. A stochastic scenario is a statistical analysis of tens to hundreds of individual trajectories resulting from the same release event, with each trajectory starting at a randomized time from a relatively long-term window. The stochastic approach analyzes the same type of release under varying environmental conditions to provide the anticipated variability in probable movement and behavior of the release. In order to reproduce the natural variability of winds and currents, the model requires both spatially- and temporally-varying datasets (e.g., hourly to daily time scales) spanning at least five years. A sufficient number of model runs will adequately sample the variability in wind and current speed and direction in the region of interest, and will result in a prediction of the many possible oil pathways for a release at the prescribed location.

In a stochastic analysis, multiple model runs (10's to 100's of releases) are laid upon one another to create a cumulative footprint of releases. Further analyses provide two types of information for specific thresholds of interest including: 1) the probability that a given area may experience contamination, and 2) the shortest amount of time required for oil to reach any point within the predicted area. To analyze the probability or likelihood of potential effects, specific thresholds for surface oil thickness and shoreline oiling are used (Table 2-2). Figures and further analyses in this study include the lower socioeconomic thresholds of concern calculated from stochastic results.

Table 2-2: Stochastic thresholds used to define regions with potential effects.

Stochastic Threshold	Cutoff Threshold	Rationale
Surface Oil Thickness	*0.04 μm	Visible threshold used to determine impacts on socioeconomic resources (e.g., possibility of fisheries closure). This minimum thickness would relate to a slick being barely visible as a colorless or silver sheen (Lewis 2007; Bonn Agreement).
	10 μm	Biological threshold for ecological impacts to organisms using the water surface (e.g., birds) (French et al. 1996; French McCay 2009). Oil appears dark brown.
Shoreline Oil Mass	*1 g/m^2	The threshold for potential effects on socio-economic resource uses, as this amount of oil would conservatively trigger the need for shoreline cleanup on amenity beaches. Oil would appear as a dull brown sheen (Lewis 2007; Bonn Agreement).
	100 g/m^2	A conservative screening threshold for potential ecological effects to shoreline habitats, which has typically been 100 g/m^2, based on a literature synthesis showing shoreline effects at this degree of oiling (French et al. 1996; French McCay 2009). The oil appears as a dark brown coat or opaque/black oil.

*Thresholds used in supporting figures. For comparison, a bacterium is 1-10 μm, a strand of spider web silk is 3-8 μm, and paper is 70-80 μm. 1 g/m^2 is roughly equivalent to 1 μm.

2.3 Model Uncertainty and Validation

The SIMAP model has been developed over many years to include as much information as possible to simulate the trajectory, fate, and effects of oil spills. However, there are limits to the complexity of processes that can be modelled, as well as gaps in knowledge regarding the affected environment. Assumptions based on available scientific information and professional judgment were made in the development of the model, which represent a best assessment of the processes and potential mechanisms for effects that could result from oil spills.

The major sources of uncertainty in the oil fates effects models are:

- Oil contains thousands of chemicals with differing physical and chemical properties that determine their fate in the environment. The model must of necessity treat the oil as a mixture of a limited number of components, grouping chemicals by physical and chemical properties.
- The fates model contains a series of algorithms that are simplifications of complex physical-chemical processes. These processes are understood to varying degrees.
- The model treats each spill as an isolated, singular event and does not account for any potential cumulative effects.
- A number of physical parameters including but not limited to hydrodynamics, water depth, total suspended solids concentration, and wind speed were not sampled extensively throughout the entire modelled domain. However, the data that did exist was sufficient for this type of modelling. When data was lacking, professional judgment and previous experience was used to refine the model inputs.

In the unlikely event of an actual oil spill, the trajectory, fate, and effects will be strongly determined by the specific environmental conditions, the precise locations and types of organisms present, and a myriad of details related to the event and specific timeframe. Modelled results are a function of the scenarios simulated and the accuracy of the input data used. The goal of this study was not to forecast every detail that could potentially occur, but to describe a range of possible consequences and effects of oil spills under various representative scenarios.

3 Model Input Data

3.1 Oil Characterization

A Bay du Nord crude oil was modelled in this study. BdN is a light crude oil with low viscosity and a high aromatic content (Table 3-1 & Table 3-2). The low viscosity and high aromatic content of the BdN provides a conservative approximation of anticipated effects within the water column, as a larger proportion of constituents has the potential to dissolve. The physical and chemical data used to specify this oil was provided by Statoil, with additional assays and measurements by SL Ross and Intertek (SL Ross 2016; Intertek 2016). The physical and chemical parameters of BdN are similar to those of Hibernia crude oil, which was used in previous studies (SL Ross 2016; ESTC 2001) as identified in Statoil's response to the C-NLOPB (Statoil 2016). These two oils would likely behave similarly in a release event. The "pseudo-component" approach is used to simplify oils for use in SIMAP. Chemicals in the oil mixture are grouped by physical-chemical properties, and the resulting component category behaves as if it were a single chemical with characteristics typical of the chemical group. In this component breakdown, aromatic (AR) groups are both soluble (i.e., dissolve into the water column) and volatile (i.e., evaporate to the atmosphere), while the aliphatic (AL) groups are only volatile. The total hydrocarbon concentration (THC) within a boiling range is the sum of AR+AL. Residual oil is considered relatively inert, but will decay over time.

Table 3-1: Physical properties for the oil product used in modelling.

Physical Property	Bay du Nord crude oil
Density (g/cm^3)	0.84553 @16°C 0.85800 @0°C
Viscosity (cP)	5.0 @20°C 53.0 @0°C
API Gravity	35.850
Pour Point (°C)	-9
Interface Tension (dyne/cm)	15.5
Emulsion Maximum Water Content (%)	72

Table 3-2: Fraction of the whole oil comprised of different distillation cuts for Bay du Nord crude oil. Numbers of carbons (C#) in the included compounds are listed.

Distillation Cut	Boiling Point (°C)	Description	Fraction of Bay du Nord Crude Oil
AR1	< 180	highly volatile and soluble monoaromatic hydrocarbons (BTEX and MAHs; C9-C10)	0.023739
AR2	180 – 264	semi-volatile and soluble 2-ring aromatics (MAHs and PAHs; C11-C12)	0.004166
AR3	265 – 380	low volatility and solubility 3-ring aromatics (PAHs; C13-C16)	0.066998
AL1	< 180	highly volatile aliphatics (C4-C10)	0.206261
AL2	180 – 264	semi-volatile aliphatics (C10-C15)	0.160834
AL3	265 – 380	low volatility aliphatics (C15-C20)	0.168002
Residuals	> 380	aromatics ≥ 4 rings and aliphatics > C20 that are neither volatile nor soluble	0.37000

3.2 Environmental Data

3.2.1 Habitat, Shoreline, and Bathymetry

For geographical reference, SIMAP uses a rectilinear grid to designate the location of the shoreline, the water depth (bathymetry), bottom roughness, and the shore or habitat type (e.g., bottom type and vegetation found in subtidal areas, areas of extensive mud flats and wetlands) (Figure 3-1). Grid cells are coded based upon digital shoreline and other geographic and environmental data sources (Table 3-3).

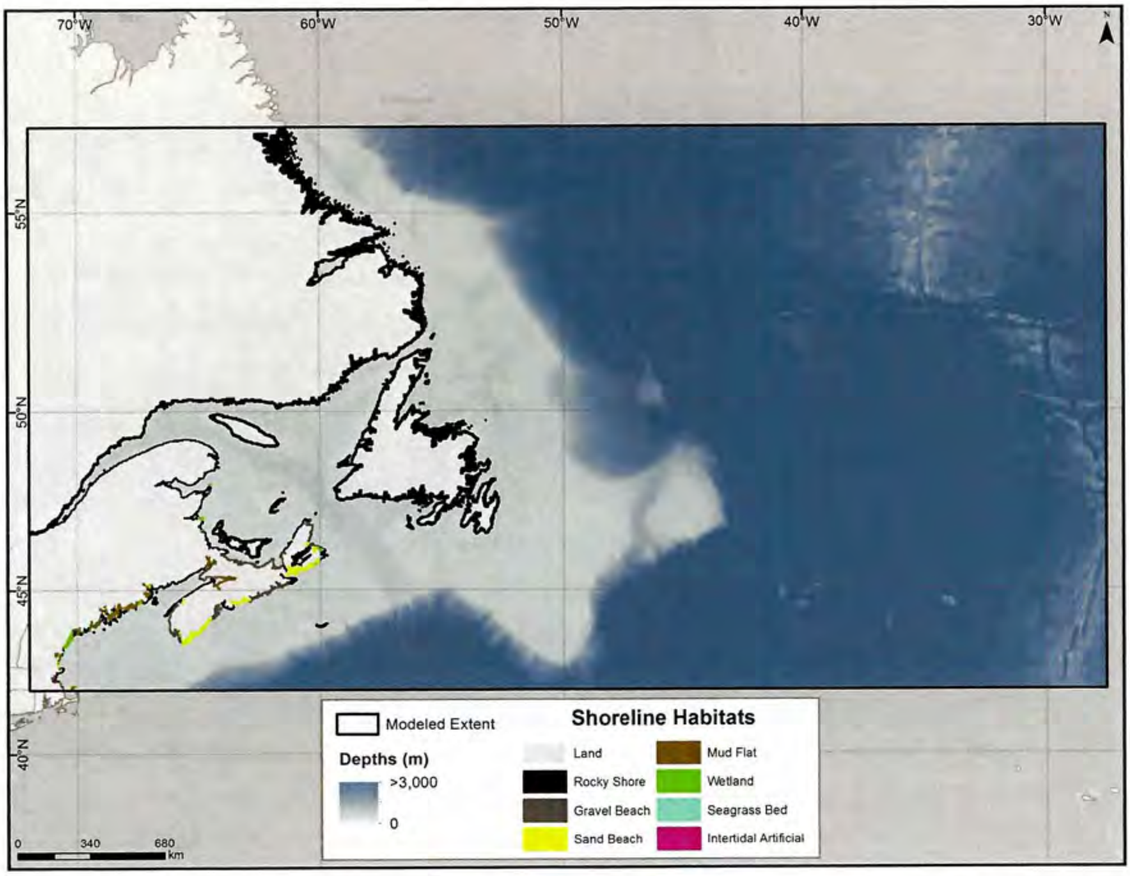


Figure 3-1: Data used to prepare the study area habitat and depth grids. Black box represents modelling extent.

Table 3-3: Sources for habitat, shoreline, and bathymetry data.

Data Type	Data Source	Geographic Location	Reference
shoreline	Fisheries and Oceans Canada Shoreline Classifications	Canada	Greenlaw et al. 2013
habitat	New Brunswick Department of Natural Resources	New Brunswick Wetlands	SNB 2010
habitat	Nova Scotia Department of Natural Resources	Nova Scotia Wetlands	NSDNR 2015
habitat	National Oceanic and Atmospheric Administration Environmental Sensitivity Index	United States (except Maine)	NOAA 2016
habitat	Maine Environmental Vulnerability Index	United States - Maine	MDEP 2016
bathymetry	General Bathymetric Chart of the Oceans Digital Atlas	global	GEBCO 2003

3.2.2 Currents & Winds

For this study, regional currents were obtained from a hindcast re-analysis using inputs from the HYCOM 1/12 degree global simulation assimilated with Navy Coupled Ocean Data Assimilation data from the U.S. Naval Research Laboratory (Halliwell 2002; HYCOM 2016). Daily data were obtained for the period January 2006 through December 2010 for the North Atlantic region. The variability in winds and currents would therefore sample daily, weekly, seasonal, and inter-annual variability, which included calm periods, seasonal storms, and the full range of environmental forcing over the entire five years. While this subset of data is not the most recent five years of data, currents and winds in the study area are very similar to those from 5-10 years ago and the data used in this study would be representative of environmental conditions present today. Surface forcing is derived from 1-hourly CFSR wind data with a horizontal resolution of 0.3125° and induces wind stress, wind speed, heat flux, and precipitation and bathymetry is derived from the GEBCO dataset (HYCOM 2016).

Wind data for this study were obtained from the National Centers for Environmental Prediction Climate Forecast System Reanalysis (CFSR) product for 2006 through 2010. The CFSR was designed and executed as a global, high-resolution, coupled atmosphere-ocean-land surface-sea ice system to provide the best estimate of the state of these coupled domains (Saha et al. 2010). The CFSR includes coupling of atmosphere and ocean and assimilation of satellite radiances. The CFSR global atmospheric resolution is ~38 km, with 64 vertical levels extending from the surface to 0.26 hPa. The CFSR time series acquired for this study is available at 0.5 degree horizontal resolution at 6-hourly intervals. CFSR winds were included as one of the main driving forces in the HYCOM current dataset.

3.2.3 Water Temperature & Salinity

Temperature and salinity values throughout the water column influence a number of oil transport and fate calculations. Temperature and salinity data have been obtained from the World Ocean Atlas 2013 high-resolution dataset, Version 2, which is compiled and maintained by the U.S. National Oceanographic Data Center (WOA; Levitus et al. 2014). The WOA originated from the Climatological Atlas of the World Ocean (Levitus 1982) and was updated with new data records in 1994, 1998, 2001 (Conkright et al. 2001), and 2013. These data records consist of observations obtained from various global data management projects. The dataset includes up to 57 depth bins from the sea surface to the seabed and include averaged yearly, seasonally, and monthly data over a global grid with a 1/4 degree horizontal resolution.

3.2.4 Ice Cover

Under winter conditions, snow and ice cover can greatly affect the transport and fate of oil. Ice cover could limit or prevents evaporation of oil and could also result in substantially greater dissolution of hydrocarbons into the water column. Ice cover also reduces surface mixing, emulsification, and entrainment as wind and wave energy are reduced. Coverage above approximately 30% begins to affect the movement of surface oil. If oil is released under ice, the potential for adverse environmental effects in the aquatic environment can be greater than during open water conditions, due to the "capping" effect of the ice, which may reduce or prevent evaporative losses.

Ice data was obtained from the Canadian Ice Service (ECCC 2017) in weekly files from 2006 to 2010. Polygon data with information on total ice concentration and stage of development were downloaded. For each ice polygon, concentration codes were converted to concentration percentages. Average thickness of ice was calculated based on the stages of ice present. The resolution of ice data was formatted to match the habitat grid (0.0225 degrees).

4 Model Results

The results from both the subsurface blowouts and topside releases from the NFP release location presented below illustrate the spatial extent of the water surface and shoreline oil contamination. Stochastic Results include:

- The probability footprints for surface oil in excess of 0.04 µm;
- The corresponding minimum time for surface oil to exceed a threshold of 0.04 µm;
- The probability footprints of shoreline oil in excess of 1 g/m^2; and
- The corresponding minimum time for surface oil to exceed a threshold of 1 g/m^2.

The probabilities of oiling were based on a statistical analysis of the ensemble of individual trajectories modelled for each release scenario. The fundamental assumption for this modelling was that a release did occur. Therefore, probability contours should be interpreted as "In the unlikely event of a release, the probability that any one specific area may experience contamination above a given threshold is X%". Stochastic figures do not imply that the entire contoured area would be covered with oil in the event of a single release, nor do they provide any information on the quantity of oil in a given area. Additionally, these figures do not provide the likelihood of a blowout occurring in any given year. Rather, these stochastic figures denote the probability of oil exceeding socioeconomic effects thresholds over all stochastic runs (each individual modelled release), at all modelled time steps (over 160 days), and for each point within the modelled domain. Note that only probabilities of ≥1% were included in the map output.

The minimum time footprints correspond with the associated probability of oiling map. Each figure illustrates the shortest amount of time required (from the initial release) for each point within the footprint to exceed the defined threshold. The time reported is the minimum value for each point from the entire ensemble of trajectories. Together, probability and minimum time figures can be interpreted together to read: "There is X% probability that oil is predicted to exceed the identified threshold at a specific location, and this exceedance can occur in as little as Y days". The Exclusive Economic Zone (EEZ) for Canada and the U.S., as well as the international border, are depicted on each map to provide context in regards to the spatial extent and potentially affected territorial waters from any potential release (VLIZ, 2014). Figures for subsurface blowouts and topside releases are provided in Sections 4.1 and 4.2, respectively.

As mentioned above, stochastic analyses include many tens to hundreds of individual modelled releases. This study included modelling 119 individual releases for 160-days over the course of 5 years (i.e., included five Januaries, five Februaries, etc.). The same set of 119 randomized start dates were used for both the topside release and subsurface blowout. Ice cover is known to affect the trajectory and fate of oil releases. Individual model runs were therefore separated into two groups based upon the specific time periods modelled that included ice cover or ice-free conditions. Statistics for all 119 releases are referred to as "annual," as they include all releases in any month over the course of an entire year. Ice cover in the region is present from November through April, while May through October is mostly ice free. Modelled releases that have the majority of their modelled days (≥81 of the 160-day modelled duration) experiencing mostly ice free periods are referred to as "summer" analyses (64 modelled release), while those that have a majority of days experiencing periods with ice cover are referred to as "winter" analyses (55 modelled releases). Ice cover never extended out to the release location, however was present along much of the coastline. Note that predicted percentage exceedance in the following results figures are dependent on the total number of releases investigated in each seasonal subset. Therefore, while only 1 scenario may be required to exceed the 1% threshold for visualization in summer and winter scenarios, 2 scenarios would be required to exceed the very same threshold in the annual analysis, due to more modelled releases in the annual set.

Two mass balance plots have been provided for a single representative 36-day topside release scenario to depict the general weathering trends (focusing on evaporation) of BdN crude oil (Figure 4-1). Results are presented over two time scales including 0-30 days and 0-160 days within the simulation to illustrate the amount of time over which the lighter fractions of BdN crude oil on the water surface evaporate into the atmosphere. Approximately 37% of surface oil evaporates in the first 2 days and evaporation rates rapidly decline after that point. By 48 days, only 12 days following the modelled the end of flow rate, approximately 45% of the total released mass of BdN crude oil is predicted to evaporate. Two oil mass balances illustrate the time history of oil at 30 days and at the end of the 160-day simulation demonstrating a consistent amount of evaporation (42-46%), a decrease in water column contamination, an increase in the amount decayed, and approximately 11% of the oil leaving the modelled domain (Table 4-1).

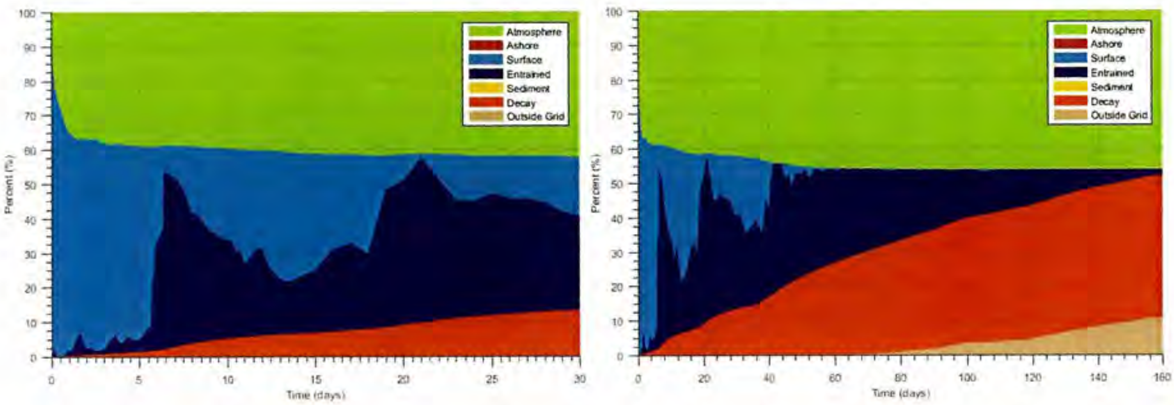


Figure 4-1: Mass balance for a single representative topside release scenario over days 0 – 30 (top) and days 0 – 160 (bottom). Note the flow of fresh oil ceases on day 36.

Table 4-1: Oil mass balance, given in percent of the total release volume, at 30 days and at the end of the 160-day simulation.

Timeframe	Surface	Evaporated	Water column	Ashore	Decayed	Outside Grid
30 days	17%	42%	27%	0%	13%	0%
160 days	0%	46%	2%	0%	41%	11%

4.1 NFP Subsurface Blowouts

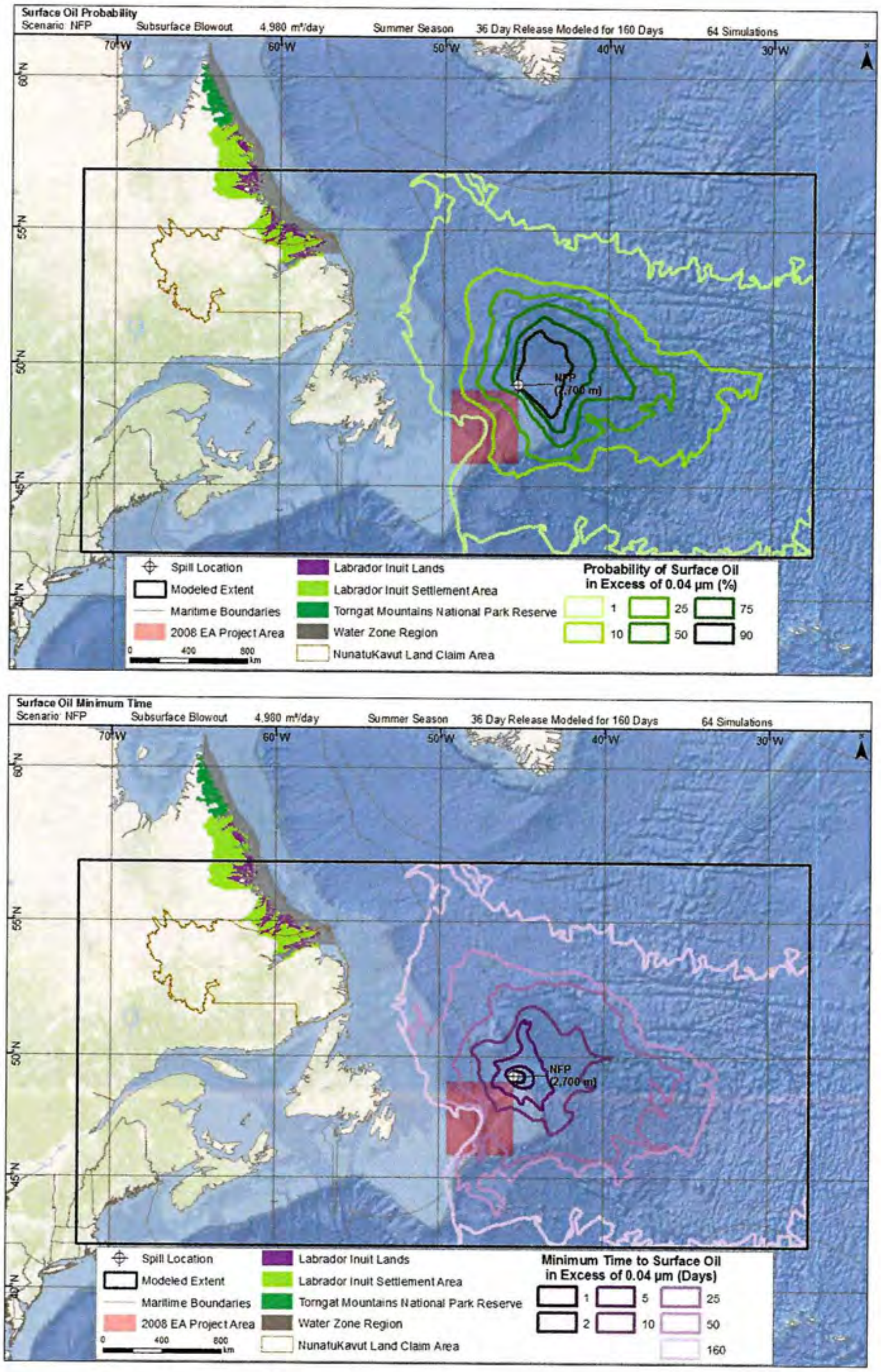
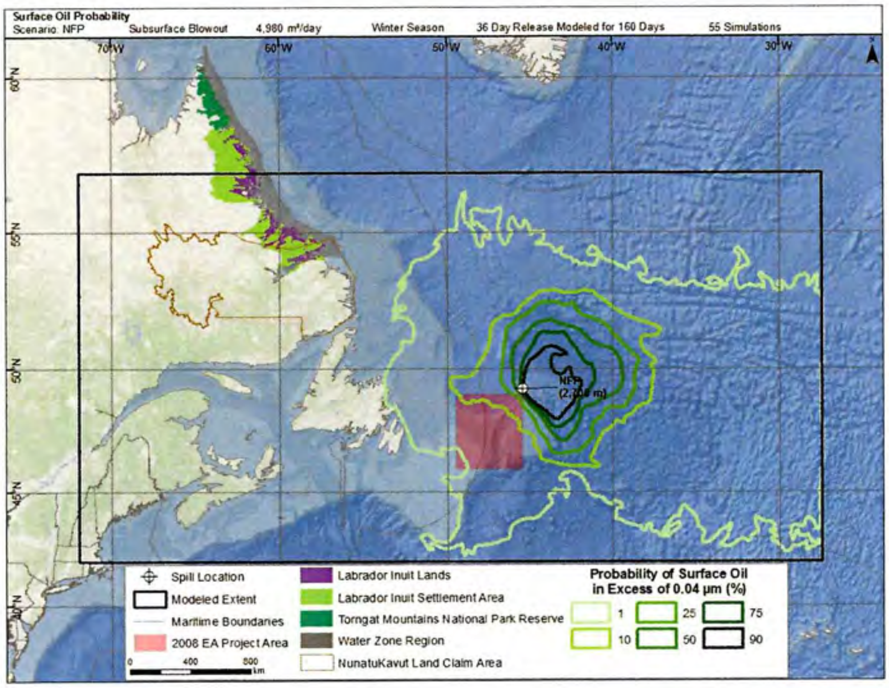


Figure 4-2: Summer surface oiling probability above 0.04 µm thickness (top) and minimum time in days for threshold exceedance (bottom) for 64 modelled subsurface blowouts of Bay du Nord crude oil.



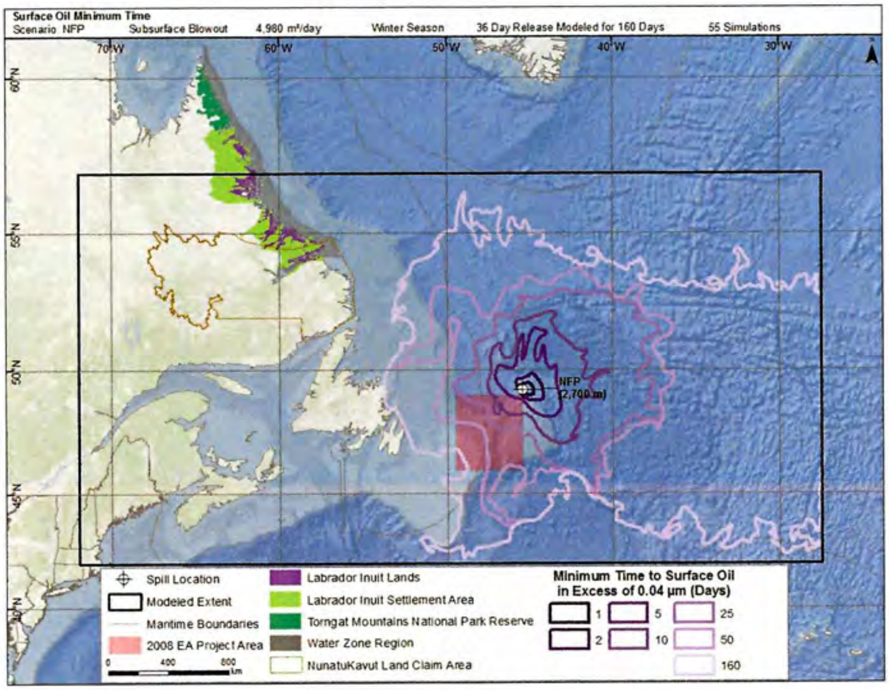


Figure 4-3: Winter surface oiling probability above 0.04 µm thickness (top) and minimum time in days for threshold exceedance (bottom) for 55 modelled subsurface blowouts of Bay du Nord crude oil.

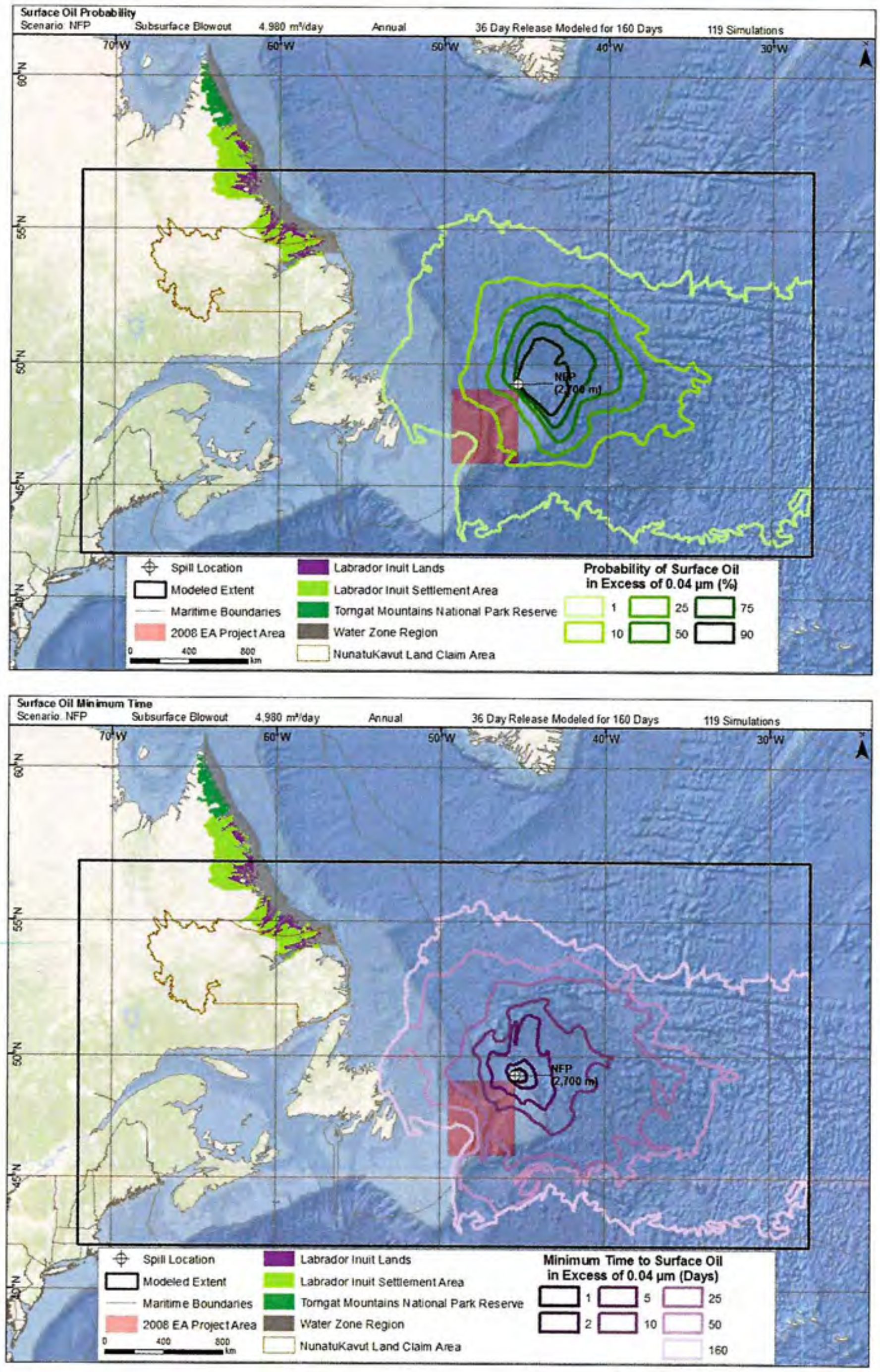


Figure 4-4: Annual surface oiling probability above 0.04 µm thickness (top) and minimum time in days for threshold exceedance (bottom) for 119 modelled subsurface releases of Bay du Nord crude oil.

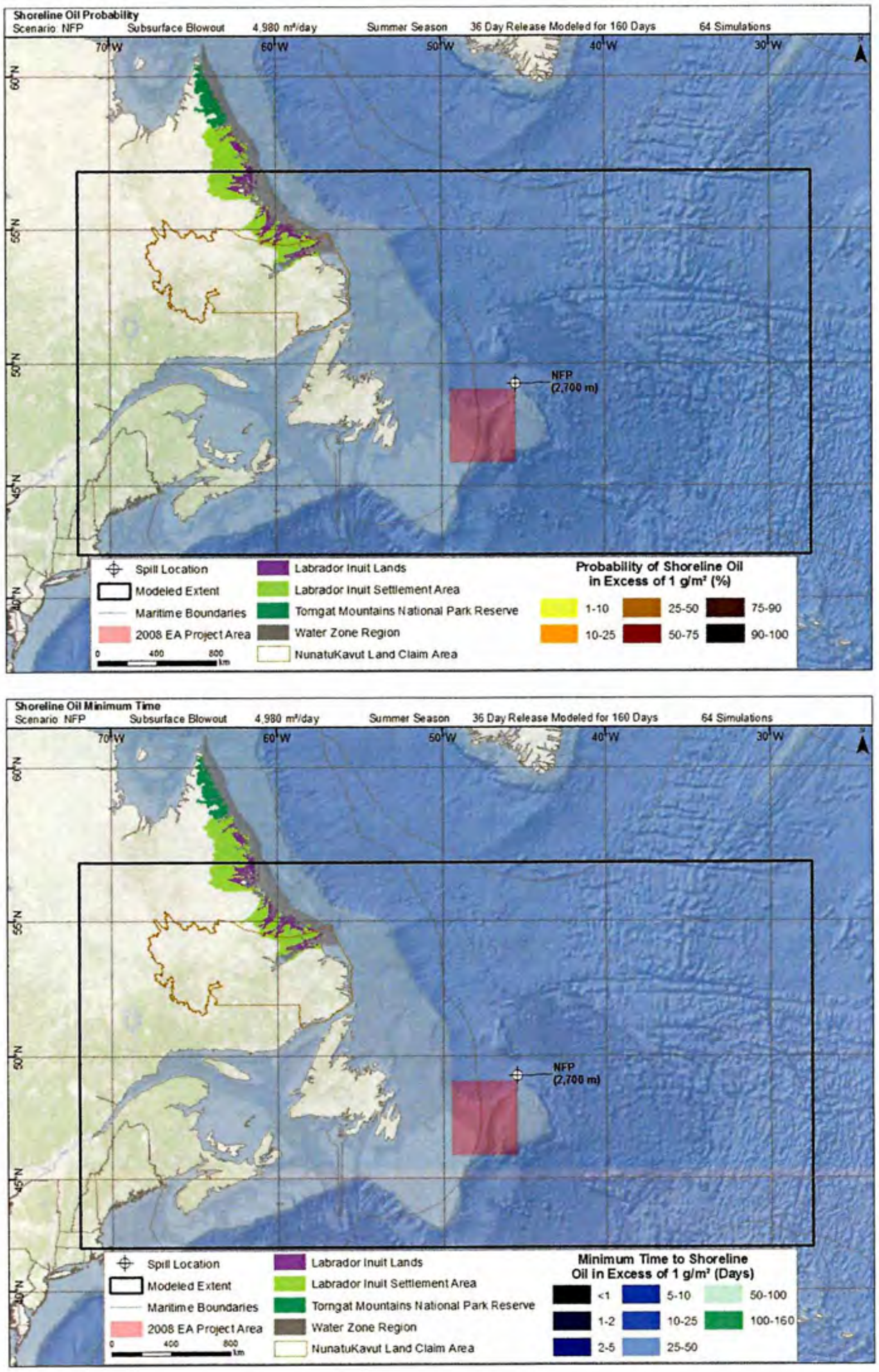


Figure 4-5: Summer shoreline oiling probability above 1 g/m^2 (top) and minimum time in days for threshold exceedance (bottom) for 64 modelled subsurface blowouts of Bay du Nord crude oil.

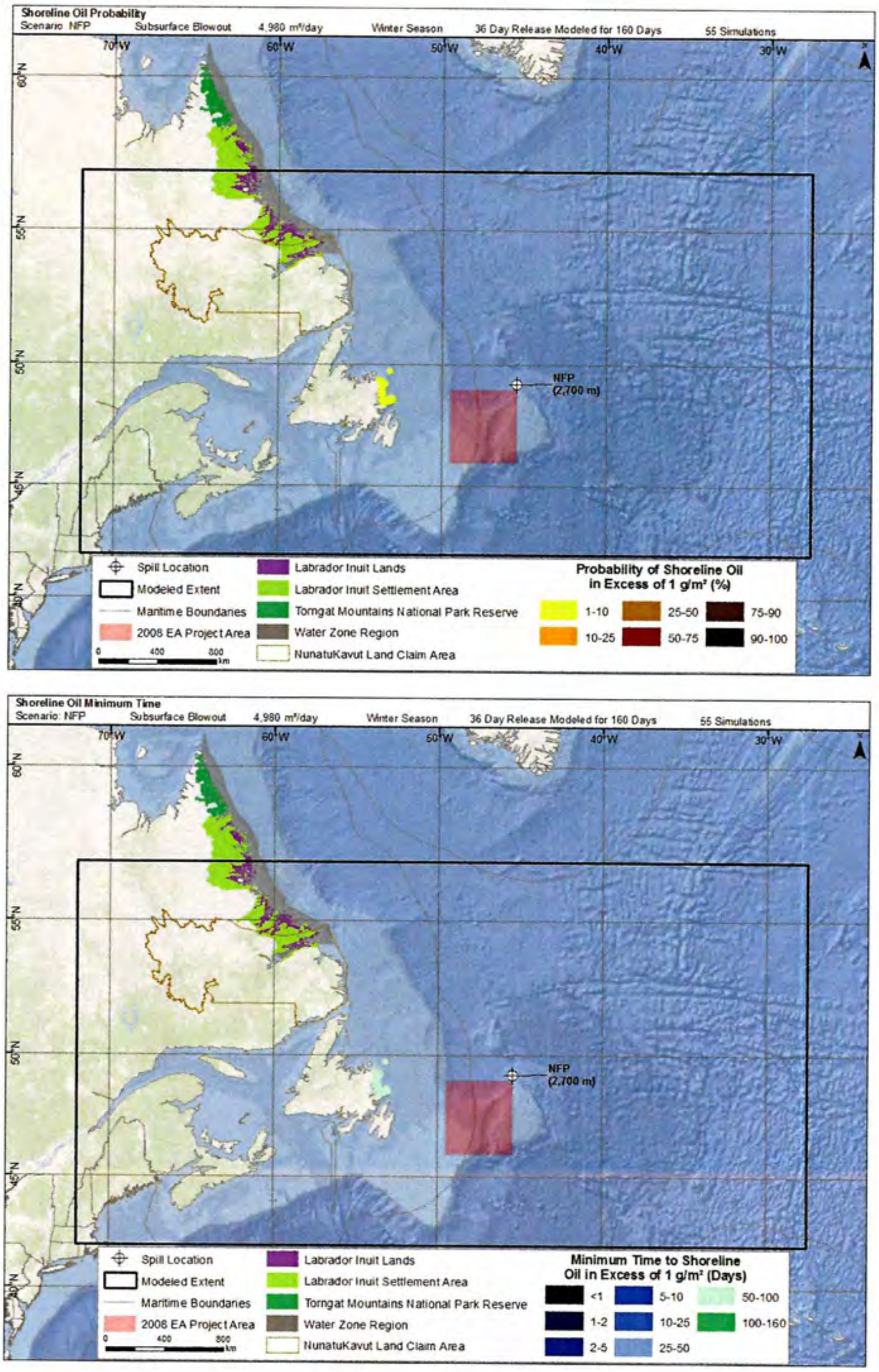


Figure 4-6: Winter shoreline oiling probability above 1 g/m^2 (top) and minimum time in days for threshold exceedance (bottom) for 55 modelled subsurface blowouts of Bay du Nord crude oil.

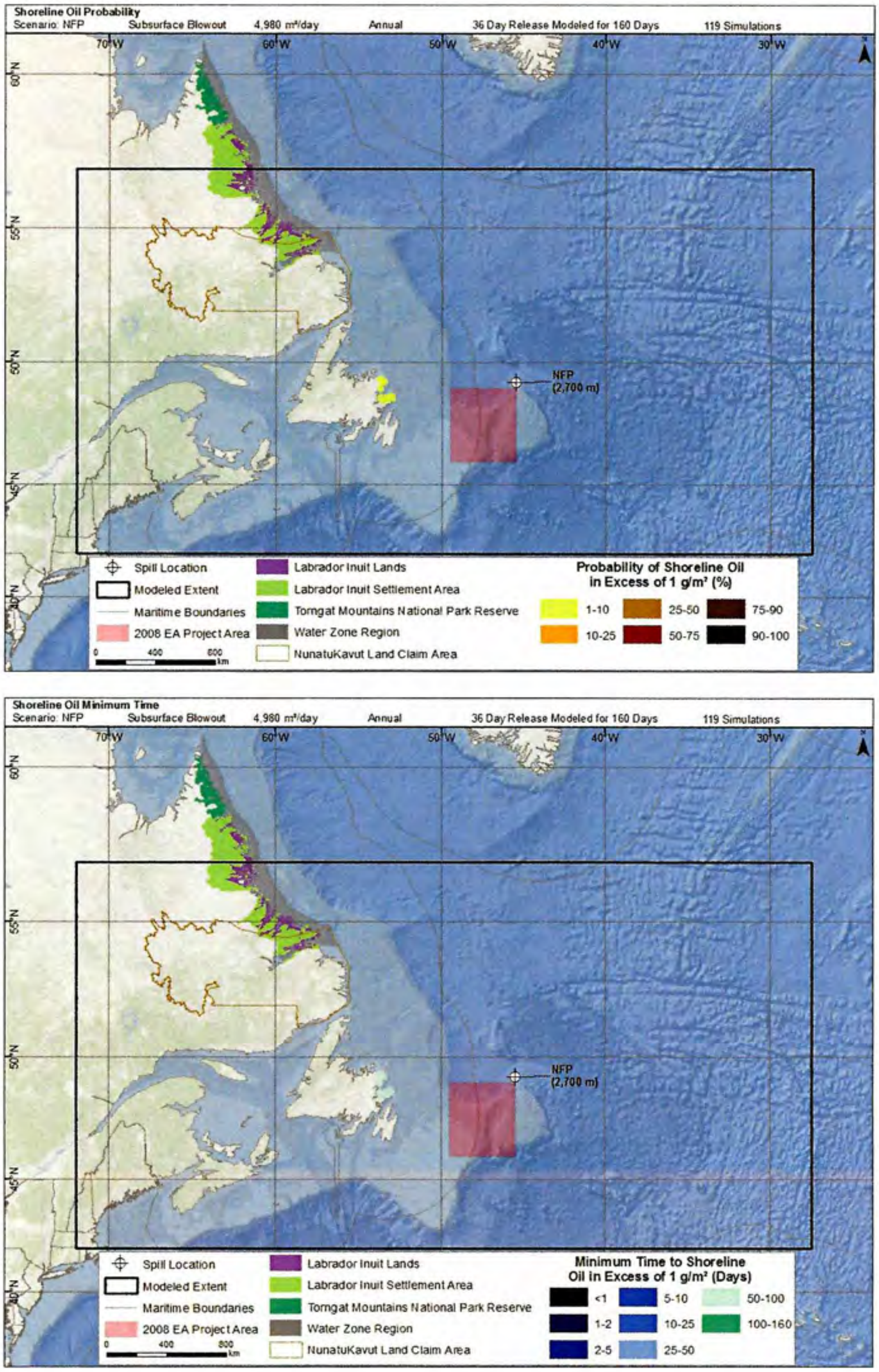


Figure 4-7: Annual shoreline oiling probability above 1 g/m^2 (top) and minimum time in days for threshold exceedance (bottom) for 119 modelled subsurface blowouts of Bay du Nord crude oil.

4.2 NFP Topside Releases

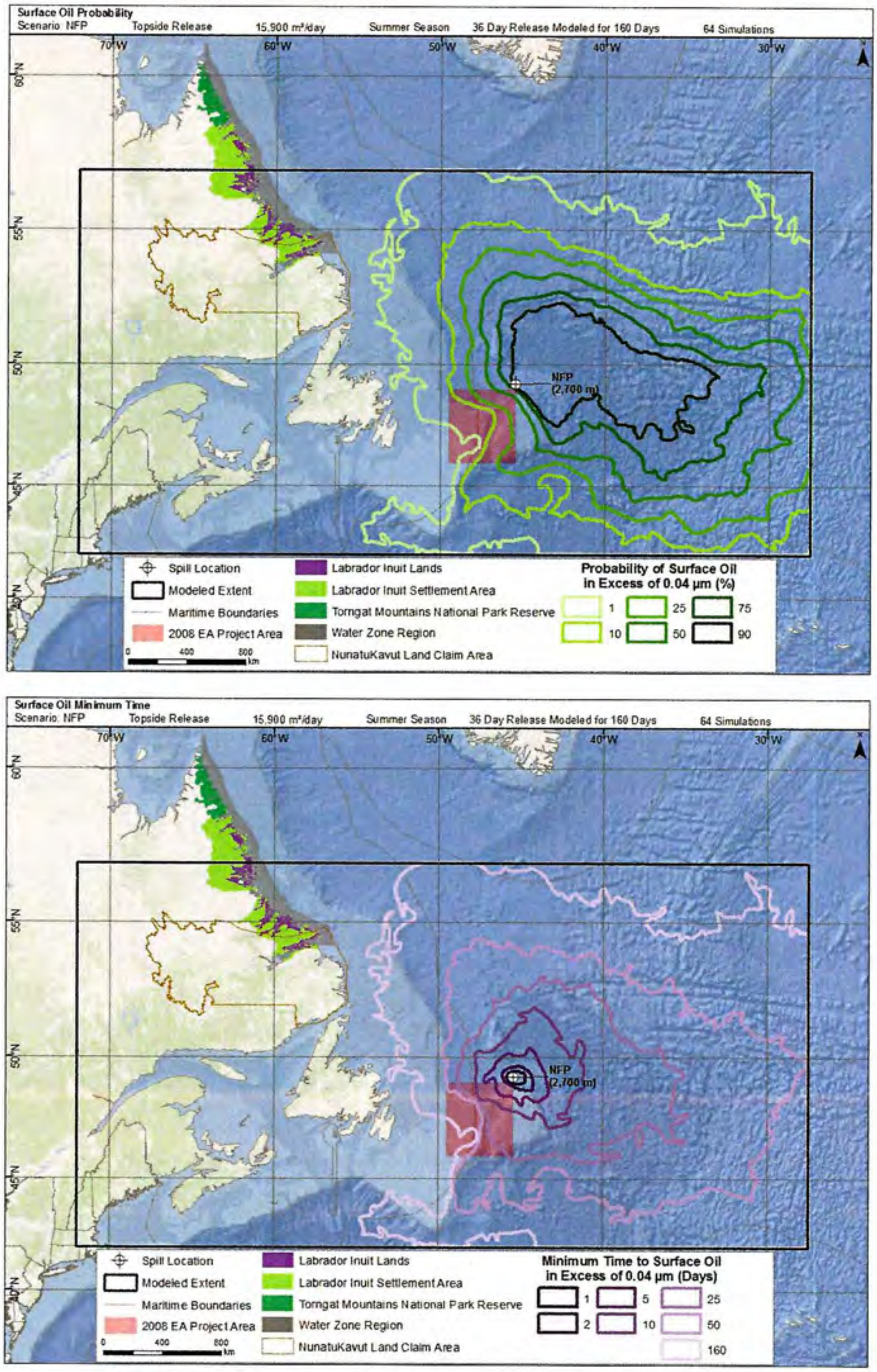


Figure 4-8: Summer surface oiling probability above 0.04 µm thickness (top) and minimum time in days for threshold exceedance (bottom) for 64 modelled topside releases of Bay du Nord crude oil.

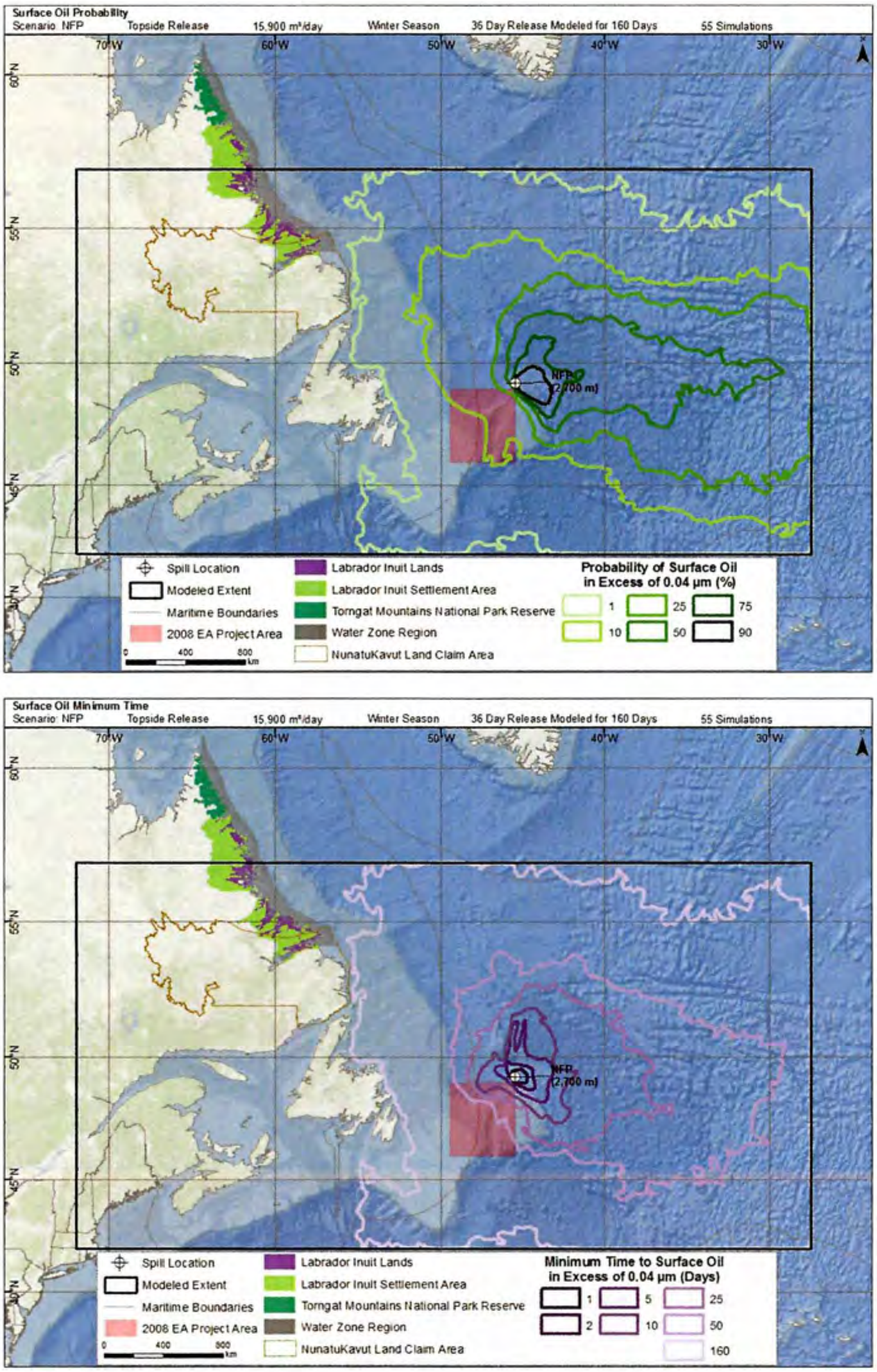


Figure 4-9: Winter surface oiling probability above 0.04 µm thickness (top) and minimum time in days for threshold exceedance (bottom) for 55 modelled topside releases of Bay du Nord crude oil.

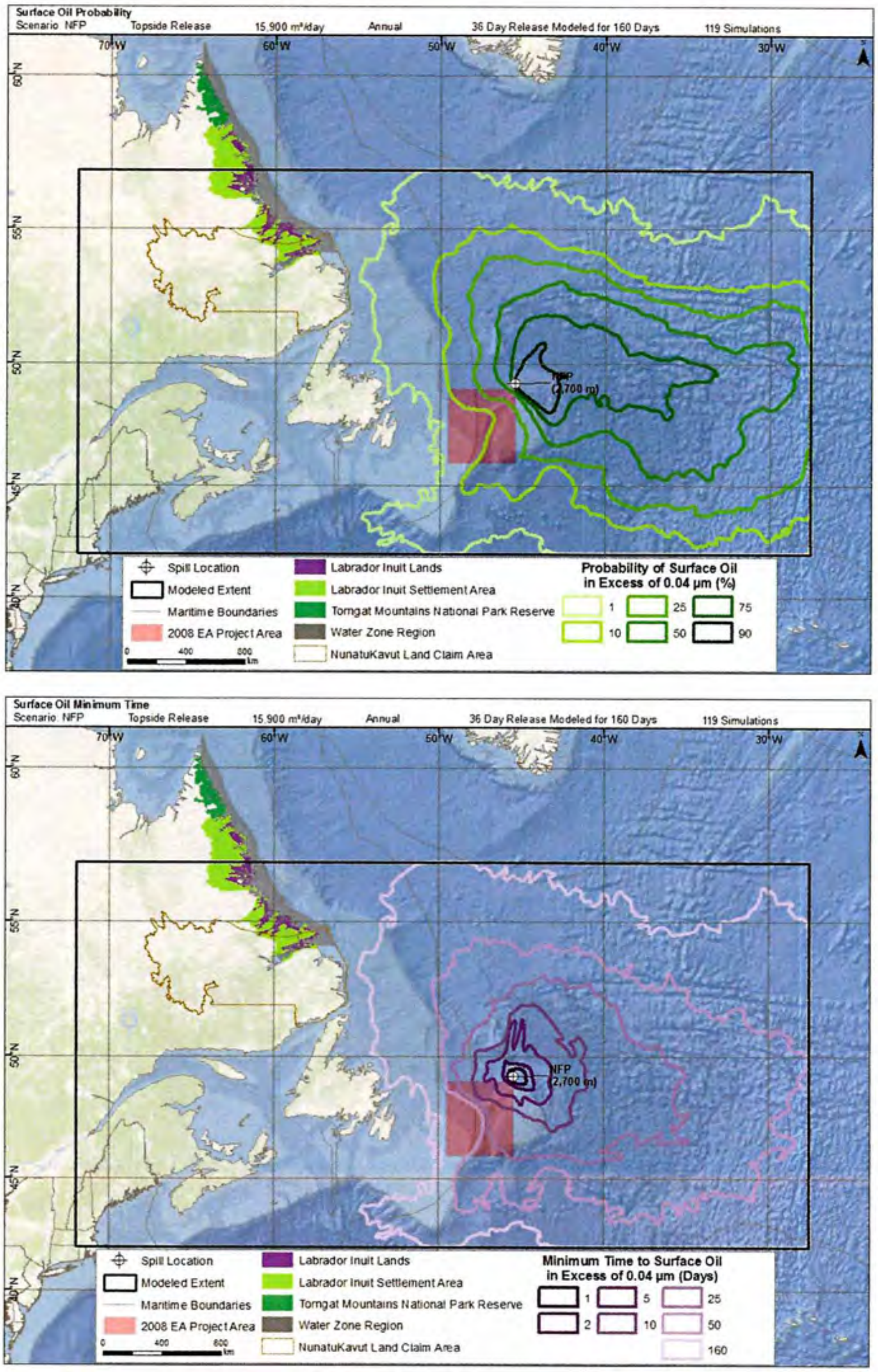
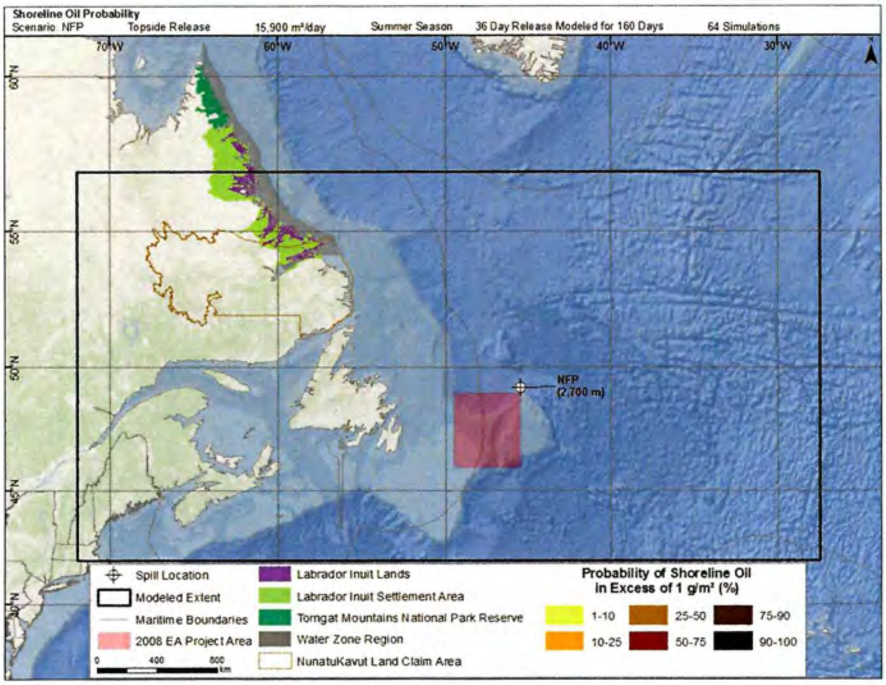


Figure 4-10: Annual surface oiling probability above 0.04 µm thickness (top) and minimum time in days for threshold exceedance (bottom) for 119 modelled topside releases of Bay du Nord crude oil.



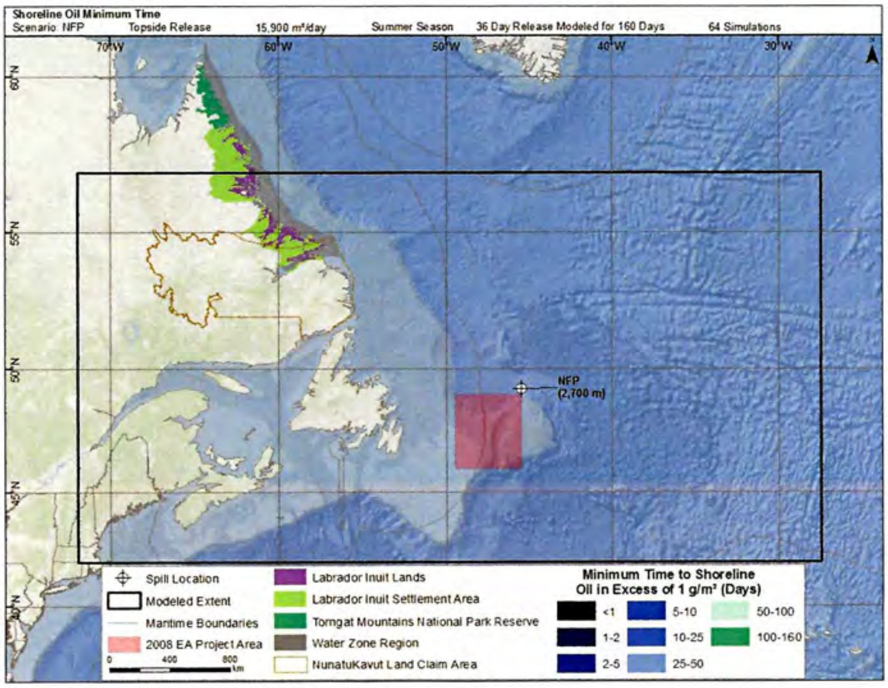
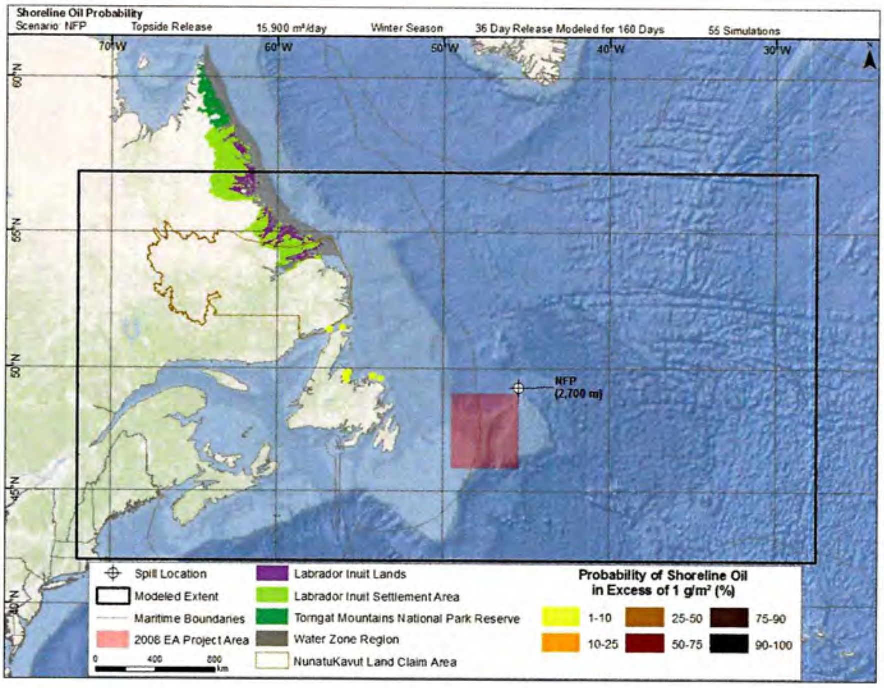


Figure 4-11: Summer shoreline oiling probability above 1 g/m^2 (top) and minimum time in days for threshold exceedance (bottom) for 64 modelled topside releases of Bay du Nord crude oil.



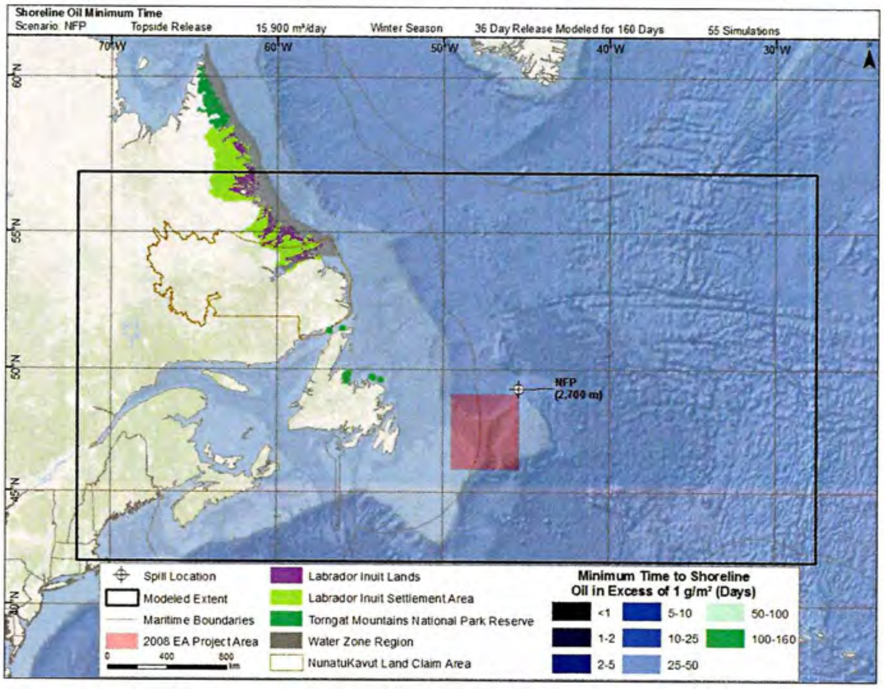
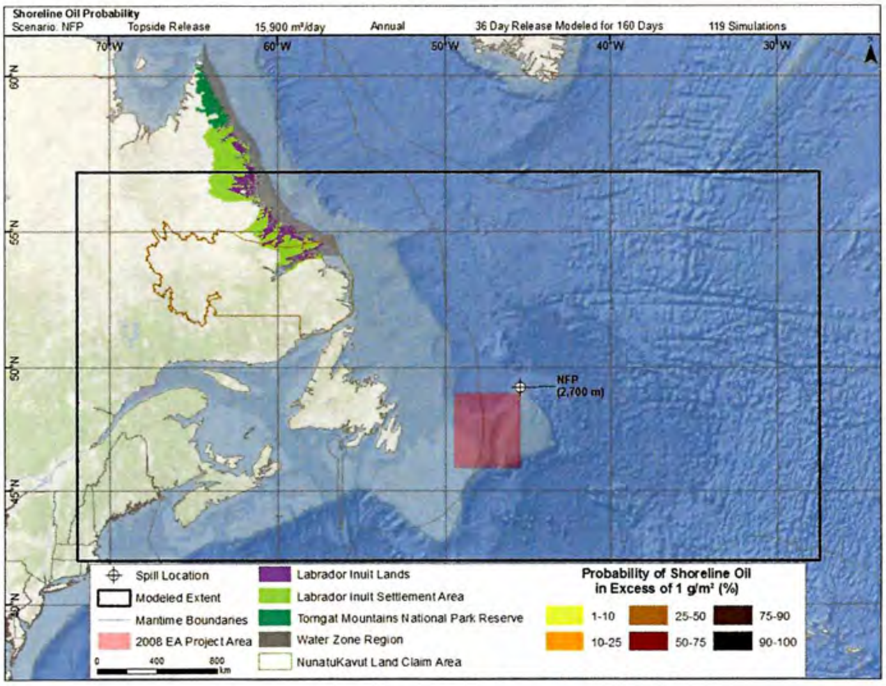


Figure 4-12: Winter shoreline oiling probability above 1 g/m^2 (top) and minimum time in days for threshold exceedance (bottom) for 55 modelled topside releases of Bay du Nord crude oil.



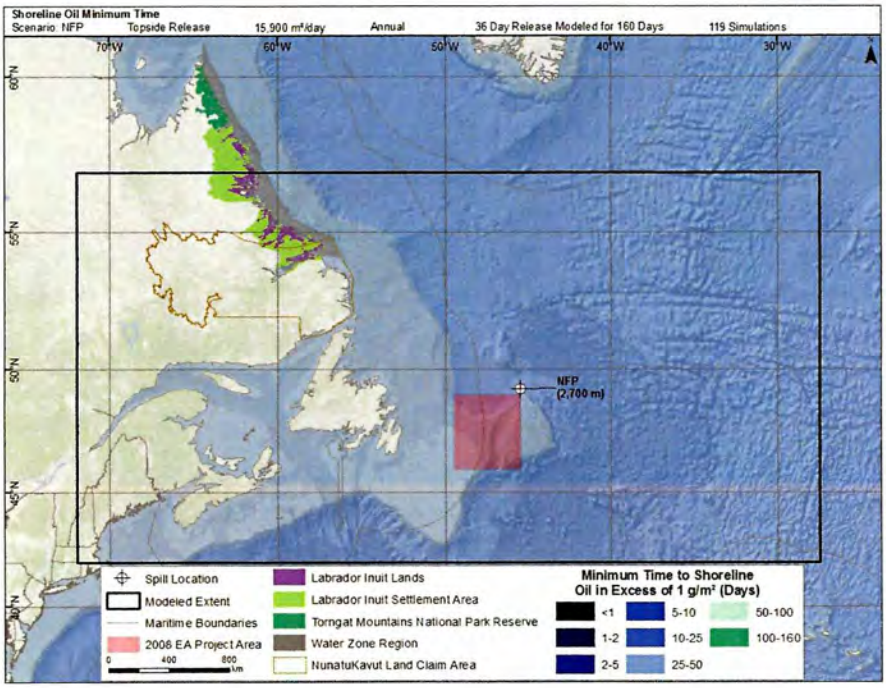


Figure 4-13: Annual shoreline oiling probability above 1 g/m^2 (top) and minimum time in days for threshold exceedance (bottom) for 119 modelled topside releases of Bay du Nord crude oil.

5 Discussion and Conclusions

The highest probabilities of surface oil exceeding a threshold of 0.04 µm are predicted to the east of the release location for both the subsurface blowout and topside releases (Figure 4-2 through Figure 4-4 and Figure 4-8 through Figure 4-10). Threshold exceedance is generally predicted to be greater at each location within the grid for topside releases, when compared to the subsurface blowouts, due to the total volume of the topside release being over threefold higher than the subsurface release (Table 2-1). In other words, larger volumes of released oil typically result in higher predicted probabilities of oil exceeding the threshold within the defined footprint. In addition to the value of probability contours being closely linked to the release volume, the total area of the footprint is as well. As an example, the footprint of ≥1% contour for the annual topside release (119 individual spills) covered 2,511,880 km^2, while the annual subsurface blowout, which had a release volume that was three times smaller, covered 1,827,690 km^2.

To reiterate a prior point, stochastic figures do not imply that the entire contoured area would be covered with oil in the event of a single release, nor do they provide any information on the quantity of oil in a given area. The large threshold exceedance footprints in annual results are not the expected oiling from any single release of oil, but rather 119 releases on top of one another (Figure 4-4 and Figure 4-10). The majority of the predicted area of exceedance represents a probability of oiling at less than 25%. Much of the predicted surface oil above 10% probability would occur within the first 50 days following a release (Figure 4-2 through Figure 4-4 and Figure 4-8 through Figure 4-10).

Seasonal investigation yields different predicted surface results for summer and winter scenarios. During the topside summer release scenario, a much larger 90% probability surface oil footprint is predicted, when compared to the annual scenario (Figure 4-8). Lower wind speeds during summertime conditions reduce the likelihood of entrainment (i.e., surface oil forced into the water column), resulting in oil on the surface being transported great distances by wind and currents, thereby increasing the size of that probability footprint. Under stormier wintertime conditions, wind induced waves result in greater amounts of entrainment, thereby reducing the amount of oil on the surface and reducing the likelihood that oil will be found on the surface (Figure 4-9). For the subsurface blowouts, winter and summer scenario contour lines are smaller in overall area than topside releases due to the lower release volume (Figure 4-2 and Figure 4-3). However, the same trend in summer vs. winter is observed in the subsurface blowout scenario, with smaller surface area footprints during wintertime conditions.

In general, only annual and winter release scenarios were predicted to have surface oil reaching the coastline, but with a probability of only 1-3%. The maximum probabilities of shoreline oiling in excess of 1 g/m^2 are predicted to range between 1-3% for subsurface blowouts and approximately 1% for topside releases (Table 5-1). The small amount of shoreline oiling that does occur is located on the northeastern shores of Newfoundland and the southeastern shore of Labrador. The oil that is predicted to make it to shorelines is expected to be highly weathered, as minimum time estimates for shoreline oiling range from approximately 50-160 days (Table 5-1). The oil that would make its way to shore is expected to be patchy and discontinuous. Oil from a topside release is predicted to strand on shorelines in excess of 1 g/m^2 under wintertime conditions only. This is the result of each modelled parcel of oil (i.e., Lagrangian element) being transported by its own local current speed and direction, and wind speed and direction. Oil from subsurface releases is transported by subsurface currents, which have higher potential to transport subsurface oil to the west and southwest prior to surfacing than do surface currents. This subsurface transport increases the likelihood that over the course of 160 days, oil from a subsurface release may impact a shoreline. However, this "increased likelihood" is still unlikely (<3%).

Table 5-1: Shoreline contamination probabilities and minimum for oil exceeding 1 g/m^2 for each scenario. Note that several scenarios are not predicted to result in shoreline oil contamination.

Scenario	Average Probability of Shoreline Oil Contamination (%)	Maximum Probability of Shoreline Oil Contamination (%)	Minimum Time to Shore (days)	Maximum Time to Shore (days)
Topside Release – Annual*	--	--	--	--
Topside Release - Winter Season	1	1	140.2	159.7
Topside Release – Summer Season	--	--	--	--
Subsurface Blowout - Annual	1	1	50.9	69.9
Subsurface Blowout - Winter Season	2	3	50.3	88.6
Subsurface Blowout – Summer Season	--	--	--	--

* Note that there is no minimum time (or probability) reported for the annual topside release, while the winter season did have a predicted time. This discrepancy is the result of the total number of releases (119 vs. 55) and the fact that only probabilities ≥1% were investigated.

The term "weathered "refers to the chemical composition of the crude oil in question. As oil weathers, it loses more soluble and volatile fractions, which are typically attributed to the negative biological effects following a release. As time after a release progresses, evaporation, dissolution, biological degradation, photo-oxidation, and other processes break down portions of the oil into a more inert (i.e., less harmful) mixture of compounds. Ultimately, the more weathered the crude oil becomes, the lower potential there is for negative biological effects.

5.1 Comparison with Previous Modelling

The most notable differences between the results from this study and the previous 2008 study are 1) footprints are much larger in this study, and 2) no shoreline oiling was predicted in the previous study. In this study, release volumes were similar in the subsurface blowouts (4,890 m^3/day), but threefold higher for surface releases (15,900 m^3/day), the duration of flow was similar (36 days verses 30 days), and the threshold of concern was identical to this study (0.04 µm, which is equivalent to 1 gram per 25 m^2). The larger amount of oil modelled here has a higher likelihood of exceeding the very conservative surface oil threshold. Additionally, because the modelling was conducted over a 160-day period in this study, over five times the duration of the previous study, oil was transported much further distances. Because of this increased time, this most recent study does predict that some regions of Newfoundland and a very small portion of Labrador may have up to 3% probability of being oiled, however most cases are closer to 1% or lower.

5.2 Potential Variability in Releases

While it is understood that the hypothetical releases modelled in this study are in no way intended to predict a specific future event, rather they are used as a planning tool for use in environmental assessments and spill contingency planning. The results presented in this document demonstrate that there are a range of potential trajectories and fates that may result following a release of crude oil based upon the environmental variability that may occur over the course of a year or many years. If there were an event such as a subsurface blowout or topside release, it is likely that a different volume of oil may be released from a different location than modelled here. While it is impossible to know the exact trajectory and fate of an oil release in the future, inferences may be made from this study.

Should there be a release of oil that was smaller in volume than the releases modelled here, it is anticipated that each probability contour would have a smaller extent. It is anticipated that the footprint of minimum time to oiling would remain roughly the same. The only differences would be at the outer edge, if the released volume were sufficiently smaller. Should there be a release of oil that was larger in volume than the releases modelled here, it is expected that the probability of threshold exceedance would be higher throughout the modelled domain. It is anticipated that footprint of minimum time to oiling would remain roughly the same; although the outer edges could push out further if the probability footprint was larger. With a higher amount of surface oiling, the total amount of persistent oil could be greater and may result in a slight increase in shoreline oiling.

The releases modelled in this study could be considered representative of other potential releases in the Project Area. The depth of release (2,700 m) is on the upper end of the range found in the Project Area, with many exploration licenses in the 1000-1,500 m range. Potential releases from shallower locations may result in more rapid surfacing of released subsurface oil, slightly more evaporation and less dissolution. While the NFP release location is slightly outside of the 2008 EA Project Area, the currents and winds that occur at this location are similar to those found within. In general, the boundary set up by the Labrador Current and the Gulf Stream has the potential to result in dynamic currents, however general flow would be towards the east. Due to the proximity of land, should there be a release in the western-most region of the Project Area, there may be a higher potential for surface oil to result in shoreline oiling. However, the overall probability would likely still be considered low, as was predicted in the previous modelling (SL Ross 2008).

5.3 Overall Summary

In general, the majority of surface oil from both a topside release and subsurface blowout is predicted to move to the east of the hypothetical release location. Winds and currents in the Project Area are similar throughout the year, with most notable differences in wind intensity. The increased winds during wintertime conditions enhances surface breaking waves and results in the entrainment of oil, which lowers the likelihood that oil will remain on the surface for extended periods of time. Shoreline oiling is not likely at this release location with <3% probability of shoreline oil exceeding 1 g/m^2 for subsurface releases and approximately 1% for surface releases. The difference in shoreline oiling between subsurface blowouts and surface releases is the result of rising oil in the water column (from the subsurface blowout) being transported by subsurface currents, which tended to force oil slightly more to the west.

This study included modelling unmitigated release volumes that were three times greater than the previous 2008 study and tracked the trajectory and fate of oil for over five times the previous duration. Therefore, surface oil footprints exceeding 0.04 µm were much larger in this study. However, even with the larger volume and longer duration, shoreline oiling in excess of 1 g/m^2 (≥1% probability) was still unlikely, with <3% likelihood for subsurface releases and <1% for surface releases.

The two modelled hypothetical releases in this study are intended to bound the potential range in trajectory and fate that may result from releases that span depths of 2,700 m up to the surface. Should a release occur at a shallower depth (e.g., 1,000 m) it is expected that the trajectory and fate would more closely mirror the surface release, with a surface oil probability footprint extending to the east and a lower likelihood of shoreline oiling. However, if the release location was substantially closer to shore, there may be an increased likelihood of shoreline oiling. Should the hypothetical release have a release volume that is lower than modelled here, it is expected that the values and extent of the probability footprint would be lower, and vice versa. It is important to note that every oil spill is unique and it is impossible to predict an exact release down to every possible release parameter. However, the results of this modelling study do suggest that if oil were to be released in the Project Area, it has a high likelihood of moving away from shore to the east with little likelihood of shoreline oiling.

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Appendix 2: Fishing Activity Maps for Cod, Redfish, American Plaice

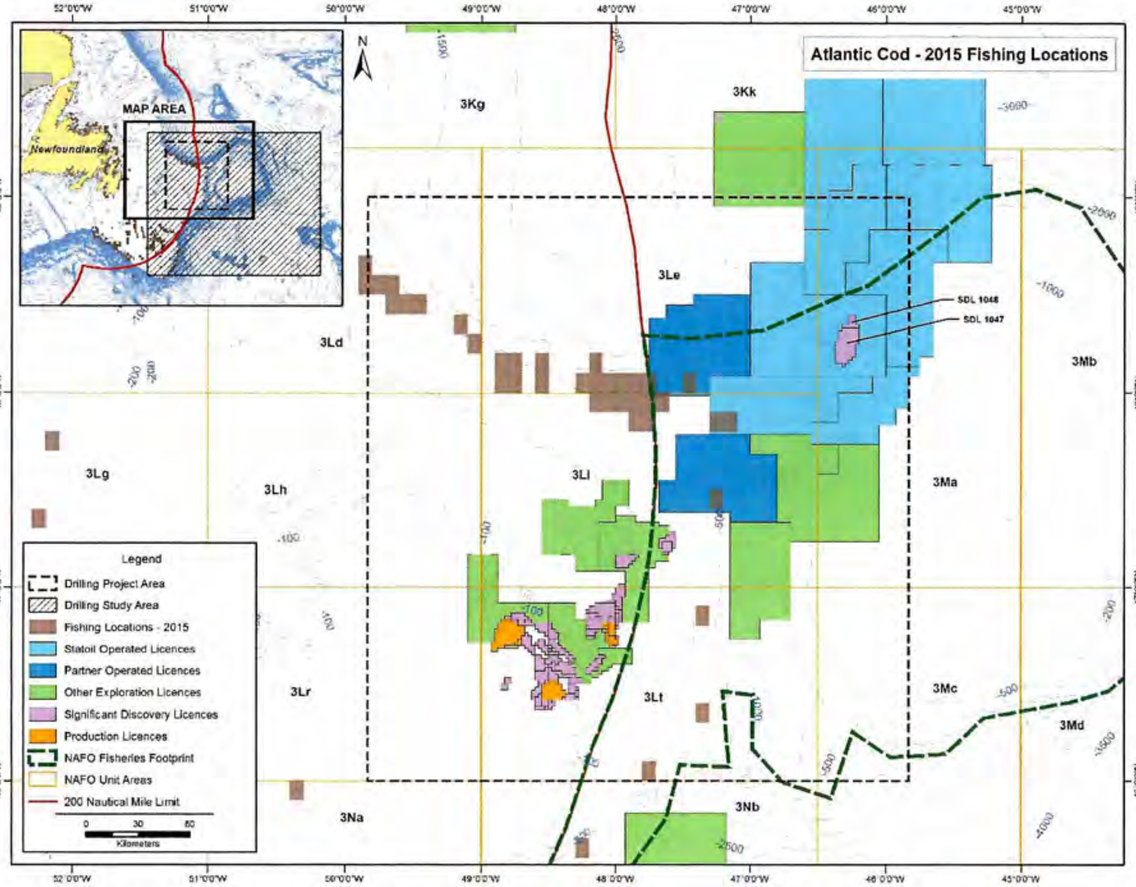

Figure A11: Canadian domestic fishing activity for Atlantic Cod in 2015 from DFO data

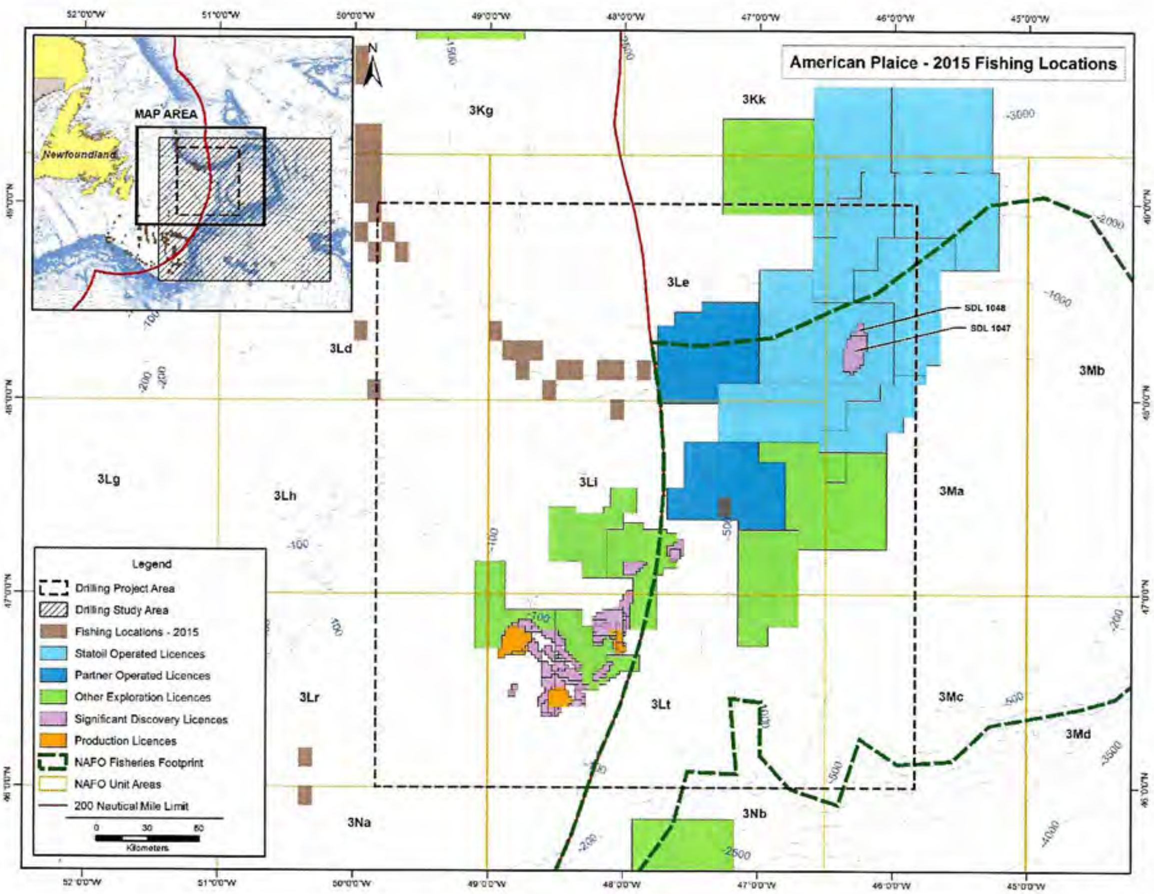

Figure A12: Canadian domestic fishing activity for American Plaice in 2015 from DFO data.

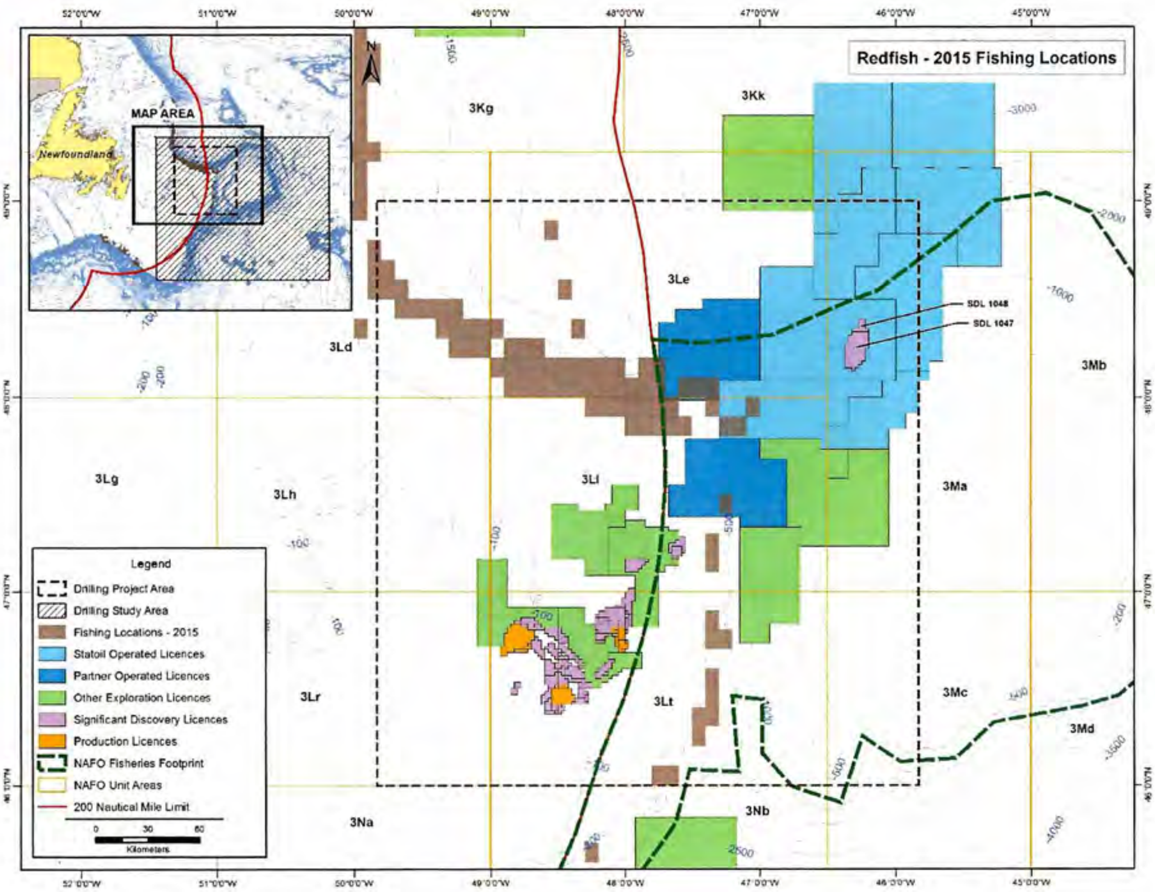

Figure A13: Canadian domestic fishing activity for Redfish in 2015 from DFO data

Appendix 3 - Listing of SARA and COSEWIC Listed Species in the Statoil Project Area

Family	Species		Federal		Provincial
	Common Name	Scientific Name	SARA Status (Schedule 1)	COSEWIC Designation	
MARINE FISH					
Anarhichadidae	Atlantic wolffish	*Anarhichas lupus*	Special Concern	Special Concern	
Anarhichadidae	Northern wolffish	*Anarhichas denticulatus*	Threatened	Threatened	
Anarhichadidae	Spotted wolffish	*Anarhichas minor*	Threatened	Threatened	
Anguillidae	American eel	*Anguilla rostrata*		Threatened	Vulnerable
Cetorhinidae	Basking shark	*Cetorhinus maximus*		Special Concern	
Gadidae	Atlantic cod (Newfoundland and Labrador population)	*Gadus morhua*		Endangered	
Gadidae	Cusk	*Brosme brosme*		Endangered	
Lamnidae	Porbeagle	*Lamna nasus*		Endangered	
Lamnidae	Shortfin mako	*Isurus oxyrinchus*		Threatened	
Lamnidae	White shark	*Carcharodon carcharias*	Endangered	Endangered	
Macrouridae	Roughhead grenadier	*Macrourus berglax*		Special Concern	
Macrouridae	Roundnose grenadier	*Coryphaenoides rupestris*		Endangered	
Phycidae	White hake (Atlantic and Northern Gulf of St. Lawrence population)	*Urophycis tenuis*		Threatened	
Pleuronectidae	American plaice (Newfoundland and Labrador population)	*Hippoglossoides platessoides*		Threatened	
Rajidae	Smooth skate (Funk Island Deep Population)	*Malacoraja senta*		Endangered	
Rajidae	Thorny skate	*Amblyraja radiata*		Special Concern	
Rajidae	Winter Skate (Eastern Scotain	*Leucoraja ocellata*		Endangered	

Family	Species		Federal		Provincial
	Common Name	Scientific Name	SARA Status (Schedule 1)	COSEWIC Designation	
	Shelf – Newfoundland)				
Salmonidae	Atlantic salmon (South Newfoundland Population; outer Bay of Fundy population)	*Salmo salar*		Threatened (South Newfoundland Population); Endangered (outer Bay of Fundy population)	
Scombridae	Atlantic bluefin tuna	*Thunnus thynnus*		Endangered	
Scorpaenidae	Acadian redfish (Atlantic population)	*Sebastes fasciatus*		Threatened	
Scorpaenidae	Deepwater redfish (Northern Population)	*Sebastes mentella*		Threatened	
Squalidae	Spiny dogfish	*Squalus acanthias*		Special Concern	
MARINE BIRDS					
Laridae	Ivory Gull	*Pagophila eburnea*	Endangered	Endangered	Endangered
Scolopacidae	Red-necked Phalarope	*Phalaropus lobatus*		Special Concern	
Scolopacidae	Red Knot *rufa* subspecies	*Calidris canutus rufa*	Endangered	Endangered	Endangered
MARINE MAMMALS AND SEA TURTLES					
Balaenopteridae	Blue Whale - Atlantic Population	*Balaenoptera musculus*	Endangered	Endangered	
Balaenopteridae	Fin Whale - Atlantic Population	*Balaenoptera physalus*	Special Concern	Special Concern	
Balaenidae	North Atlantic Right Whale	*Eubalaena glacialis*	Endangered	Endangered	
Ziphiidae	Northern Bottlenose Whale - Davis Strait, Baffin Bay, Labrador Sea population; Scotian Shelf population	*Hyperoodon ampullatus*	Endangered (Scotian Shelf population)	Special Concern (Davis Strait, Baffin Bay, Labrador Sea population); Endangered (Scotian Shelf population)	
Ziphiidae	Sowerby's Beaked Whale	*Mesoplodon bidens*	Special Concern	Special Concern	
Delphinidae	Killer Whale (Northwest Atlantic	*Orcinus orca*		Special Concern	

Family	Species		Federal		Provincial
	Common Name	**Scientific Name**	**SARA Status (Schedule 1)**	**COSEWIC Designation**	
	/ Eastern Arctic population)				
Phocoenidae	Harbour Porpoise (Northwest Atlantic population)	*Phocoena phocoena*		Special Concern	
Dermochelyidae	Leatherback Sea Turtle	*Dermochelys coriacea*	Endangered	Endangered	
Cheloniidae	Loggerhead Sea Turtle	*Caretta caretta*		Endangered	

Appendix 4 – Nationally, Provincially, and Internationally Designated Sensitive and Special Areas

National, provincial, and international areas designated as sensitive or special that are located within the modelled surface oiling probability (above 0.04 µm thickness) and / or shoreline oiling probability (above 1 g/m^2) contours as presented in the Trajectory Modelling in Support of Statoil Exploration Drilling at the Northern Flemish Pass Site (RPS (Applied Science Associates, Inc.). 2017) are provided in the following tables.

National Designations

Marine Protected Areas

Marine Protected Area (MPA)	Rationale for Identification / Designation	Area
Eastport – Duck Islands MPA and Eastport-Round Island MPA	Established in 2005 to limit fishing with an aim to ensure a viable American lobster population and to protect other threatened or endangered species.	2.1 km^2 on 2 islands
Source: EMPAAC (2013); DFO (2016)		

Federal Fishing Closure Areas

Closure Area	Rationale for Identification / Designation	Area
Eastport Peninsula Lobster Management Area	In 1995, Eastport Peninsula lobster fishers voluntarily limited lobster fishing in an area of Bonavista Bay to protect prime lobster habitat. In 1997, DFO provided protection through the *Fisheries Act* and designated two portions of the area as MPAs under the *Oceans Act*.	400 km^2
Funk Island Deep Box	In 2002, DFO closed (through the *Fisheries Act*) an area of the Funk Island Deep to gillnetting to protect bottom habitat. DFO also closed the area to small vessel bottom trawling in 2005. The fishing industry has voluntarily closed the area to the large vessel shrimp fleet.	7,272 km^2
Source: DFO (2007, 2014); EMPAAC (2013)		

Ecologically and Biologically Significant Areas (EBSA)

EBSA	Rationale for Identification / Designation	Area
Northeast Shelf and Slope	High aggregations of Greenland halibut and spotted wolffish which congregate in spring. Concentrations of cetaceans, pinnipeds and corals.	13,885 km^2
Virgin Rocks	High aggregations of capelin and other spawning groundfish such as Atlantic cod, American plaice and yellowtail flounder. Seabird feeding areas. Unique geological features and habitat.	6,843 km^2
Orphan Spur	High concentrations of corals. Densities of sharks and species of conservation concern (e.g. northern, spotted and striped wolffish, skates, roundnose grenadier, American plaice, redfish).	21,569 km^2

EBSA	Rationale for Identification / Designation	Area
Lilly Canyon-Carson Canyon	Concentration, reproduction and feeding area for Iceland scallop. Aggregation and refuge / overwintering for cetaceans and pinnipeds.	1,145 km^2
Southeast Shoal and Tail of the Banks	Highest benthic biomass in the Grand Banks; aggregation, feeding, breeding and / nursery habitats for capelin, yellowtail, cetaceans, seabirds, American plaice and Atlantic cod. Reproduction of striped wolfish. Unique populations of particular species. Unique sandy habitat with important glacial history.	30,935 km^2
Notre Dame Channel	Recognized for cetacean feeding and migration. Frequented by several species of seabirds. Harp seals feed in the area during winter.	6,222 km^2
Smith Sound	Atlantic Cod use the area for spawning and nursery grounds and as an overwintering refuge.	148 km^2
Fogo Shelf	Funk Island, the largest common murre colony in the western North Atlantic and the only northern gannet breeding colony in the Newfoundland and Labrador Shelves Bioregion. Other bird species aggregations. Abundance of beach and sub-tidal capelin spawning areas. Important cetacean feeding areas. Several areas of marine mammals presence.	9,403 km^2
Labrador Slope	High diversity of corals, sponges, rare or endangered species, core species and fish functional groups. Rare or endangered species: Atlantic, spotted and northern wolffish. Significant concentrations of roundnose grenadier, skates, northern shrimp, Greenland halibut, redfish, Atlantic cod and American plaice.	29,746 km^2
Southwest Shelf Edge and Slope	Critical to a wide variety of seabirds, providing the highest density of pelagic seabird feeding within the PB / GB LOMA. Many marine mammals and leatherback sea turtles aggregate in summer.	16,644 km^2
Grey Islands	Important for waterfowl and seabirds in coastal areas and on the shelf. Common eider and harlequin duck occur in high concentrations. Important breeding colonies for great black-backed gulls, herring gulls and terns. High diversity of seabird species aggregate along the inner shelf area.	11,301 km^2
Labrador Marginal Trough	Core fish species and various marine mammals. High densities of shrimp, snow crab, Greenland halibut, American plaice, witch flounder and capelin. Potential corridor for several fish and mammal species. Part of the highest probability of use for harp seal whelping and feeding. Aggregations of plank piscivores, and small and medium benthivores. Aggregations of cetaceans in summer and fall. Important for seabirds including murres, black-backed kittiwake, great black-backed gull, herring gull, northern fulmar, Atlantic puffin, skuas, jaegers, Sooty Shearwater and the endangered Ivory Gull.	16,952 km^2
Southern Pack Ice	Seasonal pack ice recognized for its importance to marine mammals and seabirds.	n/a
Source: Templeman (2007); DFO (2013); AFW (2014); DFO 2016a		

Preliminary Representative Marine Areas (RMA)

Preliminary RMA	Rationale for Identification / Designation	Area
Virgin Rocks	Unique geological features and habitat within the PB / GB LOMA. Important spawning habitat for Atlantic cod, American plaice and yellowtail flounder. Congregation area for capelin. Congregation and feeding area for seabirds. Large winter colonies of common eiders.	6,740 km^2
South Grand Bank Area	Relatively high coral species richness. High fish species richness. Significant groundfish biomass. Unique species biodiversity includes seabirds, Fea's petrel and other rare birds. Feeding area for aggregations of seabirds, cetaceans and leatherback turtles.	18,201 km^2
Northwestern Conception Bay[1]	Capelin spawn in high concentrations. Greatest abundance and diversity of seabird species in eastern North America. Largest seabird island and greatest diversity of breeding seabirds in the province. Largest Leach's storm petrel breeding colony in the world. One of six known breeding colonies of Northern Gannets in North America. One of four islands in eastern Canada where northern fulmars breed.	608 km^2

[1] due to graphics scaling, this unit appears to be on the perimeter of the modelled contour and/or modelled shoreline impact area
Source: CPAWS (2009); AFW (2014)

Migratory Bird Sanctuaries (MBS)

MBS	Rationale for Identification / Designation	Area
Terra Nova	Designated in 1967 to protect an area adjacent to Terra Nova National Park. About 30 shorebird, waterfowl and seabird species. Important sanctuary during fall migration. Shorebirds frequent tidal flats during summer and early fall. Newman Sound is an important area for waterfowl species year round.	12 km^2
Shepherd Island[1]	Designated in 1991 to protect one of the largest breeding sites (together with Île aux Canes) for common eider in insular Newfoundland.	0.18 km^2
Île aux Canes[1]	Designated in 1991 to protect nesting colonies of common eider. Together with Shepherd Island, one of the largest breeding sites for the common eider in insular Newfoundland.	1.62 km^2

[1] due to graphics scaling, this unit appears to be on the perimeter of the modelled contour and/or modelled shoreline impact area
Source: Environment Canada (2016)

Coastal National Parks and Historic Sites

Park / National Historic Site	Rationale for Identification / Designation
Ryan Premises National Historic Site	Restored merchant's premises, displaying artifacts focusing on traditional Newfoundland seafaring life.
Terra Nova National Park	Protects 400 km^2 of boreal forest and rocky coastlines as a representative example of Natural Region 35: Eastern Newfoundland Atlantic Region.

Park / National Historic Site	Rationale for Identification / Designation
Source: AFW (2014); Parks Canada (2008, 2016a)	

Provincial Designations

Coastal Provincial Ecological Reserves

Reserve	Rationale for Identification / Designation	Area
Baccalieu Island Seabird Ecological Reserve[1]	Established as a provisional ecological reserve in 1991, to protect breeding seabird habitat, and granted full status in 1995. Has more breeding seabirds than any other area of the province. Largest Leach's Storm Petrel colony in the world. Second largest Puffin colony in North America.	22.9 km^2
Funk Island Seabird Ecological Reserve	Established as a wildlife reserve in 1964 to protect the largest colony of common murre in the Western North Atlantic. Designated as an ecological reserve (under new legislation) in 1983.	5.4 km^2
[1] due to graphics scaling, this unit appears to be on the perimeter of the modelled contour and/or modelled shoreline impact area Source: AFW (2014); DOEC (2016a); UNESCO (2016)		

Coastal Provincial Parks and Protected Areas

Park / Protected Area	Rationale for Identification / Designation	Area
Dungeon Provincial Park	Protects a beach with a collapsed sea cave and natural archway carved by sea action. Natural or scenic attraction. Park Type: Day use.	0.02 km^2
Windmill Bight Provincial Park Reserve	Protects a plateau bog as an element of provincial Ecoregion 7. Park Type: Reserve.	2.86 km^2
Deadman's Bay Provincial Park	Protects a sandy beach. Iceberg watching. Natural or scenic attraction. Park Type: Day use.	0.70 km^2
Dildo Run Provincial Park	Protects a rocky coastline with rolling hills and valleys. Park Type: Camping.	3.28 km^2
Source: DOEC (2016b)		

Coastal Provincial Historic Site

Historic Site	Rationale for Identification / Designation
Cape Bonavista Lighthouse[1]	Historic lighthouse, built in 1843, includes traditional seal oil fueled catoptric light apparatus used in the 1800s. Also demonstrates the work of light keepers of the period.
[1] due to graphics scaling, this unit appears to be on the perimeter of the modelled contour and/or modelled shoreline impact area Source: DBTCRD (2016)	

International Designations

Vulnerable Marine Ecosystems (VME)

VME	Rationale for Identification / Designation	Approximate Area
Sackville Spur	High density of sponges.	3,961 km^2
Northern Flemish Cap	High density of sea pens, soft corals and black corals and, to a lesser extent, solitary stony corals and small gorgonians. Vulnerable fish species: northern wolffish and spiny dogfish.	6,650 km^2
Northeast Shelf and Slope (within Canadian Exclusive Economic Zone)	Abundance of gorgonian and black corals.	4,150 km^2
Southern Flemish Pass to Eastern Canyons	Large gorgonians and high density of sponges. Vulnerable fish species: striped wolffish, redfish, spiny tailed skate, northern wolffish, some black dogfish, deep sea cat shark.	7,928 km^2
Beothuk Knoll	Abundant gorgonian corals and high density of sponges. Vulnerable fish species: northern wolffish, spiny tailed skate, roundnose grenadier, deep sea cat shark, black dogfish.	6,685 km^2
Deep Water Coral Area	An area where VMEs for deep-water corals are thought to be likely.	1,502 km^2
Flemish Cap East	Large gorgonians and high density of sponges. Vulnerable fish species: black dogfish and smooth skate.	2,098 km^2
South East Shoal and Adjacent Shelf Edge / Canyons	Unique spawning grounds on South East Shoal, marine mammal feeding grounds, long-lived and relict bivalve populations in sandy shoal habitat. Vulnerable fish species: spawning capelin, northern wolffish, redfish, striped and spotted wolffish, roundnose grenadier, black dogfish.	11,930 km^2
Division 3O Coral Closure Area	Existing closure based on coral concentrations, high density of sea pens and solitary stony corals. Vulnerable fish species: white hake, redfish, black dogfish, smooth skate and deep-sea cat shark.	16,877 km^2
Source: WG-EAFM (2008)		

NAFO Fishing Closure Areas and Candidate Closure Areas

Closure Area	Rationale for Identification / Designation	Closure Period
Sackville Spur	• Closed to protect the high coral and sponge concentrations. • The Sackville Spur is an elongate sediment drift feature that extends from the Grand Banks across the northern limit of the Flemish Pass and along the northern slope of the Flemish Cap. Its southern flank gently slopes toward the 900 m isobath in the Flemish Pass, and steeper northern flank extends to the floor of the Orphan Basin at 2500 m depth. • Dominant sponge species in are demosponges of the order Astrophorida. Geodiids (mostly Geodia barretti), Stelletta normani and Stryphnus ponderosus occur in the deeper water. These large-sized sponges, sometimes grow to more than 25 cm in diameter. The upper	January 1, 2010 to December 31, 2020

Closure Area	Rationale for Identification / Designation	Closure Period
	limit of the sponges is at about 1,300 m depth and extending down to about 1,800 m. These sponge grounds host a high diversity and abundance of associated megafaunal species.	
Northern Flemish Cap	• Together identified as NAFO Coral Closures, these areas were closed to protect the high coral and sponge concentrations. • The Flemish Cap is a plateau of approximately 200 km radius at the 500 m isobaths, with depths of less than 150 m at its centre and separated from Grand Bank by the approximately 1,200 m deep Flemish Pass. • Flemish Cap has a patch of sand in its centre, in the shallower water, but most of the Cap is covered with muddy sand and sandy mud. • Sea pens are key biophysical components of soft-bottom VMEs in the NAFO regulatory area. Aggregations of sea pens, known as "fields", provide important structure in low-relief sand and mud habitats where there is little physical habitat complexity. Fields provide refuge for small planktonic and benthic invertebrates that may be preyed upon by fish. A system of seapen VMEs has been identified extending around the edge of the Flemish Cap. Crinoids and cerianthids and black corals have been found associated with this seapen system. Sponges, seapens, cerianthids and crinoids are also found outside the FCA.	January 1, 2010 to December 31, 2020
Northern Flemish Cap		January 1, 2010 to December 31, 2020
Northern Flemish Cap		January 1, 2010 to December 31, 2020
Northwest Flemish Cap		January 1, 2010 to December 31, 2020
Northwest Flemish Cap		January 1, 2010 to December 31, 2020
Northwest Flemish Cap		January 1. 2014 to December 31, 2020
Flemish Pass / Eastern Canyon	• Closed to protect extensive sponge grounds. • Area was expanded to protect large gorgonian corals in Flemish Pass. • The Flemish Pass, approximately 1,200 m deep, separates the Flemish Cap from Grand Bank. Includes canyons on the eastern slope of Grand Bank, a portion of Flemish Pass in the south, and western slope of the Flemish Cap. Straddles the 2,000 m NAFO fishing footprint on the slopes except on Flemish Cap. • The Flemish Pass contains sandy muds with accumulations of pebbles and stones apparently deposited by icebergs floating along this course. The area has complex hydrography owing to the occurrence of two water masses. VME indicator elements include canyons and shelf-indenting canyons. • Biological composition is similar to Sackville Spur. These sponge grounds have been shown to house high species diversity compared with non-sponge ground habitat at similar depths. Some sponge, large gorgonians and seapen VMEs have also been identified outside the FCA.	January 1, 2010 to December 31, 2020
Orphan Knoll	• Closed to protect seamounts. • Orphan Knoll is a single peak, with depths of a minimum of 1,800 m. Mounds are found at depths of between 1,800 and 2,300 m. Einarsson	January 1, 2007 until December 31, 2020

Closure Area	Rationale for Identification / Designation	Closure Period
	Mound is 1,500 to 2,000 m wide and 300 m tall, and Nader Mound is between 400 and 800 m wide and 300 m tall, including the height of the base which is covered in sediment. • Physical properties indicate that mid-depth waters above Orphan Knoll are in a boundary region between outflow from the Labrador Sea (subpolar gyre) and northward flow of the North Atlantic Current (subtropical gyre). • A west-east gradient in nutrients is likely related to water mass differences between Orphan Basin and the area east of Orphan Knoll. • The Orphan Basin-Orphan Knoll region is biologically rich and complex, and strongly influenced by local processes and advection. Coral, including stony coral, and sponges observed on the flanks. Near-bottom anti-cyclonic circulation could have important implications for the benthic community.	
Northeast Flemish Cap	• Closed to protect the high coral and sponge concentrations. • See Northern and Northwest Flemish Cap. The complexity of the bottom is increased along the southern slope of the Flemish Cap by numerous submarine canyons and steep cliffs. Steep flanks are the important VME indicator element in this area. The FCA straddles the NAFO fishing footprint. • This FCA encompasses a gradient of benthic communities, transitioning from coral dominated communities at ~2,450 m depth, corals intermixed with sponges around 2,000 m, sponge dominated grounds at 1,500 m, and a diverse community of corals, sponges and other benthic taxa at approximately 1,300 m depth.	January 1, 2010 until December 31, 2020
Seapen Candidate Areas	• Proposed for closure due to significant concentrations of seapens, a VME indicator species. Two high concentration sea pen locations have been identified as corresponding with candidate areas 13 and 14 and a third is located between them. Several	Approved for closure in January 2017
Beothuk Knoll	• Closed to protect the high coral and sponge concentrations. • Physical VME indicator elements include the Beothuk Knoll, steep flanks and canyons with heads greater than 400 m.	January 1, 2015 until December 31, 2020
Eastern Flemish Cap	• Closed to protect the high coral and sponge concentrations. • See Northern, Northwest and Northeast Flemish Cap. High densities of the stalked crinoids Gephyrocrinus grimaldii together with several structure-forming sponges inside the FCA. A sponge and large gorgonian VME has been identified outside the FCA. Crinoids and cerianthids have also been found in this area.	January 1, 2010 until December 31, 2020
Beothuk Knoll	• Closed to protect the high coral and sponge concentrations. • Beothuk Knoll is a discrete steep-sided plateau that forms an abrupt projection from the southwest edge of Flemish Cap. Adjacent	January 1, 2010 to December 31, 2020

Closure Area	Rationale for Identification / Designation	Closure Period
	sediment drifts consist of sands. Beothuk Knoll has an iceberg turbate with isolated deep-water scours. Knolls are recognized as VME indicator elements. Sponge and large gorgonian VMEs have been identified outside this FCA.	
Tail of the Bank	• Closed to protect the high coral and sponge concentrations. • The Tail of the Bank is a small FCA on the continental slope of the tail of Grand Bank straddling the fishing footprint around 2,000 m in depth. • Deep-sea sponge grounds are aggregations of large sponges that develop under certain geological, hydrological and biological conditions to form structural habitat. More recent studies to the south of this closure identified significant concentrations of erect bryozoans, large sea squirts (Boltenia ovifera) and small gorgonian VME indicator species, along with crinoids and cerianthids.	January 1, 2010 to December 31, 2020
Newfoundland Seamounts	• Closed to protect seamounts. • The Newfoundland Seamounts include 6 seamount peaks all with summits deeper than 2,400 m, with most of the area being than 3,500 m. These seamounts were volcanically active in the late Cretaceous period. • Seamounts are uniquely complex habitats that rise into bathyal and epi-pelagic depths. In general, seamounts owing to their isolation tend to support endemic populations and unique faunal assemblages.	2007-01-01 until 2020-12-31
3O Coral Closure	• Closed to protect corals. • The 3O FCA is located on the continental slope from 800 m and is the only NAFO FCA that straddles national and international waters. The area includes mostly soft bottoms with rocky outcrops. • Sea pen and small gorgonian VMEs have been identified in the vicinity of the FCA and species distribution models indicate a high probability of sea pens. • VME indicator elements are present: shelf-indenting canyons and canyons with heads > 400 m in depth in the FCA have potential to have VMEs.	January 1, 2008 to December 31, 2020
Source: NAFO (2015, 2016b, 2016c); FAO 2016b		

Coastal Important Bird Areas

IBA	Rationale for Identification / Designation	Area
Baccalieu Island[1]	Greatest seabird species abundance and diversity in Eastern North America. Largest Leach's storm-petrel colony in the world. Significant breeding populations of other seabirds. Designated as Baccalieu Island Provincial Ecological Reserve.	45.2 km^2
Grates Point[1]	Supports a large number of wintering common eiders; typically around 2,800 individuals, and as many as 12,000. Other winter species include black-legged kittiwake, thick-billed murre and dovekie. Atlantic puffin and northern gannet are found in the area in summer.	66.5 km^2
Funk Island	Supports a very large concentration of nesting seabirds, including a globally significant common murre population, and large numbers of northern gannets. Designated as Funk Island Provincial Ecological Reserve.	135.2 km^2
Cape Freels Coastline and Cabot Island	Large number of nesting common murre and a few pairs of Razorbills. Breeding Atlantic puffins have been reported. Up to 25,000 wintering common eiders.	334.5 km^2
Terra Nova National Park	Supports numerous forest species, including two subspecies with restricted ranges: the federally-listed red crossbill and ovenbird. Shorebirds found on flats at the outlet of Big Brook, and in Newman Sound. Frequented by gulls and waterfowl. At least six tern colonies total between 1000 and 1500 pairs include both common and Arctic terns. Designated as Terra Nova National Park of Canada and Terra Nova Migratory Bird Sanctuary.	655.8 km^2
Wadham Islands and adjacent Marine Area	Composed of seven main islands and several smaller rocks and shoals. Supports globally significant numbers of wintering common eiders (approximately 25,000 in a 1995 survey). Many nesting seabirds including large numbers of Atlantic puffin, Leach's storm-petrel and razorbill.	159.3 km^2

[1] due to graphics scaling, this unit appears to be on the perimeter of the modelled contour and/or modelled shoreline impact area
Source: AFW (2014); IBA (2016)

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