16 ACCIDENTAL EVENTS (REVISED – FEBRUARY 2019)

During an offshore exploration drilling project, an accidental event or malfunction is an unlikely, although potential, occurrence. Environmental incidents that may be associated with offshore drilling activities include potential subsurface/subsea releases, as well as spills of hydrocarbons or other substances from a MODU or associated supply and support vessel activities. These events may vary considerably in terms of their nature, scale, duration and potential environmental consequences. This section describes possible accidental events and malfunctions and assesses potential effects that could result for each identified VC. The assessment includes a detailed description of the modelling undertaken to better understand the potential effects.

This Section has been organized to provide an overview of the CNOOC Petroleum North America ULC (CNOOC) management systems and governance frameworks that systematically manage the core aspects of CNOOC's business through consistently applied standards, processes, procedures, and assurance. It discusses CNOOC's prevention and response practices and provides details around specific potential accidental event scenarios. Following the description and rationale for selection of the assessed scenarios, this section provides an overview of the associated risk and probabilities for each scenario. It is important to note that the modelled and assessed scenarios in this section are unmitigated events to provide a conservative basis for the environmental effects assessment. However, the effects assessment considered in this section does consider the use of mitigation measures when determining residual effects.

16.1 Spill Prevention and Response

As described previously in Section 1.1 of the Environmental Impact Statement (EIS), Health, Safety, Environment and Social Responsibility (HSE&SR) are core values at CNOOC. The success of every activity undertaken by the company is measured on its ability to execute the work in a safe and environmentally responsible manner.

16.1.1 Accident Prevention

CNOOC's first priority is to prevent incidents from occurring. CNOOC achieves this by providing a high degree of stewardship, risk assessment and scrutiny of potential hazards through its Leadership and Safety culture, its personnel competency and training programs, the CNOOC Management System, CNOOC's robust Process Safety Management (PSM) system, and the Well Delivery Process (WDP).

Process Safety is a disciplined framework for managing the integrity of operating systems and processes, handling hazardous substances by applying good design principles, engineering, and operating practices. It deals with the prevention and control of incidents that have the potential to release hazardous materials or energy. Such incidents can cause toxic effects, fire, or explosion and could ultimately result in injuries, environmental effects, property damage, and/or lost production.

The CNOOC hazard identification and risk assessment processes form a key component of PSM and allow CNOOC to identify hazards and potential incidents, develop preventative barriers and recovery measures, identify the necessary training and conduct response exercises to mitigate potential risk.

16.1.1.1 Leadership and Safety Culture

"Safety First" is a CNOOC core cultural belief and is a key component of the CNOOC commitment to create a safe work environment for our personnel (employees and contractors). Utilizing clear direction and instruction about occupational health and safety, CNOOC applies job performance standards and workplace rules in a fair and consistent manner to all CNOOC and contractor personnel. The CNOOC Stop Work Authority is an integral part of the Safety First culture and is vital to ensuring the safety and well-being of our personnel where every individual is accountable to protect the safety and well-being of themselves, co-workers and the communities and environment in which they work. All CNOOC personnel, no matter at what level of the organization, have the authority to stop work if they determine it to be unsafe.

16.1.1.2 Competency and Training

The CNOOC Standard for Assuring Competency and Verifying Safety Critical Positions sets out corporate competency requirements. The Standard provides the basis for required functional training and competency management across the CNOOC organization for safety critical roles.

The CNOOC global drilling and completions team has a robust competency management program that aligns with the Standard. The foundation for the program is job position profile maps that identify required critical competencies. This includes regulatory, technical, and business requirements, and notably HSE/PSM training and any advanced certifications (e.g., advanced well control certification for those involved in the planning and execution of wells). All CNOOC drilling and completions personnel undergo a formal assessment based on critical competency criteria.

16.1.2 Process Safety Management

In order to protect the public, our workers and the environment, process safety hazards are minimized and controlled through the diligent application of systematic PSM practices and procedures as part of a PSM Framework. The CNOOC PSM Framework requires that the organization identify and manage risks associated with its operations. In order to comply with this requirement, CNOOC is committed to design, construct, commission, inspect, and maintain all physical assets and aspects associated with well construction, completion, intervention, and abandonment, so as to prevent, mitigate, respond and restore to a safe situation should any process safety event occur.

CNOOC's PSM Framework is based on the Center for Chemical Process Safety (CCPS) four Pillar, 20 Element Framework which is well recognized within the oil & gas industry. The four pillars (see Figure 16.1 below) include:

- *Commit to Process Safety*: Employees and contractors of companies with core values of safety will tend to do the right things, in the right ways at the right time.
- *Understand Hazards and Risks*: Understanding potential hazards and associated risk is the foundation of a risk based approach.
- *Manage Risk*: Management of risk is the ongoing execution of risk based process safety activities.
- *Learn from Experience*: Learning from experience furnishes the opportunities for improvement. Metrics including leading indicators provide a direct feedback.

16.1.2.1 Risk Management

The CNOOC PSM Hazard Identification and Risk Analysis (HIRA) element defines the methodology used to systematically identify hazards/threats, understand and evaluate the associated risk, recognize the exposures, and develop and implement controls to reduce the likelihood and/or consequence of a process safety incident/event.

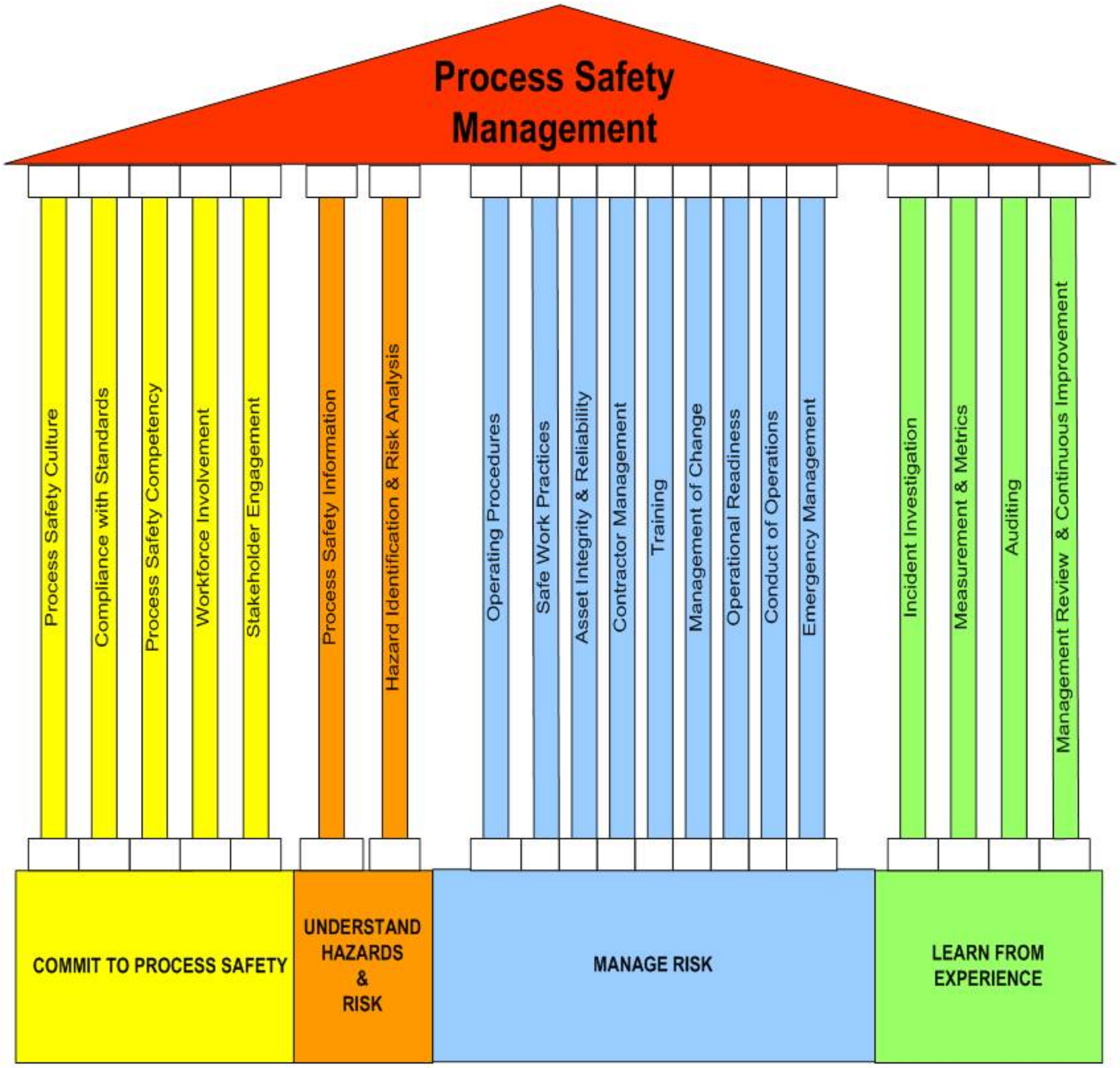


Figure 16.1 CNOOC PSM Framework

CNOOC uses the "Bow Tie" analysis method (Figure 16.2) in the assessment of major hazards and risks. The Bow Tie is comprised of the following three main components:

- *Left Side of the Bow Tie:* Barriers that prevent a hazard from becoming an incident by stopping the threat and minimizing the likelihood of an incident occurring; (e.g., well control training, kick detection system, real time pore pressure assessment);
- *Middle of the Bow Tie*: An incident/event, such as the loss of well control, or release of a hazard (e.g., an uncontrolled flow of hydrocarbons into the wellbore);
- *Right Side of the Bow Tie*: Responses and recovery measures that mitigate the incident from becoming a more severe consequence (e.g., the BOP shutting in the well as a result of an uncontrolled flow of hydrocarbons into the wellbore, Oil Spill Response Plans, capping stack deployment, relief well drilling, etc.).

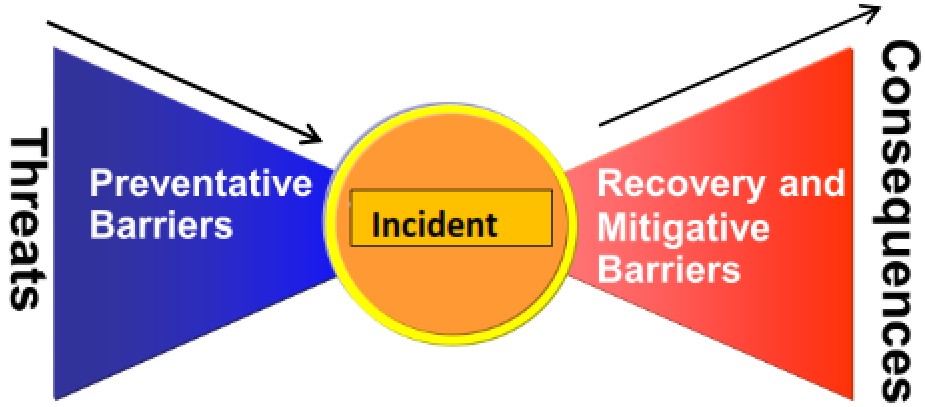


Figure 16.2 Bow Tie Analysis

CNOOC's primary focus is on prevention (left side of the Bow Tie) with the goal being to put in place sufficient barriers in order to never have to implement the response and recovery measures (right side of the Bow Tie). Increasing the number and/or quality of the prevention barriers reduces the probability of an incident occurring and increasing the number and or quality of response and recovery barriers reduces the potential consequences of such an incident, in the unlikely event it is occurrence.

16.1.2.2 Asset Integrity and Reliability

The CNOOC PSM Asset Integrity and Reliability element defines the minimum criteria and standards required for the procurement of major well work service contractors and the purchase/acquisition of equipment for drilling, completion, workover and abandonment operations for CNOOC-operated projects. An Atlantic Canada Regional Quality Plan, which will reflect the expectations of the CNOOC global governance documents, is in the process of being created. It will ensure that materials, products, tools, and equipment meet or exceed regulatory requirements, codes, specifications, standards, purchase requirements, and that they are fit for purpose. Testing and inspection schedules will be established for all equipment, with particular emphasis on well control, fluids handling and storage, and fluid transfer systems.

The MODU intake and acceptance process will be carried out in accordance with internal CNOOC requirements, which meets or exceeds industry best practices and standards as well as regulatory requirements. It will ensure that MODUs are accepted in a state of readiness to perform as intended during the contract term and function in a safe and reliable manner. This includes verification of the BOP / well control equipment.

16.1.2.3 Financial Responsibility

As part of the Authorization process CNOOC will demonstrate to the C-NLOPB that it is capable of acting in a responsible manner for the life of the proposed work or activity. This includes suitable incident response plans, clean up measures and claim payments. For offshore drilling the C-NLOPB *Guidelines Respecting Financial Requirements* (August 2017, require an Operator to demonstrate Financial Responsibility and Financial Resources.

Proof of Financial Responsibility is required to allow the C-NLOPB access to funds, if required, for incident response or reparation, in the event an operator has not taken appropriate action in response to an incident. CNOOC will provide proof of Financial Responsibility for $100 million to the C-NLOPB, which will remain in force for the duration of the work or activity for which the Authorization is issued. This will be provided through an agreed financial mechanism.

Proof of Financial Resources are required to ensure that the operator has the ability to respond to an incident, and pay for actual losses and damages incurred by any person as a result of the incident. CNOOC will demonstrate proof of the financial resources necessary to meet a liability obligation of $1 billion, by providing a Statement of Net Assets or Funding Arrangements, together with one or more of the prescribed Financial Resource documents.

16.1.3 CNOOC Global Drilling and Completions Governance

CNOOC's Management System provides overall corporate governance. CNOOC's global drilling and completion governance leverages industry best practices as well as the company's operational experience of executing drilling and completions projects globally, both onshore and offshore.

This system of governance results in control measures which reduce the risk of a well control event or release by yielding an appropriate well design (including casing, cementing, and fluids), properly specified well control equipment, robust drilling and monitoring procedures, suitably trained and competent workers, and reliable equipment.

A core element is the WDP which establishes the tasks, assurance, documentation, and other deliverables that a well project must address during the project life-cycle. There are also a number of other governance documents which set out the requirements and expectations for all of CNOOC's global well operations.

One of the CNOOC governing standards that is directly linked to the WDP is the Well Integrity Standard, the focus of which is to maintain full control of wellbore fluids at all times in order to prevent the loss of primary containment as well integrity concerns; safety of personnel; protection of the environment; the preservation of the asset; and the company's reputation. The main premise of this standard is to ensure that two independently tested well pressure barriers (or pressure containment envelopes) are available during all well activities and operations. This fundamental premise aligns with CNOOC's corporate Process Safety governance.

16.1.3.1 Well Delivery Process

The WDP is a six stage process which covers well design, planning, and execution as well as post-well review and is a CNOOC requirement to undertake the construction, modification, intervention, and/or operation of wells. The goal of the WDP is to ensure that all wells are planned, designed, and executed to meet regulatory requirements, industry and CNOOC corporate standards.

The WDP affects the entire well and project life cycle, from exploration through field development and ultimately to field abandonment. Each stage of the WDP has a set of defined tasks including HIRA activities, technical assurance, and specific deliverables and each stage ends with a decision gate prior to proceeding into the next stage of work activity.

All elements of the primary and secondary well barrier envelopes including the BOP, marine riser, drilling fluid, casing, cement, wellhead, downhole tools, etc. will be verified ahead of and monitored throughout drilling operations. As mentioned above, steel pipe or casing is installed and cemented into place to stabilize the well bore, isolate pressure/fluids and prevent drilling fluid losses prior to drilling ahead with the next hole section. The BOP is run on the marine riser pipe and is connected to the wellhead system, creating a conduit between the MODU and the well. Verification and monitoring of this equipment involves a series of pressure tests, after it is installed and at regular intervals, in accordance with company and regulatory requirements. During drilling, the formation pressure is continuously assessed and the density of drilling fluid is adjusted to overbalance the well. If this primary barrier fails, the secondary barrier elements, including the BOP system, are used to prevent the well from flowing and regain control of the well. The BOP is a safety critical piece of equipment. It is comprised of high pressure valves that prevent hydrocarbons from escaping into the environment and multiple rams that are capable of shearing the drill string and sealing the well. It is generally capable of being activated from various locations on the MODU as well as from other support vessels using secondary BOP control intervention systems.

16.1.4 Contingency Planning and Emergency Response

In the unlikely event of a spill incident, effective preparedness measures can ensure a timely and coordinated response limiting any adverse environmental effects or other consequences. CNOOC will have the necessary Emergency Response Plans (ERPs) in place to ensure a timely and effective response to potential major incidents. Although CNOOC maintains the capability to respond to an incident, the potential for additional support may be contracted with external resources or providers and integrated where relevant into the ERPs. Spill response coordination in the oil and gas industry allows the industry to access additional relevant technical assistance and response resources in the event of a major incident.

16.1.4.1 CNOOC Emergency Response Hierarchy

The CNOOC emergency response management system is based on the Incident Command System (ICS). ICS is an international, standardized on-scene emergency management system specifically designed to allow users to adopt and integrate an organization structure equal to the complexity and demands of single or multiple incidents without being hindered by jurisdictional boundaries. CNOOC has highly trained specialists and resources ready at all levels of the organization, from site and field first responders to Crisis Management teams.

For this Project, CNOOC will employ a tiered system to categorize and respond to any type of incident:

- *Tier 1*: Response is within the capability of on-site resources.
- *Tier 2:* Response is within capability of regional resources.
- *Tier 3:* Response requires both national and international resources.

Determining the appropriate tiered response level and method for response to an incident will be dependent upon several factors including, but not limited to, the type of incident, location, size or volume of spill, time of year, weather, sea state, and resource availability.

CNOOC has contractual arrangements in place that allow it to call upon various response contractors and support agencies to provide additional resources, depending on the size and scale of the incident. The specific resources or capabilities identified in an ERP will be in place prior to commencing operations. The additional resources are expected to include the following:

Tier 1 Response Resources

- Locally trained personnel and equipment onboard the MODUs, support vessels and the onshore Incident Command Post or Emergency Operations Centre (EOC).

Tier 2 & 3 Response Resources

- Regional organizations such as Eastern Canada Response Corporation (ECRC) which is certified by Transport Canada – Marine Safety, as a Response Organization under the Canada Shipping Act, 2001. ECRC was established to provide oil spill response services to companies operating in Canadian navigable waters in ECRC's geographical area of response south of the 60th parallel, including a response centre in St. John's, NL.
- International organizations such as Oil Spill Response Limited (OSRL) which is the largest international oil spill response cooperative that exists to respond to oil spills wherever in the world they may occur, by providing preparedness, response and technical advisory services.
- Specialized contractors such as Wild Well Control, which consists of various areas of expertise including: 1) Well Control which is responsible for firefighting, capping, surface and subsurface intervention; 2) Well Engineering and Technical Services which covers well modeling, risk management and response planning; and 3) Marine Well Services and Well Containment providing offshore emergency response, unconventional and platform decommissioning, subsurface intervention and containment.
- Mutual aid agreements with other oil and gas companies operating in the region.
- Government Agencies: At the provincial and federal levels of government, there are various agencies/departments that could provide regulatory oversight and advice in the event of a spill. These would include but not be limited to the C-NLOPB, Canadian Coast Guard Environmental Response Division, Environment and Climate Change Canada (Environmental Emergencies), Department of Fisheries and Oceans, Joint Rescue Coordination Centre, Transport Canada and the Government of Newfoundland and Labrador.

16.1.4.2 Emergency Response Contingency Plans

CNOOC is committed to responding to an incident with a full complement of response tools and strategies. Project specific ERPs will be developed for all critical activities contemplated for this Project including plans for all vessels and MODUs in addition to the onshore Emergency Response support teams at the local, regional and corporate level. Where necessary, bridging documents that clearly outline the requirements, interfaces and responses used among various parties will be developed for the Project. Outlined below is a list of proposed plans that will be developed for Project operations:

- *Vessel ERP*: A vessel-specific ERP that deals with managing emergency events related to the supply / support vessels used for the Project.
- *MODU ERP*: A MODU-specific ERP that outlines how various emergency teams (medical, fire, etc.) respond to and interface with the MODU EOC dealing with an emergency event related to the MODU.
- *CNOOC Onshore ERP* (St. John's): This Plan will detail CNOOC's emergency response organization, process and tactical support activities to assist the field asset (vessel or MODU) dealing with an emergency event.
- *Well Control ERP*: A regional well control ERP to reduce the potential effects of a release by preparing contingency equipment, procedures, and agreements in advance of an event and to facilitate a prompt and immediate response.
- *Oil Spill Response Plan* (OSRP): This Plan will detail CNOOC's response protocols and strategies for responding to an oil spill of any size.

Well Control ERP

As noted above, CNOOC will develop an Atlantic Canada Well Control ERP to reduce the potential effects of a release by preparing contingency equipment, procedures, and agreements in advance of an event and to facilitate a prompt and immediate response. A MODU / well specific addendum will be created for each well planned in Atlantic Canada. All of these documents will be submitted to the relevant regulatory authority (C-NLOPB) as part of the Operations Authorization process. In the unlikely event that each of the preventative barriers fail and an uncontrolled well event has occurred, where secondary BOP control intervention systems (ROV intervention, remote acoustic activation of the BOP) were unsuccessful, CNOOC would immediately commence with mobilizing multiple contingency plans, including well capping / containment and relief well operations.

The Atlantic Canada Well Control ERP will include information and procedures related to:

- Initial Organization and Operations;
- Incident Response Levels and Action Plans;
- Notification and Contacts;
- Incident Command System Overview;
- Well Control Response Progression;
- Onsite Well Control Operations Team;
- Well Control Response Organization;
- Equipment Mobilization / Logistics Plan;
- Site Survey Procedure;
- Dispersant System Deployment Procedure;
- Debris Removal Procedure;
- Capping Stack Deployment and Installation Procedure (primary and contingency capping stack);
- Capping Stack Shut-In Procedure (primary and contingency capping stack);
- Decontamination / Demobilization Procedures;
- Relief Well Planning General Guidance; and
- Well Kill Equipment and Procedures.

Well Containment Procedure (Capping Stack)

A capping stack is a contingency well isolation device used to "cap'" a well while work to permanently control it is undertaken (Figure 16.3). The capping stack is employed in the event of primary drilling BOP failure. The capping stack is mated to the primary BOP stack by connecting to the top profile of the BOP, Lower Marine Riser Package (LRMP), or wellhead using a compatible connector. Once mated, the well is isolated via sets of rams or valves, depending on the system, and the well flow is stopped or diverted to surface vessels for management and recovery. Capping stacks have been successfully deployed on land and offshore wells.

For CNOOC's Atlantic Canada wells, the plan, if necessary, would be to access a capping stack located in Montrose, UK, supplied by Wild Well Control. This capping stack is comprised of an 18-3/4 in. 15,000 psi-rated Cameron Type TL ram assemblies and a drilling spool with four 4-1/16-in. outlets, which facilitates the installation of chokes for soft shut-in operations or gooseneck assemblies for extended flow back/well kill operations. The capping stack also features chemical injection as well as internal pressure and temperature monitoring capability. The stack can be connected to a BOP or on top of a wellhead. The capping stack is deployable on either drill pipe or wire, and deployment is aided by a MODU or by crane / winch wire with quick change out of the running tool interface. CNOOC would also have access to a contingency capping stack, located in Singapore.

Figure 16.3 Example Capping Stack

CNOOC's base plan would be to transfer the capping stack directly from Montrose, UK, to the wellsite by a vessel with sufficient capability for an indirect or offset installation. The transit time will vary based on seasonal metocean conditions. The mobilization and deployment of the capping stack is expected to range from 15 to 30 days depending on weather conditions, vessel availability, and the state of the equipment (deployment system, capping stack, and BOP/wellhead). The capping stack requires a specialized support vessel with sufficient crane capacity and a specialized crew for servicing, deployment, and installation. During well operations, CNOOC will monitor and verify on a weekly basis the available vessel pool in the North Sea and maintain a list of vessels of opportunity capable of transporting and handling the capping stack.

Relief Well Contingency Plan

A relief well contingency plan will also be developed as a part of the MODU / well specific plan referenced above. Capping the well will be the primary plan to secure the well and stop the flow. A relief well may also be required to permanently eliminate the flow and would be initiated at the time of the release, in parallel with the deployment of the capping stack. The relief well would be drilled using a similar operational plan as the blown out well. The primary relief well objectives are to perform a direct intersection with the blown out well, gain hydraulic communication, and pump kill fluid from the relief well into the release well. CNOOC estimates that it could take 120 days to mobilize a relief well MODU / equipment, drill the relief well, and permanently kill the well.

Oil Spill Response Plan

Determining the appropriate tiered level and method for response to a hydrocarbon release at sea will be dependent upon several factors including, but not limited to, the type of incident involved, its location, volume of oil, oil type, time of year, weather, sea state and resource availability. Response actions will begin immediately upon the detection of a spill, provided it is safe to do so. The ability to control or eliminate the source of the spill will be a key step in limiting the volume of the spill to the marine environment. A decision analysis on the appropriate type and level of response will be conducted as soon as possible once a spill is detected. The effectiveness of any response option will be constantly evaluated throughout the entire spill response.

16.1.4.3 Potential OSRP Tactics

In order to assess the potential risks and consequences of the various response options, including chemical dispersants, as part of its pre-drilling regulatory applications, CNOOC will conduct a Net Environmental Benefits Analysis (NEBA). This assessment will allow spill responders and stakeholders to choose the best response options that will result in the maximum possible benefit and minimal potential effects to the environment. Response tools and strategies in the event of an oil spill may include, but are not limited to: mechanical recovery, surface/aerial/subsurface dispersants, in situ burning, shoreline protection and recovery, and well control.

Surveillance and Monitoring

In order to understand the extent, trajectory and behavior of any spill to help decide the most appropriate tactical response actions, one of the first priorities will be to establish appropriate surveillance and monitoring procedures. This can include observations from on the water and air resources as well as tracking using satellite spill tracker buoys. Surveillance and monitoring will provide not only the necessary information on extent, trajectory and behavior of a spill, but also help determine the effectiveness of any tactical response activities that have been implemented.

Mechanical Containment and Recovery

Offshore mechanical containment and recovery involves the use of booms to contain or corral the oil. Skimmers are then used to remove the oil from the surface of the ocean and transfer it back to a receiving tank onboard a vessel. Surveillance will also be required in order to locate and evaluate the effectiveness of this response option. MODUs and vessels will be equipped with Tier 1 response equipment such as sorbent boom which can be used to recover oil from the surface. Oil will adhere to the surface area of the boom or oleophilic material that can then be recovered back to the vessel.

Chemical Dispersion

The use of chemical dispersants as a potential response tool will also be considered as part of the above described decision analysis and ongoing response evaluations. This response option would be considered for larger, more persistent hydrocarbon releases and/or releases which have the potential to affect environmentally sensitive areas or the shoreline, or for smaller spills where it would be an effective response option. It may also be used when a release threatens the health and / or safety of personnel.

Where there is risk of harm to wildlife, coastlines or sensitive environments, the use of dispersant is often one of the most effective means of mitigating the effects of hydrocarbons in an open water environment. Effective dispersant application requires accurate spill detection. The slick location, thickness, and movement must be clearly identified and communicated to response managers and operations personnel. Dispersants do not remove the oil from the marine environment, but break it into very small droplets that mix into the upper water column, promoting rapid degradation. Dispersants may be deployed subsurface at or near the wellhead location or on the surface by vessel or aircraft.

The NEBA will help guide CNOOC and regulatory agencies as to whether or not this response tool would provide the overall greatest environmental benefit while minimizing any negative effects to the environment. CNOOC will seek regulatory approval prior to the use of any dispersants.

In Situ Burning

In situ burning is a method used to quickly reduce the volume of oil on the ocean surface where oil is burned from the ocean's surface. In this situation, fire-resistant booms are used to contain the oil, which is then set on fire in a controlled burn. This response option will require suitable environmental conditions (wind and sea state) and specialized experts to execute. CNOOC would seek regulatory approval prior to using this response option.

Natural Degradation

Natural dispersion occurs when the existing weather conditions help to disperse the oil into the water column. There are a number of different strains of bacteria in the ocean that break down the hydrocarbons into carbon and water. The marine environment has the capability to eliminate spilled oil through this long-term process of biodegradation. An important aspect to this response option will be to ensure that a monitoring/surveillance program has been established to ensure that the oil does not resurface or form emulsions.

Shoreline Protection and Clean Up Measures

In the unlikely event that oil threatens the shoreline, booms or barriers can be used to help protect sensitive areas and divert any surface oil to a suitable collection location. Should oil reach the shoreline, shoreline cleanup teams will be mobilized to assess the situation. The assessment will determine the response actions to be used to treat any oiled shoreline area, which may be different for different oiled areas. Treatment options can include, among other options, low pressure flushing, mechanical recovery, manual cleaning, soil washing, plowing, and other procedures. As with any option, monitoring and surveillance will be important to evaluate the effectiveness of this response.

Oiled Wildlife Response

In the unlikely event of a spill that affects wildlife, CNOOC will have contractual arrangements in place for expert personnel and equipment required to support an oiled wildlife response. Select personnel onboard the MODU and vessels will receive training in oiled seabird handling prior to the commencement of any drilling program. Surveillance will be required to identify the location any oiled wildlife and concentration of wildlife near the spill area. Responders may also attempt to deter fauna from affected or potentially affected areas and apply pre-emptive capture and exclusion strategies. Any oiled wildlife that can be recovered will be transported to a treatment facility for rehabilitation.

Longer Term Remediations

Depending on the nature of any spill, a remediation program may be required to ensure that any potential post spill effects have been identified, characterized and a program established until the receiving environment has been restored to an appropriate and acceptable condition. This could involve sample collection and analysis to determine the residual effects of a spill and how these can be mitigated, and eventually eliminated. This remediation program would involve consultation with key regulatory agencies and affected stakeholders to ensure a holistic/all-inclusive approach will be implemented.

16.1.5 Applicable Regulatory Requirements

In addition to CNOOC derived and implemented mitigations and precautionary approaches, an added layer of precaution comes from the various post-EA regulatory review and planning processes that will apply to this exploration drilling program (see Sections 1.3 and 1.5 for details). The regulatory review and approval processes and other requirements that apply to oil and gas activities in the Canada-NL Offshore Area are amongst the most rigorous and stringent in the world, and operators are required to demonstrate that they have the ability to undertake such activities in a safe and environmentally responsible manner through various project design measures, operational procedures, and response mechanisms. As part of its regulatory review and decision-making regarding proposed drilling programs and other activities in this jurisdiction, for example, the C-NLOPB receives and considers information from operators that detail the proposed drilling location and activities, the equipment and procedures involved, and the qualifications and training of personnel. The C-NLOPB's regulatory approval process requires, firstly, an authorization of the overall drilling program in the form of an Operations Authorization (OA), and secondly, a well approval in the form of an Approval to Drill a Well (ADW) for each well to be drilled.

CNOOC is committed to obtaining all required permits, approvals and authorizations for the proposed Project, and the company and its contractors will comply with these and all relevant regulations and guidelines in planning and implementing the proposed marine exploration program that is the subject of this EIS. This includes the various mitigations identified and committed to in the preceding sections and/or as otherwise required by relevant regulatory authorities as part of Project planning and implementation, the implementation and effectiveness of which will be directed, managed and monitored in accordance with the company's applicable policies and procedures.

16.2 Potential Accidental Event Scenarios

A Major Accident Hazard (MAH) is an unplanned event with escalation potential for multiple fatalities, substantial environmental damage, significant asset damage that may include the loss of the asset, and high negative financial and/or reputational effects. MAH events are typically high consequence – low frequency (HCLF) events, which tend to make standard risk assessment processes unsuitable due to the unlikely chance of occurrence and the potential catastrophic consequences.

CNOOC utilizes a MAH governance document for drilling and completions which describes the management of MAH events that have the potential to cause multiple fatalities, serious damage including environmental damage, and/or large financial or reputational loss. The purpose of the document is to provide a proactive and consistent approach that emphasizes the identification, prevention, mitigation, control and response of major accident hazards. It supplements the CNOOC PSM Framework. For all drilling and completions projects, a MAH Risk Register is created based on a dedicated MAH risk assessment which has the advantage of focusing on aspects of high consequence – low frequency (HCLF) events.

MAH scenarios may include but would not necessarily be limited to the following:

- Vessel collision;
- Dropped objects (onboard the MODU or subsurface);
- Loss of MODU stability or structural integrity; and
- Loss of well control results in mudline release with hydrocarbon release.

The sections below outline some of the potential causes of the MAHs listed above along with some potential safeguards and plans to mitigate the risk and control the hazard.

16.2.1 Vessel Collision

MAH: Vessel collision with MODU could result in worker injury or death, equipment loss / damage, and/or discharge to the marine environment.

Potential Causes:
- Human error;
- Procedure deficient or missing;
- Equipment failure;
- Weather / environmental conditions; and
- Unauthorized vessel.

Safeguards / Contingencies:
- Highly trained / competent personnel with appropriate certification;
- Safety zone around the MODU monitored by the MODU and standby vessel;
- Boundaries of safety zone will be communicated to mariners through a Notice to Shipping;
- Marine contractor selection process;
- Appropriate DP Class for vessels and MODU;
- MODU / vessel intake process;
- MODU / vessel specific operating criteria;

- Regular collision drills / vessel collision assessment;
- Robust positioning systems, certified watch-keepers, navigation aids, weather radars and alarms;
- 24/7 manned bridge and engine room;
- Man overboard response plan and fast rescue craft;
- Weather forecasting / precautionary riser disconnect or MODU evacuation; and
- Emergency disconnect.

16.2.2 Dropped Objects

Dropped objects include two MAHs; dropped objects on the MODU and dropped objects subsurface.

MAH: Major dropped object on the MODU could result in worker injury or death, equipment loss / damage, and/or discharge to the marine environment.

Potential Causes:

- Human error;
- Procedure deficient or missing; and
- Equipment failure.

Safeguards / Contingencies:

- Highly trained / competent personnel with appropriate certification;
- Strictly follow / enforce the vessels barrier policy for red zones / travel path to avoid sensitive areas;
- Pre-tour safety meetings, lifting assessment plans, Job Safety Analysis prior to heavy lifts;
- Minimize lifts in heavy seas. Heavy lifts are planned operations;
- Ensure manifests with load weights are available and accurate;
- Follow contractor's procedures for proper handling and storage of materials as well as proper use, inspection, and maintenance of lifting / hoisting equipment;
- Inspection of drill string, handling tools, lifting equipment, derrick components, etc.;
- Dropped object prevention scheme (DROPS) in place;
- Medical response plan and use of correct PPE; and
- Audit of shore base prior to operations.

MAH: Major dropped object subsurface in equipment loss / damage and/or a breach of well integrity and hydrocarbon release to environment.

Potential Causes:

- Human error;
- Procedure deficient or missing;
- Equipment failure; and
- Weather / environmental conditions.

Safeguards / Contingencies:

- Highly trained / competent personnel with appropriate certification;
- Riser analysis including Vortex Induced Vibration, drive off/drift off, and transit analyses;
- Riser management system;

- Periodic inspection of riser components, handling tools, hoisting equipment (especially after harsh weather event);
- MODU / vessel specific operating criteria;
- Run and pull BOP in designated safe zone;
- Follow procedures for pulling / running riser;
- Two hold points on the riser and BOP at all times;
- Keep MODU floor / moon pool clear of non-essential personnel;
- Safe handling zone identified and utilized; and
- Weather forecasting.

If transiting with riser and BOP still attached to the MODU, additional mitigations include limiting MODU transit speed, use of a BOP tracking beacon, and ROV lead to assess potential upcoming obstacles.

16.2.3 Loss of MODU Stability or Station Keeping

MAH: Loss of MODU stability or station keeping could result in worker injury or death, MODU loss or damage, and/or spill to the environment (riser evacuation or well control event).

Potential Causes:

- Human error;
- Procedure deficient or missing;
- Equipment failure;
- Structural failure;
- Extreme weather event;
- Ice accumulation on the MODU structure;
- Ballast system failure;
- Fire / explosion; and
- Vessel collision.

Safeguards / Contingencies:

- Highly trained / competent personnel with appropriate certification;
- Ballast control / positioning system manned 24/7;
- Marine safety inspection during MODU acceptance process;
- Ballast control procedures and computerized daily stability calculations;
- Ballast control drills and MODU alarms;
- Maintenance and inspection processes to test and regularly check equipment;
- Safety equipment and lifeboats to accommodate personnel onboard;
- Weak point analysis to detect potential system failure above the BOP;
- ROV intervention / Deadman auto shear back up;
- MODU classification audit / inspection;
- MODU positioning system, controls, and alarms;
- Mooring analysis (single or multi line failure);
- MODU / vessel specific operating criteria;
- Emergency disconnect protocol to shut in well and allow MODU to move off location; and
- Weather forecasting.

16.2.4 Loss of Well Control

MAH: Total Loss of Well Control results in mudline release with hydrocarbon release.

Potential Causes:

- Lack of offset well information / minimal drilling history;
- Significant uncertainty on pore pressure fracture gradient (PPFG) estimate;
- Lost circulation – loss zone / formation break down;
- Poor cement job - design and/or execution;
- Human error;
- Equipment failure;
- Inadequate well design;
- Procedure deficient or missing; and
- Loss of riser margin (drift off / drive off, riser damage, poor planning).

Safeguards / Contingencies:

- Commitment to strong well control culture by operator and drilling contractor;
- Shallow hazard survey and assessment - wells to be positioned away from potential hazards;
- Special shallow gas procedures during drilling of riserless sections;
- Real time pore pressure assessment while drilling; ensure fluid weight overbalances predicted pore pressure including a safety margin;
- Highly trained / competent personnel (operator, drilling contractor, and third party services) with appropriate level of deepwater well control training;
- Kick detection instrumentation and procedures;
- Well design / kick tolerance follows CNOOC governance;
- Well control procedures and equipment / kick plan in drilling program and posted on the MODU floor / well control drills and table top exercises;
- Inspection, testing, and maintenance of well barriers including casing, wellhead, and BOP equipment;
- Rigorous audit / assurance process for drilling contractor and tangible equipment ordered;
- BOP enabled with Autoshear and Deadman features; ROV equipped with intervention equipment to manually function the BOP;
- Maintain riser margin or ensure other mitigation for two barriers prior to disconnect; and
- Well Control / Oil Spill Response Plans.

16.2.5 Potential Spill Scenarios

Some of the risks and potential accidental events described above could result in an unplanned release of hydrocarbons, chemicals, synthetic based drill cuttings or emissions, potentially resulting in adverse environmental effects. Additionally, there are some potential operational spill events that could occur anywhere that hydrocarbons or chemicals are stored or transferred on the MODU or support vessels.

Based on a consideration of Project activities and potential environmental risk, three accidental spill scenarios were selected for detailed spill fate and behaviour modelling. These spill scenarios are considered representative of credible worst case spill scenarios that could result from an accidental event, and include:

- Diesel spills;
- Subsurface release; and
- Drill fluid (SBM) spills.

16.2.5.1 Marine Diesel Spills

Spills to the marine environment can occur during the standard and routine use, storage and movement of fuels on MODUs and supply vessels. These often comprise instantaneous or short-duration discharges into the marine environment during planned drilling activities. A large diesel spill could also occur as a result of a vessel collision and complete loss of cargo or fuel from a supply vessel.

16.2.5.2 Subsurface Release

A release is an unplanned and uncontrolled release of petroleum from a well after a failure in the drilling system and its associated pressure control barriers, resulting in the continuous discharge of hydrocarbons into the surrounding waters. Release events could potentially occur at various stages of drilling, the nature, duration, behaviour and outcomes of which depend on various factors, such as water depth, the amount and properties of the hydrocarbons involved, currents and other oceanographic features, and other factors.

16.2.5.3 Drill Fluid (SBM) Spill

Another potential spill scenario involves a spill of synthetic-based drilling muds (SBM) during drilling operations in the Project Area. SBMs are defined as drilling fluids in which the continuous phase consists of a synthetic base fluid, while the dispersed phase consists of brine and other additives. As further discussed in Section 8.3.4, SBMs have been developed as a more environmentally friendly alternative to oil-based muds (OBMs), as the synthetic fluids that comprise the continuous phase exhibit low toxicity to aquatic life and are more biodegradable in marine sediments than OBMs. These spills may occur as a result of an accidental deck release, a subsurface release through a crack or orifice in a flex joint, riser or lines, or a bottom release due to an emergency riser disconnect event (due to hazardous weather or other cause).

16.2.5.4 Potential Nearshore Accidental Events

As described in Section 2.5, the Project will include supply vessel and aircraft traffic between an existing port facility in Eastern Newfoundland (typically St. John's) and the Project Area as required throughout the duration of the Project. Supply vessels that are involved in Project activities will travel directly between the MODU operating within an EL in the Project Area and an established port facility in Eastern Newfoundland, a practice which is common in the oil and gas industry that has been active in this region for several decades. This component of the Project will therefore involve standard and relatively routine vessel traffic to and through a portion of the Eastern Newfoundland Offshore Area.

While there is some potential for an accidental event to occur during any such activity, the possibly of, and potential environmental effects that may be associated with, any such incident are very low. The supplying and off-loading of Project-related supply vessels will again occur within an existing industrial port facility, which handles vessel activity associated with multiple offshore operations and which operates in compliance with relevant legislation and regulations around materials handling, marine transits and required spill prevention and response. Similarly, vessel traffic to and from these facilities in the nearshore environment will likewise be subject to applicable regulatory requirements, including requirements for vessel pilotage as required.

There have been no known near-shore supply vessel groundings or spills over the history of oil and gas exploration in the Canada-NL Offshore Area. Given the absence of such incidents, the routine nature and limited frequency and duration of these vessel activities for this Project, the various prevention and response measures in place for these activities, and the fact that the offshore trajectory and fate model for possible batch spills showed that most released diesel is predicted to evaporate and degrade quickly (Section 16.4), with little predicted contamination, there are no plausible adverse environmental effects resulting from such a scenario. Other analysis of potential hydrocarbon spills in the near shore environment off St. John's NL have likewise indicated that such a spill event would see oil moving to the east and not contacting the shoreline (RMRI nd).

The measures to be put in place to prepare for, prevent, and respond to such a scenario are largely the same as those for offshore incidents, presented in Section 16.1. Likewise, the existing mechanisms and arrangements with response organizations for emergency response are the same as those for offshore incidents presented in that section.

The likelihood of an offshore spill reaching shore is presented in Section 16.4, and the subsequent effects (including effects on species at risk and their critical habitat, colonial nesters and concentrations of birds, and their habitat) of any such spills are presented in Section 16.6.

16.3 Spill Risk and Probabilities

16.3.1 Historical Spill Data - Canada-NL Offshore Area

Exploration and production hydrocarbon spill information for the Canada-NL Offshore Area is available from the C-NLOPB web site (C-NLOPB 2017). Figure 16.4 presents an annual inventory count of oil spills for the Canada-NL Offshore Area for the period 1997 to 2017 (updated November 2, 2017 for spills greater than 1 L; October 3 for those less than 1L) by spill size, where three categories have been defined: a) 1 L or less; b) between 1 and 7,950 L (about 50 bbl in order to generally align with the US Outer Continental Shelf threshold); and c) greater than 7,950 L.

Spills have occurred in every year since 1997. The historical total during this 21-year period is 526 spills: 269 spills less than or equal to 1 L, 249 spills of 1 L to 7,950 L, and eight spills greater than 7,950 L. Smaller spills of size less than or equal to 1 L have ranged in number from none in 1997 to 34 in 2007, with an average of 12.8 and a median of eight spills per year. Spills between one and 7,950 L have ranged in number from one in 2016 and 2017 to 38 in 1999, with an average of 11.9 and a median of nine spills per year. The eight recorded spills of over 7,950 L occurred one each in the years 2002, 2003, 2007, 2011 and 2015, and three in 2004; with a historical average of 0.4 spills of this size per year.

Figure 16.5 presents corresponding annual total spill volumes, including all spill sizes. The maximum annual spill total volume was 274,008 L in 2004 resulting from the November spill of 165,000 L of crude oil at Terra Nova due to produced water separation process failure, and the October spill of 96,600 L of SBM at White Rose due to a diverter line source. The total spill volume over the 21-year 1997-2017 period is 492,697 L, with an average of 23,462 L and a median of 5,327 L of oil spilled per year.

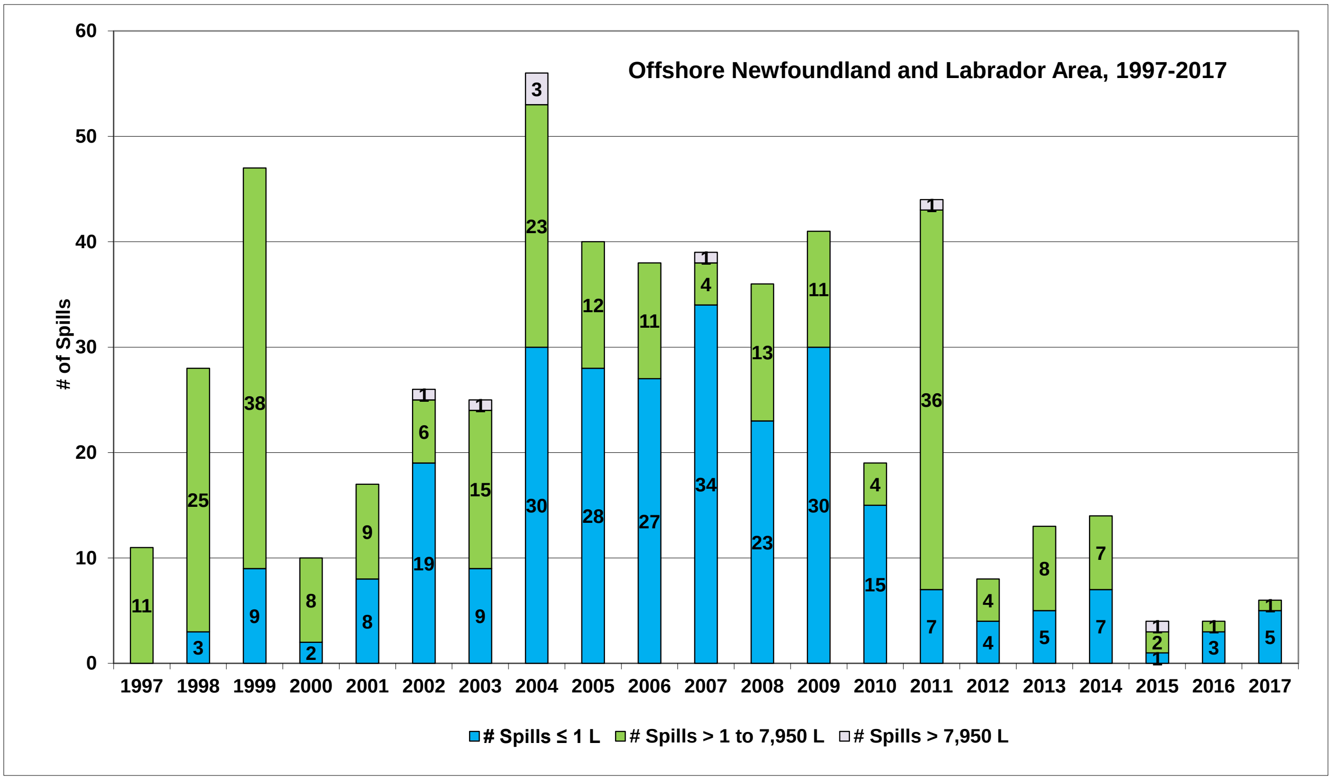


Figure 16.4 Number of Spill Incidents Canada- NL Offshore Area (1997-2017)

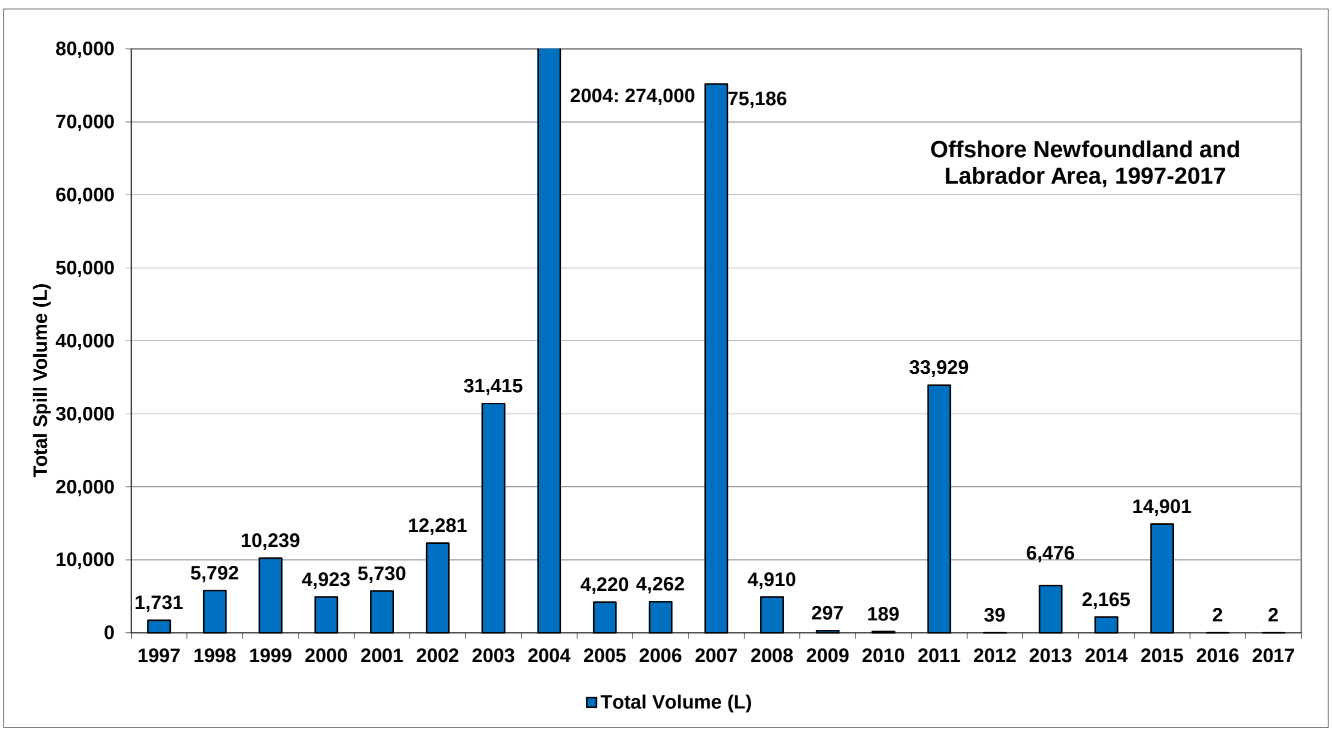


Figure 16.5 Total Spill Volume, Canada-NL Offshore Area (1997-2017)

Figure 16.6 presents a breakdown of the spill product associated with each incident for which the spill volume was greater than 1 L. As indicated, hydraulic and lubricating oil accounted for about 32 percent (82 of 257) of the spill incidents, while crude oil accounted for about 25 percent (63 incidents). Since 2011 there has been a noticeable reduction in for the number of spills and amount of oil spilled, while there are no clear trends in which types of product are spilled.

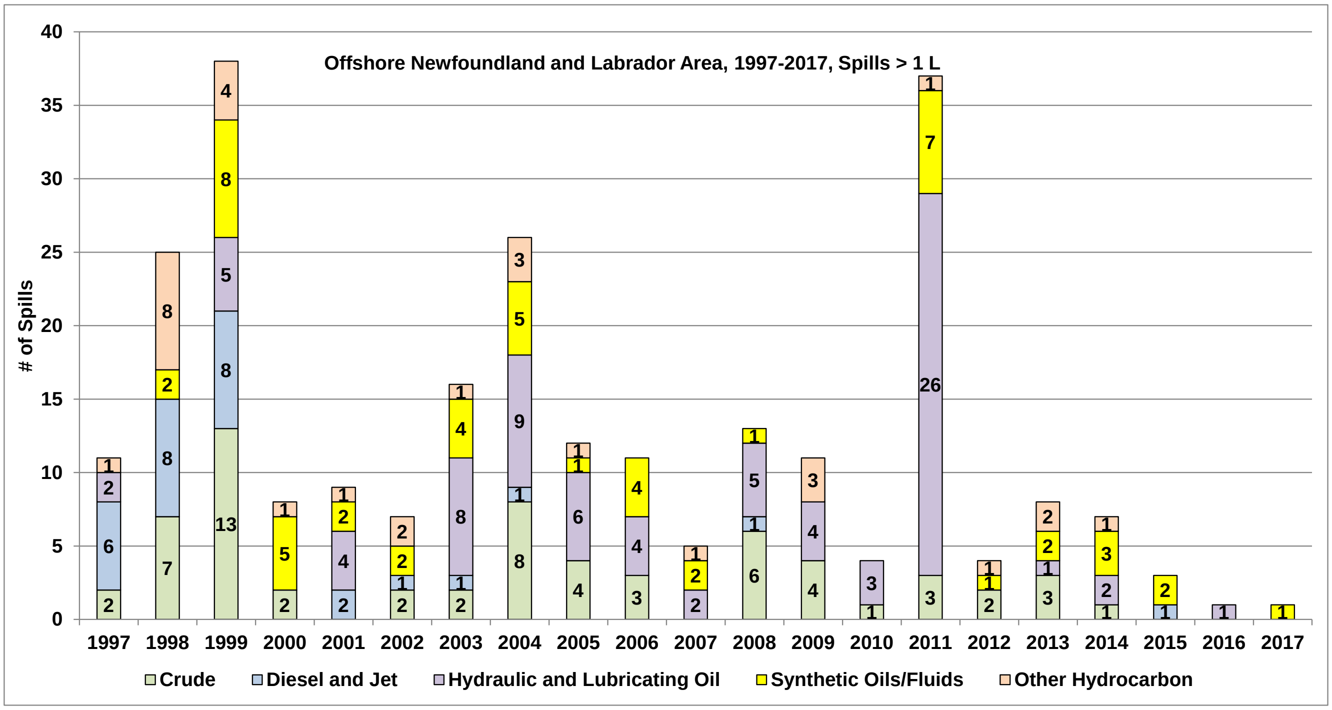


Figure 16.6 Spills by Year by Type, Canada-NL Offshore Area (1997-2017, Spills > 1 L)

The following figures present the cumulative (1997-2016) spill frequency and spill volume by type for both exploration drilling (Figures 16.7 and 16.8) and development drilling and production (Figures 16.9 and 16.10) in the Canada-NL Offshore Area, based on available C-NLOPB statistics.

For exploration drilling in the Canada-NL Offshore Area from 1997-2016, synthetic oils and fluids constituted 18.6 percent of all spill incidents, while making up 95.6 percent of the total volume of spills. For development drilling and production, synthetic oils and fluids constitute a similarly low proportion (10.6 percent) of all spill incidents, while making up 49.6 percent of the total volume of spills. Spills of crude oil in the Canada-NL Offshore Area from 1997-2016 accounted for 2.1 percent of the total volume of materials spilled during exploration drilling and 49.3 percent of spilled volumes as a result of development drilling and production activities.

Table 16.1 provides annual and overall spill statistics for exploration and production activities in the Canada-NL Offshore Area for the five-year period from 2012-2016. Over that timeframe there were from 4 to 14 spills (of any size) per year, and a total of 44 spills, which resulted in 23,578 L of SBM and all other hydrocarbons being spilled into the marine environment. The total number of spills resulting specifically from exploration activities off Newfoundland and Labrador over that five-year period is five, which collectively totalled 15,640 L of spilled material. Almost all of the material spilled during that period was comprised of SBMs, with the remaining less than one percent coming from two spills totalling 2 L of other hydrocarbons (Table 16.1).

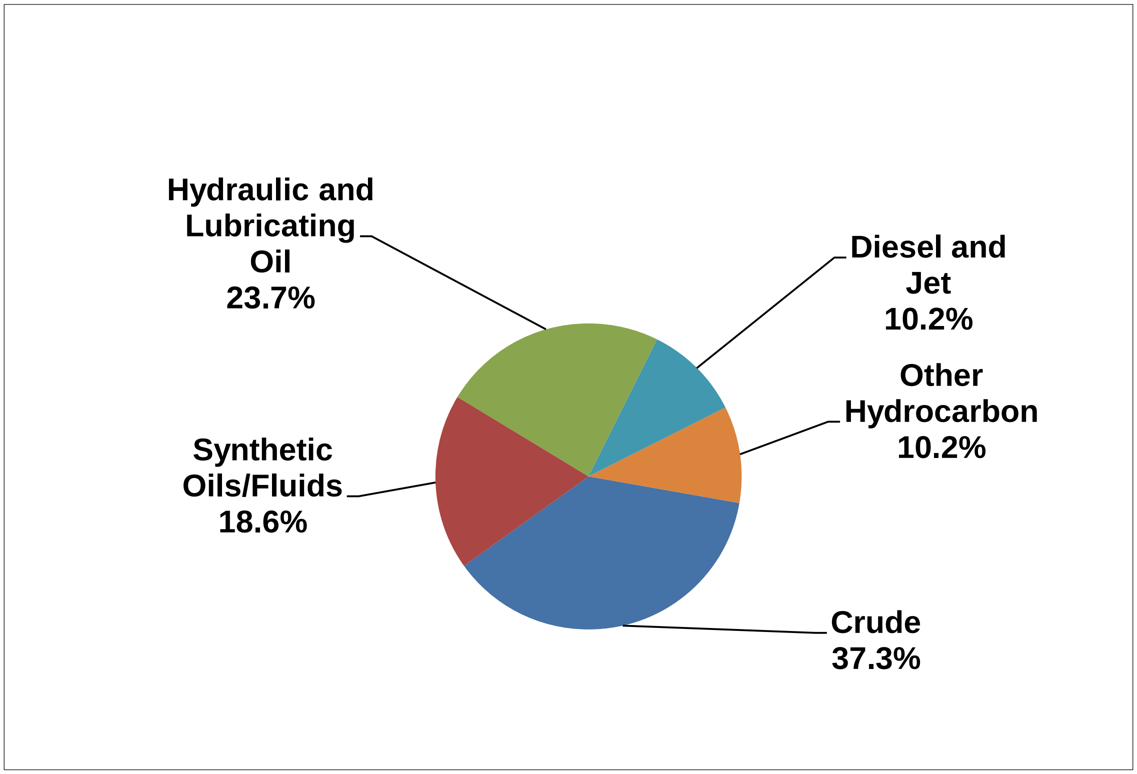


Figure 16.7 Spill Frequency by Type, Exploration Drilling - 1997-2016 (% of Incidents)

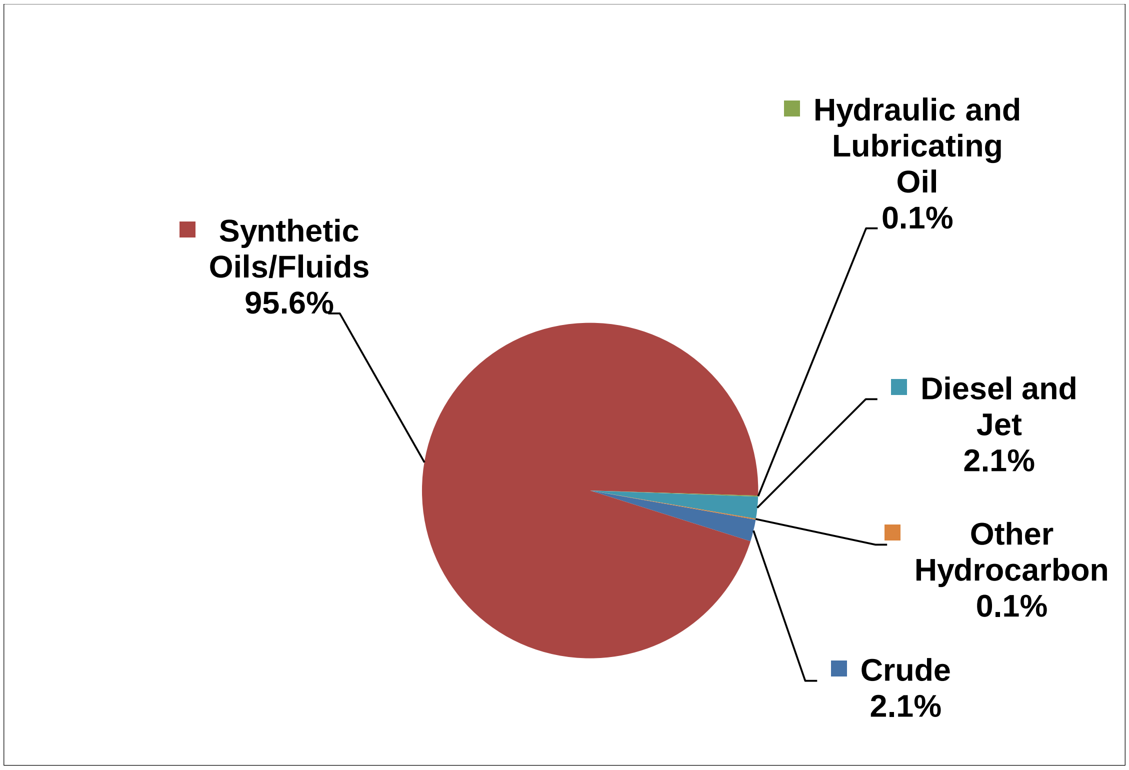


Figure 16.8 Spill Volume by Type, Exploration Drilling - 1997-2016 (% of Volume)

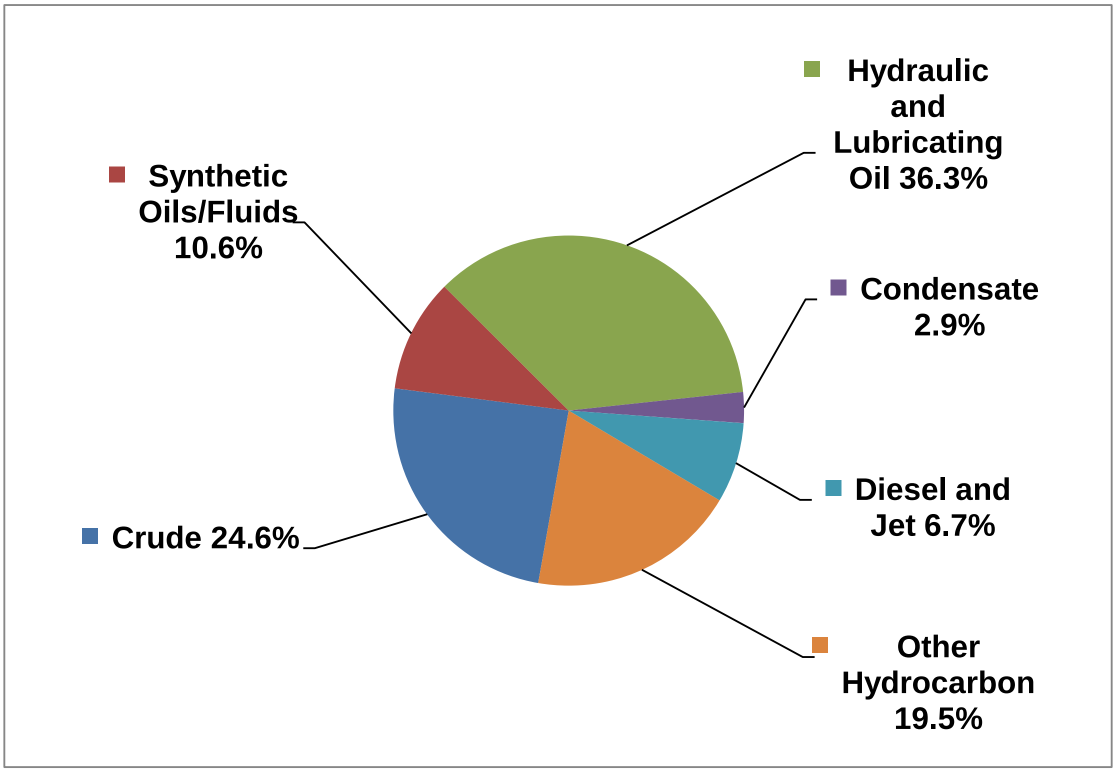


Figure 16.9 Spill Frequency by Type, Development Drilling & Production - 1997-2016 (% of Incidents)

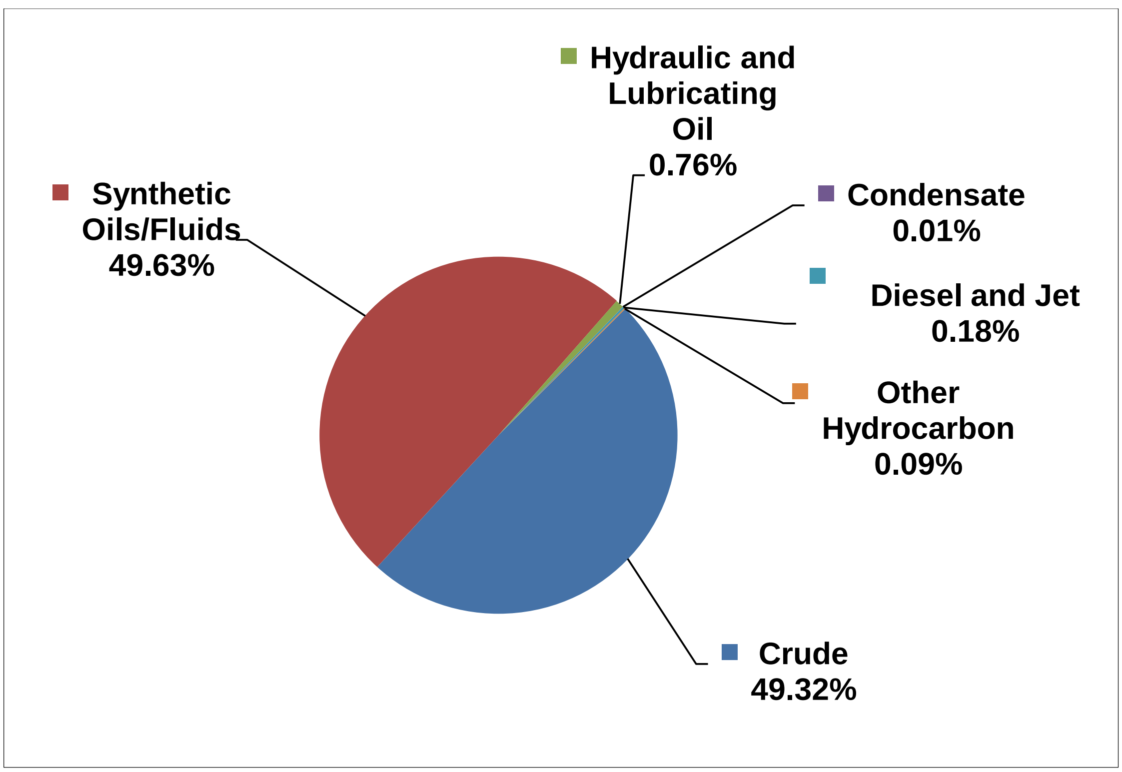


Figure 16.10 Spill Volume by Type, Development Drilling & Production - 1997-2016 (% of Volume)

Table 16.1 Exploration and Production Hydrocarbon Spill Information, Canada-NL Offshore Area (2012 – 2016)

	2012		2013		2014		2015		2016		Total 2012-2016	
	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)	Number	Volume (L)
Exploration Drilling												
Synthetic Based Drilling Fluid	1	27.70	0	0.00	1	860.0	1	14,750.00	0	0.00	3	15,637.70
All Other Hydrocarbons	0	0.00	0	0.00	0	0.00	1	0.01	1	2.00	2	2.01
TOTAL	1	27.70	0	0.00	1	860.00	2	14,750.01	1	2.00	5	15,639.71
Development Drilling and Production												
Synthetic Based Drilling Fluid	0	0.00	2	223.00	3	1,075.50	1	143.00	0	0.00	6	14,415.00
All Other Hydrocarbons	7	11.10	12	6,253.17	10	229.05	1	3.00	3	0.36	33	6,496.68
TOTAL	7	11.10	14	6,476.17	13	1,304.55	2	146.00	3	0.36	39	20,911.68
Total: Exploration and Production												
Synthetic Based Drilling Fluid	1	27.70	2	223.00	4	1,935.50	2	14,893.00	0	0.00	9	17,079.20
All Other Hydrocarbons	7	11.10	12	6,253.17	10	229.05	2	3.01	4	2.36	35	6,498.69
TOTAL	8	38.80	14	6,476.17	14	2,164.55	4	14,896.01	4	2.36	44	23,577.89
Source: Environment Statistics, Summary Information (1997-2016) Spill Frequency and Volume, C-NLOPB (2017)												

16.3.2 Calculated Probabilities of Spills from the Project

The probability and frequency of potential release and batch spills that may result from the various activities that comprise this Project were calculated based on a review of national and international records of historical offshore spill events (SL Ross 2017, see detailed report in Appendix F). The calculated oil spill probabilities and frequencies for the Project, expressed on a per well drilled basis, are summarized In Table 16.2.

Table 16.2 Calculated Oil Spill Probabilities and Frequencies

Event	Spill Probability (Spills Per Well Drilled)	Spill Frequency
Release (All Types)[1]		
Deep release during exploration drilling	3.10×10^{-4}	1 per 3,226 wells
Release Resulting in Large Spill[2]		
Extremely Large (> 150,000 bbl)	3.92×10^{-5}	1 per 25,510 wells
Very Large (> 10,000 bbl)	7.84×10^{-5}	1 per 12,755 wells
Large (> 1,000 bbl)	9.80×10^{-5}	1 per 10,204 wells
Non-Release Batch Spill of Petroleum[3]		
Large (> 1,000 bbl)	6.33×10^{-5}	1 per 15,787 wells
Medium (50 to 999 bbl)	3.34×10^{-3}	1 per 298 wells
Small (1 to 49.9 bbl)	1.45×10^{-2}	1 per 69 wells
Very Small (<1 bbl)	1.50	1 per 0.67 wells
SBM Spills[4]		
Large (> 1,000 bbl)	-	-
Medium (50 to 999 bbl)	2.33×10^{-2}	1 per 2,100 wells
Small (1 to 49.9 bbl)	8.33×10^{-2}	1 per 12 wells
Very Small (<1 bbl)	0.17	1 per 5.9 wells

[1] Based on exploration wells drilled to North Sea Standard, 1985 to 2005.
[2] Based on world-wide release spills from exploration drilling, all time.
[3] Large and medium spill data based on U.S. OCS exploration drilling, 1980 to 2011; small spill data based on Newfoundland and Labrador exploration and delineation drilling, 2000 to 2016; very small spill data based on Newfoundland and Labrador exploration, delineation and production drilling, 2000 to 2016.
[4] Based on Newfoundland and Labrador exploration, delineation and production drilling, 1997 to 2016

As noted, the highest potential frequencies are for the smaller, operational spills. Spills less than one barrel in size (less than 159 litres) may occur one to two times per well, based on recent petroleum development experience off Newfoundland and Labrador. Although these smaller spills may occur more often, the median volume is four litres. Historical spill records for very small spills do not differentiate between production and exploration activities, and so the probability of very small spills during exploration activities may be overestimated. Batch oil spills during exploration drilling that are larger than one barrel but less than 50 barrels have about a 1-in-70 (1.43 percent) chance of occurring per well. Oil spills in the 50 to 999 barrel range may have about a 1-in-300 (0.33 percent) chance of occurring per well, based on experience in the U.S. Outer Continental Shelf (OCS). There is about a 1-in-3,200 (0.03 percent) chance per well of having any sort of release. (i.e., liquid or gas) during normal drilling, after the release preventer is installed.

The chances of an extremely large (greater than 150,000 barrel), very large (greater than 10,000 barrel), and large (greater than 1,000 barrel) oil well release during exploration drilling are very small: about a 1-in-25,000 (0.004 percent), 1-in-13,000 (0.008 percent) and 1-in-10,000 (0.01 percent) chance per well, respectively. It should also be noted that due to the infrequency of these occurrences, these predictions are based on worldwide data, and are strongly influenced by releases that occurred in parts of the world where drilling regulations may be less rigorous than those in the Canada-NL Offshore Area, and in most cases occurred prior to modern safety improvements.

16.4 Fate and Behaviour of Potential Oil Spills

In order to assess the fate and behavior of potential spill scenarios, RPS (2018, 2019) conducted trajectory and fate modelling related to potential hypothetical exploration wells at EL 1144 and EL 1150 (example wells). Modelling and analyses were performed to help support and give context to the accidental events effects assessment reported in this section. To be conservative, the oil spill modelling did not include consideration of mitigations such as response procedures.

16.4.1 Locations and Scenarios

As noted in Section 16.2, several oil spill scenarios were modelled to capture the potential range of scenarios listed in Tables 16.3 and 16.4. Two hypothetical release locations of different water depths were used for modelling subsurface releases, including one site in each of EL 1144 and 1150 (see Figure 8.2).

The example well site locations were selected to represent the potential range of credible drilling scenarios. The criteria used included: reservoir type and properties; administrative boundaries (e.g., licence area boundaries); and the physical environment (e.g., potential range of water depths, proximity to more sensitive areas, potential range of ocean currents). The sites were placed on either side of the Flemish Pass with one example well as deep water and deep reservoir depth and one example well as shallower water and shallower reservoir depth.

Table 16.3 Modelled Spill Scenarios for EL 1144 and EL 1150 Example Well Sites

Hypothetical Spill Location	Depth of Release	Release Duration	Release Rate (bbl/d)	Model Duration	Number of Model Runs	Released Product	Release Type	Release Volume
EL 1144	1,137 m	30 days	184,000	60 days	119**	BdN	Subsurface or Subsea Release	5,520,000 bbl
EL 1150	378 m		44,291					1,329,000 bbl
EL 1144	1,137 m	120 days	184,000	160 days	171***			22,080,000 bbl
EL 1150	378 m		44,291					5,314,920 bbl
EL 1144	Surface	Instantaneous		30 days	2	Marine Diesel	Batch Spills	100 L & 1,000 L
VCL*					1		Vessel Collision	750,000 L

* The Vessel Collision Location (VCL) represents the midpoint between St. John's, Newfoundland and the Project Area
**119 model runs consisted of 59 winter and 60 summer for each site
***171 model runs consisted of 81 winter and 90 summer for each site

Table 16.4 Selected Representative Deterministic Scenarios

Scenario Parameter	Release Parameters for Representative Deterministic Scenarios								
	95th Percentile – EL 1144 Example Well			**95th percentile – EL 1150 Example Well**			**Marine Diesel Releases**		
Representative Scenario	Surface Oil Exposure Area	Water Column Oil Mass	Shoreline Contact Length*	Surface Oil Exposure Area	Water Column Oil Mass	Shoreline Contact Length	Small Volume	Large Volume	Full Tank Release
Release Site	EL 1144			EL 1150			EL 1144		VCL
Release Type	**Subsurface or Subsea Release (Capping Stack Scenario) – RPS (2018)**						Bunkering		Supply Vessel Collision
Depth of Release	1,137 m			378 m			Surface		
Released Product	BdN			BdN			Marine Diesel		
Release Rate	184,000 bbl/day			44,291 bbl/day			n/a		
Release Duration / Model Duration	30d / 60d			30d / 60d			Instantaneous/ 30d		
Total Release Volume	5,520,000 bbl			1,328,730 bbl			100 L	1,000 L	750,000 L
Modelled Start Date and Season	06/13/2006 Summer	03/22/2008 Winter	10/2/2008 Summer	04/20/2007 Summer	12/03/2006 Winter	No Shore Contact	6/15/2009 summer (calmest site-specific period identified between 2006-2010)		6/14/2009 summer (calmest site-specific period identified between 2006-2010)
Release Type	**Subsurface or Subsea Release (Relief Well Scenario) – RPS (2019)**								
Depth of Release	1,137 m			378 m					
Released Product	BdN			BdN					
Release Rate	184,000 bbl/day			44,291 bbl/day					
Release Duration / Model Duration	120 d/160 d			120 d/160 d					
Total Release Volume	22,080,000 bbl			5,314,920 bbl					
Modelled Start Date and Season	10/22/2009 Winter	06/19/2012 Summer	03/7/2006 Summer	02/5/2008 Winter	05/28/2009 Summer	07/22/2006 Summer			
*The 99th percentile shoreline contact length case was identified for analysis for the 30 day release cap-stack scenario as the 95th percentile case resulted in no shoreline oiling.									

The EL 1144 location was a deeper Jurassic example well and the EL 1150 location was a shallower Cretaceous example well. Releases near the seafloor (subsurface or subsea release) were modelled separately with OILMAPDeep and SIMAP at each example well location in a stochastic analysis that included 119 individual model runs per location for the 30-day release scenarios and 171 individual model runs for the 120-day release scenarios. This analysis investigated the influence of environmental variability, throughout the year over multiple years, on trajectory and fate. Results from stochastic analyses were broken into two seasons depending on the majority of modelled days during ice free conditions (summer) from May – October or periods with ice-cover (winter) from November – April. Analysis of representative deterministic scenarios were conducted for individual trajectories that were identified as the 95th percentile for surface oil exposure, contact with shoreline, and water column contamination from releases near the seafloor modelled in the stochastic analysis, as well as for instantaneous surface "batch spills" of marine diesel. Two hypothetical release locations were used for the modelling of the batch spills and a vessel collision scenario; the surface batch spills were modelled at the EL 1144 example well site and the Vessel Collision Location (VCL) spill was modelled at the midpoint between St. John's, NL and the Project Area.

16.4.2 Overall Modelling Approach

Stochastic modelling provides a probabilistic view of the likelihood that a given region might be exposed to released hydrocarbons over specified thresholds given the range of possible environmental conditions that may occur within and across multiple years. A deterministic analysis then provides a view of the time history of the specific movement and behavior of released product from a given (e.g., representative) individual release. Together, these methods provide a comprehensive analysis of both the likelihood and degree of potential exposure. Both modelling approaches are discussed below and give complementary information that helps to frame the potential exposure regime for the environmental effects assessment of the hydrocarbon spill scenarios.

16.4.2.1 Stochastic Approach

The modelling studies (RPS 2018, 2019) employed a stochastic approach to determine the range of potential trajectories and fates of hypothetical hydrocarbon releases based upon the variable forcing conditions (e.g. wind and currents). In order to reproduce the natural variability of winds and currents, the model requires both spatially- and temporally-varying datasets. Historical observations and models of multiple-year wind and current records were used to perform the simulations within the coinciding time period. These datasets allow for reproduction of the natural variability of the wind and current speeds and directions. Optimally, the minimum time window for stochastic analysis is at least five years so that various weather patterns from year to year are represented. Using wind and current data from throughout this long time period, a sufficient number of model runs will adequately sample the variability in the time sequences of wind and current speeds and directions in the region of interest and result in a prediction of the probable oil pathways for a release at the prescribed location. 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.

The region where the initial momentum of the discharge and the buoyancy flux dominates the mixing process is referred to as the near-field region of the model. As the plume moves away from the discharge source, the characteristics at the source become less important and the ambient conditions have more influence on the fate of the discharge plume. This is referred as the far-field region. These near-field plume dynamics include the location and size of the subsea 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. Hypothetical release scenarios were simulated using two three-dimensional trajectory and fate models developed by RPS to capture both the near-field and far-field region; the OILMAPDeep and SIMAP modelling packages. OILMAPDeep was used to define the near-field dynamics of the subsurface release plume which was then used as the initial conditions for the far-field modelling conducted in SIMAP. These models are described in detail in the RPS 2018 and RPS 2019 oil spill modelling reports.

SIMAP was used 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 placed upon one another to create a cumulative footprint of releases. Further analyses provide two types of information for specific thresholds of interest (Tables 16.5 and 16.6) including:

1) the probability that a given area may experience oil exposure, 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. Figures and further analyses include the lower socioeconomic thresholds of concern calculated from stochastic results.

It is important to note that although relatively large footprints of oil contamination are depicted for stochastic analyses, they are not the expected distribution of oil from any single release. These maps do not provide any specific information on the quantity of oil in a given area. They simply denote the probability of oil exceeding the given threshold passing through each grid cell location in the model domain over the entire model duration (60 days or 160 days), based on the entire ensemble of runs (119 or 171 individual releases for both locations). Only probabilities of greater than or equal to one percent were included in the map output, as lesser probabilities represent random noise in each set of trajectories. Stochastic maps of water column contamination of dissolved hydrocarbons depict the likelihood that concentrations will exceed the identified threshold at any depth within the water column, but do not specify the depth at which this occurs and do not imply that the entire water column (i.e., from surface to bottom) will experience a concentration above the threshold.

In addition to their use in Environmental Assessments, stochastic results are useful in helping plan any required oil spill response, as they characterize the probability that regions may experience contamination above specified thresholds, taking into account the natural variability (i.e., winds, currents, etc.) that is expected from many potentially-different release scenarios over time.

Table 16.5 Thresholds Used to Define Areas and Volumes Exposed Above Levels of Concern

Threshold Type	Cutoff Threshold	Rationale/Comments (Socioeconomic, Response, Ecological)	Visual Appearance	References
Oil Floating on Water Surface	0.04 g/m² (~0.04 µm)	*Socioeconomic*: A conservative threshold used in several risk assessments to determine effects on socioeconomic resources (e.g., fishing may be prohibited when sheens are visible on the sea surface). Socioeconomic resources and uses that would be affected by floating oil include commercial, recreational and subsistence fishing; aquaculture; recreational boating, port concerns such as shipping, recreation, transportation, and military uses; energy production (e.g., power plant intakes, wind farms, offshore oil and gas); water supply intakes; and aesthetics.	Fresh oil at this minimum thickness corresponds to a slick being barely visible or scattered sheen (colorless or silvery/grey), scattered tarballs, or widely scattered patches of thicker oil.	French McCay et al, (2011); French McCay et al (2012); French McCay (2016); Lewis (2007), Bonn Agreement
	10 g/m² (~10 µm)	*Ecological*: Mortality of birds on water has been observed at and above this threshold. Sublethal effects on marine mammals, sea turtles, and floating Sargassum communities are of concern.	Fresh oil at this thickness corresponds to a slick being a dark brown or metallic sheen.	French et al, (1996); French McCay (2009) (based on review of Engelhardt, 1983, Clark, 1984, Geraci and St. Aubin 1988, and Jenssen 1994 on oil effects on aquatic birds and marine mammals); French McCay et al (2011); French McCay et al (2012); French McCay (2016)

Threshold Type	Cutoff Threshold	Rationale/Comments (Socioeconomic, Response, Ecological)	Visual Appearance	References
Shoreline Oil	1.0 g/m²	*Socioeconomic/Response:* A conservative threshold used in several risk assessments. This is a threshold for potential effects on socioeconomic resource uses, as this amount of oil may trigger the need for shoreline cleanup on amenity beaches, and affect shoreline recreation and tourism. Socioeconomic resources and uses that would be affected by shoreline oil include recreational beach and shore use, wildlife viewing, nearshore recreational boating, tribal lands and subsistence uses, public parks and protected areas, tourism, coastal dependent businesses, and aesthetics.	May appear as a coat, patches or scattered tar balls, stain	French-McCay et al (2011); French McCay et al (2012); French McCay, (2016)
	100 g/m²	*Ecological***:** This is a screening threshold for potential ecological effects on shoreline flora and fauna, based upon a synthesis of the literature showing that shoreline life has been affected by this degree of oiling. Sublethal effects on epifaunal intertidal invertebrates on hard substrates and on sediments have been observed where oiling exceeds this threshold. Assumed lethal effects threshold for birds on the shoreline.	May appear as black opaque oil.	French et al, (1996); French McCay (2009); French McCay et al, (2011); French McCay et al, (2012); French McCay, (2016)
In Water Concentration	1.0 ppb (µg/L) of dissolved PAHs; corresponds to approximately 100 ppb (µg/L) of whole oil (THC) in the water column (soluble PAHs are approximately 1% of the total mass of fresh oil)	Water column effects for both ecological and socioeconomic (e.g., seafood) resources may occur at concentrations exceeding 1 ppb dissolved PAH or 100 ppb whole oil; this threshold is typically used as a screening threshold for potential effects on sensitive organisms.	N/A	Trudel et al (1989); French-McCay (2004); French McCay (2002); French McCay et al (2012)

Threshold Type	Cutoff Threshold	Rationale/Comments (Socioeconomic, Response, Ecological)	Visual Appearance	References
*Thresholds used in supporting stochastic results figures. For comparison, a bacterium is 1-10 µm in size, a strand of spider web silk is 3-8 µm, and paper is 70-80 µm thick. Oil averaging 1 g/m² is approximately equivalent to 1 µm ** Parts per Billion (PPB), Total Hydrocarbon Concentration (THC), and Polycyclic Aromatic Hydrocarbons (PAHs)				

Table 16.6 Defined Ecological and Socioeconomic Thresholds for Oil Related Environmental Effects

Oil Type	Ecological Threshold	Socioeconomic Threshold
Surface Oil	10 g/m^2	0.04 g/m^2
Shoreline Oil	100 g/m^2	1 g/m^2
Water Column Oil	1 ppb dissolved PAH or 100 ppb whole oil.	

Note: Oil averaging 1 g/m² is approximately equivalent to 1 µm

16.4.2.2 Deterministic Approach

While the stochastic analysis provides insight into the probable behavior of oil releases given historic meteorological and oceanographic data for the Project Area, the deterministic analysis provides individual trajectory, oil weathering information, expected concentrations or thicknesses of oil contamination, mass balance, or other information related to a single release at a given location and time.

Representative deterministic scenarios (i.e., single trajectory) were identified from each set of stochastic subsurface release results. Individual scenarios were selected based upon the size of the surface oil footprint, the mass of oil on shorelines, and the concentration of dissolved hydrocarbons in the water column, based upon a set of highly conservative socioeconomic thresholds:

- Surface oil average thickness >0.04 µm;
- Shore oil average concentration >1.0 g/m^2; and
- Subsurface (within the water column) dissolved hydrocarbon concentrations >1.0 µg/L.

The selected scenarios included the 95th and 99th percentile runs for surface oil footprint, shoreline oil length, and water column contamination were identified for both release locations when appropriate. Because there was no oil predicted on the shoreline in the 95th percentile case for the 30-day cap and stack scenarios (RPS 2018), the 99th percentile scenario for shoreline oil mass was used in the investigation. The 120-day relief well scenarios have oil predicted at the shoreline for the 95th percentile (RPS 2019). In addition to these deterministic scenarios, three surface releases of marine diesel were modelled, including two batch spill release volumes (100 L and 1,000L) at the EL 1144 example well site and a full volume release of a supply vessel fuel tank (750,000 L) mid-way between St. John’s and the Project Area (RPS 2018).

16.4.3 Model Input Data

Geographical data including habitat mapping and shoreline identification and classification were obtained from multiple data sources as summarized in Table 16.7. In addition, the hydrocarbon products that were modelled for this study (marine diesel for the batch spill and the vessel collision and Bay du Nord (BdN) crude oil for the well release events) are characterized in Table 16.8.

The physical and chemical data used to characterize these oils were developed by CNOOC in consultation with other operators, with additional assays and measurements by S.L. Ross Environmental Research Ltd. (2016) and Petroforma (2013).

BdN is a light crude oil with low viscosity and a high aromatic content (Tables 16.8 and 16.9). The marine diesel modelled is a standard diesel that also has a low viscosity and high content of soluble hydrocarbons. The low viscosity and high soluble content of these oil products provides conservative approximations of anticipated concentrations in the water following a release, as a relatively large proportion of constituents have the potential to dissolve into the water column, when compared to oils with lower soluble content. The physical and chemical parameters of BdN are similar to those of Hibernia crude oil, which was used in previous studies (SL Ross 2016; Environmental Science and Technology Center 2001). These oils would likely behave similarly in the event of a release, with marine diesel being least persistent.

Table 16.7 Model Input Data

Data Type	Data Source	Notes
Oil Type	SL Ross (2016)	BdN Light Crude
Habitat Shoreline	Therrien. (2017) (Canada) NOAA (2016) and MDEP (2016) (US)	
Bathymetry	GEBCO (2003)	
Ice Cover	CIS, ECCC (2017)	206 to 2010 weekly files from Canadian Ice Service
Wind Data	Saha et al. 2010	
Currents	HYCOM	Hybrid Coordinate Ocean Model hindcast and forecast
Water Temperature and Salinities	Levitus et al. (2014)	World Ocean Dataset

Table 16.8 Physical Properties for the Two Oil Products Used in Modelling

Physical Property	BdN Crude Oil	Marine Diesel
Density (g/cm^3)	0.84553 @16°C 0.85800 @0°C	0.83100 @25°C 0.83089 @16°C
Viscosity (cP)	5.0 @20°C 53.0 @0°C	2.76 @25°C 2.76 @15°C
API Gravity	35.85	38.8
Pour Point (°C)	-9	-50
Interface Tension (dyne/cm)	15.5	27.5
Emulsion Maximum Water Content (%)	72	0

Table 16.9 Fraction of the Whole Oil Comprised of Different Distillation Cuts for the Two Oil Products

Distillation Cut[1]	Boiling Point (°C)	Description	BdN Crude Oil	Marine Diesel
AR1	< 180	Highly volatile and soluble monoaromatic hydrocarbons (BTEX[2] and MAHs C6-C9)	0.023739	0.019333
AR2	180 – 264	Semi-volatile and soluble 2-ring aromatics (MAHs and PAHs C10-C12)	0.004166	0.011410
AR3	265 – 380	Low volatility and solubility 3-ring aromatics (PAHs C13-C18)	0.066998	0.015605
AL1	< 180	Highly volatile aliphatics (C4-C8)	0.206261	0.144667
AL2	180 – 280	Semi-volatile aliphatics (C9-C16)	0.160834	0.478690
AL3	280 – 380	Low volatility aliphatics (C17-C23)	0.168002	0.303295
THC1[3]	< 180	Total hydrocarbon fraction 1 (sum of AR1 and AL1)	0.230000	0.164000
THC2	180 – 280	Total hydrocarbon fraction 2 (sum of AR2 and AL2)	0.165000	0.490100
THC3	280 – 380	Total hydrocarbon fraction 3 (sum of AR3 and AL3)	0.235000	0.318900
Residuals	> 380	Aromatics ≥ 4 rings and aliphatics > C20 that are neither volatile nor soluble	0.37000	0.02700

[1]Note that the terms “aromatic” and “aliphatic” are used in a modelling context. “Aromatic” refers to all soluble and volatile hydrocarbons and may include actual aliphatic compounds in the chemical sense that are soluble. In the modelling context, “aliphatic” refers to insoluble and volatile hydrocarbons.
[2]BTEX (benzene, toluene, ethylbenzene, xylene), MAHs (monocylic aromatic hydrocarbons), and PAHs (polycyclic aromatic hydrocarbons) are the more soluble, bioavailable, and potentially toxic components in oil
[3] Note that the total hydrocarbon concentration (THC) is the sum of the aromatic (AR) and aliphatic (AL) groups. Numbers of carbons in the included compounds are listed.

16.4.4 Model Results

The results from both the subsurface/subsea releases and topside releases 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. Stochastic figures again do not imply that the entire contoured area would be covered with oil in the event of a release, nor do they provide any specific 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 or 171 individual releases for the annual scenario), at all modelled time steps (over 60 or 160 days), and for each point within the modelled domain. Note that only probabilities of greater than or equal to one percent were included in the map output.

16.4.4.1 Summary of Stochastic Results (30- and 120-day release scenarios)

A total of 119 (30-day capping stack; RPS 2018) and 171 (120-day relief well; RPS 2019) individual model runs were conducted for the statistical analysis for each modelled release at the EL 1144 and EL 1150 example well sites, representing subsea releases (30-day and 120-day) in waters offshore of Newfoundland. Two 30-day releases and two 120-day releases were modelled at the EL 1144 (1,137 m water depth) and EL 1150 (378 m water depth) example well sites to represent capping stack response scenarios (30 day release modelled for a total of 60 days) and the relief well scenarios (120 day release modelled for a total of 160 days). The largest areas are presented in this section (Table 16.10 and 16.11), but details on all runs are available in RPS (2018, 2019).

Summaries of the stochastic analyses of potential surface oil exposure and water column contamination by dissolved hydrocarbons for both the 30-day and 120-day scenarios depict areas with the highest potential likelihood (over 90 percent) to exceed thresholds primarily to the east and south of the release sites. Much lower probabilities of threshold exceedance are predicted to the north and east (Figures 16.11 to 16.23). For the 30-day scenarios, releases were predicted to have potential effects on Canadian and international waters. The 120-day scenarios similarly included Canadian and international waters but also includes US and Portuguese EEZs. In many cases, oil contamination above the identified threshold was predicted to extend beyond the extent of the model domain to the east and south. In these scenarios, the environmental forcing mechanisms (i.e., wind and currents) and long timeframes modelled (up to 160 days) allowed for the transport of highly weathered oil outside of the model domain.

30-Day Release - The hypothetical 30-day release at the EL 1144 example well site was predicted to lead to a larger stochastic surface oil probability footprint, where oil may exceed the 0.04 μm thickness threshold in over one percent of releases, when compared to the release at EL 1150 example well site (Table 16.10) due to the larger release volume (5,520,000 bbl at EL 1144 vs. 1,329,000 bbl at EL 1150). The over 90 percent probability footprints threshold exceedances were predicted to extend to the south and east of EL 1144 example well site approximately 300-600 km for surface oil and 800-1,200 km for in water contamination (Figures 16.11 to 16.13). For EL 1150, the surface oil extents were closer to 200-400 km and in water contamination closer to 400-800 km (Figure 16.14 to 16.17). Predicted threshold exceedance footprints were typically similar in size for each release location between seasons, however the surface oil exceedance was larger in the summer, due to calmer winds resulting in less entrainment and therefore more surface oil (Table 16.10). The larger release volume at the EL 1144 example well site resulted in larger surface oil and in water contamination predictions than the EL 1150 example well site. The EL 1144 example well site is located closer to shore than the EL 1150 example well site and was therefore predicted to result in a very small probability (less than three percent) of shoreline oil contamination at Sable Island within 60 days (Table 16.10; Figure 16.13). Releases at the EL 1150 example well site were not predicted to make contact with the shore (Figures 16.16 to 16.17).

In general, model results were very similar for the EL 1144 example well site, when compared to the EL 1150 example well site, especially for the lowest probability contours. However, the hypothetical releases at the EL 1144 example well site were deeper, farther offshore, and had a release volume that was over four times larger than those at the EL 1150 example well site, resulting in much larger predicted areas for the 10 percent and 90 percent likelihood of threshold exceedance (Table 16.10).

120-day Release – The hypothetical 120-day release at the EL 1144 example well site was predicted to lead to a larger stochastic surface oil probability footprint, where oil was predicted to exceed the 0.04 μm thickness threshold in >1% of releases, when compared to the release at the EL 1150 example well site (Table 16.11). The difference in the size of the predicted footprints was due to the larger release volume of 22,080,000 bbl associated with the modelled release at the EL 1144 example well site, when compared to the 5,314,920 bbl release modelled at the EL 1150 example well site. Note that the conservative 0.04 μm surface oil thickness threshold is an average surface oil thickness over the modelled grid cell that corresponds with an observed surface slick that would be both patchy and discontinuous within the region. The >90% probability footprints for surface oil threshold exceedances were predicted to extend approximately 2,000 km to the south and east of the EL 1144 example well site for surface oil and 1,200-1,500 km for in water contamination, with respective total areas of 2,236,000 km2 and 133,600 km2 (Figures 16.18 through Figure 16.20; Table 16.11). For the EL 1150 example well site, the >90% probability of surface oil extents were predicted to be closer to 2,000 km to the east with a total area of 2,069,000 km^2, and water column contamination extents reached closer to 500-600 km with a total area of 23,960 km^2 (Figure 16.21 through Figure 16.23; Table 16.11). Predicted differences between the seasonal threshold exceedance footprints were minor for each example release location, with a slightly larger surface oil exceedance for >90% footprints in the summer, due to calmer winds, which resulted in less entrainment and therefore more surface oil (Table 16.11). Shoreline oiling probabilities were predicted to be higher along the Canadian coast and the Azores with a release at the EL 1144 example well site, which was located closer to shore than the EL 1150 example well site (Figure 16.18 through Figure 16.20 and Figure 16.21 through Figure 16.23). Shoreline oiling probabilities from both example well site releases are highest along the Azores in the summer, due to prevailing westerlies, while probabilities were highest along the Canadian coast in the winter, due to more variable winds during winter storms. General findings for the lowest probability contours were very similar for the EL 1144 and EL 1150 example well sites. This is representative of the same underlying metocean conditions providing information on the presence or absence of oil. However, the hypothetical releases at the EL 1144 example well site had a release volume that was over four times larger than that of the EL 1150 example well site, resulting in much larger predicted areas with between 10% and 90% likelihood that a threshold would be exceeded (Table 16.11 and Table 16.12).

As stated previously, 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 each area. The large threshold exceedance footprints in annual results are not the expected exposure from any single release of oil, but rather areas where there is over one percent probability that exposure above the threshold could occur, based on the combination of either annual, summer, or winter individual releases analyzed together. Any oil that was predicted to make contact with shorelines would be expected to be highly weathered, as minimum time estimates for first shoreline oil exposure ranged from approximately 15-53 days (Table 16.12). The oil that did make its way to shore would therefore likely be patchy and discontinuous. Oil from the subsea releases was transported by subsea currents, which had a higher potential to transport subsea oil to the west and southwest prior to surfacing than did surface currents.

Table 16.10 Predicted Areas Exceeding the Identified Thresholds for Surface Oil Thickness, Water Column Concentration, and Mass per Unit Area on Shorelines for the EL 1144 and EL 1150 Example Well Sites (30-day Release)

Stochastic Scenario Parameters				Areas Exceeding Threshold (km^2)		
Component and Threshold	**Scenario**	**Example Well Site**	**Probability Contour or Bin**	**Annual Results**	**Winter (ice cover)**	**Summer (ice-free)**
Surface Oil > 0.04 µm, on average	30-day release	EL 1144 (184,000 bpd)	1%	1,942,000	2,102,000	1,927,000
			10%	1,140,000	1,115,000	1,145,000
			90%	56,100	24,750	128,300
		EL 1150 (44,291 bpd)	1%	1,783,000	1,945,000	1,776,000
			10%	849,200	789,900	899,300
			90%	16,750	10,180	51,470
Water Column Dissolved Hydrocarbons > 1 µg/L at some depth within the water column	30-day release	EL 1144 (184,000 bpd)	1%	223,600	215,100	2,346,000
			10%	162,000	171,900	1,513,000
			90%	32,950	26,810	456,000
		EL 1150 (44,291 bpd)	1%	210,100	225,000	203,500
			10%	146,000	155,800	136,200
			90%	18,550	10,610	28,790
Shoreline Oil > 1 g/m^2, on average	30-day release	EL 1144 (184,000 bpd)	1 - 5%	9	18	-
			5 - 15%	-	-	-
			15 - 35%	-	-	-
		EL 1150 (44,291 bpd)	1 - 5%	-	-	-
			5 - 15%	-	-	-
			15 - 35%	-	-	-
Bins are based on stochastic probabilities; for example, 56,100 km^2 of the ocean surface exceeded the 0.04 µm surface oil threshold in 90% of the 119 modelled simulations over the entire modelled duration						

Table 16.11 Predicted Areas Exceeding the Identified Thresholds for Surface Oil Thickness, Water Column Concentration, and Mass per Unit Area on Shorelines for the EL 1144 and EL 1150 Example Well Sites (120-day Release)

Stochastic Scenario Parameters				Areas Exceeding Threshold (km²)		
Component and Threshold	**Scenario**	**Example Well Site**	**Probability Contour or Bin**	**Annual Results**	**Winter (ice cover)**	**Summer (ice-free)**
Surface Oil > 0.04 µm, on average	120-day release	EL 1144 (184,000 bpd)	1%	8,211,000	8,371,000	8,339,000
			10%	7,003,000	7,208,000	6,657,000
			90%	2,236,000	2,205,000	2,532,000
		EL 1150 (44,291 bpd)	1%	8,152,000	8,309,000	8,304,000
			10%	6,733,000	6,877,000	6,483,000
			90%	2,069,000	2,053,000	2,328,000
Water Column Dissolved Hydrocarbons > 1 µg/L at some depth within the water column	120-day release	EL 1144 (184,000 bpd)	1%	726,800	763,600	709,200
			10%	468,000	468,800	463,800
			90%	133,600	130,900	149,700
		EL 1150 (44,291 bpd)	1%	280,700	315,800	120,200
			10%	128,800	139,200	87,810
			90%	23,960	24,620	25,530
Shoreline Oil > 1 g/m², on average	120-day release	EL 1144 (184,000 bpd)	1 - 5%	8,211,000	8,371,000	8,339,000
			5 - 15%	7,003,000	7,208,000	6,657,000
			15 - 35%	2,236,000	2,205,000	2,532,000
		EL 1150 (44,291 bpd)	1 - 5%	8,152,000	8,309,000	8,304,000
			5 - 15%	6,733,000	6,877,000	6,483,000
			15 - 35%	2,069,000	2,053,000	2,328,000
Bins are based on stochastic probabilities; for example, 2,236,000 km² of the ocean surface exceeded the 0.04 µm surface oil threshold in 90% of the 171 modelled simulations over the entire modelled duration						

Table 16.12 Shoreline Contamination Probabilities and Minimum Time for Oil Exposure Exceeding 1 g/m²

Scenario	Example Well Release Site	Scenario Timeframe	Average Probability of Shoreline Oil Contamination (%)	Maximum Probability of Shoreline Oil Contamination (%)	Minimum Time to Shore (days)	Maximum Time to Shore (days)
All Shorelines						
30-day release	EL 1144 (184,000 bpd)	Annual	2	2	52	54
		Winter	2.5	3	53	54
		Summer	-	-	-	-
	EL 1150 (44,291 bpd)	Annual	-	-	-	-
		Winter	-	-	-	-
		Summer	-	-	-	-
All Shorelines						
120-day release	EL 1144 (184,000 bpd)	Annual	1	63	15	146
		Winter	1	48	15	160
		Summer	1	77	34	160
	EL 1150 (44,291 bpd)	Annual	9	56	15	141
		Winter	9	41	15	159
		Summer	19	70	51	160
Labrador, Canada						
120-day release	EL 1144 (184,000 bpd)	Annual	2	2	83	130
		Winter	2	2	83	160
		Summer	1	1	159	159
	EL 1150 (44,291 bpd)	Annual	2	2	68	136
		Winter	3	3	68	156
		Summer	1	1	159	160
Azores, Portugal						
120-day release	EL 1144 (184,000 bpd)	Annual	36	36	61	83
		Winter	27	27	45	111
		Summer	44	44	51	103
	EL 1150 (44,291 bpd)	Annual	32	32	45	89
		Winter	20	20	45	115
		Summer	26	26	51	110

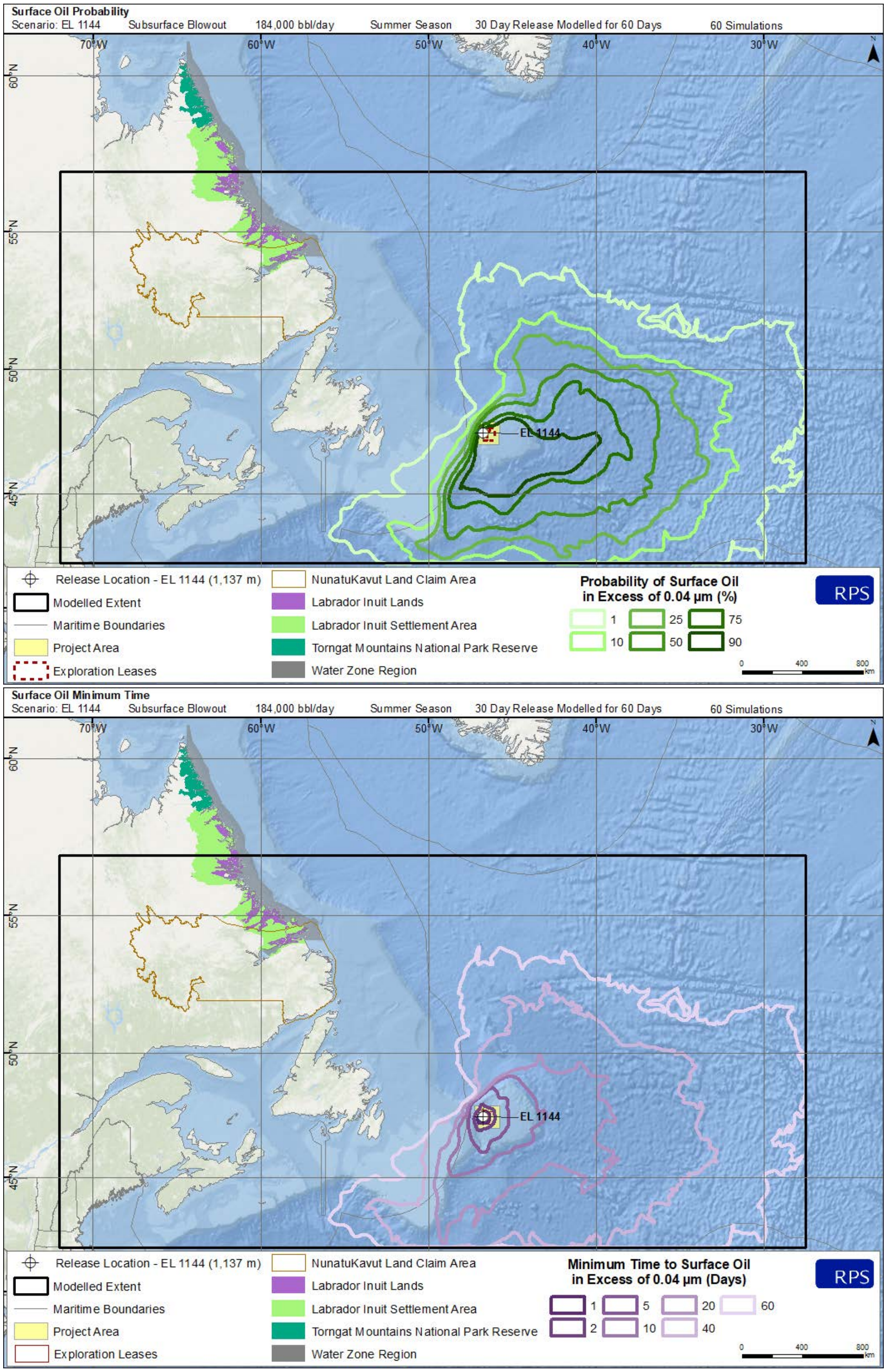
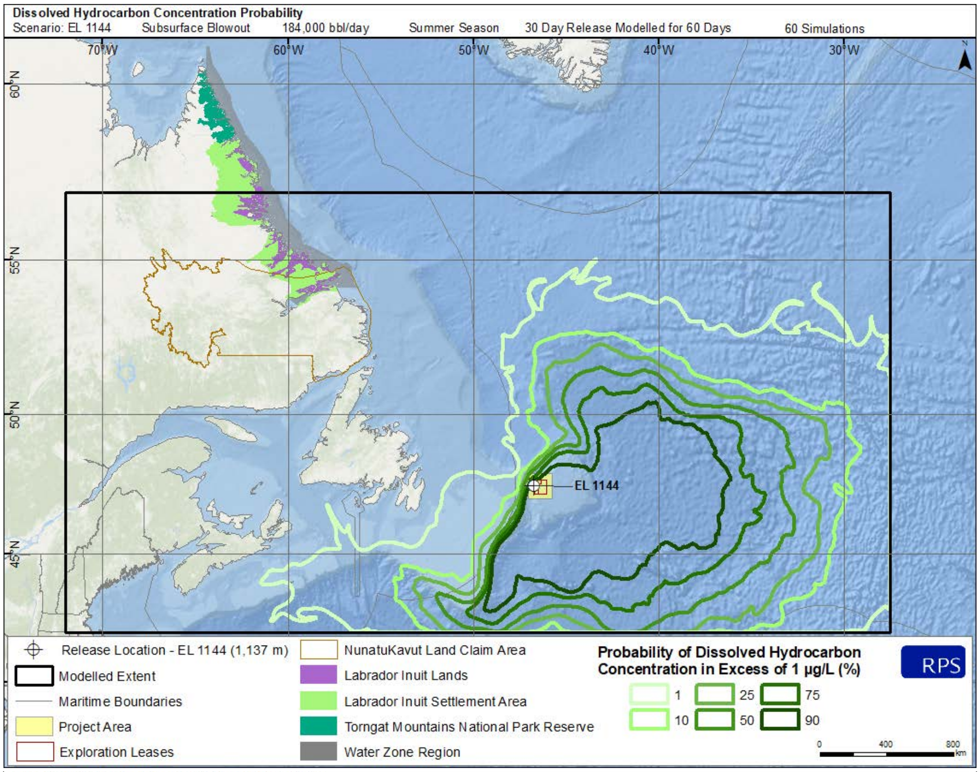


Figure 16.11 Summer Probability of Average Surface Oil Thickness >0.04 µm (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 30-Day Subsurface/Subsea Release at the EL 1144 Example Well Site



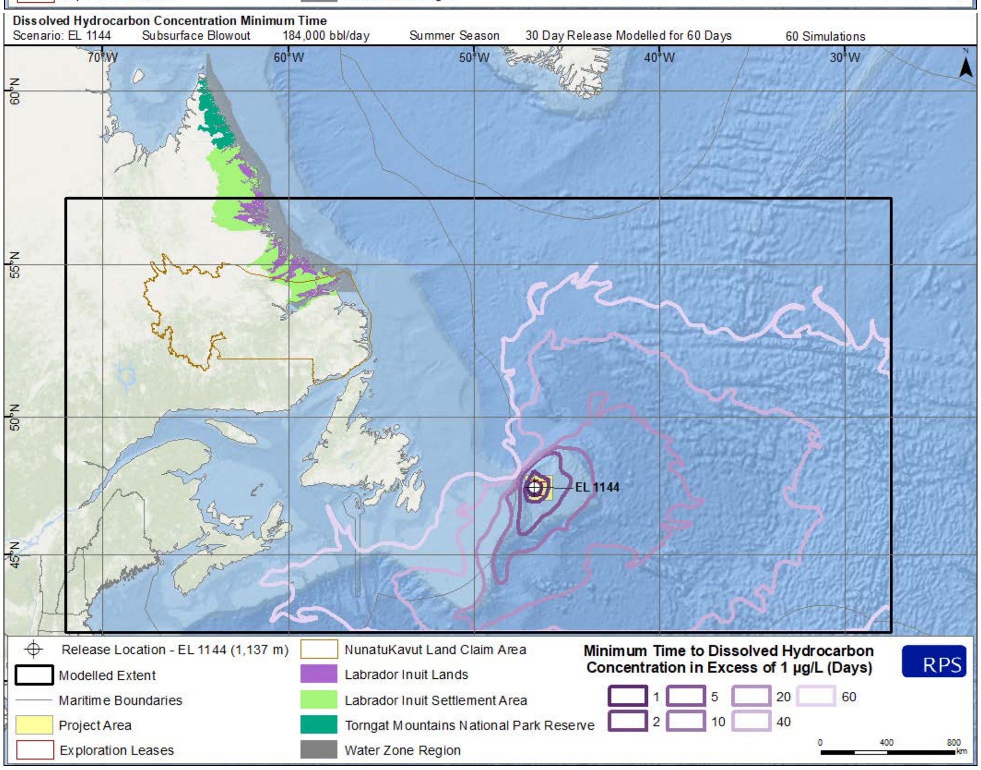


Figure 16.12 Summer Probability of Dissolved Hydrocarbon Concentrations >1 µg/L at Some Depth in the Water Column (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 30-Day Subsurface/Subsea Release at the EL 1144 Example Well Site

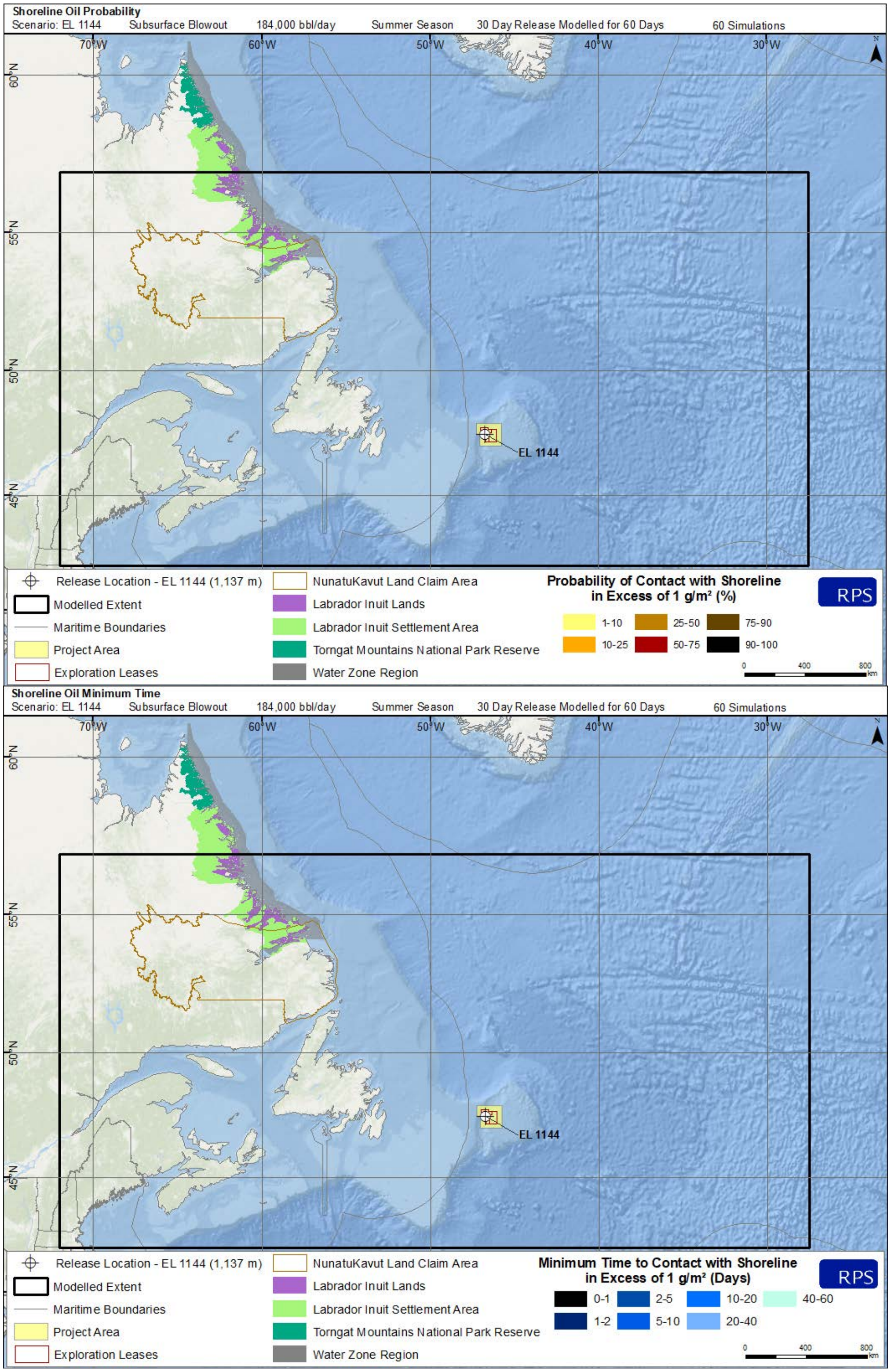
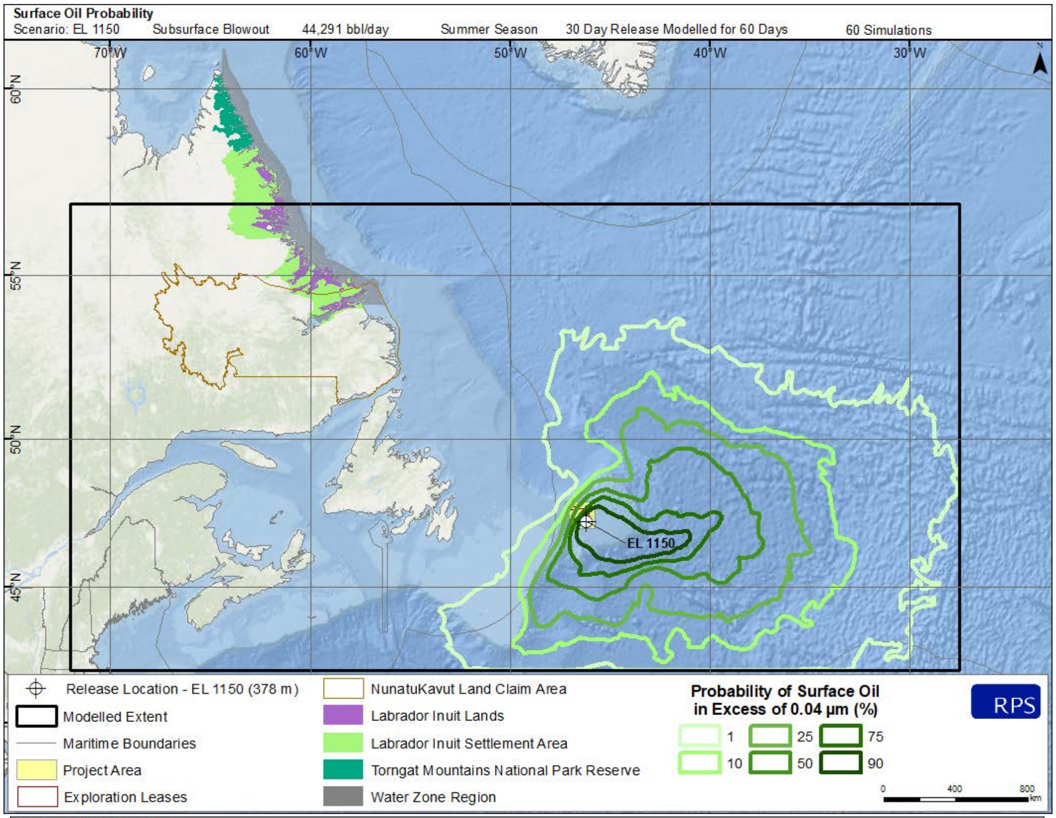


Figure 16.13 Summer Probability of Shoreline Contact >1 g/m² (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 30-Day Subsurface/Subsea Release at the EL 1144 Example Well Site



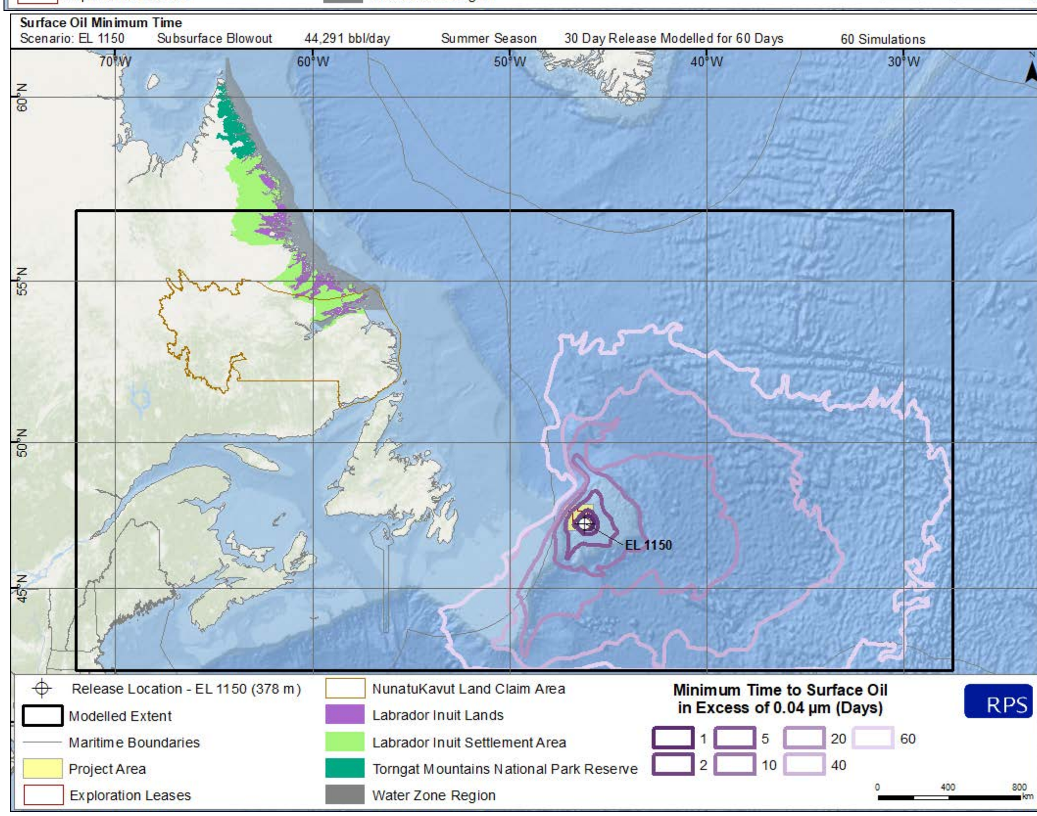


Figure 16.14 Summer Probability of Average Surface Oil Thickness >0.04 µm (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 30-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

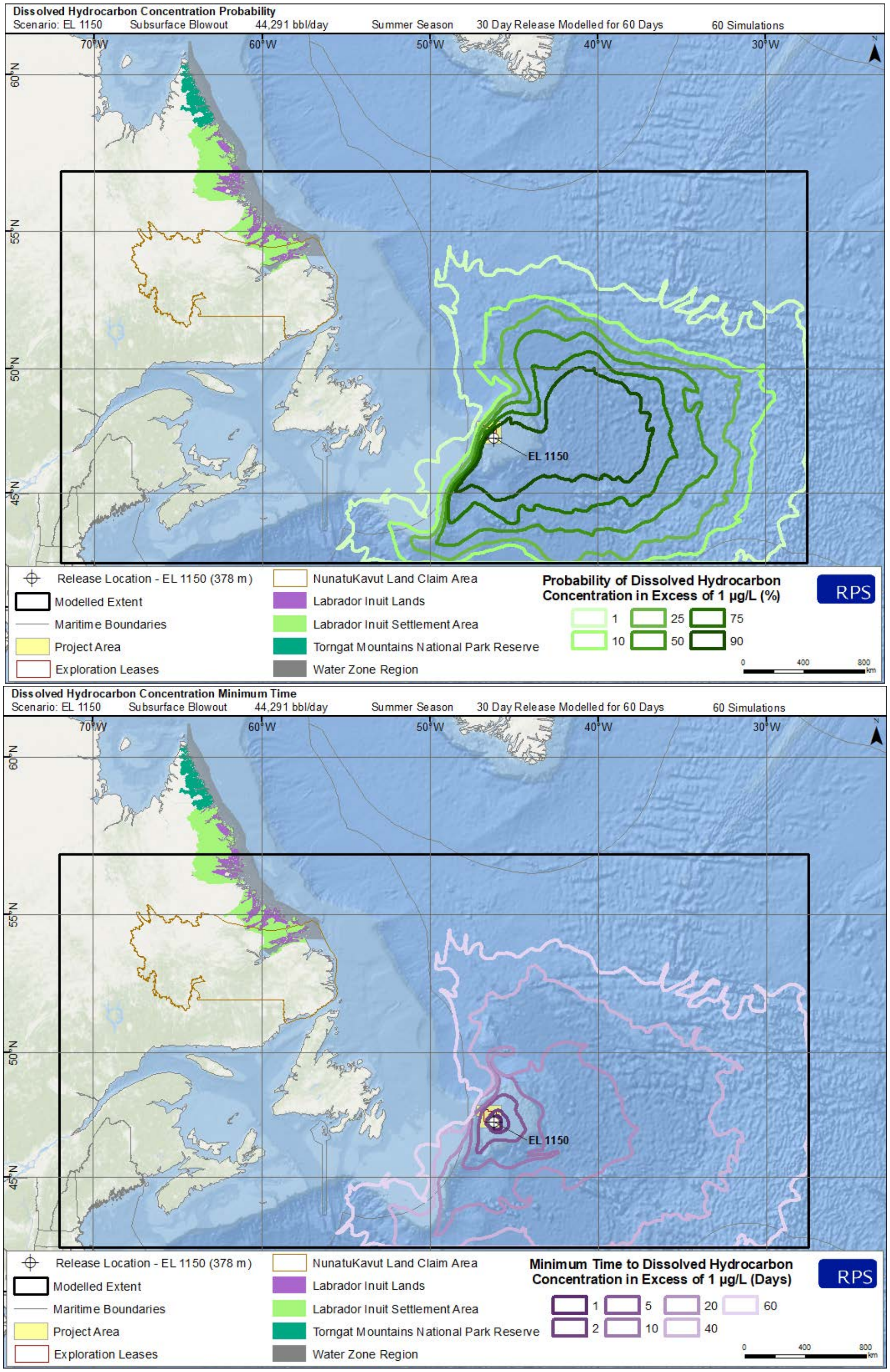


Figure 16.15 Summer Probability of Dissolved Hydrocarbon Concentrations >1 µg/L at Some Depth in the Water Column (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 30-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

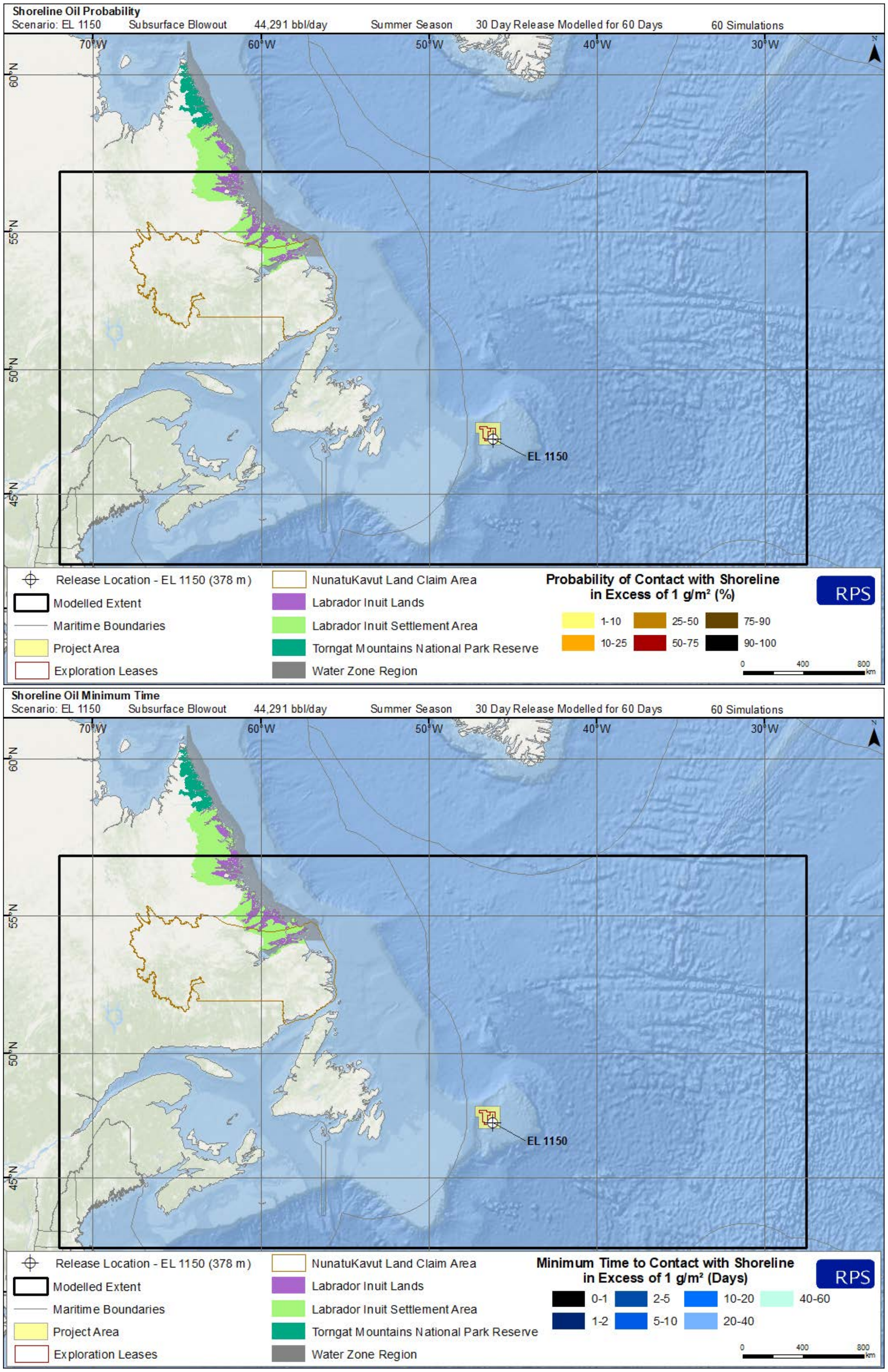


Figure 16.16 Summer Probability of Shoreline Contact >1 g/m^2 (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 30-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

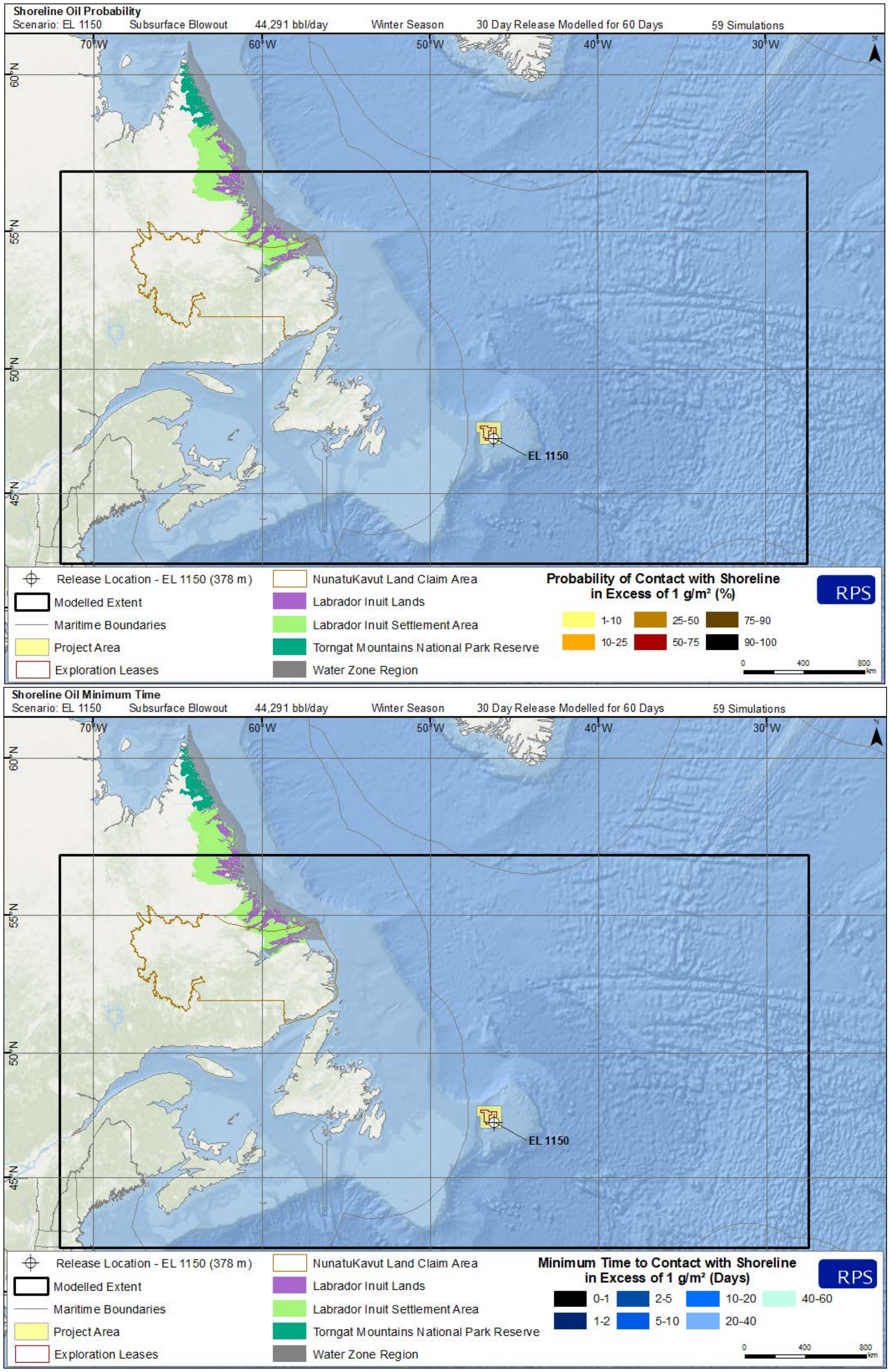


Figure 16.17 Winter Probability of Shoreline Contact >1 g/m^2 (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 30-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

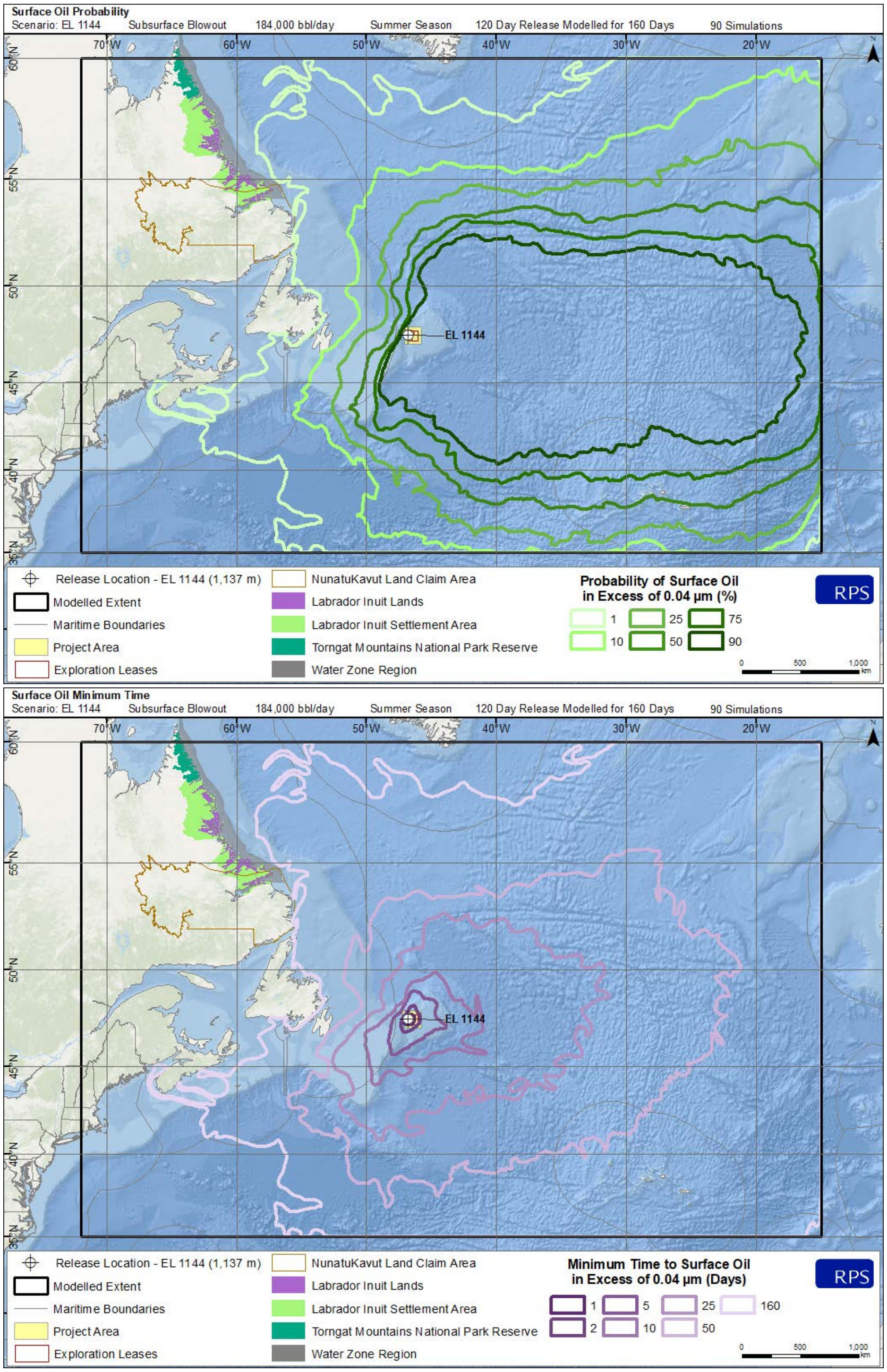


Figure 16.18 Summer Probability of Average Surface Oil Thickness >0.04 µm (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 120-Day Subsurface/Subsea Release at the EL 1144 Example Well Site

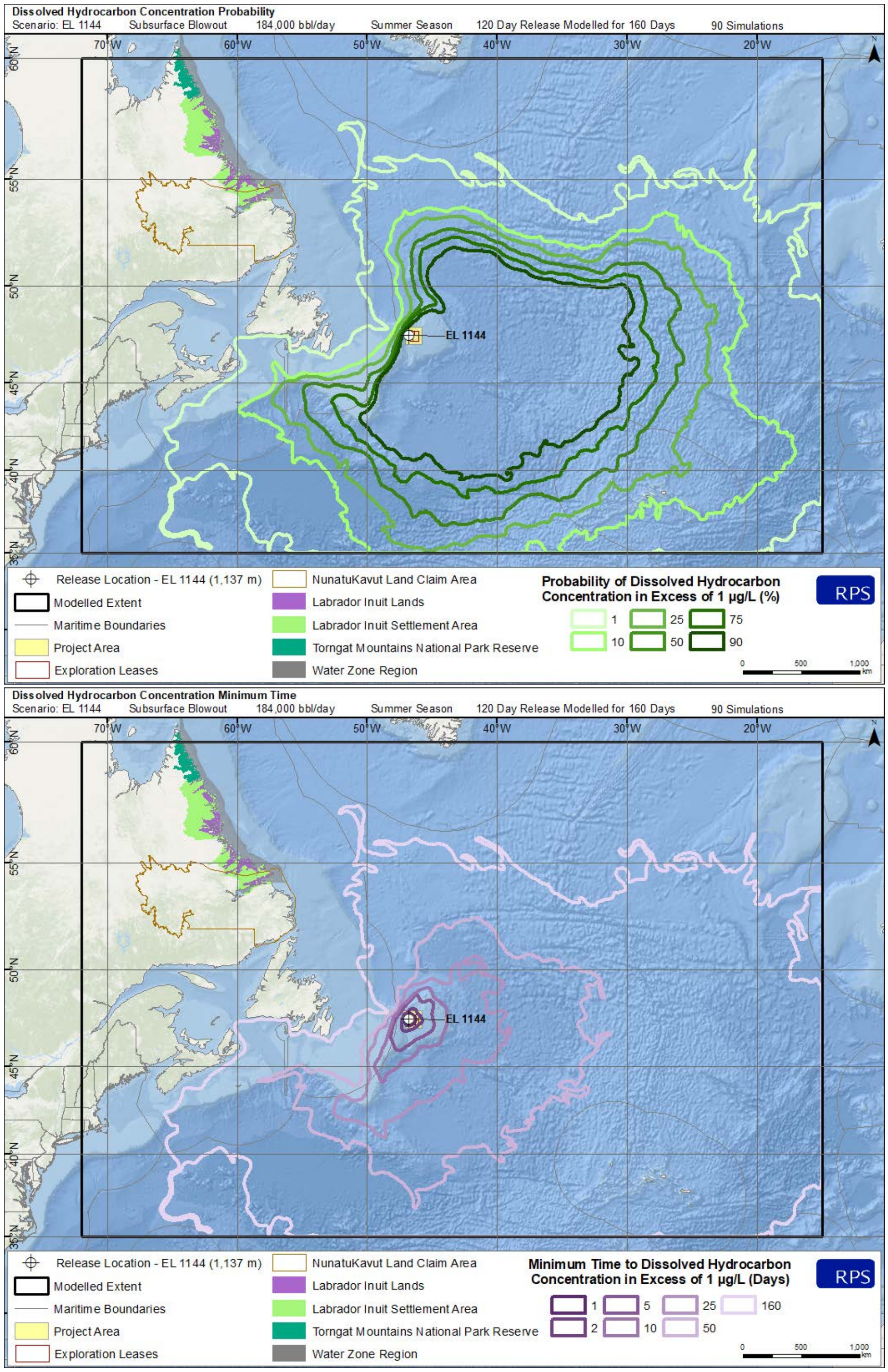


Figure 16.19 Summer Probability of Dissolved Hydrocarbon Concentrations >1 µg/L at Some Depth in the Water Column (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 120-Day Subsurface/Subsea Release at the EL 1144 Example Well Site

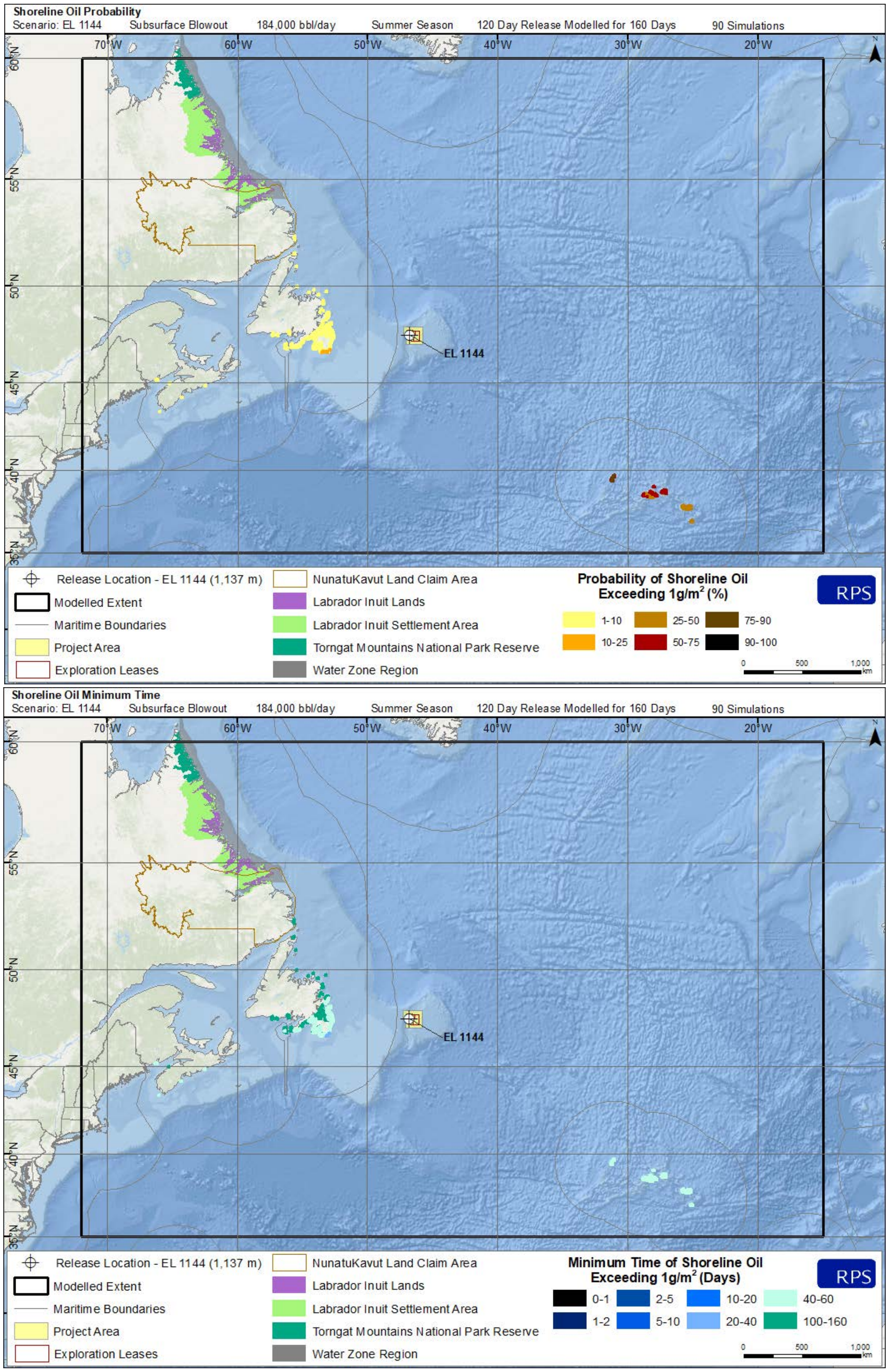


Figure 16.20 Summer Probability of Shoreline Contact >1 g/m² (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 120-Day Subsurface/Subsea Release at the EL 1144 Example Well Site

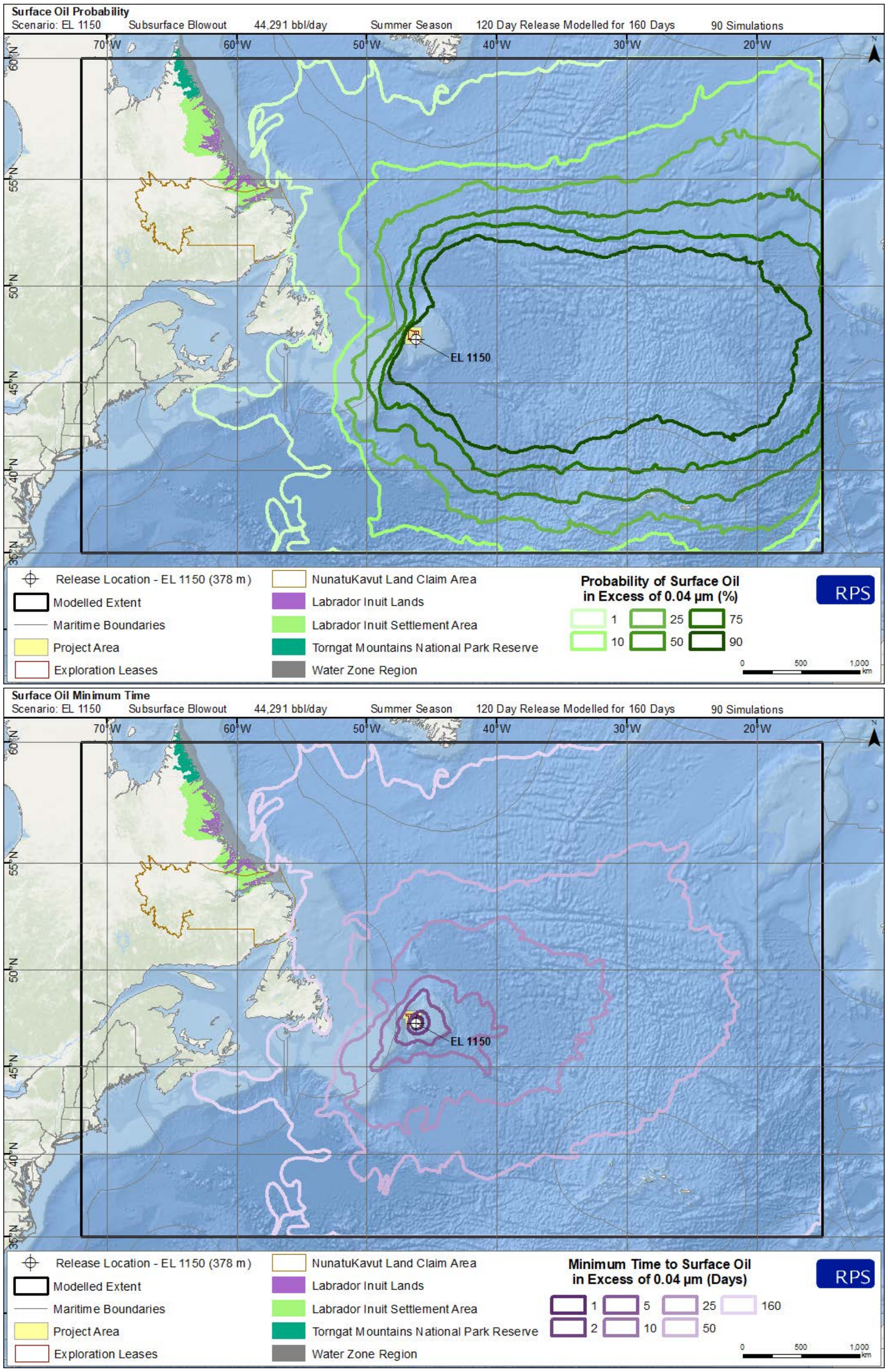


Figure 16.21 Summer Probability of Average Surface Oil Thickness >0.04 µm (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 120-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

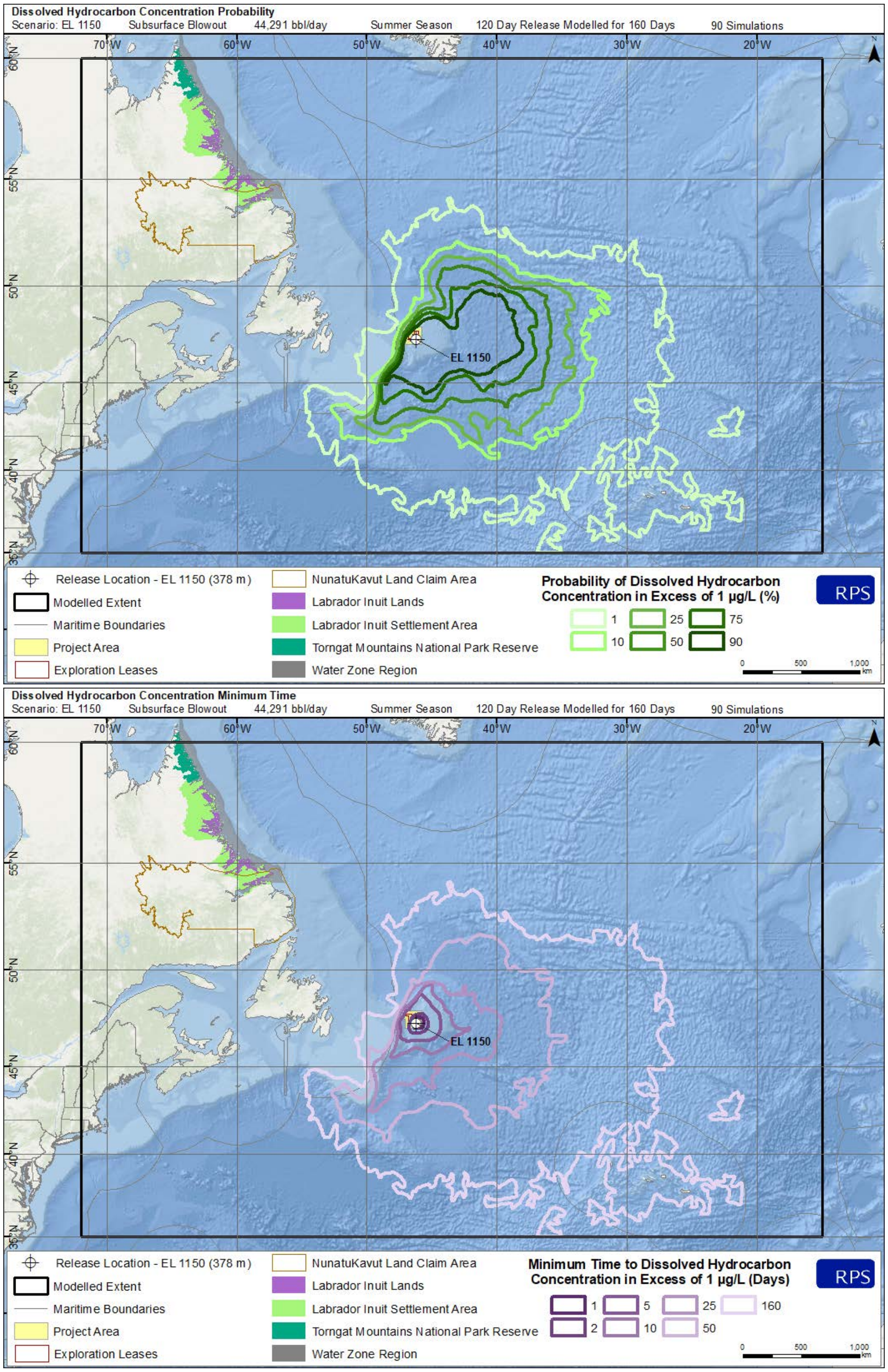


Figure 16.22 Summer Probability of Dissolved Hydrocarbon Concentrations >1 µg/L at Some Depth in the Water Column (Top) And Minimum Time to Threshold Exceedance (Bottom) Resulting from a 120-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

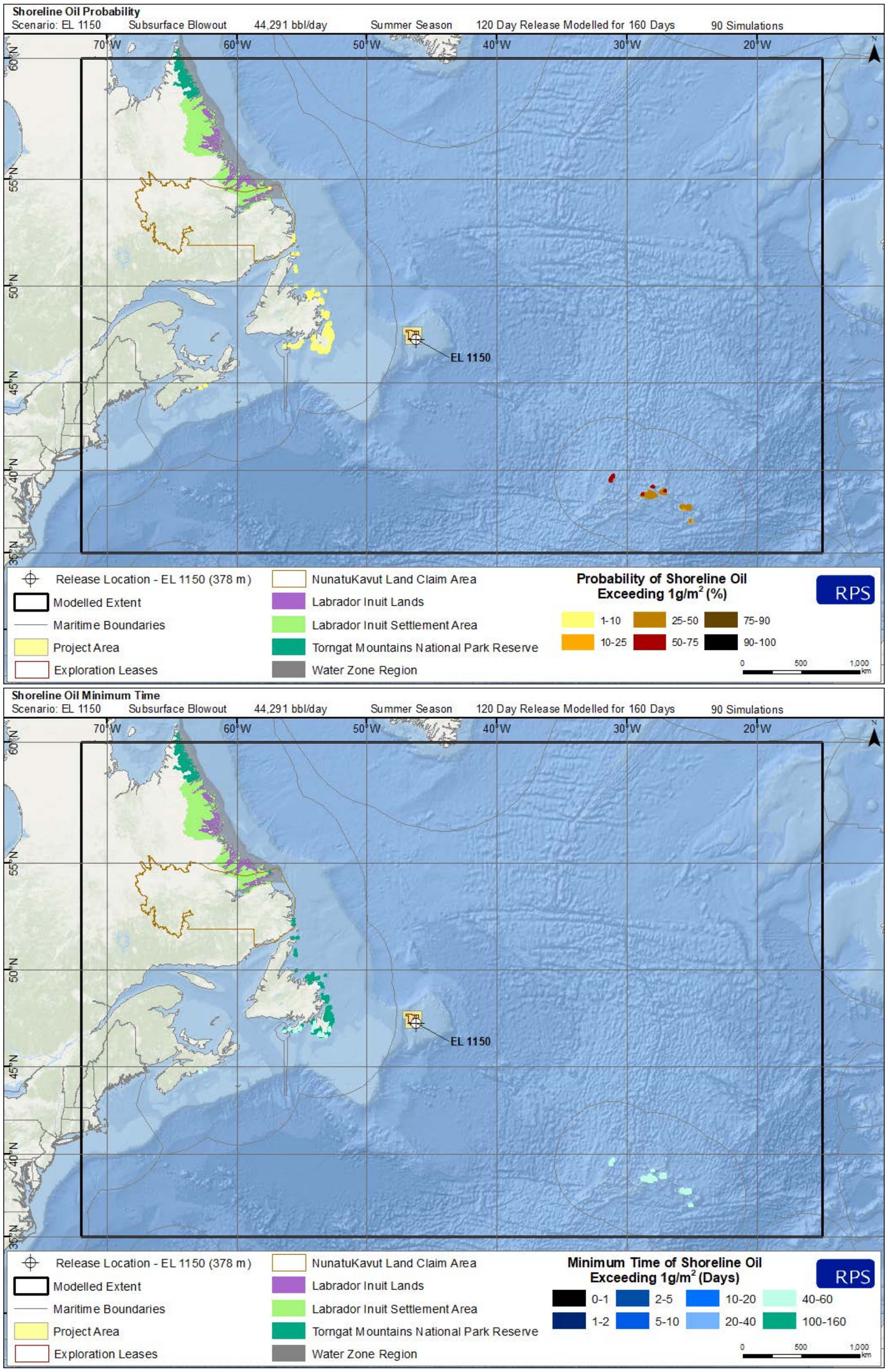


Figure 16.23 Summer Probability of Shoreline Contact >1 g/m² (Top) and Minimum Time to Threshold Exceedance (Bottom) Resulting from a 120-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

16.4.4.2 Summary of Deterministic Results (30- and 120-day release scenarios)

For all representative deterministic scenarios, the majority of the surface oil (94-99 percent) was predicted to either entrain, evaporate, or degrade by the end of the simulation, with less than 1-6 percent predicted to remain on the surface after 60 days for 30-day release scenarios and 7-12 percent after 160 days for the 120-day release scenarios (Table 16.13). For the marine diesel releases, less than 0.01 percent of marine diesel was predicted to remain on the surface after 30 days. This high volatility and solubility of the oil and marine diesel facilitated the large amount of predicted evaporation to the atmosphere (35-50 percent for oil and 40-76 percent for diesel) and dissolution into and degradation within the water column (32-38 percent for oil and 16-45 percent for diesel). For the 30-day release scenarios, predicted entrained oil in the water column ranged between 20 percent and 27 percent for the releases of oil and 8-14 percent for the marine diesel releases after 30 and 60 days, respectively. For the 120-day release scenarios, predicted entrained oil in the water column ranged between three and seven percent for the releases. For the 30-day release, shoreline oiling was not predicted for approximately 97 percent of the modelled release simulations. As predicted in the 99th percentile shoreline contact case, less than 0.01 percent of the released oil reached the shores of Sable Island after more than 50 days. For the 120-day release, the predicted shoreline oiling from the release at the EL 1144 example well site was predicted to occur on Newfoundland and the Azores. The length of shoreline where oil was predicted to exceed the 1 g/m^2 totaled 767 km for EL 1144 (120-day release). However, shoreline oil was predicted to comprise an extremely small portion of the total mass of released oil (<0.03% or <662,400 bbl) in this case. At the EL 1150 example well site (120-day release), shoreline oiling was predicted only to the east of the release site, contacting 634 km of shoreline along the Azores. In all cases (including 30 and 120-day scenarios), oil on the sediments was predicted to be extremely limited, with less than 0.02 percent of the release making its way to the bottom. In many simulations, some portion of the released oil mass was predicted to travel outside of the model domain, in some cases up to two percent.

Surface Oil Exposure Cases (30- and 120-day release scenarios)

30-day Release: For surface oil, both the 95th percentile release cases at the EL 1144 and EL 1150 example well sites occurred during the summer season (defined as ice-free for more than half the days of the model run) where wind speeds were sufficiently low to prevent entrainment and allow for more extensive surface slicks (Figure 16.24). The 99th percentile shoreline oiling case was identified in the late summer, where weather patterns were sufficient to transport oil to the south and west, where a small fraction of oil (less than 0.01 percent) was transported to the shores of Sable Island. For the 95th percentile water column contamination cases, scenarios were always during winter months, where high wind speeds were sufficient to generate surface breaking waves with entrained surface oil and resulted in the largest amounts of oil in the water column. For the representative "batch spills" and vessel collision, low wind speed periods were identified for each of the three scenarios which occurred during the summer.

Table 16.13 Summary of the mass balance information for all scenarios. All values represent a percentage of the total amount of released oil at the end of the 60 day (for 30-day release) or 160 day (for 120-day release) modelled simulations

Summary of Mass Balance Information at the End of the Simulation (Percentage of Released Oil)									
Scenario Information			Surface (%)	Evaporated (%)	Water Column (%)	Sediment (%)	Ashore (%)	Degraded (%)	Outside Grid (%)
Example Well Site	Scenario	Product							
30 – Day Release (end of 60-day simulation)									
EL 1144	95th percentile surface oil exposure case	BdN	1.08	41.66	24.63	0.01	0.00	32.02	0.59
	95th percentile water column case		0.19	40.40	26.96	0.01	0.00	32.37	0.08
	99th percentile shoreline contact case		3.47	34.80	23.34	0.01	<0.01	37.64	0.73
EL 1150	95th percentile surface oil exposure case		5.58	40.91	19.52	0.01	0.00	32.17	1.82
	95th percentile water column case		0.13	40.89	26.95	0.02	0.00	31.98	0.02
	95th percentile shoreline contact case		NA	NA	NA	NA	NA	NA	NA
EL 1144	100 L Batch Spill	Marine Diesel	<0.01	75.65	8.40	<0.01	0.00	15.95	0.00
	1,000 L Batch Spill		<0.01	62.84	10.71	<0.01	0.00	26.45	0.00
VCL	750,000 L Batch Spill		<0.01	40.11	14.45	0.01	0.00	45.43	0.00
120 – Day Release (end of 160-day simulation)									
EL 1144	95th percentile surface oil exposure case	BdN	12.19	43.34	4.16	0.01	0.01	40.21	0.08
	95th percentile water column case		9.80	48.11	5.27	0.01	0.02	36.66	0.13
	95th percentile shoreline contact case		12.13	47.12	3.13	0.01	0.03	37.41	0.18
EL 1150	95th percentile surface oil exposure case		10.82	47.40	3.52	0.01	<0.01	36.49	1.75
	95th percentile water column case		7.95	50.56	6.47	0.01	0.01	34.20	0.80
	95th percentile shoreline contact case		7.16	50.22	6.59	0.01	0.09	34.36	1.57

*Note that there was no shoreline oil contamination from the 30-day release at the EL 1150 example well site. Therefore, a 95th percentile could not be selected.

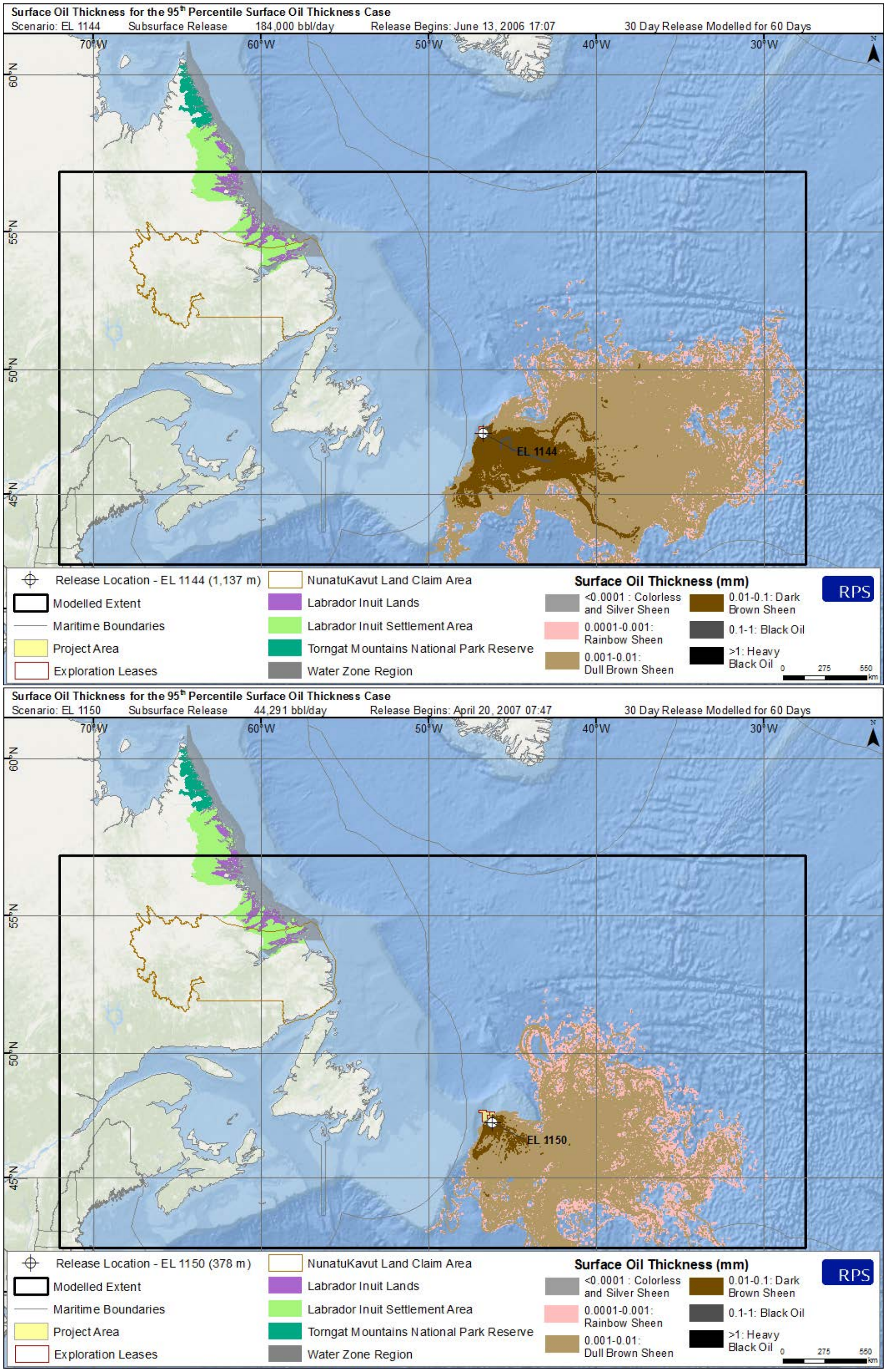


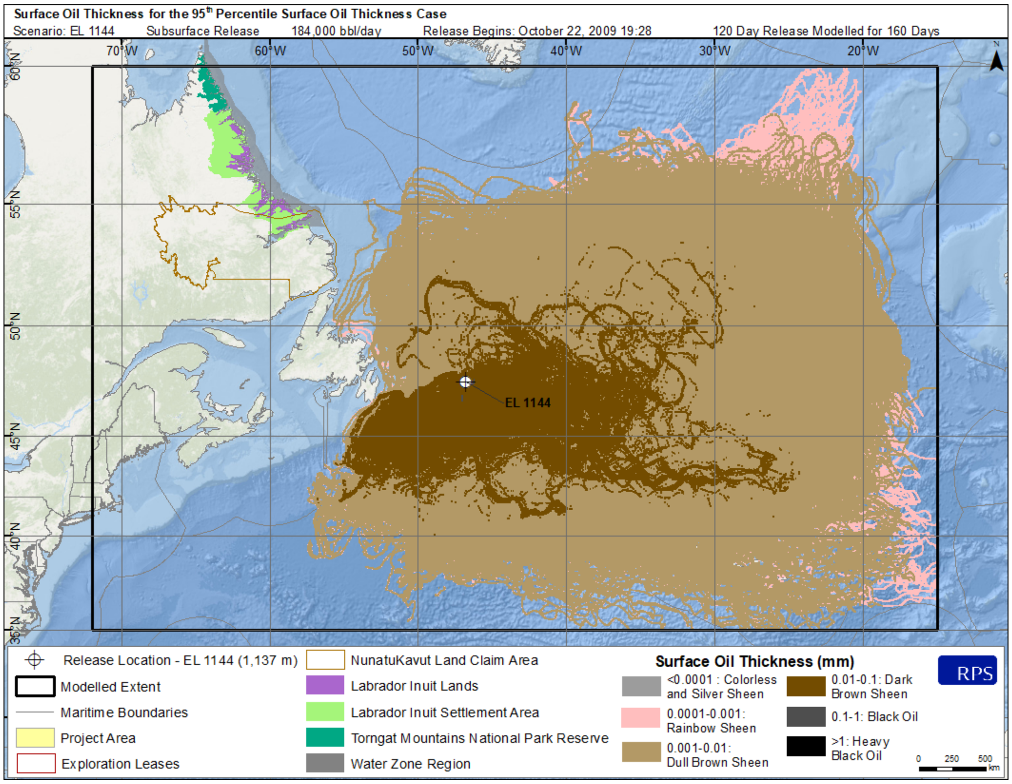
Figure 16.24 Representative Scenario for 95th Percentile Average Surface Oil Thickness Resulting from a 30-Day Subsurface/Subsea Release at the EL 1144 (Top) and the EL 1150 (Bottom) Example Well Sites

120-day Release: Results for the identified 95th percentile scenarios for floating surface oil exposure >0.04 µm for the 120-day releases at the EL 1144 and EL 1150 example well sites are provided. Note that the modelled release dates for the representative scenarios at each site differed (Table 16.4). The 120-day release at the EL 1144 example well site was modelled for 160 days spanning mid-October 2009 through March 2010, while at the EL 1150 example well site it spanned early-February through June 2008 (Table 16.4). For both sites, the released oil was predicted to rise rapidly to the surface where it was transported by surface winds and currents to the east, south, and north (Figure 16.25). Although surface oil was transported in a similar direction for both releases (even with the different start dates and underlying environmental forcing), the extent of surface oiling was larger at EL 1144 when compared to EL 1150 due to the larger volume of oil released at the EL 1144 example well site. Variable weather events within the first 10 days of both simulations resulted in a large amount of variability in the amount of oil to surface and entrained within the water column (see Water Column Exposure Cases Section below). During calmer events, oil rose to the surface forming slicks, while during windier periods, surface breaking waves were formed which entrained surface oil into the water column. Surfaced oil was predicted to evaporate quickly, ultimately totaling approximately 45% of the total release, while the amount degraded increased through time totaling approximately 35-40% of the release.

For both the 30 and 120-day release scenarios, the depth of release and the total release volume affected results for the subsurface/subsea releases. The EL 1150 example well site was the shallower of the two example release sites (378 m), which contributed to faster surfacing of subsea oil. However, even though the release at the EL 1144 example well site was much deeper (1,137 m), the much larger release volume (over four times that of the EL 1150 example well site) was predicted to result in thicker surface area over broader areas. There were some limited areas with the potential for black oil (0.1 – 1 mm) at distances greater than 10 km from the release point and a greater areal extent of dark brown sheens (0.01-0.1 mm). For releases at the EL 1150 example well site, surface thicknesses were predicted to be closer to dark brown sheens away from the release point over a smaller area due to the smaller release volume (Figure 16.18). For the 120-day release scenarios, the thickest oil was predicted to be within several kilometers of the release locations as black oil and dark brown sheen (Figure 16.25). Predicted visual appearance of surface oil following both releases for the vast majority of the cumulative maximum footprints was predominantly in the dark brown sheen to dull brown sheen range due to the light and low viscosity nature of the BdN crude oil. At the EL 1144 example well site, small amounts of black oil were predicted to travel upwards of 100 km from the release site, while for EL 1150, the thickest surface oil predicted was in the range of a dark brown sheen.

The thicker oil at the EL 1144 example well site was the result of the larger release volume. Similarly, thicker oil was predicted over broader areas for the larger modelled release at the EL 1144 example well site due to the larger release volume, when compared to the EL 1150 example well site.

For all representative deterministic scenarios, the majority of the surface oil (94-99 percent) was predicted to either entrain, evaporate, or degrade by the end of the simulation, with less than 1-6 percent predicted to remain on the surface for the 30-day release scenarios (after 60 days) <13% for 120-day scenario (after 160 days). For the marine diesel releases, less than 0.01 percent of marine diesel was predicted to remain on the surface after 30 days. This high volatility and solubility of the oil and marine diesel facilitated the large amount of predicted evaporation to the atmosphere (35-42 percent for oil and 40-76 percent for diesel) and dissolution into and degradation within the water column (32-38 percent for oil and 16-45 percent for diesel). Predicted entrained oil in the water column ranged between 20 percent and 27 percent for the 30-day releases, 4% for the 120-day releases, and 8-14 percent for the marine diesel releases after 30 and 60 days, respectively.



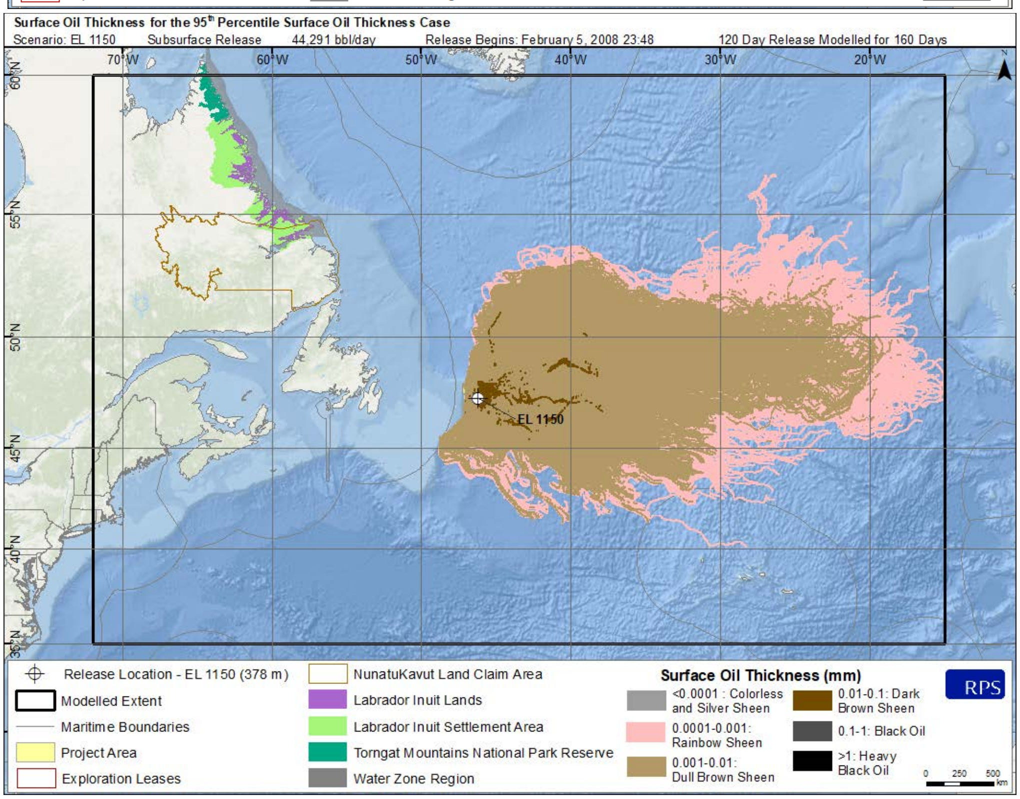


Figure 16.25 Representative Scenario for 95th Percentile Average Surface Oil Thickness Resulting from a 120-Day Subsurface/Subsea Release at the EL 1144 (Top) and the EL 1150 (Bottom) Example Well Sites

Water Column Exposure Cases

30-day Release: The maximum subsurface water volume exposed to THC concentrations above 1 µg/L for the two 95th percentile water column cases are comparable to one another, with 58,842 km^3 predicted for the EL 1144 example well site and 54,943 km^3 predicted for the EL 1150 example well site (Figure 16.26). This volume is comparable to the predicted areal footprints of contamination for surface oil down to mixed layer depths (tens of meters). For the 95th percentile water column contamination cases at the EL 1144 example well site, the region that may experience concentrations of over 200 µg/L for dissolved hydrocarbons at any point over the 60-day simulation was predicted primarily within 200 km to the southeast and north of the release site. At the EL 1150 example well site, dissolved hydrocarbon concentrations of over 200 µg/L were found to the southeast of the release within approximately 150 km. Entrained oil concentrations in surface waters were predicted to vary considerably from day to day, as would be expected due to the dependence on variable wind induced surface breaking wave formation.

120-day Release: The combined effects of the modelled subsurface/subsea releases and the entrainment of surface oil from wind-induced surface breaking waves into the water column were predicted to result in both dissolved and total hydrocarbon concentrations in the water column that exceeded the identified thresholds of concern (Figure 16.27; Table 16.10). Concentrations of dissolved and total hydrocarbons were predicted to be highest around the modelled release sites, dissipating as contaminants dispersed and were transported away from the release location where they continued to evaporate to the atmosphere, dissolve, disperse/dilute within the water column, and degrade. As total hydrocarbons represent the sum of the dissolved phase (i.e., soluble fraction making up approximately 1% of the whole oil) and the particulate phase (i.e., whole oil droplets) within the water column, THC was predicted to have a larger footprint and a higher concentration than the dissolved phase. The EL 1144 example well site was predicted to have higher concentrations and a larger cumulative footprint, compared to that of the EL 1150 example well site, due to the release volume being over four times larger at the EL 1144 example well site. Due to the winds and currents in the area at the modelled times, concentration exceedances were predicted to the east, south, and north of the release locations (Figure 16.26). While the highest concentrations of THC were predicted near the release location at the trap height, the majority of the predicted THC concentrations outside of a few kilometers radius from the release locations were within a few tens of meters of the surface. This result was due to the majority of the predicted THC deriving from entrained oil from wind-induced surface breaking waves, which occurs in the upper water column (i.e. mixed layer depth).

Shoreline Exposure Case

30-day Release: The 99th percentile shoreline exposure case was identified for the EL 1144 example well site rather than the 95th percentile, as no shoreline oiling was predicted for the 95th percentile case. For the EL 1150 example well site, there was no scenario that resulted in shoreline exposure within 60 days. The predicted shoreline oiling from the release at the EL 1144 example well site was predicted to occur on Sable Island (Figure 16.28). The area of shore where shoreline oil exceeded the 1 g/m^2 threshold was predicted to be approximately 13 km^2. However, shoreline oil was predicted to comprise an extremely small portion of the total mass of released oil (less than 0.01 percent) in this case.

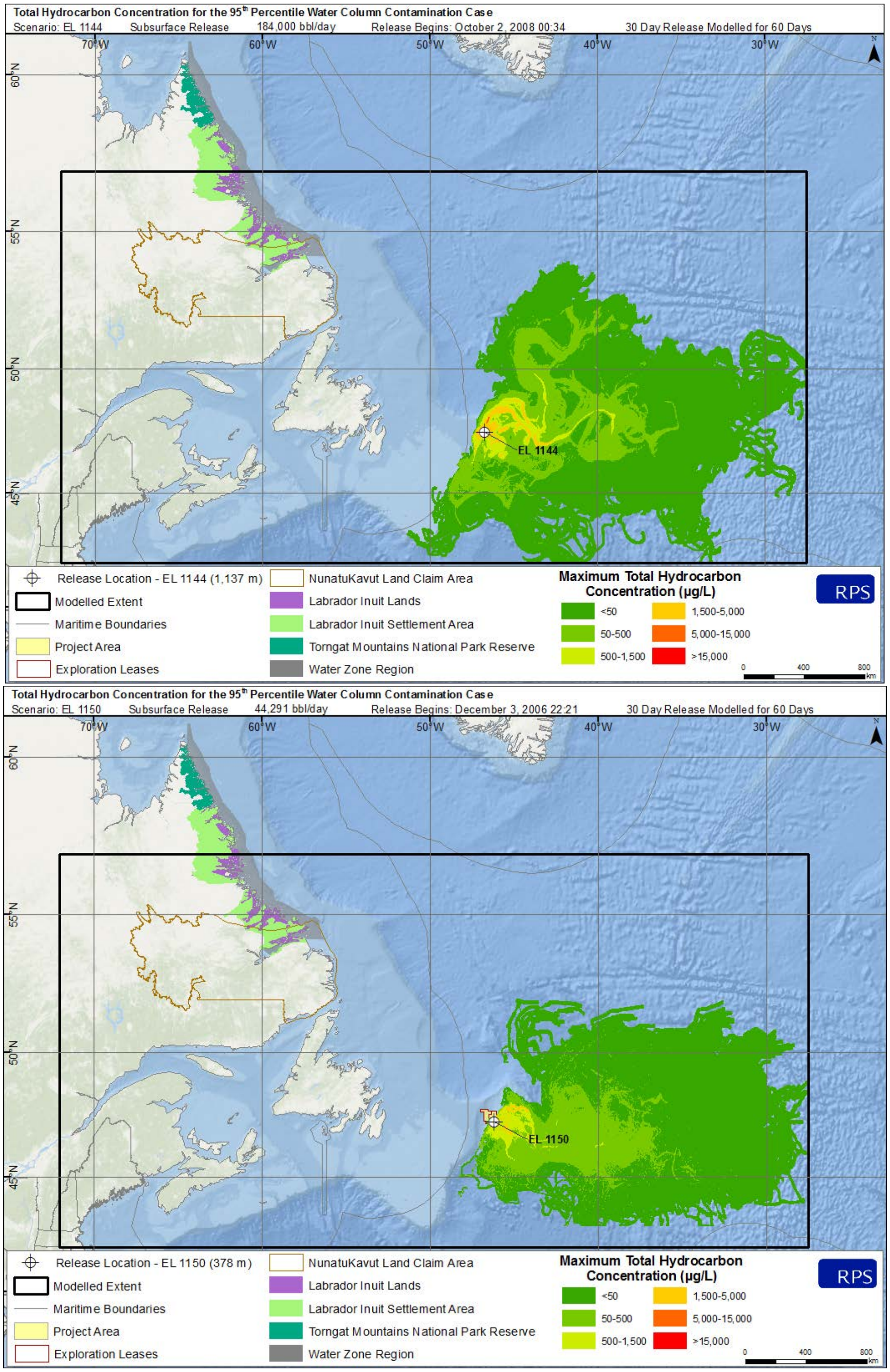


Figure 16.26 Maximum Total Hydrocarbon Concentration (THC) at Any Depth in the Water Column for the 95th Percentile Water Column Contamination Case Resulting from a 30-Day Subsurface/Subsea Release at the EL 1144 (Top) and the EL 1150 (Bottom) Example Well Sites

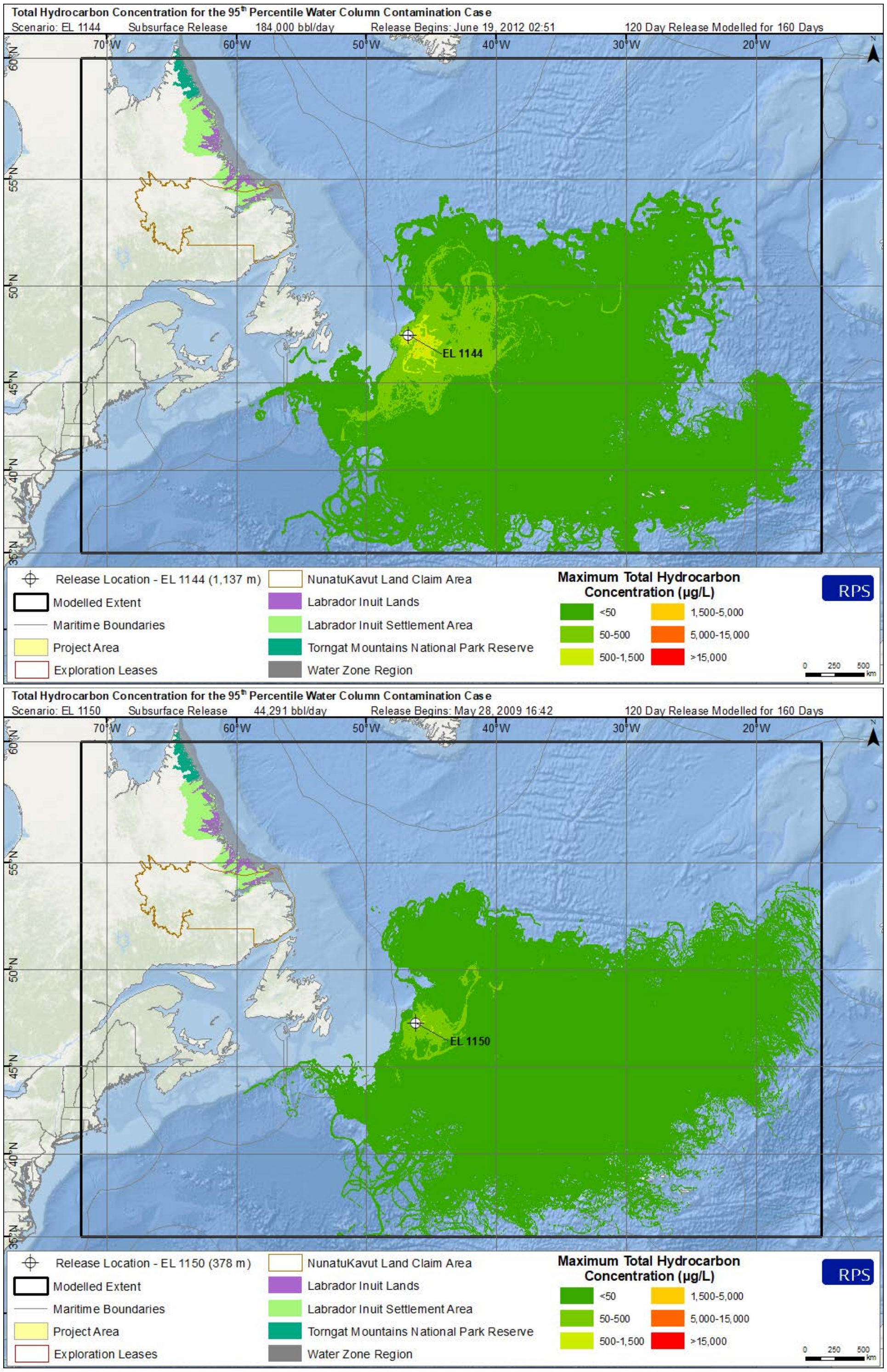


Figure 16.27 Maximum Total Hydrocarbon Concentration (THC) at Any Depth in the Water Column for the 95th Percentile Water Column Contamination Case Resulting from a 120-Day Subsurface/Subsea Release at the EL 1144 (Top) and the EL 1150 (Bottom) Example Well Sites

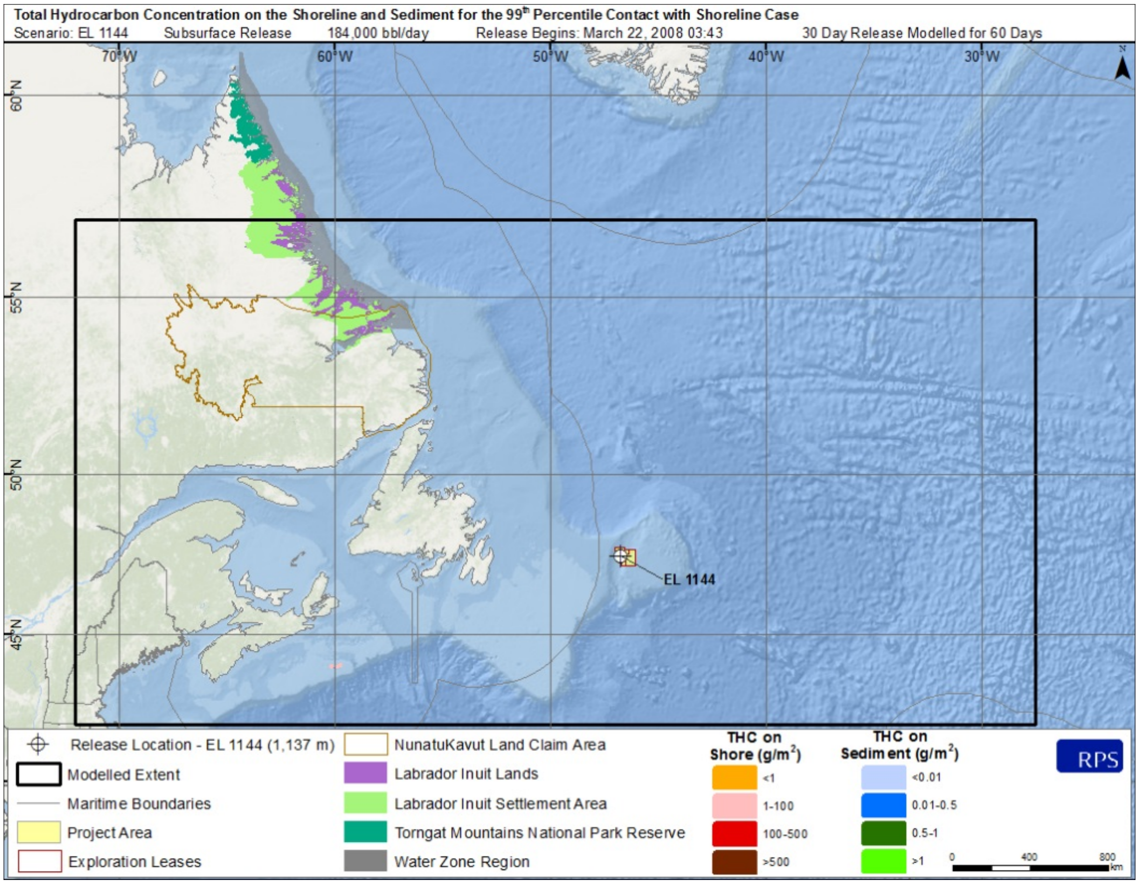


Figure 16.28 THC on the Shore and Sediment for the 99th Percentile Contact with Shoreline Case Resulting from a 30-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

120-day Release: The predicted shoreline oiling from the release at the EL 1144 example well site was predicted to occur on Newfoundland and the Azores (Figure 16.29). The length of shoreline where oil was predicted to exceed the 1 g/m^2 totaled 767 km for the EL 1144 example well site. However, shoreline oil was predicted to comprise an extremely small portion of the total mass of released oil (<0.03% or <662,400 bbl) in this case. At the EL 1150 example well site, shoreline oiling was predicted only to the east of the release site, contacting 634 km of shoreline along the Azores.

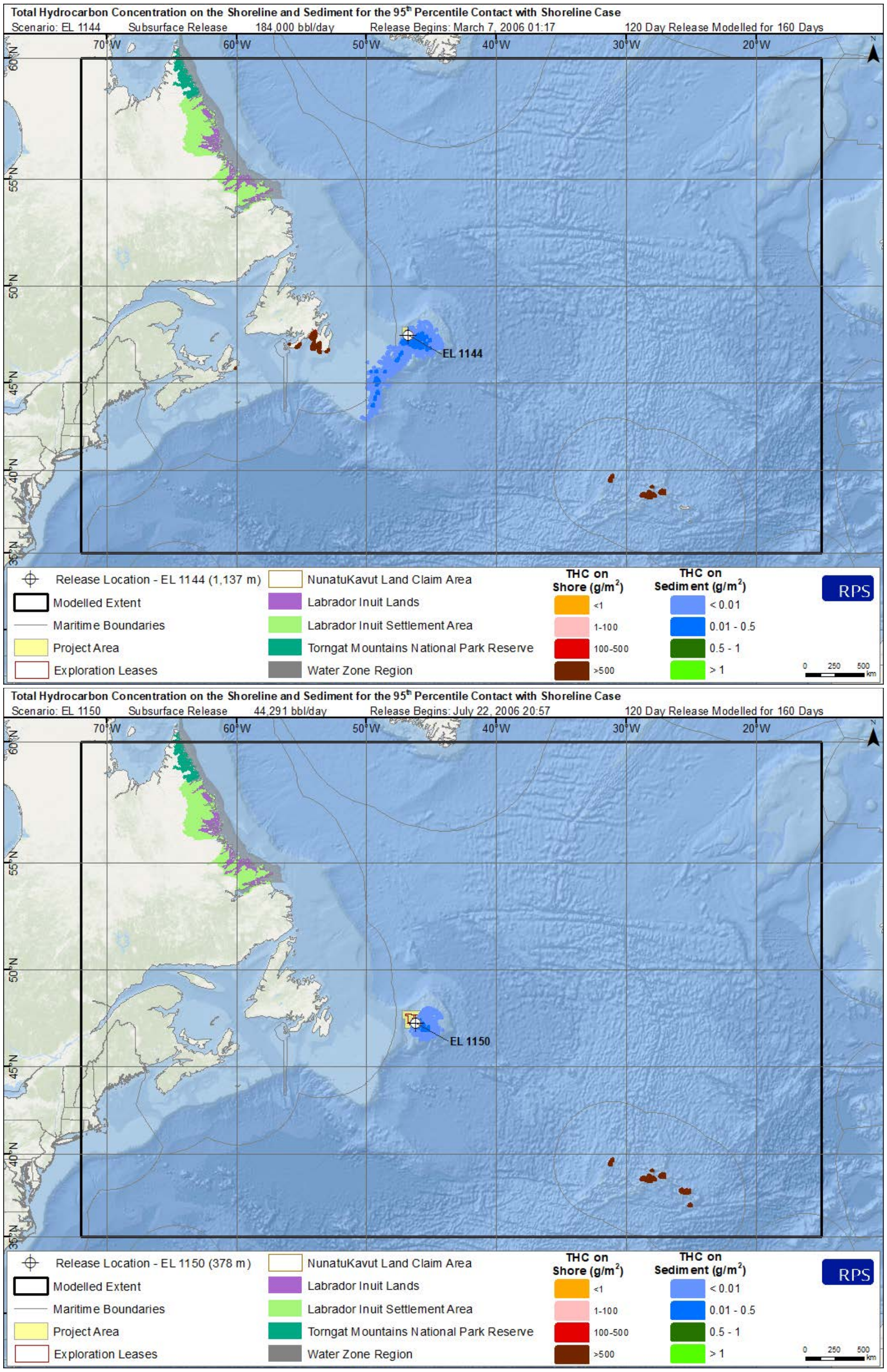


Figure 16.29 THC on the Shore and Sediment for the 99th Percentile Contact with Shoreline Case Resulting from a 120-Day Subsurface/Subsea Release at the EL 1150 Example Well Site

16.4.4.3 Marine Diesel Batch Spills

For the “batch spill” releases of marine diesel, mass balance predictions portray the rapid entrainment of a large portion (30-45 percent) of surface oil within several hours of the release (Figure 16.30). After 24 hours, 52-66 percent was predicted to evaporate, with less than three percent remaining on the surface. Some of the entrained oil was predicted to resurface within a day or two, however by day seven nearly all the surface oil was either evaporated, entrained, or degraded.

For the hypothetical vessel collision release, a large portion (approximately 80 percent) of the marine diesel was predicted to entrain within the first two days. More quiescent conditions resulted in the resurfacing of approximately five percent of the released oil and rapid evaporation of approximately 40 percent. On day eight, another wind event resulted in the complete entrainment of the surface oil and mixing within the water column, which reduced the amount of evaporation and resulted in degradation being a major fate pathway for this release, accounting for approximately 45 percent of the release volume. For all three batch spill cases, less than 0.01 percent of marine diesel was predicted to remain on the surface by the end of the 30-day simulation, with a significant portion evaporated (40-76 percent), a portion in the water column (8-14 percent), and the rest degraded (16-45 percent). No shoreline oiling and negligible oil on the sediments was predicted.

For the small volume “batch spills” modelled at the EL 1144 example well site, patchy and discontinuous colorless and silver sheens <0.0001 mm (0.1 μm) were predicted over limited distances (Figure 16.31). The cumulative area of average surface oil thickness >0.04 μm was <1 km^2 for the 100 L release and approximately eight km^2 for the 1,000 L release. Total hydrocarbon concentrations were not predicted to exceed 1 μg/L for the 100 L release and the vertical maximum THC concentrations for the 1,000 L release were only predicted to reached 2 μg/L within about five km of the release site. Note that water column contamination for the marine batch release cases was reported as THC, as opposed to dissolved hydrocarbons reported for the other deterministic and stochastic scenarios, as release volumes were insufficient to create reportable concentrations.

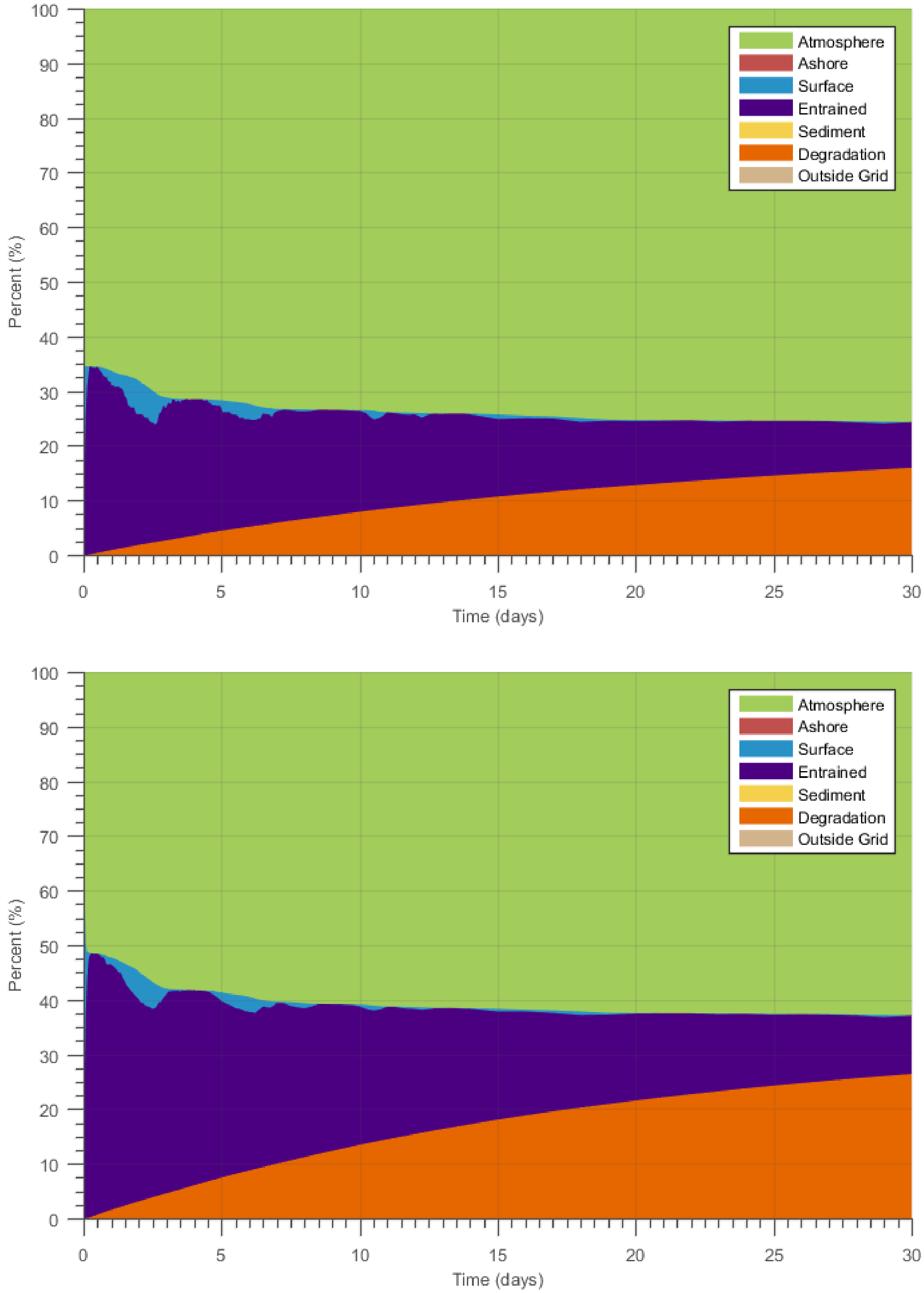
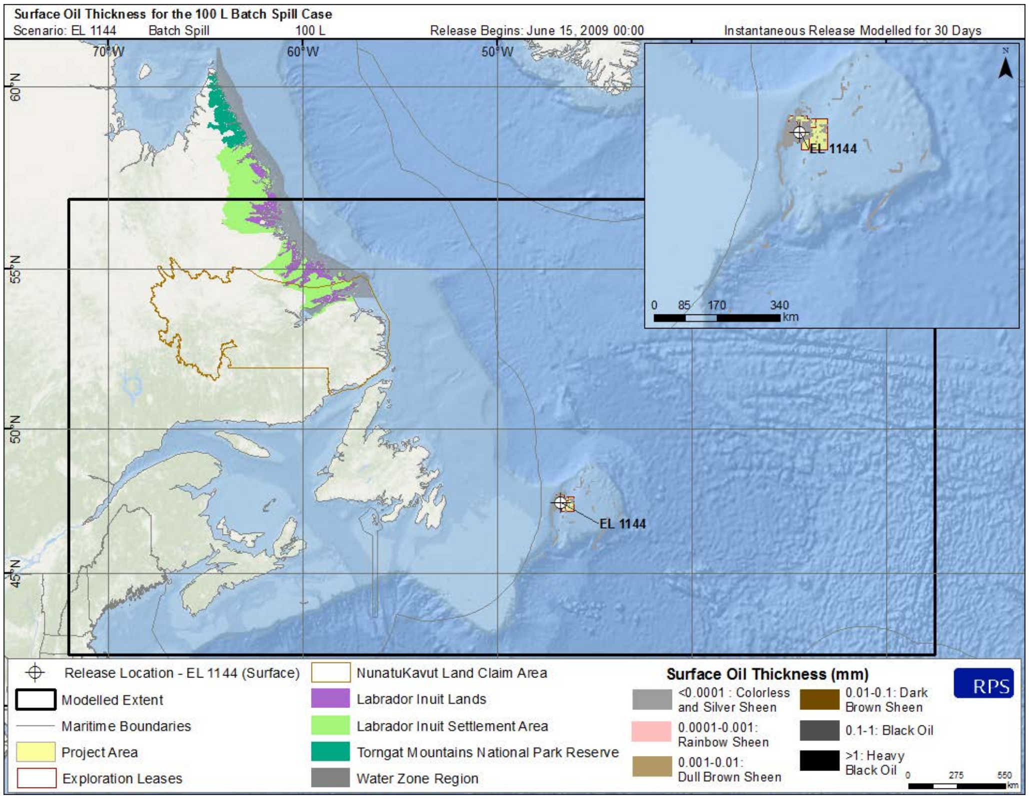


Figure 16.30 Mass Balance Plots of the EL 1144 Example Well Site Release of Marine Diesel from Batch Spills of 100 L (Top) and 1,000 L (Bottom)



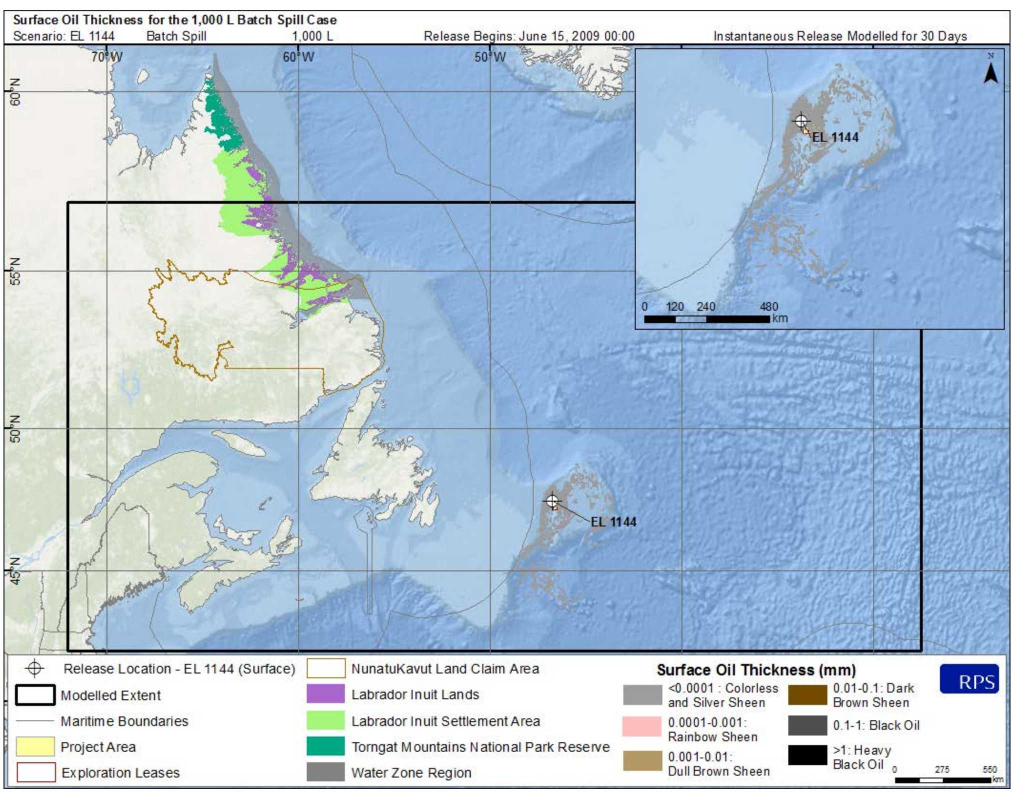


Figure 16.31 Surface Oil Thickness Resulting from the EL 1144 Example Well Site Release of Marine Diesel from Batch Spills of 100 L (Top) and 1,000 L (Bottom)

16.4.4.4 Vessel Collision Scenario

The hypothetical (and unlikely) 750,000 L marine diesel spill from a vessel collision was predicted to result in more extensive surface oil and a smaller percentage of oil evaporating (Figure 16.32), when compared to the modelled "batch spills." The release would be predicted to result in patchy and discontinuous surface sheens, although the large release volume would likely result in a rainbow sheen for approximately 40 km before transitioning to the colorless and silver sheen that was predicted for the "batch spills." The predicted exposure area for surface oil from the vessel collision was 925 km^2 for the lower 0.04 µm socioeconomic threshold and 13 km^2 for the higher 10 µm ecological threshold (Figure 16.33).

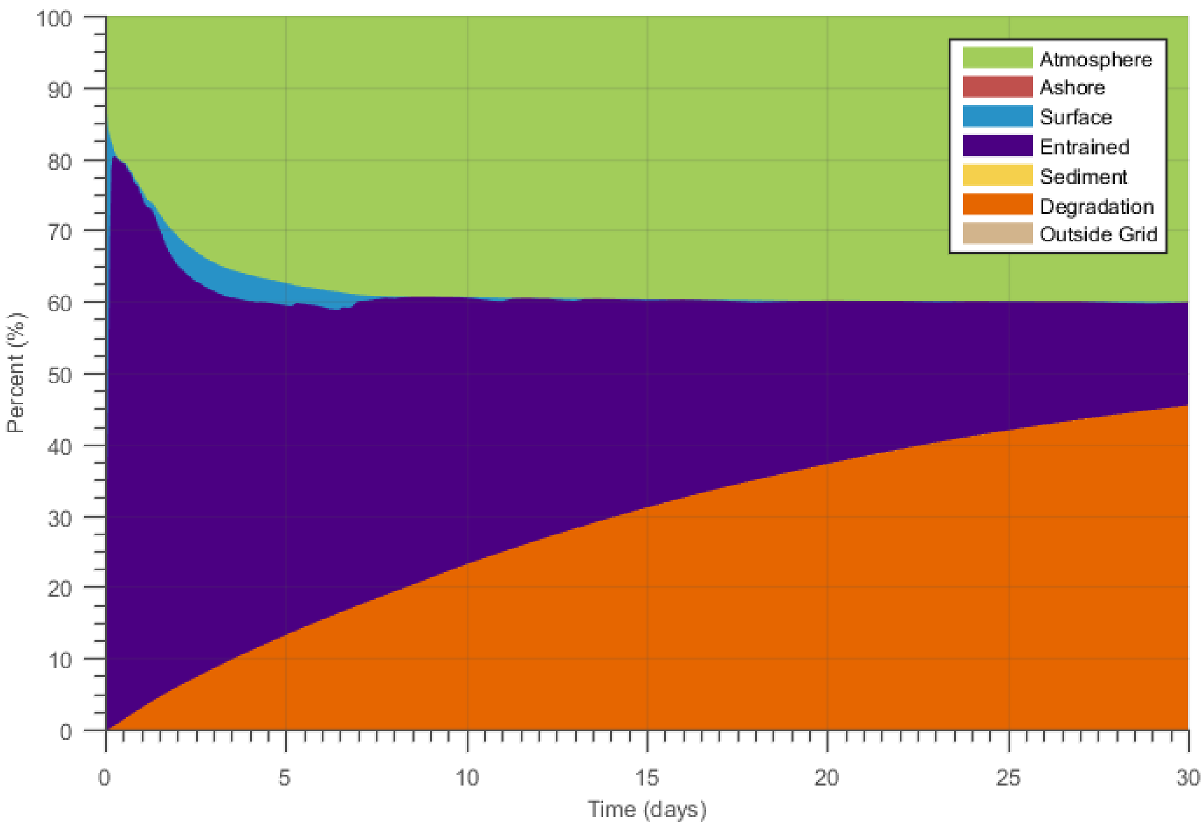


Figure 16.32 Mass Balance Plots of the VCL Release Site of Marine Diesel from the Vessel Collision Release of 750,000 L

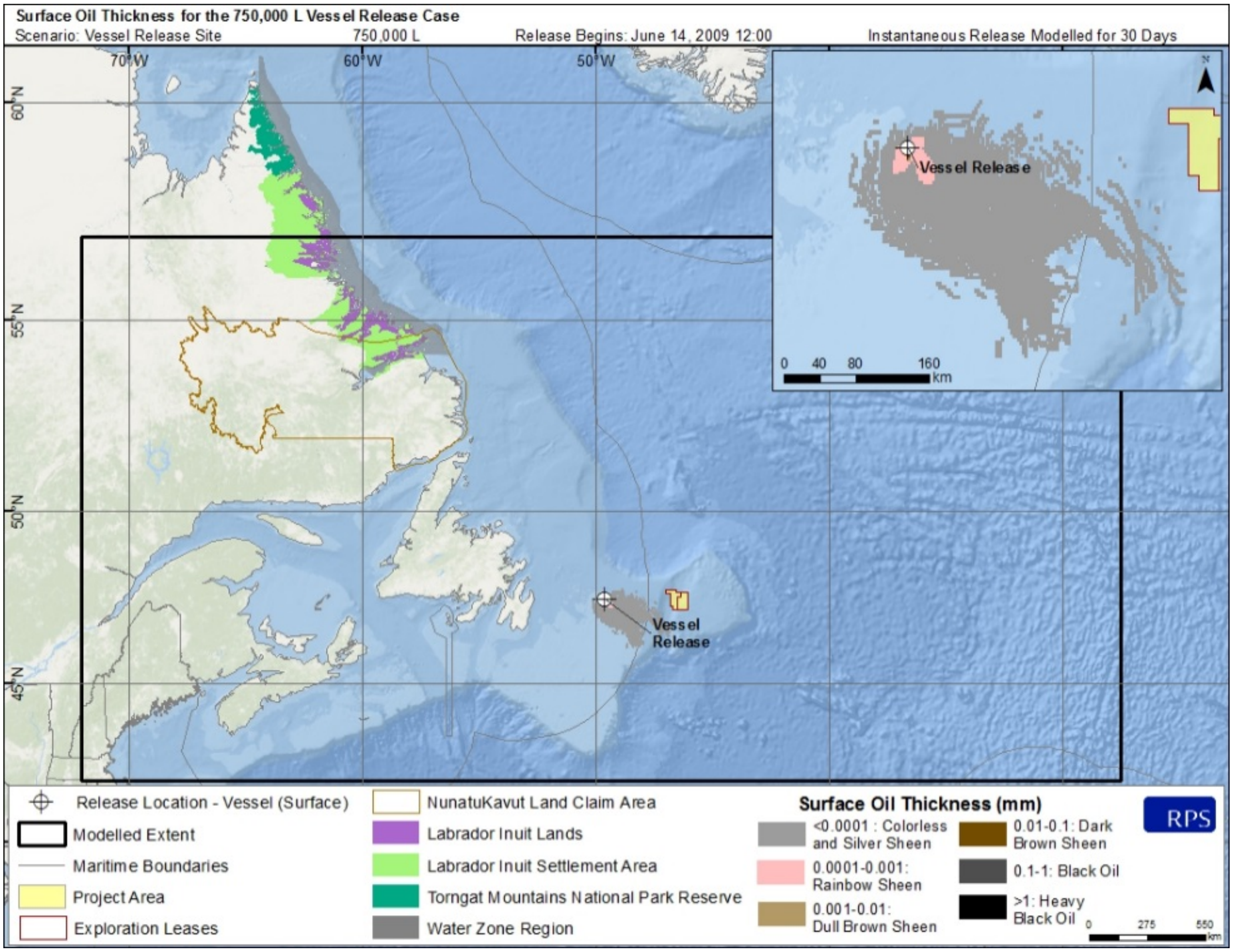


Figure 16.33 Surface Oil Thickness Resulting from the VCL Release of Marine Diesel from the Vessel Collision Release of 750,000 L

16.4.4.5 Key Uncertainties

The SIMAP model has been developed over several decades to include past and recent information from laboratory-based experiments and real-world releases to simulate the trajectory and fate of discharged oil. 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 exposures that could result from oil releases.

The major sources of uncertainty in the oil fate model is:

- Oil contains thousands of chemicals with differing physical and chemical properties that determine their fate in the environment. The model must, out 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 release as an isolated, singular event and does not account for any potential cumulative exposure from other sources of contamination.
- Several 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 release of oil, the trajectory, fate, and potential biological exposure will be strongly determined by the specific environmental conditions, the precise locations, and a myriad of details related to the event and specific timeframe of the release. 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 exposures of oil releases under various representative scenarios.

16.4.4.6 Summary of Modelling Results (30- and 120-day release scenarios)

30-day Release: For each of the modelled releases, oil on the surface was most likely to move to the east due to the prevailing westerly winds and surface currents within the region. Winds and currents in and around the Project Area are similar throughout the year, with most notable differences in wind intensity. The increased winds during wintertime conditions have the potential to enhance surface breaking waves and results in more complete entrainment of oil, which lowered the amount of oil that would remain on the surface for extended periods of time. In general, after 60 days, the majority of the oil was predicted to evaporate, entrain, and degrade, with very little oil remaining on the surface after 30 or 60 days, negligible sediment oiling, and extremely limited or non-existent shoreline oiling. Shoreline contact with oil was not predicted to be likely from any of the modelled releases. Of the 59 individual oil spill trajectory simulations for wintertime releases at the EL 1144 example well site, only three percent had shoreline oiling and only at Sable Island. There was no shoreline oiling predicted from summer scenarios for the EL 1144 example well site.

120-Day Release: For each of the modelled releases, oil on the surface was most likely to move to the east due to the prevailing westerly winds and surface currents within the region. Winds and currents in the Project Area are similar throughout the year, with most notable differences in wind intensity. The increased winds that typically occurred during wintertime conditions enhanced surface transport and formation of surface breaking waves that resulted in more complete entrainment of oil, which lowered the amount of oil that would remain on the surface for extended periods of time. In general, after 160 days, the majority of the oil was predicted to evaporate, entrain, and degrade, with a small percentage of the total release volume remaining on the surface after 160 days. In addition, small portions of each modelled release were predicted to make contact with shorelines (<0.1%) or oil sediments (<0.01%). Shoreline contact with oil was predicted to occur along portions of Newfoundland, specifically the Avalon Peninsula, and the Azores. The highest potential for shoreline oiling from the stochastic analysis was 77 and 70% for the EL 1144 and EL 1150 example well sites, respectively.

The releases modelled in this study may be considered representative of other potential releases in the Project Area. The depth of release of the EL 1144 and EL 1150 example well sites (1,137 and 378 m, respectively) are within the range of depths found throughout the Project Area.

The hypothetical releases modelled for this EIS are not intended to predict a specific future event, but rather to be used as a tool in environmental assessment and release contingency planning. The results presented (see Appendix G) demonstrate that there are a range of potential trajectories and fates that could result if a release of crude oil or a batch spill of marine diesel were to occur, and those trajectories and fates vary based upon the environmental conditions occurring at the time. While each oil release is unique and therefore uncertainties exist, the results of this modelling study suggest that if oil were to be released in the Project Area, it has the highest likelihood of moving away from shore to the east.

16.5 Fate and Behaviour of Potential Drill Fluid (SBM) Spills

In order to assess the fate and behavior of potential SBM spill scenarios, Amec Foster Wheeler (2017, see Appendix H) conducted trajectory and fate modelling in support of this EIS.

A numerical SBM droplet dispersion model, developed by Amec Foster Wheeler, employs a transport computation to simulate the advection of dispersed SBM droplets in three dimensions through the water column, following accidental release into the sea, until the particles come to rest on the sea bottom. Key inputs for the model include SBM droplet characterizations and ocean currents. The primary outputs are predictions of the probable area and locations of the SBM footprints on the seabed for each seasonal scenario (e.g., footprint length, area, thickness and distance from the drilling site).

Two plausible worst-case accidental SBM release modes were identified and considered in the modelling study:

- Inadvertent surface release of the entire volume (64 m^3) of the active fluid system over a period of 1-2 hours; and
- Subsurface SBM release from the marine riser and associated transport lines, during an emergency BOP disconnect event (255 m^3 at EL 1144, 89 m^3 at EL 1150), over a period of about two hours.

The seafloor footprints resulting from the modelled accidental SBM spills at the EL 1144 example well site are summarized in Tables 16.14 and 16.15 for the intermediate and production drilling phases, respectively. The results include the distance of the spill footprint centers from the drilling site, whereby the footprint centers represent the location with the maximum spill thickness per unit area.

The SBM footprint statistics for the intermediate drilling phase at the deep site indicate that most SBM spills at the surface would reach the seafloor within a maximum of one km from the drilling site, with the median spill distance ranging from 184 m (in summer) to 743 m (in fall) from the drilling site. The variability of footprint locations among seasons is due to differences in the magnitude and direction of the mean seasonal currents. However, the median and maximum footprint sizes are comparable among seasons, due to the relatively small variability of currents within the brief SBM release periods, with footprint length (along the longer axis) median values of up to 124 m (spring), and maximum values of up to 220 m (summer) for the surface release scenarios. Total SBM footprints for the surface spill scenarios are predicted to have median areas of about 4,500 m^2 and maximum areas of 9,000 m^2, resulting in initial SBM spill deposits with average thicknesses of 1.7 cm, and maximum thicknesses of 7.1 cm.

The surface spill statistics are similar for the two SBM density values considered at the EL 1144 example well site, although the slightly denser SBM used during the production drilling phase is expected to be transported to slightly shorter distances (median values of 136 m in summer, and 554 m in fall) from the drilling site than the lighter, intermediate phase SBM. The footprint lengths and areas for the production phase are also correspondingly smaller than in the intermediate phase, with median lengths of up to 98 m (spring and fall), and maximum lengths of about 168 m (summer). Footprint areas for the production phase surface releases are smaller than those for the intermediate phase, with median values of 3,600 m^2 and maximum values of 7,200 m^2 for all seasons. While the maximum modelled thicknesses of 7.1 cm are the same as in the intermediate phase scenarios across seasons, the average thickness is slightly higher at about 2.2 cm.

The results of the surface spill of the EL 1144 example well site illustrate that for both drilling phases the spills are expected to result in deposits up to several hundred meters to the east-southeast of the EL 1144 example well site, depending on the prevailing ambient current conditions for each season. The modelling results indicate notably narrower spatial distributions of the possible footprint center locations for the denser SBM in the production phase compared to the intermediate phase, consistent with the higher terminal fall velocities and lower travel times.

The SBM originating from a potential BOP disconnect scenario at the EL 1144 example well site for both drilling phases is expected to contact the seafloor much closer to the drilling site (within about 40-60 m in all seasons), resulting in smaller initial footprint areas, but potentially larger initial SBM layer thicknesses in the range of 23-28 cm. The relatively small vertical distance to the seafloor, and the low ambient near-bottom currents result in low SBM dispersion rates and similar outcomes for all seasons and SBM densities. The final size and thickness distribution of the SBM footprints in these cases is expected to vary based on the features of the local seafloor.

The seafloor footprints resulting from the modelled accidental SBM spills at the EL 1150 example well site are summarized in Table 16.16. The modelled spill distances from the drilling site are generally shorter compared to the deepwater site, with median footprint center distances ranging from 106 m (summer) to 201 m (winter), and maximum distances ranging from 322 m (summer) to 424 m (winter).

Footprint length scales at the EL 1150 example well site are slightly shorter than at the EL 1144 example well site, with median values ranging from 81-84 m across seasons, however the maximum lengths are slightly higher than at the deepwater site, ranging from 237 m (fall) to 250 m (summer). These findings can be attributed to a slightly larger range of current variability at the shallow water EL 1150 example well site compared to the deepwater EL 1144 example well site, resulting in a wider range of individual spill sizes within each seasonal scenario. This is also reflected in the modelled footprint areas, with median values of 2,700 m^2, and maximum values of 9,900 m^2. Due to the lower median footprint sizes, the average SBM deposit thickness is higher at about 2.6-2.7 cm, but the maximum thickness of 7.1 cm is comparable to the deepwater site.

The seasonal probability maps of spill center locations indicate that SBM spill deposits are most likely to reach the seafloor within the quadrant northeast of the EL 1150 example well site consistent with the prevailing seasonal mean currents at this location.

Table 16.14 EL 1144 Deepwater Jurassic Example Well Site, Seasonal SBM Footprint Statistics, Intermediate Phase

SBM DISPERSION		Distance from Site (m)		Footprint LENGTH (m)		Footprint AREA (m2)		Layer Thickness (cm)	
		max	median	max	median	max	median	max	avg
Surface	winter	620	422	165	95	7200	3600	7.1	2.2
	spring	441	273	157	98	7200	3600	7.1	2.1
	summer	264	136	168	93	7200	3600	7.1	2.2
	fall	726	554	161	98	7200	3600	7.1	2.2
BOP	winter	57	57	32	31	3600	900	28.3	25.1
	spring	57	57	32	31	3600	900	28.3	23.7
	summer	57	41	33	31	3600	900	28.3	23.6
	fall	57	57	32	31	1800	900	28.3	27.2

Table 16.15 EL 1144 Deepwater Jurassic Example Well Site, Seasonal SBM Footprint Statistics, Production Phase

SBM DISPERSION		Distance from Site (m)		Footprint LENGTH (m)		Footprint AREA (m2)		Layer Thickness (cm)	
		max	median	max	median	max	median	max	avg
Surface	winter	838	573	215	119	9000	4500	7.1	1.7
	spring	589	370	205	124	9000	4500	7.1	1.7
	summer	364	184	220	117	9000	4500	7.1	1.7
	fall	982	743	210	123	9000	4500	7.1	1.7
BOP	winter	57	57	33	32	3600	900	28.3	25.1
	spring	57	57	33	32	3600	900	28.3	23.7
	summer	57	41	33	32	3600	900	28.3	23.6
	fall	57	57	33	32	1800	900	28.3	27.2

Table 16.16 EL 1150 Shallow Water Cretaceous Example Well Site, Seasonal SBM Footprint Statistics

SBM DISPERSION		Distance from Site (m)		Footprint LENGTH (m)		Footprint AREA (m2)		Layer Thickness (cm)	
		max	median	max	median	max	median	max	avg
Surface	winter	424	201	246	82	9900	2700	7.1	2.6
	spring	388	170	247	84	9900	2700	7.1	2.6
	summer	322	106	250	81	9000	2700	7.1	2.7
	fall	338	146	237	83	9900	2700	7.1	2.6
BOP	winter	41	14	39	33	2700	900	9.9	8.2
	spring	57	41	39	33	2700	900	9.9	7.7
	summer	57	41	39	33	2700	900	9.9	7.9
	fall	57	41	38	33	2700	900	9.9	7.7

16.6 Environmental Effects Assessment

The sections that follow assess and evaluate the potential environmental effects that may occur in the unlikely event that an accident such as a marine diesel spill or release occurs at some point over the course of the Project.

The assessment is based largely on the various spill modelling exercises conducted for this Project, as summarized earlier in Sections 16.4 (oil spill modelling) and 16.5 (SBM spill modelling), and described in further detail in Appendices G and H of the EIS and Appendix B of this Addendum. As discussed, the modelling has been completed based on a credible worst-case, unmitigated approach for each spill scenario, where no preventative or spill response measures were considered. The environmental effects assessment for each VC considers each of the following potential and modelled accidental event scenarios, and considers the various spill prevention and response procedures and requirements described in Section 16.1:

- Marine Diesel Spill Scenarios:
  - 100 litre batch spill at the EL 1144 example well site;
  - 1,000 litre batch spill at the EL 1144 example well site; and
  - 750,000 litre spill at the hypothetical vessel collision location.
- Drilling Fluid (SBM) Spill Scenarios:
  - 64 m^3 surface spill at the EL 1144 and the EL 1150 example well sites;
  - 255 m^3 subsurface/subsea spill at the EL 1144 example well site; and
  - 89 m^3 subsurface/subsea spill at the EL 1150 example well site.
- Uncontrolled Well Events:
  - Release at the EL 1144 example well site (30 and 120-day release); and
  - Release at the EL 1150 example well site (30 and 120-day release).

The relevant VCs identified and assessed for the effects assessment for planned Project components were carried forward for the accidental events environmental effects assessment, namely the following:

- Marine Fish and Fish Habitat;
- Marine and Migratory Birds;
- Marine Mammals and Sea Turtles;
- Special Areas;
- Indigenous Peoples; and
- Fisheries and Other Ocean Uses.

It should be reiterated that the accidental even scenarios are modelled as unmitigated spills / releases and do not take into account the CNOOC procedures aimed to prevent and/or respond to such an incident (Section 16.1) or the overall potential of such an event occurring, based on the spill probability statistics and analysis (Section 16.3). The accidental event assessment discussed below, however does consider the mitigation measures to minimize the probability of a spill occurring and minimize the potential effects of a spill. Although the atmospheric environment has been assessed in the environmental effects assessment for planned Project activities (see Appendix A of this addendum document), and it is recognized that there are possible air quality implications that would result from the presence of hydrocarbons in the marine environment during a spill event, air quality has not been included as a VC in the assessment for accidental events.

Several previous studies have evaluated the effects of large oil spills on air quality and have shown relatively limited effects based on actual release events. Studies during the Deepwater Horizon (DWH) spill in the Gulf of Mexico, for example, assessed the resulting air quality in terms of aromatics, particulate matter, ozone concentration, and gaseous hydrocarbons and compared them to the air quality in major urban areas (Ravishankara and Goldman 2011). They found that most of the resulting air pollution was trapped to the lower layer of the atmosphere (Marine Boundary Layer, 1st 600 m). The aromatic concentrations (benzene, toluene, etc.) near the spill were higher than urban areas but particulate matter and ozone concentrations were comparable to urban areas. Measured gas-phase hydrocarbons were found to be emitted from a relatively small area near the DWH spill site. The actual aromatic, particulate, or other atmospheric emissions would be highly variable and influenced by the weather and oceanographic conditions and hydrocarbon properties.

The environmental effects assessment that follows is focussed on those aspects of the environment which are considered to be of primary concern with regard to such an unplanned event in the marine environment and its possible environmental consequences, namely, the various VCs listed above. Notwithstanding the potential, temporary, implications of such a spill event for air quality in the area, the rapid evaporation of spilled hydrocarbon materials into the atmospheric environment is considered preferable as opposed to its extended presence in the marine environment, and resulting effects on the VCs noted above. The oil spill modelling completed for this EIS (RPS 2018, 2019) provides an analysis of anticipated evaporation rates for the various spill events modelled.

Further analysis and consideration of the possible atmospheric emissions associated with a large spill event may, for example, be undertaken as part of the analysis of possible spill response options, such as in situ burning, where the potential environmental effects and benefits of these various response options will be evaluated by CNOOC and appropriate regulatory authorities.

16.6.1 Key Modelling Results Integrated into the Assessment

For some of the hydrocarbon spill scenarios (marine diesel spills and subsurface crude oil releases), the assessment considers a number of established ecological and socioeconomic thresholds related to surface oil thickness, mass of shoreline oiling, and concentration of contaminants in the water column in assessing the potential for adverse effects to occur, as summarized in Table 16.17 below. This information is further detailed in Section 16.4.

Table 16.17 Ecological and Socioeconomic Thresholds for Oil Related Environmental Effects

Oil Type/Component	Ecological Threshold	Socioeconomic Threshold
Surface Oil	10 µm thickness (equivalent to 10 g/m^2)	0.04 µm thickness (equivalent to 0.04 g/m^2)
Shoreline Oil	100 g/m^2	1 g/m^2
Water Column Oil	1 ppb (1 µg/L) dissolved PAH or 100 ppb whole oil (100 g/L THC)	

The relevant modelling results are summarised here in the overall context of their ecological and socioeconomic relevance and the specific component of the ocean that is potentially affected (surface, water column, coastal, seafloor). It should be reiterated that the accidental even scenarios are modelled as an unmitigated spill and do not take into account the CNOOC procedures aimed at preventing and/or responding to such an incident (Section 16.1). In addition, the overall potential for any such event to take place is discussed in the spill probability statistics and analysis section of this EIS (Section 16.3). The accidental event assessment as discussed below, however does consider both the mitigation measures and probability of a spill event occurring.

16.6.1.1 Marine Diesel Spills Scenarios (Batch Spills/Vessel Collision Scenarios)

Modelling of batch spills (100 L and 1,000 L) at the EL 1144 example well site suggest a patchy and discontinuous colorless and silver sheens of less than 0.0001 mm (0.1 µm) thickness predicted over limited distances. With regard to the potential for surface effects, the thicknesses above the ecological threshold (10 µm thickness) would be less than one km^2 for both batch spill events. With regard to the areas that are predicted to exceed socioeconomic thresholds (0.04 µm surface thickness) the area exceeding this level would be less than one km^2 was predicted for the 100 L release scenario and eight km^2 for the 1,000 L scenario. In the water column, the ecological thresholds were not predicted to be exceeded, due to the combination of small volume releases and grid resolutions used to determine concentrations. The threshold for potential water column effects (100 µg/L THC) was only predicted for the subsurface volumes of water for less than one km^3 subsurface volume for both scenarios. Contaminant concentrations would be predicted to be highest in the immediate vicinity of the release location but would be predicted to remain offshore, dissipating rapidly (ultimately to less than 0.01 percent of the released volume remaining on surface after 30 days) due to evaporation, dissolution/dispersion, and degradation. For the 100 L and 1,000 L release, the model predicted no shoreline interaction and less than 0.01 percent of the total mass of the released oil reaching the seafloor after 30 days.

The hypothetical vessel collision with 750,000 L spill event was predicted to result in more extensive contamination (including surface and subsurface oil), when compared to the modelled "batch spills." The release was predicted to result in patchy and discontinuous surface sheens that would likely result in a rainbow sheen over approximately 40 km of sea surface before transitioning to the colorless and silver sheen that was predicted for the batch spills. The larger release volume was predicted to result in larger exposure areas for surface oil including 13 km^2 for the 10-µm ecological threshold and 925 km^2 for the socioeconomic threshold (0.04 µm). The threshold for water column concentration (100 µg/L THC) was predicted to be reached for a subsurface volume totaling 100 km^3. These concentrations would be highest in the immediate vicinity of the release location but are predicted to dissipate rapidly (ultimately less than 0.01 percent of the released volume remaining on surface after 30 days) with distance. For the 750,000 L release the model predicted no shoreline interaction and 0.01 percent of the total mass of the released oil reaching the seafloor after 30 days.

16.6.1.2 Drill Fluid (SBM) Spill Scenarios

The modelling completed for a potential accidental release of SBM during Project-related drilling indicates that a surface SBM spill would reach the seafloor within a maximum of one kilometre from the drill site for the deeper EL 1144 example well site and less than 0.5 km at the shallower EL 1150 example well site. The average thickness of the SBMs on the seafloor for the EL 1144 example well site subsurface spill are predicted to be 1.7 cm with a maximum thickness of 7.1 cm. For a subsurface/subsea spill at the EL 1150 example well site, the SBMs would reach the seafloor faster with a smaller (within about 40-60 m from source in all seasons) but thicker seafloor footprint (average 2.6-2.7 cm) when compared to a surface spill.

16.6.1.3 Uncontrolled Well Events

The uncontrolled well event scenarios were undertaken in two separate modelling reports and results. The first modelling effort represented the 'capping stack installation stage' (30-day release, 60 day modelling duration, RPS 2018; See Appendix G of EIS) and the second round represents the 'relief well installation stage' (120-day release,160 day modelling duration, RPS 2019; See Appendix B of this Addendum). Although these are two separate modelling reports (RPS 2018, 2019), both sets of results (30-day and 120-day release) are discussed below.

30-day Release (capping stack scenario)

The subsurface release scenario for the EL 1144 example well site was a 30-day unmitigated flow of 184,000 bbl/day for 60 days modelling duration at 1,137 m depth (see section 16.4 and Appendix G of the EIS for detailed modelling results). Results indicate that the areas most likely (i.e., over 90 percent; based on stochastic results) to reach or exceed the ecological threshold for in-water concentration (1 µg/L PAH or 100 µg/L THC) includes areas to the east and south of the release site that extend 800 – 1,200 km. The stochastic model predicted a less than three percent probability of shoreline contact at Sable Island after 52-53 days of an unmitigated release. The oil that was predicted to contact the shoreline would be <0.01 percent of original spill (99th percentile) and would be highly weathered. The 52-53 day timeline would provide time to implement shoreline response measures to reduce the quantity of oil reaching the coastal areas. The model also predicts that the oil concentrations at the shoreline exceeding the ecological threshold of 100g/m^2 would occur across less than one km^2. The socioeconomic threshold (1 g/m^2) would be exceeded at 13 km^2. The model predicted 0.01 percent of the total release reaching the seafloor after 60-day modelling duration.

The subsurface release scenario for the EL 1150 example well site was a 30-day unmitigated flow of 44,291 bbl/day release modelled for 60 days at 378 m depth (see Section 16.4 and Appendix G of the EIS for detailed modelling results). Results indicate that the areas most likely (i.e., over 90 percent; based on stochastic results) to reach or exceed the ecological threshold for water column concentration (1 µg/L PAH or 100 µg/L THC) includes areas to the east and south of the release site that extend 400 – 800 km. For surface oil concentrations, the ecological threshold (10 µm thickness) is reached at approximately 200-400 km to the east and south of the release site. Releases at the EL 1150 example well site were not predicted to make contact with shorelines. The model predicted 0.02 percent of the total release reaching the seafloor after 30 days.

120-day release (relief well scenario)

The subsurface release scenario for the EL 1144 example well site was a 120-day unmitigated flow of 184,000 bbl/day for 160 days modelling duration at 1,137 m depth (see section 16.4 and Appendix B of this Addendum for detailed modelling results). The cumulative stochastic footprints for potential surface oil exceeding a thickness of 0.04 µm were between 8,152,000-8,211,000 km^2. These footprints depict areas with the highest predicted likelihood of potential oil contamination to the east of the release sites, with a much lower probability (1-10% and 10-25%) for oil to be transported to the west towards Canadian waters. While these areas are quite large, most of the footprint represents a relatively low probability (<10%) of surface oil thickness >0.04 µm. Seasonal variations were evaluated yielding different predicted surface oil results for summer versus winter scenarios. Larger surface oil footprints associated with >90% probability contours were predicted for summer scenarios indicating more coherency in the release.

The highest predicted potential (77% and 70%) for oil to make contact with any shoreline exceeding 1 g/m2 occurred only in the summer scenarios, associated predominantly with oil reaching the islands of the Azores. The maximum probability of oil reaching the shores of Newfoundland is less than 25% (and typically less than 10%) and for Labrador was always less than 10%. The minimum predicted time for oil to contact shorelines for the modelled 95th percentile representative deterministic shoreline scenario at the EL 1144 example well site was 81 days into the release for the shores of Newfoundland, 111 days for the Azores, and no oil was predicted to reach the shores of Labrador. For the EL 1150 example well site, oil was only predicted to contact the shores of the Azores, 80 days into the release for the modelled 95th percentile shoreline scenario. In all cases, based upon the minimum time to shore, oil was predicted to be extremely weathered by the time it reached shorelines.

For most representative deterministic scenarios, the amount of evaporation and degradation was relatively consistent between model runs. Approximately 43-51% of the releases were predicted to evaporate and another 34-40% to degrade by the end of the 160-day modelling duration. Most of the remaining variability in the mass balances was associated with the amount of oil found either on the surface or entrained within the water column. Predicted surface oil was <12%, while entrained oil in the water column ranged between 3% and 7%. The mass of oil contacting shorelines was minimal (<0.09%) with respect to the total release volume for these modelled scenarios, where even the 95th percentile shoreline contact case was predicted to have 0.03% and 0.09% of the total volume of released oil reaching shore. Oil on sediments was typically 0.01%, making up the smallest portion of the predicted mass balance.

Comparison of the 30-day and 120-day release scenarios

The larger potential for oil making contact with shorelines (70-77% in the second round modelling study (RPS 2019) versus 3% in the first round study (RPS 2018)) is based upon the much longer release duration (120-day releases modelled for 160 days vs. the 30-day releases for 60 days) and the much larger model domain used in the second study, which included the Azores to the east (which accounted for as much as 44% of the increase in potential shoreline oiling). While the larger model domain used in the second study suitably captured the larger area over which oil would be expected to be transported, the simulation duration was nearly three times longer and the release duration (and resulting release volume) was four times larger than was used in the first round modeling. Therefore, the longer (and subsequently larger) release and longer simulation duration (60 vs. 160 days) negated a portion of the benefits of this spatially and temporally broader analysis.

16.6.1.4 VC-Specific Context

The environmental effects assessment for each VC considers the potential spill events (as modelled) in the context of the characteristics of the particular VC in question and its known spatial and temporal distributions (see Sections 6-7). As the trajectory modelling reports (Section 16.4, RPS 2018,2019) covered two modelling interpretations (stochastic and deterministic) with 71 separate illustrative maps, some deductions had to be made in the assessment analysis to obtain meaningful comparisons of the most relevant modelling results related to the subsurface/subsea release scenarios with the corresponding VCs.

For example, for the Marine Fish and Fish Habitat VC, a key focus of the assessment was predicted oil concentrations in the water column. A conservative approach to assess the effects on fish and fish habitat was to take the 95th percentile to represent credible worst case scenarios for total hydrocarbon concentrations in the water column. For marine and migratory birds, oil concentrations at the sea surface and possible shoreline exposure were more relevant. Table 16.18 and Table 16.19 lists the various VCs under consideration and identifies the most relevant model results in context of the environmental effects assessment for the 60-day and 160-day modelling results, respectively.

It should be reiterated that while the environmental effects assessment is informed by the modelling of potential unmitigated spill events, it also considers the overall potential of such an event occurring, based on the spill probability statistics and analysis presented earlier (Section 16.3), and the various regulatory processes and CNOOC procedures aimed to prevent and/or respond to such an incident (Section 16.1). The modelling results (RPS 2018, 2019) did not consider these prevention and response measures.

It also considers the planned application of mitigation measures to respond to any such spill event in the unlikely event that it did occur, and their implications for preventing or reducing spill volumes and the geographic extent and duration of a spill event (Section 16.1). The assessment concludes with a determination of the significance of such effects, based on the same VC-specific definitions used for planned Project components and activities.

In the unlikely event of an accidental event, such as a spill or a release, specific environmental monitoring programs may be required, which will be developed and implemented in consultation with the appropriate regulatory agencies.

Table 16.18 VCs and Corresponding Relevant Modelling Results for Subsurface/Subsea Release (30-day release)

	Component[1]				
VC	**Sea Surface**	**Water Column**	**Shoreline**	**Relevant Deterministic Model Results**	**Corresponding Model Iteration (Representing 95th or 99th Percentile)**
Marine Fish and Fish Habitat	L	**H**	L	95th Percentile Water Concentration[2]	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)
Marine and Migratory Birds	**H**	M	**H**	95th Percentile Oil Thickness	June 13, 2006 (EL 1144)/April 20, 2007 (EL 1150)
				99th Percentile Shoreline Exposure[2]	October 2, 2008 (EL 1144)[3]
				95th Percentile Water Concentration	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)
Marine Mammals and Turtles	**H**	**H**	M	95th Percentile Oil Thickness	June 13, 2006 (EL 1144)/April 20, 2007 (EL 1150)
				95th Percentile Water Concentration	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)
Special Areas	**H**	**H**	**H**	95th Percentile Water Concentration[2]	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)
				99th Percentile Shoreline Exposure	October 2, 2008 (EL 1144)[3]
				95th Percentile Oil Thickness	June 13, 2006 (EL 1144)/April 20, 2007 (EL 1150)
Indigenous Peoples	**H**	**H**	**H**	95th Percentile Water Concentration	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)
				99th Percentile Shoreline Exposure	October 2, 2008 (EL 1144)[3]
				95th Percentile Oil Thickness[2]	June 13, 2006 (EL 1144)/April 20, 2007 (EL 1150)
Fisheries and Other Ocean Uses	**H**	**H**	L	95th Percentile Water Concentration	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)
				95th Percentile Water Concentration[2]	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)

[1]High(H), Medium(M), and Low (L) chance of interaction of the VC with the component
[2]To give further spatial context relating the oil spill scenarios and the corresponding VCs, these deterministic modelling results were overlaid on the relevant VC information in the following sections
[3]Only EL 1144 example well site had a model prediction that reached the shoreline

Table 16.19 VCs and Corresponding Relevant Modelling Results for Subsurface/Subsea Release (120-day release)

	Component[1]				
VC	**Sea Surface**	**Water Column**	**Shoreline**	**Relevant Deterministic Model Results**	**Corresponding Model Iteration (Representing 95th Percentile)**
Marine Fish and Fish Habitat	L	**H**	L	95th Percentile Water Concentration[2]	June 19,2012 (EL 1144)/May 28, 2009 (EL 1150)
Marine and Migratory Birds	**H**	M	**H**	95th Percentile Oil Thickness	Oct. 22, 2009 (EL 1144)/Feb. 5, 2008 (EL 1150)
				95th Percentile Shoreline Exposure[2]	Mar. 7, 2006, 2008 (EL 1144)/Jul. 22, 2006 (EL 1150)
				95th Percentile Water Concentration	June 19,2012 (EL 1144)/May 28, 2009 (EL 1150)
Marine Mammals and Turtles	**H**	**H**	M	95th Percentile Oil Thickness	Oct. 22, 2009 (EL 1144)/Feb. 5, 2008 (EL 1150)
				95th Percentile Water Concentration	March 22, 2008 (EL 1144)/Dec. 3, 2006 (EL 1150)
Special Areas	**L**	**H**	**H**	95th Percentile Water Concentration[2]	June 19,2012 (EL 1144)/May 28, 2009 (EL 1150)
				95th Percentile Shoreline Exposure	Mar. 7, 2006, 2008 (EL 1144)/Jul. 22, 2006 (EL 1150)
				95th Percentile Oil Thickness	Oct. 22, 2009 (EL 1144)/Feb. 5, 2008 (EL 1150)
Indigenous Peoples	**H**	**H**	**H**	95th Percentile Water Concentration	June 19,2012 (EL 1144)/May 28, 2009 (EL 1150)
				95th Percentile Shoreline Exposure	October 2, 2008 (EL 1144)[3]
				95th Percentile Oil Thickness[2]	Oct. 22, 2009 (EL 1144)/Feb. 5, 2008 (EL 1150)
Fisheries and Other Ocean Uses	**H**	**H**	L	95th Percentile Water Concentration[2]	June 19,2012 (EL 1144)/May 28, 2009 (EL 1150)
				95th Percentile Oil Thickness	Oct. 22, 2009 (EL 1144)/Feb. 5, 2008 (EL 1150)

[1]High(H), Medium(M), and Low (L) chance of interaction of the VC with the component
[2]To give further spatial context relating the oil spill scenarios and the corresponding VCs, these deterministic modelling results were overlaid on the relevant VC information in the following sections

16.6.2 Marine Fish and Fish Habitat (including Species at Risk)

Marine fish and fish habitat components relevant to the Project Area and larger RSA include plankton, benthos and finfish. The presence, abundance and distribution of particular species varies considerably based on habitat characteristics (both abiotic and biotic) and variability across this large and diverse marine environment, which includes parts of the Newfoundland Shelf, Flemish Cap and adjacent slope and deepwater habitats in the Flemish Pass. Within these areas and associated habitat types, a variety of fish species and assemblages occur with such factors as water depths and habitat complexity being key determining factors of species presence and prevalence.

The Project Area and RSA also host a number of commercially relevant fish and shellfish species which are important for both Canadian and/or international fishers. Deep-sea corals, sea pens, and sponges are often of environmental interest due to the habitat-forming capacity of these benthic invertebrates, their importance in supporting early life stages of fish and invertebrates, and their relative sensitivity to anthropogenic stressors. Existing and available information for corals, seamounts, and sponges indicates that portions of the Project Area and RSA overlap with several areas of known occurrence for these species. Secure and at risk fish and invertebrate species of commercial, cultural and/or ecological value are known to occur in the Project Area and RSA and could therefore be affected by an accidental event.

The potential effects of the accidental release of hydrocarbons in the marine environment on marine fish and fish habitat are largely dependent on a variety of biotic (species, life history, behaviour, resistance) and abiotic (oceanographic conditions, exposure duration, oil type, oil treatment methods) factors. The extent of the potential effects depends on how the spill trajectory and the various components of the VC overlap in both space and time.

16.6.2.1 Potential Issues and Interactions

The potential environmental effects included in the assessment of planned Project components and activities (Section 8) included changes in:

- habitat availability and quality;
- food availability and quality;
- fish mortality, injury, health; and
- fish presence and abundance (behavioral effects).

These potential effects remain relevant to the assessment of accidental events, although the mechanisms or pathways of effects may be different. The extent of any potential effects on marine fish and fish habitat may depend largely on the level and timing of exposure to any toxic components of the oil. Potential accidental effects considered involve varying degrees of hydrocarbon exposure including batch spills and subsurface releases. Given the known injury and behavioural responses of marine species to hydrocarbon interactions (described below), batch spills and subsurface releases were assessed through the Project specific modelling that considers various scenarios of hydrocarbon release.

Existing Knowledge of the Effects of Hydrocarbons on Marine Fish and Fish Habitat

A review of the potential effects of oil and dispersants is presented below for plankton, fish, invertebrates and sensitive coral and sponge species. Information on the potential effects of hydrocarbons on fish and fish habitat are derived primarily from laboratory studies and known responses of North Atlantic species to anthropogenic disturbances. Recent in situ studies of large-scale hydrocarbon spill events are based largely on the DWH that describe the fate and effects of oil, and oil dispersants on the environment. While the studies are based on an event in a relatively warm environment, they are relevant to an overall understanding of the potential effects on fish and fish habitat in more temperate environments, including the Project Area and RSA. A review of the potential environmental effects on Arctic marine environments also provides useful information for temperate areas (Peterson et al 2003; Olsen et al 2011; AORST-JIP 2014; Bejarano et al 2017).

Plankton and Microbes

Plankton are a key component of primary and secondary production in ocean environments, and potential effects on these organisms may have implications for higher trophic levels. The response of plankton and other microbial communities to oil spills is diverse and largely dependent on exposure level. In general, plankton and other microorganisms do not have an avoidance response to contaminants, as oceanographic conditions largely control their horizontal movements. However, certain coastal and estuarine zooplankton have been shown to be able to detect and avoid small patches (1-7 cm) of hydrocarbon- contaminated water (Seuront 2010), resulting in localized distribution changes.

Oil exposure of phytoplankton to oil may result in altered productivity and growth, with possible population-level effects on abundance and community composition (Buskey et al 2016). Depending on the species involved, crude oil concentrations up to 1 mg/L may have stimulant effects on phytoplankton growth, whereas concentrations over 1 mg/L may cause growth inhibition, and concentrations over 100 mg/L result in severe or complete growth inhibition (Rabalais 2014). This may shift community composition, depending on species presence and relative tolerances (Ozhan et al 2014). For example, five-day crude oil exposures to 8.6-23 mg/L resulted in decreased oceanic phytoplankton and large diatoms and stimulant effects on small diatoms (González et al 2009 in Ozhan et al 2014). Laboratory studies on Arctic phytoplankton resulted in growth inhibitions for two diatom species found in and around sea ice (Van Baalen and O'Donnell 1984) at crude oil concentrations over 50 mg/L and green flagellates have showed increased growth for an exposure regime of 10 mg/L (Hsiao et al 1978). Some arctic field studies on diatoms from ice algal communities found no decreases in cell densities, chlorophyll a concentrations or productivity when exposed to a field release of dispersed weathered oil (Cross 1987). Changes in both plankton population (biomass) and community assemblages on the Louisiana Shelf after the DWH spill where there with a shift from ciliates and phytoflagellates to diatoms and cyanobacteria (Parsons et al 2015). Remote sensing of chlorophyll a after the DWH spill indicated a strong but short-lived stimulation in regional phytoplankton, however the reduction in photosynthetic capacity in near-surface waters from the spill likely had negative population effects on phytoplankton (Ozhan et al 2014).

Laboratory oil exposure studies have shown lethal and sublethal effects on zooplankton (Sueront 2010; Almeda et al 2013; AOSRT-JIP 2014; Busky et al 2016) but with few documented mass mortality events related to oil slick episodes (Seuront 2010). Zooplankton may take up oil components passively, through ingestion of hydrocarbon exposed phytoplankton, or direct ingestion of crude oil droplets (Almeda et al 2014, 2016). Lethal concentrations of dispersed oil from the DWH spill are estimated to be approximately 27 ppm (Almeda et al 2014, 2016). Sublethal effects range from physiological, feeding fecundity, and behavioral responses related to predator avoidance (Almeda et al 2013). Various studies have observed reduced reproductive success in copepods exposed to a range of hydrocarbon concentrations including reductions in egg production and reductions or delays in hatching. Comparison of fresh and weathered crude oil indicated that weathered was generally considered less toxic to zooplankton due to the loss of volatile fractions (Almeda et al 2013). Laboratory exposure studies comparing arctic and temperate-boreal copepod species have found that Arctic species are less sensitive to oil exposure (Hansen et al 2011; Gardiner et al 2013) but this may be related to a delayed response time for the Arctic species (Hansen et al 2011).

Seasonal plankton blooms generally coincide with increased presence of ichthyoplankton (fish eggs and larvae) that capitalize on increased food levels in the water column. Exposure to oil has potentially lethal and sublethal effects on these sensitive early life history stages (Lee et al 2015; Sørensen et al 2017; O'Shaughnessy et al 2018). Ichthyoplankton likely have limited avoidance abilities. Laboratory experiments with Atlantic herring larvae exposed to total PAH levels of 0.129-6.019 µg/L for 12 days resulted in higher mortalities compared to control groups (Ingvarsdóttir et al 2012). Although there were no further differences in mortalities compared to control groups during a two month recovery period, increased deformities and reduced growth were observed in exposed larvae (Ingvarsdóttir et al 2012). Similarly, exposure of embryos of Atlantic cod and Atlantic haddock to dispersed crude oil (10-600 µg/L) resulted in heart and craniofacial deformities (Sørensen et al 2017). Exposures of bay anchovy to varying levels of weathered oil indicated that more weathered oil had a higher toxic effect at the embryonic and hatching stages (O'Shaughnessy et al 2018). Ichthyoplankton responses can be species specific as demonstrated by ichthyoplankton surveys before and after the DWH spill where there were no documented changes in body condition of Spanish mackerel, but relatively poorer body condition of red snapper was recorded (Hernandez et al 2016; Ransom et al 2016). While changes in body condition were noted, ichthyoplankton abundances of both species did not change between pre- and post-DWH spill surveys (Hernandez et al 2016; Ransom et al 2016). Experimental exposure of larval echinoderm and bivalve invertebrate species to oil from the DWH spill indicated that weathered oil had no effect on survival and development, however fresh oil resulted in adverse effects (Stefansson et al 2016). While potential effects on larval stages have been identified, overall reductions may not necessarily have population-level negative effects on adult populations (Gallaway et al 2017; Carroll et al 2018).

Microbes and plankton serve an important role in moving surface oil from the waters into the deep ocean through formation of marine snow. Marine snow is a continuous shower of mostly organic detritus that has been degraded by microbes, clumps together, and settles from the upper layers of the water column. A similar pathway has been seen after oil spills in which microbes degrade hydrocarbons into marine snow helping to shunt degraded hydrocarbons through the water column (Passow et al 2012; Daly et al 2016). Flocculated hydrocarbon material may also be ingested by zooplankton as it settles, expelled through fecal pellets which further enhances settling of hydrocarbon material to benthic environments (AOSRT-JIP 2014; Almeda et al 2016). This natural mechanism is an important link between benthic and pelagic environments that brings important nutrients and organic matter from surface waters to the deep sea, however, during spill events, may serve to contaminate deep sea corals and benthic communities through this pathway (Rabalais 2014). Based on laboratory and field studies, similar mechanisms of microbial degradation of oil have been shown in the Arctic (Prince et al 2013), though at slower rates than in more temperate environments (AOSRT-JIP 2014). Gelatinous zooplankton such as jellyfish, may also help move oil from surface waters to the water column through increased production and shedding of mucous when exposed to the physiological stress of oil exposure (Gemmell et al 2016). However, oil degrading bacteria were also shown to be able to grow faster in the contaminated mucous and increase rates of oil degradation (Gemmell et al 2016) which may reduce hydrocarbon transport to benthic areas.

Depending on the persistence of hydrocarbons in the environment, influences on the planktonic phase of fish and invertebrate species may limit distributions, recovery, and recolonization. The potentially longer term lethal and sublethal effects on plankton and microbes may reduce overall food resources and affect higher trophic levels such as pelagic fish and benthic organisms. Many fish and invertebrate species also have one or more life stages in a planktonic phase, hence affecting recruitment to adult fish and invertebrate populations.

Invertebrates and Fish

The primary hydrocarbon spill exposure mechanism to marine biota is through the dissolved portion in the water column as the most acutely toxic compounds are both volatile and water soluble (i.e., PAHs) (French-McCay 2009). Exposure studies using the dissolved fraction of oil have found lethal and sublethal values for fish in the range of 0.3 to 60 µg/L dissolved PAHs (0.03-11 mg/L TPH) (Lee et al 2015). Cold water fish species have been shown to have comparable ranges with lethal values for fish of 0.7 – 4.0 mg/L TPH (AOSRT-JIP 2014). These ranges coincide with the ecological threshold of 1.0 µg/L dissolved PAHs (corresponding to approximately 100 µg/L of whole oil or THC), that was used as a modelling reference in this study and serves as a threshold to predict the hydrocarbon exposure effects on marine species. Laboratory exposure studies, in general, have shown more severe effects than measurements taken in situ during and after actual spills. It is generally agreed that development stages of fish and invertebrates are more sensitive to oil than adult stages (Ingvarsdóttir et al 2012; Lee et al 2015; Sørensen et al 2017; O'Shaughnessy et al 2018), however effects on larval stages do not necessarily result in effects on adult populations (Gallaway et al 2017; Carroll et al 2018).

Acute toxicity (short-term exposures) would be more representative of exposure during a discrete batch spill event. The ecological risks for this type of exposure would be reduced as the more toxic components of the spill, lower molecular weight compounds (LMW), evaporate and dilute rapidly (Lee et al 2015). There are however, documented sublethal effects such as reduced feeding (Lari et al 2015) and larval deformities (Mager et al 2014). Potentially lethal effects (associated with LMW) include a variety of responses related to lipid membrane receptors in effects collectively termed narcosis (Peterson et al 2003). Continued exposure can result in symptoms that range from depression in respiratory-cardiovascular activity, tissue hypoxia and ultimately respiratory paralysis (death) if exposure continues. These effects are short term as the LMW volatize from the oil on the order of days (Lee et al 2015). Cold water invertebrate taxa (bivalves, gastropods, crustaceans) have been shown to have comparable reactions in terms of specific PAH sensitivities when compared to temperate species (Olsen et al 2011). These short-term effects can be recoverable if exposure does not continue.

Chronic, long-term exposure would have a range of potential effects from genetic and molecular responses of cells to effects on reproduction, growth, disease, and survival (Lee et al 2015; Busky et al 2016). The uptake pathways vary but can include respiratory uptake, direct contact, diet, or maternal transfer to eggs (Lee et al 2015). Studies on finfish have shown that the dissolved oil components can travel across respiratory membranes in gills (Lee et al 2015). More recent studies have identified that the PAH phenanthrene disrupts cardiac function and is associated with heart malformations in developing fish and it becomes proportionally more toxic as the spilled oil weathers (Brette et al 2017). Long term exposure may also affect fish health and condition through susceptibility to higher parasite loads (Khan et al 1990). Uptake of PAHs in a bivalve indicated that it primarily accumulated in the gonads resulting in reproductive delays (Frouin et al 2007). Like invertebrates, deep-sea fish species typically have lower metabolisms, are slower growing, have longer life spans, and would likely be more susceptible to disturbances such as oil spills (Cordes et al 2016). As previously discussed, the early life stages are likely more sensitive to hydrocarbon exposures than adults (Lee et al 2015; Sørensen et al 2017).

Community and population-level effects from the DWH spill on regional fisheries were observed (Felder et al 2014; Murawksi et al 2016) that resulted in temporary effects on productivity (Murawski et al 2016). Recovery, however, was largely influenced by fisheries closures (Murawski et al 2016). These findings are in general agreement to population modelling studies on Arctic cod that predicted that even if large mortalities of Arctic cod juvenile and eggs were to occur due to a hypothetical spill event (as the early life stages are potentially the most susceptible to a spill), the effects on the regional cod population would be insignificant (Gallaway et al 2017; Carroll et al 2018).

Species-specific population structure would be an important consideration as in the case of Arctic cod where diverse age distributions would help mitigate effects of single year recruitment reductions to the adult population (Carroll et al 2018). Studies from the DWH spill also showed strong declines in species richness and diversity in the decapod crustacean community post-spill (2010-2012) relative to earlier surveys (2004-2006) (Felder et al 2014). It has been theorized that hydrocarbon exposure may have caused localized mortalities, reduced the fecundity of surviving females or reduced recruitment (Felder et al 2014). The number of lesions observed on deep-water shrimp species surveyed after the spill increased nearly threefold (Felder et al 2014). It is also important to highlight that deep-sea invertebrate species (less motile, lower metabolism, slower growing, long life spans) are likely to be more sensitive to anthropogenic disturbance (Cordes et al 2016). For example, severe reductions in benthic invertebrate abundance and community diversity was observed up to three km away from the Macondo well, with moderate effects up to 17 km away (Montagna et al 2013 in Busky et al 2016).

Unlike plankton and microorganisms, fish and invertebrates are generally motile and have higher capability to avoid oiled areas in the event of an accidental spill (Lee et al 2015). However, these reactions are species and life stage specific. As noted above, the embryonic life stages of both fish and invertebrates are more often less motile than their adult counterparts thereby more susceptible to spills. These effects on the early life stages are further compounded by their lower toxicity thresholds to spilled oils (Lee et al 2015). Laboratory exposure studies capelin (Frantzen et al, 2012) and larval sculpin (Gardiner et al 2013) have found similar results with increased embryo mortality rates and decreased hatching success. Deep-sea species of fish and invertebrates may be more susceptible to anthropogenic effects (Cordes et al 2016) as they would likely to have less successful avoidance strategy than their more pelagic counterparts.

Deep Sea Corals and Sponges

Corals and sponges have an important functional role and act as nurseries, refugia, spawning and breeding grounds for many aquatic species (Beazley et al 2013; DFO 2016). In deep sea ecosystems that are largely composed of flat and featureless soft-bottom areas, corals and sponges serve as ecosystem engineers creating complex three-dimensional features that are critical habitat to other taxa (Beazley et al 2013; Ragnarsson et al 2017). In general, their life histories (planktonic larvae, slow growing, long life spans, and slow recovery) and feeding mechanisms (suspension feeding) makes them susceptible to accidental events (Fisher et al 2014; Prouty et al 2016; Cordes et al 2016). Sessile adult and planktonic larvae of corals and sponges also have no known avoidance mechanisms to oil spill events.

The effects of hydrocarbons on corals are typically assessed in situ using visual indicators of stress (White et al 2012). Visual indicators of coral stress related to the DWH spill included partial tissue loss, excessive mucus production, retracted polyps, partial coverage by brown flocculant sourced to the spill and death (Busky et al 2016; Prouty et al 2016; Ragnarsson et al 2017). Follow-up studies on the DWH spill has shown a patchy distribution of effects which were highly site specific and included incidence of hydroid colonization, a sign of deterioration on affected coral branches (Hsing et al 2013). For example, one site 13 km to the southwest of the Macondo wellhead (lease block MC294) showed that over half of the corals were partially covered by a brown flocculant material but follow up surveys 16 months later indicated that recovery was occurring (Fisher et al 2014).

Sponges have been shown to have relatively high bioaccumulation capabilities for PAH compounds (Batista et al 2013, Gentric et al 2016). However, sponges exposed to hydrocarbons may exhibit highly variable accumulations as they may alter their filtering behaviours in response to contaminants (Kutti et al 2016). In short exposure experiments, altered feeding behaviours allowed sponges to cope with exposure to oil and dispersant contaminated sediments (Vad and Duran 2017). The PAH benzo(a)pyrene, a type of carcinogen, has been observed to be strongly bioaccumulated in sponges (Gentric et al 2016) with potential damage to sponge DNA (Zahn et al 1983). Presence of hydrocarbons may also have effects on larval distribution with experimental studies showing decreased larval settlement in the presence of hydrocarbons (500 and 100 ng/L PAH) and copper (Cebrian and Uriz 2007).

Existing Knowledge of the Effects of Dispersants on Marine Fish and Fish Habitat

Chemical dispersants do not remove oil from the environment but are utilized to disperse oil slicks from the sea surface into the water column, increasing hydrocarbon exposure to the microbes which should result in accelerated microbial degradation of spilled oil (Lee et al 2013; AOSRT-JIP 2014; Coelho et al 2017). Dispersant use after a spill has the potential to increase the exposure within the water column (i.e., plankton, pelagic fish) and eventually, the benthos (demersal fish, benthic invertebrates) (Ramachandran et al 2004). The dispersant serves to shear an oil slick into small droplets and mix them in the water column making them more accessible to marine microbes that can metabolize and degrade the hydrocarbons (Gemmell et al 2016). Although it is generally agreed that dispersants increase the availability of oil to microbes in the water column by reducing oil droplets size, there remains some debate on the effects on oil degradation rates (Brakstad et al 2014, 2015; Kleindienst et al 2015; Seidal et al 2016). For example, certain concentrations and ratios of oil to dispersant (15 percent oil: 1.5 percent dispersant) have been shown to reduce the effectiveness of certain degradation pathways related to the formation of microbial marine snow (Passow 2012; Seidel et al 2016).

Chemical dispersants are of toxicological concern due to the resulting interaction and effects of chemically dispersed oil on fish and fish habitat (DeLeo et al 2016). The main toxicological pathway is increased exposure to the more toxic components of oil (i.e., PAHs) to taxa occupying the water column (Pace et al 1995). Chemically dispersed oil has more pronounced effects on the early life stages of fish and invertebrates; specifically eggs and larvae (Cordes et al 2016, DeLeo et al 2016). For example, chemically dispersed oil is known to reduce larval settlement, cause abnormal development, and tissue degradation in sessile invertebrates (Cordes et al 2016). Similarly, laboratory studies on Atlantic herring eggs showed an increase rate of deformities and mortalities for dispersed oil exposure (1 mg/L total hydrocarbons; up to 14-day exposure) (Greer et al 2012). Plankton may be sensitive to the combined toxicity of dispersants and crude oil. The dispersal of crude oil increases prevalence of small oil droplets compared to natural dispersal, that may be ingested by zooplankton (Almeda et al 2014). Dispersed oil was shown to be 2.3-3.4 times more toxic to copepods compared to crude oil alone with further increases in toxicity with exposure to sunlight (Almeda et al 2013). Experimental toxicity studies on rotifers indicated that oil and the chemical dispersant Corexit 9500a ® utilized during the DWH spill event were of similar toxicity, but the combined resulted in a 52-fold increase in toxicity (Rico-Martinez et al 2013).

Laboratory studies on deep sea coral from the Gulf of Mexico indicated that dispersed oil solutions were more toxic to the coral than untreated oil solutions (DeLeo et al 2016). These studies used three initial oil concentrations of 250 μM (high), 150 μm (medium), and 50 μM (low) with total initial dispersant concentrations of 176.7 mg/L (high), 106.0 mg/L (medium) and 35.3 mg/L (low). Like other invertebrates, the most dramatic effects related to early (larval) coral life stages with decreasing settling abilities and post-settlement survival (DeLeo et al 2016). In experiments with gorgonian corals, coral fragments were largely unaffected by weathered oil, but fragment mortality occurred within 48 hours of exposure to both chemical dispersants and combined oil and dispersants (Fromet et al 2017). While responses to dispersed oil are species-specific, there is evidence that relative sensitivity to dispersed oil is similar among arctic, temperate, and tropical species (Olsen et al 2011; Bejarano et al 2017).

Existing Knowledge of the Effects of Drill Fluids (SBMs) on Marine Fish and Fish Habitat

As described and discussed in Section 2.5.2.2, SBM-associated cuttings will be discharged in accordance with regulatory requirements as a component of drilling wastes for ongoing operations. The potential effects of SBMs in general are discussed in detail in Section 8.3.4 including SBM-associated drill cuttings. The effects described below relate exclusively to an accidental discharge of SBM (i.e., drill fluid only).

Potential pathways of potential effects on fish and fish habitat would be the direct toxicity of the fluid and potential changes to fish habitat (i.e., degradation of benthic habitat, elevated TSS in the water column).

SBMs were developed to replace oil-based muds (OBMs) that were historically used in drilling activities. The toxic components of the OBMs have been essentially removed in synthetic based fluids, resulting in drilling fluids that have lower acute toxicity (Tsvetnetko et al 2000; Hamoutene et al 2004; Paine et al 2014; Tait et al 2016). Potential base fluids for SBMs may include esters, poly alpha olefins, internal olefins, linear alpha olefins and others. Acute toxicity of SBMs is relatively low based on laboratory experiments and field evaluations of SBM-associated drill-cutting piles (Still et al 2000; Tsvetnetko et al 2000; Hamoutene et al 2004; Paine et al 2014; Tait et al 2016). Lobsters injected with high levels of SBM, for example, did not change aspects of their lipid and protein metabolism or show any other adverse health effects after approximately 20 days (Hamoutene et al 2004). Toxicity experiments with fish indicated that acute toxicity of SBMs was generally low (96-h LC50 toxicity of over 30,000 mg/L, Jagwani et al 2011), but there were potential health effects with chronic exposure to SBM associated cuttings (Jagwani et al 2011; Gagnon and Baktyar 2013; Vincent-Akpu 2013). Any potential effects are likely to be temporary in nature as SBMs biodegrade within a few years (Terrens et al 1998; Ellis et al 2012; IOGP 2016).

Other potential effects include changes to fish habitat in terms of surface, water column, and the seafloor (benthos). A surface SBM spill would likely result in a surface sheen similar to that described for batch spills but more limited in nature. SBMs, however, are a heavy, dense fluid which sinks rapidly so the effects on the water's surface would be limited as it sinks through the water column. Water column quality could be affected by increased SBM concentrations within the immediate area (increased TSS) but the area would be small and would generally become a source of organic matter which could be consumed by microbial processes before it reached the seafloor. This is largely dependent on the resident time of the SBMs within water column. If SBMs do reach the seafloor, there is the potential to create anoxic conditions through local eutrophication due to degradation of SBM organic components (Schaanning et al 2008; Ellis et al 2012).

16.6.2.2 Environmental Effects Assessment

The potential environmental effects of an accidental spill event on marine fish and fish habitat are assessed in the following subsections.

Marine Diesel Spills (Batch Spills and Vessel Collision Scenario)

The relevant model results for marine diesel spills (100L and 1000L batch spills and 750,000 L VCL spill) are summarized in Section 16.4. The model results suggest that both the potential for exposure and the likelihood of adverse effects on fish and fish habitat from any such diesel releases are low. Fish in the immediate vicinity near the surface at the time of the spill may be exposed. At the concentrations predicted, change in habitat availability and quality will likewise be of low magnitude. Batch spills would cause a decrease in water quality around the spill site, but it would be short-term until the surface slick naturally disperses through surface wave action in the offshore environment. Fish within the immediate area near the surface may be able to avoid exposure until the slick is dispersed by surface wave action in the offshore environment). Fish unable to avoid the area may be affected by PAH exposure. However, change in fish health, mortality or injury is predicted to be of low magnitude because most of the oil would dissipate quickly; even the risk to those fish in the immediate vicinity unable to avoid the spill is considered relatively low. Plankton communities, including early life history stages of fish and invertebrates, would not be able to avoid exposure to a batch spill and therefore interactions with plankton communities in the immediate area may have lethal and sub-lethal effects.

It is predicted that there would be localized and limited change in fish presence, abundance, and habitats for the duration and extent of the batch spill. Due to the short-term nature of small batch spills and overall quantity released, the presence of fish in the immediate area may decrease temporarily (mostly due to avoidance) but could return once the slick disperses (8,11, and 14 percent oil remaining entrained in water column after 30-day stimulation for 100L and 1000L batch spills and 750,000 L VCL spill, respectively). It is possible that some zooplankton and ichthyoplankton would face mortality in the immediate footprint with the potential for a subsequent increase in phytoplankton (Ozhan et al 2014; Rabalais 2014; Busky et al 2016). Depending on the timing of the spill such as during seasonal spawning events, there may also be limited mortality and injury to planktonic early life stages of benthic organisms. However, these potential localized changes are not predicted to affect the overall population or abundance of the plankton community and therefore would have limited effects on higher trophic levels.

Modelling also predicts 0.01 percent or less of the hydrocarbons would reach the seafloor at the end of the 30-day simulations for all diesel spills, suggesting minimal effects on the benthic community, including corals and sponges. While there would be some flocculation of oil resulting in transport to benthic environments (Passow et al 2012; Daly et al 2016), the overall quantity and interaction with the benthos would be limited.

With spill prevention plans and response procedures in place, the potential environmental effects of a diesel spill (100, 1,000L, 750,000 L) on marine fish and fish habitat are predicted to be adverse, low to medium magnitude, localized to within the RSA, short- to medium-term in duration, and reversible. These predictions were determined with an overall moderate level of confidence.

Drill Fluid (SBM) Spill

The relevant drill fluid model results are summarized in Section 16.5. A SBM spill would have the potential to result in seabed disturbance, chemical toxicity, and bioaccumulation (uptake of contaminants by fish and the presence or perception of taint). As discussed in detail in Section 8.3.4, the acute toxicity of SBMs considered relatively low and below environmental guidelines, would not result in adverse effects from contamination of marine biota or habitats. Potential effects of a drill fluid spill on fish and fish habitat are predicted to be adverse, negligible to low in magnitude, short-term in duration, localized to within the Project Area, and reversible. These predictions were determined with a high level of confidence.

Uncontrolled Well Event

The relevant model results for uncontrolled well events are summarized in Section 16.4. In the event of a subsurface/subsea release scenario, there could be potential effects within the water column, which could affect habitat availability and quality. Dissolved oil fractions in the water column constitute a physical and chemical change to the water column, especially for the first few meters (RPS 2018, 2019). While the spilled oil is predicted to have minimal interaction with sediments based on the modelled scenarios (0.01-0.02 percent of spilled oil is predicted to remain within sediment after 30 days), interactions with benthic fish habitat are likely due to flocculation and sinking events associated with plankton and microbial pathways (Passow et al 2012; Daly et al 2016).

Fish health and mortality may also be affected by an uncontrolled well event. Fish presence and abundance could also be affected with temporary avoidance of oiled areas. Local abundance may also be adversely affected depending on mortality levels resulting from interactions with hydrocarbons and dispersants. The effect on fish would depend on the timing of the event as some fish exhibit seasonal migrations or seasonally timed life stages. Oil events during or soon after seasonal spring and fall phytoplankton blooms are likely to interact with early life stages of various fish and invertebrates that coincide with these natural processes and are sensitive to hydrocarbon interactions.

Adult demersal and pelagic fish could potentially avoid the area, but juvenile and early life stages of fish and benthic invertebrates in the immediate areas would likely experience sublethal and lethal effects as described for a batch spill, but an uncontrolled well event would be over a greater area. Sublethal effects on juvenile and early life stages may also have species-specific implications (i.e., decreased reproductive success, deformities). Further potential effects on fish and fish habitat related to a large oil spill could amplify decreases in populations of fish that are already in decline. While an unmitigated spill event would have adverse effects on fish health and mortality, responses are largely species specific and there may be stimulant effects on particular species (Hernandez et al 2016; Ransom et al 2016). The overall effect could result in community composition changes during and after the spill.

Food availability and quality would be adversely affected in the case of an accidental spill event. Local reductions in plankton due to injury or mortality from hydrocarbon exposure (Ozhan et al 2014; Rabalais 2014; Busky et al 2016) may reduce foraging opportunities for fish especially if an accident were to occur during the spring and fall phytoplankton bloom. A chemically dispersed spill combined with photo-enhanced toxicity would result in relatively high mortality in plankton communities near surface waters (Almeda et al 2016). These potential adverse effects on plankton communities would potentially have food availability implications for higher trophic levels.

Fish habitats would be affected by an uncontrolled well event for the duration of the spill, depending on how oil is dispersed. As described above, fish would be displaced from the water column by crude oil presence. Furthermore, the combined effects of chemically dispersed crude oil and flocculation to create marine oil snow would potentially transport hydrocarbon components to benthic environments. Sensitive coral and sponge species in benthic environments would likely be adversely affected which may have implications for other deep-sea species.

EL 1144 Example Well Site

For a potential subsurface/subsea release at the EL 1144 example wellsite, the nature and extent of potential effects on this VC will again depend on how the spill trajectory and fish and fish habitat overlap in both time and space. The extent of the modelled unmitigated spills (greater than 90 percent of in-water oil concentration of THC is greater than 1 µg/L) for the 30-day (Figure 16.12) and 120-day (Figure 16.13) scenarios includes the Flemish Pass, shelf and slope areas of the Flemish Cap and Newfoundland Shelf and ocean basin areas east of the release site. The footprint for the 120-day unmitigated spill also extends further north, east, and south compared to the 30-day scenario. These areas include productive and diverse fish habitats and areas of high abundance and biomass of various fish and invertebrate species. The deeper slopes along the Grand Banks and Flemish Cap that contains cold water and deepsea taxa less resilient to perturbations would also be affected. Negligible oil on the sediments was predicted by the model (0.01 percent), and therefore a large-scale direct effect on benthic fish habitat is not anticipated.

Such a spill would also affect fish health and mortality. Adult demersal and pelagic fish could potentially avoid spill areas, but the juvenile and the early life stages of fish and benthic invertebrates in the immediate areas of the spill would likely suffer from sublethal and lethal effects as described above. A spill of this magnitude would also have potential mortality, injury and sublethal effects on plankton that would have further implications on foraging opportunities and overall health of higher trophic levels.

Fish presence and abundance would also be affected by this unmitigated scenario as mobile fish species would temporarily avoid the spill footprint within the model results. The range of the predicted oil spill indicates potential displacements from highly productive areas including the southern Grand Banks and the Flemish Cap. There would likely be decreased presence and abundance of mobile fish and invertebrates for the duration of the spill, with subsequent recolonization.

In the 30-day unmitigated release, there is a less than 10 percent probability that oil above the socio-economic threshold (1 g/m^2) will contact shorelines on Sable Island in approximately 40-60 days from release. No other shoreline contact is predicted in this scenario. In the 120-day unmitigated release, there is a less than 25 percent probability that oil above 1 g/m^2 may contact the shores of Newfoundland and Labrador. Minimum time of shoreline oil exceeding this threshold is 10-40 days for the Avalon Peninsula, and more than 40 days for remaining Newfoundland and Labrador shores. There is also 25 to 75 percent probability that oil will reach the shores of the Azores archipelago in more than 40 days from release. Only the deterministic model (120-day) predicts that oil in contact with the shore would be above the ecological threshold (100 g/m^2) for both the Avalon Peninsula and the Azores. Oil predicted to make contact with shorelines, however, would be expected to be highly weathered, patchy and discontinuous. With the implementation of mitigation measures, including shoreline protection measures, it is unlikely that oil would reach the shoreline and therefore residual effects on coastal fish populations and coastal fish habitat are considered of low probability and minor overall.

As noted in Section 6.1.8, there are various fish species that are known to occur in the RSA which are designated as species at risk or species that are otherwise of conservation concern. In the unlikely event of an uncontrolled release into the marine environment, these species have the potential to be adversely affected, if the timing of the spill occurs at the same time of fish presence. Potential effects would be similar to those described above for secure species. However, the likelihood of this type of incident occurring with the relevant mitigations in place has been calculated to be extremely low (Section 16.3). In an actual event, emergency response measures would be implemented to limit the magnitude, duration, and extent of a spill. The modelling indicates an unmitigated spill is unlikely to reach the shoreline and the implementation of emergency response measures will further reduce this likelihood.

With spill prevention plans and response procedures in place, the potential effects of a subsurface/subsea release at the EL 1144 example well site on marine fish and fish habitat are predicted to be adverse, medium in magnitude, medium to long-term in duration, occurring within the RSA, and reversible. This was determined with a moderate level of confidence.

EL 1150 Example Well Site

The potential effects of a possible subsurface/subsea release at the EL 1150 example well site will likewise depend on how the spill trajectory and fish and fish habitat overlap in both time and space. At the EL 1150 example well site, the modelled hypothetical releases were not predicted to make contact with any shoreline.

The extent of the modelled unmitigated spills (greater than 90 percent of in-water oil concentration of THC is greater than 1 µg/L) is illustrated for the 30-day (Figure 16.15) and the 120-day (Figure 16.19) and includes the Flemish Cap and ocean basin areas east of the release site. The 30-day and 120-day unmitigated releases have similar spatial footprints. These areas include productive and diverse fish habitat in the RSA and areas of high abundance and biomass of various fish and invertebrate species.

No shoreline contact is predicted in the 30-day unmitigated release scenario. In the 120-day unmitigated release, there is a less than 25 percent probability that oil above 1 g/m^2 may contact the shores of Newfoundland and Labrador. Minimum time of shoreline oil exceeding this threshold is 10-40 days for the Avalon Peninsula, and more than 40 days for remaining Newfoundland and Labrador shores. There is also 10 to 50 percent probability that oil will reach the shores of the Azores archipelago in more than 40 days from release. Only the deterministic model for the 120-day spill predicts oil in contact with the shore would be above the ecological threshold (100 g/m^2) from the Azores. Oil predicted to make contact with shorelines would be expected to be highly weathered, patchy and discontinuous. With the implementation of mitigation measures, including shoreline protection measures, it is unlikely that oil would reach the shoreline and therefore residual effects on coastal fish populations and coastal fish habitat are considered of low probability and minor overall.

As noted in Section 6.1.8, there are various fish species that are known to occur in the in the LSA and/or RSA which are designated as species at risk or species of conservation concern. In the unlikely event of an uncontrolled release into the marine environment, these species have the potential to be adversely affected, if the timing of the release occurs at the same time of fish presence. Potential effects will be similar to those described above for secure species. Negligible oil on the sediments was predicted by the model (0.02 percent), and therefore a large-scale direct effect on benthic fish habitat is not anticipated. However, the likelihood of a subsurface/subsea release occurring with the relevant mitigations in place has been calculated to be extremely low (Section 16.3). In an actual event, emergency response measures would be implemented to limit the magnitude, duration and extent of the event.

With spill prevention plans and response procedures in place, the potential effects of a subsurface release at the EL 1150 example well site on marine fish and fish habitat are predicted to be adverse, medium in magnitude, medium to long-term in duration, occurring within the RSA, and reversible. These predictions were determined with a moderate level of confidence.

16.6.2.3 Summary and Determination of Significance

Table 16.20 provides a summary of predicted residual environmental effects of accidental event scenarios for marine fish and fish habitat. Residual effects incorporate the conservative approach used during spill modelling and the implementation of mitigation measures to prevent and reduce effects from any such spill.

Table 16.20 Summary of Residual Accidental Event-Related Environmental Effects on Marine Fish and Fish Habitat

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Certainty**
Potential Effects: • Change in habitat availability and quality • Change in food availability and quality • Change in fish mortality, injury, health, and • Change in fish presence and abundance (behavioral effects)							
100 litre Diesel Spill	A	N-L	L-PA	S	N-O	R	H
1,000 litre Diesel Spill	A	L-M	L-PA	M	N	R	M
750,000 litre Diesel Spill	A	L-M	RSA	M	N	R	M
Drill Fluid (SBM) Spill	A	N-L	L-PA	S	N	R	H
30-day Subsurface Release – EL 1144 Example Well Site	A	M	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1144 Example Well Site	A	H	RSA	L	N	R	M
30-day Subsurface Release – EL 1150 Example Well Site	A	M	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1150 Example Well Site	A	H	RSA	L	N	R	M

KEY

Nature / Direction:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude:
N Negligible
L Low
M Medium

Frequency:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Duration:
S Short term

Certainty in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty
H High			M Medium term				
			L Long term				
Geographic Extent:			P Permanent				
L Localized							
PA Within Project Area			Reversibility:				
LSA Within LSA			R Reversible				
RSA Within RSA or Beyond			I Irreversible				

In consideration of marine fish and fish habitat occurrence in the RSA, spill modelling scenarios, and planned mitigation, the predicted residual environmental effects from an accidental event scenario on marine fish and fish habitat (including species at risk) are predicted to be not significant.

In the unlikely event of an offshore hydrocarbon release, residual adverse effects to marine fish and fish habitat in the area at the time of the accident or malfunction are expected. The type and level of any effects would be dependent on such factors as the degree of exposure, spill type and size, time of year, and species presence and occurrence within the affected area. Potential adverse residual effects may result in decline or change to food availability and quality with implications for higher trophic levels. Interactions with hydrocarbons would also result in sublethal and lethal mortality on fish and invertebrates depending on the species-specific responses and degree of interaction. These potential effects would be similar for both secure and at-risk species.

For the duration of any accidental offshore hydrocarbon release, there would be reductions in availability or access to fish habitat. The eventual break down of hydrocarbon material in the water column and surface may become transported to benthic habitats through sinking and flocculation. This pathway would allow for contamination of deep sea environments and potential hydrocarbon interactions with sensitive coral and sponge species. In the context of a batch spill, the potential residual effects would be greatly reduced due to the limited quantities released and therefore localized nature of such an event.

In the context of applied mitigations, accidental offshore hydrocarbon releases and associated adverse environmental effects are considered unlikely. Therefore, it is not likely to result in an overall detectable decline in population-level fish abundance or change in the spatial and temporal distribution of fish populations in the RSA. It is also unlikely that the overall abundance, distribution or health of any species at risk and its eventual recovery will be negatively affected. With applied mitigations, these unlikely adverse environmental effects are not predicted to have significant effects on fish and fish habitat. Spill prevention techniques and response measures will be incorporated into the design and operations for all Project activities as part of contingency planning. This planning will further help ensure that effects do not occur, and in the unlikely event of an occurrence, that these events would not have significant adverse effects to fish populations and fish habitats in the RSA.

16.6.3 Marine and Migratory Birds (including Species at Risk)

A variety of avifauna species occur within the marine and coastal environments off Eastern Newfoundland at various times of the year, as described in Section 6.2. These include seabirds as well as other avifauna that inhabit offshore and nearshore regions for breeding, feeding, migration and other activities according to their individual life histories and habitat requirements, and could therefore be present in the RSA at the time of an accidental event. Seabirds, waterfowl and divers, and shorebirds are the most vulnerable to perturbation as they spend much of their life in the marine environment. However, certain landbird species may also be affected, particularly those associated with coastal habitats and any that migrate nocturnally over offshore waters. The timing of species presence and overall density can vary considerably depending on the species, with some taxa abundant year-round (such as large gulls and kittiwakes, many alcid species, fulmars, and shearwaters) while some are more likely to be present in the winter (Ivory Gulls, waterfowl) or fall (Leach's Storm-petrels). Several nesting colonies and important habitats (IBAs and MBSs) for birds have also been identified at locations along the eastern coast of Newfoundland and Labrador. In addition, there are several EBSAs in the Northwest Atlantic designated, in part, due to their importance to seabirds.

The description of the existing environment for marine and migratory birds in the EIS, while regional in nature, has focused primarily on the Eastern Newfoundland Offshore Area and immediately adjacent marine environments, as it is within this area that any Project-related environmental interactions and effects would most likely occur. General information on birds and any key areas in the larger surrounding region is available for reference through the various SEAs completed by the C-NLOPB, including recent SEA updates for Western Newfoundland (Amec 2014) and Southern Newfoundland (C-NLOPB 2010, 2015).

The accidental release of hydrocarbons in the marine environment has the potential to adversely affect marine and migratory birds and their habitats in the offshore environment and, potentially, in the nearshore environment. The extent of these potential effects depends on several factors, including the location, magnitude and trajectory of the spill, the time of year, and the presence and abundance of marine and migratory birds in the area.

16.6.3.1 Potential Issues and Interactions

As outlined in Section 9 of the EIS, the key potential environmental effects included in the assessment of planned Project components and activities include change in:

- mortality / injury levels and bird health;
- avifauna presence and abundance (behavioral effects);
- habitat availability and quality; and
- food availability or quality.

These potential effects remain relevant to the assessment of accidental events. However, the contributing Project-related environmental change (the mechanism of the effect) may differ. Effects of accidental releases on avifauna prey are detailed in Section 16.6.2 (marine fish and fish habitat).

Existing Knowledge of the Effects of Hydrocarbons on Marine and Migratory Birds

Accidental events such as oil spills can have important, adverse consequences for marine-associated birds, leading to potential changes in their presence, abundance, distribution and/or health at both the individual and population level. Marine birds are amongst the biota most at risk from oil spills, as they spend much of their time upon the surface of the ocean (LGL Limited 2005; Barron 2012; Boertmann and Mosbech 2011). In the event of a spill, and depending upon project and area specific factors, coastal birds may also be at risk on beaches and in intertidal zones.

Accidental discharges of hydrocarbons may lead to sheens of crude oil and other substances on the water's surface, to which avifauna (especially pelagic seabirds) may be exposed (Wiese and Robertson 2004; O'Hara and Morandin 2010; Morandin and O'Hara 2016). The possible physical effects of oil exposure on birds include changes in thermoregulatory capability (hypothermia) and buoyancy (drowning) due to feather matting (Clark 1984;

Montevecchi et al 1999), as well as potential toxicity effects from oil ingestion through excessive preening (Hartung 1995). Birds that feed on organisms from affected areas are also at heightened risk of contamination from their food sources (Engelhardt 1983). Even small quantities of oil from sheens have been shown to affect the structure and function of seabird feathers (O'Hara and Morandin, 2010), which has the potential to result in water penetrating the plumage and displacing the layer of insulating air. This can result in loss of buoyancy and hypothermia, which can cause a heightened metabolic rate (increased energy expenditure) and behavioral changes (e.g., increased time spent preening at the expense of foraging and breeding), which can potentially cause death of affected individuals (Morandin and O’Hara 2016). The long lifespan and low fecundity of many seabird species suggests that oil-related effects can potentially have longer term population effects (Wiese and Roberston 2004). While the primary exposure potential for, and resulting direct effects, on seabirds would occur within the spatial extent of a spill, the ecological effects of oiled areas may be transported from the affected site due to the highly mobile nature of marine-associated avifauna (Henkel et al 2012).

Morandin and O’Hara (2016) reviewed several short- and long-term studies of marine oil spills and found that effects can result in increased mortality rates, physiological impairment, reduced reproductive success and in severe cases, possible long-term population declines. Once birds are exposed to oil, even with rescue and cleaning efforts, the chances of survival are often quite low (French-McCay 2009). If direct exposure to spilled oil is conservatively assumed to result in close to 100 percent mortality of affected birds, then the key factor in predicting the total extent of mortality of marine birds becomes the probability of exposure. Probability of exposure is dependent on the fate and behavior of the released oil, as well as the distribution and behaviour of the taxa involved. For example, aerial species migrating through the site of a spill are unlikely to become oiled, whereas species that may forage in the spill site are likely to become oiled. Birds at greatest risk are those that spend considerable time resting or foraging on the water surface (Wiese and Roberston 2004; Boertmann and Mosbech 2011). Vulnerability indices of various taxa have been developed by French-McCay (2009), as follows:

- 99 percent mortality for birds that sit on the surface (e.g., dovekies, murres);
- 35 percent mortality for birds that are mostly in flight, but dive frequently for prey (e.g., petrels, terns); and
- 5 percent mortality for birds that are mostly in flight, such as migratory landbirds in transit.

The potential effects of oil exposure on birds varies with different types of oil (Gorsline et al 1981), weather conditions, season, migratory patterns, and other activities (Wiese et al 2001; Montevecchi et al 2012). Mortality rates and potential changes in bird populations due to accidental releases of oil are poorly known. However, it is often cited as the main risk to marine birds from the offshore oil and gas industry (Fraser and Ellis 2008; Ellis et al 2013). Seabirds are generally long-lived and have very low annual reproductive rates, thus, mortality in adults can have serious effects on populations. It is difficult to assess the direct relationship between volume of oil spilled and number of seabirds oiled (Burger 1993), but it is clear that the timing and location of a spill (and not just its size) have an important influence on avifauna mortality and injury rates (Weise et al 2001).

The potential for toxic effects from small amounts of ingested oil by seabirds is somewhat unclear. While acute toxic effects from exposure to sheens are considered unlikely (Morandin and O’Hara 2016) and some studies have shown little or no effects from exposure (ingestion) to low doses of oil on adult seabirds (Ainley et al 1981; Stubblefeld et al 1995; Alonso-Alvarez et al 2007), other studies have shown both lethal and sublethal effects of oil exposure on adult birds (Miller et al 1980; McEwan and Whitehead 1980; Trivelpiece et al 1984; Butler et al 1986, 1988). Effects of ingested oil on birds have been found to include liver damage (Khan and Ryan 1991), pneumonia (Hartung and Hunt 1966), brain damage (Lawler et al 1978) and immunotoxic effects (Barron 2012), in addition to starvation due to increased energy needs to compensate for heat loss resulting from oiling and loss of insulation (Peakall et al 1980; 1982; MMS 2001).

Existing Knowledge of the Effects of Dispersants on Marine and Migratory Birds

The use of dispersants is beneficial for marine and migratory birds in that it reduces the potential for exposure to floating oil (and, thus, the risk of adverse effects) on the sea surface within the spill area. The measured toxicity of dispersants themselves is very low (Prince 2015). Application of chemical dispersants results in a far greater rate of biodegradation of oil, reducing the duration to a matter of weeks rather than of years (Baelum et al 2012). Further, this relatively rapid rate of degradation greatly reduces the chance of accidentally released oil reaching shorelines where it could potentially cause great harm to shorebirds and seabird nesting colonies (Prince 2015). Conversely, however, the use of dispersants results in increased oil within the water column, potentially resulting in exposure of food sources (fish and water column invertebrates) to oil, and exposure of diving birds to the dispersed oil. Dispersed oil has similar effects to that of untreated oil, but the size of the slick and exposure concentrations would be lower than non-dispersed oil. Hence, a dispersant mitigates the potential adverse effects of oil on birds compared to untreated oil.

Existing Knowledge of the Effects of Drill Fluids (SBMs) on Marine and Migratory Birds

A SBM spill from the surface would likely result in a surface sheen similar to what has been described for batch spills, but more limited in nature. The possible physical effects of SBM exposure on birds would be similar to other hydrocarbons and would include changes in thermoregulatory capability (hypothermia) and buoyancy (drowning) due to feather matting (Clark 1984; Montevecchi et al 1999), as well as potential toxicity effects from oil ingestion through excessive preening (Hartung 1995). Birds that feed on organisms from affected areas are also at heightened risk of contamination from their food sources (Engelhardt 1983). The primary potential for exposure, and resulting direct effects, on seabirds would occur within the spatial extent of a spill. The ecological effects of oil spills may be transported from the affected site due to the highly mobile nature of marine-associated avifauna (Henkel et al 2012). However, SBMs are a heavy, dense fluid which sinks rapidly and the effects on the water's surface would be limited compared to marine diesel or crude oil spills.

16.6.3.2 Environmental Effects Assessment

The potential environmental effects of an accidental hydrocarbon release on marine and migratory birds are assessed in the following subsections.

Marine Diesel Spills (Batch Spills and Vessel Collision Scenario)

The model results for marine diesel spills (100 L, 1,000 L, 750,000 L) are summarized in Section 16.4. Batch spills resulting from the Project would cause a temporary decrease in water and habitat quality around the spill site. This would be short-term in nature, lasting until the slick disperses when aided by surface wave action in the offshore environment. The model results suggest that both the potential for exposure and the likelihood of adverse effects on marine and migratory birds from a batch release are low; with only those individuals occupying the immediate footprint of the spill at the time of the spill being affected.

Based on observations (industry-reported to C-NLOPB) of sheens in Atlantic Canada between 2003 and 2014, the average annual number of reported sheens near platforms on the Grand Banks was 24 (Morandin and O'Hara 2016). Based on the perceived colour of these sheens, the thickness was estimated to be in the range of 0.00007 to 0.001 mm (where quantitative descriptions were provided), and it is thought that thicker sheens are rare in offshore operations (Morandin and O'Hara 2016). Sheen persistence is related to thickness; data from ERIN Consulting Ltd and OCL Services Ltd (2003) for example, showed that sheens of 0.001 mm persisted for up to 24 h, while thinner (0.0001 mm) sheens tended to disperse in less than an hour.

If a sheen was produced from a Project-related batch spill, it would be temporary (less than 24 hours) and limited in size, affecting only birds in the immediate area of the spill itself. There would be an increased risk of mortality for individual birds that physically encountered the sheen, particularly for diving birds and those that spend large amounts of time on the water. Potential sublethal toxicity effects on metabolic rate and chick growth in marine birds is also possible; chicks and eggs are more susceptible to negative effects of exposure to oil even at very low levels). Exposure of breeding adults (and, consequently, eggs and nestlings) of most seabirds to hydrocarbon sheens within or near the Project Area is unlikely because the Project Area is several hundred kilometers from shore, well outside the foraging range of most seabirds. However, the Leach's storm-petrel is known to make foraging trips of thousands of kilometers during the breeding season (Pollet et al 2014), and breeding adults may be exposed to hydrocarbon emissions while foraging within the affected area within 24 hours of the spill. The northern gannet is also known to make extensive multi-day foraging trips (Garthe et al 2007). This has the potential to result in changes in avifauna presence and abundance (behavioral effects), as hydrocarbon exposure could influence the occurrence and success of key life history stages of these species.

A potential marine diesel spill from a Project-related MODU or supply vessel would be responded to through various mitigation measures outlined previously and would therefore be limited in terms of its overall magnitude, extent and duration, and thus, its potential environmental consequences. In the unlikely event that such spills did occur, they would be limited in terms of the magnitude, spatial, and temporal nature of the sheen and the number of birds that would be affected through direct interaction.

With spill prevention plans and response procedures in place, potential effects of a marine diesel spill (100 L, 1,000 L, 750,000L) on marine and migratory birds are predicted to be adverse, low to medium in magnitude, localized to within the RSA in extent, short- to medium-term in duration, and reversible. These predictions were determined with an overall moderate level of confidence.

Drill Fluid (SBM) Spill

The relevant drill fluid model results are summarized in Section 16.5. A spill of drill fluids can potentially result in similar effects described for a marine diesel spill. However, SBMs are a heavy, dense fluid which sinks rapidly so the effects on the water surface would be more limited than diesel or crude oil spills as it sinks through the water column. Potential effects of a drill fluid spill on marine and migratory birds are predicted to be adverse, but negligible to low in magnitude, short-term in duration, localized to within the Project Area, and reversible. These predictions were determined with a high level of confidence.

Uncontrolled Well Event

The relevant model results for uncontrolled well events are summarized in Section 16.4. An uncontrolled well event, or subsurface/subsea release, can potentially result in a change in mortality or injury level and bird health (individuals or populations), change in avifauna presence and abundance (behavioural effects), change in habitat availability and quality, and / or change in food availability or quality. The ecological risk to marine birds was assessed by using the species vulnerability metrics (Section 16.6.3.1) in combination with ecological/marine bird threshold concentrations for the oil floating on the surface (10 g/m^2, 10μm thickness) and shoreline oil (100 g/m^2). The main potential effect on seabirds is through direct contact with oil.

Generally, the greatest risk of seabird interactions with an oil spill comes in the winter months when conditions are cold and thermoregulation is most difficult; increasing the likelihood of mortality for affected birds (Morandin and O'Hara 2016). However, for any given species, the risk of interaction with an oil spill varies with the species' abundance in the area, which depends on the season. For example, Northern gannets and Leach's storm-petrels are at greatest risk in the fall, when young fledglings depart the colony for rich offshore feeding grounds. Fledgling common murres and thick-billed murres are also vulnerable during this period, as chicks are flightless for one to two months as they accompany their male parent to foraging areas. As detailed in Section 9, the waters off Atlantic Canada provide important wintering habitat for several species, including great skua, dovekie, black-legged kittiwakes and common and thick-billed murre. Most of the world's great shearwaters are found in the northwest Atlantic during the summer months (i.e., the non-breeding season for this southern hemisphere species). However, the potential consequences of oil making contact with shorelines is substantially greater in the summer months, during the birds' breeding season. Potential for oil making contact with shorelines ranged from 70 to 77 percent in the 120-day modelling scenario (RPS 2019). In all cases, based upon the minimum time to shore (80 days), oil was predicted to be extremely weathered by the time it reached shorelines.

EL 1144 Example Well Site

Based on the vulnerability indices (French-McCay 2009), the mortality risk would range from 35-99 percent for birds that contact a slick in the 0.01-0.1 mm thickness range. Murres and dovekies, which spend most of their time sitting on the water surface, are most vulnerable (estimated 95 percent mortality), while species that dive or feed at the water's surface for their prey but otherwise spend little time on the water, including Leach's storm-petrels, great shearwaters, and great skuas, are predicted to have a lower mortality rate of 35 percent. Black-legged kittiwakes and northern gannets, which do often sit on the water but spend more time in the air than alcids (murres and dovekies), would be expected to have an intermediate mortality rate.

While the consequences of shoreline oil exposure would be serious for marine birds, shoreline exposure in the summer months is unlikely with the highest predicted potential being one to less than three percent in the event of an unmitigated subsurface release scenario. Sable Island is a bird sanctuary and a breeding area for the Roseate Tern, a SARA species listed as endangered. According to RPS (2018), in the 30-day release scenario, the probability of oil reaching Sable Island is very low (less than three percent in the stochastic modelling; 99th percentile deterministic) with a long response time (over 52 days for first shoreline contact after spill), increasing the ability to put mitigation measures in place to further reduce the chances of oil-shoreline interaction. In the 120-day release scenario, although the potential for reaching shoreline is higher (particularly in the summer months), the minimum predicted time for oil to contact shorelines for the modelled 95th percentile representative deterministic shoreline scenario was 81 days after release for the shores of Newfoundland and 111 days for the Azores. No oil was predicted to reach the shores of Labrador (RPS 2019).

As noted in Section 6.2.6 there are two marine-associated avian species at risk that are known to occur in the LSA and/or RSA, and several others that are associated with coastal habitats in Newfoundland and Labrador. Within offshore Nova Scotia, there are seven marine bird species and two coastal species that breed on Sable Island which are listed as either species at risk or species that are of conservation concern (BP 2016). Seven of these are discussed in Section 6.2.6. In the unlikely event of an uncontrolled release into the marine environment, these species have the potential to be adversely affected, if the timing of the spill occurs at the same time of presence of marine-associated avian species at risk. Potential effects will be similar to those described above. The likelihood, however, of a subsurface release occurring with the relevant mitigations in place has been calculated to be extremely low (Section 16.3). In an actual event, emergency response measures would likely be effective in limiting the magnitude, duration and extent of the spill.

With spill prevention plans and response procedures in place, including the implementation of shoreline protection measures, potential effects of a subsurface release from the EL 1144 example well site on marine and migratory birds are predicted to be adverse, potentially medium to high in magnitude, medium to long-term in duration, occurring within the RSA, and reversible. These predictions were determined with a moderate level of confidence.

EL 1150 Example Well Site

Based on the vulnerability indices (French-McCay 2009) the estimated mortality risk would again range from 35-99 percent (the latter percentage for birds sitting on the water surface such as murres and dovekies, and the former for diving birds such as storm-petrels, shearwaters and skuas) for the birds that come in contact with a slick in the 0.01-0.1 mm thickness (RPS 2018, 2019). For the EL 1150 example well site, in the 120-day release scenario (RPS 2019), oil was only predicted to contact the shores of the Azores, 80 days after the release for the modelled 95th percentile shoreline scenario. No shoreline contact was predicted based on the 30-day release scenario (RPS 2018).

As noted in Section 6.2.6, there are two marine-associated avian species at risk that are known to occur in the LSA and/or RSA, and several others that are associated with coastal habitats in Newfoundland and Labrador. With spill response procedures in place, potential effects of a subsurface release from the EL 1150 example well site on marine and migratory birds are predicted to be adverse, potentially medium to high in magnitude, medium to long-term in duration, occurring within the RSA, and reversible. These predictions were determined with a moderate level of confidence.

16.6.3.3 Summary and Determination of Significance

Each of the potential accidental events that have been identified and are assessed, including possible diesel spills and releases, have the potential to adversely affect marine birds. However, the potential for, and possible magnitude of, these effects will depend on the specific nature, degree and other characteristics of the event, inducing the type and quantity of material spilled, its eventual geographic extent, and the persistence of these materials in the environment.

The modelled oil spill fate and behavior, and associated effects analysis provided above, relate to the probability of an unmitigated release scenario occurring and interacting with marine-associated avifauna and their habitats. The modeling is inherently conservative. Such a release event is both unlikely (Section 16.3), and would be avoided or addressed through various oil spill prevention and response measures indicated in Section 16.1 and required under regulatory approval processes for the drilling program. These mitigations, including response measures such as the use of dispersants or other means, will serve to prevent or reduce any adverse effects on marine-associated avifauna including the magnitude, extent and duration of any such exposure and thus its potential environmental effects.

Table 16.21 provides a summary of predicted residual environmental effects of accidental event scenarios for marine and migratory birds. Residual effects incorporate the conservative approach used for the spill modelling and consider the implementation of mitigation measures to prevent and reduce effects from a spill.

Table 16.21 Summary of Residual Accidental Event-Related Environmental Effects on Marine and Migratory Birds

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty
Potential Effects: • Change in mortality / injury levels and bird health • Change in avifauna presence and abundance (behavioral effects) • Change in habitat availability and quality • Change in food availability or quality							
100 litre Diesel Spill	A	L	L-PA	S	N-O	R	H
1,000 litre Diesel Spill	A	M	PA-LSA	M	N	R	M
750,000 litre Diesel Spill	A	M	RSA	M	N	R	M
Drill Fluid (SBM) Spill	A	N-L	L-PA	S	N	R	H
30-day Subsurface Release – EL 1144 Example Well Site	A	M-H	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1144 Example Well Site	A	M-H	RSA and beyond	M-L	N	R	M
30-day Subsurface Release – EL 1150 Example Well Site	A	M-H	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1150 Example Well Site	A	M-H	RSA and beyond	M-L	N	R	M
KEY Nature / Direction: P Positive	Frequency: N Not likely to occur				Certainty in Predictions: L Low level of confidence		

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty

A	Adverse	O	Occurs once	M	Moderate level of confidence
N	Neutral (or No Effect)	S	Occurs sporadically	H	High level of confidence
		R	Occurs on a regular basis		
Magnitude:		C	Occurs continuously	N/A	Not Applicable
N	Negligible				
L	Low	Duration:			
M	Medium	S	Short term		
H	High	M	Medium term		
		L	Long term		
Geographic Extent:		P	Permanent		
L	Localized				
PA	Within Project Area	Reversibility:			
LSA	Within LSA	R	Reversible		
RSA	Within RSA or Beyond	I	Irreversible		

In consideration of the present knowledge of marine and migratory bird occurrence in the RSA, the known effects of oil spills on marine-associated avifauna, the result of spill modelling, and planned mitigation, it is concluded that residual environmental effects from an accidental subsurface/subsea release on marine and migratory birds could potentially be significant depending on the specific occurrence, and nature and degree of the event. But an accidental subsurface/subsea release is unlikely to occur. Spill response and prevention strategies will be incorporated into the Project as part of contingency planning, thus ensuring the likelihood and potential severity of such events, and their potential effects on the VC, is minimized.

In the unlikely event of a large scale offshore hydrocarbon release, residual adverse effects to marine and migratory birds present in the area, including SAR, are expected. The magnitude of these effects would depend on the size and duration of the spill, location, time of year, and species presence and abundance within the affected area. For a release scenario, environmental effects could be significant, resulting in a detectable decline in overall bird abundance or change in the spatial and temporal distribution of bird populations in the overall RSA for multiple generations. However, this is considered unlikely given the very low probability of a large spill or subsurface release to occur, and in consideration of the mitigative response measures that will be implemented. Birds are highly mobile; therefore, presence and abundance within the Project Area (and the RSA) are variable, as is the likelihood of interaction with Project-related accidental events.

16.6.4 Marine Mammals and Sea Turtles (including Species at Risk)

As described in Section 10 of the EIS, various species of marine mammals and sea turtles have been reported in the RSA, including several that are at risk or otherwise of special conservation concern. There is the potential for these [to be present during, and thus affected by, an accidental event. Overall abundance of marine mammals is highest from late spring to autumn, but some species may be present year-round. Small-toothed whale, dolphin, and porpoise species are present in both coastal and offshore waters of the RSA, whereas sperm whale sightings are more often associated with continental slope waters. The most commonly expected baleen whale species in the RSA are humpback, minke, fin, and sei whales. Harbour seals are concentrated primarily in coastal areas, while grey, harp, and hooded seals are more widespread and can be found in deeper waters of the RSA, when not breeding or whelping on land or pack ice. Just one sea turtle species is regularly found in the area; the Leatherback occurs in Eastern Newfoundland waters from April to December. No designated critical habitat for marine mammals or sea turtles is present within or near the RSA, but there are several Environmentally and Biologically

Significant Areas (EBSAs) that overlap with, or are close to, the Project Area. These EBSAs are important feeding and seasonal refuge areas for marine mammals and sea turtles (Section 10 of the EIS).

The likelihood and severity of potential interactions with accidental events (specifically, hydrocarbon releases) on marine mammal and sea turtle species are very much dependent on several factors, such as the time of year, duration and volume of the release, and its location relative to species' preferred habitats.

16.6.4.1 Potential Issues and Interactions

As outlined in Section 10 of the EIS, the key potential environmental effects included in the assessment of planned Project components and activities include change in:

- mortality / injury levels and health (individuals or populations);
- habitat availability, quality and use (behavioral effects); and
- food availability or quality.

These potential interactions and effects are relevant to assessment of accidental effects; however, the contributing Project-related environmental change (the mechanism of the effect) may differ, as described below.

Existing Knowledge of the Effects of Hydrocarbons on Marine Mammals and Sea Turtles

Potential adverse effects to marine mammals and sea turtles resulting from an accidental hydrocarbon release include: potential oiling of fur, baleen, skin and flippers; ingestion of contamination in food and water; reduction in prey availability; and potential inhalation of volatiles through respiration. Depending on the level of exposure, these effects can result in behavioural changes, physiological and neurological damage, challenges to movement, or death.

The primary pathways through which oil spills may directly affect marine mammals and sea turtles are ingestion, absorption and inhalation. Direct evidence is lacking for long-term effects from exposure to hydrocarbons through contact or ingestion for marine mammals and sea turtles, although long-term studies have demonstrated evidence implicating oil spills with the mortality of cetaceans (Dahlheim and Matkin 1994; Matkin et al 2008). Seals and cetaceans have a thick layer of subcutaneous fat (blubber) which serves a thermoregulatory function; therefore, contact with oil has little effect on thermoregulation compared to that observed in seabirds (Geraci 1990). However, irritation and increased susceptibility to infection can occur with skin exposure, particularly in the sensitive membranes of the eyes and mouth (Perrin et al 2002). Oil can also coat baleen, causing a temporary reduction in feeding efficiency of mysticetes (Geraci 1990).

Inhalation and aspiration of aerosolized and volatile oil compounds can result in inflammation of the mucous membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Cetaceans may also ingest oil with water or by consuming contaminated prey. Ingested oil can be absorbed into the tissues and have toxic effects (Geraci 1990); for example, top-level predators such as killer whales are known to be susceptible to accumulating high concentrations of persistent organic pollutants (Ross et al 2000, 2002). Ingested oil may eventually leave the system when an organism returns to uncontaminated waters (Engelhardt 1978, 1982, 1983). For example, only small traces of oil were found in grey whale blubber and in the liver of a killer whale exposed to oil from the Exxon Valdez spill (Bence and Burns 1995). While there is some evidence suggesting that cetaceans may be able to detect oil spills, most species do not exhibit avoidance behaviours (Geraci et al 1983, St. Aubin et al 1985, Harvey and Dahlheim 1994, Matkin et al 1994). Smultea and Würsig (1995) did observe that dolphins tend to decrease respiration rate and increase dive durations in the presence of surface oil.

The 2010 DWH spill is probably the most-studied oil spill to date; however, it occurred in waters warmer than those of the RSA, and therefore direct comparisons of the effects of this spill cannot always be made. Nonetheless, many of the effects are expected to be similar, and because so many marine mammal and sea turtle species have extremely large ranges, many of the same species affected by the DWH spill occur within the Project Area and RSA. NMFS (2014) reported that following the DWH spill, 171 dolphins and whales were collected through stranding or directed captures in open water, of which 153 dead individuals were collected. Almost 90 percent of these mortalities were bottlenose dolphins and about five percent showed visible oiling (NMFS 2014). A significant reduction of reproductive success and increase in calf mortality in the common bottlenose dolphin following the DWH spill was observed by Lane et al (2015).

Exposure to oil may result in mortality of some pinnipeds; pups appear to be most vulnerable in colder waters (St. Aubin 1990). Temporary or even permanent damage to sensitive eye tissues has been reported (St. Aubin 1990; Spraker et al 1994) which results in reduced foraging efficiency (Levenson and Schusterman 1997). With heavy oil exposure, seals may have difficulty with locomotion (Davis and Anderson 1976, Sergeant 1991). Harbour seals observed immediately after oiling from the Exxon Valdez spill appeared lethargic and disoriented, which was thought to be attributed to lesions that were subsequently found in the thalamus of the brain (Spraker et al 1994). Oil ingested from contaminated prey or even from nursing contaminated milk may be absorbed into the tissues, resulting in kidney, liver, and brain lesions (Geraci and Smith 1976, Spraker et al 1994).

Sea turtles surface to breathe, and because they do not appear to show avoidance of oil spills and take large inhalations prior to diving, they may be particularly susceptible to inhalation of volatiles (Vargo et al 1986; NOAA 2010; Vander Zanden et al 2016). The effects of inhalation of oil by sea turtles include a reduction of lung capacity and decreased oxygen uptake (Lutz and Lutcavage 1989). Ingestion and absorption of oil can also occur from both surfacing and ingestion of oiled prey which may lead to reduced digestion efficiency and damage to sensitive tissues such as eyelids and nasal passages (Lutz and Lutcavage 1989). Temporary skin damage (lesions) has been observed in loggerhead sea turtles following exposure to oil, with healing of lesions observed within ten days post-exposure (Bossart et al 1995). Following the DWH spill, Beyer et al (2016) reported an increase in sea turtle strandings, particularly Kemp's ridley turtles, while NMFS (2014) documented at least 18 visibly oiled dead turtles and an additional 450 rescued and rehabilitated sea turtles, 95 percent of which were loggerhead sea turtles.

Existing Knowledge of the Effects of Dispersants on Marine Mammals and Sea Turtles

The use of dispersants, which enhance the natural microbial degradation, may be beneficial for marine mammals and sea turtles within a spill area by reducing the sea surface exposure to oil. This results in a far greater rate of biodegradation of oil to a matter of weeks rather than of years (Baelum et al 2012). This relatively rapid rate of degradation greatly reduces the chance of accidentally released oil reaching shorelines (Prince 2015). The measured toxicity of dispersants themselves is very low (Prince 2015). Therefore, use of dispersants is predicted to reduce potential adverse environmental effects on marine mammals and sea turtles. However, use of dispersants may expose marine mammals and sea turtles to a greater amount of oil in the water column, and thus, a greater likelihood of oiled skin or fur, ingestion of contaminated food sources (such as fish and water column invertebrates), and potential clogging of baleen (Lee et al 2015). Ingested hydrocarbons can be metabolized and excreted by marine mammals; however, some may be stored in fat deposits and ultimately released into circulation during periods of physiological stress such as low food availability, migration and lactation. These hydrocarbons may become bioavailable and potentially toxic to the individual and its young (Lee et al 2015).

Existing Knowledge of the Effects of Drill Fluids (SBMs) on Marine Mammals and Sea Turtles

The possible physical effects of SBM exposure on marine mammals and sea turtles would be similar to other hydrocarbons described above. However, SBMs are a heavy, dense fluid which sinks rapidly, so the effects on the water surface and water column would be more limited than other hydrocarbon spills.

16.6.4.2 Environmental Effects Assessment

The potential environmental effects of an accidental hydrocarbon release on marine mammals and sea turtles are assessed in the following subsections. Note that in both the batch spill and subsurface/subsea release scenarios, pinnipeds (i.e., seals) are at higher risk of adverse effects of oil exposure than cetaceans and sea turtles and may encounter oil either in the water or when hauling out on oiled shorelines.

Marine Diesel Spills (Batch Spills and Vessel Collision Scenario)

The model results for marine diesel spills (100 L, 1,000 L, 750,000 L) are summarized in Section 16.4. The model results suggest that both the potential for exposure and the likelihood of adverse effects on marine mammals and sea turtles from a batch release (e.g., fouling, inhalation of vapours) is low. Only animals in the immediate vicinity at the time of the spill may be exposed, and at the concentrations predicted, change in mortality or injury is considered unlikely and changes in health are predicted to be of low magnitude (e.g., temporary inflammation of mucous membranes). Changes in habitat quality or use will also be of low magnitude. Batch spills are not expected to affect haulout areas on distant shorelines. While there will be a decrease in water quality around the spill site, this would be short-term until the slick disperses (aided by surface wave action in the offshore environment).

Spill prevention measures will ensure that the potential for an accidental event is very low. With spill response procedures in place, potential effects of a diesel spill (100 L, 1,000 L, and 750,000 L) on marine mammals and sea turtles are predicted to be adverse, negligible to medium in magnitude (depending on spill size), short to medium term in duration, localized to within the RSA, and reversible. These predictons were determined with an overall moderate level of confidence.

Drill Fluid (SBM) Spill

The drill fluid model results are summarized in Section 16.5. SBMs are a heavy, dense fluid which sinks rapidly, so the effects on the water surface would be more limited than diesel or crude oil spills. Potential effects of a drill fluid spill on marine mammals and sea turtles are predicted to be adverse, negligible to low in magnitude, short-term in duration, localized to within the Project Area, and reversible. These predictions were determined with a high level of confidence.

Uncontrolled Well Event

The model results for uncontrolled well events are summarized in Section 16.5. An uncontrolled well event, or subsurface/subsea release, can potentially result in a change in mortality or injury of individuals, change in health, change in habitat quality / availability or use, and change in food availability. The potential for effects would be greatest near the location of the hydrocarbon release and will depend on the distribution and abundance of marine mammals and sea turtles in the area at the time of the release. The magnitude of the effects will increase with the volume and duration of hydrocarbon release. Modelling results for potential subsurface release scenarios are discussed below.

Effects are predicted to be low to high magnitude and short to medium-term in duration depending on the nature of the release. The degree of change in mortality or injury and change in health will depend in large part on the occurrence and distribution of marine mammals and sea turtles at the time of the release, as well as the duration and extent of oil release. Given the highly mobile nature of this VC, the magnitude of effects will be higher for subsurface releases of larger scale and extended duration, as was observed during the DWH spill (e.g., Takeshita et al 2017). Depending on the exact nature, extent, and duration of a release, marine mammals and sea turtles in the spill area are likely to experience a combination of exposures from contaminated air, water, and sediment and therefore via a combination of pathways (inhalation, ingestion, aspiration, and adsorption). Marine mammals and sea turtles that are closer to the site of the release are more likely to be exposed to a more constant flow and higher concentrations of oil, as compared to nearshore species or individuals that are further from the release site.

EL 1144 Example Well Site

In this scenario, species that haulout on potentially affected shorelines are most likely to interact with hydrocarbons (e.g., grey seals on Sable Island). In the unlikely event of shoreline oiling, fur-bearing marine mammals that haulout in the affected area may experience a change in mortality or injury and a change in health upon exposure to hydrocarbons, although it is probable that only a small proportion of local populations would be affected. Predatory marine mammals that prey on seals (e.g., killer whales) may also experience changes in mortality, injury, or health following consumption of oiled prey species. Change in habitat quality or use of terrestrial habitats is predicted to be low in magnitude and short-term in duration.

As noted in Section 10.4, there are nine marine mammal and two sea turtle species at risk or species of conservation concern that are known to occur in the LSA and/or RSA. In the unlikely event of an uncontrolled release into the marine environment, these species have the potential to be adversely affected if the timing of the spill occurs at the same time as their presence. Other species such as the Kemp's ridley turtle and green sea turtle are found south of the RSA, off coastal United States and further south; based on the 120-day release scenario (RPS 2019), individuals of these species could potentially be adversely affected. Potential effects would be similar to those described above. The likelihood, however, of a subsurface release occurring with the relevant mitigation measures in place has been calculated to be extremely low (Section 16.3). In an actual event, emergency response measures would likely be effective in limiting the magnitude, duration and extent of the spill.

Spill prevention measures will ensure that the potential for an accidental event is very low. With spill response procedures in place, any potential effects of a subsurface/subsea release from the EL 1144 example well site on marine mammals and sea turtles are predicted to be adverse, low to high in magnitude, occurring within the RSA and beyond, medium to long-term in duration, and reversible. These predictions were determined with a moderate level of confidence.

EL 1150 Example Well Site

As discussed in 16.6.1, the model results exceed the ecological thresholds in the surface and the water column. Releases at the EL 1150 example well site were not predicted to contact the shore. Change in habitat quality or use of terrestrial habitats is therefore predicted to be low in magnitude and short-term in duration. As noted in Section 10.4, there are nine marine mammal and two sea turtle species at risk or species of conservation concern that are known to occur in the LSA and/or RSA. In the unlikely event of an uncontrolled release into the marine environment, these species have the potential to be adversely affected, if the timing of the spill occurs at the same time as their presence. Potential effects would be as those described above. However, the likelihood of a subsurface release occurring with the relevant mitigations in place has been calculated to be extremely low (Section 16.3). In an actual event, emergency response measures would limit the magnitude, duration and extent of the spill.

Spill prevention measures will ensure that the potential for an accidental event is very low. With spill response procedures in place, any potential effects of a subsurface/subsea release from the EL 1150 example well site on marine mammals and sea turtles are predicted to be adverse, low to high in magnitude, occurring within the RSA and potentially beyond, medium to long-term in duration, and reversible. These predictions were determined with a moderate level of confidence.

16.6.4.3 Summary and Determination of Significance

Table 16.22 provides a summary of predicted residual environmental effects of accidental event scenarios on marine mammals and sea turtles.

In the unlikely event of a hydrocarbon release, residual adverse effects on marine mammals and sea turtles present in the area, including species at risk (SAR), are expected; however, these are not anticipated to result in a long-term detectable change in abundance or distribution of populations within the RSA. The magnitude of these effects would depend on the size and duration of the release, location, time of year, and species presence and abundance within the affected area. Marine mammals and sea turtles are highly mobile, and most show migration or movement patterns across broad ranges. Therefore, presence and abundance within the Project Area (and the RSA) are variable, as, consequently, is the likelihood of interaction with Project-related accidental events.

An accidental event is not likely to result in significant (population level) adverse environmental effects on marine mammal and sea turtles, including SAR. This conclusion has been reached with a moderate to high level of confidence based on current understanding of the effects of similar projects on the VC, the availability of literature and data used to characterize existing conditions and Project effect mechanisms, and the known effectiveness of proposed mitigation measures (Section 16.1). Spill response and prevention strategies will be incorporated into the Project as part of contingency planning, thus ensuring the likelihood and potential severity of such events, and their potential effects on the VC, are minimized.

Table 16.22 Summary of Residual Accidental Event-Related Environmental Effects on Marine Mammals and Sea Turtles

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty
Potential Effects: • Change in mortality / injury levels and health (individuals or populations) • Change in habitat availability, quality and use (behavioral effects) • Change in food availability or quality							
100 litre Diesel Spill	A	N-L	L-PA	S	N-O	R	H
1,000 litre Diesel Spill	A	L	L-PA	S	N	R	M
750,000 litre Diesel Spill	A	L-M	RSA	S-M	N	R	M
Drill Fluid (SBM) Spill	A	N-L	L-PA	S	N	R	H
30-day Subsurface Release – EL 1144 Example Well Site	A	L-M	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1144 Example Well Site	A	L-H	RSA and beyond	M-L	N	R	M
30-day Subsurface Release – EL 1150 Example Well Site	A	L-M	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1150 Example Well Site	A	L-H	RSA and beyond	M-L	N	R	M

KEY

Nature / Direction:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude:
N Negligible

Frequency:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Certainty in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty
L Low			Duration:				
M Medium			S Short term				
H High			M Medium term				
			L Long term				
Geographic Extent:			P Permanent				
L Localized							
PA Within Project Area			Reversibility:				
LSA Within LSA			R Reversible				
RSA Within RSA or Beyond			I Irreversible				

16.6.5 Special Areas

Various marine and coastal areas in Newfoundland and Labrador and elsewhere in Eastern Canada have been designated as protected under provincial, federal or other legislation and processes, or have otherwise been identified as being special or sensitive due to their ecological, historical or socio-cultural characteristics and importance. These special areas are valued for environmental, economic and/or socio-cultural reasons, and there are often regulatory, stakeholder and Indigenous interests in their intrinsic ecological or anthropogenic value and uses. These areas and their environmental characteristics may therefore be particularly vulnerable to an accidental event, as any further degradation of their environmental conditions may affect their underlying integrity and value.

The description of the existing environment for special areas in this EIS (Section 6.4) by necessity focused primarily on the Eastern Newfoundland Offshore Area and immediately adjacent marine environments, as it is within this area that Project-related environmental interactions and effects would be most likely to occur. General information on special areas in the larger Atlantic Canada region is available for reference, as required, through the various SEAs completed by the C-NLOPB, including SEA updates for Western Newfoundland (Amec 2014) and Southern Newfoundland (C-NLOPB 2015) and the Labrador SEA (Sikumiut 2008, currently being updated), the former also provides regional information and mapping for this VC throughout the Gulf of St. Lawrence region.

As described and mapped in Section 11.3.3, there are several special areas offshore Eastern Newfoundland that overlap in whole or in part with the offshore Project Area including various EBSAs, VMEs and NAFO FCAs. Most identified special areas in this region are, however, located on land or in coastal and nearshore areas, well outside of the Project Area and the likely environmental zone of influence of most of the planned components and activities that comprise the Project. Although the Project-specific environmental effects assessment for the Special Areas VC (Section 11 of the EIS) has therefore predicted no potential interactions with these coastal or on land special areas, there is concern about the potential for an accidental event such as large oil spill to eventually reach and adversely affect these areas and their key environmental features and processes. These potential issues and interactions are described below.

16.6.5.1 Potential Issues and Interactions

Special areas are often identified and designated to recognize their importance and to protect exceptional or sensitive environmental features. In certain cases, this is based on the objective of conserving the presently pristine and ecologically important nature of these areas, while in others their designation is intended to help prevent further damage to already affected and sensitive environmental components. In either situation, these areas and their environmental characteristics may therefore be particularly vulnerable to disturbance and effects, as any further degradation of their environmental conditions may affect the underlying integrity and value of these areas.

As described in the Project-specific environmental analysis for this VC (Section 11 of the EIS), the potential effects of offshore oil and gas activities on special areas may be direct and indirect in nature. Specifically, they may result both from the direct interaction of Project activities and emissions with these areas, as well as by otherwise affecting the marine fish, birds, mammals or other environmental components that move to and through these areas. Whatever the environmental and effects pathways involved, any direct or indirect changes to the existing natural or human environments in a special area due to Project-related interactions may affect the key ecological characteristics and processes that define and distinguish these areas, and thus, affect their overall and underlying characteristics, integrity and value.

The potential environmental effects on Special Areas identified and used in the earlier effects assessment for planned Project activities (Section 11 of the EIS) included changes in:

- environmental features and/or processes; and
- human use and/or societal value.

These potential effects remain relevant to the assessment of accidental events. The extent of the potential effects will depend on how the spill trajectory and the VC overlap in both space and time. Potential effects on special areas in the event of an accidental release of hydrocarbons includes degradation of the ecological integrity of the special area such that it is not capable of providing the same ecological function for which it is designated. The special areas VC is closely linked to the other VCs considered in this assessment, particularly the biological VCs discussed previously.

16.6.5.2 Environmental Effects Assessment

The potential environmental effects of an accidental hydrocarbon release on special areas are assessed in the following subsections.

The determination of effects for oil concentrations in the marine environment for special areas required consideration of both ecological and socioeconomic thresholds. However, as the socioeconomic thresholds are lower (0.04 μm oil thickness) and therefore more conservative, these are used in the assessment of potential effects on this VC.

Marine Diesel Spills (Batch Spills and Vessel Collision Scenario)

The results for marine diesel spills (100 L, 1,000 L, 750, 000 L) are summarized in Section 16.4. Based on modelling of batch spills, total hydrocarbon concentrations would be highest in the immediate vicinity of the spill and would be limited in terms of overall magnitude, extent and duration, and thus, its potential adverse environmental consequences. Given that such a spill could conceivably occur at any location in the ELs within the Project Area, or along the associated vessel traffic route, it is possible that any such spill could overlap, and to a degree interact, with the identified special areas that are located within these boundaries.

The results of modelling prepared for marine diesel spills for this Project indicate that the effects of such spills would be limited spatially. For instance, the total subsurface volume expected to exceed threshold for water column concentrations (i.e., 1.0 ppb of dissolved PAHs) would be a maximum of 1 km^3 for both the 100 L and 1,000 L releases. The model predicted that less than 0.01 percent of the total mass of released oil would reach the seafloor after 30 days. For the hypothetical vessel collision with release of 750,000 L of diesel fuel, the predicted threshold for subsurface water column exceedance would be 100 km^3. Again, 0.01 percent of the total mass of released oil was predicted to reach the seafloor after 30 days. Based on estimates of distances for surface dispersion of oil from these potential spills, the effects would be limited to the LSA surrounding the Project Area or distance of less than 30 km from the ELs.

Special areas that intersect with the Project ELs and the Project Area and in waters adjacent to these areas could potentially be affected by diesel spills due to Project activities. Those special areas within the LSA are mainly identified and / or protected for the presence or sensitive benthic habitats and species such as corals, sponges and to a lesser extent sea pens. The VME and UNCBD EBSA are identified for fish species and the latter is also identified for a commercial fishery. Detailed information on special areas can be found in Section 6.4 of the EIS and in IR-47 of this Addendum.

Table 16.23 Special Areas Intersecting the LSA

Special Area Type	Name
NAFO FCA	• Flemish Pass / Eastern Canyon (2)
	• Northwest Flemish Cap (10)
	• Northwest Flemish Cap (11)
VME	• Southern Flemish Pass to Eastern Canyons
UNCBD EBSA	• Slopes of the Flemish Cap and Grand Bank

The primary spill exposure mechanism for marine fish and fish habitat is through the portion of dissolved hydrocarbon in the water column (French-McCay 2009). The potential effects of such spills on the defining features of these special areas are summarized below. Detailed information on potential effects of accidental events on marine fish and fish habitat including Species at Risk is provided in Section 16.6.2.

Documented nonlethal effects on marine fish include reduced feeding (Lari et al 2015) and larval deformities (Mager et al 2014). Continued exposure can result in symptoms ranging from reduced respiratory-cardiovascular activity, tissue hypoxia and ultimately respiratory paralysis (death) if exposure continues. These effects are short term as the more toxic compounds associated with this type of event volatize in the order of days (Lee et al 2015) and can be recoverable if exposure does not continue. For benthic species, the small portion of hydrocarbon predicted to reach the seafloor would be negligible.

Based on current information on marine fish and fish habitat in the RSA, spill modelling scenarios, and planned mitigation, the potential residual effects from an accidental event scenario on marine fish and fish habitat (including species at risk) are predicted to be not significant (detailed information is provided in Section 16.6.2). In the unlikely event of an offshore hydrocarbon release, residual adverse effects to marine fish and fish habitat in the area at the time of the accident or malfunction are expected. The type and level of any effects would be dependent on such factors as the degree of exposure, release type and size, time of year, and species presence and occurrence within the affected area. Potential adverse residual effects may result in decline or change to food availability and quality with implications for higher trophic levels. Interactions with hydrocarbons would also result in nonlethal effects or mortality on fish and invertebrates depending on the species-specific responses and degree of interaction.

Section 16.6.2 concluded that with the application of appropriate mitigations, adverse residual effects would be unlikely and thus an overall detectable decline in population-level fish abundance or change in the spatial and temporal distribution of fish populations in the RSA is unlikely. It is also unlikely that the overall abundance, distribution or health of any species at risk and its eventual recovery will be negatively affected. With applied mitigations, these unlikely adverse environmental effects are not predicted to have significant effects on marine fish and fish habitat. Spill prevention techniques and response measures will be incorporated into the design and operations for all Project activities as part of contingency planning. This planning will ensure that such effects do not occur, and in the unlikely event of an occurrence, that these events would not have significant adverse effects on marine fish and fish habitat.

Any such spills, in the event that they did occur, are unlikely to have a detectable effect on any special areas, and to measurably affect their key environmental and socio-cultural characteristics. With operational spill prevention plans and response procedures in place, potential effects of a marine diesel spill (100 L, 1,000 L, 750,000 L) on special areas are predicted to be adverse, of negligible to medium magnitude (depending on spill size and location), short-to medium term in duration, localized to the RSA, not likely to occur and reversible. These predictions were determined with a medium to high level of confidence.

Drill Fluid (SBM) Spill

The results of modelling prepared for potential SBM spills for this Project indicate that the effects of such a spill at the EL 1144 example well site, would be limited to within 1 km of a drill site and the maximum thickness of SPMs on the seafloor would be an average of 1.7 cm. For an SBM fluid spill at the EL 1150 example well site, the maximum predicted distance of deposition is less than 0.5 km with an average thickness of 2 cm. Thus, the effects of SPM spills would be limited to the Project Area.

Special areas intersecting with the Project Area are the Slopes of the Flemish Cap and Grand Bank UNCBD EBSA, Flemish Pass / Eastern Canyon (2), Northwest Flemish Cap (10) and Northwest Flemish Cap (11), which are described in Table 16.23. These areas are identified for sensitive benthic habitats, marine fish and commercial fisheries. The potential effects of SPMs on the defining features of these special areas are summarized below. Detailed information is provided in Section 16.6.2.

Potential pathways of effects on fish would be direct toxicity of the fluid and potential changes to fish habitat (e.g., degradation of benthic habitat). Acute toxicity of SBMs was shown to be low in laboratory experiments and field evaluations of SBM-associated drill-cutting piles (Still et al 2000; Tsvetnetko et al 2000; Hamoutene et al 2004; Paine et al 2014; Tait et al 2016). Toxicity experiments with fish have indicated that acute toxicity of SBMs was generally low (Jagwani et al 2011), but potential health effects were associated with chronic exposure to SBM associated cuttings (Jagwani et al 2011; Gagnon and Baktyar 2013; Vincent-Akpu 2013). Any potential effects are likely to be temporary in nature as SBMs biodegrade within a few years (Terrens et al 1998; Ellis et al 2012; IOGP 2016).

Potential effects include changes to fish habitat in terms of surface, water column, and the seafloor (benthos). SBMs are heavy, dense fluids, which sink rapidly through the water column resulting in limited effects on the water’s surface. Water column quality could be affected by increased SBM concentrations within the immediate area (increased TSS) but the area would be small and generally become a source of organic matter, which could be consumed by microbial processes before it reached the seafloor. This is largely dependent on the resident time of the SBMs within water column. If SBMs do reach the seafloor, there is the potential to create anoxic conditions through local eutrophication due to degradation of SBM organic components (Schaanning et al 2008; Ellis et al 2012).

Based on the modelling results, a drill fluid (SBM) spill is not predicted to have any detectable adverse effects on marine fish and fish habitat (Section 16.6.2). As discussed in detail in Section 8.3.4, the acute toxicity of SBMs is considered relatively low and below environmental guidelines and therefore would not result in adverse effects from contamination of fish and fish habitat in the Project Area. Potential effects of a drill fluid spill on special areas are predicted to be adverse, negligible to low in magnitude, short-term in duration, not likely to occur, localized to within the Project Area, and reversible. These predictions were determined with a high level of confidence.

Uncontrolled Well Event

The relevant model results for uncontrolled well events are summarized in Section 16.4. A subsurface/subsea release represents the accidental event with the most potential to affect adjacent Special Areas. This is due to the potentially large amount of discharged oil that could conceivably be associated with a release event and the possibility for such a spill to extend to adjacent areas and resources. In addition, a subsurface release has the potential to result in changes to environmental features and/or processes, and changes in human use and/or societal value of special areas. Thus, such an event would be the most widespread and of greatest environmental and socioeconomic concern for this VC.

EL 1144 Example Well Site

Model results for a 120-day uncontrolled subsurface/subsea release at the EL 1144 example well site shows that hydrocarbons would be expected to move generally east. Most of the footprints showed relatively low probability (<10%) of surface oil thickness greater than the ecological threshold to the west of the example well site. The surface footprints would be anticipated to be larger for summer events. Shoreline contact above socioeconomic threshold in Newfoundland and Labrador is anticipated to occur along the southern Avalon Peninsula including St. Mary's Bay, Placentia Bay and to a lesser extent at the bottom of the Burin Peninsula. Oil concentration in the water column was anticipated to exceed threshold in the offshore mainly to the east of the well site and to some extent to the north and south. A very limited portion of oil (0.01%) is anticipated to reach bottom sediments.

Table 16.24 identifies special areas within the predicted area for oil in the water column above ecological threshold for EL 1144 example well site. Most these special areas (e.g., NAFO FCAs, VMEs and UNCBD EBSAs) are designated due to the importance of bottom habitats including coral and sponge assemblages. Some of these special areas are also identified for the presence of fish species, marine mammals and sea turtles. The Seabird Foraging Area in the Southern Labrador Sea UNCBD EBSA and the Southwest Slope Canadian EBSA is identified for marine bird habitat.

Table 16.25 identifies special areas within the predicted area of oil surface shoreline contact above ecological threshold for the EL 1144 example well site. Most of these special areas (e.g., Provincial Ecological Reserves, IBAs, the PRMA and Canadian EBSAs) are designated due to important marine and migratory bird habitat. Two of the EBSAs are identified for the presence of marine mammals and sea turtles. Gooseberry Cove Provincial Park protects beach habitat and Mistaken Point protects fossils. The two Provincial parks provide recreational opportunities.

Table 16.24 Special Areas with Above Threshold Water Column Concentration from the Subsurface/Subsea Release at the EL 1144 Example Well Site

Special Area Type	Name
Vulnerable Marine Ecosystem	• Division 3O Coral Closure
	• South East Shoal and Adjacent Shelf Edge / Canyons
	• Beothuk Knoll
	• Southern Flemish Pass to Eastern Canyons
	• Flemish Cap East
	• Northern Flemish Cap
	• Sackville Spur
	• Deep Water Coral Area
NAFO FCA	• Orphan Knoll Seamount
	• Newfoundland Seamounts
	• 3O Coral Closure
UNCBD EBSA	• Seabird Foraging Zone in the Southern Labrador Sea
	• Orphan Knoll
	• Slopes of the Flemish Cap and Grand Bank
Canadian EBSA	• Lilly Canyon-Carson Canyon
	• Southwest Slope
Snow Crab Stewardship Exclusion Zone	• Crab Fishing Area 8B

Table 16.25 Special Areas with Above Threshold Shoreline Contact from the Subsurface/Subsea Release at the EL 1144 Example Well Site

Special Area Type	Name
Provincial Ecological Reserve	• Cape St. Mary's • Mistaken Point
Provincial Park	• Chance Cove • Gooseberry Cove
Important Bird Area	• Cape St. Mary's • The Cape Pine and St. Shotts Barren • Mistaken Point • Placentia Bay
Canadian EBSA	• Placentia Bay • Eastern Avalon • St. Mary's Bay
Preliminary Representative Marine Area	• Southern Coast of Burin Peninsula and Southeastern Placentia Bay
Snow Crab Stewardship Exclusion Zone	• 8A • 9A

Table 16.26 and Figure 16.34 identify special areas within the predicted area for oil surface thickness above ecological threshold for the EL 1144 example well site. Most of these special areas (e.g., NAFO FCAs, VMEs, UNCBD EBSAs, Marine Refuge) are identified and / or protected due to the presence of high densities of corals and sponges, though VMEs may also be noted for the presence of vulnerable fish species. One of the UNCBD EBSAs (i.e., the Seabird Foraging Zone in the Southern Labrador Sea), four of the Canadian EBSAs (i.e., Southeast Shoal, Virgin Rocks, Eastern Avalon and Southwest Shelf), both PRMAs (i.e., Virgin Rocks and South Grand Bank Area) are identified for marine and migratory birds. EBSAs and PRMAs may also be identified for the presence of vulnerable fish species and / or marine mammals and sea turtles. The potential effects on the defining features of these special areas are discussed below.

Table 16.26 Special Areas with Above Threshold Surface Thickness from Subsurface/Subsea Release at the EL 1144 Example Well Site

Special Area Type	Name
NAFO Fisheries Closure Area	• Tail of the Bank (1) • Flemish Pass / Eastern Canyon (2) • Beothuk Knoll (3) • Eastern Flemish Cap (4) • Northeast Flemish Cap (5) • Sackville Spur (6) • Northern Flemish Cap (7) • Northern Flemish Cap (8) • Northern Flemish Cap (9) • Northwest Flemish Cap (10) • Northwest Flemish Cap (11) • Northwest Flemish Cap (12) • Beothuk Knoll (13) • Eastern Flemish Cap (14) • Fogo Seamounts (1) • Orphan Knoll Seamount • Newfoundland Seamounts • 3O Coral Closure
Vulnerable Marine Ecosystem	• Division 3O Coral Closure • South East Shoal and Adjacent Shelf Edge / Canyons • Beothuk Knoll • Southern Flemish Pass to Eastern Canyons • Flemish Cap East • Northern Flemish Cap • Sackville Spur • Northeast Shelf and Slope (within Canadian EEZ) • Deep Water Coral Area
UNCBD EBSA	• Seabird Foraging Zone in the Southern Labrador Sea • Orphan Knoll • Slopes of the Flemish Cap and Grand Bank
Marine Refuge	• Northeast Newfoundland Slope Closure
Preliminary Representative Marine Area	• Virgin Rocks • South Grand Bank Area
Canadian EBSA	• Lilly Canyon-Carson Canyon • Southeast Shoal

Special Area Type	Name
	• Haddock Channel Sponges • Southwest Slope • Northeast Slope • Eastern Avalon • Virgin Rocks • Orphan Spur
Snow Crab Stewardship Exclusion Zone	• 6C • 8A • 8B • Midshore • Nearshore

Fish and invertebrates are generally motile and have capability to avoid oiled areas from an accidental spill (Lee et al 2015). However, reactions are species and life stage specific. The embryonic life stages of both fish and invertebrates are more often less motile than their adult counterparts and thus, more susceptible to the effects of spills. Early life stage effects are compounded by lower toxicity thresholds (Lee et al 2015). Laboratory exposure studies of capelin (Frantzen et al, 2012) and larval sculpin (Gardiner et al 2013) found similar results with increased embryo mortality rates and decreased hatching success. Also, deep-sea fish and invertebrate species may be more susceptible (Cordes et al 2016) as they would likely have lower avoidance capabilities than their more pelagic counterparts.

Studies from the DWH spill also showed strong declines in species richness and diversity in the decapod crustacean community post-spill (2010-2012) relative to earlier surveys (2004-2006) (Felder et al 2014). It has been theorized that hydrocarbon exposure may have caused localized mortalities, reduced the fecundity of surviving females or reduced recruitment (Felder et al 2014). The number of lesions observed on deep-water shrimp species surveyed after the spill increased nearly threefold (Felder et al 2014).

Benthic species are susceptible to accidental events through dissolved hydrocarbons in the water column and particularly from the small portion that may settle to the seafloor. Planktonic larvae of corals and sponges and sessile adults have no known mechanisms to avoid injury. For the DWH spill, visual stress indicators included partial tissue loss, excessive mucus production, retracted polyps, partial coverage by brown flocculant sourced to the spill and death (Busky et al 2016; Prouty et al 2016; Ragnarsson et al 2017). Severe reductions in benthic invertebrate abundance and community diversity was observed up to three km from the Macondo well, with moderate effects up to 17 km (Montagna et al 2013 in Busky et al 2016). Effects were patchy and included highly site-specific evidence of deterioration on affected coral branches (Hsing et al 2013). Follow-up surveys 16 months after the event indicated that, at a site 13 km to the southwest of the Macondo wellhead, more than half of the corals were partially covered by a brown flocculant material, but recovery was occurring (Fisher et al 2014).

Sponges have been shown to experience relatively high bioaccumulation of PAH compounds (Batista et al 2013, Gentric et al 2016). The PAH benzo(a)pyrene, a type of carcinogen, has been observed to be strongly bioaccumulated in sponges (Gentric et al 2016) with potential damage to sponge DNA (Zahn et al 1983). However, sponges exposed to hydrocarbons exhibit variable responses to accumulations as they may alter their filtering behaviours in response to contaminants (Kutti et al 2016).

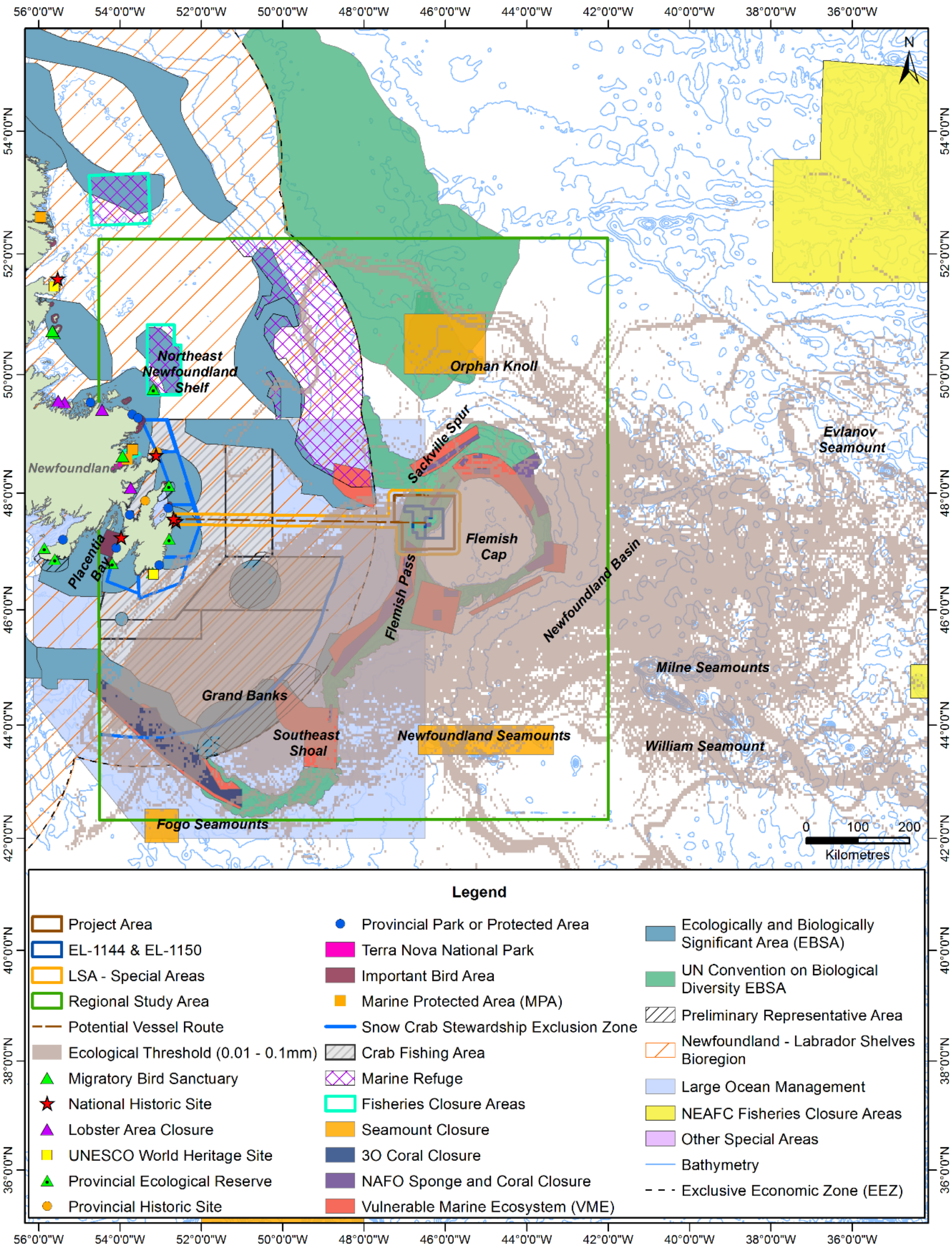


Figure 16.34 Model Results (Surface Oil Concentration; Ecological Threshold) for Subsurface/Subsea Release at the EL 1144 Example Well Site in Relation to Special Areas

In short exposure experiments, altered feeding behaviours allowed sponges to cope with exposure to oil and dispersant contaminated sediments (Vad and Duran 2017). Presence of hydrocarbons may also affect larval distribution with experimental studies showing decreased larval settlement in the presence of hydrocarbons (500 and 100 ng/L PAH) and copper (Cebrian and Uriz 2007).

Population modelling studies have indicated that population level effects from exposure to oil spills are unlikely. For instance, studies on Arctic cod have predicted that even if large mortalities of Arctic cod juvenile and eggs were to occur due to a hypothetical spill event (as the early life stages are potentially the most susceptible to a spill), the effects on the regional cod population would be insignificant (Gallaway et al 2017; Carroll et al 2018). Species-specific population structure is an important consideration as diverse age distributions would help mitigate effects of single year recruitment reductions to the adult population (Carroll et al 2018).

Section 16.6.2 concluded that based on current information on marine fish and fish habitat in the RSA, spill modelling scenarios, and planned mitigation, that an accidental event from the Project is unlikely to result in significant adverse residual effects on marine fish and fish habitat. In the unlikely event of an offshore hydrocarbon release, residual adverse effects to marine fish and fish habitat in the area at the time of the accident or malfunction are expected. The type and level of any effects would be dependent on factors such as the degree of exposure, spill type and size, time of year, and species presence and occurrence within the affected area. Potential adverse residual effects may result in decline or change to food availability and quality with implications for higher trophic levels. Interactions with hydrocarbons would also result in nonlethal effects or mortality on fish and invertebrates depending on the species-specific responses and degree of interaction. Negligible oil on the sediments was predicted by the model, therefore a large-scale direct effect on marine fish and fish habitat is not anticipated.

Accidental events such as oil spills can have important, adverse consequences for marine-associated birds, leading to potential changes in their presence, abundance, distribution and / or health at both the individual and population level. Marine birds are among the biota most at risk from oil spills, as they spend much of their time upon the surface of the ocean (LGL Limited 2005; Boertmann and Mosbech 2011; Barron 2012). In the event of a spill, and depending upon project and area specific factors, coastal birds may also be at risk on beaches and in intertidal zones.

Accidental discharges of hydrocarbons may lead to sheens of crude oil and other substances on the water's surface, to which avifauna (especially pelagic seabirds) may be exposed (Wiese and Robertson 2004; O'Hara and Morandin 2010; Morandin and O'Hara 2016). The possible physical effects of oil exposure include changes in thermoregulatory capability (hypothermia) and buoyancy (drowning) due to feather matting (Clark 1984; Montevecchi et al 1999), as well as potential toxicity effects from oil ingestion through excessive preening (Hartung 1995). Birds that feed on organisms from affected areas are at heightened risk of contamination from food sources (Engelhardt 1983). Even small quantities of oil from sheens have been shown to affect the structure and function of seabird feathers (O'Hara and Morandin, 2010), which has the potential to result in water penetrating the plumage and displacing the layer of insulating air. This can result in hypothermia and loss of buoyancy, which can cause a heightened metabolic rate (increased energy expenditure) and behavioral changes (e.g., increased time spent preening at the expense of foraging and breeding), and can potential death of affected individuals (Morandin and O'Hara 2016). The long lifespan and low fecundity of many seabird species suggests that oil-related effects can potentially have longer term population effects (Wiese and Roberston 2004). While the primary exposure potential for, and resulting direct effects, on seabirds would occur within the spatial extent of a spill, the ecological effects of oiled areas may be transported from the affected site due to the highly mobile nature of marine-associated avifauna (Henkel et al 2012).

Several short- and long-term studies of marine oil spills found that effects can result in increased mortality rates, physiological impairment, reduced reproductive success and in severe cases, possible long-term population declines (Morandin and O'Hara 2016). Once birds are exposed to oil, even with rescue and cleaning efforts, the chances of survival are often quite low (French-McCay 2009). If direct exposure to spilled oil is conservatively assumed to result in close to 100 percent mortality of affected birds, then the key factor in predicting the total extent of mortality of marine birds is the probability of exposure. Probability of exposure is dependent on the fate and behavior of released oil, as well as distribution and behaviour of the bird species involved. For example, aerial species migrating through a spill site are unlikely to become oiled, whereas species that may forage in the spill site are likely to become oiled. Birds at greatest risk are those that spend considerable time resting or foraging on the water surface (Wiese and Roberston 2004; Boertmann and Mosbech 2011). Vulnerability indices of various taxa follow (French-McCay 2009):

- 99 percent mortality for birds that sit on the surface (e.g., dovekies, murres);
- 35 percent mortality for birds that are mostly in flight, but dive frequently for prey (e.g., petrels, terns); and
- 5 percent mortality for birds that are mostly in flight (e.g., migratory landbirds in transit).

Potential effects of oil exposure on birds varies with different types of oil (Gorsline et al 1981), weather conditions, season, migratory patterns, and other activities (Wiese et al 2001; Montevecchi et al 2012). Mortality rates and potential changes in bird populations due to accidental oil releases are poorly understood though often cited as the main risk to marine birds from the offshore oil and gas industry (Fraser and Ellis 2008; Ellis et al 2013). Seabirds are generally long-lived and have low annual reproductive rates. Therefore, mortality in adults can have serious effects on populations. Although it is difficult to assess the direct relationship between volume of oil spilled and number of seabirds oiled (Burger 1993), the timing and location of a spill (not just its size) have an important influence on avifauna mortality and injury rates (Weise et al 2001).

The potential for toxic effects from small amounts of ingested oil by seabirds is unclear. While acute toxic effects from exposure to sheens are considered unlikely (Morandin and O'Hara 2016) and some studies have shown little or no effects from exposure (ingestion) to low doses of oil on adult seabirds (Ainley et al 1981; Stubblefeld et al 1995; Alonso-Alvarez et al 2007), other studies have shown both lethal and nonlethal effects of oil exposure on adult birds (Miller et al 1980; McEwan and Whitehead 1980; Trivelpiece et al 1984; Butler et al 1986, 1988). Effects of ingested oil on birds have been found to include liver damage (Khan and Ryan 1991), pneumonia (Hartung and Hunt 1966), brain damage (Lawler et al 1978) and immunotoxic effects (Barron 2012), in addition to starvation due to increased energy needs to compensate for heat loss resulting from oiling and loss of insulation (Peakall et al 1980; 1982; MMS 2001).

Marine and migratory birds congregate in large numbers in coastal colonies from spring to fall during breeding, incubation, rearing, feeding and migration activities. While the consequences of shoreline oil exposure would be serious for marine birds, the maximum predicted potential for shoreline exposure above threshold in Eastern Newfoundland was less than 25 percent and typically less than 10 percent with a minimum timeline of 81 days for the 120-day modelling scenario. Thus, mitigations would be in place to reduce the chances of oil-shoreline interaction. No oil was predicted to reach the shores of Labrador (RPS 2019).

Based on present knowledge of marine and migratory birds in the RSA, the known effects of oil spills on marine-associated avifauna, the results of spill modelling exercises, and planned mitigation, Section 16.6.3 of the EIS presents a conclusion that residual environmental effects from an accidental subsurface/subsea release on marine and migratory birds, including marine-associated avian species at risk, could potentially be significant. The magnitude of any effects would depend on the size and duration of the spill, location, time of year, and species presence and abundance within the affected area. For a release scenario, environmental effects could result in a detectable decline in overall bird abundance or change in the spatial and temporal distribution of bird populations in the RSA for multiple generations. However, this is considered unlikely given the low probability of a large spill to occur, and in consideration of the response measures that will be implemented. Birds are highly mobile; therefore, presence and abundance within the Project Area (and the RSA) are variable, as, consequently, is the likelihood of interaction with Project-related accidental events. Spill response and prevention strategies will be incorporated into the Project as part of contingency planning, thus ensuring the likelihood and potential severity of such events, and their potential effects on marine and migratory birds, would be minimized.

Potential adverse effects to marine mammals and sea turtles resulting from an accidental hydrocarbon release include oiling of fur, baleen, skin and flippers; ingestion of contamination in food and water; reduction in prey availability; and potential inhalation of volatiles through respiration. Depending on the level of exposure, these effects can result in behavioural changes, physiological and neurological damage, challenges to movement, or death. While there is some evidence suggesting that cetaceans may be able to detect oil spills, most species do not tend to exhibit avoidance behaviours (Geraci et al 1983, St. Aubin et al 1985, Harvey and Dahlheim 1994, Matkin et al 1994). Behaviour changes may result from the presence of hydrocarbons. Smultea and Würsig (1995) observed that dolphins tended to decrease respiration rate and increase dive durations in the presence of surface oil.

The primary pathways through which oil spills may directly affect marine mammals and sea turtles are ingestion, absorption and inhalation. Inhalation and aspiration can result in inflammation of mucous membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Irritation and increased susceptibility to infection can occur with skin exposure, particularly in the sensitive membranes of the eyes and mouth (Perrin et al 2002). Oil can also coat baleen, causing a temporary reduction in feeding efficiency of mysticetes (Geraci 1990).

Cetaceans may ingest oil with water or by consuming contaminated prey. Ingested oil can be absorbed into the tissues and have toxic effects and (Geraci 1990). For example, top-level predators such as killer whales are known to be susceptible to accumulating high concentrations of persistent organic pollutants (Ross et al 2000, 2002). However, ingested oil may eventually leave the system when an organism returns to uncontaminated waters (Engelhardt 1978, 1982, 1983). For example, only small traces of oil were found in grey whale blubber and in the liver of a killer whale exposed to oil from the Exxon Valdez spill (Bence and Burns 1995). Direct evidence of the long-term effects from exposure to hydrocarbons through contact or ingestion for marine mammals and sea turtles is lacking, although long-term studies have demonstrated evidence implicating oil spills in the mortality of cetaceans (Dahlheim and Matkin 1994; Matkin et al 2008).

The DWH spill is well-studied, but it occurred in waters warmer than those of the RSA, and therefore direct comparisons of the effects of this spill cannot always be made. Nonetheless, many of the effects are expected to be similar, and because so many marine mammal and sea turtle species have extremely large ranges, many of the same species affected by the DWH spill occur within the Project Area and RSA. NMFS (2014) reported that following the DWH spill 171 dolphins and whales were collected through stranding or directed captures in open water, of which 153 collected individuals were dead. Almost 90 percent of these mortalities were bottlenose dolphins and about five percent showed visible oiling (NMFS 2014). A significant reduction of reproductive success and increase in calf mortality in the common bottlenose dolphin following the DWH spill was observed by Lane et al (2015).

Exposure to oil may result in mortality of some pinnipeds. Seal pups appear to be most vulnerable in colder waters (St. Aubin 1990). Temporary or even permanent damage to sensitive eye tissues has been reported (St. Aubin 1990; Spraker et al 1994) which results in reduced foraging efficiency (Levenson and Schusterman 1997). With heavy oil exposure, seals may experience difficulty with locomotion (Davis and Anderson 1976, Sergeant 1991). Harbour seals observed immediately after oiling from the Exxon Valdez spill appeared lethargic and disoriented, which was thought to be attributed to lesions that were subsequently found in the thalamus of the brain (Spraker et al 1994). Oil ingested from contaminated prey or even from nursing contaminated milk may be absorbed into the tissues, resulting in kidney, liver, and brain lesions (Geraci and Smith 1976, Spraker et al 1994).

Sea turtles surface to breathe, and because they do not appear to show avoidance of oil spills and take large inhalations prior to diving, they may be particularly susceptible to inhalation of volatiles (Vargo et al 1986; NOAA 2010; Vander Zanden et al 2016). The effects of inhalation of oil by sea turtles include a reduction of lung capacity and decreased oxygen uptake (Lutz and Lutcavage 1989). Ingestion and absorption of oil can also occur from both surfacing and ingestion of oiled prey, which may lead to reduced digestion efficiency and damage to sensitive tissues such as eyelids and nasal passages (Lutz and Lutcavage 1989). Temporary skin damage (lesions) has been observed in loggerhead sea turtles following exposure to oil, with healing of lesions observed within ten days post-exposure (Bossart et al 1995). Following the DWH spill, Beyer et al (2016) reported an increase in sea turtle strandings, particularly Kemp’s ridley turtles, while NMFS (2014) documented at least 18 visibly oiled dead turtles and an additional 450 rescued and rehabilitated sea turtles, 95 percent of which were loggerhead sea turtles.

Section 16.6.4 concluded based on present knowledge of marine mammals and sea turtles in the RSA, the known effects of oil spills on marine-associated avifauna, the results of spill modelling exercises, and planned mitigation, that accidental events are not likely to result in significant adverse environmental effects on marine mammals and sea turtles including marine mammal and sea turtle species at risk or species of conservation concern. This conclusion is based on current understanding of the effects of similar projects on the VC, the availability of literature and data used to characterize existing conditions and Project effect mechanisms, and the known effectiveness of proposed mitigation measures. Spill response and prevention strategies will be incorporated into the Project as part of contingency planning, thus ensuring the likelihood and potential severity of such events, and their potential effects, are minimized.

The degree of change in mortality or injury and change in health will depend in large part on the occurrence and distribution of marine mammals and sea turtles at the time of the release, as well as the duration and extent of oil release. Depending on the exact nature, extent, and duration of a release, marine mammals and sea turtles in the spill area are likely to experience a combination of exposures from contaminated air, water, and sediment and therefore via a combination of pathways (inhalation, ingestion, aspiration, and adsorption). Marine mammals and sea turtles that are closer to the site of the release are more likely to be exposed to a more constant flow and higher concentrations of oil, as compared to nearshore species or individuals that are further from the release site. In the event of shoreline oiling, fur-bearing marine mammals (e.g., seals) that haulout on shorelines and are present at the time of an incident in an affected area (e.g., Placentia Bay EBSA or Eastern Avalon EBSA) may experience injury or mortality upon exposure to hydrocarbons. It is likely that only a small proportion of local populations would be affected.

With spill prevention plans and response procedures in place, any potential residual effects of an unlikely subsurface/subsea release from the EL 1144 example well site on special areas are predicted to be adverse, medium to high in magnitude, medium to long-term in duration, occurring within the RSA and beyond but reversible. This is based on the worst-case scenario of effects on special areas identified for marine and migratory birds and was determined with a moderate level of confidence.

EL 1150 Example Well Site

Table 16.27 and Figure 16.35 identify several special areas within the predicted 95th percentile for oil in the water column for the EL 1150 example well site. Many of these special areas (e.g., NAFO Fisheries Closure Areas, VMEs, UNCBD EBSAs) are designated due to the presence of bottom habitats including coral and sponges, though some are noted for the presence for marine and migratory birds and marine mammals and sea turtles. The modelled footprints for the EL 1150 example well site showed limited extents for surface oil and water column concentration when compared to modelling for the EL 1144 example well site. Similar to the release at the EL 1144, example well site, negligible oil on the sediments was predicted by the model of subsurface release in EL 1150, and therefore a large-scale direct effect on bottom habitat is not anticipated. There was no predicted shoreline contact by hydrocarbons for this scenario.

Table 16.27 Special Areas with Water Column Exposure above Threshold from the Subsurface/Subsea Release at the EL 1150 Example Well Site

Special Area Type	Name
Vulnerable Marine EcosystemVME	• South East Shoal and Adjacent Shelf Edge / Canyons • Beothuk Knoll • Southern Flemish Pass to Eastern Canyons • Flemish Cap East • Northern Flemish Cap • Sackville Spur • Deep Water Coral Area
NAFO FCA	• Orphan Knoll Seamount • Newfoundland Seamounts
UNCBD EBSA	• Seabird Foraging Zone in the Southern Labrador Sea • Orphan Knoll • Slopes of the Flemish Cap and Grand Bank
Canadian EBSA	• Lilly Canyon-Carson Canyon
Snow Crab Stewardship Exclusion Zone	• Crab Fishing Area 8B
Preliminary Representative Marine Area	• South Grand Bank Area

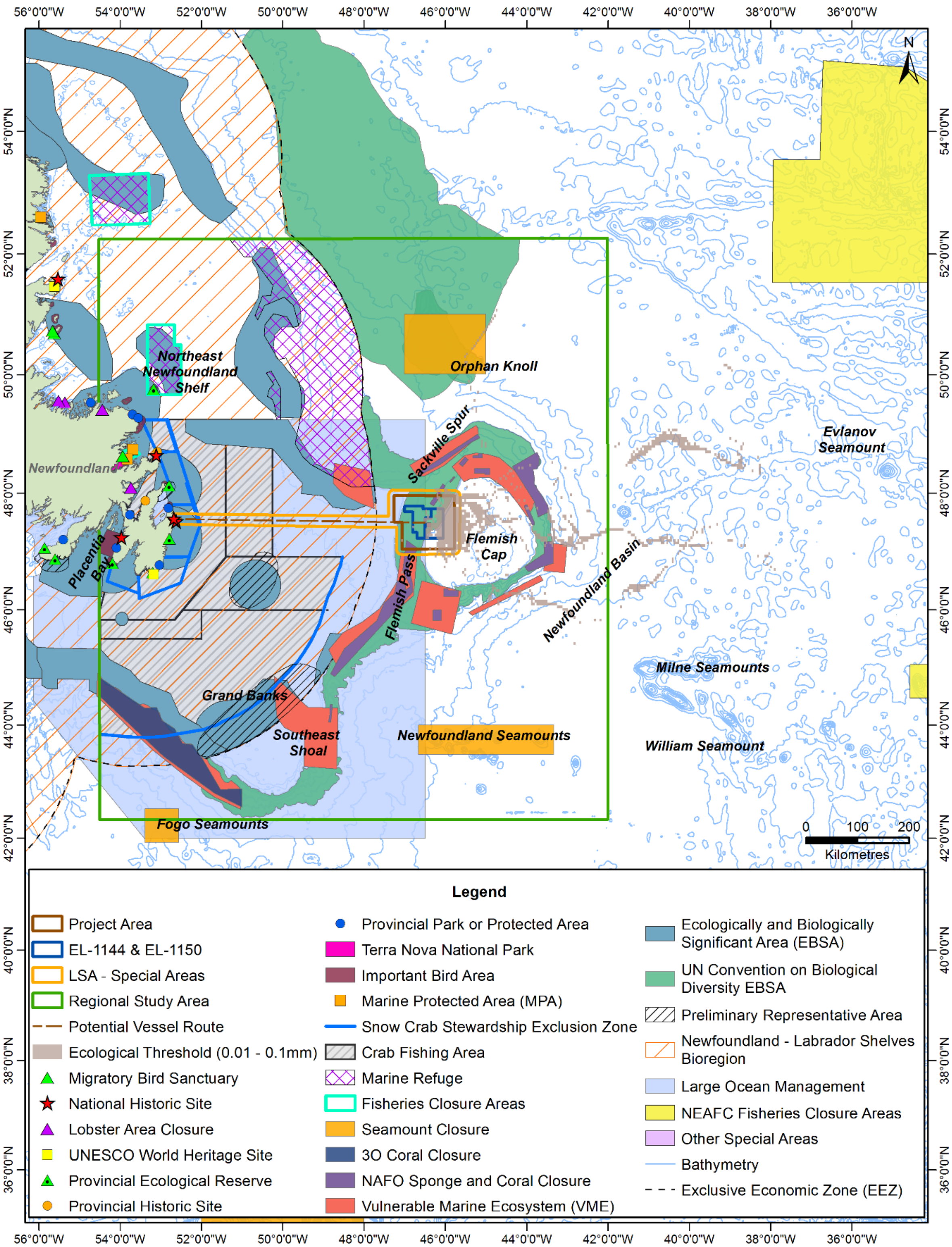


Figure 16.35 Model Results (Surface Oil Concentration; Ecological Threshold) for Subsurface/Subsea Release at the EL 1150 Example Well Site in Relation to Special Areas

Table 16.28 and Figure 16.35 identify special areas within the predicted area for surface oil thickness above threshold for the EL 1150 example well site. Most of these special areas (e.g., NAFO FCAs, VMEs, UNCBD EBSAs) are identified and / or protected due to the presence of high densities of corals and sponges, though VMEs may also be noted for the presence of vulnerable fish species. The Seabird Foraging Zone in the Southern Labrador Sea UNCBD EBSA and South Grand Bank Area PRMA are identified as marine and migratory bird habitat. EBSAs and PRMAs may also be identified for the presence of vulnerable fish species and / or marine mammals and sea turtles.

Table 16.28 Special Areas with Surface Thickness above Threshold from Subsurface/Subsea Release at the EL 1150 Example Well Site

Special Area Type	Name
NAFO FCA	• Flemish Pass / Eastern Canyon (2) • Eastern Flemish Cap (4) • Northeast Flemish Cap (5) • Northwest Flemish Cap (10) • Northwest Flemish Cap (11) • Eastern Flemish Cap (14) • Orphan Knoll
Vulnerable Marine Ecosystem	• Southern Flemish Pass to Eastern Canyons • Flemish Cap East • Northern Flemish Cap • Deep Water Coral Area
UN Convention on Biological Diversity EBSA	• Seabird Foraging Zone in the Southern Labrador Sea • Orphan Knoll • Slopes of the Flemish Cap and Grand Bank

The potential effects on the defining features of special areas identified and / or protected for the presence of various marine species are similar to those described for the EL 1144 example well site. As stated, the results of modelling showed smaller footprints for the EL 1150 example well site and no shore line contact. Thus, they are not repeated in this section.

With spill prevention plans and response procedures in place, any potential residual effects of an unlikely subsurface release from the EL 1150 example wellsite on special areas are predicted to be adverse, medium to high in magnitude, medium to long-term in duration, occurring within the RSA and beyond, but reversible. This is based on the worst-case scenario of effects on special areas identified for marine and migratory birds and was determined with a moderate level of confidence.

16.6.5.3 Summary and Determination of Significance

Table 16.29 provides a summary of predicted residual environmental effects of accidental event scenarios on special areas. Residual effects incorporate the conservative approach that was used for the spill modelling and the implementation of mitigation measures to prevent and reduce effects from a spill. This analysis is based on potential Project effects on the defining features of special areas that intersect with locations predicted to intersect with areas above thresholds of concern for marine fish and fish habitat, marine and migratory birds and marine mammals and sea turtles such as those found in special areas in the RSA.

Table 16.29 Summary of Residual Accidental Event-Related Environmental Effects on Special Areas

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty
Potential Effects: • Change in environmental features and/or processes • Change in human use and /or societal value							
100 litre Diesel Spill	A	N-L	L-PA	S	N	R	H
1,000 litre Diesel Spill	A	L-M	L-PA	M	N	R	M
750,000 litre Diesel Spill	A	L	RSA	M	N	R	M
Drill Fluid (SBM) Spill	N	N-L	L-PA	S	N	R	H
30-day Subsurface Release – EL 1144 Example Well Site	A	M-H	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1144 Example Well Site	A	M-H	RSA and Beyond	M-L	N	R	M
30-day Subsurface Release – EL 1150 Well Site	A	M-H	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1150 Well Site	A	M-H	RSA and Beyond	M-L	N	R	M

KEY

Nature / Direction:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude:
N Negligible
L Low
M Medium
H High

Geographic Extent:
L Localized
PA Within Project Area
LSA Within LSA
RSA Within RSA or Beyond

Frequency:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Duration:
S Short term
M Medium term
L Long term
P Permanent

Reversibility:
R Reversible
I Irreversible

Certainty in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

The modelled oil spill fate and behavior, and associated effects analysis provided above, relate to the probability of an unmitigated release scenario occurring and interacting with special areas identified and / or protected for marine-associated avifauna and their habitats. The modeling is therefore inherently conservative, in that such a release event is both unlikely (Section 16.3) and would be avoided through various oil spill prevention measures and addressed through various response measures committed to by CNOOC in Section 16.1 and required under subsequent (post-EA) regulatory approval processes for the drilling program. These mitigations, including response measures such as the use of dispersants or other means, will serve to prevent or reduce any adverse effects, on marine-associated species, including the magnitude, extent and duration of any such exposure (if it occurs) and thus its potential environmental effects.

Table 16.29 provides a summary of predicted residual environmental effects of accidental event scenarios for special areas. Residual effects incorporate the conservative approach used for the spill modelling and consider the implementation of mitigation measures to prevent and reduce effects from a spill.

Given the present knowledge of special areas in the RSA, the known effects of oil spills, the results of spill modelling exercises, and planned mitigation, a precautionary conclusion is drawn that residual environmental effects from an accidental subsurface release, on special areas identified and / or protected for marine and migratory birds, could potentially be significant depending on the nature of the event, though such an event is unlikely to occur. The magnitude of effects would depend on the size and duration of the spill, location, time of year, and species presence and abundance within the affected area. As birds are highly mobile, presence and abundance are variable. Environmental effects could be significant, resulting in a detectable decline in overall bird abundance or change in the spatial and temporal distribution of bird populations in the overall RSA for multiple generations. However, this is considered unlikely given the very low probability of a large spill to occur. Spill prevention and response strategies will be incorporated into the Project as part of contingency planning, thus ensuring the likelihood and potential severity of such events, and their potential effects on this VC, is minimized.

16.6.6 Indigenous Peoples

As described in Sections 7.4 and 12.0 of the EIS, several Indigenous groups reside in Eastern Canada, including communities in Newfoundland and Labrador, the Maritime Provinces and Quebec. As discussed in Section 12.4, the environmental effects assessment for the Project's planned components and activities has predicted no significant residual adverse effects upon Indigenous groups. Nonetheless, there is concern about the potential for an accidental event such as an oil spill to adversely affect Indigenous peoples in Eastern Canada. Questions and concerns about the occurrence, and potential effects, of such an accidental event were referenced by several Indigenous communities or their representative organizations during CNOOC's EIS engagement program (Section 3.3 of the EIS). An accidental event could have adverse effects on Indigenous peoples, including effects on fisheries resources and/or fishing activity, as well as the various socio-cultural components and activities specified in Section 5(1)(c) of CEAA 2012. The potential for, and nature and degree of, any such effects depends largely on whether and how the spill trajectory and the various components of this VC overlap in space and time.

16.6.6.1 Potential Issues and Interactions

The potential environmental effects on Indigenous peoples identified and used in the earlier environmental effects assessment for planned Project activities (Section 12.2 of the EIS) include the change in:

- health and socio-economic conditions;
- the current use of lands and resources for traditional purposes;
- physical and cultural heritage; and
- any structure, site or thing that is of historical, archaeological, paleontological or architectural significance.

These potential effects remain relevant to the assessment of accidental events. The effects of offshore oil and gas activities, including accidental events, on Indigenous peoples may be direct or indirect in nature. They may, for example, result from accidental events such as oil spills extending to and interacting directly with locations and environmental components that are used or otherwise valued by Indigenous people, including their communities, asserted or established traditional territories and resources, and other components of the health (physical or social), heritage (physical or cultural) and other socioeconomic conditions of an Indigenous group. Indirectly, any biophysical effects resulting from an accidental event such an oil spill on marine fish, birds, marine and migratory birds, and marine mammals and sea turtles that are used for traditional purposes can affect the physical health of persons who encounter these, through either direct exposure with the contaminants or through consumption of affected fish and wildlife (see Section 16.6.7.1 for a discussion of potential effects related to tainting). These biophysical effects may also have consequences for the availability or quality of the water, air, vegetation, fish or wildlife used by Indigenous peoples, thereby affecting the current use of these resources for traditional purposes, and in turn, the overall quality of life and well-being of a community. The Indigenous peoples VC is therefore closely linked to other VCs, particularly the biological VCs, for which the effects assessment has predicted no significant adverse residual effects.

This section assesses and evaluates the potential effects of potential accidental events on Indigenous peoples, including the various socio-cultural components and activities specified in Section 5(1)(c) of CEAA 2012.

Fish Species Used by Indigenous Groups

As described in Section 3.3 and 12.0, several individual fish species have been identified through CNOOC's EIS engagement program as being used for traditional purposes by various Indigenous groups. Therefore, additional information related to the potential effects of an oil spill on these species is provided here.

As stated in Section 8.4.4, Atlantic salmon (post-smolt and adult) are concentrated throughout the year in the Labrador Sea where they feed and overwinter. In the spring, both grilse and multi-sea-winter (MSW) adults appear to congregate in two general locations: near the eastern slope of the Grand Banks of Newfoundland; and approximately 480 km east of the Strait of Belle Isle (Reddin and Friedland 1993; Reddin 2006) prior to their spawning migrations back to their natal rivers. Smolt ages indicate that salmon congregating off the east Grand Banks area are likely from more southern populations from South Newfoundland, a portion of the Gulf of St. Lawrence, as well as Eastern – Southern Nova Scotia and Outer Bay of Fundy. While post-smolt do not likely overwinter in the Flemish Pass area (Reddin and Friedland 1993; Reddin 2006), migration as adults to the east Grand Banks area must occur. Although the exact migration route is not known, it may include areas within and near the Project Area, particularly during time periods when sea-surface temperatures are favourable (over 4°C).

The effects of an accidental release on marine fish, including salmon, have principally been described using laboratory studies with farm raised fish or caged fish that are unable to avoid oil exposure (e.g., Barnett and Toews 1977; Thomas and Rice 1987; Fraser 1992; Pineiro et al 1996; Zhou et al 1997; Stagg et al 1998; Meador et al 2006; Stieglitz et al 2016). Many of these studies showed effects on feeding, food conversion, or changes in enzyme levels based on exposure; however, returns to baseline were generally noted in 2-8 weeks (Fraser 1992; Stagg et al 1998). Many of the concentrations used in lab studies were high compared to the results of subsurface release modelling. For example, Stagg et al (1998) investigated the effects of the Braer oil spill on the Shetland Isles, Scotland. They characterized reference sites in the north of Shetland as having oil in water concentrations between 2 and 5 μg/L and regarded these as being typical background values for the local inshore environment. No effects on farmed salmon enzyme and protein levels were detected at these concentrations. Barnett and Toews (1977) observed no mortality in post-smolt Atlantic salmon during 96-hour acute lethal bioassays with concentrations up to 32 mg/L.

Few studies have been conducted on avoidance behaviour of returning adult salmon to hydrocarbons in water under natural conditions. Weber et al (1981) conducted a behavioural study on adult Pacific salmon (*Oncorhynchus sp.*) where hydrocarbons that closely approximated the water-soluble fraction of Prudhoe Bay crude oil were added in one of two fishways as salmon were migrating upriver. The study found that migrating salmon substantially avoided (i.e., when 50 percent of fish avoided a fishway they were expected to ascend) hydrocarbons in the water at concentrations of 3,200 μg/L.

Based on available information, oil spil concentrations during a batch spill event would not be considered capable of altering the migratory behavior of salmon. In the event of a subsurface release, the potential concentrations that have been shown to cause avoidance behaviour in salmon (3,200 μg/L) would be limited in extent and located very near the release site (i.e., deeper water). Any salmon that would be located in the general offshore area would be in the process of migrating to their home river to spawn. Therefore, a subsurface release during migration may cause a slight alteration of course but with the limited extent of concentrations greater than 3,200 μg/L, it would be considered a minor deviation and with the biological drive to return to spawn, it would not expect to delay the timing of return to their natal rivers (also see IR13 Part 8).

American eel are occasionally present in the RSA as adults migrate from coastal areas to the Sargasso Sea (Scott and Scott 1988). Migrations of adults and larvae generally follow continental shelf areas (Wang and Tzeng 1998), reducing likelihood of passing through any potentially affected area. Like other fish, oil exposure has been shown to induce oil degrading enzymes like CYP1A (Schlezinger and Stegeman 2000) with a 5 mg/kg dose response, a sensitivity that is less than that of other fish. It has been speculated that this is due to the species' life history, as they spend a portion of their life in estuaries where they have increased chance of exposure to contaminants and therefore less sensitivity (Schlezinger and Stegeman 2000).

The RSA is within the areas used by swordfish, whose overall distribution and migration patterns include most of the North Atlantic Basin (Dewar et al 2011, Trenkel et al 2014). Swordfish numbers and their overall ranges and migration patterns (Section 6.1.7) therefore make it unlikely that they would be present within the affected area during an accidental event, and the highly mobile nature of this species would likely allow individuals to avoid affected areas.

Detailed assessments and evaluations of the potential environmental effects of a Project-related accidental event on marine fish and fish habitat, marine and migratory birds, and marine mammals and sea turtles, were provided in the preceding sections.

16.6.6.2 Environmental Effects Assessment

The potential environmental effects of an accidental hydrocarbon release on the various components of this VC are assessed in the following subsections.

Marine Diesel Spills (Batch Spills and Vessel Collision Scenario)

A potential batch spill from a Project-related MODU or supply vessel would be limited in terms of its overall magnitude, extent and duration, and thus, its potential environmental consequences.

The geographic extent of such Project-related batch spills and their effects, if they did occur, would be localized to the Project Area or elsewhere in the offshore marine environment several hundred kilometers from the Island of Newfoundland, and thus at considerable distance from any Indigenous communities or their known activities or other interests (Section 7.4). No direct effects on Indigenous peoples are therefore predicted to occur due to such an accidental event. Moreover, given the distances involved, they would not interact with nor adversely affect the physical and cultural heritage of any Indigenous group. The Project Area is not known to contain resources of historical, archaeological, paleontological, or architectural significance, and given their location far offshore Eastern Newfoundland, are not likely to contain such resources or materials that are relevant to and valued by any Indigenous group.

As discussed and illustrated in Section 7.4, there are no known Indigenous groups that hold, claim or assert Aboriginal or Treaty rights or otherwise undertake traditional activities within or near the Project Area, and thus, within the environmental zone of influence of any such batch spills. Although fishing enterprises associated with several of these organizations undertake commercial fishing activity within NAFO Divisions that overlap parts of the Project Area (Section 7.2), it is understood that these organizations undertake fishing activities off Eastern Newfoundland and these contemporary, commercial land and resource use activities may not be considered traditional in that they are not a continuation of ancestral activities that took place historically within this area offshore Eastern Newfoundland. The potential effects of the Project on commercial fishing activities by Indigenous groups are addressed as part of the Fisheries and Other Ocean Uses VC (Section 16.6.7).

As described earlier in this section for the various preceding biophysical VCs, any such batch spill events are not expected to result in any significant adverse effects upon marine fish, birds, or mammals (including those known to be or potentially used for traditional purposes), and the various environmental mitigation measures identified and proposed throughout the EIS will help avoid or reduce any associated effects on these species. There is almost no potential for the biophysical effects of the Project to have an adverse effect on the presence, abundance, distribution or quality of such resources in any area, and especially, on their overall availability for resource use activities by Indigenous groups within their traditional harvesting areas. There will be no potential for any such biophysical effects (should they occur) to translate into any decrease in the overall nature, intensity, distribution (location or timing), quality or cultural value of these traditional activities by any Indigenous group. Similarly, any such effects are unlikely to extend to or affect the physical (i.e., ingestion of toxic materials) or social health and well-being of any Indigenous persons or communities.

With spill prevention plans and response procedures in place, there is a very low probability of a large spill event occurring. If such a spill did occur, it is not likely to directly interact with or adversely affect Indigenous peoples, nor to have effects on marine-associated resources used by these groups in a manner or to a degree that would affect their availability, quality or use.

Adverse effects of a marine diesel spill on Indigenous peoples are therefore not anticipated. This was determined with a moderate to high level of confidence.

Drill Fluid (SBM) Spill

The relevant drill fluid model results are summarized in Section 16.5. An SBM spill would have the potential to result in seabed disturbance, chemical toxicity, and bioaccumulation (uptake of contaminants by fish and the presence or perception of taint). As discussed in detail in Section 8, the acute toxicity of SBMs is considered relatively low and below environmental guidelines and therefore will not result in adverse effects from contamination to marine biota or habitats. An authorized discharge of spent SBMs (i.e., mix of SBM and cuttings) would be similar in terms of extent and duration to the effects of drill fluid cuttings during normal operations, where a localized increase in total suspended solids would be expected. Adverse effects of a drill fluid spill on Indigenous peoples are therefore not anticipated. This was determined with a high level of confidence.

Uncontrolled Well Event

The model results for uncontrolled well events are summarized in Section 16.4. Given the potentially large amount of discharged oil that could conceivably be associated with such a subsurface/subsea release event, and the possibility for such a spill to extend to areas beyond the well site and Project Area, an uncontrolled release represents the accidental event with the most potential to affect Indigenous peoples in Newfoundland and Labrador and elsewhere in Eastern Canada.

Notwithstanding the much larger size and magnitude of such a release as compared to a smaller batch spill during routine operations, most of the potential issues, key considerations and general principles associated with the potential effects of a batch spill on this VC, as described above, also apply here. Specifically, the potential for direct interaction between the oil spilled during a release and any Indigenous group and its activities (such as hunting and fishing) are extremely low given the present knowledge that no traditional activities occur in the offshore surrounding the Project and the overall distances between the Project Area and any Indigenous community (at least 635 km).

While the oil spill modelling indicates a potentially large area being affected in the event of an unmitigated event, many of the areas delineated have very low probabilities of being affected, and in an actual incident, appropriate spill response measures will be implemented to help reduce the magnitude, duration and geographic extent of the spill and thus its environmental effects.

EL 1144 Example Well Site

As shown in the modelled release at the EL 1144 example well site, oil on the surface during such an event was most likely to move to the east due to the prevailing westerly winds and surface currents within the region. There is therefore very little potential for any such spill to reach and adversely affect any Indigenous communities in Eastern Newfoundland or elsewhere in Eastern Canada. It is thus unlikely to result in any effects on any Indigenous group or its activities or other interests, including physical and cultural heritage or any structure, or site that is of historical, archaeological, paleontological, or architectural significance.

In terms of potential indirect effects due to associated biophysical changes resulting from such a release, while it is not possible to determine with certainty whether a migratory individual of any species used for traditional purposes by any group may be present in the affected area before moving to an area that is the subject of traditional harvesting activity, as illustrated in Section 12 there is limited potential for any degree of interaction. The probability of a spill occurring is extremely low, and in the event of a spill, the species (individual fish, bird or marine mammal) would have to be present in the area at that time to be potentially affected. As described for the various preceding biophysical VCs, any such accidental events are, with appropriate mitigation in place, not expected to result in any significant adverse effects upon marine fish, birds, or mammals. Any potential effects on individuals from a marine-associated species are not likely to result in measurable effects on the use of such species for traditional purposes by an Indigenous group in Eastern Canada.

With regard to Atlantic salmon, based on laboratory experiments it is unlikely that concentrations comparable to laboratory-observed effects would be present during an accidental event beyond the immediate Project Area. In situ experiments indicate that salmon in natural conditions (not a lab or a cage) can likely detect hydrocarbons at concentrations approximately ten percent of those shown to cause mortality and avoid them. As shown in the accidental release modelling, predicted concentrations will generally be lower than those shown to cause avoidance in salmon and spill trajectories are in a predominantly eastern and south-eastern direction. Based on modelling for an accidental release in EL 1144, concentrations of 500 µg/L or greater of dissolved hydrocarbons in the water column could be experienced to the east of the release site. Salmon, in laboratory experiments, have been shown to avoid such concentrations. Thus, if an accidental release occurred during the spring migration and/or congregation of returning Atlantic salmon to the east of the Grand Banks (though the likelihood of migrating salmon using the area is uncertain), salmon would likely avoid the area. However, given the predicted extent of these concentrations, it is unlikely that migration and behaviour would be affected to the extent that they would not be capable of navigating to their home river.

For all species, as noted throughout, the probability of such a spill occurring is extremely low, and in the event of a spill, the resources in question, would have to be present in the area at that time to be potentially affected.

With spill prevention plans and response procedures in place, any adverse effects of a subsurface release from the EL 1144 example well site on Indigenous peoples (if they did occur) are predicted to be adverse, negligible to low in magnitude, medium to long-term in duration, occurring within the RSA, and reversible. These predictions were determined with a moderate level of confidence.

EL 1150 Example Well Site

Based on the unmitigated scenario, it is predicted that a release of hydrocarbons into the marine environment is likely to move eastward due to the prevailing westerly winds, and thus away from any Indigenous communities and territories in Newfoundland and Labrador, the Maritime Provinces or Quebec. There was no predicted shoreline contact from the modelled releases at the EL 1150 example well site. Such a release is therefore unlikely to result in any effects on any community or its activities or other interests, including physical and cultural heritage or any structure, or site that is of historical, archaeological, paleontological, or architectural significance.

In terms of potential indirect effects on such activities, the environmental effects assessment for this VC again considers whether and how Project-related changes in and effects on the biophysical environment within the potential zone of influence of such a spill may affect resources that are used for traditional purposes by Indigenous groups, including as a result of the known migration and movement patterns of marine-associated biota that are known to be used for these purposes. While it is again not possible to determine with absolute certainty whether any particular individual of any species (in any life history stage) used for traditional purposes by any Indigenous group may be present in the affected area before moving to an area that is the subject of traditional harvesting activity. As indicated in Section 12 there is limited potential for any degree of connection. For the various preceding biophysical VCs, any accidental events are, with appropriate mitigation in place, not expected to result in any significant adverse effects upon marine fish, birds, or mammals (including those used for traditional purposes). There is therefore little potential for any effects on marine-associated species in general (and individuals in particular) to translate into a detectable effect on the use of such species for traditional purposes by an Indigenous group elsewhere in Eastern Canada. Adverse effects on the health of Indigenous peoples are also not predicted to occur as a result of the Project given the imposition of a temporary harvesting closure around the affected area.

The probability of such a spill occurring is extremely low, and with spill prevention plans and response procedures in place, the potential effects of a subsurface/subsea release from the EL 1150 example well site on Indigenous peoples are predicted to be adverse, negligible to low in magnitude, medium to long-term in duration, occurring within the RSA, and reversible. These predictions were determined with a moderate level of confidence.

16.6.6.3 Summary and Determination of Significance

Table 16.30 provides a summary of predicted residual environmental effects of the various accidental event scenarios on Indigenous peoples.

An accidental event such as a large marine diesel spill or a subsurface/subsea release will be prevented through the application of mitigations measures in Project planning and implementation, and reinforced through the various post-EA regulatory review processes and requirements that will apply to the proposed drilling activities that comprise this Project. The probability of such an accidental event occurring, and resulting in adverse effects on this VC or any other component of the environment, is therefore very low. This is further reinforced through the oil spill probability analysis summarized in Section 16.3, and presented in detail in Appendix F of the EIS.

Large marine diesel spills from MODUs or vessels are both unlikely to occur. In the event that one were to occur, the relatively localized and short term nature of any resulting environmental disturbance and associated effects, coupled with the lack of Indigenous communities and activities in this offshore area, would mean that there is little or no potential for adverse effects on the various components of this VC. These would be addressed through the various response procedures outlined previously, which will further serve to prevent any adverse effects from occurring.

A subsurface/subsea release is unlikely to occur, especially with the various prevention measures that are required and committed to in the EIS. In the unlikely event that an accidental event such as a release did occur, the (conservative, without mitigation) oil spill modelling carried out for the EIS predicts a very low probability of oil moving west and thus reaching the shoreline of Eastern Newfoundland and other areas of Atlantic Canada, and thus, coming into direct contact with any Indigenous communities or activities. As described for the various preceding biophysical VCs, any such event is also not expected to result in significant adverse residual effects upon marine fish, birds, or mammals, and would thus not have a significant effect on the presence, abundance, distribution or quality of such resources in the area, and thus, their availability for resource use activities by these groups within their traditional harvesting areas. There would be no potential for any residual direct and/or indirect biophysical effects on marine species to translate into a decrease in the overall nature, intensity, distribution, quality or cultural value of these traditional activities by Indigenous peoples.

Any accidental events that may be associated with the Project are therefore not likely to result in significant adverse environmental effects on Indigenous peoples.

Table 16.30 Summary of Residual Accidental Event-Related Environmental Effects on Indigenous Peoples

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty
Potential Effects: • Changes in health and socioeconomic conditions; • Changes in the current use of lands and resources for traditional purposes; • Changes in physical and cultural heritage; and • Changes in any structure, site, or thing that is of historical, archaeological, paleontological, or architectural significance.							
100 litre Diesel Spill	N	-	-	-	-	-	H
1,000 litre Diesel Spill	N	-	-	-	-	-	H
750,000 Diesel Spill	N	-	-	-	-	-	M
Drill Fluid (SBM) Spill	N	-	-	-	-	-	H
30-day Subsurface Release – EL 1144 Example Well Site	A	N-L	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1144 Example Well Site	A	N-L	RSA	M-L	N	R	M
30-day Subsurface Release – EL 1150 Example Well Site	A	N-L	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1150 Example Well Site	A	N-L	RSA	M-L	N	R	M

KEY

Nature / Direction:
P Positive
A Adverse
N Neutral (or No Effect)

Frequency:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis

Certainty in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty

Magnitude:
N Negligible
L Low
M Medium
H High

Geographic Extent:
L Localized
PA Within Project Area
LSA Within LSA
RSA Within RSA or Beyond

C Occurs continuously

Duration:
S Short term
M Medium term
L Long term
P Permanent

Reversibility:
R Reversible
I Irreversible

N/A Not Applicable

16.6.7 Fisheries and Other Ocean Uses

Sections 7.2 to 7.3 of the EIS describe the relevant socially and economically important marine activities that occur in and near the Project Area and RSA, as well as the fisheries management and regulatory regimes within Canada's EEZ and the NAFO Regulatory Area. The current commercial domestic fisheries in the general area, including Indigenous commercial licences, consist primarily of snow crab harvesting, using fixed gear, and some groundfishing (mainly turbot/Greenland halibut and redfish using mobile and fixed gears), while foreign fishing beyond the EEZ is directed primarily towards groundfish. Northern shrimp had been a key species for both domestic and foreign harvesters before recent conservation-based closures. Fisheries research programs (industry and government sponsored) also occur on and near the eastern Grand Banks, while other fisheries activities (seal harvesting, recreational fishing, aquaculture) are focused closer to shore and outside of the Project Area. No known Indigenous food, social, or ceremonial fishing takes place within or near the Project Area.

Fisheries in the broader RSA (described in Section 7.2 of the EIS) are similar in the offshore areas, but include a greater mix of species and harvesting methods closer to shore. As with the Project Area fisheries, NAFO 3KLMNO domestic commercial harvests have been predominantly shellfish, mainly snow crab and Northern shrimp (which is still permitted in 3K), but with an important component of lobster and some other shellfish harvests (e.g., sea urchins) from the coastal waters of 3K and 3L. Groundfish and pelagic species harvests are also more diverse throughout the RSA, and deep-sea clams are a very important commercial species in offshore areas south and south-west of the Project Area, in 3N and 3L. Aquaculture facilities are located at various sites around the Newfoundland coast, particularly within Notre Dame Bay, in NAFO 3K. Seal harvesting, recreational fisheries and science research surveys are also expected to occur within 3KLMNO, as described in Section 7.2 of the EIS. Some of these fisheries may take place year-round, though most marine activities are concentrated in the spring and summer months.

Other human uses of the marine environment in the region are important for their economic and/or socio-cultural value. As described in Section 7.3 of the EIS, other components and activities that do or may occur within or near the Project Area and RSA and are considered as components of this VC include general marine shipping, other oil and gas related activities (seismic exploration, production platforms and associated marine traffic and support vessels), military operations (surveillance, monitoring, training, rescue), tourism and recreation, heritage sites, other submarine infrastructure (communication cables) and the possible presence of UXO.

16.6.7.1 Potential Issues and Interactions

Most of the potential environmental interactions and resulting effects on fisheries and other ocean uses associated with planned, routine activities and identified for the purposes of the assessment in Section 13 of the EIS are also relevant for potential accidental events. These include:

Fisheries

- Temporary lost or reduced/delayed access to commercial species (from interference, excluded fishing grounds, decreased harvesting efficiency, or species availability, abundance, and distribution) by fishers and science surveys;
- Increased expenses associated with fishing more distant grounds, detours to avoid affected areas, and reduced availability of affected fishing gear;
- Costs to repair or replace damaged fishing gear, facilities or vessels caused by spilled hydrocarbons or debris; and
- Actual or perceived quality of fisheries resources and resulting market/price effects.

Other Ocean Uses

- Direct contact with and damage from in situ component of spill and/or debris; and
- Interference with other marine activities.

In the case of an accidental event such as a batch spill or a subsurface/subsea release, the potential for negative interactions with fish harvesting and other ocean uses, although the actual effects from any such event will depend on the interaction of several factors such as the quantity and type of hydrocarbons released, the specific location of the release, the time of year, the prevailing environmental conditions, the duration of the hydrocarbon release, the location of hydrocarbons in the water column, the effectiveness of clean-up or other response actions and, overall, the fate of the released substance. These conditions will determine the severity of the effects of a spill, and the type and extent of any effects on fisheries. Other ocean uses (particularly any activities at or near the ocean surface) could also be impeded by the presence of an oil slick and clean-up activities, which would have to be avoided while present.

Existing Knowledge of the Effects of Hydrocarbons on Fisheries and Other Ocean Uses

The abundance, distribution, and quality of commercial marine species in a given area might be negatively affected because of direct biological effects from the presence of spilled hydrocarbons in the water, or indirectly through biological effects on prey species and habitat, which could in turn affect the availability and quality (condition of fish, tainting) of the resources that are able to be accessed by commercial harvesters. The assessment of potential biophysical effects on marine fish and fish habitat that might result from hydrocarbon spills (including from clean-up methods, such as the application of dispersants) are addressed in Section 16.6.2 and those effects related to commercial species are not addressed here in any detail. Consequently, this section focuses specifically on potential effects on harvesting opportunities and related economic returns, and on similar potential effects on other ocean uses.

Interference with commercial fishing would occur if active fishing areas are closed because of a spill, either due to a regulatory decision or closure because of hydrocarbons in the water. Alternatively, a spill may prolong the duration of an previously closed fishery that is closed due to other reasons. Interference might include the need to avoid an oil slick, to change grounds (if possible under the licence conditions) or stop fishing for other reasons (e.g., as a precaution to prevent a potentially tainted product from entering the marketplace). Even if benthic species were not affected by surface hydrocarbons, hauling these catches through oily waters could cause some concern in terms of potential or perception of taint. For commercial harvesters, such interferences could translate into direct economic effects as fishers delay or cease fishing activity until the area has been re-opened, or move to other more distant fishing grounds, curtailing harvesting opportunities and increasing costs. For example, after the DWH spill in 2010, short-term marine closures affected approximately 207,200 km^2 (80,000 square miles) of the US EEZ (DFO 2013). The magnitude of these effects in Newfoundland and Labrador waters would depend on such factors as the size of area closed to commercial fishing, the time of year, and the length of the closure time. Similarly, opportunities for, and the quality of, routine marine science research could be affected through closures, fouled equipment, or contaminated results because of hydrocarbons on surface water or in the water column. Offshore exercises such as military training could also be compromised by the presence of a spill, as could the activities of other ocean uses if impeded in their operations or in their use of regular transit routes.

Damage to fishing vessels and gear could result from contact with the spilled oil, which might affect the efficiency of harvesting, or cause them to stop fishing, resulting in extra costs (replacing, cleaning or repairing gear) and consequent lost income (IPIECA 1997).

Spills can also affect consumer perceptions of, and confidence in, product quality, which may affect the price paid to harvesters and within the consumer marketplace (ITOPF 2004, 2011; IPIECA 1997), or might temporarily close markets completely if catches are tainted or otherwise unfit (IPIECA 1997; Amec 2014). Tainting occurs when fish species are exposed to hydrocarbons and absorb oil-derived substances into their tissues, which can cause unpleasant odours and flavours until lost through metabolic processes. Both chemical analysis and organoleptic testing are usually conducted before a species is declared safe to consume or re-introduce into the marketplace. Even if an oil spill does not reach commercial fishing grounds and fish species are determined not to be tainted, publicity related to accidental events can affect consumer perceptions of fish harvested even in areas beyond the area physically affected, potentially reducing the value of a product because of real or perceived public health concerns. Market confidence, consumer behaviour, and resulting effects based on perceptions of products are difficult to predict, and may only be measured after an event occurs (ITOPF 2011).

Although there are no aquaculture operations near the Project Area, if a spill were to reach the shoreline, effects on these operations could also occur (e.g., biophysical effects, gear and vessel fouling, actual and/or public perception of taint). This would result in similar economic effects on aquaculture as on inshore commercial fisheries, with the exception that, unlike wild fisheries, there is no possibility to relocate business activities from an affected area. Seal fishing and recreational fishing activities might be similarly restricted in affected areas until remediation is sufficiently complete.

Existing Knowledge of the Effects of Dispersants on Fisheries and Other Ocean Uses

As described and assessed in Section 16.6.2 chemical dispersants that might be used to mitigate or manage spills also have the potential to affect fish and fish habitat, and therefore have a potential to indirectly affect commercial fisheries through tainting and/or market perceptions with the similar consequences as from hydrocarbon spills. Indirect effects from the use of dispersants can also affect other ocean uses such as fisheries research if targeted species are involved and the ability to make management decisions is compromised. However, as also discussed in Section 16.6.2, DWH spill studies of commonly used dispersant on key species found little to no bioaccumulation and rapid depuration (24 to 72 hours; Tjeerdema et al 2013). As with the presence of spilled hydrocarbons, the presence of spill cleanup and remediation operations could also interfere with or limit fishing opportunities. Other ocean uses might be similarly restricted by clean-up if impeded in their operations or their use of efficient transit routes.

Existing Knowledge of the Effects of Drill Fluids (SBMs) on Fisheries and Other Uses

The effects of an accidental spill of drill fluids on fisheries and other uses would be similar in nature to a small batch spill (as described above). However, SBMs are a heavy, dense fluid which sinks rapidly, so the effects on the water surface would be limited as it sinks through the water column. Therefore, harvesting opportunities would not be affected and the main concern would likely be the perception of taint.

16.6.7.2 Environmental Effects Assessment

In addition to the accidental events mitigation and response measures detailed in Section 16.1, and specific to this VC, CNOOC will develop and implement a compensation program for any economic damages suffered by fish harvesters caused by any unauthorized discharge, emission or escape of petroleum, or the escape of debris. This program will serve as a means of mitigation for any residual economic effects on the fisheries that could not be prevented or fully mitigated by other measures. It will be developed to resolve claims in an efficient and timely manner, in consideration of best practices, precedents and industry guidelines, and in accordance with the C-NLOPB's Compensation Guidelines Respecting Damages Relating to Offshore Petroleum Activities (2017).

This program will outline compensation procedures for actual loss or damages to commercial fishers, including loss of income, future loss of income, and costs and expenses incurred for action taken to remedy a situation involving a spill, such as measures to control or clean spilled hydrocarbons from gear and equipment. Requirements from the C-NLOPB include the ability of an operator to demonstrate the financial resources to meet a liability obligation of CAD $1 billion relating to damages, and to pay a deposit of $100 million for financial responsibility in case an accidental event might occur. One Ocean is currently developing a best practices document related to petroleum industry compensation in Newfoundland and Labrador waters, which aims to provide additional details and information to assist with processes and procedures for applying and receiving compensation in the event of an incident. Notices to Shipping / Mariners related to an accidental event will provide contact information for compensation claims, as well as for information about response activities in the event of a spill.

As noted above, compensation planning for accidental fishing gear and/or vessel damage occurring as a result of planned operations is described in Section 16.6.7.3.

Marine Diesel Spills (Batch Spills and Vessel Collision Scenario)

The results for marine diesel spills (100 L, 1,000 L, 750, 000L) are summarized in Section 16.4. The predicted area where any spilled diesel may spread overlaps with active commercial fishing grounds. In the event of a batch spill, there is potential for temporary closure of commercial fish harvesting in the immediate area due to the potential of gear fouling. However, it is expected that this closure would be short-term. Due to the oceanic conditions and expected quick weathering of any such spilled materials, and the ability of mobile adult fish species to either avoid the spill or metabolize and depurate hydrocarbons, it is expected that this interaction would also be limited to the immediate area of the spill, and short-term in duration.

It is anticipated that with the implementation of mitigation measures, the geographic extent and concentration of a spill would be limited. A change in the distribution or quality of marine resources, including commercial fish species, is considered unlikely, given that the oceanic conditions and mitigation measures would likely result in the spill being contained to a smaller area and for a shorter period of time.

With spill prevention plans and response procedures in place, including compensation plans, potential effects of a marine diesel spill (100 L 1,000 L, 750,000 L) on fisheries and other ocean uses are predicted to be adverse, negligible to low in magnitude, short to medium-term in duration, localized within the RSA (depending on spill size and location), and reversible. These predictions were determined with a high level of confidence.

Drill Fluid (SBM) Spill

SBMs are a heavy, dense fluid which sinks rapidly, so the effects on the water surface would be limited as it sinks through the water column. Harvesting opportunities would not be affected and the main concern would be the perception of taint. The model predicts a limited footprint on the seafloor. With spill prevention plans and response procedures in place, potential effects of a drill fluid spill on fisheries and other ocean uses are predicted to be adverse, negligible in magnitude, short -term in duration, localized, and reversible. These predictions were determined with a high level of confidence.

Uncontrolled Well Event

The relevant model results for uncontrolled well events (30-day and 120-day releases at both example well sites) are summarized in Section 16.4. The potential effects from uncontrolled well events on fisheries and other ocean uses include direct effects resulting from potential fisheries closure areas and fouling of fishing gear, vessels and equipment and indirect effects related to the biophysical effects on fish species that may be targeted as part of a commercial fishery. Effects from an oil spill on fish and fish habitat, including the use of dispersants on an oil spill are assessed in Section 16.6.2. It is anticipated that most free-swimming mature fish species may be able to avoid exposure to oil in the water column; however, if oil reached the seafloor, some slow moving or sessile organisms could be exposed to interactions with hydrocarbons. With the implementation of mitigation measures, it is not anticipated that there would be a long-term exposure of fish to hydrocarbons either at the surface or within the water column. The ability of some fish species to metabolize and depurate hydrocarbons also promotes a relatively short-term interaction.

The maps in this Section (Figures 16.36 – 16.39) show recent (2011-2016) domestic harvesting intensity and the NAFO international fisheries footprint in relation to different modeled probability levels for the presence of surface oil at or exceeding the socioeconomic threshold, as described and illustrated in Section 16.4.4. The modelling provides an indication of where surface oil equal to or exceeding (i.e. thicker than) .00004 mm (.04 μm) is likely to be found at various probability intervals based on the model results. The modelling does not mean that these areas would be covered with oil at these concentrations; rather that patches of oil would be likely to occur somewhere within these contours at the indicated probabilities. Similarly, these contours do not imply that these areas would be closed to fishing, but rather that some grounds within these contour areas might need to be closed if oil were found to be present.

EL 1144 Example Well Site

The modelling illustrated in Figure 16.36 predicts that a 30-day release from the EL 1144 example well site is most likely to result in an oil surface thickness of > 0.04 µm in some eastern parts of NAFO 3L beyond 200 NMi, but with the greater potential presence after 30 days being in NAFO Division 3M, primarily near and over the Flemish Cap, and eastward. The main domestic commercial fisheries (Section 7.2 of the EIS) in these areas are for snow crab within Crab Fishery Area (CFA) 3L200 near the EEZ boundary, and groundfish harvesting (including Atlantic cod, turbot/Greenland halibut, haddock and redfish), mainly on and around the Cap. Northern shrimp harvesting was also active in these areas before it was closed, particularly around the Nose of the Grand Banks and on the Cap, as Section 7.2 of the EIS indicates. Foreign fishing in the area (approximated by the NAFO Footprint outline, Figures 16.36 – 16.39) is now primarily for various groundfish species, mainly Atlantic redfishes, Atlantic cod and turbot/Greenland halibut (Section 7.2 of the EIS).

For a 120-day release at the EL 1144 example well site – as in the 30-release modelling – the greatest likelihood is that occurrences of surface-associated oil at or exceeding the 0.04 µm surface thickness threshold would remain in areas east of the EEZ, in the eastern parts of NAFO Divisions 3LMN and waters farther east (Figure 16.37). As described above and in Section 7.2 of the EIS, these areas are currently fished primarily for groundfish (foreign and domestic harvesters) and snow crab (domestic, in CFA 3L200). However, the 120-day scenario also indicates some probability that this threshold might be exceeded within some areas to the west on the Grand Banks inside the EEZ, within NAFO Divisions 3LMNO and northward within eastern portions of Division 3K. Fisheries activities on the Grand Banks in the areas indicated are mainly snow crab harvesting (spring and summer), but also include a variety of groundfish species (potentially year-round), and to a lesser extent pelagic species harvesting (e.g. mackerel). Deep-sea clam dredging might also be active in parts of 3L and 3N. The outer portions of 3K that are most likely to be affected have little or no history of harvesting. The figures in Section 7.2.4.5 of the EIS indicate reported locations for key fisheries by species.

Given the distances from shore for the most likely occurrences of surface oil exceeding the socioeconomic threshold, it is not likely to interact with recreational fishing or known non-commercial indigenous fisheries, based on this modelling.

As discussed above, releases could result in interactions with commercial fishing activities and with other ocean uses, including the implementation of fisheries closure areas, delay in re-opening of already closed areas, shipping closures or rerouting, and the fouling of gear and vessels and/or economic impacts in the marketplace. It is important to note that these models represent a worst-case scenario with no mitigation measures being implemented. The subsequent effects on commercial fishing and other ocean uses would depend on the volume of oil released, the time of year, and the implementation of mitigation and response measures. A temporary closure of one or more areas to fishing activities might result in the event of a subsurface release, including areas larger than those where surface oil is present if hydrocarbons in the water column or on the sea floor indicated a risk of fish tainting. However, the geographic and temporal extent of such closures would be reduced through the implementation of emergency response plans and mitigation measures as described in Section 16.1.4. The issuance of a Notices to Shipping, Notices to Mariners and Notices to Fish Harvesters as well as direct communications with fisheries interests and representatives will provide timely notice of closure areas, providing fishers opportunity to make alternative plans, thereby reducing effects on commercial harvesting success to the extent feasible. In the event of gear fouling, the compensation program for damages would be activated, reimbursing the cost of damaged or lost fishing gear. Likewise, other commercial damages or losses associated with the spill would be addressed through a financial compensation program in accord with the C-NLOPB

Compensation Guidelines. Fouling also has the potential to affect other ocean uses, as equipment and vessels related to research and military training could be affected and result in adverse effects on those operations.

As described in Section 16.4.4, the 30-day modelling for this release site predicts that no oil from will reach any shoreline at or exceeding 1g/m^2, with the possible (low probability) exception of Sable Island. Modelling for a 120-day spill scenario does indicated a low probability of some shoreline contact on the Island of Newfoundland and southern Labrador, with a greater likelihood in the case of a winter spill, although any oil that might reach shore is expected to be highly weathered, patchy and discontinuous. As Figure 16.20 indicates, contact might occur – though at a low probability level – in some locations from the south coast of the Island to southern Labrador where a variety of other inshore harvesting occurs, such as lobster, whelk and herring in addition to snow crab and groundfish, though these are typically spring/summer fisheries. In some northern areas, seal harvesting might also be affected depending on the time of year and contact locations. As indicated in Figure 7.68 of the EIS, there are also aquaculture operations in some of these areas, and there is recreational / food fishery use of these coastal waters which could be affected, depending on the time of year, if oil reached shorelines. The length of time before making contact, the expected condition of the oil, and the implementation of mitigation measures by CNOOC before oil reaches shore, and should further reduce the likelihood of shoreline contact and/or resulting effects. Compensation would be available if such contact were to occur and result in financial loss.

With spill prevention plans, response procedures and CNOOC's required compensation program in place, potential effects of a subsurface release from the EL 1144 example well site (30 days or 120 days) on fisheries and other ocean uses are predicted to be adverse, low in magnitude, medium to long-term in duration, occurring primarily within the RSA and waters to the east, and reversible. This was determined with a moderate level of confidence.

EL 1150 Example Well Site

As Figure 16.38 illustrates, a 30-day subsurface release at the EL 1150 example well site is also most likely to affect fishing areas outside Canada's EEZ over the Flemish Cap and the Flemish Pass within some parts of NAFO 3M, with somewhat lower probabilities of reaching the shelf edges compared to a release at the EL 1144 example site. Based on the available data, the principal domestic fishery usually occurring within most of the probability contours shown is for groundfish. As noted above, most foreign fishing in the general area is for various groundfish species as well, such as Atlantic redfishes, Atlantic cod and Greenland halibut/turbot.

In the case of the 120-day release scenario (Figure 16.39), the locations and probability levels are similar to those for a release from EL 1144, though not tending as far west on the Grand Banks at most probability levels. The same species fisheries in NAFO Divisions 3LMNO potentially would be involved as for the EL 1144 release scenario, mainly snow crab on some parts of the Grand Banks and groundfish species in most areas.

Possible interactions with fisheries and other ocean uses are as discussed above, including fisheries closure areas, shipping closures or rerouting, fouling of gear and/or vessels, and possible market effects. Again, it is important to note that these models represent a very large release with no mitigation measures being implemented. As noted, the actual effects on commercial fishing and other ocean uses of any release would depend on the volume, time of year, and the implementation of mitigation and other response measures, as described above for a release from the EL 1144 example site. As discussed, CNOOC's compensation program would also be in place to address any consequent economic losses to harvesters.

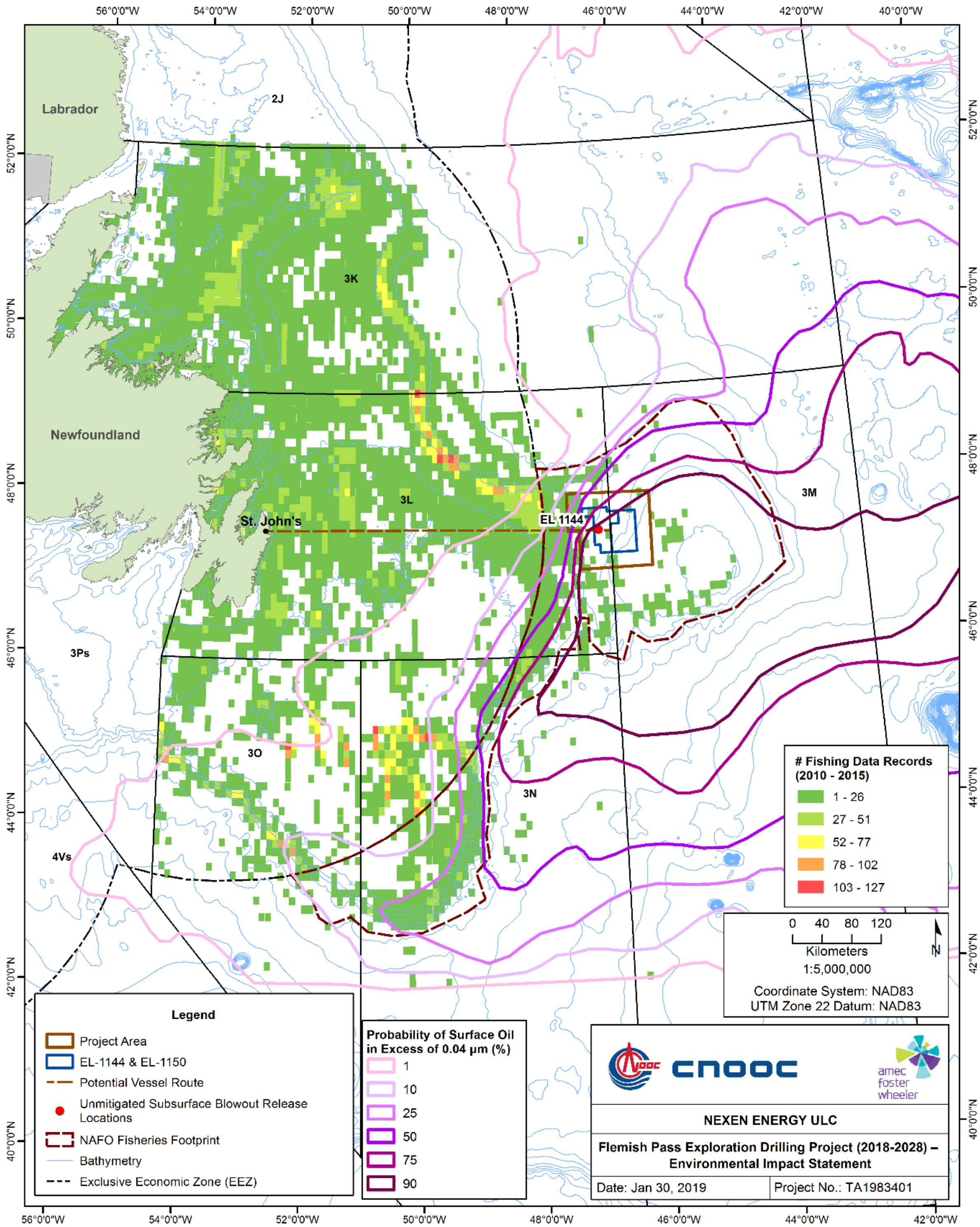


Figure 16.36 Model Results for 30-Day Subsurface/Subsea Release at the EL 1144 Example Well Site in Relation to NAFO Unit Areas and Domestic Fishing Intensity

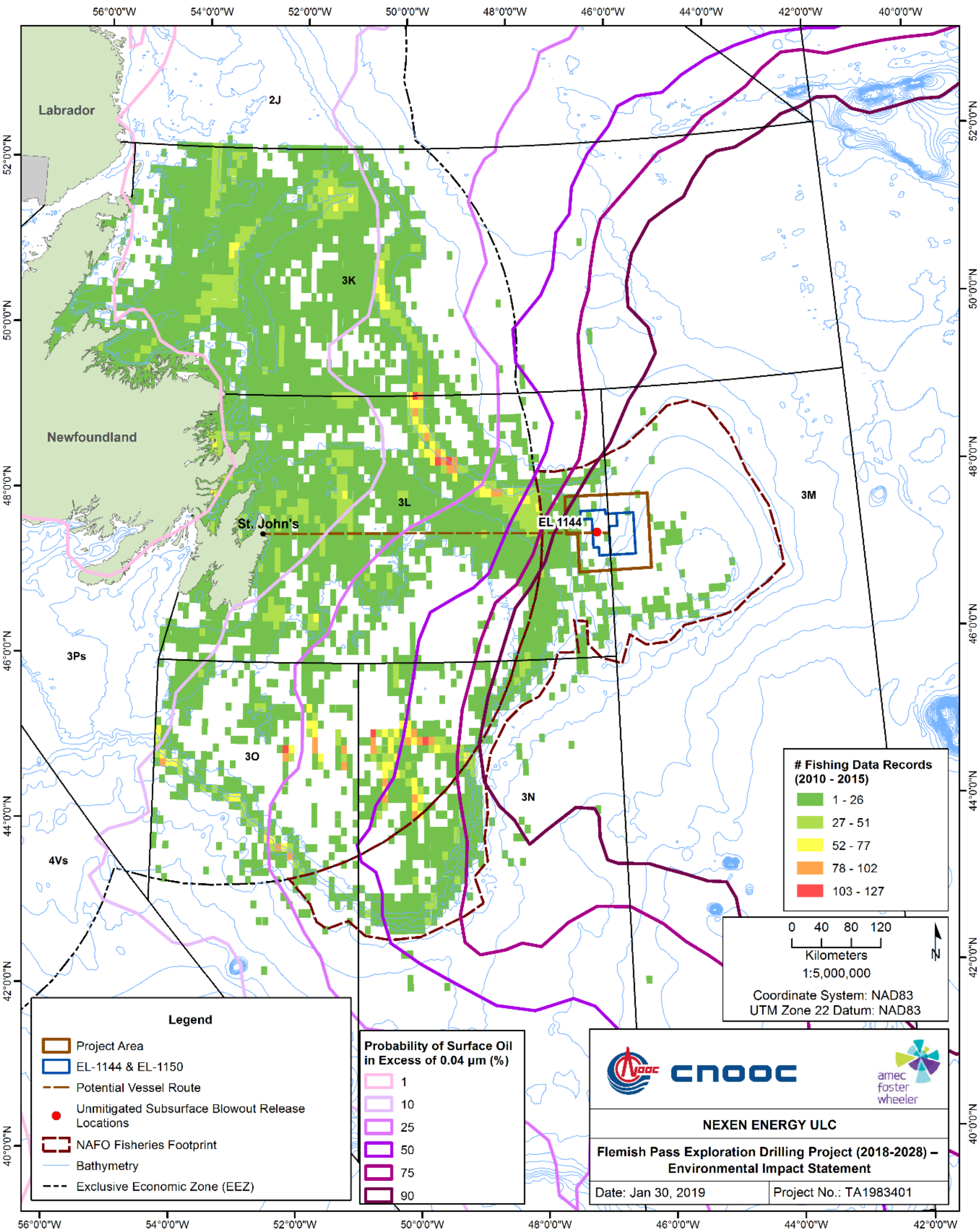


Figure 16.37 Model Results for 120-Day Subsurface/Subsea Release at the EL 1144 Example Well Site in Relation to NAFO Unit Areas and Domestic Fishing Intensity

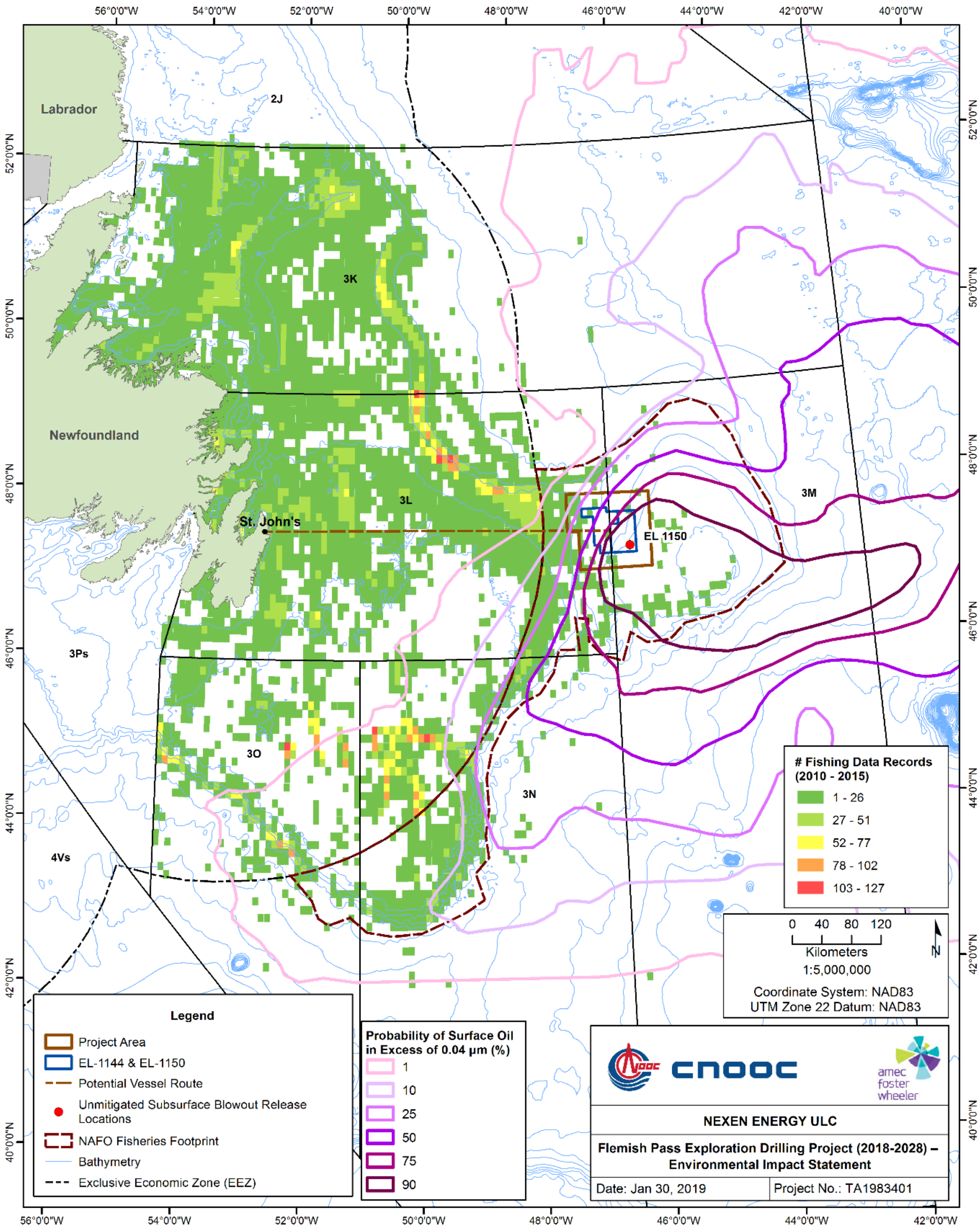


Figure 16.38 Model Results for 30-Day Subsurface/Subsea Release at the EL 1150 Example Well Site in Relation to NAFO Unit Areas and Domestic Fishing Intensity

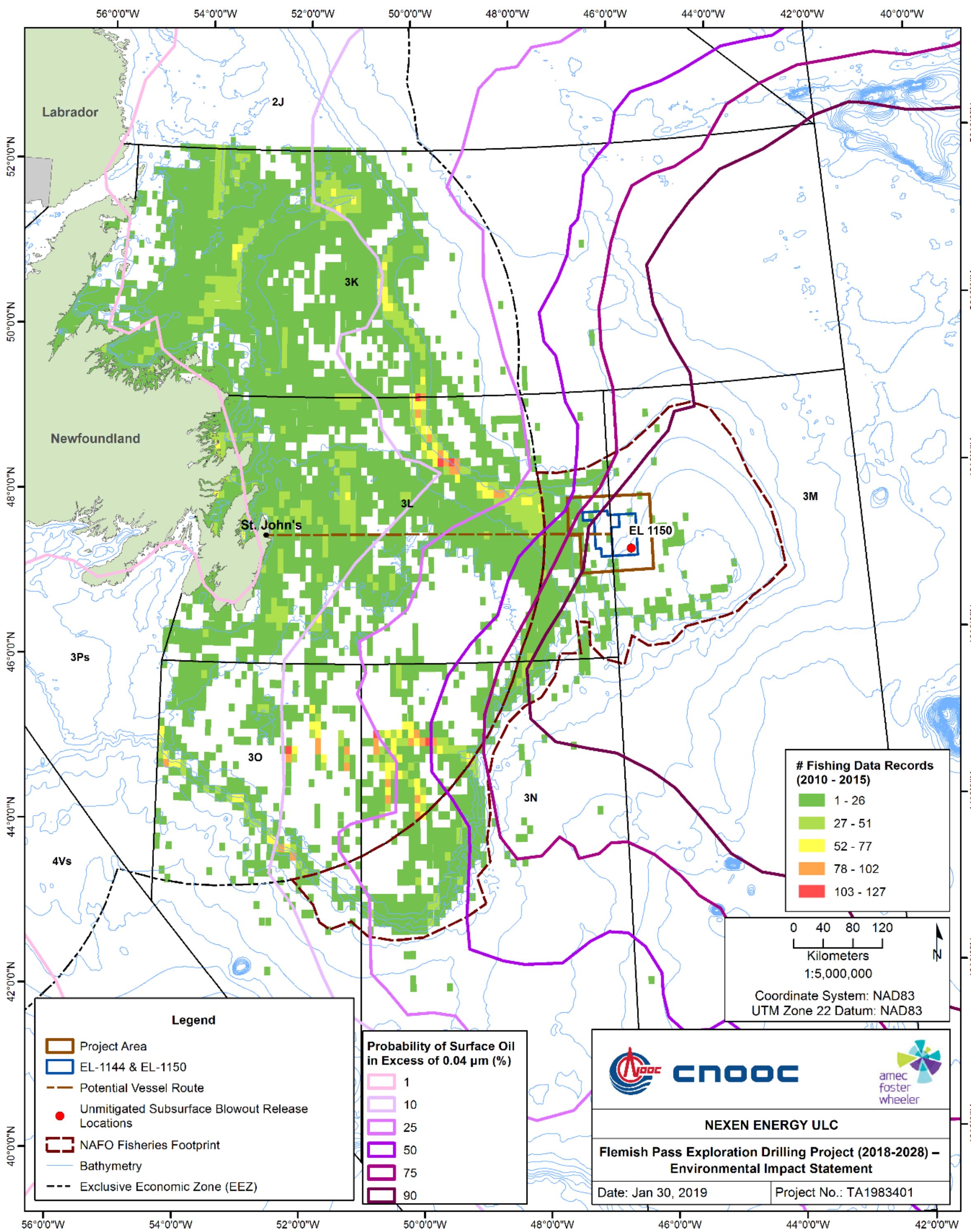


Figure 16.39 Model Results for 120-Day Subsurface/Subsea Release at the EL 1150 Example Well Site in Relation to NAFO Unit Areas and Domestic Fishing Intensity

While the 30-day modelling for the EL 1150 release site predicts that no oil from will reach any shoreline, the modelling for a 120-day spill does indicated a low probability of some shoreline contact in areas similar to those for an EL 1144 release, though less extensive overall, but potentially involving some of the same fisheries. The time to contact with the shore, the expected condition of the oil when it reached shore, and the implementation of mitigation measures would reduce the likelihood of contact and/or effects, with compensation available if such contact were to occur and result in financial loss.

With spill prevention plans, response procedures and the compensation program in place, potential effects of a subsurface release at the EL 1150 example well site for both modelling scenarios (30-days or 120-day releases) on fisheries and other ocean uses are predicted to be adverse, low in magnitude, medium to long-term in duration, occurring primarily within the RSA, and reversible. This was determined with a moderate level of confidence.

16.6.7.3 Summary and Determination of Significance

Table 16.31 provides a summary of predicted residual environmental effects of accidental event scenarios on fisheries and other ocean uses, based on the conservative approach employed for oil spill modelling, and the implementation of mitigation measures to prevent and reduce potential effects from a spill.

Based on the result of spill modelling, Project prevention and response plans and mitigation provisions, and the availability of financial compensation, the predicted residual environmental effects from an accidental event on fisheries and other ocean uses are considered to be not significant. Not only is a large spill unlikely, but if it were to occur, its extent and duration would be reduced through response measures. Affected fishers would be compensated under the Operator Compensation Program, which includes provisions for lost and future lost income replacement, in accordance with the C-NLOPB Compensation Guidelines Respecting Damages relating to Offshore Petroleum Activities (2017).

Spill prevention techniques and response measures will be incorporated into the design and operations for all Project activities as part of contingency planning, which will further help to ensure that accidental events and potential effects do not occur, and in the unlikely event they did, that these would not have significant adverse effects on fisheries and other ocean uses.

Table 16.31 Summary of Residual Accidental Event-Related Environmental Effects on Fisheries and Other Ocean Uses

Accidental Event Scenario	Residual Environmental Effects Summary Descriptors						
	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Certainty
Potential Effects: Fisheries • Direct interference with fishing or exclusion from established fishing grounds • Damage to fishing gear or vessels • Decreases in the abundance, distribution and actual or perceived quality of fisheries resources **Potential Effects: Other Ocean Uses** • Direct contact with and damage to in situ component • Interference with other marine activities							
100 L Diesel Spill	A	N-L	L-PA	S	N-O	R	H
1,000 L Diesel Spill	A	L	PA	M	N	R	H

Accidental Event Scenario	**Residual Environmental Effects Summary Descriptors**						
	Nature	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Certainty**
750,000 Diesel Spill	A	L	PA-RSA	M	N	R	M
Drill Fluid (SBM) Spill	A	N	L	S	N	R	H
30-day Subsurface Release – EL 1144 Example Well Site	A	L	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1144 Example Well Site	A	L	RSA	M-L	N	R	M
30-day Subsurface Release – EL 1150 Example Well Site	A	L	RSA	M-L	N	R	M
120-day Subsurface Release – EL 1144 Example Well Site	A	L	RSA	M-L	N	R	M

KEY

Nature / Direction:
P Positive
A Adverse
N Neutral (or No Effect)

Magnitude:
N Negligible
L Low
M Medium
H High

Geographic Extent:
L Localized
PA Within Project Area
LSA Within LSA
RSA Within RSA or Beyond

Frequency:
N Not likely to occur
O Occurs once
S Occurs sporadically
R Occurs on a regular basis
C Occurs continuously

Duration:
S Short term
M Medium term
L Long term
P Permanent

Reversibility:
R Reversible
I Irreversible

Certainty in Predictions:
L Low level of confidence
M Moderate level of confidence
H High level of confidence

N/A Not Applicable

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