8.0 Accidental Events

This section of the EIS has been compiled and organized to provide a detailed overview as well as assessment of the effects of potential Project-related accidents and malfunctions. As a starting point, Section 8.1 outlines Shell's prevention and response practices and procedures including details regarding preventative safeguards and response capabilities that will be in place to reduce the likelihood and associated consequences of any accidental events. Section 8.2 outlines the accidental event scenarios chosen for assessment, inclusive of low-probability large scale events (*i.e.*, subsea blowout), as well as smaller scale spills (*i.e.*, batch spills). Following the descriptions and rationale for selection of the assessed scenarios, Section 8.3 provides an overview of the associated risk and probabilities for each of the chosen accidental event scenarios and is provided as a summary of a more detailed probability analysis presented in Appendix F. Additionally, to appropriately support the effects assessment an overview of fate and behaviour modelling conducted for the various spill scenarios is provided in Section 8.3 with the full modelling reports provided in Appendix G (batch spills and blowout) and Appendix C (SBM whole mud spill). In consideration of the supporting technical reports and analysis, a detailed discussion of environmental effects from each of the chosen scenarios is provided by VC in Section 8.5.

It is important to note that the modelled and assessed scenarios in this section are unmitigated events to provide a conservative basis for environmental effects assessment. These assessed scenarios do not take into account the prevention and response measures detailed in Section 8.1 below that will be in place during the Project to prevent and reduce the potential effects and consequences of any accidental event.

8.1 SPILL PREVENTION AND RESPONSE

Shell is committed to conducting safe and environmentally responsible operations and is recognized internationally as a responsible operator having been the first offshore operator in the Gulf of Mexico to receive approval for a drilling plan and licence following the Deepwater Horizon Oil Spill. As part of this commitment to safe operations, spill prevention and response are of critical importance in Shell's project planning and operations. While the possibility of a large-scale spill occurring during exploration drilling is considered highly unlikely given the statistical probabilities and the preventative measures in place, Shell's response capabilities and contingency plans will provide the ability to respond to any size of spill that could potentially occur.

Shell uses the "Bow Tie" method (Figure 8.1.1) in the assessment of high-risk hazards (*i.e.*, risks with the greatest potential to impact People, the Environment and Assets). The Bow Tie makes the link between risk controls and risk prevention management systems, and is comprised of the following aspects:

- 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

- Middle of the Bow Tie – An incident, such as the loss of control or release of a hazard (*e.g.*, an uncontrolled flow of hydrocarbons into the wellbore)

- Right side of the Bow Tie – Response 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*.)

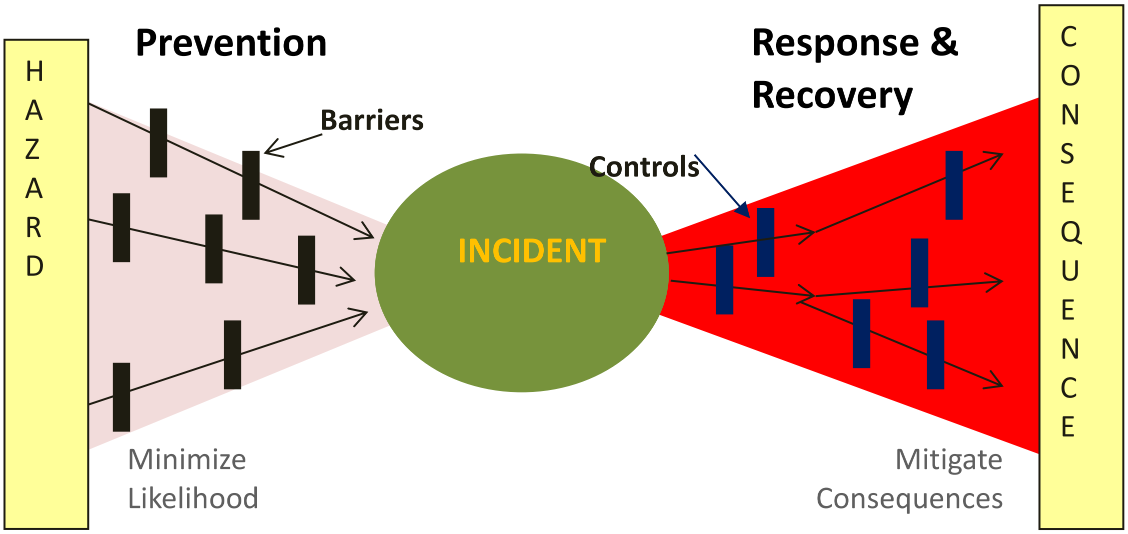


Figure 8.1.1 Bow Tie Method

Shell's operational focus is on the prevention side (left side) of the Bow Tie, with the goal to put in place sufficient barriers in order to never have to implement the response and recovery side (right side) of the Bow Tie.

In the unlikely event that an incident occurs, the focus shifts to the response and recovery side (right side) of the Bow Tie, with the goal to mitigate the incident so that the full potential impact (consequence) of an incident is never realized.

Increasing the number and/or quality of barriers (prevention measures) on the left side of the Bow Tie reduces the probability of an incident occurring. Increasing the number and/or quality of barriers (response and recovery measures) on the right side of the Bow Tie reduces the consequences (*i.e.*, effects) of the potential incident. Overall, reducing the probability and/or the effects of the incident thereby reduces the risk.

8.1.1 Spill Prevention

Process Safety Management is about the prevention of incidents involving Shell-operated assets, including preventing unintentional releases of hydrocarbons or hazardous substances. Shell's approach to Wells Process Safety is focused on keeping hydrocarbon in the pipe, the well or in the reservoir. Process safety also involves ensuring facilities and infrastructure are well designed, safely operated and properly maintained. To prevent incidents and accidents that may harm people or the environment, Shell manages safety in a formal, systematic and stringent way. Shell's approach to Wells Process Safety is depicted in Figure 8.1.2, which outlines the Ten

BARRIERS
Know your physical well barriers and confirm they are tested.

LOST BARRIER
If a barrier is lost, immediately stop and fix it.

SUBSURFACE UNCERTAINTIES
Know and communicate subsurface uncertainties.

WELL CONTROL EQUIPMENT
Know your well control equipment and confirm it's certified and tested.

THESE TEN COVER REQUIREMENTS CRITICAL TO **WELLS PROCESS SAFETY**

TRAINED PEOPLE
Confirm all people are trained and competent for the task.

STANDARDS & PROCEDURES
Follow standards and procedures or get approval to deviate.

RISK ASSESS
Perform risk assessments during planning and for changes.

WALK THE LINE
'Walk the line' on temporary rig-ups and confirm set-up = layout drawing.

EMERGENCY RESPONSE
Test your emergency responses and conduct regular drills.

REPORT/LEARN
Report Wells Process Safety incidents – investigate, share, learn.

Elements of process safety for wells.

Figure 8.1.2 Shell Wells – Think Process Safety: The Ten Elements

The goal for Shell's deepwater drilling operations is for safe and reliable well operations. These are achieved through the Ten Process Safety Elements described above, and are specifically underpinned by the following safeguards.

Leadership and Safety Culture

Safety is Shell's top priority, driven and enforced by programs such as Goal Zero, the 12 Life Saving Rules, and the Think Process Safety initiative.

Global Standards & Procedures

Shell's global standards and procedures are based on international best practice and are put in place to ensure a consistent first class operational and HSSE & SP performance approach is taken throughout Shell's operations.

Robust and Assured Well Design / Equipment Testing/Certification

Shell has strict certification and Quality Assurance/Quality Control (QA/QC) processes for all of the wells' installed equipment, such as casing strings, casing connections, liner hangers and the wellhead. As such, well design goes through multiple reviews before final internal approval is given. Reviews are carried out and approved by appropriate qualified internal discipline authorities and technical experts. The same principles apply to the input parameters, which are used as the basis for the well design.

Two Barrier Policy

A barrier is defined as any system or device that can be used to contain fluid or pressure within the confines of the well. Two independent barriers to flow are maintained at all times once the BOP is installed on the wellhead. Independent barriers include high pressure wellhead housings, multiple casing strings cemented in place, blowout preventers and weighted drilling fluids. All barriers are verified by testing both prior to and following installation, as well as at regular intervals during operations. Should one barrier be lost, operations are stopped and the focus will shift to re-gaining a two-barrier status.

Extensive Training / Competent Staff / Stringent Contractor Requirements

Shell's Wells staff are required to undergo extensive training inclusive of the Round 1 and Round 2 program, which is a two-round, Shell-specific comprehensive training program required for all well engineers. This program is inclusive of training courses with classroom-based lectures, practicum-based learning and certification exams. In addition to the Round 1 and Round 2 program, operational staff are required to take additional specialized training, such as "Advanced Well Control" for individuals in HSSE & SP critical positions, as well as regular competency reviews. The competence of contractor personnel is also verified by requiring them to meet Shell minimum requirements prior to travelling to any Shell installation.

Remote Monitoring

Shell employs a sophisticated Real-Time Operations Centre (RTOC) called "Well Vantage" used to improve operational performance, but also to serve as an additional line of defense to a process safety incident. This system monitors all data streams associated with the MODU 24 hours a day to provide real time information to the staff onboard as well as to the onshore technical staff. In association with this monitoring capability, the RTOC will look for any anomalies in the information coming off the MODU and notify staff to allow for early identification and correction of any noted issues.

Safety Case Approach (Rig Safety Case)

The HSE/Safety Case approach is used to identify the proper management of major hazards prior to the commencement of Project operations.

8.1.2 Spill Response and Recovery

While prevention barriers are critical to prevent an incident such as a spill or blowout, adequate attention must be also given to recovery and response measures in order to mitigate the impact and scale of a potential incident should one occur. These response and recovery initiatives, and associated mitigation measures are captured by the right side of the Bow Tie. The following provides an overview of the response measures and plans employed by Shell to mitigate an incident.

8.1.2.1 Response Coordination and Management

In the event of a spill, effective preparedness measures can ensure a timely and coordinated response, thereby limiting the adverse environmental effects or other consequences. Shell will have Spill Response Plans and Emergency Response Plans in place to ensure a timely and effective response in the event of any type of incident. Although Shell maintains its own capabilities to respond to an incident, broader spill response coordination may also be employed. Spill response coordination allows industry to access additional relevant technical assistance and response resources in the event of a spill incident, allows development of regional and national capacity to prepare for, and respond to, incidents and allows exchange of information related to new research, best practices and practical experiences.

Shell uses the Incident Command System (ICS) as its primary response management system. ICS is a standardized emergency response management system specifically designed to provide for an integrated organizational structure and systematic response capability that can be implemented in any emergency, and in a manner that reflects and accommodates the complexity and demands of the emergency and the response. ICS uses the combination of facilities, equipment, personnel, procedures, and communications operating within a common organizational structure to meet the command’s objectives.

Shell has ICS trained staff at the local, regional and global level immediately available to assist in response to an incident. Through the Shell Americas Response Team and the Shell Canada National Response Team, Shell has over 1000 employees located in its Americas area of operations (*e.g.*, Canada, United States, Brazil) trained up to an ICS-300 level. These employees are available to assist in response efforts to large-scale incidents, as required. Shell will have available local staff and agencies, including Aboriginal representatives, trained and able to respond, as well. Dependent on the size and scale of the incident, Shell will draw on various support organizations/agencies to provide the appropriate and necessary resources and response. These resources and organizations include:

- Local Tier I Resources and Contractors
    - Staff trained in ICS and local incident command post
- Tier II and Tier III Spill Contractors
    - Oil Spill Response Limited (OSRL): This organization provides global emergency access to oil spill response personnel and equipment for incident management including technical advisors and specialist expertise in spill response operations. Shell is a member of the internationally funded oil spill service provider.
    - Oil Spill Response Limited-OSRL/ Subsea Well Intervention Service (OSRL/SWIS): This organization provides global emergency access to response tools for serious subsea well control incidents, including capping stacks and containment equipment. Shell is a founding member of OSRL/SWIS.
    - Eastern Canada Response Corporation (ECRC): Organization established to provide oil spill response services, when requested, to companies operating in Canadian navigable waters in ECRC's Geographic Area of Response south of the 60th parallel, and has equipment in seven Primary Areas of Response including in Dartmouth, NS.
    - Marine Spill Response Corporation (MSRC): United States-based oil spill removal organization, which could be made available through the CANUSLANT agreement between the United States and Canada.
- Local/Federal Agencies
    - There are various local and federal governmental agencies that can provide response assistance and regulatory oversight in the event of incident occurring during Project operations, such as the Canadian Coast Guard (CCG), the Joint Rescue Coordination Centre (JRCC), the CNSOPB, the Nova Scotia Emergency Management Office (EMO), and Environment Canada (Environmental Emergencies Program/ Science Table).

8.1.2.2 Contingency Planning

Shell is committed to responding to an offshore oil spill with a full complement of response tools and strategies including surface, aerial and subsea dispersants; mechanical recovery; in-situ burning; shoreline protection and recovery; and well control. Contingency plans will be in place to detail the associated practices and procedures for responding to an emergency. The Project Emergency Response Plan (ERP) is an all-hazard document, which will include a number of separate incident-specific contingency plans including an Oil Spill Response Plan (OSRP) and

Well Containment Plan (WCP). These plans require submission and approval by the CNSOPB prior to receipt of Project authorization. Figure 8.1.3 illustrates the various contingency plans that will be in place for the Project and how they relate to the ERP. Further information in relation to these plans is provided below.

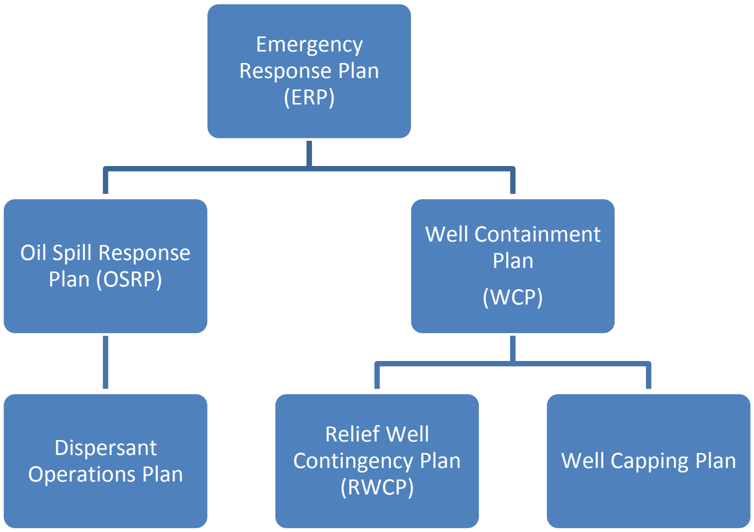


Figure 8.1.3 Emergency Response and Preparedness Plans

8.1.2.3 Emergency Response Plan (ERP)

Shell's ERP for the Project will comprise one of the main response documents that Shell would utilize during emergency response. The ERP will define Shell's organizational structure, and response process and tools that will be employed to facilitate an effective, efficient and safe response, regardless of the size, type or complexity of an incident. The ERP will be designed in accordance with the applicable Federal and Provincial regulations, industry practice and Shell standards and will be submitted to the CNSOPB for review prior to commencing drilling operations. Additionally, this plan will be tested through a mock-exercise prior to the commencement of Project activities.

The intent of this ERP is to ensure effective measures are in place for Shell to:

- coordinate with government agencies and stakeholders, and
- notify and protect the workers and the public
- minimize environmental impact
- minimize emergency response times
- maximize response effectiveness

8.1.2.4 Oil Spill Response Plan (OSRP)

Shell will prepare an OSRP to address the capability and procedures of responding to any size of incident. The OSRP must be reviewed and approved by the CNSOPB prior to the Project commencing. The OSRP will detail specific spill response information, including:

- Incident Management Team structure, roles and responsibilities
- notification procedures and contact information
- procedures, strategies and tactics for response to spills of any sizes (Tier I, II, III)
- safety and security procedures
- monitoring and predicting spill movement
- identifying, prioritizing and protecting sensitive areas
- mobilizing and deploying equipment and personnel
- storage, transfer and disposal of recovered oil
- removal of oil and oiled debris from shallow areas and shorelines
- procedures for wildlife protection, recovery and rehabilitation
- Dispersant Operations Plan, outlining the process for approval from the CNSOPB to deploy dispersants
- response measures, including protection and recovery operations (*e.g.*, skimmers, booms, in-situ burning, *etc.*)
- contingency measures (extreme weather scenarios, potential health effects on responders, interactions with other ocean users/industry)

Personnel potentially involved in oil spill response will receive specialized training, and drills will be conducted periodically to familiarize personnel with on-site equipment, proper deployment techniques and maintenance procedures, and management of incidents.

Response personnel and equipment will be available when critical drilling operations in hydrocarbon-bearing zones are underway, providing spill containment and response capability in the unlikely event of an actual oil spill incident.

Dispersants Operations Plan

While mechanical recovery can be used on small operational spills, dispersants can become an important response tool for larger scale spills offshore. As a result, a Dispersants Operations Plan will be developed as part of the OSRP, which will outline the process and procedures for determining whether to utilize dispersants and initiate deployment of dispersants in the unlikely event of an oil spill incident. Dispersants may be deployed subsea at the well, or on the surface (via aerial or vessel) of the water.

Updates are currently being made to the Accord Acts to allow for the authorization of dispersant use for the purposes of emergency response. In order for authorization to be granted, consideration must be given to the intended use of dispersants and whether their use would achieve a net environmental benefit. To facilitate regulatory authorization for the use of dispersants in the event of a spill, Shell will undertake a Net Environmental Benefit Analysis (NEBA) to understand the potential risks and consequences of using dispersants. The NEBA considers the application of dispersants to move the oil into the water column where it can rapidly dilute and biodegrade, relative to oil remaining on the water surface.

The objective of a NEBA, when applied to oil spills, is to conduct an evaluation that will allow spill responders and stakeholders to choose the best response options that will result in the greatest overall benefits and lowest overall negative impact on the environment. A NEBA takes many factors into account, for example:

- concentrations of dispersed oil that may be expected under a dispersant treated slick or above a subsea injection point, and the dilution potential in that specific body of water
- toxicity of the likely concentrations of dispersed oil to local flora and fauna
- distribution and fate of the dispersed oil in water, sediments and organisms
- distribution, fate and biological effects of the oil if it is not treated with dispersant—for example, whether it will harm shore habitats or wildlife
- expected ability of affected ecosystem populations to recover from potential impacts

Dispersant Deployment and Application

If need arises to supplement mechanical recovery resources, Shell will provide surface (from vessels and planes) and subsea dispersant injection capabilities and will work to secure required regulatory approval to deploy dispersants.

Surface application of dispersants offers the following advantages:

- Dispersants can be used over a wider range of environmental, meteorological, oceanographic conditions than other response options. They can be applied in rough seas (up to 3 m) and on thinner oil slicks (<1 mm).

- Dispersant aircraft can typically travel to spill locations at speeds over 150 knots (275 km/h) compared to 7 knots (13 km/h) which is the typical speed of a response vessel transiting to a spill location. Arriving at the spill location quicker allows an effective response to start before slicks have spread, moved, or broken apart into smaller surface slicks.

- Large oiled areas can be rapidly treated by aircraft compared to alternative response methods.

- Aircraft are also able to travel between slicks located few miles apart in a matter of minutes.

- Dispersants remove oil from the water surface, therefore decreasing the risk for marine birds and mammals to come into contract with oil. The oil that disperses into the water column may pose temporary elevated exposures to organisms in the immediate area, but research and experience has shown that those exposures are rapidly mitigated by the effects of dilution and microbial degradation of the dispersed oil. Dispersants use is usually recommended in the offshore areas deeper than 10 m.

- Dispersants help to protect shorelines. Surface oil may be driven by winds towards shorelines, while dispersed oil is typically carried away by currents.

- Dispersants delay/prevent formation of stable water-in-oil emulsions and, in some cases, break emulsions already formed.

Subsea dispersants application offers several additional advantages (API 2013):

- Safety — subsea injection reduces the amount of oil coming to the surface and this, in turn:
    - reduces the potential for exposure of surface vessels and personnel to volatile components of the oil and
    - reduces the need for surface recovery, in-situ burn, and surface dispersant operations, thereby reducing the potential for exposure of response personnel to accidents during these operations.

- Subsea application can reduce the potential for worker and public exposures by treating the oil subsea where it is being discharged and preventing it from spreading or coming closer to shore.

- Oil Removal — Natural biodegradation processes will remove the oil from the environment as petroleum-degrading bacteria found world-wide consume the oil as a food source. Dispersant-treated oil is rapidly diluted in the water column to the point that biodegradation can occur at very low concentrations without depleting oxygen or nutrient levels.

- Efficiency — Subsea injection may reduce the amount of dispersant required.

- Precision — Subsea application ensures that all dispersant is mixed with the oil at one manageable location before it spreads, instead of trying to treat widely spread oil slicks at the surface.

- Application — Subsea dispersant injection from a vessel can proceed in a broad range of conditions.

- Timing — Application subsea can occur around the clock, whereas surface (aerial and vessel) response measures are usually restricted to daylight hours.

- Effectiveness — The operational effectiveness of dispersant applications subsea is likely to be more effective as the oil being treated has not undergone extensive weathering. Turbulence naturally associated with the blowout jet could create droplets more effectively than breaking waves at the surface.

- Encounter Rates — Subsea injection has higher oil encounter rates than any other response technique.

Environmental Effects of Dispersant Use

In general, the toxicity of modern dispersants is much less than the toxicity of the crude oil itself. This was demonstrated through extensive testing of dispersants and chemical cleaners conducted by Environment Canada (Fingas *et al.* 1991, 1995) using standard tests with rainbow trout to assess the toxicity of more than 60 products. Common household detergents (such as Palmolive, Sunlight, Bioorganic, and Mr. Clean) were included for comparative purposes, and demonstrated that today's dispersants are an order of magnitude less toxic to rainbow trout than common household detergents.

As part of the NEBA evaluation, the consequences of using dispersants to move the oil into the water column for surface spills or maintain it within the water column for subsurface spills are evaluated against the potential impacts of oil remaining on, or rising to, the water surface. In the event of a blowout scenario, dispersed and dissolved hydrocarbons will already be present in the water column. Oil dispersed within the water column poses a localized, short-term and decreased risk to aquatic organisms, while oil on the water surface and oil stranded on shorelines poses more persistent risks to wildlife and shallow water marine life. Dispersed oil rapidly dilutes (French-McCay and Payne 2001; French-McCay *et al.* 2006; McAuliffe *et al.* 1980; Cormack and Nichols 1977; Daling and Indrebo 1996), and concentrations above known toxicity thresholds do not persist for more than a few hours after effective dispersant application. Thus, the potential for acute impacts to the environment from dispersed oil is limited in duration and extent. Further consideration of the environmental effects of dispersant use will be included as part of the NEBA to be completed for the Project.

8.1.2.5 Well Containment Plan (WCP)

The WCP will be prepared and submitted to the CNSOPB for approval as part of the well authorization process. The WCP details the technical procedures and operations involved with subsea source control and containment in the event of an emergency release. Specifically, the WCP will include both a Well Capping Plan and a Relief Well Contingency Plan. Both of these plans are outlined in detail in the following sections.

The WCP will include the following key components:

- Communications Management (notification and activation)

- Resource Planning (equipment, personnel, marine, shore bases)

- Emergency Procurement and Contracting Procedures (authority for expenditures)
- Response Scheduling and Simultaneous Operations (SIMOPS)
- Vessel Logistics Planning (route planning, decontamination, safety, personal protective equipment, air quality monitoring)
- Intervention on BOP
- Well Capping Plan (Mobilization of Capping Stack and Subsea Intervention Equipment, Debris Removal Operations), and
- Relief Well Contingency Plan

Well Capping Plan

A Well Capping Plan will be developed and included as part of the WCP for the Project. This plan will outline the initiation, mobilization and deployment of capping stacks to the Project Area in the unlikely event of a well blowout.

As part of the response to a well blowout incident, a capping stack can be deployed to the wellhead in the unlikely event that primary and secondary well control measures fail to control the well. The Well Capping Plan will outline the plan to mobilize and deploy a capping stack, if required. Figure 8.1.4 illustrates a typical capping stack.

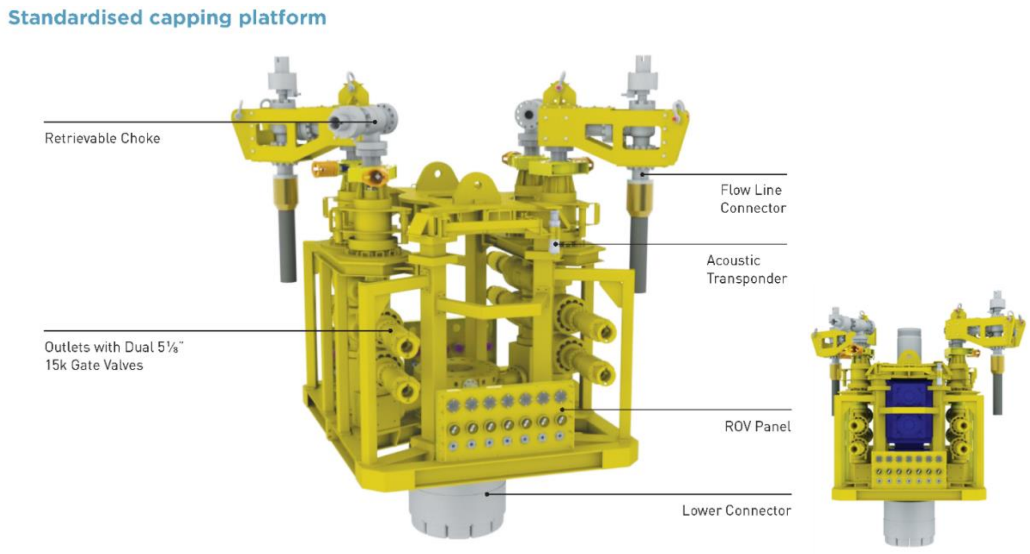


Figure 8.1.4 Typical Capping Stack (Source: OSRL)

Capping stacks function in two ways:

- They seal the well and are capable of withstanding the maximum anticipated wellhead pressure to shut-in the well and stop the spill.
- They divert the flow to surface vessels for management and recovery of the hydrocarbons from the well.

While the deployment and installation of a capping stack will shut-in the well, stop the spill and allow for temporary hydrocarbon recovery from the wellhead, a relief well will need to be drilled to permanently stop the flow of hydrocarbons from the well. A Relief Well Contingency Plan (RWCP) is therefore included in the WCP, and described in further detail below.

In the unlikely event of a well blowout, Shell would begin the immediate mobilization of the primary capping stack and associated equipment for the Project. For the Project, Shell will have access to the OSRL/SWIS Capping Stack located in Stavanger, Norway. In addition to this primary stack, Shell would also concurrently deploy a back-up stack to the Project Area, which would be mobilized from either Aberdeen, South Africa, Singapore or Brazil.

Shell is confident that the primary capping stack could be mobilized, deployed and the well capped within approximately 12–21 days. This estimation is based on recent capping stack wet deployment demonstrations combined with metocean data for the Project Area. The estimated deployment timelines from Stavanger, Norway to the Project Area for the primary stack has been included below in Table 8.1.1.

Relief Well Contingency Plan (RWCP)

A RWCP will also be developed and will be included as part of the WCP for the Project. The RWCP will outline the plan and the process for mobilizing and drilling a relief well in the unlikely event of a well blowout. Capping of the wellbore will be the primary intervention to stop the spill in the event of a blowout. A relief well will be required to secure the well at the reservoir and permanently shut-in flow to the well.

Relief well drilling operations will be initiated at the time of a well blowout, concurrently with the mobilization of a capping stack and supporting response equipment. Shell currently estimates that it will take a maximum of 165 days to mobilize, drill and complete a relief well, thereby enabling well kill operations and ending the blowout. This timeline takes into consideration the time required to mobilize a drilling vessel from the Gulf of Mexico to the Project Area, combined with a maximum estimated time to drill a relief well of approximately 130 days.

Table 8.1.1 Primary Capping Stack (Stavanger, Norway) Deployment Timeline

	Activity	Start Day	End Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Shell notifies OSRL of need to mobilize stack	-	-														
2	Shell mobilizes transport vessel to dock in Norway	-	3.0	▨	▨	▨											
3	Shell mobilizes equipment for loading capping stack		0.5	▨													
4	Load stack onto trucks and transport to dock	0.5	1.0	▨													
5	Capping stack function and pressure test	1.5	2.5		▨	▨											
6	Load stack onto vessel	3.0	3.5				▨										
7	Transport stack to wellsite	3.5	12.0				▨	▨	▨	▨	▨	▨	▨	▨	▨		
8	Deploy stack	12.0	14.0													▨	▨

8.2 IDENTIFICATION OF ACCIDENTAL EVENT SCENARIOS

Four accidental event scenarios were selected for assessment based on consideration of Project parameters as well as potential to pose the greatest risk to VCs in the unlikely event of an occurrence. The event scenarios are:

- Operational batch spill (100 bbl and 10 bbl)
- SBM whole mud spill
- subsea blowout
- vessel spill (offshore and nearshore)

Each of the event scenarios is further described and considered in the subsections below. Only those accidental events that could result in adverse environmental effects are assessed in this EIS. Shell's Safety Plan, Emergency Response Plan and Environmental Protection Plan, to be submitted to the CNSOPB as part of the Operations Authorization process, will address any reasonably foreseeable event that might compromise worker safety.

Although extremely unlikely, a fire or explosion on the MODU may potentially result in a temporary release of emissions to the atmosphere, and spills to the marine environment. Previous offshore spills have demonstrated that the resulting release of hydrocarbons into the marine environment is the principal environmental consequence of such an event. As a result, the analysis of effects of a fire or explosion will focus on spills to the marine environment as captured through other scenarios (*e.g.*, batch spill and subsea blowout).

The potential for both a surface blowout and an underground blowout were considered for assessment as part of the EIS, but were not selected as scenarios requiring assessment. The following information is the associated rationale for not including consideration of these two alternative scenarios.

A surface blowout refers to a situation in which hydrocarbons are released on the rig floor of the MODU and can result from two scenarios: through the drill string (a kick occurs, the well is shut in at the mud line BOP, but for some reason the drill string is not shut or is leaking at the rig floor) or through the riser. In both scenarios, the MODU would attempt to close the shear rams of the subsea BOP to stop the flow. If this does not result in shutting in the well, one of two additional scenarios may follow, both of which would ultimately result in a subsea blowout (assessed below). The primary action following a failure to shut in the well will be to activate the emergency disconnect system to move the MODU off location; the blowout would continue as a subsea blowout (assessed below). Alternatively, if the MODU has been compromised and the emergency disconnect fails, the situation would ultimately degrade to a subsea blowout (assessed below). Because the MODU will not require mooring or anchoring to remain in place, a surface blowout may be rapidly contained, resulting in low spill volumes (~ max 500 bbl) or may, in the unlikely worst-case scenario, deteriorate and escalate to a subsea blowout (assessed below). As a result, any surface release on the MODU would not result in a material or lasting blowout scenario, and thus was not selected for assessment in this EIS.

Shallow gas accumulations are one of the most common causes of surface blowouts. As noted in Section 5.1.1.2, there is the potential to encounter shallow gas pockets in the Project Area. Shell's Shelburne Basin Venture Seabed Survey proposed for 2014 will identify geohazards, including shallow gas pockets and other pore pressure phenomena, which may require special consideration during Project planning. In addition, typical drilling procedure is to drill a pilot hole in order to maintain better control if shallow gas pockets are encountered.

An underground blowout, while considered very unlikely, could occur if two underground permeable zones in one open hole section of drilling have different pore pressures. Usually the shallower zone is at a low pressure and the deeper zone at significantly higher pressure. An underground blowout could occur if the shallow zone cannot support the hydrostatic mud pressure required to balance the pore pressure of the deeper zone resulting in the shallow zone breaking down under the weight of the hydrostatic pressure (which is detected by mud losses into that zone). In the unlikely event that such situations are left unresolved, hydrocarbons from the deeper higher pressure zone could start to flow into the shallow zone.

As a result of integrity measures taken in well design, underground blowouts do not typically result in the release of hydrocarbons into the sea and instead usually remain underground, quickly addressed through natural bridging or mechanical separation by intervention of the rig crew. In April 1985, a subsurface blowout occurred at the Mobil exploratory gas well N-91 at West Venture. In this case the natural gas was contained underground with no release to the ocean or to the atmosphere (Angus and Mitchell 2010).

In summary, the subsea blowout event scenario has been further assessed below as it is the most plausible scenario given how a blowout could occur, and it has the greatest potential for environmental effects.

8.2.1 Operational Batch Spills

Batch spills are instantaneous or short-duration discharges that could occur from accidents on the MODU where fuel oil and other petroleum products are stored and handled. These spills could result from diesel tank ruptures, or equipment malfunctions or failures. Having regard for these potential types of spills, of greatest effect would be a batch spill of diesel from the MODU to the marine environment. Batch spills can occur during transfer of materials to the MODU or in the event of an emergency situation on the MODU. Shell's spill prevention and response procedures detailed in Section 8.1 will reduce the risk of any size of operational spills from occurring and the potential environmental effects should one take place.

In the US, statistics indicate that nearly 52% of batch spills are due to equipment failure, with another 24% due to weather-related events such as storms or hurricanes (see Appendix F). The spill risk and probability analysis conducted for this Project (refer to Section 8.3 and Appendix F) incorporates small spill data from the CNSOPB as well as from other North American sources. For offshore Nova Scotia for the period 1999 to 2013, the largest spill was 22 bbl, with an average spill volume of 0.4 bbl and a median spill volume of 0.013 bbl. For the purposes of this assessment two batch spill volumes have been modelled and assessed.

8.2.1.1 100 bbl Batch Spill

MODUs can contain over 100 000 bbl of fuel, however, historical data demonstrate that the probability of a large volume operational spill occurring is extremely low. Total release of bunker fuels occurs in about 4% of non-tank vessel impact accidents and 2% of non-impact related incidents (*e.g.*, structural failure, fire, sinking). In association with determining plausible worst-case scenarios for batch spills, a comparison with non-tank vessel spills in US waters was considered. This analysis shows that the average spill volume is about 50 bbl. Almost 80% of the spills that occurred from US oil and gas activity from 1968 to 2012 were less than 100 bbl. In consideration of these statistics, a release of 100 bbl of fuel was modelled and is considered an appropriate conservative basis for effects assessment purposes (see Appendix G).

8.2.1.2 10 bbl Batch Spill

Although a spill of 100 bbl is considered a plausible worst-case batch spill scenario, it is recognized that some species (particularly high densities of marine bird assemblages) may be extremely vulnerable to small amounts of oil pollution (Wiese *et al.* 2001). Small spills are also of interest since small spills have traditionally been under reported (Fraser and Ellis 2008). As a result, a small batch spill has been modelled and considered in this EIS.

Small batch spills to the marine environment are defined as those less than 50 bbl. Based on spill data from historic exploration drilling, the most likely operational spill would be a relatively small accidental release during a refuelling operation, particularly during overwater fuel transfers between an OSV and the MODU drilling vessel. Ninety-nine percent of all spills that have occurred offshore Nova Scotia from 1999 to 2013 in association with the oil and gas industry are less than 10 bbl, with the largest spill (not including SBM whole mud) being 22 bbl. As such, a 10 bbl spill scenario is considered an appropriate scenario for modelling and assessing small batch spills.

8.2.2 SBM Whole Mud Spill

Synthetic-based whole muds are recovered and reused as much as possible during the drilling process; however, accidental bulk discharges into the marine environment are possible and have occurred during offshore operations in Nova Scotia and Newfoundland. Synthetic-based whole muds could be released from a surface tank discharge, riser flex joint failure or a BOP disconnect. The mode of release and the ocean current conditions at the time of release will influence the spill deposition footprint, with the distance from the release site largely dependent on the height of release above the sea bottom, the droplet fall velocity and the seasonal currents. Two scenarios were modelled for this assessment with results detailed in Appendix C: a spill of 377.4 bbl; and a spill of 3604.2 bbl. The larger volume spill (3604.2 bbl) was modelled to coincide with a full riser release scenario associated with a disconnection of the riser at the BOP, which is considered the worst-case subsea discharge scenario. The smaller volume spill (377.4 bbl) was chosen to represent a worst-case surface discharge of a full mud tank on the MODU. Both scenarios are considered to have an extremely low probability of occurring and have return periods (*i.e.*, the amount of time that would typically be required for an event to occur once) for each of these spill scenarios of at least 1000 years (refer to Appendix F).

8.2.3 Subsea Blowout

The accident event scenario with the greatest potential environmental risk is a loss of well control that results in a subsea blowout. A blowout is an uncontrolled continuous spill/release that could discharge petroleum gas into the atmosphere and hydrocarbons such as crude oil and gas condensate into surrounding waters. As noted above, subsea blowouts have been selected as the event scenario for this assessment.

The probability of a well blowout occurring depends on a large number of factors related to the location, well characteristics and operating conditions. However, historical data demonstrates that the probability of a large spill resulting from a blowout is extremely low (refer Appendix F). Worldwide, there have been about 50 000 exploratory wells drilled with only two extremely large spills (>150 000 bbls): the 1979 Ixtoc I well blowout, and the 2010 Deepwater Horizon Oil Spill.

Generally, the duration of flow for blowouts is relatively short, which would limit the total volume of material spilled. Nearly 40% of blowouts from exploratory wells flow for less than five days (refer to Appendix F). There is no specific data on durations of flow after five days.

If the exploratory well blowout or release lasts for more than five days, it may flow until a capping and containment system is effectively installed. As discussed in Section 8.1, Shell will have access to global capping and containment systems in case of a blowout during the Project. According to the analysis in Holand (2013), the maximum time for capping and containing a well was determined to be 25 days, with 10 days to collect and prepare the appropriate equipment and 15 days for the actual operation. Based on desktop analysis and wet deployment demonstrations, Shell estimates that the capping and containment system for the Project could be effectively deployed within 12-21 days of an incident occurring. A 30-day unmitigated release scenario (as modelled for this Project) has therefore been selected as a conservative duration to account for this estimated response timing and evaluate effects of a worst-case scenario.

Return periods (*i.e.*, the amount of time that would typically be required for an event to occur once) for a subsea blowout resulting in large to extremely large volumes spilled range from 200 to > 500 years (refer to Appendix F).

8.2.4 Vessel Spill

A vessel collision, equipment malfunction or other accidental event could result in a spill of diesel fuel from an OSV into the marine environment. Shell and its contractors will have measures in place to reduce the potential for vessel collisions and other accidental that may result in spills. This includes:

- all activities adhering to Annex I of MARPOL
- adherence to standard navigation procedures, Transport Canada regulations and CCG requirements
- special attention to activities presenting increased risks for marine traffic including loading and offloading, docking and extreme weather events

Using US statistics from 1968 to 2012, spills from OSVs during servicing of offshore facilities has averaged about 50 bbl per year (refer to Appendix F). During the past decade these spills have diminished to an average of 10 bbl per year in US waters. While an OSV could contain 2830 bbl of fuel, the release of this volume is not considered a plausible scenario. The fuel storage on an OSV is divided into several tanks, only some of which may be vulnerable or exposed in the event of an accident. The bulk of the fuel will be in tanks positioned well beyond a potential breach of the hull caused by an accidental event. As such, the likelihood of a spill occurring that would release the maximum fuel volume is extremely remote, and therefore not considered appropriate for the analysis in this EIS. A spill of diesel fuel from a vessel while at the Project site is addressed through the modelling of batch diesel spills (100 bbl and 10 bbl scenarios). The potential for a spill while the OSV is in transit has been considered qualitatively, recognizing the possibility for a spill to occur anywhere along the transit route. The assessment considers in particular the potential effects of a diesel spill along the nearshore portion of the route, as this accidental event scenario is the only one with potential to affect Halifax Harbour and shoreline habitat in the vicinity.

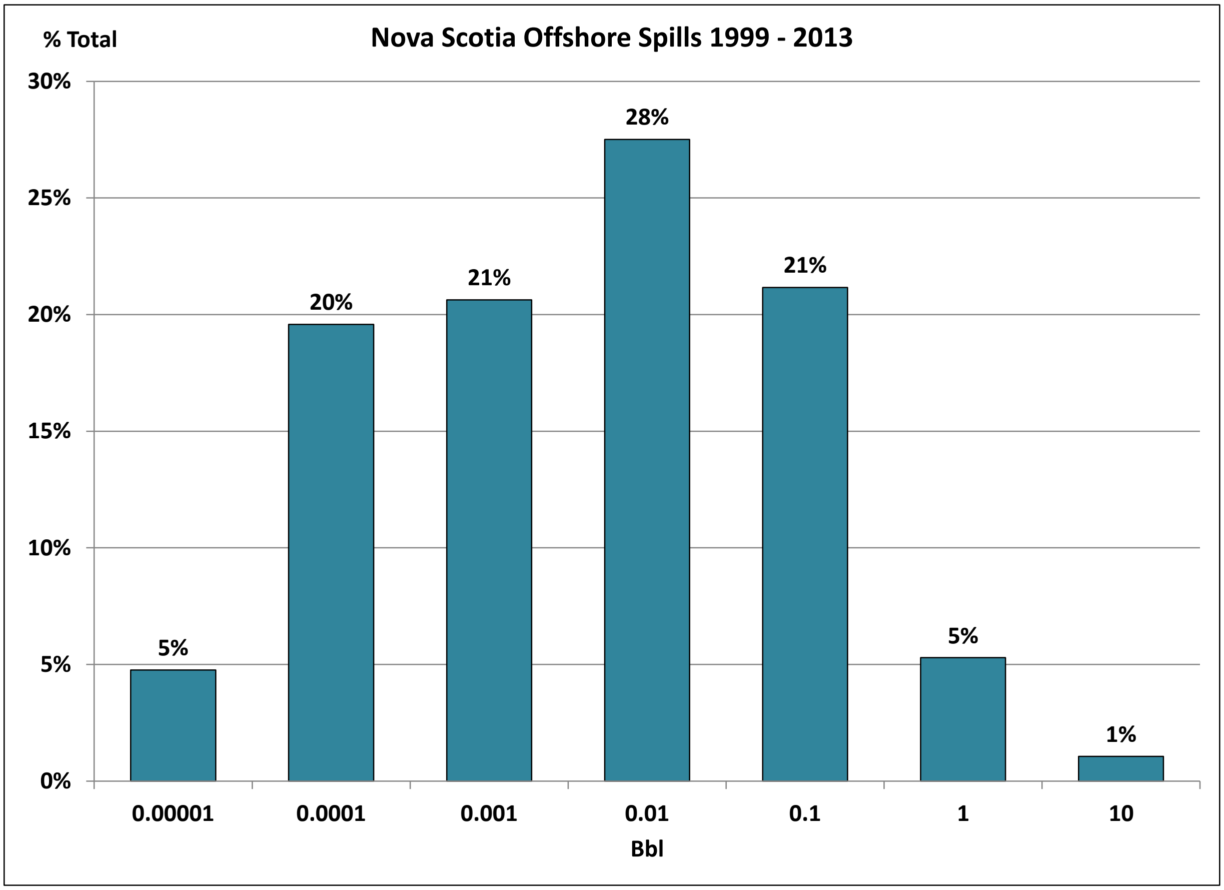
8.3 SPILL RISK AND PROBABILITIES

A detailed analysis of the probability of potential blowouts and spills from offshore wells and activities was conducted by Environmental Research Consulting and is presented in Appendix F; summaries are provided in the subsections below.

8.3.1 Statistics for Canada

In 1984, a gas well, Shell Canada's Uniacke G-72 , blowout occurred off Sable Island, Nova Scotia. This event involved the release of about 1500 bbl of gas condensate over the course of 10 days, as well as 1.11 to 1.83 x 106 m^3/day of natural gas. The prevention and response measures now practiced by Shell and outlined in Section 8.1 have been shaped by the lessons learned by this incident as well as incidents like the Deepwater Horizon Oil Spill.

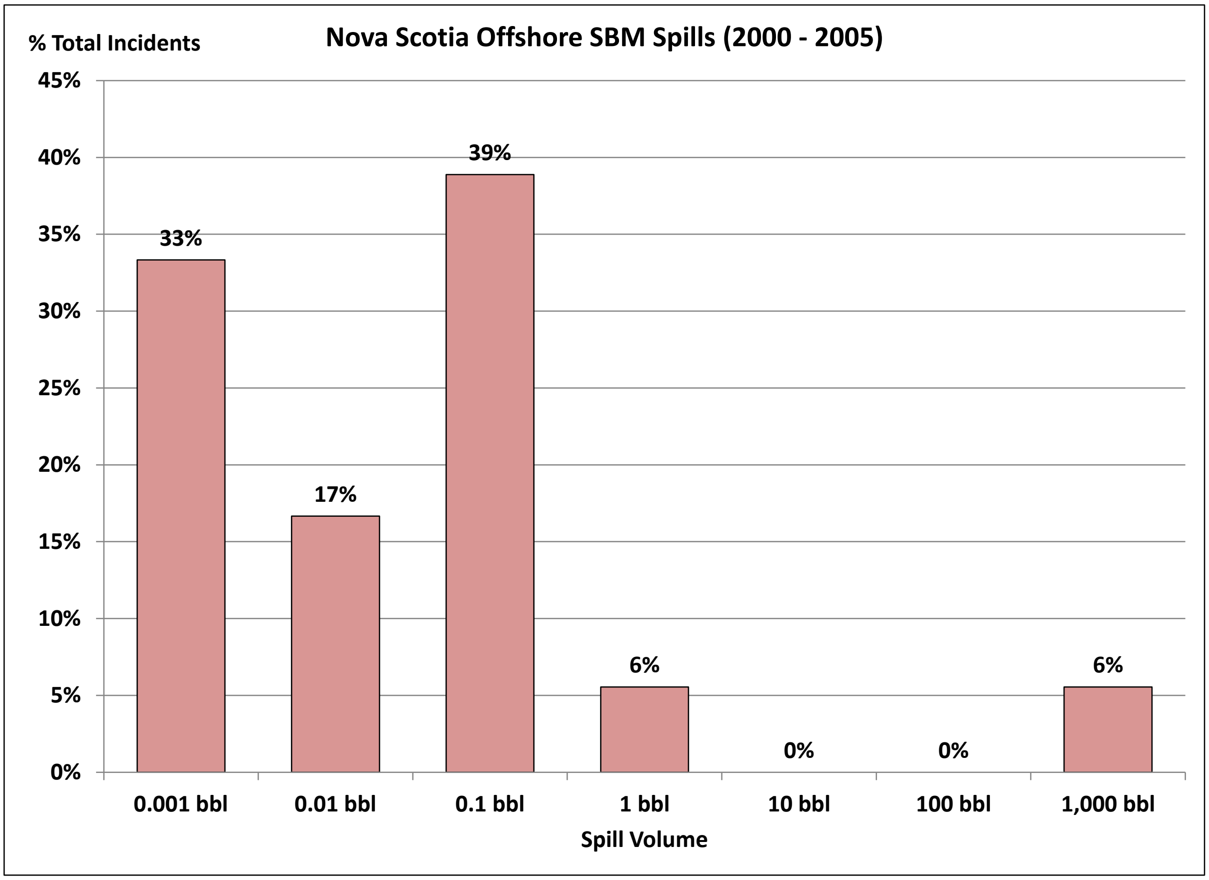
During the 1990s, total inputs of oil from anthropogenic sources in coastal areas of Eastern Canada have averaged 9000 bbl annually, and in offshore areas, 2700 bbl annually, for a total of 11 700 bbl. Spill volumes off Nova Scotia have decreased significantly in the last decade to about 600 bbl annually. Offshore exploration and production facilities off Nova Scotia have spilled a total of 78 bbl of oil in 189 incidents over the last 15 years. Ninety-four percent of these incidents involved less than one barrel of oil. The largest spill was 22 bbl. The average spill volume was 0.4 bbl and the median (50th percentile) spill volume was 0.013 bbl. Overall, the probabilities of spills from offshore exploration and production facilities are very low and if spills occur, the volumes are likely to be relatively small (Figure 8.3.1).



Source: ERC 2014

Figure 8.3.1 Probability Distribution of Volume of Nova Scotia Offshore Spills (1999 – 2013)

SBM spills are reported separately and are not included in the above figure. Between the years 2000 and 2005, 18 spills occurred with an annual average of 3. While, the majority (89%) of the spills were very small (<1 bbl), the average per spill was 186 bbl (Figure 8.3.2). No SBM spills were reported during the period 2006 to 2013. SBM spills during exploration drilling were also reported by the C-NLOPB for the years 1997 through 2011. There have been 16 incidents since 1997, the largest of which involved 4655 bbl. The average spill size was 301 bbl.



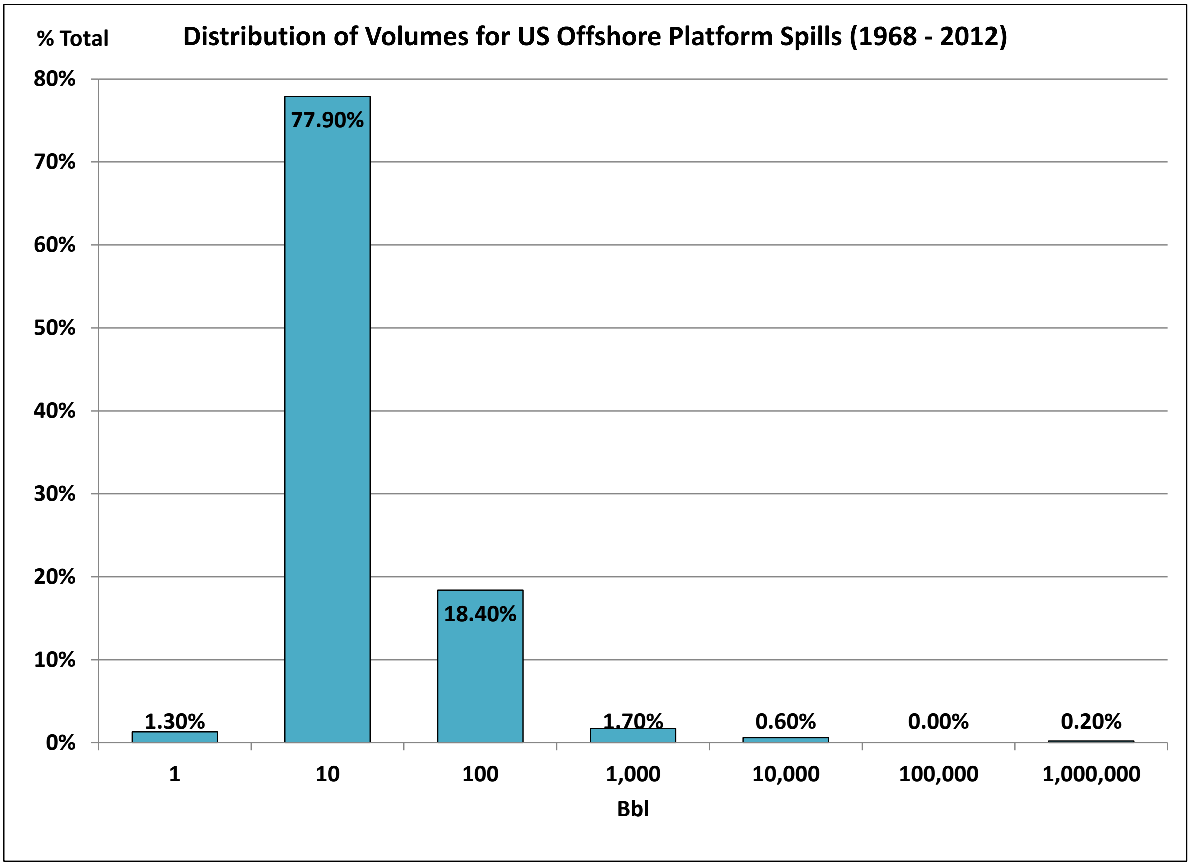
Source: ERC 2014

Figure 8.3.2 Volume Distribution of Nova Scotia Offshore SBM Spills (2000 – 2005)

Occasional tanker spills have provided the greatest risk of oil spillage to the region. In addition to spills and other anthropogenic sources (*e.g.*, urban runoff, vessel, facility operations), natural seepage may also contribute to overall hydrocarbon inputs in the region. Several natural seeps have been identified in the region, though there are no quantifications of annual inputs from this source.

8.3.2 Statistics for the US

Because larger spills have not occurred in Canada, there is a lack of statistical spill data for larger spills. As a result, offshore data from jurisdictions outside of Canada were referenced to provide a general perspective on larger spills from exploration and production activities. Based on US data, well-related spills occur relatively infrequently during offshore operations. Most well spills involve releases of less than 100 bbl over less than one day (Figure 8.3.3). Additionally, large-scale exploratory well blowouts are very rare events, with the greatest concern being the potential volume that may be released into the environment. This concern has become particularly heightened after the 2010 Deepwater Horizon Oil Spill in the US Gulf of Mexico, which was highly publicized. While this blowout released a large amount of oil, blowouts, in general, are infrequent and are statistically shown to involve much smaller quantities of oil. The significance of the volume of material spilled from the Deepwater Horizon Oil Spill is that it skews the volume distribution for historical spills; it does not, however, affect the probability that there will be a blowout or other well release event.



Source: ERC 2014

Figure 8.3.3 Probability Distribution of US Offshore Platform Spill Volumes (1968 – 2012)

8.3.3 Project Spill Probability

The probability of spills and blowouts of various volumes from the Project to potentially result in effects (*i.e.*, consequence) on the environment, needs to take into account both the probability of occurrence for an event and the probability distribution of potential spill volumes (*i.e.*, where a spill might be in space and time). Generally, “risk” is defined as the probability of the occurrence of an event multiplied by the consequence of that event. The probability of the event is the relative frequency of the event, in this case, the relative frequency (rate per well or well-year) of spills or blowouts. In this case, one of the “consequences” is the relative volume of material spilled. Effects on VCs are also consequences.

The overall probability of a spill from each individual or specific well is, on average, 0.000866, or once in 1154 years. For seven wells, the total probability that there will be a spill from any of the wells is 0.006064 or once in 165 years. For blowouts specifically, the probability is 0.000777 per well or once in 1287 years. For any of the seven wells, the probability is 0.005437 or once in 184 years. For other non-blowout releases, the probability per well is 0.00009 or once in 11 146 years. For a release from any of the seven wells, the probability is 0.000628 or once in 1592 years.

The estimated probabilities of the specific spill volumes associated with the scenarios that were modelled for this Project are shown in Table 8.3.1. The return period is the amount of time (generally in years) during which a particular event might be expected to occur once, on average. Smaller diesel spills from MODUs have return periods of 40 to 810 years. Spills of SBM during operations have return periods of at least 1000 years. The blowout scenarios have return periods of about 3700 and 18 000 years.

Table 8.3.1 Probabilities of Project Scenario Spills

Scenario	Volume (bbl)	Probability	Return Period (years)
Batch Spill – 10 bbl (Diesel)	10 bbl	0.121940	41
Batch Spill – 100 bbl (Diesel)	100 bbl	0.006200	806
SBM Spill-1	377.4 bbl	0.004960	1008
SBM Spill-2	3604.2 bbl	0.000620	8065
Spill (Site-1) – Blowout	1 474 500 bbl	0.000054	18 392
Spill (Site-2) – Blowout	747 000 bbl	0.000270	3678

Source: ERC 2014

8.3.4 Probability of Blowouts

Only 41% of blowouts involve the release of any oil, as opposed to brine, water, or gas. The majority of surface blowouts from exploratory wells last less than five days. The proposed Project wells would all be at water depths in the 1000 to 3000 m range. Exploratory well blowouts are statistically observed 30% less likely in water depths of 1000 to 2500 m than at shallower depths; other well releases are statistically observed 45% less likely at these depths. There have been no well blowouts or releases recorded at water depths over 2500 m.

Blowout release and flow rates are generally poorly documented, with varying estimates of average and peak flow. The total spill volume is less than 1000 bbl for 67% of US blowout incidents, and 83% are less than 10 000 bbl; therefore, flow rates for most incidents are generally considerably less than 10 000 bbl or even 1000 bbl per day (Appendix F).

The estimated probabilities of large well blowouts from the Project are summarized in Table 8.3.2. Return periods are the amount of time that would typically be required for an event to occur once. Note that the exploratory operations of the Project are expected to take five years in consideration of the initial exploration phase of the Project.

Table 8.3.2 Probabilities of Project Well Blowouts by Volume Category

Volume Category	Probability (Incidents per Well)	Return Period
Large (1000 – 10 000 bbl)	0.0049	202 years
Very Large (10 000 – 150 000 bbl)	0.0045	222 years
Extremely Large (>150 000 bbl)	0.0018	541 years

Source: ERC 2014

8.3.5 Probability of Batch Spill

There are no specific data from which to derive probabilities of MODU spills. Most of the data on vessel-sourced spills have involved offshore supply or service vessels. For vessels (OSVs and MODUs) associated with US Gulf of Mexico operations, there have been 0.0018 vessel spill incidents per well per year; this equals a return period of 557 years. To more closely reflect the experience in the Nova Scotia offshore, spill inventory data from CNOSPB during 1999 – 2013 were analyzed. These data include vessel spills and other small spills associated with offshore opreations. The probability (incident rate) of a small (< 1 bbl) spill during the five-year Project period is 17 or once in 0.3 years. For spills of one to 10 bbl, the probability is 0.12 in five years, or once in 41 years. Other calculated probabilities for batch spills are provided in Table 8.3.3 with assumptions provided in Appendix F.

Table 8.3.3 Probabilities of Project Batch Spills by Volume Category

Volume Category	Probability		Return Period (years)
	1-Year	5-Year	
Small (< 1 bbl)	3.4	16.8	0.3
Small/Moderate (1 – 10 bbl)	0.02439	0.12194	41
Moderate/Large (100 – 1000 bbl)	0.00124	0.00620	806
Large (1000 – 10 000 bbl)	0.00006	0.00031	16 129
Very Large (10 000 – 150 000 bbl)	0.00001	0.00006	80 645
Extremely Large (>150 000 bbl)	0	0	N/A

Source: ERC 2014

8.3.6 Probability of SBM Spill

There were, on average annually, six SBM spills of 10 bbl or more, in the US Outer Continental Shelf (OCS) during 1999 through 2012 (Appendix F). An average of 1350 bbl of SBM spills were reported from all 3430 wells in the US OCS per year, or about 0.4 bbl per well. The number of incidents per well is about 0.00175 per year.

For this Project and based on the data above, the average number of incidents of SBM spills is estimated to be 0.00175 incidents per well per year, or one incident in 571 years. Applying this statistic to seven wells for the Project, gives an expected frequency of 0.062 for the duration of the Project. The best estimate for the volume distribution of spill volumes for SBM incidents for the Project is based on a combination of data from the US OCS and Nova Scotia offshore data. Other calculated probabilities for SBM spills are provided in Table 8.3.4 with assumptions provided in Appendix F.

Table 8.3.4 Probabilities of Project SBM Spills by Volume Category

Volume Category	Probability		Return Period (years)
	1-Year	5-Year	
Small (< 1 bbl)	0.01116	0.05580	90
Moderate (1 – 1000 bbl)	0.00062	0.00310	1613
Large (1000 – 10 000 bbl)	0.00012	0.00062	8065
Very Large (10 000 – 150 000 bbl)	0	0	N/A

Source: ERC 2014

8.3.7 Probability of Vessel Spill

OSVs have had occasional spills during their servicing of offshore facilities and drilling operations. For the US, from 1968–2012, average total annual spills from these vessels has been about 50 bbl (Appendix F). As the probability of platform batch spills was developed from statistics that included spills from OSVs, these probabilities are also considered applicable to vessel spills (refer to Section 8.3.5).

8.4 SPILL FATE AND BEHAVIOUR

Three-dimensional oil spill fate and trajectory modelling and analyses were performed to support the evaluation of the potential effects from accidental spills associated with a blowout or batch spill from the MODU/OSV. The ultimate effect on a VC will depend on how the spill and the VC interact in both space and time. The modelling also supports oil spill response planning. This section provides an overview of the approach and results from the modelling study undertaken by RPS ASA on behalf of Shell in support of the effects assessment in Section 8.5. More detail is provided in the full technical data report, *Trajectory Modelling Services in Support of the Shelburne Basin Exploration Program*, provided in Appendix G. The current section comprises text from RPS ASA's (2014b) report and text prepared by Stantec to summarize the approach and findings of the report.

In addition, the likely fate and behavior of a SBM whole mud spill for two different volumes was modelled and the results of this modelling is presented in detail in Appendix C and summarized below in Section 8.4.9.

8.4.1 Blowout and Batch Spill Modelling Approach

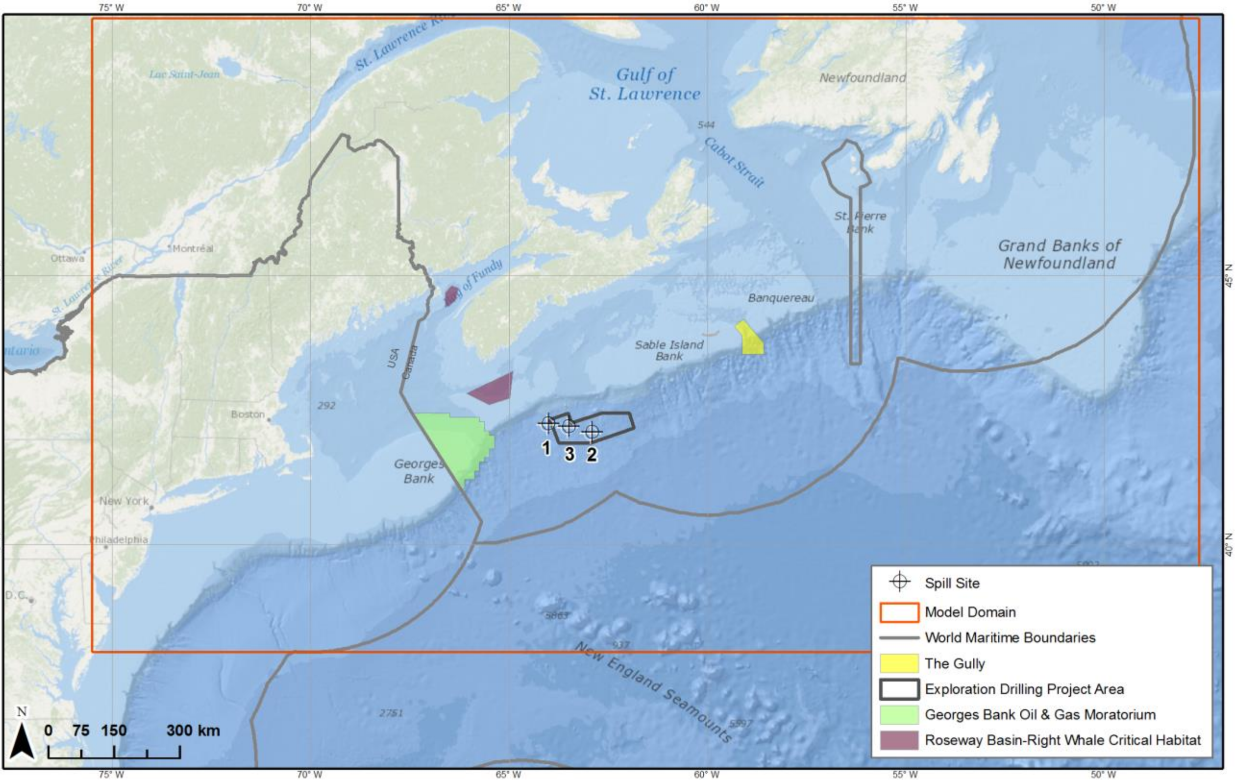
The objective of the spill modelling conducted for the Project was to assess the transport, fates and effects of oil associated with deepwater blowouts at the wellhead and operational spills of marine diesel at the surface (*i.e.*, associated with the MODU or OSV).

All modelled scenarios were conservatively run without any mitigation in order to constitute a worst-case scenario. In the unlikely event of an actual spill and as previously described in Section 8.1, response measures inclusive of oil spill containment, recovery and shoreline protection operations would serve to reduce adverse effects to marine and coastal resources thereby mitigating the full impact of a spill.

Continuous and unmitigated subsurface blowout scenarios were developed at two locations (Site 1 and Site 2), which bound the expected water depths that may be drilled within the Project Area and have considered estimated well parameters for the various depths(refer to Figure 8.4.1). Additionally, as exact well site locations have not presently been identified, modelling site locations for the purposes of the assessment of environmental effect have been situated in proximity to sensitive area (*i.e.*, Georges Banks and Scotian Shelf). Additional to these conservative measures, stochastic modelling has been conducted to consider the full temporal and spatial extent of environmental effects from a large scale spill incident.

Stochastic analysis models multiple spill runs over a full range of environmental conditions using inputs from multi-annual datasets of meteorological and oceanographic conditions, applicable to the Shelburne Basin. Stochastic analyses were conducted for each of the twelve months per year for each spill location. As such results of stochastic modelling and the resultant maps are inclusive of trajectories of multiple spills commenced at various times of the year and tracked over the specified spill duration; the results do not constitute the spatial extent of any one release. In contrast, deterministic scenario modelling considers a single spill trajectory chosen based on specific parameters noted during stochastic modelling. Deterministic scenarios were modelled, at specific times of the year, at the 95th percentile (with respect to degree of oil exposure), to determine the likely transport and fate of oil from a single spill event given representative seasonal conditions. Both stochastic and deterministic models were run over 30 days, to simulate a continuous 30-day unmitigated blowout scenario. Federated Crude Oil was chosen as a representative product for the modelling given similar chemical and physical properties to that expected for the oil in the proposed reservoir. Use of this oil type is considered an additional conservative modelling measure based on the low viscosity and higher aromatic content of this product.

In addition to deterministic blowout modelling, instantaneous surface releases of 10 bbl and 100 bbl of marine diesel were modelled at a third location (Site 3) between Sites 1 and 2 (refer to Figure 8.4.1).



Source: RPS ASA 2014b

Figure 8.4.1 Spill Modelling Locations

For the three locations, the expected surface oiling exceeding 0.04 µm, shoreline oiling exceeding 1.0 µm thicknesses, and in-water concentrations of dissolved aromatics exceeding 1 ppb were reported for stochastic scenarios and representative deterministic cases. Rationale for the parameter thresholds used in the modelling scenarios is discussed further in Section 8.4.3 (refer to Table 8.4.4).

This study used the Spill Impact Model Application Package (SIMAP^{TM}) modification of the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME) model (developed by RPS ASA) for use by the US Department of the Interior in CERCLA NRDA type A regulations and for oil spill assessments under the US *Oil Pollution Act* (OPA)). This model comprises 3D oil fate and biological effects models that assess acute effects and provide data to estimate potential effects of spills in marine and freshwater environments.

Specifically, the 3D physical fates model estimates distribution (as mass and concentrations) of whole oil and oil components on the water surface, on shorelines, in the water column, and in sediments. Oil fate processes accounted for in the model are oil spreading (gravitational and by shearing), evaporation, transport, randomized dispersion, emulsification, entrainment (natural and facilitated by dispersant), dissolution, volatilization of dissolved hydrocarbons from the surface water, adherence of oil droplets to suspended sediments, adsorption of soluble and sparingly-soluble aromatics to suspended sediments, sedimentation, and degradation (refer to Appendix G for detail on each of these processes).

The trajectory and fate of spilled hydrocarbons were assessed using RPS ASA's blowout model OILMAP Deep™, coupled with the SIMAP™ model. OILMAP Deep™ was used to determine the fate of the oil and gas within the blowout plume, including the range of oil droplet sizes generated during a changing release rate. SIMAP™ was then used to run a matrix of representative oil spill simulations in the far-field, covering monthly scenarios that provide a range of trajectories using environmental conditions applicable to the Shelburne Basin.

In order to determine the range of potential outcomes and effects, multiple subsea release scenarios and environmental conditions were evaluated. Three locations were modelled to predict the range of potential effects from various spills for this Project (Table 8.4.1). The selected spill sites for hypothetical blowouts included two deepwater well locations (Sites 1 and 2). Site 1, at 1700 m depth, and Site 2, at 2500 m depth, were chosen to represent the range of depths likely to be drilled within the Project Area. The blowouts were modelled as a continuous 30-day release of Federated Crude Oil using multi-annual datasets of environmental conditions for the region that occurred between September 2008 and December 2013. As noted previously in Section 8.1 and 8.2, the 30-day duration was chosen as a conservative temporal frame based on Shell's estimated response timeline in the event of a spill. Release rates for the modelled blowout scenarios have been established to represent plausible worst-case scenarios and were calculated based on reservoir modelling and outflow characteristics anticipated for wells at the modelled site depth. Representative surface releases of marine diesel were modelled at a third location (Site 3), located between the modelled wellsites. Release volumes for batch spills were chosen based on spill risk and probability analysis, as well as to provide an appropriate and conservative basis for assessing environmental effects.

Table 8.4.1 Locations for Blowout and Batch Spill Modelling Scenarios

Spill Location	Depth of release	Model Duration	Release Duration	Number of Model Runs	Released Product	Release Volume
Site 1 (42.3 °N, 64.0 °W)	1700 m	30 days	30 days	40 per month X 12 months	Federated Crude Oil	74 000 bbl (24 900 bpd)
Site 2 (42.15 °N, 62.9 °W)	2500 m	30 days	30 days	40 per month X 12 months	Federated Crude Oil	1474 500 bbl (49 150 bpd)
Site 3 (42.25 °N, 63.48 °W)	Surface	30 days	Instantaneous	2 releases	Marine Diesel	10 bbl & 100 bbl
Notes: Stochastic analyses for Sites 1 & 2 included 480 individual model runs per site. Additional deterministic analyses were conducted for 95th percentile (representing quasi-worst-case) scenarios for threshold exceedance of surface oiling, water column oiling, and shoreline oiling at Sites 1 and 2. Deterministic analyses for instantaneous surface releases of marine diesel were also modelled at Site 3. A total of 962 individual model runs were conducted for this study.						

Source: RPS ASA 2014b

8.4.2 Blowout and Batch Spill Model Input Data

8.4.2.1 Environmental Data

The SIMAP^{TM} model uses current velocity data, environmental conditions (*e.g.*, winds, temperature, salinity, suspended sediment concentrations), and transport and weathering algorithms to calculate mass balance in various environmental compartments (water surface, shoreline, water column, atmosphere, sediments, *etc.*), surface oil distribution over time (trajectory), concentrations of the oil components in water, and mass loadings to shoreline soils and sediments.

Section 2 of Appendix G describes the environmental data used as input to the models. Geographical data (habitat mapping and shoreline location) were obtained from the US National Oceanic and Atmospheric Administration's Environmental Sensitivity Index (NOAA ESI), with slight modifications using the Maine Environmental Vulnerability Index (EVI) from the Maine Department of Environmental Protection. For the Canadian shoreline, data from New Brunswick Department of Natural Resources and Nova Scotia Department of Natural Resources was used. Hourly wind speed and direction data were obtained from the US Navy Operational Global Atmospheric Prediction System (NOGAPS). Local wind speed was validated using hourly data from a nearby meteorological station on the DFO buoy on the East Scotian Slope (Reference: c44137).

Hydrodynamics data, that describe oceanic currents, are the most significant environmental forcing parameters for trajectory modelling. To simulate oceanic circulation in the Project Area, a combined approach included both the Global HYbrid Coordinate Ocean Model (HYCOM) general circulation model and the TOPEX/Poseidon Global Inverse Solution TPXO8.0 tidal forcing.

8.4.2.2 Oil Properties

The oil types modelled in this study included Federated Crude Oil and Marine Diesel. Federated Crude Oil (2002) is a relatively "light" crude with low viscosity and a high aromatic content. The oil properties of this chosen oil type are a good match for the fluids expelled by multiple basin model runs over the Project Area with a Type II marine source rock. The marine diesel is a standard diesel that is also low viscosity with a high aromatic content. The physical and chemical properties of these oils were measured by Environment Canada (ESTC 2013).

The physical and chemical properties of the oils were taken from ESTC datasheets for Federated Crude Oil. The concentrations of Monocyclic Aromatic Hydrocarbons (MAH), Polycyclic Aromatic Hydrocarbons (PAH), and volatile aliphatics were calculated from data in ESTC (2013). The three aromatic pseudo-components and three aliphatic pseudo-components were then modelled in SIMAP^{TM}, along with the total hydrocarbons. The volatile aliphatics are evaporated and volatilize from the surface water and so their mass is accounted for in the overall mass balance. However, as they do not dissolve in significant amounts, they have little influence on the biological effects on water column and benthic organisms. Minimum oil slick thicknesses were determined based on McAuliffe (1987). A summary of the physical parameters for each oil is provided in Table 8.4.2.

Table 8.4.2 Oil Parameters for the Modelled Oils

Physical Parameters	Federated Crude Oil (2002)	Marine Diesel
Oil Type	Light oil, may form emulsion	Diesel
Minimum Slick Thickness (µm)	0.1	0.01
Surface tension (dyne/cm)	28.0	27.5
Pour Point (C)	-24	-24
API Gravity	38.9	38.8
Density at 25°C (g/cm^3)	0.8250	0.8310
Viscosity (cP) @ 25°C	4.0	2.76

Source: RPS ASA 2014b

8.4.2.3 Blowout Model Inputs

The blowout model was used to simulate the plume trap height and droplet size distributions for two different sites situated at different water depths, each with one flow rate and oil, and an annually averaged water column profile. The pertinent modelling inputs for each scenario are summarized in Table 8.4.3. Additional information on the blowout model scenarios and results are included in Section 3 of Appendix G.

Table 8.4.3 Blowout Scenario Input Parameters

Spill Site	Water Depth (m)	Oil Release Rate (bpd)	Oil Density @ 15 °C (g/cm^3)	Oil-Water Interfacial Tension (dyne/cm)	Gas to Oil Ratio (GOR) (scf/stb)	Pipe Diameter (inches)	Discharge Temperature (°C)
Site 1	1770	24 900	0.83	28	1000	12.13	85
Site 2	2500	49 150	0.83	28	1000	12.13	85

Source: RPS ASA 2014b

8.4.3 Stochastic and Deterministic Blowout and Batch Spill Modelling Approaches

Stochastic and deterministic modelling approaches were used to respectively provide first a probabilistic view that a given region may experience effects from a spill over many possible environmental conditions, and second a representative view of a given individual spill, based upon specific parameters for a single given release. Together, these approaches provide a clearer view of both likelihood and magnitude of any potential effects.

The stochastic approach sampled the variability of meteorological and oceanographic conditions in the modelling study area over the anticipated operational period and provided insight into the probable behaviour of the potential oil spills. A stochastic scenario is comprised of many individual trajectories (*i.e.*, tens to hundreds of trajectories) of the same spill scenario, each initiated on a different date and thus under different conditions. The purpose of this type of modelling is to account for and capture in the assessment the natural variability in conditions that may occur. When combined with one another, the many individual deterministic footprints generate an area of probability that describes the possible area of oil contamination from the entire suite of modelled conditions. Stochastic footprints are therefore much larger than the expected effects from any single incident.

Individual or "deterministic" trajectories of interest (*e.g.*, representative of specific wind conditions, or 95th percentile surface area oiled) were identified and selected from the range of stochastic results. The deterministic trajectory simulations provide an estimate of the oil's fate and transport for a specific set of environmental conditions, whereas the stochastic outputs provide overall probability of oiling extent and travel time given a wide range of environmental conditions.

To analyze the probability or likelihood of potential effects, specific thresholds for surface oil thickness, in-water concentration, and shoreline oiling were used. Table 8.4.4 provides cutoff thresholds that define the minimum value for expected potential effects, along with higher thresholds for comparative purposes. Variability in the observation and measurement of oil thickness and visible appearance does exist. The visible threshold for a colourless and silver sheen potentially may be observed at a lower threshold; however, a value of 0.04 µm was chosen as a conservative approximation (French-McCay *et al.* 2011).

Table 8.4.4 Stochastic Thresholds Used to Define Regions with Potential Effects

Stochastic Threshold	Cutoff Threshold	Rationale
Surface Oil Thickness	*0.04 µm	Visible threshold used to determine potential impacts on commercial resources (*e.g.*, possibility of fisheries closure). This minimum thickness would relate to a slick being barely visible as a colourless or silver sheen (French-McCay *et al.* 2011).
	10 µm	Biological threshold for ecological impacts to the water surface (*i.e.*, birds) (French-McCay 1996 & 2009 oil spill fate and effects model). Oil would appear as a dark brown.
Shoreline Oil Mass	*1.0 g/m^2	This thickness is the threshold for potential effects on socio-economic resource uses, as this amount of oil would conservatively trigger the need for shoreline cleanup on amenity beaches. Oil would appear as a dull brown sheen (French-McCay *et al.* 2011).
	10.0 g/m^2	This thickness provides a more conservative screening threshold for potential ecological effects to shoreline habitats, which has typically been 100 g/m^2, based upon a synthesis of the literature showing that shoreline life has

Table 8.4.4 Stochastic Thresholds Used to Define Regions with Potential Effects

Stochastic Threshold	Cutoff Threshold	Rationale
		been affected by this degree of oiling (French *et al*. 1996; French-McCay 2009). The oil would appear as dark brown coat or opaque/black oil.
In-Water Concentration	*1.0 ppb of dissolved aromatics, roughly equivalent to 1.0 ppm TPH	Exposure concentration below which no significant biological effects are expected for sensitive marine resources (Trudel *et al*. 1989; French-McCay 2004 in S.L. Ross 2012 modelling for Old Harry in Gulf of St. Lawrence). This value is a conservative threshold for early contact on herring larvae.
*Thresholds used in supporting figures in Appendix G		

Source: RPS ASA 2014b

8.4.4 General Oil Spill Behaviour

During a blowout incident, oil and gas released from the seabed are driven into the water column as a jet for a short length. As the discharge moves upward, the density difference between the expanding gas bubbles in the plume and the receiving water result in a buoyant force, which drives the plume upward. As the plume rises, it continues to entrain ambient seawater due to the velocity difference between the rising plume and the receiving water. This entrainment reduces the plume's velocity and buoyancy and increases its radius. Under specific conditions, there is the potential for the rising plume to reach the point of neutral buoyancy, where a portion of the plume may terminate its rise and be trapped at depth.

For oil discharged during a deep water blowout, the oil droplet size distribution has a profound effect on how oil is transported after the initial release as a buoyant plume, as the size of the individual droplets dictates how long the oil will remain suspended in the water column. Large droplets will reach the surface faster than small ones, potentially generating a floating oil slick that is transported by winds and surface currents. Small droplets will remain in the water column longer than the large droplets and be subjected to the subsurface advection-diffusion transport. As the oil is transported by subsurface currents away from the wellsite, natural dispersion of the oil droplets quickly reduces aromatic and hydrocarbon component concentrations in the water column, with decreasing concentration at increasing distance away from the wellsite. However, lower rise velocities of the oil droplets correspond to longer residence times of oil suspended in the water column and thus a larger volume of affected water.

The mass loading of floating oil is expressed as g/m^2, where 1 g/m^2 corresponds to an oil layer that is approximately 1 micron (μm) thick. Spilled oil observed as a dull brown sheen is approximately 1 μm thick, rainbow sheen is approximately 0.2–0.8 g/m^2 (0.2–0.8 μm) thick, and silver sheens are approximately 0.05–0.8 mg/m^2 (0.05–0.8 μm) thick (NRC 1985). Crude and heavy fuel oil that is greater than 1 mm thick appears as black oil. Spills of light fuels and diesel that are greater than 1 mm thick are not black in appearance but appear brown or reddish.

Floating oil may not always have these appearances, as weathered oil may be in the form of scattered floating tar balls and tar mats where currents converge.

8.4.5 Stochastic Modelling Results

8.4.5.1 Explanation of Model Results

Stochastic modelling results illustrate the spatial extent of surface oiling, water column concentrations of dissolved aromatics, and shoreline oiling probabilities and associated minimum travel times for the spills. The following information is provided to assist with the interpretation of Figures 8.4.2 to 8.4.7.

Probability of Oiling

For a given scenario, figures depicting the probability of oiling define the area and the associated probability that sea surface oiling, shoreline oiling, or water column contamination by dissolved aromatics, would be expected to exceed the specified thresholds (provided in Table 8.4.4). The coloured lines in the stochastic figures signify the boundary for given percentiles that may receive oil pollution in the event of that particular spill scenario. The darker the colour, the more likely an area would be affected. The lighter colours denote that an area is less likely to be affected. In the lower probability areas, the exact location of a particular spill event would be more difficult to predict.

The probability of oiling was based on a statistical analysis of the resulting ensemble of individual trajectories for each spill scenario (480 for annual figures). These figures do not imply that the entire contoured area, or even a large portion of that, would be covered with oil in the event of an unmitigated spill. These figures do not provide any information on the quantity of oil in a given area. They simply denote the probability of oil exceeding the given threshold over the entire ensemble of runs at each point. Only probabilities of 1% or greater were included in the map output. Probabilities of < 1% for oiling to exceed threshold values at a given location were considered negligible for the purposes of the assessment. Stochastic figures showing water column contamination by dissolved aromatics depict oiling frequency but do not specify the given depth at which this occurs nor do they imply that the entire water column (*i.e.*, from surface to sea bed) will experience a concentration above the threshold.

Minimum Travel Times

The footprint on the “minimum travel times” figures corresponds to the associated probability of oiling figures. Each figure illustrates the shortest time required for oil to exceed the defined thickness or concentration thresholds (Table 8.4.4), at each point within the footprint, considering all individual trajectories for that scenario.

8.4.5.2 Oil Fates Results

A total of 480 individual releases were modelled for 30 day periods for both Site 1 and Site 2. Site 1 was a smaller volume and shallower release (24 900 bpd of Federated Crude oil at a depth of 1700 m), while Site 2 was a larger volume and deeper release (49 150 bpd of Federated Crude oil at a depth of 2500 m). Annual summaries of stochastic analyses of potential surface oiling (Figures 8.4.2 and 8.4.3) and water column contamination by dissolved aromatics (Figures 8.4.4 and 8.4.5) depict an area of potential oil contamination in Canadian waters south of Nova Scotia and Newfoundland and a portion of the ocean in US waters to the east of the New England area, for Sites 1 and 2, respectively.

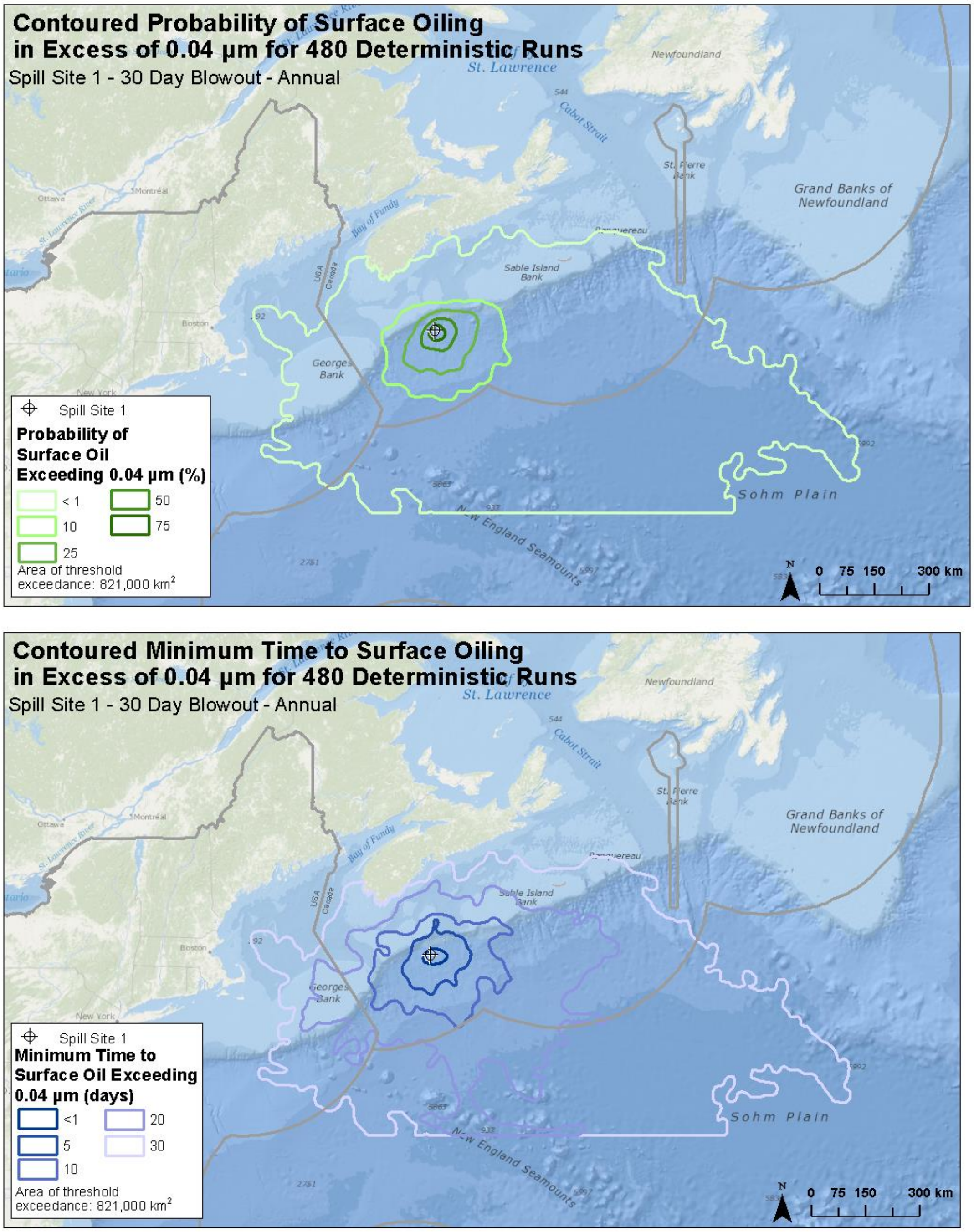
As noted above, these footprints are not the expected extent of oiling from any single release of oil. In fact, the majority of the area represents a probability of oiling at less than 10%. The area with greater than 10% probability of surface oiling exceeding the threshold is much smaller (approximately 300 km x 300 km), while only an area of 50 km x 50 km has a probability greater than 75% (Figures 8.4.2 and 8.4.3). Water column dissolved aromatic threshold exceedance follows this general trend as well, although the area of probability > 10% is slightly larger (Figures 8.4.4 and 8.4.5). The Site 2 stochastic figures are shifted slightly to the east, with respect to the Site 1 figures, as the hypothetical release location is further offshore and to the east.

The shortest time for a threshold exceedance in either the surface oil or water column dissolved aromatic concentration to reach an area near shore (Nova Scotia) in an unmitigated release scenario is in excess of 20 days for Site 1 and in excess of 30 days for Site 2.

For the two modelled scenarios, the probability of shoreline oiling was very low, between 0.83 and 1.88% (Figures 8.4.6 and 8.4.7). Only 9 scenarios out of 480 for the modelled Site 1 release, and only 4 scenarios out of 480 for the modelled Site 2 release resulted in shoreline oiling. All shoreline oiling cases occurred during the summer season, limited to the months of May, June, and July. The reason that shoreline oiling is so unlikely is a combination of the forcing parameters for surface oil and the location of the release. The modelled sites are far offshore and oil would need to remain on the surface for order of one month or more to be transported the hundreds of kilometres towards shore. During more quiescent summer conditions, where a higher percentage of oil remains on the surface, there is a slightly increased probability (although still unlikely) that winds may come from the east and northeast, thus transporting surface oil towards land.

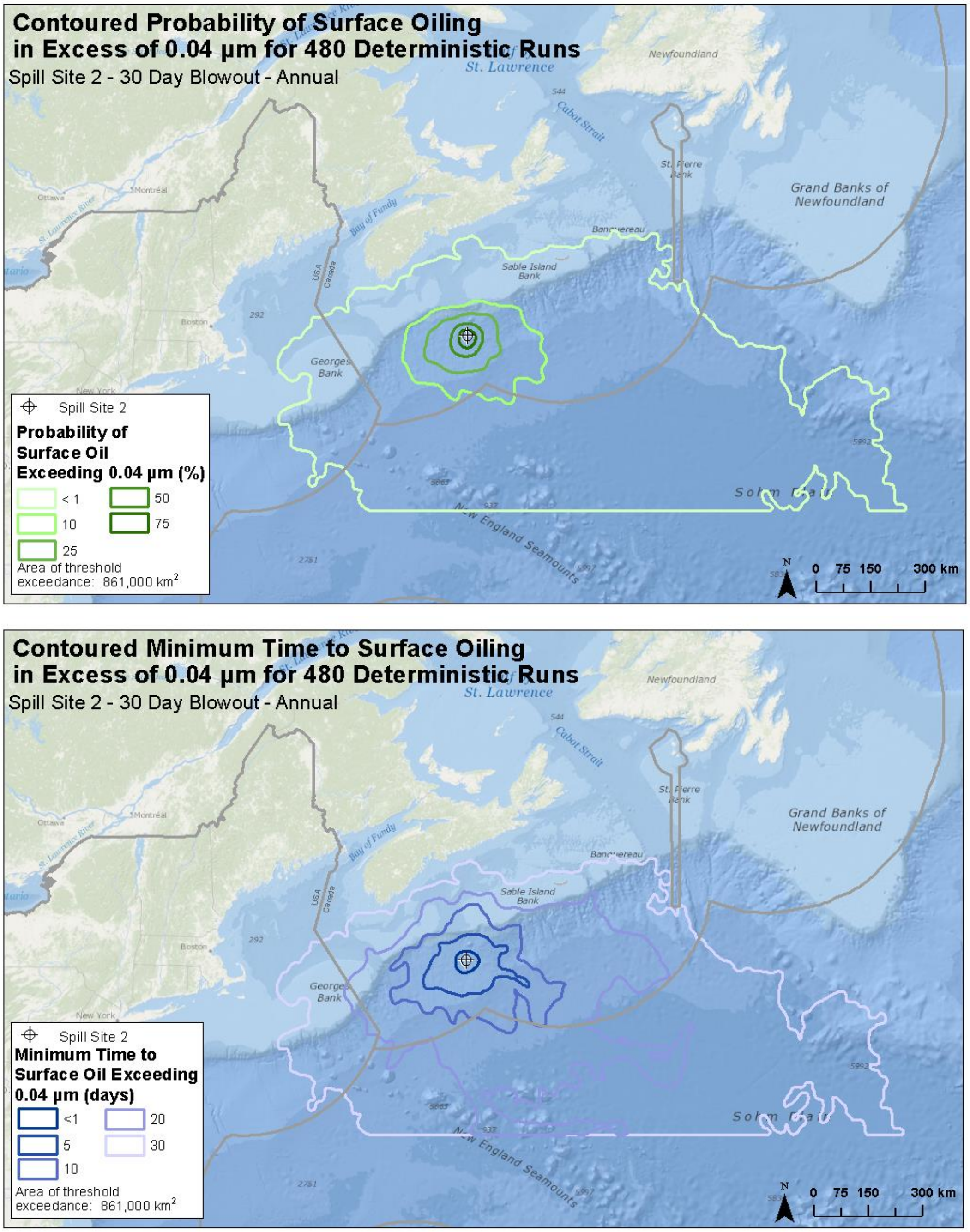
It is expected that any stranded oil would be highly weathered, as the minimum time to shore would be 20–30 days. The regions susceptible to potential shoreline oiling within 30 days following a release at Site 1 include the southern tip of Nova Scotia, including the Yarmouth, Barrington, and Shelburne region, as well as Sable Island National Park Reserve. The only region susceptible to potential shoreline oiling within 30 days following a release at Site 2 is the Sable Island National Park Reserve. It is important to note that the modelled scenarios illustrate a 30 day unmitigated release. Shell's current response timeline detailed in Section 8.1 estimates a maximum response time of 21 days for a large scale spill such as that being considered here. As a result in the unlikely event of an actual blowout, it is anticipated that response procedures would have been activated, reducing the likelihood of any hydrocarbons reaching shore.

Figures showing annual stochastic results, as described above, are included within this section, although monthly stochastic analyses were also conducted. During the winter, strong prevailing winds from the north and west are observed, which would transport surface oil to the east, out to sea. During the summer months, wind speeds are lower and are predominantly from the south and west, resulting in a more variable spill trajectory pattern. Additionally, there is a higher probability of winds from the east-northeast during the summer months, which would transport surface oil towards shore. Local hydrodynamics in this region are more directionally variable at the surface. The resulting combination of wind and currents yields slightly more circular (increased variability in trajectory) patterns with a higher likelihood of shore oiling during the summer, and slightly more skewed (higher probability of transport offshore and to the east) patterns during the winter. As a note, the sharp cut off in the southern portion of the outermost contour in the maps below is an artefact of the spatial extent of the modelled domain (see Figure 1 of Appendix G).



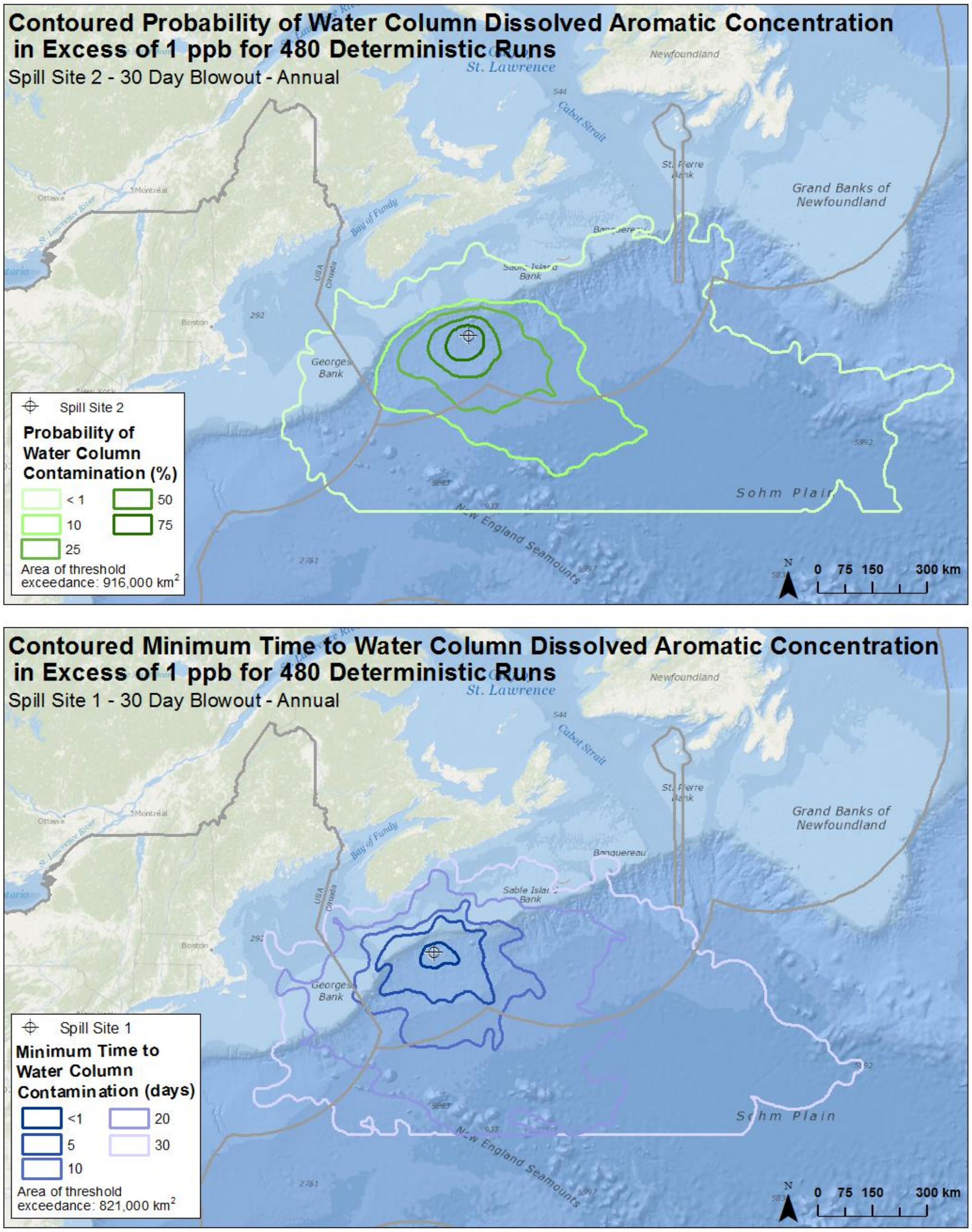
Source: RPS ASA 2014b

Figure 8.4.2 Annual stochastic model output (480 individual model runs) showing maps of the predicted probability of sea surface oiling exceeding the 0.04 µm thickness threshold (top panel) and the associated minimum travel times (bottom panel) for a 24 900 bpd, 30-day continuous blowout of Federated crude at Site 1



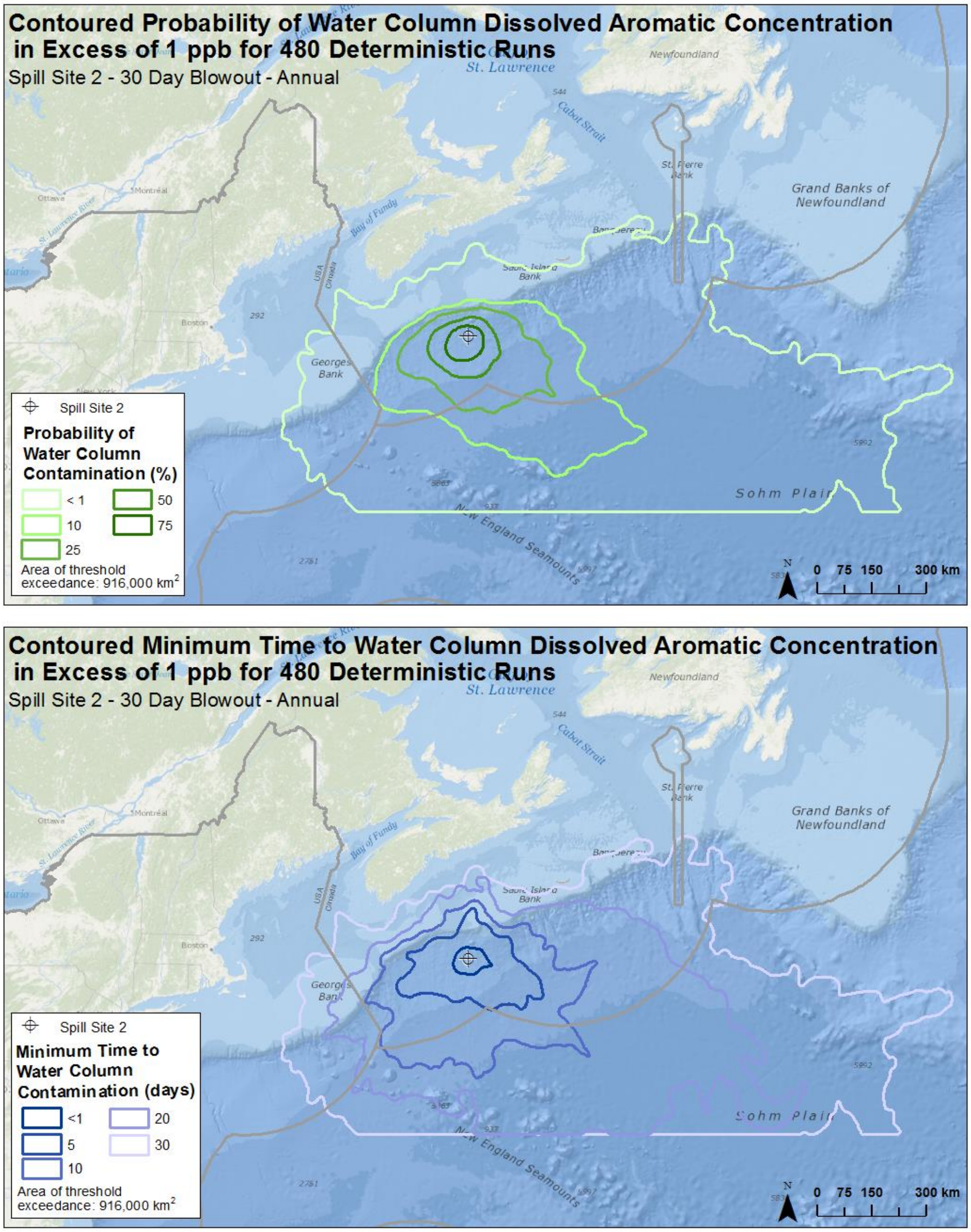
Source: RPS ASA 2014b

Figure 8.4.3 Annual stochastic model output (480 individual model runs) showing maps of the predicted probability of sea surface oiling exceeding the 0.04 µm thickness threshold (top panel) and the associated minimum travel times (bottom panel) for a 49 150 bpd, 30-day continuous blowout of Federated crude at Site 2



Source: RPS ASA 2014b

Figure 8.4.4 Annual stochastic model output (480 individual model runs) showing maps of the predicted probability of water column dissolved aromatic concentrations exceeding the 1 ppb threshold (top panel) and the associated minimum travel times (bottom panel) for a 24 900 bpd, 30-day continuous blowout of Federated crude at Site 1



Contoured Probability of Water Column Dissolved Aromatic Concentration in Excess of 1 ppb for 480 Deterministic Runs

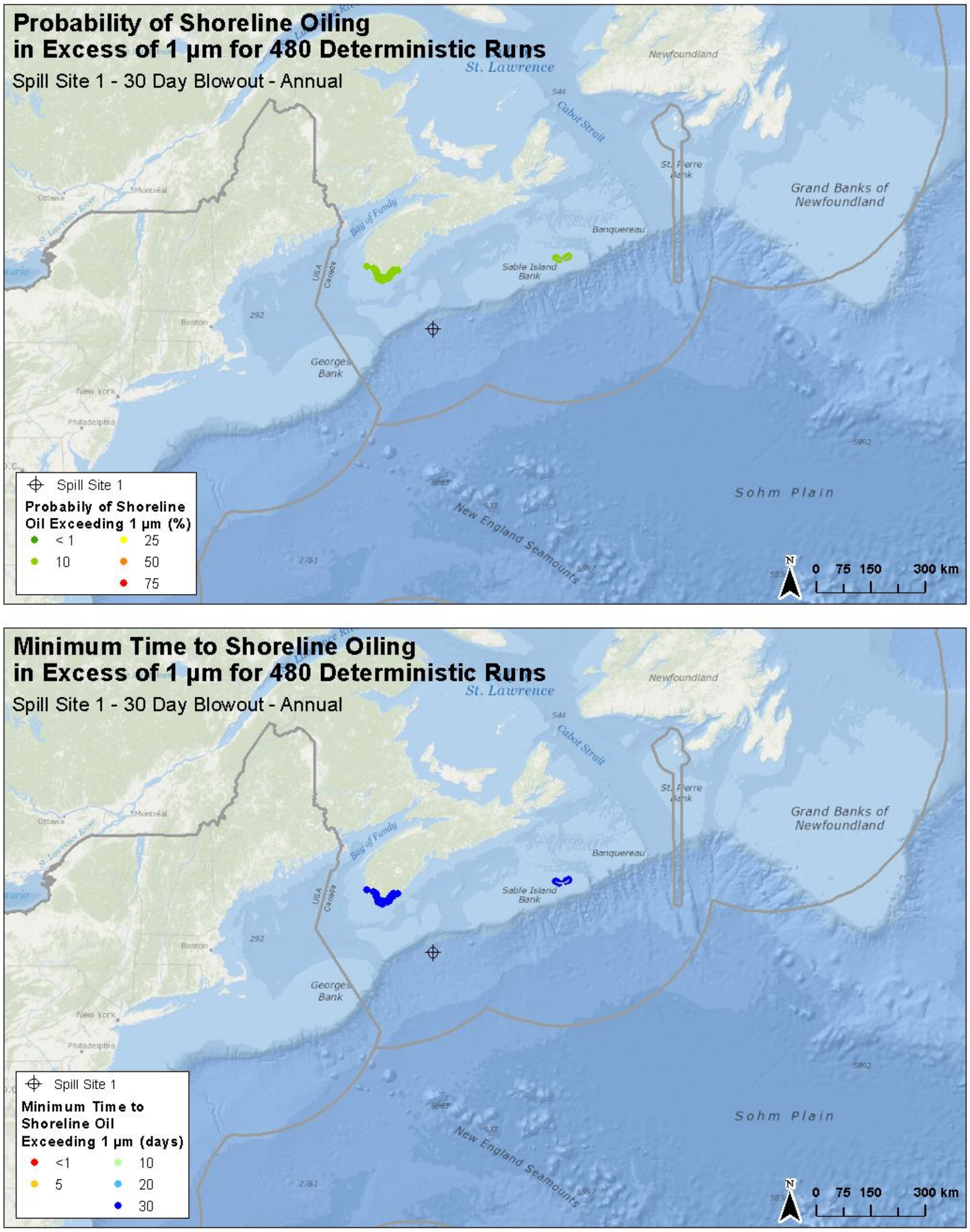
Spill Site 2 - 30 Day Blowout - Annual

Contoured Minimum Time to Water Column Dissolved Aromatic Concentration in Excess of 1 ppb for 480 Deterministic Runs

Spill Site 2 - 30 Day Blowout - Annual

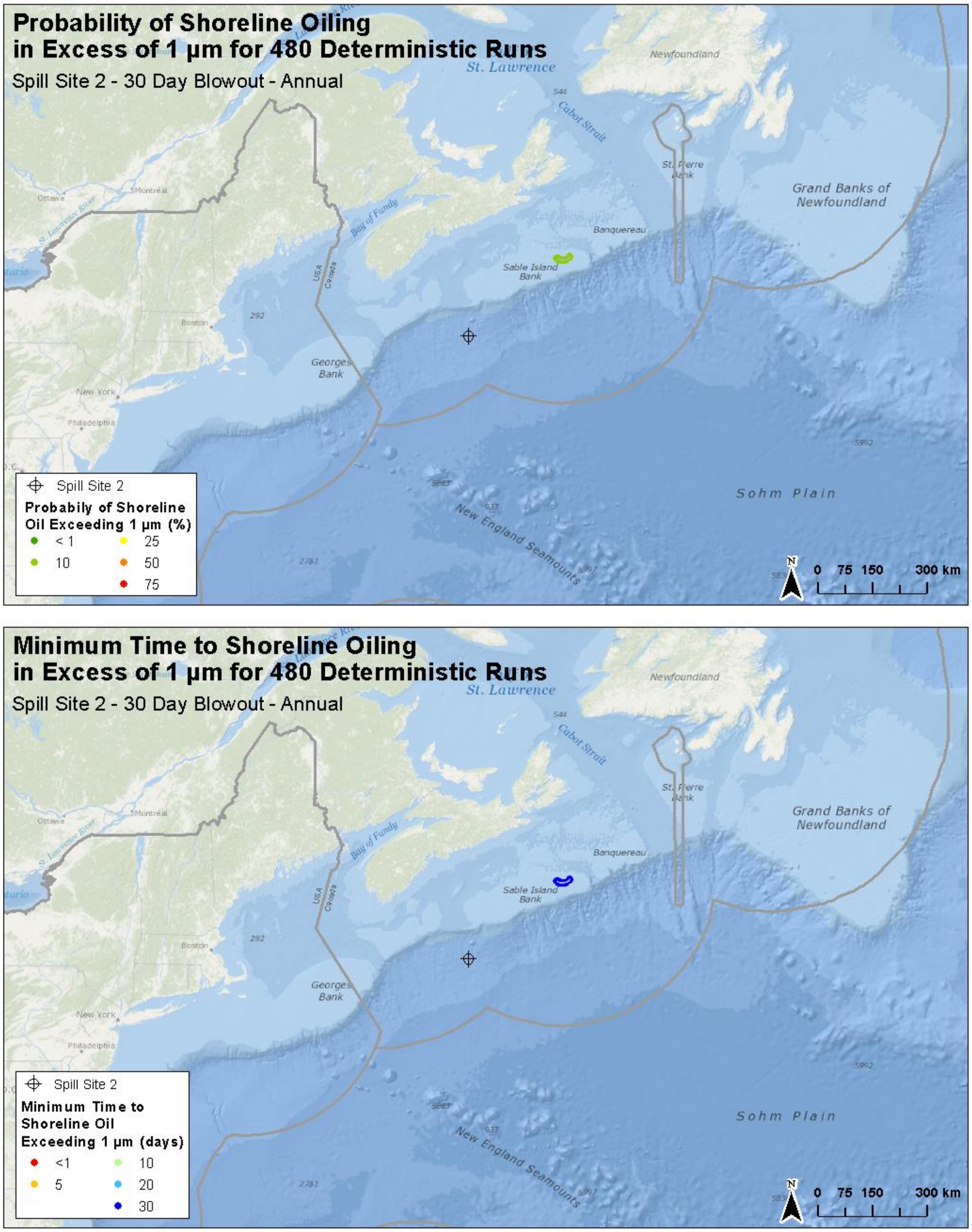
Source: RPS ASA 2014b

Figure 8.4.5 Annual stochastic model output (480 individual model runs) showing maps of the predicted probability of water column dissolved aromatic concentrations exceeding the 1 ppb threshold (top panel) and the associated minimum travel times (bottom panel) for a 49 150 bpd, 30-day continuous blowout of Federated crude at Site 2



Source: RPS ASA 2014b

Figure 8.4.6 **Annual stochastic model output (480 individual model runs) showing maps of the predicted probability of shoreline oiling exceeding the 1µm threshold (top panel) and the associated minimum travel times (bottom panel) for a 24 900 bpd, 30-day continuous blowout of Federated crude at Site 1**



Source: RPS ASA 2014b

Figure 8.4.7 **Annual stochastic model output (480 individual model runs) showing maps of the predicted probability of shoreline oiling exceeding the 1µm threshold (top panel) and the associated minimum travel times (bottom panel) for a 49 150 bpd, 30-day continuous blowout of Federated crude at Site 2**

8.4.6 Deterministic Modelling Results

8.4.6.1 Explanation of Model Results

Deterministic trajectory models were run to describe seasonal maxima in the degree of surface, shoreline, and water column oiling for a given scenario.

The 95th percentile results for oil exposure for surface oiling, water column dissolved aromatic concentrations, and shoreline oiling were identified for each of the 12 monthly stochastic model scenarios. These identified cases were separated into winter and summer bins, and the scenario with the maximum effects within each seasonal bin was identified and run as an individual deterministic trajectory. Therefore, the month and individual run for maximum surface oiling effects for summer differed from the month and individual run for maximum water column dissolved aromatics effects for summer.

The representative deterministic cases identified for surface oiling, water column dissolved aromatic contamination, and shoreline oiling, comprising the individual trajectory that resulted in the 95th percentile effects from each stochastic analysis for Sites 1 and 2 are provided for both winter and summer seasons. Table 8.4.5 describes the size of areas exceeding specific thresholds for each case.

Table 8.4.5 Representative Deterministic Cases and Associated Areas Exceeding Specified Thresholds for Sites 1 and 2

	Season	Modelled Start Date	Area Exceeding Thresholds
SITE 1			
Surface Oiling Effects (95th Percentile)	Winter	2010 Mar. 18 02:02	0.04 µm = 40 800 km² 10 µm = 2500 km²
	Summer	2009 July 14 19:08	0.04 µm = 75 300 km² 10 µm =2300 km²
Water Column Dissolved Aromatic Effects (95th Percentile)	Winter	2008 Dec. 8 04:52	1 ppb dissolved aromatics = 57 400 km² (equivalent to 1ppm TPH)
	Summer	2010 Sep. 27 17:04	1 ppb dissolved aromatics = 58 600 km² (equivalent to 1 ppm TPH)
Shoreline Oiling Effects (95th Percentile)	Summer	2009 June 10 06:22	1 µm = 110 km 10 µm = 110 km
SITE 2			
Surface Oiling Effects (95th Percentile)	Winter	2010 Mar. 16 19:17	0.04 µm = 33 100 km² 10 µm = 2300 km²
	Summer	2009 Aug. 7 06:59	0.04 µm = 83 500 km² 10 µm = 7300 km²
Water Column Dissolved Aromatic Effects	Winter	2009 Dec. 8 21:33	1 ppb dissolved aromatics = 204 000 km² (equivalent to 1 ppm TPH)

Table 8.4.5 Representative Deterministic Cases and Associated Areas Exceeding Specified Thresholds for Sites 1 and 2

	Season	Modelled Start Date	Area Exceeding Thresholds
(95th Percentile)	Summer	2010 Apr. 30 00:19	1 ppb dissolved aromatics = 74 400 km^2 (equivalent to 1ppm TPH)
Shoreline Oiling Effects (95th Percentile)	Summer	N/A	N/A

Source: RPS ASA 2014b

Figures 8.4.8 to 8.4.16 provide representative winter and summer, 30-day blowout, scenarios depicting surface oiling, total dissolved aromatics concentration, and shoreline oiling for Sites 1 and 2, as applicable. A description of these figures is provided below to assist with interpretation.

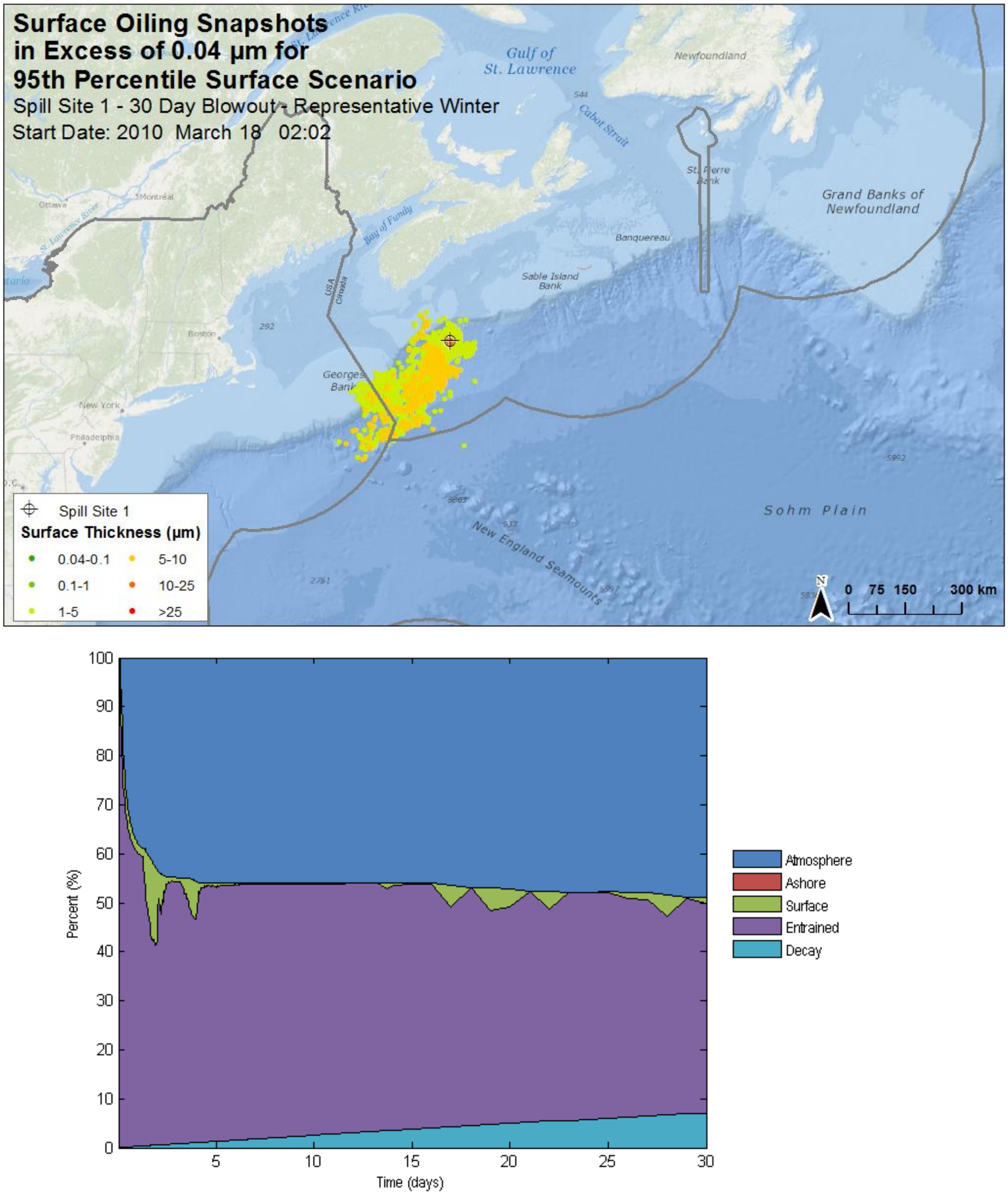
1. *Mass Balance Graphs:* The mass balance graphs provide an estimate of the oil's weathering and fate for a specific run for the entire model duration as a fraction of the oil spilled up to that point. Components of the oil tracked over time include the amount of oil on the sea surface, the total entrained hydrocarbons in the water column, amount of oil ashore, oil evaporated into the atmosphere, and that which has decayed (accounts for both photo-oxidation and biodegradation).
2. *Surface Oil Time Series Figures:* The figures show the footprint of maximum floating surface oil and the associated thicknesses (µm) at all-time steps during the individual 30-day spill simulation. Surface oil contamination figures show only thicknesses greater than 0.04 µm.
3. *Water Column Time Series Figures:* The figures show the footprint of maximum water column concentration of dissolved aromatics (ppb) at all-time steps during the individual 30-day spill simulation. Dissolved aromatics are the portion of the oil having the greatest potential to affect water column biota, and the footprints were typically smaller than the extent of total oil contamination in the water column. Water column contamination figures show only concentrations ≥1 ppb. Concentrations below 1 ppb are considered low and result in little water column impact.
4. *Shoreline Impact Figures:* Figure showing mass of oil deposited onto shoreline. Only shoreline oiling exceeding 1 µm, which is equivalent to 1 g/m^2, is depicted.

8.4.6.2 Surface Oiling Cases

Identified 95th percentile surface oiling scenarios had a maximum of approximately 10–20% of the total mass of the released oil on the surface at any one time (Figures 8.4.8 to 8.4.11). In general, strong wind and waves associated with winter conditions only had approximately 5–10% of the total mass of oil on the surface, while calmer summer conditions resulted in closer to 10–20% of the total mass of oil on the surface.

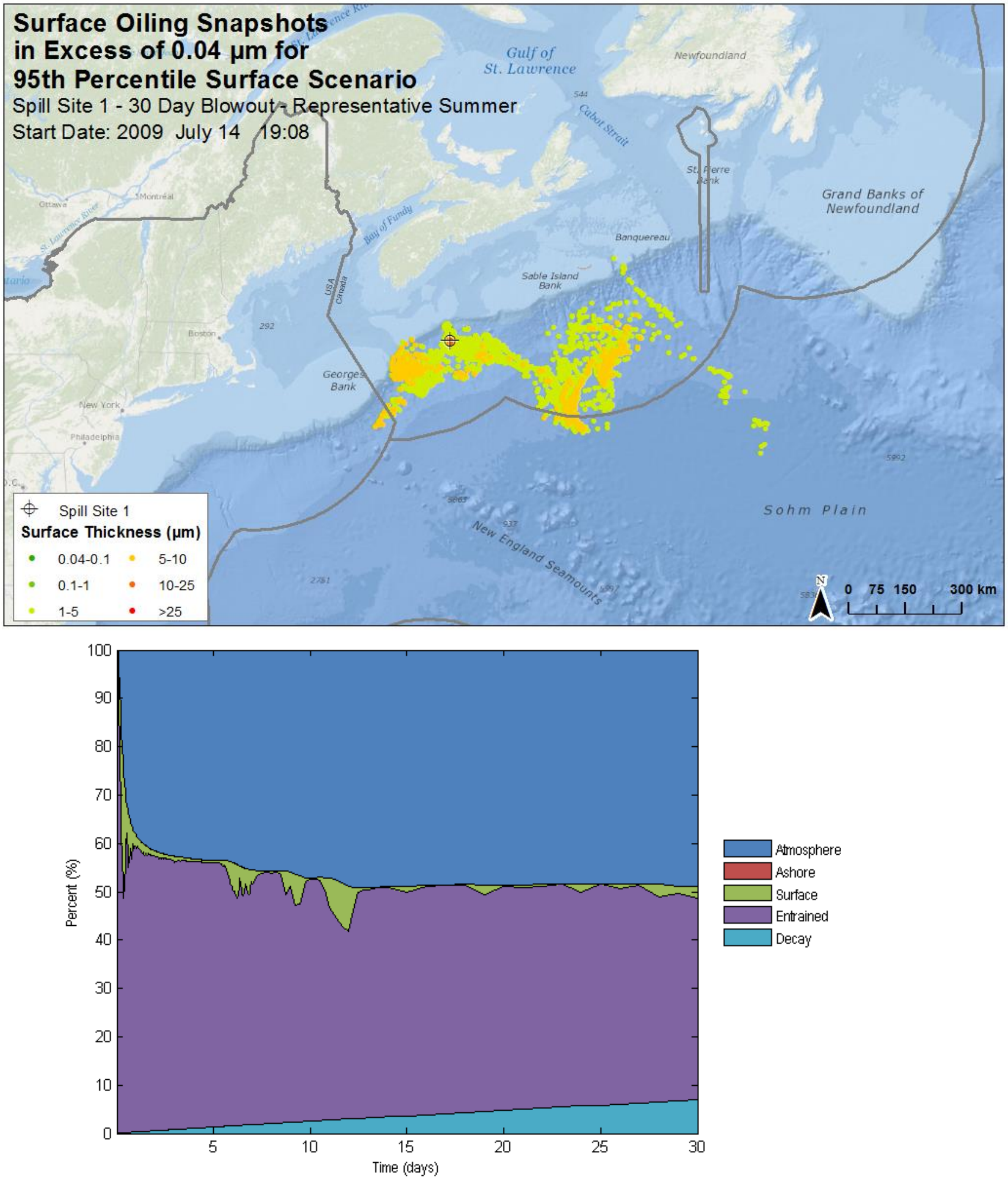
Federated crude oil is a relatively light product, with a high tendency to volatilize (evaporate into the atmosphere). For the winter scenarios, just under 50% of the total oil spilled evaporated into the atmosphere, while for the summer scenarios, just over 50% of the total oil spilled evaporates to the atmosphere. During winter conditions, lower temperatures (as opposed to summer) reduce weathering and evaporation rates, thus maintaining fresher and therefore lower viscosity oil. The higher wind speeds and associated waves result in significantly more entrainment during the winter months, forcing a larger percentage of surface oil into the water column, as small droplets, when compared to the summer.

Calmer summer conditions result in higher weathering and evaporation rates, which increases the surface oil viscosity and thickness, thus reducing the likelihood that oil will be entrained into the water column. Larger areas of surface oiling are more likely to be observed during the summer, the result of reduced entrainment and resulting surface transport. In general, only a small area of the surface water affected by oil exceeds the 1 µm threshold, as only 3–6% of the total areal coverage is in excess of 0.04 µm for Site 1, and 7–9% for Site 2. The higher values for the scenarios at Site 2 are the result of the larger volume of oil released (nearly double that of Site 1).



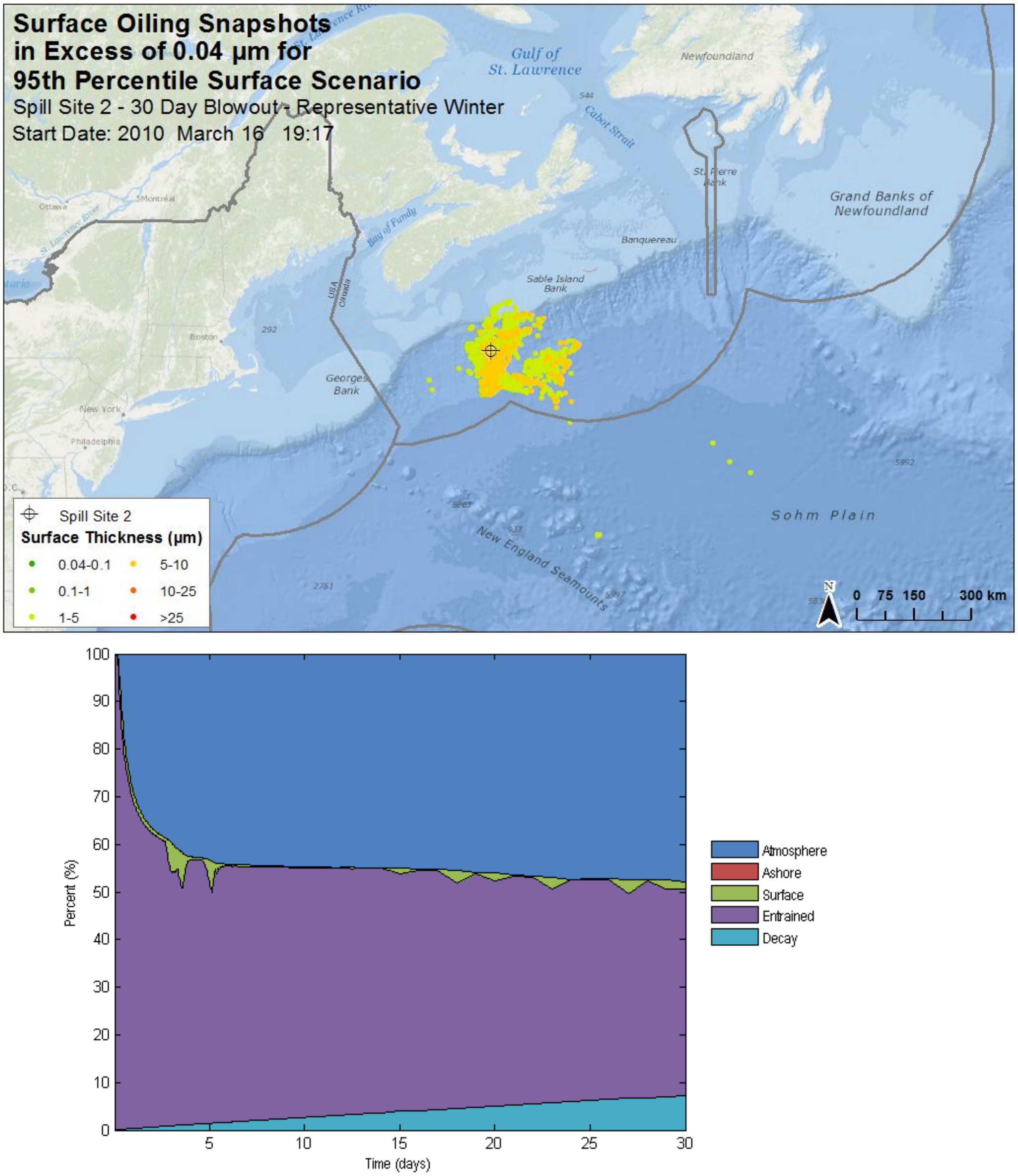
Source: RPS ASA 2014b

Figure 8.4.8 **Representative Site 1 winter deterministic scenario for 95th percentile surface oil thickness (top panel). The maximum thickness of surface oil in excess of 0.04 µm is displayed at all modelled time steps. The associated mass balance graph is included (bottom panel).**



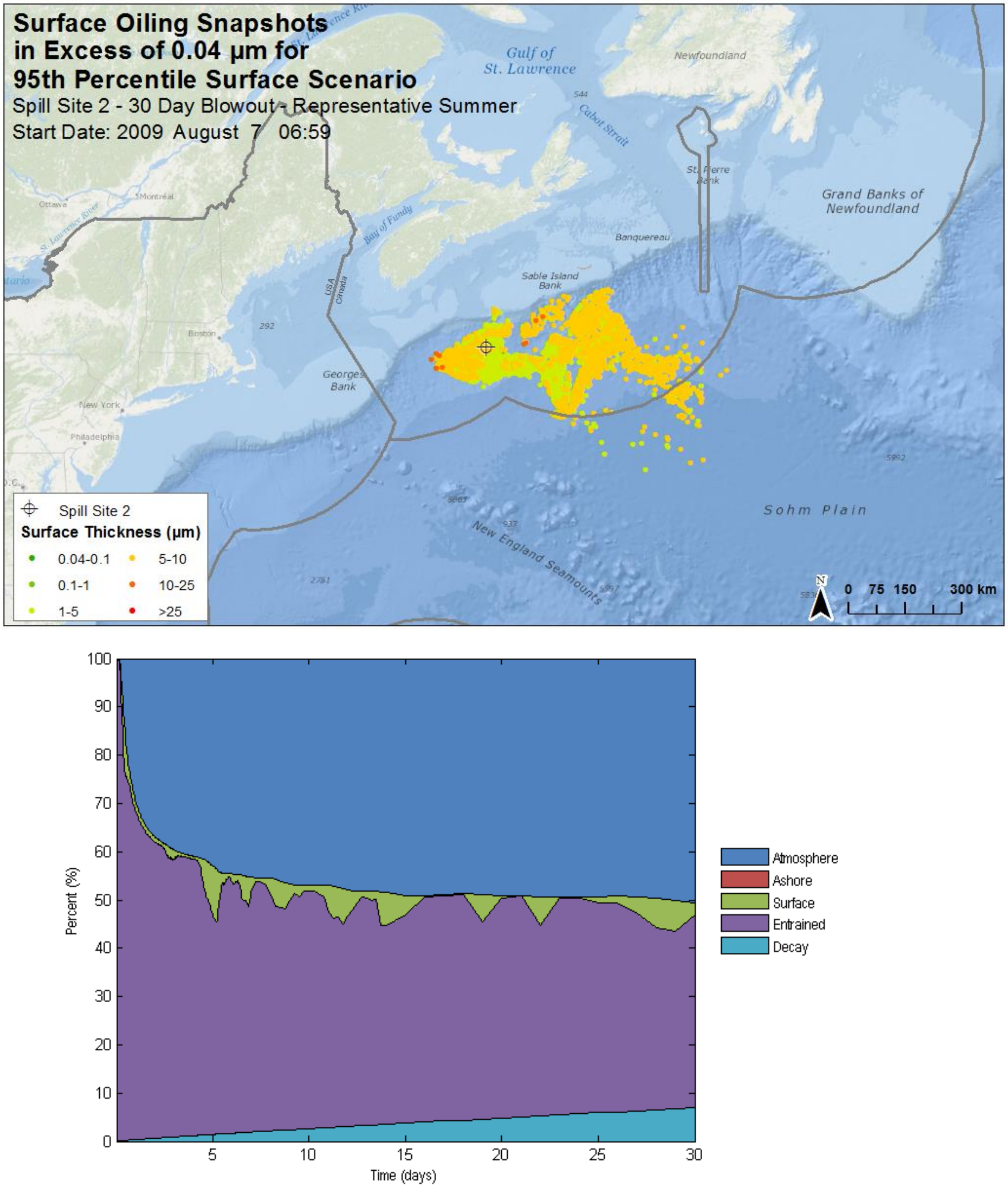
Source: RPS ASA 2014b

Figure 8.4.9 Representative Site 1 summer deterministic scenario for 95th percentile surface oil thickness (top panel). The maximum thickness of surface oil in excess of 0.04 µm is displayed at all modelled time steps. The associated mass balance graph is included (bottom panel).



Source: RPS ASA 2014b

Figure 8.4.10 Representative Site 2 winter deterministic scenario for 95th percentile surface oil thickness (top panel). The maximum thickness of surface oil in excess of 0.04 µm is displayed at all modelled time steps. The associated mass balance graph is included (bottom panel).



Source: RPS ASA 2014b

Figure 8.4.11 Representative Site 2 summer deterministic scenario for 95th percentile surface oil thickness (top panel). The maximum thickness of surface oil in excess of 0.04 µm is displayed at all modelled time steps. The associated mass balance graph is included (bottom panel).

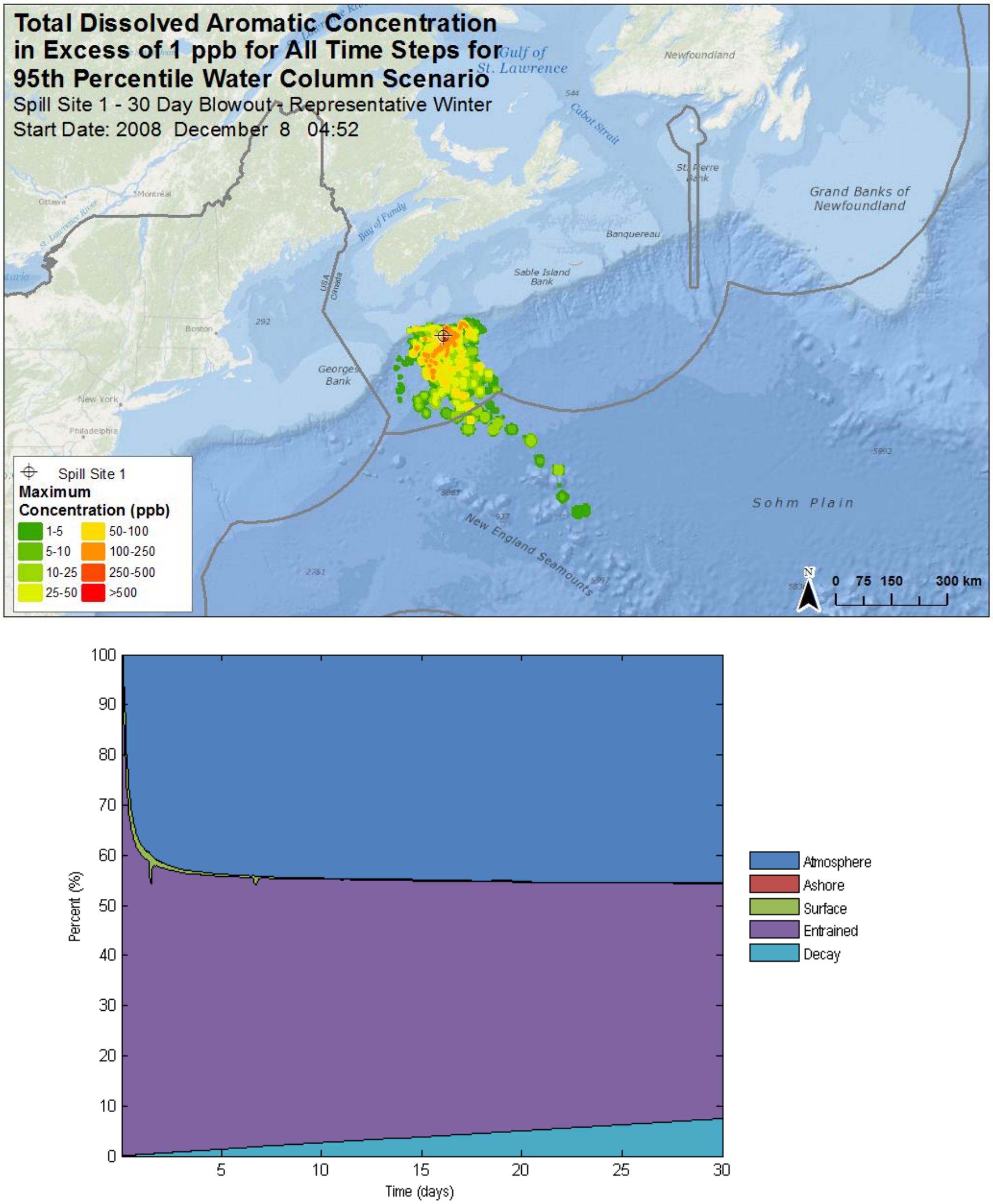
8.4.6.3 Dissolved Aromatics Exposure Cases

Identified 95th percentile water column dissolved aromatic exposure scenarios had regions of high dissolved aromatic concentrations localized around the well site, with the highest observed concentrations near the surface. Dissolved aromatic concentration in the water column dissipates as distance from the wellhead increases (Figures 8.4.12 to 8.4.15). The majority of dissolved aromatics are in the surface mixed layer, a layer that is roughly 50–100 m deep throughout the year. The large oil droplet sizes, defined by the release scenario, result in rapid rise velocities that carry oil quickly to the surface. Some high solubility fractions may dissolve at depth, however the majority of the soluble portion of the oil is found at and near the surface, where soluble aromatics in surface oil and entrained oil droplets (that may be re-entrained from wave action) dissolve into the water column. Greater than 50% of the total mass of released oil (total hydrocarbons, of which the dissolved aromatics are a small portion) is expected within the water column.

During winter conditions, a little less than 50% of the total spilled oil is observed to evaporate into the atmosphere. A portion of this volatile fraction dissolves, and results in slightly more dissolved aromatic mass in the water column. However, the increased wind and waves in winter dissipates this mass over a larger volume, resulting in concentrations >1ppb over a large area (Figures 8.4.12 and 8.4.14).

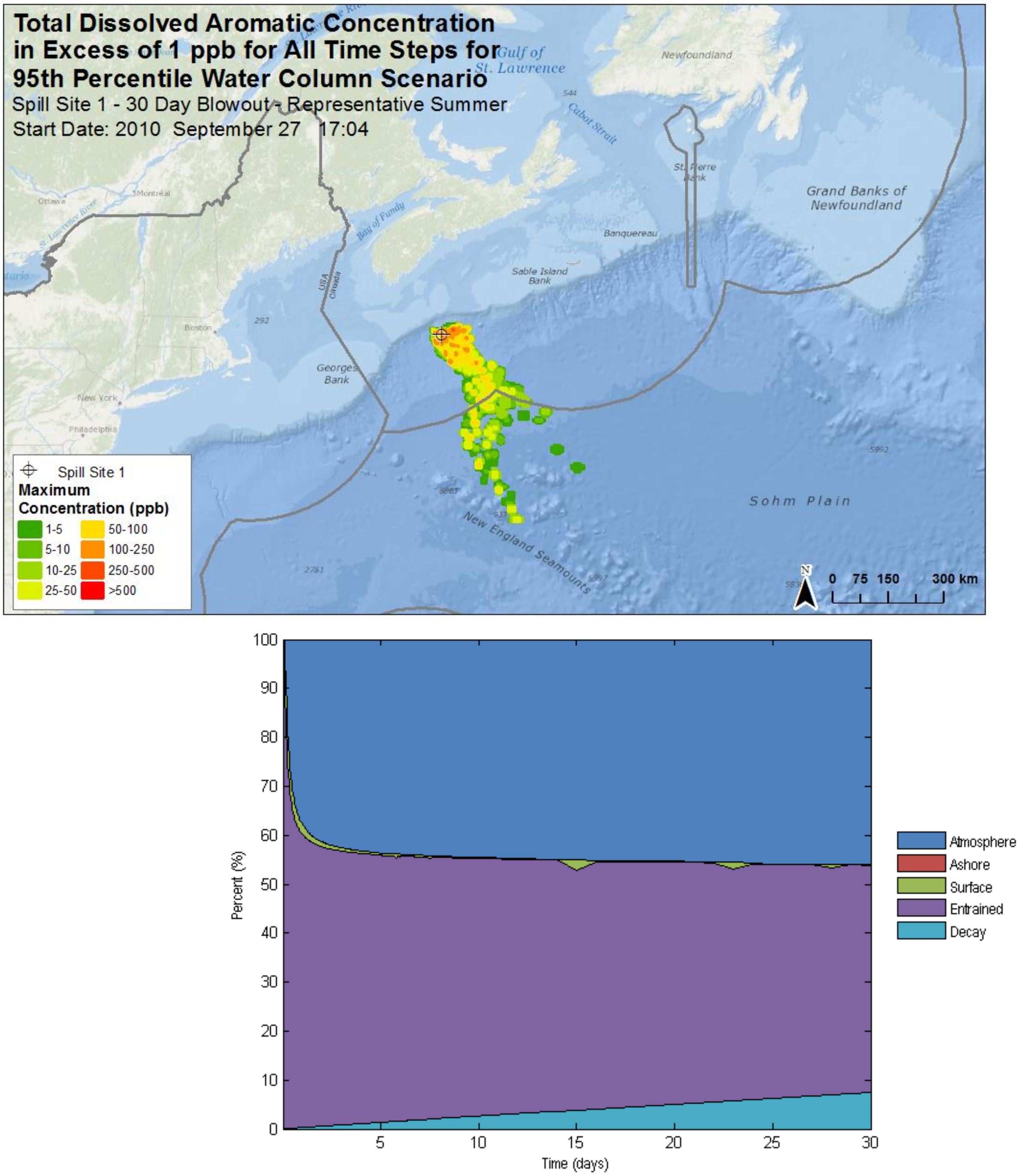
Conversely, during calmer summer conditions, enhanced evaporation results in just over 50% of the total spilled oil in the atmosphere. Decreased wind and wave action during the summer results in slightly less mass of dissolved aromatics in the water column. However, reduced transport localizes this mass, resulting in slightly higher concentrations of dissolved aromatics in the water column over a smaller area during the summer (Figures 8.4.13 and 8.4.15).

Large areas of the surface mixed-layer experience a concentration of dissolved aromatics in excess of 1 ppb at some point during each 30 day scenario. Less than 2% of this area is, however, in excess of 15 ppm total petroleum hydrocarbons (TPH), and an even smaller portion is in excess of 30 ppm TPH. The areal extent of water column concentration threshold exceedance (>1 ppb) is greater for Site 2, as the modelled volume of oil released into the environment was double that for Site 1.



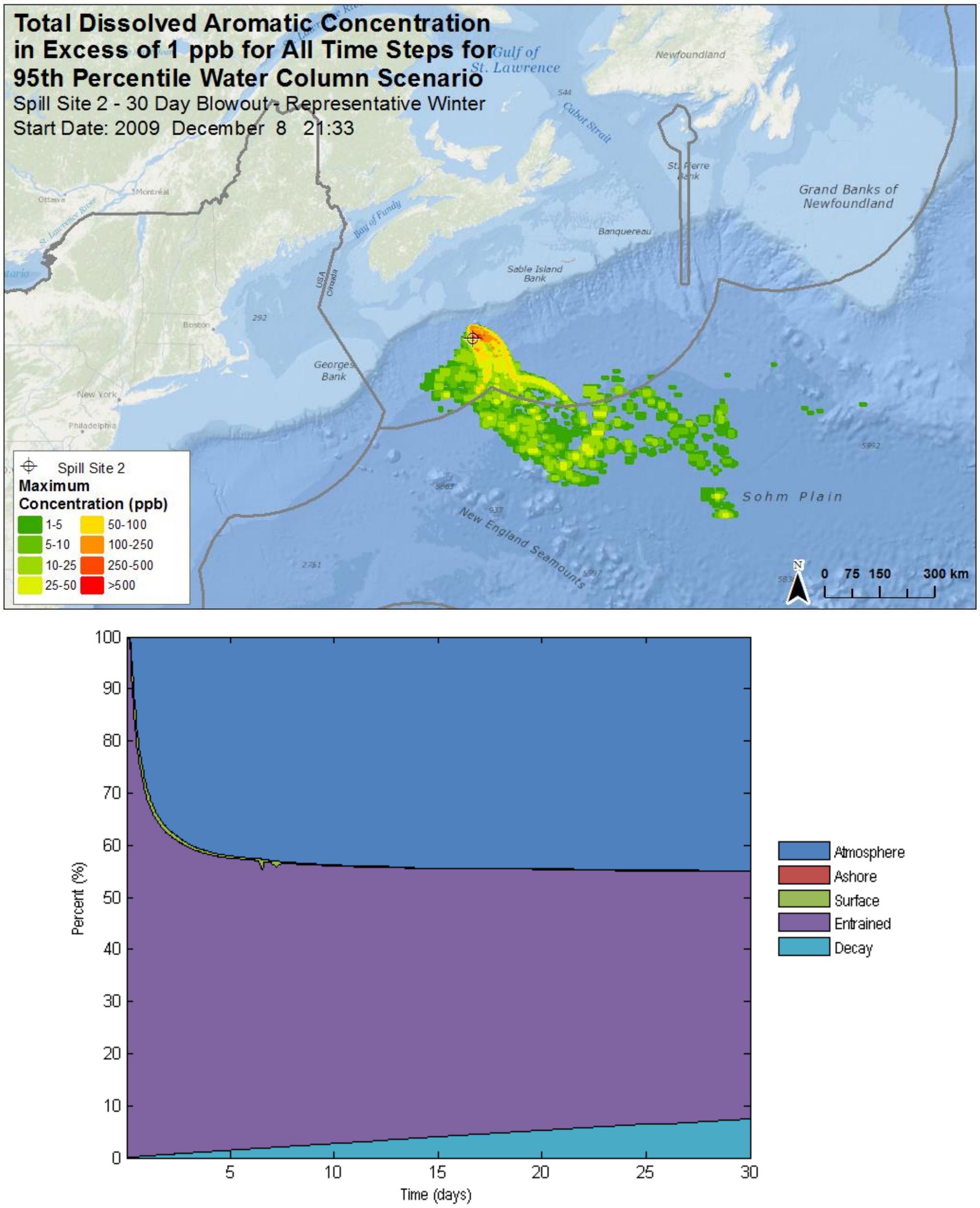
Source: RPS ASA 2014b

Figure 8.4.12 **Representative Site 1 winter deterministic scenario for 95th percentile water column dissolved aromatic concentration (top panel). The maximum concentration of dissolved aromatics in excess of 1ppb is displayed at all modelled time steps. The associated mass balance graph is included (bottom panel).**



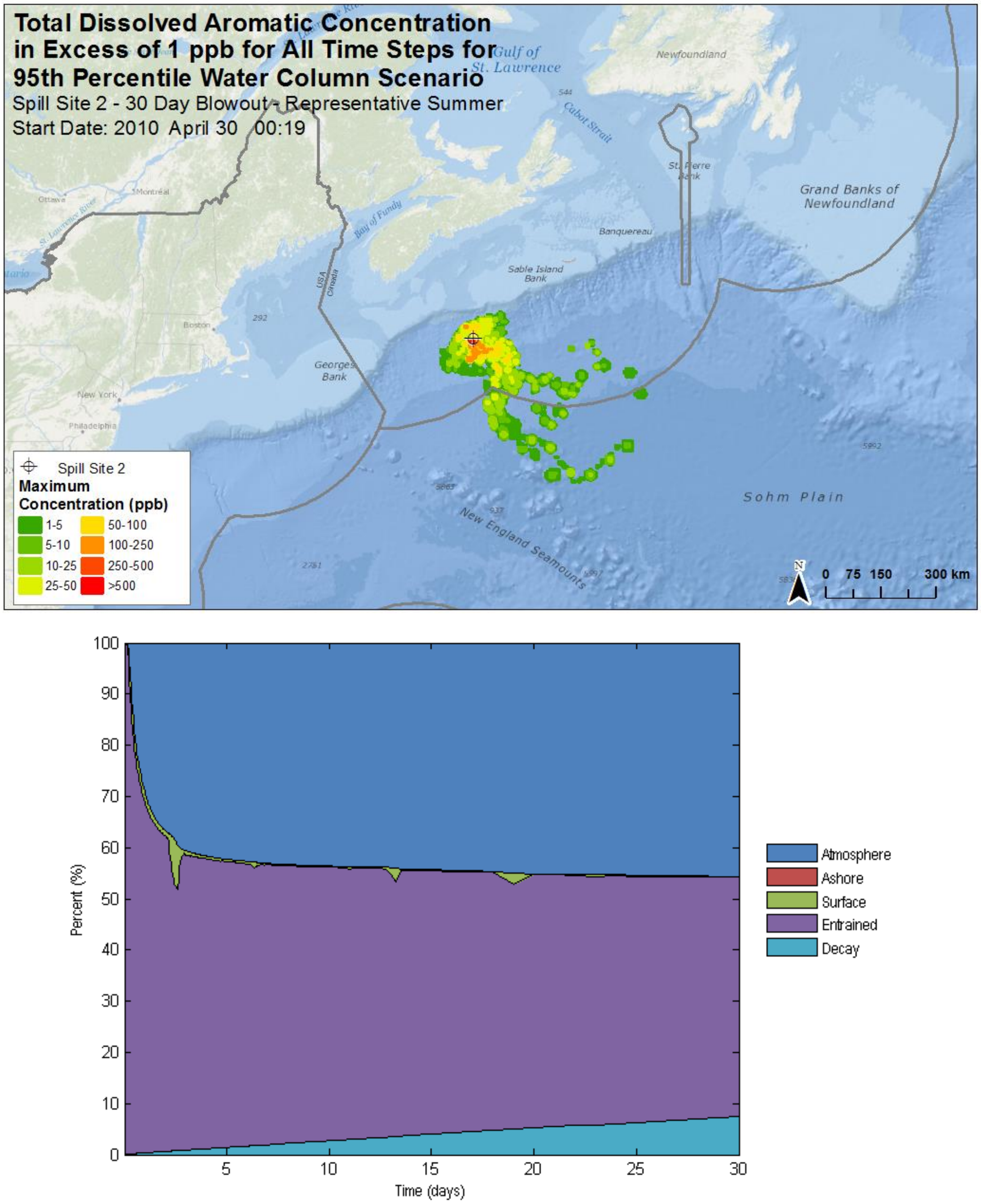
Source: RPS ASA 2014b

Figure 8.4.13 Representative Site 1 summer deterministic scenario for 95th percentile water column dissolved aromatic concentration (top panel). The maximum concentration of dissolved aromatics in excess of 1ppb is displayed at all modelled time steps. The associated mass balance graph is included (bottom panel).



Source: RPS ASA 2014b

Figure 8.4.14 Representative Site 2 winter deterministic scenario for 95th percentile water column dissolved aromatic concentration (top panel). The maximum concentration of dissolved aromatics in excess of 1ppb is displayed at all modelled time steps. The associated mass balance graph is included (bottom panel).



Source: RPS ASA 2014b

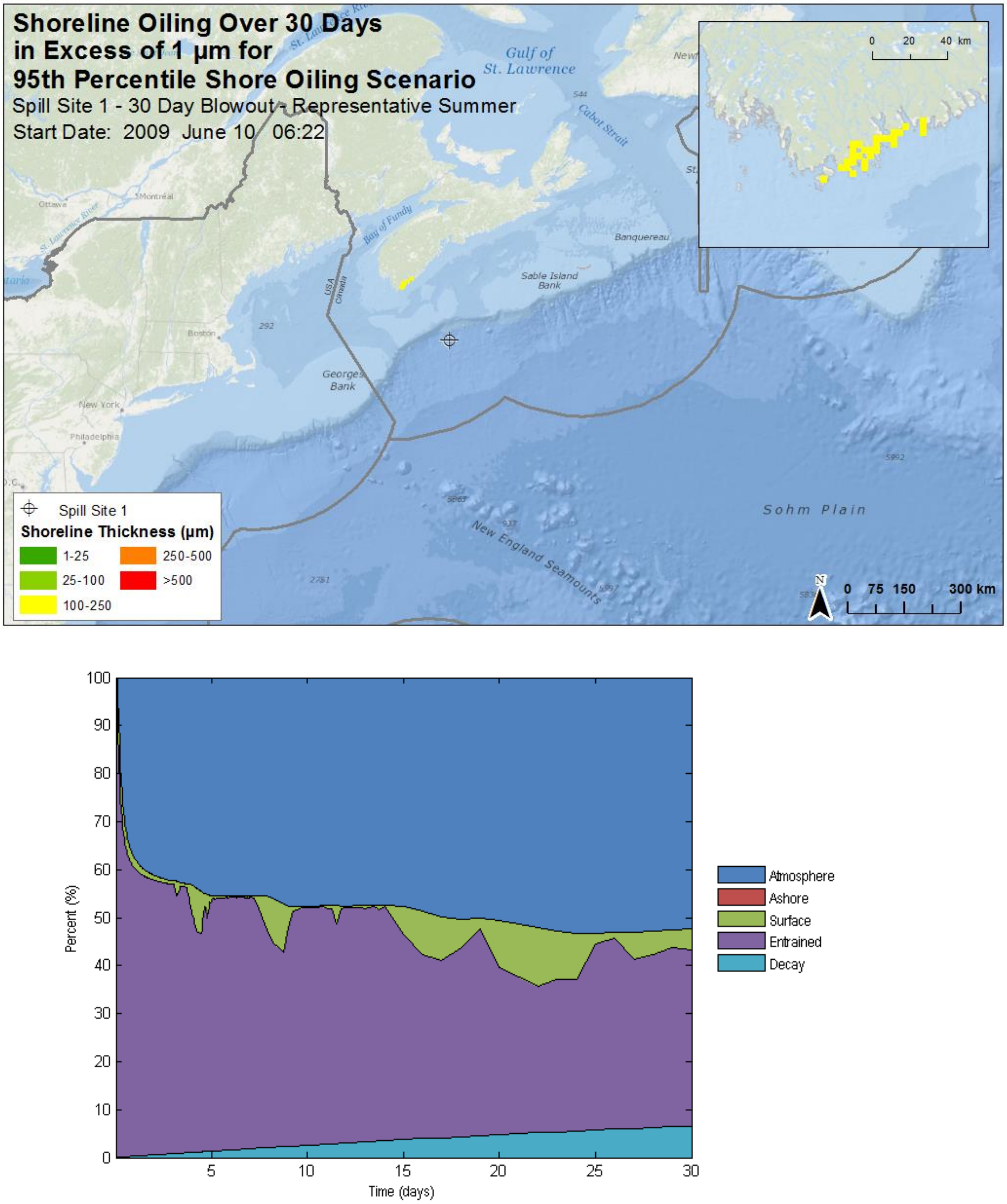
Figure 8.4.15 Representative Site 2 summer deterministic scenario for 95th percentile water column dissolved aromatic concentration (top). The maximum concentration of dissolved aromatics in excess of 1ppb is displayed at all modelled time steps. The associated mass balance graph is included (bottom).

8.4.6.4 Shoreline Oiling

The probability of shoreline oiling was very low for the modelled scenarios, between 0.83 and1.88%. Only 9, of the 480 30-day continuous blowout scenarios modelled for the Site 1 release, and only 4 scenarios out of 480 modelled for the Site 2 release resulted in any shoreline oiling. All shoreline oiling cases occurred during the summer season, limited to the months of May, June, and July. It is expected that the oil that would strand would be highly weathered, as the minimum time to shore would be between 20 and 30 days. The regions susceptible to potential shoreline oiling within 30 days from a release at Site 1 include the southern tip of Nova Scotia, including the Yarmouth, Barrington, and Shelburne region, as well as Sable Island National Park Reserve. The region susceptible to potential shoreline oiling within 30 days from a release at Site 2 includes only the Sable Island National Park Reserve.

The reason that shoreline oiling is so unlikely is a combination of the forcing parameters for surface oil and the location of the release. The modelled sites are far offshore and oil would need to remain on the surface for one month or more to be transported the hundreds of kilometres towards shore. Furthermore, the predominantly westerly winds would transport surface oil away from the coast and variable surface currents do not continuously transport surface oil in any one specific direction for significant periods of time. During calmer summer conditions, where a higher percentage of oil remains on the surface, there is a slightly increased probability (although still very low likelihood) that winds may come from the east and northeast, thus transporting surface oil towards land.

The identified 95th percentile shoreline oiling scenario for the Site 1 release predicted that 10–20% of the oil would be on the surface for nearly 15 days (Figure 8.4.16). In combination with reduced wind speeds and favourable direction, the scenario resulted in measurable oiling of the southern tip of Nova Scotia, including the Barrington and Shelburne region. The result was an expected thickness of shoreline oiling of between 100–250 μm, which would be observed as a dark brown colour, totalling approximately 16.5 MT.



Source: RPS ASA 2014b

Figure 8.4.16 Representative Site 1 summer deterministic scenario for 95th percentile shoreline oiling (top panel). The associated mass balance graph is included (bottom panel)

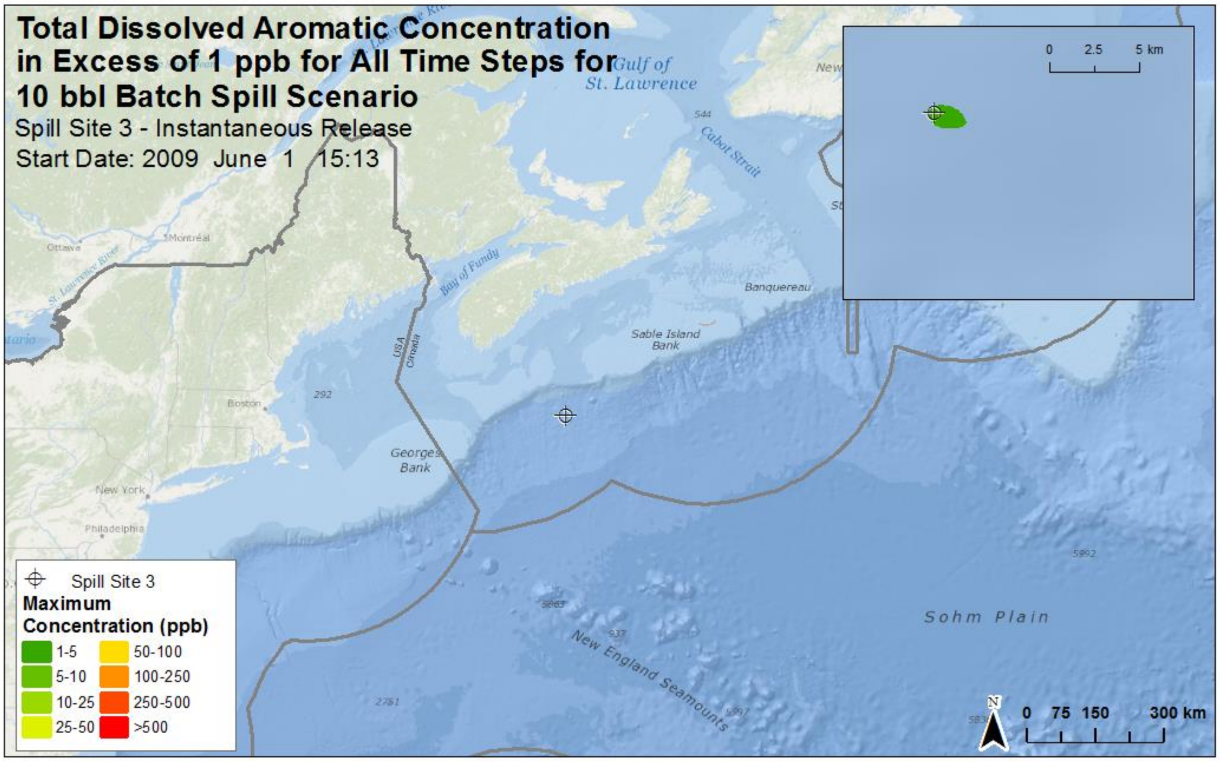
8.4.7 Oil Fates Results for Batch Spills of Marine Diesel

To simulate accidental discharges from operational vessels, two batch spills of marine diesel were modelled as surface releases using deterministic modelling. Marine diesel is a standard diesel that has a low viscosity and high aromatic content. Releases of 10 bbl and 100 bbl were modelled for 30 days following a summer release at Site 3 (Figures 8.4.17 and 8.4.18). Both releases resulted in limited modelled effects, particularly when compared to the much larger continuous blowout scenarios.

The thickness of the slick at the instant of release is greater than 25 µm. As the fresh diesel spreads, it thins to a sheen thickness, between 0.04 µm and 0.1 µm, where high rates of evaporation occur.

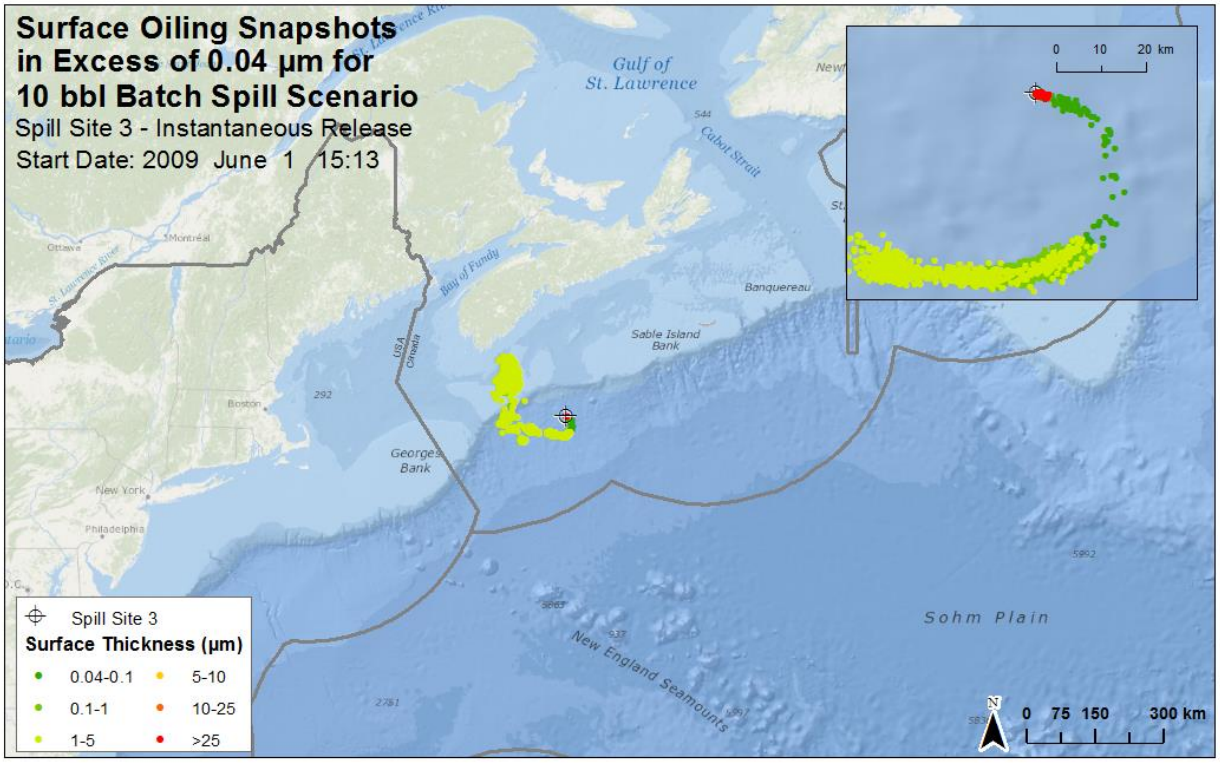
For both scenarios a total of approximately 80% of the diesel oil evaporated from the surface, within the first two to three days following release. The area of surface water exposure in excess of 1 ppb of total dissolved aromatics was approximately 2 km^2 for the 10 bbl release and approximately 20 km^2 for the 100 bbl release. A maximum of 1–5 ppb is expected for the 10 bbl release, and localized concentrations potentially exceeding 25 ppb may occur in the region directly surrounding the spill site for the 100 bbl release.

A swath of surface oiling in excess of 0.04 µm resulted from both releases extending roughly 100 km to the west and 100 km to the north. However, this is the result of a small proportion of the release, the residual oil with a thickness of approximately 1 µm, being transported by surface currents during this calmer period where a higher percentage of oil remains on the surface. Because the surface snapshot includes all time steps, the relatively few particles are swept to the west and north, appearing as a large and continuous swath. In reality, this swept area would be exposed to patchy sheen and weathered oil. None of the batch spills are predicted to reach the Nova Scotia shoreline.



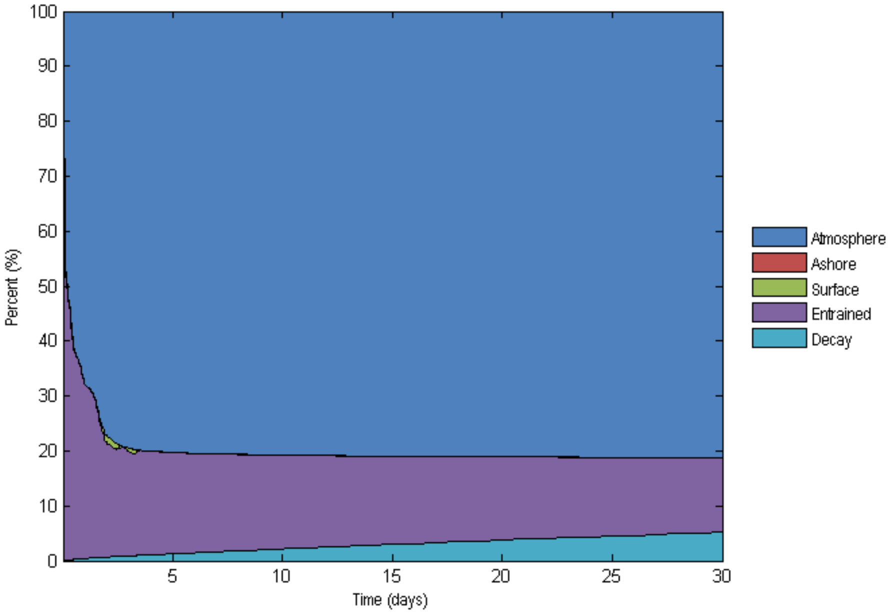
Total Dissolved Aromatic Concentration in Excess of 1 ppb for All Time Steps for 10 bbl Batch Spill Scenario

Spill Site 3 - Instantaneous Release
Start Date: 2009 June 1 15:13



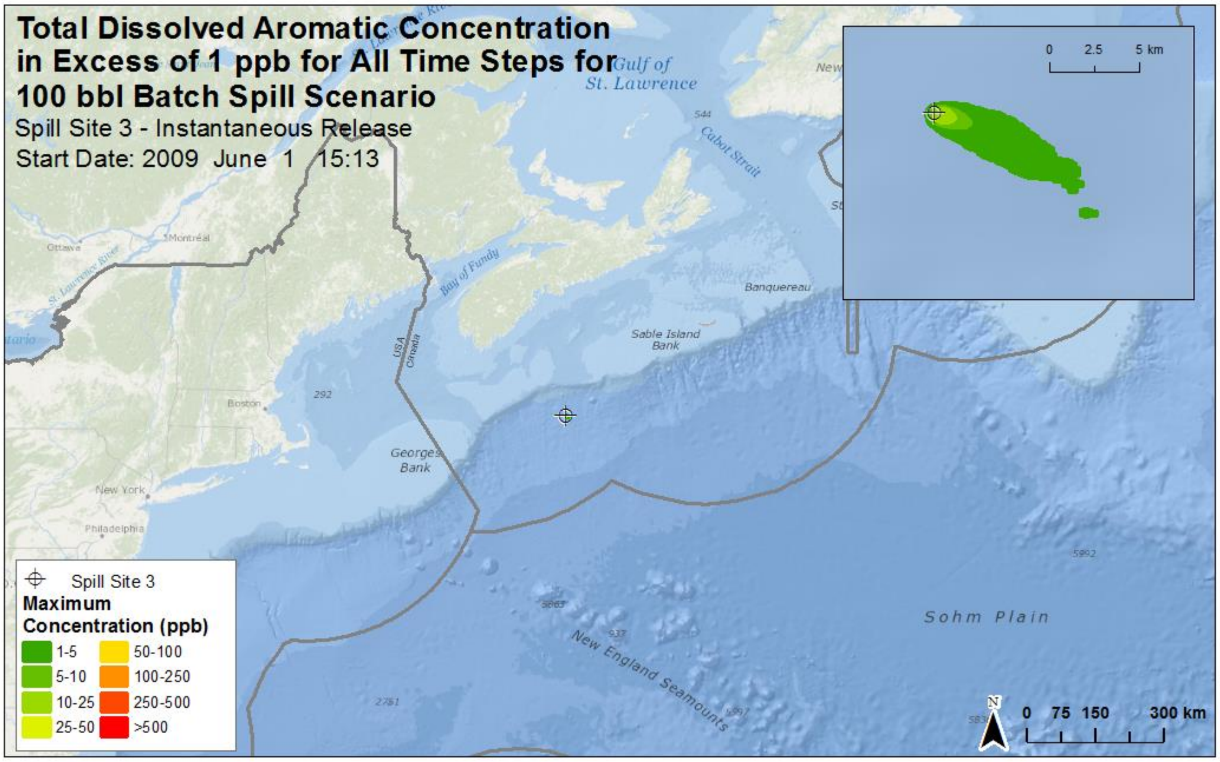
Surface Oiling Snapshots in Excess of 0.04 µm for 10 bbl Batch Spill Scenario

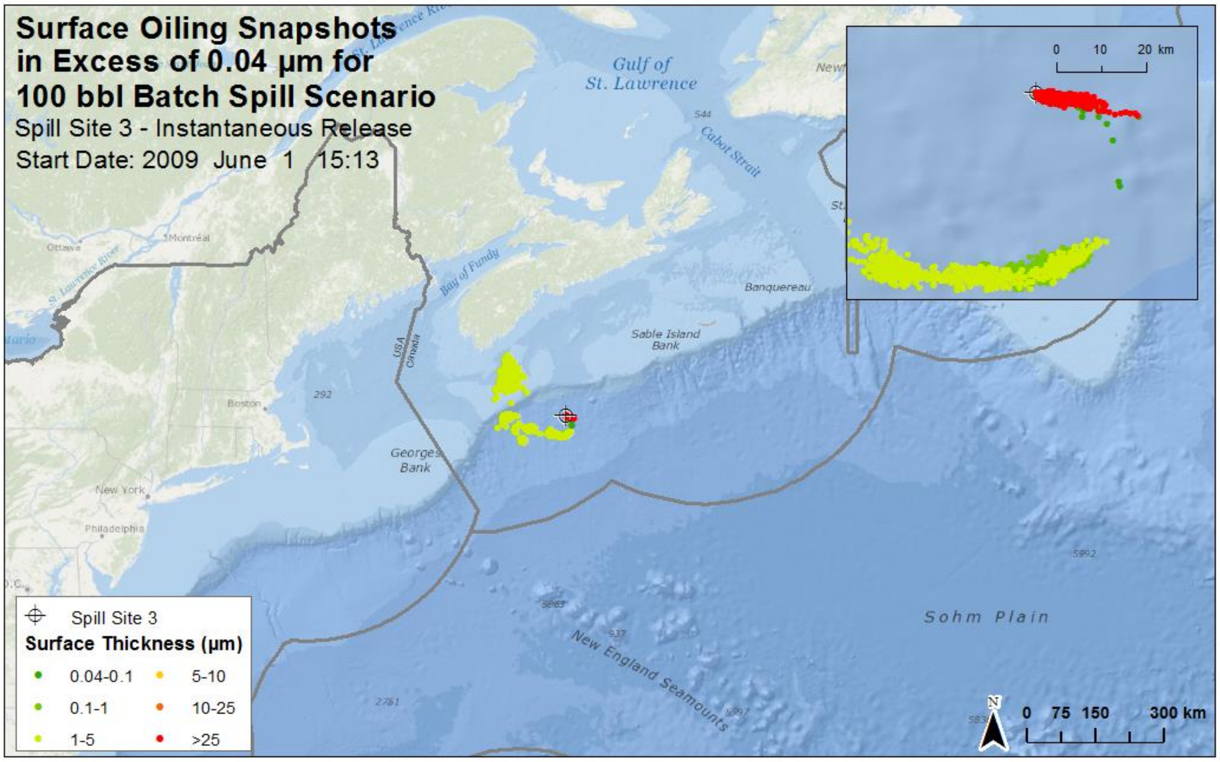
Spill Site 3 - Instantaneous Release
Start Date: 2009 June 1 15:13

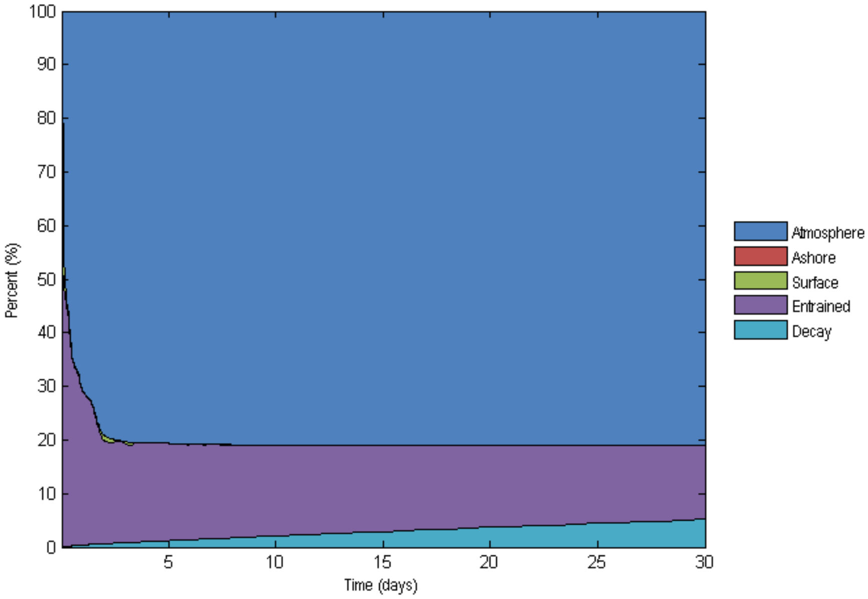


Source: RPS ASA 2014b

Figure 8.4.17 The total dissolved aromatic concentration in excess of 1ppb is depicted for the 10 bbl batch diesel spill at Site 3 (top panel), along with the associated surface thickness that is expected over the modelled 30 day period (middle panel). The associated mass balance graph is included (bottom panel).


Total Dissolved Aromatic Concentration
in Excess of 1 ppb for All Time Steps for
100 bbl Batch Spill Scenario
Spill Site 3 - Instantaneous Release
Start Date: 2009 June 1 15:13
Gulf of St. Lawrence
Cabot Strait
Bay of Fundy
Banquereau
Sable Island Bank
Georges Bank
USA Canada
Montréal
Ottawa
Boston
New York
Philadelphia
Sohm Plain
New England Seamounts
0 2.5 5 km
Spill Site 3
Maximum Concentration (ppb)
1-5
5-10
10-25
25-50
50-100
100-250
250-500
>500
N
0 75 150 300 km


Surface Oiling Snapshots
in Excess of 0.04 µm for
100 bbl Batch Spill Scenario
Spill Site 3 - Instantaneous Release
Start Date: 2009 June 1 15:13
Gulf of St. Lawrence
Cabot Strait
Bay of Fundy
Banquereau
Sable Island Bank
Georges Bank
USA Canada
Montréal
Ottawa
Boston
New York
Philadelphia
Sohm Plain
New England Seamounts
0 10 20 km
Spill Site 3
Surface Thickness (µm)
0.04-0.1
0.1-1
1-5
5-10
10-25
>25
N
0 75 150 300 km



Source: RPS ASA 2014b

Figure 8.4.18 The total dissolved aromatic concentration in excess of 1ppb is depicted for the 100 bbl batch diesel spill at Site 3 (top panel), along with the associated surface thickness that is expected over the modelled 30 day period (middle panel). The associated mass balance graph is included (bottom panel).

8.4.8 Summary of Results for Blowout and Batch Spill Modelling

Surface oiling and water column dissolved aromatic footprints from the unmitigated, 30-day release blowout scenarios (*i.e.*, no oil spill containment, recovery and shoreline protection operations) were similar across months, with transport predominantly to the east and northeast of the spill sites. A general trend was, however, observed in the results, with winter-type conditions from October through March, and summer-type conditions from April through September. During winter conditions, oil was more likely to be transported to the east, than in the summer, while under summer conditions transport was uniformly multi-directional; both patterns were consistent with hydrodynamic and wind forcing patterns throughout the year.

Higher percentages of the released oil were found within the water column during winter months; the result of increased wind and wave action, which entrains surface oil droplets into the water column. Conversely, the greatest surface oiling occurred during summer months, with calmer conditions reducing entrainment from wind and waves. Following an unmitigated release, a higher likelihood of shoreline oiling would occur during the summer months, when greater surface oiling and resulting transport may occur, given more consistent lower velocity winds that do not entrain the oil than may be expected in winter conditions. The probability of shoreline oiling was, however, very low for the modelled scenarios, between 0.83 and 1.88%, and was only observed during May, June, and July model runs.

The overall rate and extent of evaporation and degradation remained relatively consistent between model runs. The majority of mass balance variability was observed in the amount of oil either on the surface or within the water column. The maximum surface oiling scenarios resulted in approximately 10–20% of the total mass of released oil on the surface and 30–40% entrained, while the maximum water column dissolved aromatic scenarios had little surface oiling and closer to 50% was entrained in the water column. Following an incident, the majority of dissolved aromatics would be confined to the surface mixed layer, to a depth of between 50 and100 m throughout the year. Higher concentrations would occur in areas immediately surrounding the wellhead.

Accidental discharges of marine diesel resulted in limited spatial effects. Approximately 80% of the two batch spill releases evaporated within the first 2–3 days, with approximately 2 km^2 and 20 km^2 experiencing in-water concentrations of dissolved aromatics in excess of the threshold concentration 1 ppb at any time for the 10 bbl and 100 bbl spill, respectively. A portion of weathered diesel may continue to be transported at the surface for some distance (100 km); however the surface oil would likely be small in areal extent and patchy.

8.4.9 Modelling of SBM Whole Mud Spill

MUDMAP was used to predict seabed deposition and concentrations of total suspended solids (TSS) in the water column at drilling Sites 1 and 2 as a result of the accidental releases of SBM. The results of this modelling (RPS ASA 2014a) are presented in Section 4.2 of Appendix C of this EIS. The following text has been excerpted from the full report. Two deterministic scenarios were performed at each site (4 total) representing different release depths and corresponding SBM volumes. The mode of release and associated model parameters are summarized in Table 8.4.6. For each scenario, the release of SBM was assumed to occur near-instantaneously (over the course of several minutes). Releases were simulated during periods of current minima (late spring) to replicate conditions that would result in higher and more sustained plume concentrations. Following each release, the model continued to track the transport and dispersion of the plume until the maximum concentrations declined below 1 mg/L (~1 ppm).

Table 8.4.6 Summary of Model Parameters used to Characterize the Accidental Release of SBM at Sites 1 and 2

Model Scenario	Discharge Period	Mode of Release	Mud Volume (m^3)	Mud Type	Release Location
Drill Site 1					
SBM-1	1-Jun 2012	Marine Riser	573	Rheliant SBM	5 m above seafloor
SBM-2	1-Jun 2012	Mud Tank	60	Rheliant SBM	2 m below MODU

Table 8.4.6 Summary of Model Parameters used to Characterize the Accidental Release of SBM at Sites 1 and 2

Model Scenario	Discharge Period	Mode of Release	Mud Volume (m^3)	Mud Type	Release Location
Drill Site 2					
SBM-3	1-Jun 2012	Marine Riser	573	Rheliant SBM	5 m above seafloor
SBM-4	1-Jun 2012	Mud Tank	60	Rheliant SBM	2 m below MDU

Given the relatively small release volumes and fine particle sizes associated with the SBM, the sea surface releases (60 m^3) quickly disperse below levels detectible by the model. As a consequence they do not contribute to the mass accumulation on the seabed. Deposition resulting from the (573 m^3) SBM releases at the seabed is limited to thicknesses below 10 mm at both sites. Contours of 1 mm thickness extend up to 690 m from the release sites, and cover a maximum area of 0.27 ha of the seabed. Table 8.4.7 and Table 8.4.8 summarize the extent of deposition associated with each SBM release scenario.

Table 8.4.7 Areal Extent of Seabed Deposition (By Thickness Interval) for SBM release Scenarios

Deposition Thickness (mm)	Cumulative Area Exceeding (ha)			
	SBM-1 (Site 1, 573 m^3)	SBM-2 (Site 1, 60 m^3)	SBM-3 (Site 2, 573 m^3)	SBM-4 (Site 2, 60 m^3)
0.1	**21.001**	**0**	**19.145**	**0**
0.2	7.875	0	7.057	0
0.5	0.639	0	0.569	0
1	**0.269**	**0**	**0.25**	**0**
2	0.13	0	0.13	0
5	0.03	0	0.03	0
10	**0**	**0**	**0**	**0**
20	0	0	0	0
50	0	0	0	0
100	**0**	**0**	**0**	**0**
200	0	0	0	0
500	0	0	0	0

Table 8.4.8 Maximum Extent of Thickness Contours (distance from release site) for SBM Release Scenarios

Deposition Thickness (mm)	Maximum extent from discharge point (m)			
	SBM-1 (Site 1, 573 m^3)	SBM-2 (Site 1, 60 m^3)	SBM-3 (Site 2, 573 m^3)	SBM-4 (Site 2, 60 m^3)
0.1	657	0	690	0
1	40	0	41	0
10	0	0	0	0
100	0	0	0	0
500	0	0	0	0

Table 8.4.9 summarizes the maximum distance of observed excess water column concentrations for each of the four scenarios. Sediment plumes resulting from the accidental discharges of SBM are predicted to extend between 5080 m and 9620 m from the release site. As with the patterns of deposition, the extent of the plume and maximum TSS concentration are larger for the releases associated with the marine riser as compared to the surface discharges. The maximum predicted concentration of suspended sediments in the water column (corresponding to the weakest current regime) is 29 401 mg/L for the marine riser discharge and 2424 mg/L for the surface release. The slow settling velocities of the SBM and the current speeds at the sea surface cause most of the suspended sediment released from the MODU to remain within the uppermost 10–20 m of the water column.

Table 8.4.9 Maximum Distance of Excess Water Column Concentrations for each SBM Discharge Scenario

Water Column Concentration (mg/L)	Distance from Discharge Point (m)			
	SBM-1	SBM-2	SBM-3	SBM-4
1	5450	5080	9620	5310
10	1680	1550	3230	1590
100	616	284	749	320
1000	153	39	177	41
10000	32	–	33	–

For all scenarios, the SBM plume migrates from the release site immediately after the discharge event terminates. The plume travels with ambient currents until dispersion and turbulence cause the TSS concentrations to fall below the 1 mg/L threshold. Table 8.4.10 lists the distance travelled by the plume at instantaneous time steps, until water column concentrations are no longer detected. To this end, the stronger current regime at the surface has the effect of clearing the water column more quickly than weaker and more variable flow at depth. In all cases, the water column is predicted to return to ambient conditions (<1 mg/L) within 30 hours of the release.

Table 8.4.10 Instantaneous Distance Traveled by the Plume for Each SBM Discharge Scenario

Time from Start of Discharge	Distance from discharge point (m)			
	SBM-1	SBM-2	SBM-3	SBM-4
1 h	704	868	776	915
2 h	1100	1500	1250	1500
4 h	1690	2540	2070	2550
8 h	2310	3770	3810	4400
12 h	2850	4720	5270	5220
16 h	3770	–	6430	–
20 h	4070	–	7900	–
24 h	4410	–	9200	–
max distance*	5450	5080	9620	5310

*represents the maximum distance of water column concentrations observed above 1 mg/L; corresponds to the following time steps: Scenario SBM-1 (30 h 4 min), SBM-2 (15 h 24 min), SBM-3 (27 h 30 min), SBM-4 (12 h 10 min).

8.5 ACCIDENTAL EVENTS EFFECTS ASSESSMENT

The potential accidental events identified in Section 8.2 could affect Fish and Fish Habitat, Marine Mammals and Sea Turtles, Marine Birds, Special Areas, Commercial Fisheries, and the Current Aboriginal Use of Lands and Resources for Traditional Purposes.

Results of spill modelling (Refer to Section 8.4 and Appendices C and G) demonstrate that the geographic extent of an unmitigated spill will most likely be limited within the RAA. It is possible, however, that some blowout spill scenarios could result in some oil extending beyond the boundaries of the RAA. To be conservative, this potential has been considered in the individual VC assessments below, where relevant. The temporal boundaries for the assessment include the periods of mobilization, operations, and decommissioning/ abandonment. Up to seven exploration wells will be drilled sequentially over a four-year period, with each well taking up to 130 days to drill.

For each VC, the assessment considers those accident scenarios for which interactions are identified in Table 8.5.1. In identifying interactions between the VC and a potential accident scenario, a worst-case event was assumed as described in Section 8.2. In addition, unlike the approach taken with routine Project activities, no rating of the likely effects associated with these interactions has been conducted. For routine events, where past experience and professional judgment indicates that the resulting environmental effect is not significant and can be managed to acceptable levels through standard operating procedures and/or through the application of best management or codified practices, no further assessment is warranted. However, for accidental events, it is recognized that the range of circumstances under which these may occur and their unpredictability as an unplanned event make it difficult to characterize their potential effects without further assessment. In addition, given regulatory and stakeholder concern over the potential consequences of accidental events, assessment of all interactions is warranted.

As part of the assessment methods, environmental effects mechanisms are identified and discussed, including a review of available research and scientific data on these effect mechanisms. VC-specific mitigation has been identified where appropriate, although for some VCs the focus is on accident prevention and response procedures as outlined in Section 8.1. Spill modelling results presented in Section 8.4 and Appendices C and G are for unmitigated events (*i.e.*, no oil spill containment, recovery and shoreline protection operations), which adds another element of conservatism to the effects assessment. Residual effects are characterized in residual effect summary tables. The significance of residual effects is determined using the same VC-specific thresholds for determining the significance of residual environmental effects as used for routine Project activities (refer to Sections 7.2 to 7.7).

Table 8.5.1 Potential for Interactions between VCs and Accidental Event Scenarios

Accident Scenarios	VCs					
	Fish and Fish Habitat	Marine Mammals and Sea Turtles	Marine Birds	Special Areas	Commercial Fisheries	Current Aboriginal Use of Lands and Resources for Traditional Purposes
100 bbl batch spill	✓	✓	✓	✓	✓	✓
10 bbl batch spill	✓	✓	✓	✓	✓	✓
Vessel spill	✓	✓	✓	✓	✓	✓
SBM whole mud spill	✓	✓	✓	✓	✓	✓
Well blowout	✓	✓	✓	✓	✓	✓

8.5.1 Fish and Fish Habitat

As described in Section 5.2.3, the distribution of most fish species varies seasonally in response to physical or chemical changes in the surrounding environment (*e.g.*, depth, substrate, salinity, temperature) and is a result of seasonal habitat requirements (*e.g.*, spawning, feeding). Long annual migrations are undertaken by most pelagic species.

The Project Area, LAA, and RAA provide habitat for a variety of benthic, demersal, and pelagic fish species, including 26 populations identified as fish Species of Conservation Interest (refer to Table 7.2.3). Browns Bank, Emerald/Western Bank, the Georges Bank Oil and Gas Moratorium Area, and the Georges Bank Fishery Closure (5Z) are designated Special Areas with importance for fish spawning; these areas are located approximately 56 km, 60 km, 120 km, and 149 km from the Project Area, respectively (refer to Figure 7.5.1).

In the nearshore environment, at least 69 species of fish have been recorded within the 40 m depth of water (Hardy Associates Ltd. 1984), including demersal (*i.e.*, groundfish) and pelagic species, shellfish, small fishes of estuaries and tidal inlets, and exotic warm-water and Eastern-Arctic species. Anadromous fish using the Sackville River basin for spawning include Atlantic salmon and gaspereau. Brook trout (sea run) may also exploit the Bedford Basin for its abundance of food. The American eel is a member of the Anguillidae family and is the only catadromous species in Halifax Harbour (*i.e.*, the eels live in freshwater, but spawn in salt water). Depending on the lifecycle stage of the individuals, this species can be found in lakes, streams, rivers, and estuaries. The eels migrate to the mid-Atlantic ocean to spawn; the young eels are then carried by currents back to Nova Scotia, where they enter freshwater systems to mature.

8.5.1.1 Environmental Effects Mechanisms

All of the identified accidental event scenarios including Batch Spills, SBM Whole Mud Spill, Subsea Blowout, and Vessel Spill have potential to result in a Change in Risk of Mortality or Physical Injury or a Change in Habitat Quality and Use for marine fish, (Table 8.5.1). The extent of the potential effects will depend on how the spill trajectory and the VC overlap in both space and in time. As noted earlier, the assessment is conservative (*i.e.*, geographic and temporal overlap are assumed to occur). MODU and vessel spills and blowouts are discussed together in the context of hydrocarbon effects. Although SBM also has hydrocarbon content in the form of synthetic oil, the effects of a spill of SBM are discussed separately.

Hydrocarbon Effects on Fish and Fish Habitat

Hydrocarbons can affect plankton in the water column both directly and indirectly. Oil on the surface may reduce air-water gas exchange and light penetration for the phytoplankton thus causing reduced productivity and growth (Gonzalez *et al.* 2009; Abbriano *et al.* 2011). The main effect on phytoplankton following an oil spill is expected to be a change in phytoplankton community composition (Teal and Howarth 1984; Abbriano *et al.* 2011). Post-spill studies on phytoplankton were conducted in the North Inlet Estuary, South Carolina using crude oil obtained from the Deepwater Horizon Oil Spill and a mixture of Texas crude samples. It was found that total phytoplankton biomass declined with increasing concentration of oil, and that the phytoplankton community was modified. Diatoms, cyanobacteria, euglenophytes, and chlorophytes were found to be relatively resistant to contamination, while cryptophytes were found to be vulnerable (Gilde and Pinckney 2012).

Zooplankton have also been shown to be sensitive to hydrocarbons, with increased mortality, decreased feeding, and decreased reproduction (Suchanek 1993; Seuront 2011). Specific responses vary by species; mortality has been shown to be more dependent on exposure time rather than hydrocarbon concentration (Lee and Nicol 1977; Abbriano *et al.* 2011). Copepods, for example, have been known to sense and avoid oil spills, reducing contact and mortality risk (Seurant 2010). At sub-lethal levels, hydrocarbons accumulated in zooplankton after a spill can be depurated within days of moving to clean water (Trudel *et al.* 1985). Recovery of zooplankton communities are likely to occur soon after a spill due to their short generation time, high fecundity, and the ability of some zooplankton to actively avoid spill sites (Seuront 2011). During the *Prestige* spill off Spain, for example, zooplankton abundance and community structure returned to normal within days to weeks of the spill event (Davenport *et al.* 1982; Johansson *et al.* 1980; Varela *et al.* 2006).

When there is a spill of crude oil or hydrocarbons, the bacteria capable of degrading the substance proliferate and multiply quickly (ASM 2011). The local community of microbes in an area is adapted to the background supply of hydrocarbons. When a spill occurs, there is a lag time during which the microbes replicated and increase their populations in response to the influx of a new energy source. During an oil spill, the volume of oil released into the environment initially out paces the ability of bacteria to degrade the substance until the community catches up in numbers in response to the increased availability of a hydrocarbon source. In coordination with other physical processes including evaporation, dissolution, dispersion, and photo-oxidation, bacteria will eventually clean up the spill by consuming the hydrocarbon compounds which are biodegradable (ASM 2011). Studies have shown that bacterial respiration, through biodegradation of hydrocarbons, has the potential to cause oxygen depletion, eventually leading to hypoxia in areas near oil spills (Adcroft *et al*. 2010). Biodegradation of hydrocarbons by bacteria may also cause the potential for bioaccumulation and subsequent effects in the food web, although phytoplankton, zooplankton, and fish are all able to metabolize hydrocarbons (Wolfe *et al.* 1996; Graham *et al.* 2010). Finfish species are most vulnerable to hydrocarbon spills during early life stages when they cannot actively avoid oiled areas and have not developed any detoxification mechanisms (Rice 1985).

Dispersion and dissolution cause the water-soluble hydrocarbons to move from the surface oil slick into the water column. Effects of spills on pelagic organisms are most realistically examined using the water-soluble fractions of oil or light hydrocarbon products. Studies completed on capelin embryos using the water-soluble fraction of crude oil from the Hibernia field between the ages of 0 days and 5 days showed lethal effects for age 0 days at an exposure level of 2.7 ppm, and at a level of 5.3 ppm at age 5 days (Paine *et al*. 1988). Embryos exposed to sub-lethal doses were statistically significantly smaller upon hatching, had larger yolks, and lower eye pigmentation than the control group, suggesting that the water-soluble component of crude oil acts as a general stressor and metabolism inhibitor for the early life stage of capelin (Paine *et al.* 1988). Experimental studies of the effects of hydrocarbons on the early life stages for a variety of other fish species (herring, salmon, minnow, mummichog) have shown sub-lethal toxic effects including pericardial and yolk sac edema, small jaws, hemorrages, spinal deformities and overall growth inhibition (Marty *et al.* 1997; Peterson and Kristensen 1998; Carls *et al.* 1999; Heintz *et al.* 1999; Couillard 2002; Pollino and Holdway 2002; Colavecchi *et al.* 2004; Incardona *et al.* 2004; Hendon *et al.* 2008).

A recent study (Incardona *et al.* 2014) of the effects of the Deepwater Horizon Oil Spill on the spawn (embryos and larvae) of pelagic fish species including bluefin tuna, yellowfin tuna, and an amberjack demonstrated that exposure to PAHs (1–15 µg/L total PAH) caused defects in cardiac function (*e.g.*, pericardial edema and other secondary malformations, irregular atrial arrhythmia). Given the high percentage of Gulf water samples collected during the spill with

PAH concentrations exceeding toxicity thresholds observed in this study, losses of pelagic fish larvae as a result of the spill were predicted (Incardona *et al.* 2014).

The risk of exposure of fish and shellfish to an oil spill is dependent on the type of oil and the extent of the spill, but also on the habitat these species occupy, their behaviour, the time of year, their life history and the general health of the stock at the time of the spill (Yender *et al.* 2002). In general:

- Adult pelagic and benthic fish occurring in relatively deep waters have low exposure risk because they are highly mobile and able to avoid oiled areas (Irwin 1997).
- Larval and juvenile pelagic and benthic fish species may be at a greater risk of exposure as they are often less mobile than adults.
- Fish that spawn or occur in nearshore intertidal and subtidal zones and in shallow reef zones are at higher risk of exposure where there is shoreline oiling.
- Shellfish have a moderate risk of exposure because they have some mobility, but utilize benthic habitats in shallow nearshore and estuarine areas. Species that burrow into sediments that may become contaminated, are at higher risk of exposure.
- Sessile molluscs, especially bivalves, are at a high risk of contamination because they are unable to avoid exposure. They can ingest dispersed oil and oil attached to suspended sediments.
- If fish eat contaminated zooplankton, they can accumulate hydrocarbons themselves. However, fish are also able to metabolize hydrocarbons and there is no potential for bio-magnification (LGL 2005).

After the Deepwater Horizon Oil Spill, early life stages of coastal fishes using seagrass habitat in the northern Gulf of Mexico were studied. The studies concluded that immediate, catastrophic losses of 2010 cohorts were largely avoided, and that no shifts in species composition occurred following the spill. However, it was pointed out that this did not preclude potential long-term effects experienced by fishes as a result of chronic exposure and delayed, indirect effects (Fodrie and Heck 2011).

In another study, commercial fish and shellfish (crab, shrimp, oyster) species were collected after the Deepwater Horizon Oil Spill from closed fishing grounds along the Mississippi coast. Higher levels of PAHs were detected in all four taxa (fish, crab, shrimp, oyster) during the early sampling. When compared with later months, and after one year, PAH levels in the collected samples were similar to those reported in commonly consumed processed foods and below regulated levels (Xia *et al.* 2012).

Diesel is known to have immediate toxic effects on many intertidal (*e.g.*, molluscs, amphipods) and benthic organisms (Stirling 1977; Simpson *et al.* 1995; Cripps and Shears 1997) with sessile and early life stages (eggs, larvae) the most at risk as they are unable to actively avoid the diesel and/or are during sensitive life stage development periods. Benthic invertebrates, including commercial species, have experienced sub-lethal effects resulting from low-level exposure to hydrocarbons, with crustaceans being the most sensitive taxa (Sanders *et al.* 1980; Jewett *et al.* 1999).

Modelling results indicate that diesel spills from the MODU are not likely to result in biological effects on fish over a large area (RPS ASA 2014b; refer to Section 8.4 or Appendix G). For the 10 bbl and 100 bbl spill scenarios, approximately 80% of the spill evaporated within 2–3 days, with approximately 2 km^2 and 20 km^2, respectively, experiencing in-water concentrations of dissolved aromatics in excess of 1 ppb at any time. The effects from a vessel diesel spill offshore would be expected to be of similar magnitude. However, if an incident were to occur while the OSV was approaching or departing the onshore supply base, a spill could potentially affect the nearshore environment.

The effects from a blowout would be more geographically widespread, with some seasonal variations; the oil is more likely to be transported to the east during winter conditions and more likely to be subject to uniform, multi-directional transport patterns during summer conditions. Modelling showed higher percentages of the released oil within the water column during winter months, the result of increased wind and wave action, which entrains surface oil into the water column. Table 8.4.5 provides the results of modelling related to dissolved aromatics in the water column (of greatest concern to fish and fish habitat). These results demonstrate that in worst-case, with no consideration of emergency response, containment, recovery, coastal protection measures, or other mitigation, the potential for effects on fish, particularly at sensitive life stages, could be wider spread. It should be noted, however, that toxicity is the result of not only the concentration or thickness of oil, but also the duration of exposure (RPS ASA 2014b); spill response measures (refer to Section 8.1.2) would serve to reduce the area and length of time of oil exposure to marine species.

The majority of dissolved aromatics were modelled to be in the surface mixed layer (approximately 50–100 m deep throughout the year). In some cases, concentrations of up to 50–100 ppb extended beyond the RAA southern boundary into international waters (refer to Figures 8.4.12 to 8.4.15). Concentrations above 1 ppb total dissolved aromatic concentrations are not likely to reach the Scotian Shelf except as modelled for Site 1 during winter conditions, where concentrations of 50–100 ppb may reach the shelf break (refer to Figure 8.4.12). As presented in Table 5.2.3, the majority of spawning areas in the RAA occur on the Scotian Shelf (*e.g.*, nearshore and offshore banks and basins), although eggs and larvae for some species (*e.g.*, Atlantic herring, roundnose grenadier, deepwater redfish, Acadian redfish, haddock, monkfish, red hake, silver hake, white hake, and witch flounder) can be found along the Scotian Slope/shelf break.

SBM Effects on Fish and Fish Habitat

SBM is a heavy, dense fluid used during drilling operations to lubricate the drill pipe and balance reservoir pressure. The synthetic base oil used in SBM is a food-grade oil with low toxicity. Because of this, effects of SBM spills are typically limited to within hundreds of metres of a wellsite.

Potential environmental effects from an accidental SBM release include: smothering of sessile or slow moving individuals and food sources for fish and shellfish; sedimentation; and potential for contamination. Sessile species have the potential to be smothered in areas where SBMs are greater than 1 cm thick (Bakke *et al.* 1989). Modelling of accidental SBM spills at the sea floor is limited to thicknesses below 10 mm at both sites. 1 mm thickness contours extends up to 41 m from the release sites, and cover a maximum area of 0.27 ha of the seabed. This thickness is well below the thickness likely to cause smothering.

Although classified as non-toxic, bioaccumulation of PAHs from SBMs are known to occur. It is also possible that fine particles of bentonite and barite can interfere with feeding and digestion. Scallops have been found to be sensitive to effects from drilling wastes, demonstrating weight loss in somatic and reproductive tissues at levels between 0.05 and 2 mg/l of all major mud types (water-, low toxicity mineral oil-, synthetic-, and ester-based muds); effects were reversed when exposure ceased (Cranford *et al.* 2005).

When released into the water, SBM sinks to the sediment-water interface, and is not buried in sediment. As a consequence, epibenthic species and deposit feeders would be most affected (Neff *et al.* 2000). Recruitment could also be reduced locally due to decreased quality of habitat.

Two accidental releases, a surface release of 377 bbl and a subsurface release of 3604 bbl, of SBM from the Project were modelled for two different locations within the Project Area using spring currents. Spring currents were chosen as these conditions would produce higher and more sustained plume concentrations. As a result of the release, the model predicted elevated levels of TSS in the water column, and a plume extending 5 to 10 km from the site until TSS concentrations fell below the 1 mg/L threshold (*i.e.*, the level detectable by the model). The area returned to ambient conditions within 30 hours of the spill. Modelling of the relatively small volumes potentially involved in a surface release demonstrated that they quickly disperse and do not contribute to mass accumulation on the seabed.

While elevated TSS levels can have detrimental effects on fish including physiological stresses, reduced growth, and adverse effects on survival, the levels of TSS required to result in potential effects on fish and fish habitat would be limited to within a few hundred meters of the spill site (water column concentrations of greater than 1000 mg/L would be limited to within less than 200 m of the spill site) and these conditions would be temporary.

Accidental releases of SBM also have potential to result in a small, thin surface sheen, with effects similar to those discussed above for hydrocarbon spills, but more limited in nature.

8.5.1.2 Mitigation of Environmental Effects

The assessment of environmental effects of spills on fish and fish habitat was conservative and assumed no oil spill containment, recovery or shoreline protection operations.

Shell's overall accident prevention and emergency response procedures (Section 8.1) will reduce the potential for an accidental event and any associated environmental effects. A NEBA would be undertaken prior to the use of dispersants to evaluate the risks and benefits of dispersing oil into the water column, including potential effects on fish and fish habitat. Regulatory approval would be required for any use of dispersants.

8.5.1.3 Characterization of Residual Environmental Effects

For the purposes of this effects assessment, a **significant adverse residual environmental effect** on Fish and Fish Habitat is defined as a Project-related environmental effect that:

- causes a decline in abundance or change in distribution of fish populations within the LAA, such that natural recruitment may not re-establish the population(s) to its original level within one generation
- jeopardizes the achievement of self-sustaining population objectives or recovery goals for listed species
- results in permanent and irreversible loss of critical habitat as defined in a recovery plan or an action strategy or
- results in serious harm to fish as defined under the *Fisheries Act* that is unauthorized, unmitigated or not counterbalanced through offsetting measures in accordance with DFO's *Fisheries Protection Policy Statement* (2013u)

The residual effects on Fish and Fish Habitat is described below for each of the identified accidental event scenarios.

Batch Spills and Vessel Spills

With respect to Change in Habitat Quality and Use, the majority of diesel from a spill from either the MODU or OSV will evaporate and disperse within the first 2–3 days following the release (refer to Appendix G). This will create a temporary and reversible degradation in habitat quality. Depending on the location and extent of the spill, nearshore spawning and nursery areas could potentially be affected. However, given the small-scale nature of the spill, effects on nearshore areas are expected to be limited. Oil spill containment and recovery operations will further reduce residual effects on fish and fish habitat associated with dissolved aromatics.

With respect to Change in Risk of Mortality or Physical Injury, although there is a risk of mortality of phytoplankton and zooplankton (food sources), and sub-lethal and lethal effects to larval and juvenile fish species present in the mixed surface layer of the water column, these residual effects will likely be restricted to a localized area. The potential for these effects would also be temporary and reversible. Adult fish species in surface waters will largely be unaffected due to avoidance mechanisms; demersal (bottom dwelling) species are unlikely to be exposed to harmful concentrations of dissolved aromatics. Residual effects following a nearshore diesel spill from the OSV could include localized mortality and sub-lethal effects to fish eggs, larvae and juveniles.

Given the temporary, localized, and reversible nature (at a population level) of the potential effects, the residual environmental effects from a diesel spill from either the MODU or an OSV are predicted, with a high degree of confidence, to be not significant.

SBM Whole Mud Spill

Residual effects on Change in Habitat Quality and Use following a SBM whole mud spill would be highly localized (to tens of metres from the spill site). Likewise, a Change in Risk of Mortality or Physical Injury in the case of both the surface and subsurface release would be restricted to smothering effects on highly immobile individuals and benthic prey species. Results from the modelling indicate that effects from both the surface and subsurface SBM spill would be temporary, reversible and highly localized around the well site. Given these considerations, the residual environmental effect from an SBM spill are predicted, with a high degree of confidence, to be not significant.

Blowout

Of all the spill scenarios, the blowout scenario has the greatest potential for environmental effects. The actual effects of a blowout would depend in large part upon the duration and volume of the spill, as well as the environmental conditions at the time of the spill.

Following a continuous, 30-day unmitigated blowout scenario, the geographic extent of residual effects on Change in Habitat Quality and Use could extend into the RAA with a low probability of extension beyond the RAA. While the modelling demonstrates a potentially large affected area, it is important to note that many of the areas delineated through the modelling have low probabilities of occurrence and that results are based on an unmitigated release. In an actual incident, emergency response measures inclusive of containment and recovery operations are likely to have some impact on limiting the magnitude and duration of the spill and thereby limiting, the geographic extent and potential environmental effects. As indicated by the modelling, an unmitigated spill is unlikely to reach the shoreline or nearshore environments and the implementation of mitigation measures would further reduce this likelihood.

With respect to Change in Risk of Mortality or Physical Injury in offshore waters, effects on slow moving or sedentary species would be similar to those of diesel on phytoplankton, zooplankton, larval and juvenile fish species, but over a greater area. Greater concentrations of dissolved aromatics present in the surface mixed layer following an incident during winter conditions, may be expected to result in higher mortalities and sub-lethal effects on fish eggs, larvae and juveniles. In the unlikely event that dissolved aromatics are transported towards nearshore waters, residual effects on fish may extend to low level sub-lethal effects on the eggs, larvae and juveniles of demersal species and other fish species within nearshore areas, including spawning and nursing areas.

In the event of a blowout scenario, there will be a temporary decline in the abundance of phytoplankton in the immediate area of the spill. Zooplankton communities may be able to avoid exposure. Zooplankton which cannot avoid exposure and experience sub-lethal effects will depurate once the spill has subsided due to mitigation and natural weathering processes. The majority of adult fin fish will be able to avoid exposure via temporary migration. In the event that the spill encompasses areas where fish eggs or larvae are located, lethal and sub-lethal effects could occur. It should be emphasized that the majority of fish species on the Scotian Shelf and Slope spawn in a variety of large areas, over long time scales and spill is not predicted to encompass all of these areas or time scales within the RAA to such a degree that natural recruitment may not re-establish the population(s) to their original level within one generation.

Concentrations above 1 ppb of total dissolved aromatic concentrations are not likely to reach the Scotian Shelf, except during winter conditions, where concentrations of 50-100 ppb may reach the shelf break. The majority of spawning areas for fish species in the RRA occur on the Scotian Shelf, with the eggs and larvae of some species being found along the Scotian Slope and Shelf break. In the event of a large blowout, the area impacted will not encompass all of the spawning locations for any one species. The majority of fish species on the Scotian Shelf and Slope spawn in multiple locations within the RAA with the exception of a few species. There are a few species which tend to spawn in a limited geographic area. These species include the smooth skate and sand lance. However, these species have the potential to spawn over many months or the entire year and with mitigation, their spawning window will not be completely impacted by a blowout. In the event of a major blowout, due to the fact that most species spawn in multiple locations within the RRA or over long time scales, it is not likely that an entire year class would be lost due to the toxic effects of oil on early life stages of fish species.

Summary

Based on information presented above and a consideration of the significance criteria, the predicted residual adverse environmental effects from any of the accidental event scenarios on Fish and Fish Habitat would be not significant. This conclusion is based on the conservatism of the spill modelling (results show an unmitigated release), the use of mitigation measures to prevent and minimize impacts from a spill, in recognition of the low possibility of a spill reaching important spawning areas on the Scotian Shelf and Georges Bank and the nature of the potential effects as described in the literature summarized above. This prediction is made with a medium to high level of confidence. Table 8.5.2 provides a summary of residual predicted effects.

Table 8.5.2 Summary of Residual Project-Related Environmental Effects on Fish and Fish Habitat – Accidental Events

Project Activities and Components	Mitigation/ Compensation Measures	Nature of Effect	Residual Environmental Effects Characteristics						Significance	Likelihood of Significant Effects	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context				
100 bbl batch spill	• Spill Prevention • Emergency Response Plan • Oil Spill Response Plan • Source Control Response Plan • NEBA approach to evaluate response options	A	M	RAA	ST	S	R	U	N	N/A	H	VC-specific follow-up and monitoring will depend on incident-specific factors. A monitoring plan will be developed in consultation with regulators. Monitoring typically continues until specific endpoints are achieved and residual hydrocarbons reach acceptable background levels.
10 bbl spill		A	L	LAA	ST	S	R	U	N	N/A	H	
Vessel spill		A	M	RAA	ST-MT	S	R	U	N	N/A	H	
SBM whole mud spill		A	L	LAA	ST	S	R	U	N	N/A	H	
Well blowout		A	M	RAA*	ST-MT	S	R	U	N	N/A	M	

KEY

Nature of Effect:
P Positive
A Adverse

Magnitude:
N Negligible – no measurable change in marine species populations, habitat quality or quantity, or contaminant levels
L Low – a measurable change but within the range of natural variability (change in population levels or contaminant concentrations consistent with baseline levels); will not affect population viability
M Moderate – measurable change outside the range of natural variability but not posing a risk to population viability
H High – measurable change that exceeds the limits of natural variability and may affect long-term population viability

Geographic Extent:
PA – Project Area – effects are restricted to the Project Area and well site.
LAA – effects are restricted to the LAA
RAA – effects are included within the RAA; in certain scenarios, effects may extend beyond the RAA as indicated by an "*".

Duration:
ST Short-Term – effect extends for a portion of the duration of Project activities
MT Medium-Term – effect extends through the entire duration of Project activities
LT Long-Term – effects extend beyond the duration of Project activities, after well abandonment
P Permanent – measurable parameter unlikely to recover to baseline

Frequency:
O Once – effect occurs once
S Sporadic – effect occurs sporadically at irregular intervals
R Regular – effect occurs on a regular basis and at regular intervals throughout the Project
C Continuous – effect occurs continuously

Reversibility:
R Reversible – will recover to baseline conditions before or after Project completion (well abandonment)
I Irreversible – permanent

Context:
U Undisturbed – Area relatively or not adversely affected by human activity
D Developed – Area has been substantially previously disturbed by human development or human development is still present

Significance:
S Significant
N Not significant

Prediction Confidence:
Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation
L Low level of confidence
M Moderate level of confidence
H High level of confidence

8.5.2 Marine Mammals and Sea Turtles

Six species of mysticetes and ten species of odontocetes are known to occur on the Western Scotian Slope and could potentially interact with the Project. Marine mammals are present on the Scotian Shelf and Slope year-round, although more species are commonly present between May and September. There are five species of pinnipeds (seals) that can be found foraging year-round in the waters over the Scotian Shelf and Slope, although only the grey seal and harbour seal are known to breed offshore Nova Scotia. There are four species of sea turtles that can be found migrating and foraging on the Scotian Shelf and Slope, although only the endangered leatherback turtle and the loggerhead turtle are known to regularly forage in Atlantic Canada waters. These species are known to occur in the vicinity of the Project Area primarily between April and December.

Of the species which can be found in the RAA, eight species of marine mammals and two species of sea turtles are considered to be SOCI (refer to Table 7.3.3). Critical habitat identified under SARA for marine mammal SOCI also occurs in the RAA. Critical habitat for the North Atlantic right whale has been identified in Roseway Basin and critical habitat for the northern bottlenose whale has been identified in the Gully, and Shortland and Haldimand canyons (refer to Figure 7.3.1). Critical habitat for the leatherback sea turtle is expected to be designated in 2014 and will likely encompass a large area within the RAA.

Within Halifax Harbour, where OSVs will be transiting to and from the supply base, harbour seals (*Phoca vitulina*) have been observed in large numbers, particularly in the Bedford Basin, during winter; grey seals (*Halichoerus grypus*) have also been observed occasionally (Brodie 2000). Harbour porpoise (*Phocoena phocoena*), listed as a species of special concern and under Schedule 2 of SARA, have also been known to frequent Halifax Harbour. Atlantic white-sided dolphins (*Lagenorhynchus acutus*) have been sighted at locations in Halifax Harbour, including the Defence Research Establishment Atlantic (DREA) barge and the Narrows. Larger whales have been observed on occasion as well, with most sightings occurring at the approaches and marine inlet to the harbour (Brodie 2000).

8.5.2.1 Environmental Effects Mechanisms

Accidental events have the potential to result in a Change in Risk of Mortality or Physical Injury and Change in Habitat Quality and Use for Marine Mammals and Sea Turtles. All of the identified accidental event scenarios (*i.e.*, Batch Diesel Spill, Vessel Spill, Spill of SBM Whole Mud and Subsea Blowout) require assessment to determine the nature and extent of these potential accidental events and their associated effects on this VC.

While the type of product spilled (*i.e.*, “light” diesel oil or “medium” crude oil) influences its toxicity, behaviour and fate, these events are discussed together. Although SBM also contains hydrocarbons, the fate and behaviour of an SBM spill and resulting potential effects, may differ from other hydrocarbon releases and therefore this scenario is discussed separately.

Hydrocarbon Effects on Marine Mammals

Marine mammals or turtles may ingest oil with water, contaminated food, or oil could be absorbed through the respiratory tract; absorbed oil could cause toxic effects (Geraci 1990). Inhalation of vapours from volatile fractions of oil from a spill or blowout could potentially irritate respiratory membranes and hydrocarbons could be absorbed into the bloodstream (Geraci 1990). Species like the humpback whale, right whale, beluga and harbour porpoise that feed in restricted areas may be at greater risk of ingesting oil (Würsig 1990). Absorbed oil can cause toxic effects such as minor kidney, liver, and brain lesions (Geraci and Smith 1976; Spraker *et al.* 1994). Some of the ingested oil is voided in vomit or feces, but some is absorbed and could cause toxic effects (Geraci 1990). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978, 1982).

Whales exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980, 1982). In baleen whales, crude oil could coat the baleen and reduce filtration efficiency, but these effects are considered reversible (Geraci 1990). Geraci (1990) noted that adverse effects on cetaceans, such as sickness, stranding or mortality, tended to be associated with crude or bunker C oil, which is not the type of oil that would result from a spill or blowout for this Project. Most marine mammals can withstand some oiling without toxic or hypothermic effects. Whales and seals use blubber to maintain core body temperature, which is not affected by a covering of oil. Hypothermia is possible however, if a young seal pup is covered in oil because it takes several months to build up a blubber layer sufficient to maintain body heat.

While studies indicate that cetaceans can detect oil spills, they may or may not consistently avoid contact with most oil types (St. Aubin *et al.* 1985; Smultea and Würsig 1995). Even if cetaceans actively avoid slicks, indirect exposure through feeding on oiled prey may occur. Several species of cetaceans and seals have been documented behaving normally in the presence of oil (St. Aubin 1990; Harvey and Dahlheim 1994; Matkin *et al.* 1994). It is possible that cetaceans swim through oil because of an overriding behavioural motivation (for example, feeding). Captive bottlenose dolphins (*Tursiops truncatus*) avoided most oil conditions during daylight and darkness, but had difficulty detecting a thin sheen of oil (St. Aubin *et al.* 1985). Wild bottlenose dolphins exposed to the Mega Borg oil spill in 1990 appeared to detect, but did not consistently avoid contact with most oil types (Smultea and Würsig 1995). Some evidence exists that dolphins attempt to minimize contact with surface oil by decreasing their respiration rate and increasing dive duration (Smultea and Würsig 1995).

Based on a comparison of sperm whale acoustic activity from pre-spill (2007) and post-spill (2010) conditions, Ackleh *et al.* (2012) suggested that sperm whales may have relocated farther away from the Deepwater Horizon Oil Spill site in the Gulf of Mexico. Possible explanations for this relocation includes whales moving out of the areas with a high concentration of oil and pollutants (possible shortages of food) and increased boat traffic (and therefore increased anthropogenic noise) making it an uncomfortable environment for whales. Humpback whales may have shown temporary avoidance during the *Exxon Valdez* spill in Prince William Sound (von Ziegesar *et al.* 1994).

Monitoring studies of marine mammals following oil spill events in different parts of the world have demonstrated evidence implicating oil spills with the mortality of cetaceans. For example, continued monitoring over sixteen years after the *Exxon Valdez* spill indicates a measurable decrease and lack of recovery in the population size of a fish-eating killer whale pod using the area affected by the spill (Dahlheim and Matkin 1994; Matkin *et al.* 2008). Continued monitoring over sixteen years indicates that the killer whale pod had still not returned to its pre-spill population abundance, and the population's rate of increase was significantly less than other fish-eating pods in the area (Matkin *et al.* 2008). More recently, Matkin's conclusion that the killer whale deaths could be attributed to the *Exxon Valdez* spill has been challenged by Fraker (2013), who argues that there is not a clear and plausible connection given other factors (including frequency of bullet wounds) which might have factored into the documented mortalities.

Also following the *Exxon Valdez* spill, five harbour porpoises were found dead in Prince William Sound. While three autopsied animals showed elevated levels of hydrocarbons in blubber and liver tissues, the levels of assimilated oil were not high enough to determine with certainty that the animals died from exposure to crude oil (Dalheim and Matkin 1994). The deaths might have been the result of a combination of factors, including acute toxicity of crude oil, increased energy expenditure from epidermal fouling, reduced prey abundance and increased susceptibility to parasitism or disease (Albers and Loughlin 2003).

Following the *Exxon Valdez* spill, harbour seals were observed swimming through and surfacing in floating oil while feeding and moving to and from haulout sites (Lowry *et al.* 1994). Oil fouling might affect seal locomotion, with heavy oiling causing flippers to stick to the body; contact with oil also reduces the insulative value of hair, but in healthy seals this is not likely to be a major problem as they rely primarily on blubber for insulation. Seals became cleaner over time if they were not repeatedly exposed to oil. Various types of skin lesions in harbour seals were probably caused by crude oil. Examination of dead oiled seals suggested lesions may have been related to inhalation of toxic fumes and mortality could have resulted from behavioural disorientation, lethargy and stress response (Ott *et al.* 2001).

Following the Deepwater Horizon Oil Spill in the Gulf, a total of 171dolphin and whales were collected from April 30, 2010 to February 15, 2011, either from stranding or directed capture in the open water (NOAA 2014a). Of these, 13 were captured alive and 153 were collected dead, with almost 90% of individual being bottlenose dolphins. Of the 109 marine mammals collected as of November 10, 2010, only 6 individuals were visibly oiled (NOAA 2010). Notably, NOAA reported an Unusual Mortality Event (UME) for the northern Gulf of Mexico beginning in February 2010 (prior to the Deepwater Horizon Oil Spill), with 406 whales and dolphins (almost all bottlenose dolphins) reported stranded from February 2010 through April 3, 2011. The cause of these strandings is still being investigated (NOAA 2014b), with a possible contributing factor being *Brucella*, a bacterium associated with flu-like symptoms in humans, which has been identified in some bottlenose dolphins that stranded in the northern Gulf since the start of the UME.

Chronic low-level oil pollution can affect marine mammals, particularly where it occurs in the vicinity of concentrations of animals, such as breeding sites. Chronic pollution has resulted in oiling of approximately 50% of grey seal (*Halichoerus grypus*) pups at the largest breeding colony in Norway each year (Jennsen 1996). In this case, as well as in other similar cases of spills at breeding colonies, oil has resulted in little mortality or visible disturbance to the seal behaviour. The effects and mortality may be more serious following a spill of crude oil, where animals may be affected by inhalation of toxic volatile compounds. In the Baltic Sea, high body burdens of PCBs and DDTs appear to have caused skull-bone lesions and occlusions of the uteri in grey seals, with exposure to these persistent compounds suspected as a cause of reduction in the population of Baltic grey seals.

French–McCay (2009) describes biological effects associated with oil spills. Wildlife individuals that move through the area swept by floating oil (*e.g.*, slicks, emulsions, or other floating forms such as tar balls) are assumed to be oiled based on probability of encounter and those oiled above a threshold dose are assumed to die. Based on available scientific data, a combined probability of oil encounter and mortality once oiled assumed for species groups, if present in the area swept by oil exceeding a threshold thickness of 10 µm (for spillets larger than 230 m in diameter), was 0.1% for cetaceans, 75% for furbearing marine mammals and 1% for non-fur bearing pinnipeds.

For this Project, stochastic modelling of blowouts at two representative sites (Sites 1 and 2) indicate the potential for surface oiling (exceeding a threshold of 0.4 µm) in a portion of the ocean, in Canadian waters south of Nova Scotia and Newfoundland and US waters to the east of the New England area, for Sites 1 and 2, respectively (refer to Appendix G). These large footprints are not the expected oiling from any single release of oil. In fact, the majority of the area represents a probability of oiling at less than 10%. The area with greater than 10% probability of surface oiling exceeding the threshold is much smaller (approximately 300 km x 300 km), while only an area of 50 km x 50km has a probability greater than 75%.

Figures 8.4.8 to 8.4.11 show the predicted surface oiling in excess of 0.04 µm, which is a visible threshold used to determine impacts on socio-economic resources (*e.g.*, possibility of fisheries closure). This minimum thickness represents a slick that is barely visible as a colorless or silver sheen (French-McCay *et al.* 2011). Of more relevance to potential environmental effects on marine mammals and sea turtles is a surface oil thickness of 10 µm, recognizable as a dark brown sheen on the surface (French-McCay *et al.* 2011).

Table 8.4.5 summarizes the results of the deterministic modelling with respect to surface oiling effects and potential for shoreline oiling effects. Areas exceeding both thresholds (0.04 µm and 10 µm are provided). Air-breathing vertebrates such as mammals and sea turtles that move through the area swept by floating oil are assumed to be oiled based on probability of encounter. The threshold thickness of surface oil that would impart a lethal dose to an intersecting wildlife is 10 µm (French-McCay 2009).

Marine mammals can congregate in high numbers, but, except for species at risk, the number of individuals likely to be present in an area of oiling at the time of a spill are unlikely to represent a high proportion of any marine mammal population. In a worst-case scenario, where a group of non-fur bearing individuals were to come in contact with surface oil, the risk of mortality is considered low. Except in the case of a vessel spill of diesel during transit to the nearshore, the likelihood of seals coming into contact with oil from a Project-related spill would be very low. Diesel fuel would disperse faster than crude oil, limiting the potential for surface exposure, although there would be increased toxicity associated with this spill and risk of inhalation of toxic fumes is present for either type of spill (crude oil or diesel).

Stochastic modelling of offshore spills indicates a low potential (< 2%) for shoreline oiling at Sable Island and the southern tip of Nova Scotia, including the Yarmouth, Barrington, and Shelburne region. All shoreline oiling cases occurred during modelling for the summer season, limited to the months of May, June, and July. For offshore spills, it is expected that oil would be highly weathered by the times it reaches the shore 20–30 days later. This timeframe would also provide sufficient time to mobilize spill response in these areas. Despite the low potential, should oil reach the nearshore and shoreline regions, including Sable Island, there is a risk of physical effects or mortality to seals; however this risk would not be likely to result in population level effects.

Hydrocarbon Effects on Sea Turtles

It is believed that turtles do not exhibit avoidance behaviour when encountering oil (Milton *et al.* 2003). Gramentz (1988) reported that sea turtles did not avoid oil at sea, and sea turtles experimentally exposed to oil showed a limited ability to avoid oil (Vargo *et al.* 1986). Gross histologic lesions developed in loggerhead sea turtles experimentally exposed to oil, but most effects were apparently reversed by the tenth day after cessation of exposure (Bossart *et al.* 1995). Oil may also reduce lung diffusion capacity, decrease oxygen consumption or digestion efficiency, or damage nasal and eyelid tissue (Lutz *et al.* 1989).

Hall *et al.* (1983) observed seven live and three dead sea turtles following an oil well blowout in 1979; two of the carcasses had oil in the gut but no lesions, and there was no evidence of aspirated oil in the lungs. However, hydrocarbon residues were found in kidney, liver, and muscle tissue of all three dead turtles, and prolonged exposure to oil may have disrupted feeding behaviour and weakened the turtles.

In experiments, turtles showed no overall avoidance behaviour of petroleum fumes, although some were clearly disturbed by the fumes (Milton *et al.* 2010). Combined with their diving behaviour, which requires rapidly inhaling large volumes of air prior to diving and continually resurfacing, turtles are at increased risk of prolonged exposure to petroleum vapors, the most acutely harmful phase of a spill (Milton *et al.* 2003). Compared to hatchlings, juveniles and adults spend less time at the sea surface, which may reduce their exposure to smaller oil slicks.

As turtles consume anything that appears to be the same size as their preferred prey (*e.g.*, jellyfish), ingestion of tarballs is an issue for turtles of all ages (Milton *et al.* 2010). As ingested oil can be retained within a turtle's digestive tract for several days, there is increased internal contact, likelihood of absorption of toxic compounds and risk of gut impaction.

French–McCay (2009) assume a combined probability of oil encounter and mortality once oiled of 5% for juvenile and adult sea turtles and 50% for sea turtles (hatchlings). This is based on a moderate to high short-term survival rate if oiling occurs as indicated by the literature (Vargo *et al.* 1986), but also taking into consideration that there are few definitive data regarding the long-term effects of oil on any reptile. Hatchlings are observed to spend most of their in-water time at the surface, with their size and anatomy increasing their susceptibility to passing oil and suffocating as a result of this exposure. Hatchlings are particularly vulnerable to oiling from convergence zones (*i.e.*, ocean areas where currents meet to form collection points for material at or near the surface of the water) which can represent a trap for hatchlings due to their weak mobility (Milton *et al.* 2010). Once oiled, hatchlings may not be able to swim as well, thereby increasing their predation risk. French–McCay (2009) acknowledges that the likely range of probability for oiling and dying of hatchlings is 10–100%, but uses 50% as a best estimate.

Following the Deepwater Horizon Oil Spill in the Gulf, a total of 1146 turtles were collected from April 30, 2010 to February 15, 2011, either from stranding or capture in the open water (NOAA 2014c). Of these, 537 were collected alive (456 of which were visibly oiled) and 609 were dead (18 of which were confirmed to have visible oiling) (NOAA 2010). Seventy percent of those captured were Kemp's ridley turtle (*Lepidochelys kempii*). The NOAA Fisheries national sea turtle coordinator reported that of the 461 live sea turtles collected between May and September 2010, approximately 420 were rehabilitated and returned to the wild, with the longer-term, less visible effects of the oil on sea turtles remaining undetermined (NOAA 2014d). Of significance, NOAA reports thousands of sea turtle strandings every year along the Gulf of Mexico and US east coast even prior to this spill and continues to investigate possible reasons for these events.

For this Project, it is assumed that any turtles occurring within the zone of influence of an accident event scenario have the potential to be exposed to oil and experience related health effects, as described above. As the turtles occurring in the RAA would be juveniles and adults, the potential for mortality as a result of oil exposure would be much lower than for hatchlings. Turtles would experience a short-term reduction in habitat quality, during which they have the potential to ingest oil or oiled prey.

Effects of SBM Whole Mud Spill

Synthetic-based mud is a heavy, dense fluid which sinks rapidly in the water column when released. SBMs are considered to be of low-toxicity and environmental effects are mostly restricted to physical smothering effects on the sea floor (C-NLOPB 2011). Based on modelling conducted for the Project, an accidental release of SBM whole mud would result in elevated levels of TSS in the water column, with modelling of an accidental release of SBM showing that the plume travels with ambient currents until dispersion and turbulence cause the TSS concentrations to fall below the 1 mg/L threshold. These plumes extend from 5 to 10 km from the site with ambient conditions being returned to within 30 hours of the spill. There is also potential for a spill at surface to result in a small, thin sheen, with effects similar to those discussed above for hydrocarbon spills, but more limited, given the lower hydrocarbon concentration. Any interaction between an SBM whole mud spill and marine mammals and sea turtles would be limited given the scale of effects in the water column and low toxicity of the material, resulting in a temporary reduction in habitat quality. Any risk of physical injury would be limited to individuals in the immediate vicinity of the spill. A subsea release of SBM at the well site would have no expected effects on sea turtles given the depth.

8.5.2.2 Mitigation of Environmental Effects

The focus of mitigation is accident prevention; detailed information on Shell's accident prevention and response planning is provided in Section 8.1, including the Oil Spill Response Plan and Well Containment Plan (to address potential for subsea blowout). Such general measures will minimize the likelihood of potential effects on marine mammals and sea turtles. A diesel spill in the nearshore environment or a blowout reaching shore is extremely unlikely, but such an occurrence could require shoreline clean-up, including possible collection and cleaning of fur-bearing marine mammals and sea turtles. As part of spill response specific to marine mammals, hazing techniques could be used if deemed appropriate to deter animals from entering affected areas (NOAA 2014e). As part of any spill monitoring, records will be kept of any marine mammals or sea turtles encountered and any evidence of visible oiling.

8.5.2.3 Characterization of Residual Environmental Effects

For the purposes of this effects assessment, a **significant adverse residual environmental effect** on Marine Mammals and Sea Turtles is defined as a Project-related environmental effect that:

- causes a decline in abundance or change in distribution of marine mammal or sea turtle populations within the LAA, such that natural recruitment may not re-establish the population(s) to its original level within one generation
- jeopardizes the achievement of self-sustaining population objectives or recovery goals for listed species or
- results in permanent and irreversible loss of critical habitat as defined in a recovery plan or an action strategy

Blowout, Batch Spills and Vessel Spill

With respect to Change in Habitat Quality and Use, a hydrocarbon spill may indirectly reduce the amount of habitat available to marine mammals or sea turtles by rendering it unsuitable for foraging and other activities. This effect would be short-term until the slick disperses and oil content in water reaches background levels, or medium-term if prey abundance and quality is affected. No permanent or irreversible changes in habitat, including possible critical habitat, are expected to occur as a result of accidents and malfunctions.

With respect to a Change in Risk of Mortality or Physical Injury, the accidental release of hydrocarbons may affect several physical and internal functions of marine mammals and sea turtles. Hydrocarbons can be inhaled or ingested, and may cause behavioural changes, inflammation of mucous membranes, pneumonia and neurological damage (Geraci and St. Aubin 1990). Non fur-bearing marine mammals and juvenile and adult sea turtles are not considered to be at high risk from the effects of oil exposure, and it is probable that only small proportions of any populations at risk would be within the affected area and likely to be exposed. Given the mobility of marine mammals, it is expected that they could avoid areas of harmful oil concentrations. Depending on the time of year, location of animals within the affected area, and type of oil spill or blowout, the effects of an accidental release on the health of cetaceans and sea turtles is predicted to be negligible to moderate, short-term to medium-term, and reversible.

SBM Whole Mud Spill

With respect to Change in Habitat Quality and Use, a SBM whole mud spill could cause a temporary reduction in habitat quality for marine mammals and sea turtles due to increased levels in TSS and the potential for a thin sheen associated with the spill. This reduction in habitat would be temporary and localized. Potential for Change in Risk of Mortality or Physical Injury is also considered low with this accidental event scenario due to the limited and temporary nature of any surface sheen and the reduced potential for interaction with fur-bearing mammals due to the probable location of the spill. Based on this, it is predicted with a high degree of confidence that no significant residual environmental effects are predicted for marine mammals and sea turtles in association with an SBM whole mud spill.

Summary

Based on the above, it is predicted with high confidence that any accidental event scenarios associated with the Project will not result in any significant residual effects to marine mammals or sea turtles. This conclusion is based on the conservatism of the spill modelling (results show an unmitigated release), the use of mitigation measures to prevent and minimize impacts from a spill, and the nature of the potential effects as described in the literature summarized above. Refer to Table 8.5.3 for a summary of residual predicted effects.

Table 8.5.3 Summary of Residual Project-Related Environmental Effects on Marine Mammals and Sea Turtles – Accidental Events

Project Activities and Components	Mitigation/ Compensation Measures	Nature of Effect	Residual Environmental Effects Characteristics						Significance	Likelihood of Significant Effects	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context				
100 bbl batch spill	• Emergency Response Plan • Spill Prevention • Oil Spill Response Plan • Source Control Response Plan • NEBA approach to evaluate response options • Shoreline clean-up, as applicable and needed • Recovery and rehabilitation of animals	A	M	RAA	ST	S	R	U	N	N/A	H	VC-specific monitoring plans will be developed as part of spill response planning, but at a minimum, a record will be kept of any marine mammals or sea turtles recovered and with visible oiling.
10 bbl batch spill		A	L	LAA	ST	S	R	U	N	N/A	H	
Vessel spill(		A	M	RAA	ST-MT	S	R	U	N	N/A	H	
SBM whole mud spill		A	L	LAA	ST	S	R	U	N	N/A	H	
Well blowout		A	M	RAA*	ST - MT	S	R	U	N	N/A	H	

KEY

Nature of Effect:
P Positive
A Adverse

Magnitude:
N Negligible - no measurable change in marine species populations, habitat quality or quantity, or contaminant levels
L Low - a measurable change but within the range of natural variability (change in population levels or contaminant concentrations consistent with baseline levels); will not affect population viability
M Moderate – measurable change outside the range of natural variability but not posing a risk to population viability
H High – measurable change that exceeds the limits of natural variability and may affect long-term population viability

Geographic Extent:
PA - Project Area – effects are restricted to the Project Area and well site.
LAA – effects are restricted to the LAA
RAA – effects are included within the RAA; in certain scenarios, effects may extend beyond the RAA as indicated by an "*".

Duration:
ST Short-Term – effect extends for a portion of the duration of Project activities
MT Medium-Term – effect extends through the entire duration of Project activities
LT Long-Term – effects extend beyond the duration of Project activities, after well abandonment
P Permanent– measurable parameter unlikely to recover to baseline

Frequency:
O Once – effect occurs once
S Sporadic – effect occurs sporadically at irregular intervals
R Regular – effect occurs on a regular basis and at regular intervals throughout the Project
C Continuous – effect occurs continuously

Reversibility:
R Reversible – will recover to baseline conditions before or after Project completion (well abandonment)
I Irreversible – permanent

Context:
U Undisturbed – Area relatively or not adversely affected by human activity
D Developed – Area has been substantially previously disturbed by human development or human development is still present

Significance:
S Significant
N Not Significant

Prediction Confidence:
Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation
L Low level of confidence
M Moderate level of confidence
H High level of confidence

8.5.3 Marine Birds

As described in Section 5.2.6, marine related birds are present on the Scotian Shelf and Slope throughout the year, with highest abundance occurring during the summer months. During the fall and winter, significant numbers of overwintering alcids, gulls, and Northern Fulmars can be found in Atlantic Canadian waters (Brown 1986). In the summer, species assemblages are dominated by shearwaters, storm-petrels, Northern Fulmars, and gulls (Fifield *et al.* 2009). The waters of the RAA are known to support approximately 19 species of pelagic seabirds, 14 species of neritic seabirds, 18 species of waterfowl, and 22 shorebird species, with other species occurring as rare vagrants or incidentals. Many of these species have a coastal affinity and would therefore not be expected to regularly occur in waters of the offshore Project Area.

Marine bird nesting colonies are distributed all along the mainland of Nova Scotia, with a particularly dense aggregation in the area between Cape Sable Island and Yarmouth. This area has a large number of small islands which provide a high density of potential nesting sites. Nine coastal IBAs are also present within the RAA; these are discrete areas that support nationally or globally important groups of birds. Sections 5.2.6.3 and 5.2.6.4 respectively describe the marine bird colonies and IBAs that are found within the RAA.

There are six marine bird SOCI previously recorded within the RAA: Ivory Gull, Piping Plover, Roseate Tern, Red Knot, Harlequin Duck, and Barrow's Goldeneye. Critical habitat is identified for both Piping Plover and Roseate Tern within the RAA but does not occur within the LAA. These critical habitats are present in coastal areas (including Sable Island in the case of Roseate Tern).

With respect to the nearshore environment in the vicinity of Halifax Harbour, migratory bird habitat in the area has been noted for Great Blue Heron; Common Eider; Common Tern; Canada Goose; and American Black Duck. Maugher Beach, on the western shore of McNabs Island, provides unclassified Tern habitat as well as habitat for Piping Plover. There is also Piping Plover habitat at Cow Bay Beach and Rainbow Haven Beach, located to the east of the approaches to Halifax Harbour.

8.5.3.1 Environmental Effects Mechanisms

Accidental events have the potential to result in a Change in Risk of Mortality or Physical Injury and Change in Habitat Quality and Use for Marine Birds. The accidental release of fuel, oil or other petroleum products into the marine environment can adversely affect marine birds and their habitat present in the offshore or nearshore environment. While the type and volume of product spilled (*i.e.*, "light" diesel oil or "medium" crude oil) influences its toxicity, behaviour and fate, these events are discussed together. Although SBM also contains hydrocarbons, the fate and behaviour of an SBM spill and resulting potential effects, may differ from other hydrocarbon releases and therefore this scenario is discussed separately.

Hydrocarbon Effects on Marine Birds

Marine birds are among the most vulnerable and visible species to be affected by oil spills. At risk are pelagic species that come inshore only to nest, but also shorebirds such as plovers (Charadriidae) and sandpipers (Scolopacidae), sea ducks and other coastal water birds such as loons (Gaviidae), grebes (Podicipedidae) and cormorants. External exposure to oil occurs when flying birds land in oil slicks, diving birds surface from beneath oil slicks, and swimming birds swim into slicks. Reported effects vary with species, type of oil, weather conditions, time of year, volume of the spill, and duration of the spill (Gorsline *et al.* 1981). Natural inter-annual variation in other factors that affect populations (*e.g.*, prey availability and weather) complicates the assessment of oil spills on bird populations (Eppley 1992; White *et al.* 1995; Votier *et al.* 2005).

Leighton (1993) described three ways in which petroleum oils are toxic to birds. Physical alteration of feathers through oiling leads to thermal and buoyancy deficiencies that typically result in the deaths from combinations of heat loss, starvation, and drowning. Also, oiled birds can return to nests, exposing eggs to oil and causing high mortality of embryos. Mortality and developmental defects in avian embryos exposed to even small quantities of oil (*i.e.*, 1 to 20 µL) have been documented in a wide range of species (Leighton 1993). Ingestion of oil as a result of preening or consumption of contaminated food or drinking water can also result in physiological and pathological issues. These long-term physiological changes may eventually result in death (Ainley *et al.* 1981; Williams 1985; Frink and White 1990; Fry 1990), or decrease long-term survival (Esler *et al.* 2002).

The extent of bioaccumulation of the chemical components of oil in birds is limited because vertebrate species are capable of metabolizing them at rates that minimize bioaccumulation (Neff 1985, in Hartung 1995). Assuming the birds are healthy enough after a spill to continue to feed properly, they have the ability to excrete much of the hydrocarbons within a short time period (McEwan and Whitehead 1980). When assessing the neurotoxicity on marine birds of fuel oil from the *Prestige* spill in northwest Spain, Oropesa *et al.* (2007) found that PAHs from oil are unlikely to produce a neurotoxic effect through inhibition of AChE; but in some of the birds most affected by the spill (*i.e.*, razorbills and common guillemots) it might contribute to overall systemic toxicity.

Nesting seabirds that have survived oil contamination generally exhibit decreased reproductive success, including a decrease in fertilization (Holmes *et al.* 1978), egg laying and hatching (Hartung 1965; Ainley *et al.* 1981), chick growth (Szaro *et al.* 1978), and survival (adults and offspring) (Vangilder and Peterle 1980; Trivelpiece *et al.* 1984), as well as a reduction in mean eggshell thickness and strength (Stubblefield *et al.* 1995). A spill occurring during the breeding season can cause mortality of young by affecting prey availability of species with low seasonal dietary variation (Velando *et al.* 2005), changes in normal parental behaviour (Eppley and Rubega 1990), or abandonment of nests (Butler *et al.* 1988).

It is known that diving species such as Black Guillemot, murres, Atlantic Puffin, Dovekie, eiders, Long-tailed Duck, scoters, Red-breasted Merganser, loons, and grebes are considered to be the most susceptible to the immediate effects of surface slicks (Leighton *et al.* 1985; Chardine 1995;

Wiese and Ryan 1999; Irons *et al.* 2000). Other birds such as Northern Fulmar, shearwaters, storm-petrels, gulls, phalaropes, and terns are vulnerable to contact with oil because they feed over wide areas and make frequent contact with the water's surface. They are also vulnerable to the disturbance and habitat damage associated with oil spill cleanup (Lock *et al.* 1994). Shorebirds and phalaropes may be more affected by oil spills than has been suggested by carcass counts (Larsen and Richardson 1990). This may be due to the higher mobility of oiled shorebirds.

Because of the concentrations of seabirds and proximity to shipping routes, the south coast of Newfoundland has been identified as a high risk area for seabird oiling and the Canadian Wildlife Service has been coordinating beached bird surveys in the region since 1984 (Wiese and Ryan 2003). Alcids, especially Common and Thick-billed Murres, have the highest oiling rate of seabirds recovered from beaches along the south and east coasts of the Avalon Peninsula, Newfoundland (Wiese and Ryan 2003). Most oil on birds collected on beaches in Newfoundland is heavy fuel oil mixed with lubricants, the same mixture found in bilges of large vessels (Weise and Ryan 2003). Significantly higher proportions of alcids (along with other seabird groups) are oiled in winter versus summer (Wiese and Ryan 1999), with seasonal variance in effects likely reflecting the location, size, and importance (*i.e.*, percentage of a population) of bird congregations (*i.e.*, breeding colonies and their seaward extensions, migration staging areas, and wintering areas). Oil on water also persists longer in cold temperatures increasing exposure to oiling at this time of year. Winter Oil Vulnerability Indices (WOVI) were calculated by Weise and Ryan (2003) for species commonly found oiled on Newfoundland beaches from (October–March), with higher WOVI associated with birds that roost on the sea, forage by swimming, escape by diving, have small wintering areas and overlap with areas of ship traffic. These included Murres, Dovekies and Common Eiders, which are also present in greater abundance during the winter months.

Determining the numbers of birds potentially affected by a spill can be challenging and subject to various models and site-specific considerations. Many oiled birds are never recovered, causing mortalities to be under-reported. Following the Deepwater Horizon Oil Spill in the Gulf, a total of 8183 birds were collected from April 30, 2010 to November 10, 2011, with 2079 collected alive and visibly oiled, 2263 collected dead and visibly oiled, and 3827 collected dead and not visibly oiled (NOAA 2010). In comparison to spills like the *Exxon Valdez*, this was a relatively low number of detected bird causalities, given the volume of oil spilled (*i.e.*, over 4 million barrels) (Belanger *et al.* 2010). Belanger *et al.* (2010) speculate that this low number could be due to inefficient collection methods by limited personnel, lacking in training or experience.

Almost 10 000 carcasses were collected following the sinking of the tanker *Prestige* off the coast of Spain in 2002, with common guillemot, Atlantic puffin and razorbill being most affected (Oropesa *et al.* 2007). Following the *Exxon Valdez* spill, nearly 30 000 birds were collected, with total mortality estimates ranging from 100 000 to 650 000 birds (reviewed by Day *et al.* 1997). The 1984 blowout at the Uniacke G-72 well (near Sable Island) resulted in a spill of 240 m^3 (1510 bbl) of condensate. A survey of an extensive area around the well after the well was capped (11 days after the blowout) observed a total of seven oiled marine birds (three Dovekies and four murres), with no obvious oiling of gulls, kittiwakes and fulmars (Martec Ltd. 1984, in Hurley and Ellis

2004). On a broader geographical scale, estimates of the number of birds that die annually from operational spills range from 21 000 on the Atlantic coast of Canada, and 72 000 in all of Canada (Thomson *et al.* 1991). Clark (1984) estimated that 150 000 to 450 000 birds die annually in the North Sea and North Atlantic from oil pollution from all natural and anthropogenic sources.

With respect to long-term population effects on marine birds as a result of oil spills, the scientific literature is divided with some studies suggesting that oil pollution is unlikely to have major long-term effects on bird productivity or population dynamics (Butler *et al.* 1988; Boersma *et al.* 1995; Erikson 1995; Stubblefield *et al.* 1995; White *et al.* 1995; Wiens 1995, 1996; Seiser *et al.* 2000). Conversely, others (Leighton 1993) do show long-term effects of oil pollution on birds (*e.g.*, birds having ingested oil no longer contribute to the reproductive output of a species). These differences can be explained, in part, by varying circumstances of the spill event (acute or chronic exposure, location of spill, time of year) and health of bird populations (Burger 1993; Wiese and Robertson 2004). There is a difference between mortalities from big spills and those from bilge oils and other sources; the latter is more likely to result in a population effect, particularly if it involves ongoing exposure (Wiese et al 2004). For example, Wiese and Robertson (2004) reported that the chronic oiling due to bilge dumping killed around 300 000 birds annually around southeastern Newfoundland.

Seiser *et al.* (2000) examined blood parameters from pigeon guillemot (*Cepphus columba*) from oiled and unoiled areas of Alaska eight years following the *Exxon Valdez* oil spill, to help determine any role of the spill in population decline. While differences in calcium and mean cell volume were noted between chicks in oiled and unoiled areas, little evidence of continued oil injury was documented. Preliminary data from adults in the oiled area indicated elevated aspartate aminotransferase activity, consistent with hepatocellular injury, causing authors to speculate that adults have greater opportunities for exposure to residual oil than nestlings and more study was needed to draw definitive conclusions (Seiser *et al.* 2000). Franci *et al.* (2014) investigated the impact of the Deepwater Horizon Oil Spill on two hormones in Northern Gannets that influence reproductive success. Based on data from geolocators, 23.5% of the Northern Gannets breeding on Bonaventure Island were found to overwinter in the Gulf of Mexico in 2010–2011, but PAH concentrations in gannet blood cells were below detection limits, which may reflect the ability of seabirds to metabolize PAH compounds or the time elapsed between oil exposure and testing.)

Day *et al.* (1997) examined the effects of the *Exxon Valdez* oil spill on marine bird habitat use, determining that while initial effects were severe, most of the habitat use for the majority of birds species recovered within 2.5 years of the spill. They also report that migratory species were less likely to be affected than residents, and offshore species were less affected than intertidally feeding species. While initial effects to bird habitat were severe, this rate of recovery was attributed to high-latitude seabird populations which appear to be fairly resilient to environmental perturbations, as well as Prince William Sound being a high wave energy and a largely rocky substrate environment where oil does not persist as long as other settings(Day *et al.* 1997).

Murphy and Mabee (1999) assessed the effects of the *Exxon Valdez* on Black Oystercatchers population in Prince William Sound almost a decade after the spill. Authors reported that while sublethal effects to the breeding population were evident in post-spill assessments conducted between 1989 and 1993, results from 1998 indicated no oiling effects or nesting effort, breeding phenology, egg volumes, chick growth rates, or chick survival at either a regional or territorial scale.

In contrast, Trust *et al.* (2000) looking at recovery of harlequin duck populations in Prince William Sound from 1995 to 1997 concluded that chronic exposure to oil and resulting biochemical and physiological changes in individuals was hindering the population recovery of some sea duck species in Prince William Sound. Esler *et al.* (2002) further concluded that recovery of Harlequin Duck populations continued to be hindered as many as nine years after the oil spill, postulating that life history characteristics of this species and their benthic, nearshore feeding habits make them susceptible to both initial and long-term oil spill effects.

An assessment of environmental effects of oil spills in Greenland (Mosbech 2002) concluded that while major oil spills have the potential to deplete bird populations or cause single seabird colonies to be deserted, reports from many spills demonstrate the resiliency of seabird populations to single catastrophic events. They also conclude that an oil spill can play more of a role where other factors hamper the recovery of the population (*e.g.*, hunting), and the population is small or has a restricted distribution.

French–McCay (2009) describes state of the art biological effects modelling for oil spills. Wildlife individuals that move through the area swept by floating oil (*e.g.*, slicks, emulsions, or other floating forms such as tar balls) are assumed to be oiled based on probability of encounter and those oiled above a threshold dose are assumed to die. Based on available literature, the probability of mortality once oiled is assumed to be 100% for birds. French-McCay (2009) also considered the probability of exposure to oil by grouping seabirds based on their behaviour patterns and developing a combined oil encounter and mortality rate of 99% for surface divers, 35% for nearshore aerial divers, 5% for aerial seabirds and 35% for wetland birds.

Wiese *et al.* (2001) indicate that seabirds are known to aggregate around oil platforms and drilling rigs for a variety of reasons including night lighting, flaring, and food, with concentrations at the oil platform documented at up to 19 to 38 times higher than on transects leading up to the platform. Surveys conducted from 1999 to 2003 off of offshore platforms on the Grand Bank document seasonal shifts in marine bird occurrences, with higher densities of auks occurring in the fall around platforms relative to surrounding areas and shearwaters in summer (Burke *et al.* 2012). This suggests a prey enhancement effect resulting from human waste discharges and attraction of fish to lights. Oiled auks and oiled gulls were also observed in proximity to the Hibernia platform. Marquenie *et al.* (2014) report on the results of bird monitoring at large platforms in the North Sea, indicating that platforms can attract as many as 50 000 migrating birds in any one night. While not all these birds would be vulnerable to marine pollution, any aggregations of seabirds in the vicinity of the Project could be at risk in the event of a spill.

SBM Spill Effects on Marine Birds

SBM is considered to be of low-toxicity and environmental effects are mostly restricted to physical smothering effects on the sea floor (C-NLOPB 2011). A release of SBM would result in elevated levels of TSS in the water column, with modelling of an accidental release of SBM showing that the plume travels with ambient currents until dispersion and turbulence cause the TSS concentrations to fall below the 1 mg/L threshold. These plumes extend from 5 to 10 km from the site with ambient conditions being returned to within 30 hours of the spill. There is also potential for a spill at surface to result in a small, thin sheen, with effects potentially similar to those discussed above for hydrocarbon spills, but more limited in magnitude, given the comparative volume and physical property of the SBM. O'Hara and Morandin (2010) investigated the effects of thin oil sheens associated with both crude oil and synthetic based drilling fluids on the feathers of pelagic seabirds (Common Murre and Dovekie) to determine how exposure affected the microstructure of feathers. They report that feather weight and microstructure changed significantly for both species after exposure to thin sheens of both hydrocarbons, concluding a plausible link between even operational discharges of hydrocarbons and increased seabird mortality.

8.5.3.2 Mitigation of Environmental Effects

The focus of mitigation is accident prevention; detailed information on Shell's accident prevention and response planning is provided in Section 8.1, including the Oil Spill Response Plan and Well Containment Plan (to address potential for subsea blowout). A diesel spill in the nearshore environment could require shoreline clean-up, including possible collection and cleaning of any oiled marine birds. In the offshore environment, smaller scale batch spills in calm conditions may be mitigated via oil spill response measures and marine bird rehabilitation; however, these mitigations are recognized to be limited. Hazing of birds from oiled areas inshore and offshore may be implemented to prevent oiling (Wiese *et al*. 2001). Additionally, dispersants may be utilized subsea and at the surface (subject to regulatory approval) to reduce the amount of oil on the ocean surface, and thereby the risk to marine birds. Although the likelihood of a blowout reaching shore is extremely low, such an occurrence could also require shoreline clean-up and bird recovery and rehabilitation. Wiese *et al.* (2001) recommend monitoring of behaviour relative to the spill (*i.e.*, attraction, avoidance, preening), number and percentage of oiled individuals and documenting number, percentage and timing of dead birds.

8.5.3.3 Characterization of Residual Environmental Effects

For the purposes of this effects assessment, a **significant adverse residual environmental effect** on Marine Birds is defined as a Project-related environmental effect that:

- causes a decline in abundance or change in distribution of marine birds within the LAA, such that natural recruitment may not re-establish the population(s) to its original level within one generation
- jeopardizes the achievement of self-sustaining population objectives or recovery goals for listed species or

- results in permanent and irreversible loss of critical habitat as defined in a recovery plan or an action strategy for a listed species

Blowout, Batch Spills and Vessel Spill

With respect to Change in Habitat Quality and Use, hydrocarbon spills are not likely to permanently alter marine bird habitat quality for marine birds. Prey availability may be reduced or marine birds may avoid affected habitat. However, spill cleanup, weathering and biodegradation would result in the eventual recovery of such habitat.

In the remote possibility (less than 2% probability based on unmitigated modelling results for the Project) that hydrocarbons released at the Project site reached the exposed coast, a slick would likely be rapidly weathered and dispersed on the high energy coastline; therefore any direct effects on nesting habitat would be reduced. The areas with the potential to be exposed to shoreline oiling including the Yarmouth, Barrington, and Shelburne region, as well as Sable Island National Park Reserve, correspond to areas known to support breeding bird populations. A particularly dense aggregation of marine bird nesting colonies is located in the area between Cape Sable Island and Yarmouth. This area has a large number of small islands which provide a high density of potential nesting sites. The timeframe required for oil to potentially reach these areas (20 to 30 days) would allow for response measures and containment equipment to be placed in advance to reduce or avoid effects. Response measures could, however, result in hazing of nesting birds and reproductive failure. Oiling of foraging and feeding adults could also affect chicks through secondary oiling. Although potential for effects on nesting habitat is unlikely, there is greater potential for effects on foraging habitat at sea.

With respect to a Change in Risk of Mortality or Physical Injury, exposure to hydrocarbons frequently leads to hypothermia and deaths of affected marine birds. Although some may survive these immediate effects, long-term physiological changes may eventually result in lower reproductive rates or premature death. Sublethal effects of hydrocarbons ingested by marine birds may affect their reproductive rates or survival rates. Sublethal effects may persist for a number of years, depending upon generation times of affected species and the persistence of any spilled hydrocarbons. Most marine birds are relatively long-lived. Adult marine birds foraging offshore to provision their young may become oiled and bring hydrocarbons on their plumage back to the nest to contaminate their eggs or nestlings, causing embryo or nestling mortality.

There are six marine bird SOCI that occur within the RAA for the Project: Ivory Gull, Piping Plover, Roseate Tern, Red Knot, Harlequin Duck, and Barrow’s Goldeneye, with the Ivory Gull and Roseate Tern being the most likely to occur within the Project Area. Roseate Tern are known to breed on Sable Island. As a surface feeder, Ivory Gull would be less susceptible to oiling than plunge divers, such as the Roseate Tern.

SBM Whole Mud Spill

There is potential for a SBM whole mud spill to result in a surface sheen, which in turn can cause a Change in Risk of Mortality or Physical Injury for seabirds present in the immediate area. If the wind and wave conditions were such that a sheen formed, it would be temporary and limited in size, such that only birds in the immediate area of the spill would likely be affected. While the risk of mortality for individual birds that came in contact with the sheen would be increased, the limited nature of this sheen and the likely number of birds affected would be such that the resulting residual effect is not likely to be significant.

Summary

Adverse environmental effects of accidental events from a hydrocarbon spill are predicted to be low-to-high in magnitude, extend to the RAA, be short- to-medium-term in duration and occur rarely (Table 8.5.4). Although hydrocarbon spills could result in some mortality at the individual level, these environmental effects are predicted to be reversible at the population level. However, these environmental effects could be significant if carried over more than one generation according to the significance threshold used in this environmental assessment. In addition, there is potential for mortality of individual birds from at risk species, particularly Roseate Tern that could be present within the zone of influence of a spill, and the mortality of an individual bird species at risk is defined as significant. Again, this is considered unlikely given the unlikelihood of a large spill event to occur and the response procedures that would be in place to reduce the consequences of such an event.

As a result of these considerations, a precautionary conclusion is drawn here which is that the residual environmental effect of a blowout, large batch spill, or vessel spill is predicted to be significant, but not likely. Infrequent small spills, as well as a SBM whole mud release, would be not significant. A medium level of confidence is assigned to the significance determination for all accident scenarios, with the exception of a blowout (which is made with high confidence), as the significance is based on a very worst-case scenario, with the actual significance influenced by a number of factors such as volume spilled, duration, location, season, presence of birds, and effectiveness of mitigation.

Table 8.5.4 Summary of Residual Project-Related Environmental Effects on Marine Birds – Accidental Events

Project Activities and Components	Mitigation/ Compensation Measures	Nature of Effect	Residual Environmental Effects Characteristics						Significance	Likelihood of Significant Effects	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context				
100 bbl batch spill	• Spill Prevention • Emergency Response Plan • Oil Spill Response Plan • Source Control Response Plan • NEBA approach to evaluate response options • Hazing of birds from oiled areas to prevent oiling • Shoreline clean-up, as applicable and needed • Collection and rehabilitation of oiled birds as required	A	M	RAA	ST	S	R	U	S	L	M	As part of spill monitoring, record will be kept of any marine birds collected or observed with visible oiling. This may include monitoring of behaviour relative to the spill (*i.e.*, attraction, avoidance), number and percentage of oiled individuals, and number, percentage and timing of dead birds.
10 bbl batch spill		A	L	LAA	ST	S	R	U	N	N/A	M	
Vessel spill		A	H	RAA	ST-MT	S	R	U	S	L	M	
SBM whole mud spill		A	L	LAA	ST	S	R	U	N	N/A	M	
Well blowout		A	M	RAA*	ST - MT	S	R	U	S	L	H	

KEY

Nature of Effect:
P Positive
A Adverse

Magnitude:
N Negligible – no measurable change in marine species populations, habitat quality or quantity, or contaminant levels
L Low – a measurable change but within the range of natural variability (change in population levels or contaminant concentrations consistent with baseline levels); will not affect population viability
M Moderate – measurable change outside the range of natural variability but not posing a risk to population viability
H High – measurable change that exceeds the limits of natural variability and may affect long-term population viability

Geographic Extent:
PA – Project Area – effects are restricted to the Project Area and well site.
LAA – effects are restricted to the LAA
RAA – effects are included within the RAA; in certain scenarios, effects may extend beyond the RAA as indicated by an "*".

Duration:
ST Short-Term– effect extends for a portion of the duration of Project activities
MT Medium-Term – effect extends through the entire duration of Project activities
LT Long-Term – effects extend beyond the duration of Project activities, after well abandonment
P Permanent – measurable parameter unlikely to recover to baseline

Frequency:
O Once – effect occurs once
S Sporadic – effect occurs sporadically at irregular intervals
R Regular – effect occurs on a regular basis and at regular intervals throughout the Project
C Continuous – effect occurs continuously

Likelihood of Significant Effect:
L – Low likelihood (*i.e.*, unlikely to occur)
M –Moderate likelihood (*i.e.*, somewhat likely to occur)
H – High likelihood (*i.e.*, very likely or certain to occur)
N/A – effect is not predicted to be significant

Reversibility:
R Reversible – will recover to baseline conditions before or after Project completion (well abandonment)
I Irreversible – permanent

Context:
U Undisturbed – Area relatively or not adversely affected by human activity
D Developed – Area has been substantially previously disturbed by human development or human development is still present

Significance:
S Significant
N Not Significant

Prediction Confidence:
Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation
L Low level of confidence
M Moderate level of confidence
H High level of confidence

8.5.4 Special Areas

Special Areas provide important habitat and may be comparatively more vulnerable to Project-related effects, including effects from accidental events, than other areas. Adverse effects on Special Areas could degrade the ecological integrity of the Special Area such that it is not capable of providing the same ecological function for which it was designated (*e.g.*, protection of sensitive or commercially important species). The assessment of Special Areas is therefore closely linked to all of the other VCs considered in this assessment. This consideration is particularly true for accidental events where the physical effects on the biological resources found in these areas represent the potential effects of greatest concern. These potential effects are discussed in Sections 8.5.1 to 8.5.3 for Fish and Fish Habitat, Marine Mammals and Sea Turtles and Marine Birds and are not repeated in this section. In some cases, Special Areas are designated to protect populations that are considered at risk. In these cases, while the effect mechanisms are similar to species not at risk, the significance of the effect can be greater, particularly if the effect involves the loss of a species at risk.

There are 18 Special Areas on the Scotian Shelf and Slope with the potential to be affected by the identified accidental event scenarios. Other than the Scotian Slope/Shelf Break EBSA which extends across the RAA, including through the Project Area, the Special Areas located in closest proximity to the Project Area are fisheries closure areas that have been designated under the *Fisheries Act* to protect spawning and nursery areas and/or juvenile species. The Scotian Slope/Shelf Break EBSA is recognized for: unique geology; high finfish and squid diversity; value as a migratory route for large pelagic fishes, cetaceans, and sea turtles; overwintering habitat for a number of shellfish and finfish species (*e.g.*, lobster, Atlantic halibut); foraging area for leatherback sea turtles; feeding and overwintering area for seabirds; and habitat for Greenland sharks (Doherty and Horsman 2007). It has also been identified as important to the Aboriginal and commercial fishers. Approximately 97% of the Project Area falls within the Scotian Slope/Shelf Break EBSA. However, the EBSA is very large (approximately 68 603 km^2) and the Project Area constitutes about 11% of its total area.

8.5.4.1 Environmental Effects Mechanisms

Accidental events have the potential to result in a Change in Habitat Quality and Use for Special Areas. As most of the Special Areas are located at some distance from the Project site, the accidental event scenarios with greatest potential to interact with these areas are those with larger geographic extent, including the blowout scenario. Table 8.5.5 provides a summary of each accidental event scenario and the potential for its effects to overlap with the specified Special Area (based on Figures 8.4.2 to 8.4.7). Note that the only Special Area predicted to overlap with a spill of SBM whole mud is the Scotian Slope/Shelf Break EBSA (Section 8.4). Effects of this kind of spill would be localized for the most part to the wellsite area already affected by routine drilling discharges, with no measurable effect on the EBSA; this scenario is therefore not discussed further in this subsection.

Table 8.5.5 Unmitigated Probabilities of Diesel/Oil Reaching a Special Area

Special Area	Distance from Project Area/LAA	Probability of Diesel Reaching Area from Batch Spill	Probability of Diesel Reaching Area from Vessel Spill	Probability of Oil Reaching Area from Unmitigated Blowout[1]
Scotian Slope/Shelf Break EBSA[2]	0 km/0 km	As the MODU will be operating within the EBSA, a batch spill would result in both surface oiling and total dissolved aromatic concentrations in the vicinity of the spills	The LAA passes through the area; therefore, a vessel spill at this location would result in both surface oiling and total dissolved aromatic concentrations in the vicinity of the spill	> 75% probability of surface oiling exceeding the 0.04 µm thickness threshold; > 75% probability of water column oiling in excess of 1 ppb in areas closest to the drill site
Browns Bank (Haddock Spawning Closure)	56 km/ 26 km	Surface oiling could occur in this area in the form of patchy sheen and weathered oil.	Due to the proximity of this area to the LAA (26 km), a vessel spill in this area could result in surface oiling.	0 to 25% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
Haddock Nursery Closure, Emerald/Western Bank (Haddock Box)	60 km/ 0 km	No predicted interaction based on modelling results.	The LAA passes through the area; therefore, a vessel spill at this location would result in both surface oiling and total dissolved aromatic concentrations in the vicinity of the spills.	0 to 10% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
Redfish Nursery Closure Area (Bowtie)	92 km/ 33 km	Surface oiling could occur in this area in the form of patchy sheen and weathered oil.	Due to the proximity of this area to the LAA (33 km), a vessel spill in this area could result in surface oiling.	0 to 10% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
North Atlantic Right Whale Critical Habitat/Area to be Avoided	95 km/ 65 km	Surface oiling could occur in this area in the form of patchy sheen and weathered oil.	Due to the proximity of this area to the LAA (65 km), a vessel spill in this area could result in surface oiling.	0 to 10% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
Lobster Fishing Area 40 (Georges Bank)	105 km/ 75 km	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (75 km), no interaction is predicted.	0 to 25% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb

Table 8.5.5 Unmitigated Probabilities of Diesel/Oil Reaching a Special Area

Special Area	Distance from Project Area/LAA	Probability of Diesel Reaching Area from Batch Spill	Probability of Diesel Reaching Area from Vessel Spill	Probability of Oil Reaching Area from Unmitigated Blowout[1]
Georges Bank Oil and Gas Moratorium Area	120 km/ 107	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (107 km), no interaction is predicted.	0 to 25% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
Northeast Channel Coral Conservation Area	130 km/ 100 km	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (100 km), no interaction is predicted.	0 to 25% probability of water column oiling in excess of 1 ppb
Hell Hole (Northeast Channel)	135 km/ 105 km	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (105 km), no interaction is predicted.	0 to 25% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
Georges Bank Fishery Closure (5Z)	158 km/ 117 km	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (117 km), no interaction is predicted.	0 to 25% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
Sambro Bank and Emerald Basin Sponge Conservation Areas	152 km/ 0 km, 182 km/ 27 km	No predicted interaction based on modelling results.	The LAA passes through the area (0km, 27 km); therefore, a vessel spill at this location would result in both surface oiling and total dissolved aromatic concentrations in the vicinity of the spills.	0 to 10% probability of water column oiling in excess of 1 ppb
Sable Island National Park Reserve	220 km/ 185 km	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (185 km), no interaction is predicted.	0 to 10% probability of surface oiling exceeding the 0.04 µm thickness threshold and shoreline oiling
The Gully Marine Protected Area (MPA)	262 km/ 232 km	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (232 km), no interaction is predicted.	0 to 10% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb

Table 8.5.5 Unmitigated Probabilities of Diesel/Oil Reaching a Special Area

Special Area	Distance from Project Area/LAA	Probability of Diesel Reaching Area from Batch Spill	Probability of Diesel Reaching Area from Vessel Spill	Probability of Oil Reaching Area from Unmitigated Blowout[1]
Northern Bottlenose Whale Critical Habitat (Sanctuaries): The Gully, Shortland Canyon, Haldimand Canyon	273 km/ 243 km, 330 km/ 300 km, 366 km/ 366 km	No predicted interaction based on modelling results.	Due to the distance of these areas from the LAA (243 300 and 336 km), no interaction is predicted.	0 to 10% probability of surface oiling exceeding the 0.04 µm thickness threshold and water column oiling in excess of 1 ppb
Lophelia Conservation Area (LCA)	442 km/ 412 km	No predicted interaction based on modelling results.	Due to the distance of this area from the LAA (412 km), no interaction is predicted.	Less than 1% probability of water column oiling in excess of 1 ppb

Notes:

[1] Represents 49 150 bpd 30-day continuous blowout of Federated Crude Oil (unmitigated).

[2] This Special Area is the only one predicted to be affected by a SBM Whole Mud Spill as plume will be limited to 5 to 10 km from release site.

For spills of diesel from the MODU, the thickness of the slick at the instant of release is greater than 25 μm. As the fresh diesel spreads, it thins to a sheen, between 0.04–0.1 μm, where high rates of evaporation occur (approximately 80% of the total diesel). The area of surface water exposure in excess of 1 ppb of total dissolved aromatics is approximately 2 km^2 for the 10 bbl release and approximately 20 km^2 for the 100 bbl release. A maximum of 1–5 ppb is expected for the 10 bbl release, with localized concentrations as high as 25 ppb (or potentially slightly higher) in the region directly around the spill for the 100 bbl release. These effects would be limited to a very small portion of the Slope/Shelf Break EBSA. While a swath of surface oiling in excess of 0.04 μm is observed in both releases, this swept area is expected to be exposed to patchy sheen and weathered oil. This oiling could migrate to Browns Bank (Haddock Spawning Closure), Redfish Nursery Closure Area (Bowtie), and North Atlantic Right Whale Critical Habitat/Area to be Avoided. This surface oiling could interact with marine mammals (*i.e.*, North Atlantic Right Whale) and sea turtles as discussed in Section 8.5.2. However, due to the limited and temporary nature of any surface oiling, it is not expected to result in any significant effects to species or habitats residing in any of these Special Areas.

Spills of diesel fuel from a supply vessel would be expected to respond in a similar fashion to those spills modelled for the MODU, with concentrations of total dissolved aromatics affecting the immediate area, but a wider spread potential for some surface oiling. This oiling could overlap several Special Areas, as identified in Table 8.5.7. The Special Areas with the greatest potential to receive some surface oiling as a result of a vessel spill (based on proximity to the likely vessel routes) include: Scotian Slope/Shelf Break EBSA; Browns Bank (Haddock Spawning Closure); Haddock Nursery Closure, Emerald/Western Bank (Haddock Box); Redfish Nursery Closure Area (Bowtie); North Atlantic Right Whale Critical Habitat/Area to be Avoided; Sambro Bank and Emerald Basin Sponge Conservation Areas; and shoreline habitat (if a spill should occur close to port). Note that the potential for a spill to affect any of these areas would depend on the nature, volume and location of the spill along the transit route and not all of these areas would be affected by a single spill. Effects would most likely be temporary, but could result in effects to species most sensitive to surface oiling, including marine birds found in the EBSA.

The OSV route crosses through the Haddock Box and encompasses the Sambro Bank Sponge Conservation Area so both of these areas lie close to where a spill of diesel fuel from the OSV could occur while in transit. The Haddock Box is an important nursery area for the protection of juvenile haddock. Adult haddock also aggregate to spawn within the Haddock Box, including Emerald Bank, from March-June, with peak spawning in March/April. This closed fisheries area may be playing a role in increasing haddock stock and abundance of other non-target species (*e.g.*, winter flounder, plaice, silver hake) (O'Boyle 2011).

In 2013, DFO closed the Sambro Bank and Emerald Basin Sponge Conservation Areas, which are known to contain the highest density of *Vazella pourtalesi,* to bottom-contact fishing. The glass sponge is known to exist in only three locations worldwide; the Gulf of Mexico, the Azores, and in Canada, with the locations on the eastern Scotian Shelf being the only instances where large aggregations have been found (DFO 2013d. Slow growth rates, longevity, variable recruitment, and habitat-limiting factors make the sponges particularly vulnerable to physical disturbances and limit recovery (DFO 2013d). Spill modelling reported that dissolved aromatic concentrations would be limited to the surface and mixed layer of the water column (to a depth of 50–100 m throughout the year) (RPS ASA 2014b). The potential for deeper sponges to be exposed to harmful dissolved aromatic concentrations following surface spills of diesel or a blowout scenario is considered to be very low. A NEBA approach would be undertaken to evaluate response options; as part of this analysis, potential effects of dispersant use on benthic organisms such as sponges and corals would be taken into consideration.

Surface and water column oiling from a blowout at either of the modelled sites has the potential to interact with a number of the identified Special Areas in the RAA, although for the majority of these areas, the potential for oiling is low (less than 10% probability of reaching specified threshold concentration from unmitigated spill). Some of the areas located to the west of the Project Area have a higher probability of oiling (0 to 25%). However, once again this probability arises within the context of an unmitigated blowout (as modelled), which itself is an extremely unlikely event. As the Project Area is located within the Scotian Slope/Shelf Break EBSA, a blowout would result in oiling of some portion of the EBSA and subsequent biological effects on fish, marine mammals and sea turtles and marine birds. As indicated in the previous section, the greatest potential for adverse effects is to marine birds. As this area is recognized as an important overwintering and feeding area for marine birds, there is a potential for measurable, adverse effects, although effects are considered reversible. Scientific literature indicates that bird populations are likely to recover from a spill event, although the time required will depend on the species and the degree of exposure to pollutants after the initial spill. There is a less than 10% probability of oil reaching Sable Island National Park Reserve or the south west coast of Nova Scotia from an unmitigated 30-day blowout. While the probability is low, both areas support breeding bird colonies which are particularly sensitive to oiling effects. Adverse effects on critical habitat for the North Atlantic right whale and northern bottlenose whale are not anticipated based on the deterministic modelling results.

Scientific literature regarding past spill events documents that marine ecosystems mostly recover from spills (Stantec *et al.* 2012). Stantec reviewed case studies for 140 valued ecosystem components of which 69% of these were related to the marine environment, and 86% were recovered or recovering by the end of the study, with an average recovery time of 5.8 years. Rocky, exposed environments recovered faster (within a few years) relative to sheltered, soft sediment environments that take up to two decades to recover. Species with short life spans also recover at a faster rate (within days or a few years) compared to marine birds and mammals with longer life spans (Stantec *et al.* 2012). Likewise, any Special Areas affected as a result of an oil spill associated within this Project would also be expected to recover, particularly as most areas affected would be in open ocean, with limited potential for shoreline oiling.

8.5.4.2 Mitigation of Environmental Effects

The focus of mitigation is accident prevention; detailed information on Shell’s accident prevention and response planning is provided in Section 8.1, including the Oil Spill Response Plan and Well Containment Plan (to address potential for subsea blowout.) In general, mitigation measures for Special Areas are consistent with those proposed for Fish and Fish Habitat, Marine Mammals and Sea Turtles and Marine Birds. With respect to Sable Island National Park Reserve and potential oiling of the shoreline of Nova Scotia, in both cases, the minimum time for oil to reach shore would be a minimum of 20 days, which would provide time for Shell to implement response measures further limiting potential for shoreline oiling. Additional response strategy options will be implemented as applicable to protect other priority Special Areas and resources.

8.5.4.3 Characterization of Residual Environmental Effects

A **significant adverse residual environmental effect** on Special Areas is defined as a Project-related environmental effect that alters the valued habitat of the identified Special Area physically, chemically or biologically, in quality or extent, to such a degree that there is a decline in abundance lasting more than one generation of key species (for which the Special Area was designated) or species at risk; or a change in community structure, beyond which natural recruitment (reproduction and immigration from unaffected areas) would not sustain the population or community within the Special Area.

Batch Spills and Vessel Spills

A 10 bbl batch spill will be limited in magnitude, geographic extent and duration and limited to a small portion of the Slope/Shelf Break EBSA. A swath of surface oiling in excess of 0.04 µm from a 100 bbl spill could migrate to Browns Bank (Haddock Spawning Closure), Redfish Nursery Closure Area (Bowtie), and North Atlantic Right Whale Critical Habitat/Area to be Avoided. Due to the limited (patchiness) and temporary nature of any surface oiling, it is not expected to result in any substantial effects to species or habitats residing in any of these Special Areas. A vessel spill could occur anywhere along the route and therefore has the potential to affect the following Special Areas, in addition to the ones discussed above: Haddock Nursery Closure, Emerald/Western Bank (Haddock Box); Sambro Bank and Emerald Basin Sponge Conservation Areas, and shoreline habitat (if a spill should occur close to port). Spill modelling for the batch spills (similar in nature to a vessel spill) reported that dissolved aromatic concentrations would be limited to the surface and mixed layer of the water column (to a depth of 50–100 m throughout the year) (RPS ASA 2014b), therefore the potential for deeper sponges to be exposed is considered low. While haddock is a demersal species, sub-lethal and lethal effects can result for eggs and larvae present in the mixed surface layer of the water column. The relatively limited zone of influence of a vessel spill would prevent any wider spread and potentially significant adverse effects from occurring, and adverse effects would be considered temporary and reversible.

As marine birds are vulnerable to oiling from even thin sheens, a diesel spill could still result in a measurable effect, depending on the location and timing of the spill and any aggregations of seabirds in the area. For this reason, this event could result in a significant adverse effect on the Scotian Slope/Shelf Break EBSA, which is recognized as an important feeding and overwintering area for seabirds. This is a conservative prediction as a large spill of diesel is considered unlikely, and even if it were to occur, a significant residual effect would depend on a worst-case combination of time of year, weather conditions, volume of material spilled and presence of aggregations of seabirds. It also captures and reflects the same potential for significant effects assessed for the Marine Birds VC. Any change in the quality of habitat found in the EBSA would be temporary and reversible and other species occurring within the EBSA would not be expected to experience measurable adverse effects at the population level.

Blowouts

A blowout represents the accidental event with the potential for the most widespread effects. However, with the exception of the Scotian Slope/Shelf Break EBSA, the potential for either surface or water column oiling to interact with other Special Areas in the RAA is relatively low (0 to10% or 0 to 25%, refer to Table 8.5.7). These probabilities of the areas being affected are the results of modelling an unmitigated blowout scenario, which is a highly unlikely event as it precludes consideration of response and recovery measures which would be implemented to some effect in the event of an actual incident.

Similar to a diesel spill, the potential for adverse effects on marine bids, particularly species at risk, including the Roseate Tern which is known to breed on Sable Island National Park Reserve result in the precautionary prediction of a significant adverse effect. As indicated in Section 8.5.1 and 8.5.2, effects of blowouts on fish and fish habitat, marine mammals, and sea turtles are not predicted to be significant. Therefore the determination of a significant effect of a blowout on Special Areas is mainly driven by the potential presence of marine birds in the Scotian Slope/Shelf Break EBSA.

Summary

The nature and extent of the effects of an accidental event on Special Areas on Habitat Quality and Use vary considerably depending on the type and magnitude of the event, the proximity to the Special Area, and the ecological importance of the Special Area. A significant adverse effect is predicted for a 100 bbl batch spill and a vessel spill, based solely on the potential for oiling of seabirds found in the Scotian Slope/Shelf Break EBSA. This is a conservative prediction reflecting the conclusions found in the Marine Birds VC. A significant adverse effect is also predicted for a worst-case unmitigated blowout again due to the potential for effects on marine birds within the Scotian Slope/Shelf Break EBSA and breeding on Sable Island National Park Reserve. The likelihood of any significant adverse effect occurring is considered low as the probability of the event occurring is low based on historic statistics. In addition, modelling was based on unmitigated scenarios, and even in this worst-case, probabilities of oil from a blowout reaching any of the identified Special Areas (with the exception of the Scotian Slope/Shelf Break EBSA) was 25% or less. A medium level of confidence is assigned to the significance determination for batch spills and vessel spills as the significance is based on a very worst-case scenario, with the actual significance likely to be less than predicted and influenced by a number of factors, such as volume spilled, duration, location, season, presence of birds, and effectiveness of mitigation. A high level of confidence is assigned to the predicted significant effect associated with a blowout scenario, in spite of the same variable factors mentioned above. A summary of residual effects is found in Table 8.5.6.

Table 8.5.6 Summary of Residual Project-Related Environmental Effects on Special Areas – Accidental Events

Project Activities and Components	**Mitigation/ Compensation Measures**	**Nature of Effect**	**Residual Environmental Effects Characteristics**						**Significance**	**Likelihood of Significant Effects**	**Prediction Confidence**	**Recommended Follow-up and Monitoring**
			Magnitude	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Context**				
100 bbl batch spill	• Emergency Response Plan • Spill Prevention • Oil Spill Response Plan • Source Control Response Plan • NEBA approach to evaluate response options • Shoreline clean-up, as applicable • Collection and rehabilitation of oiled birds as required	A	M	RAA	ST	S	R	U	S	N/A	M	Specific monitoring plans will be developed as part of spill response planning, but at a minimum, a record will be kept of any marine birds, marine mammals or sea turtles recovered or with visible oiling.
10 bbl batch spill		A	L	LAA	ST	S	R	U	N	N/A	H	
Vessel Spill		A	H	RAA	ST-MT	S	R	U	S	L	M	
SBM whole mud spill		A	L	LAA	ST	S	R	U	N	N/A	H	
Well blowout		A	M	RAA*	ST - MT	S	R	U	S	L	H	

KEY

Nature of Effect:

P Positive
A Adverse

Magnitude:

N Negligible – no measurable change in marine species populations, habitat quality or quantity, or contaminant levels
L Low – a measurable change but within the range of natural variability (change in population levels or contaminant concentrations consistent with baseline levels); will not affect population viability
M Moderate – measurable change outside the range of natural variability but not posing a risk to population viability
H High – measurable change that exceeds the limits of natural variability and may affect long-term population viability

Geographic Extent:

PA – Project Area – effects are restricted to the Project Area or well site.
LAA – effects are restricted to the LAA
RAA – effects are included within the RAA; in certain scenarios, effects may extend beyond the RAA as indicated by an "*".

Duration:

ST Short-Term – effect extends for a portion of the duration of Project activities
MT Medium-Term – effect extends through the entire duration of Project activities
LT Long-Term – effects extend beyond the duration of Project activities, after well abandonment
P Permanent – measurable parameter unlikely to recover to baseline

Frequency:

O Once – effect occurs once
S Sporadic – effect occurs sporadically at irregular intervals
R Regular – effect occurs on a regular basis and at regular intervals throughout the Project
C Continuous – effect occurs continuously

Likelihood of Significant Effect:

L – Low likelihood (*i.e.*, unlikely to occur)
M – Moderate likelihood (*i.e.*, somewhat likely to occur)
H – High likelihood (*i.e.*, very likely or certain to occur)
N/A – effect is not predicted to be significant

Reversibility:

R Reversible – will recover to baseline conditions before or after Project completion (well abandonment)
I Irreversible – permanent

Context:

U Undisturbed – Area relatively or not adversely affected by human activity
D Developed – Area has been substantially previously disturbed by human development or human development is still present

Significance:

S Significant
N Not Significant

Prediction Confidence:

Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation
L Low level of confidence
M Moderate level of confidence
H High level of confidence

8.5.5 Commercial Fisheries

The Project Area is located within NAFO Unit Areas 4Wm, 4Xl, and 4Xn. These boundaries include Scallop Fishing Areas (SFA) 25 and 26 and Crab Fishing Areas (CFA) 24E and 24W. There is minimal fishing effort within and surrounding the Project Area. Harvesting in the LAA surrounding the Project Area is primarily focused on Atlantic halibut, Atlantic cod, Atlantic hagfish, cusk, monkfish, redfish, red hake, silver hake, swordfish, white hake, shark species such as porbeagle, and bluefin and other species of tuna.

A productive harvesting area exists approximately 50 km northwest of the Project Area between Baccaro and LaHave Banks. This region represents productive fishing grounds for Atlantic halibut, cod, haddock, pollock, cusk, flatfish, redfish, white hake, wolfish and monkfish with limited fishing for crab and lobster. Within the Project Area and LAA, in general, fishing effort is understood to be low.

In the nearshore, Halifax Harbour is located within NAFO Unit Area 4Wk. Commercial fisheries in the harbour include a small commercial finfish fishery seaward of McNabs Island, which consists of groundfish (cod, haddock, pollock and halibut) and pelagic (herring and mackerel) species (Rozee 2000). The Bedford Basin and other areas throughout the harbour support a bait fishery (pollock, herring, mackerel and smelt) for both commercial and recreational bait (Rozee 2000); these are typically fished using gillnets and hand-lines (Stantec 2012b). Commercial and recreational fisheries for clams and mussels are closed due to fecal coliform levels in the harbour. Lobster is the primary commercial species harvested within Halifax Harbour. The harbour is included within the boundaries of LFA 33, which extends from Halifax County to Shelburne County. LFA 34 extends from Shelburne county around the southern end of Nova Scotia into the Bay of Fundy and has the highest landings of any LFA in Canada (DFO 2013x).

In addition to nearshore fisheries, there are several finfish (*e.g.*, salmon, cod, trout) and shellfish (*e.g.*, oyster, mussel, scallop, sea urchin, clam) aquaculture operations in the harbours and bays along the Nova Scotia coastline in the RAA (NSDFA 2013).

8.5.5.1 Environmental Effects Mechanisms

Project-related accidental events could potentially affect commercial fisheries with respect to a Change in Availability of Fisheries Resources. Section 8.5.1 evaluates effects on fish and fish habitat and concludes that biophysical effects on fish from accidental events will not be significant. However, adverse effects could still be realized by fishers in the event of an offshore or nearshore spill, as a result of reduced access to fishing grounds (*e.g.*, fisheries exclusion), reduced catches, and/or reduced marketability. In addition, fishing gear or cultivation gear may be lost or damaged as a result of an accidental event. The significance of the potential adverse effects depends on the nature, magnitude, location and timing of a spill.

All of the identified accidental scenarios have the potential to affect Commercial Fisheries, including a Batch Spill (100 bbl and 10 bbl), Vessel Spill, SBM Whole Mud Spill, and Subsea Blowout (Table 8.5.1). Batch spills, vessel spills and blowouts are discussed together in the context of hydrocarbon effects. Although SBM also has hydrocarbon content in the form of synthetic oil, the effects of a spill of SBM are discussed separately.

Hydrocarbon Effects on Commercial Fisheries

An accidental event could result in effects on availability of fisheries resources, access to fisheries resources, and/or fouling of fishing or cultivation gear. Although the Project is not located within an area of high harvesting activity, a slick could reach an active fishing area on the Scotian Shelf or shelf break where harvesting activity is more concentrated. Fishery closures may be imposed after a spill to prevent gear from being contaminated and to protect or reassure seafood consumers (Moller *et al.* 1999).

Fishery closures are usually implemented in areas (including a buffer) where: a visible sheen exists on the ocean surface; in areas (including a buffer) with detectable levels of subsurface oil; and, as a precautionary measure, in areas where surface oil is predicted to occur based on trajectory modelling (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling n.d.). The threshold of 0.4 µm was used to present spill trajectory modelling results for surface oiling in recognition of the possibility of a fisheries closure occurring at this threshold (refer to Section 8.4).

Closures typically remain in place until: an area is free of oil and oil sheen on the surface; there is low risk of future exposure based on predicted trajectory modelling; and seafood has passed sensory sampling (smell and taste) for oil exposure (taint)and chemical analysis for oil concentration (toxicity) (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling n.d.). Fish are able to readily metabolize PAHs. Other species such as crabs, oysters, shrimp, clams, and scallops, do not as readily metabolize PAHs, which can result in elevated levels in their fatty tissues (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, n.d.). As a result, closure period may vary depending on species type.

The implementation of a fishery closure, which would likely be based on a visible sheen threshold (*e.g.*, 0.4 µm) would prevent localized or area specific harvesting of fish, and potentially alleviate concerns about marketing of tainted product, but it also represents a material concern for fishers. Following the Deepwater Horizon Oil Spill in 2010, short-term losses in the Gulf included the closure to fishing of up to 80 000 square miles of the US EEZ (DFO 2013w). Physical and chemical characteristics of oil products, along with environmental and biological factors, such as wind, water temperature, solar radiation, shoreline type, and species, influence the degree to which seafood may become contaminated (Yender *et al.* 2002). The uptake of oil and PAHs by exposed fish poses a potential threat to human consumers and affects the marketability of catches. However, even when results demonstrate safe exposure levels for consumption and closed areas are reopened for fishing, market perceptions of poor product quality (*e.g.*, tainting) can persist, thereby prolonging effects for fishers. Reduced demand for seafood that is perceived to be tainted can also lead to depressed market prices. As demonstrated in the Gulf of Mexico following the Deepwater Horizon Oil Spill, lack of consumer confidence in seafood quality and in the validity of government testing methods can have effects that persist beyond the period of actual impacts. Even after federal and state testing showed Gulf seafood to be safe to eat, sales remained depressed due to lack of consumer confidence (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling n.d.).

For this Project, modelling results indicate that batch spills from the MODU (10 bbl and 100 bbl) are not likely to result in effects on fish over a large area. Accidental discharges of marine diesel resulted in limited modelled effects. Around 80% of the spill evaporated within 2–3 days, with only approximately 2 km^2 and 20 km^2 having in-water concentrations of dissolved aromatics in excess of 1 ppb at any time for the 10 bbl and 100 bbl spill, respectively. A swath of surface oiling in excess of 0.04 μm is predicted to extend approximately 100 km to the west and 100 km to the north for both a 10 bbl or 100 bbl spill as a small portion of weathered diesel may continue to be transported at the surface. However, this swept area would be characterized as a patchy sheen with weathered oil (RPS ASA 2014b). A nearshore vessel diesel spill would be expected to behave similarly. Diesel fuel is considered to result in a moderate to high risk of seafood contamination because of the relatively high content of water-soluble aromatic hydrocarbons, which are semi-volatile and evaporate slowly (Yender *et al.* 2002). However, given the high evaporation rates and short-term exposure of fisheries resources, risk of contamination of fisheries resources would be low.

The effects from an unmitigated blowout would be more widespread, with surface oiling and water column dissolved aromatic footprints from a blowout scenario predominantly to the east and northeast of the Project Area, with some seasonal variations (*i.e.*, oil more likely to be transported to the east under winter conditions and more uniform, multi-directional transport patterns during summer conditions). Higher percentages of the released oil were found within the water column during winter months, the result of increased wind and wave action, which entrains surface oil into the water column. As indicated by Figures 8.4.2 to 8.4.5, the probability of surface oiling (in excess of 0.4 m) or dissolved aromatics (concentration in excess of 1 ppb) from an unmitigated 49 150 bpd, 30-day continuous blowout reaching the Scotian Shelf and Georges Bank is low - between 1 and 10%. Given these low probabilities reflect an unmitigated release, the likelihood of impacts to these important fisheries areas is considered very low.

Predictive modelling (refer to Figures 8.4.2 to 8.4.5) indicates that the length of time for an unmitigated blowout to reach threshold concentrations (0.4 μm for surface oiling, 1 ppb for in-water aromatic concentrations) at the shelf break or Georges Bank, where fishing effort is considerably more concentrated, would be approximately 5–10 days, thereby providing an opportunity to notify fishers of the spill and preventing the setting or hauling of gear in the affected area. Fouling of gear and/or catch of contaminated resources would therefore be reduced or avoided. Depending on the extent of the blowout and the effectiveness of mitigation, closure areas may not be widespread and fishers may also be able to fish in alternate areas.

Some modelled blowout scenarios resulted in the potential for shoreline oiling, including the Barrington and Shelburne region of Nova Scotia, although the likelihood of this occurring was very low (between 0.83 and 1.88%). This coastal area of the province in known to support aquaculture operations that could also be affected by oiling from either this unlikely blowout scenario or a diesel spill from an OSV travelling to Halifax Harbour. While the effects of oil on aquaculture are similar to other commercial fisheries (*i.e.*, potential for fouling of cultivation gear, tainting of fish and temporary shutdown of operations), aquaculture operations are unique in the type and variety of mitigation that can be used to limit effects of spills if operators are notified in a timely manner. This can include: moving floating facilities to avoid slicks; temporary sinking of specially designed cages to allow oil to pass over; and the transfer of stock to areas unlikely to be affected, although it is recognized that these mitigation measures can be technically, logistically or financially challenging depending on the circumstances (ITOPF 2004). Other options include temporary suspension of water intakes for shore tanks, ponds or hatcheries to isolate stock from potential oil contamination and suspension of feeding (ITOPF 2004). In addition, any use of dispersants would need to factor in proximity to any aquaculture operations.

SBM Whole Mud Spill Effects on Commercial Fisheries

Predictive modelling for a spill of SBM whole mud predicts that sediment plumes could travel up to 5 to 10 km from the release site to a TSS concentration of 1 mg/L and that TSS concentrations above 1 mg/L could persist up to 30 hours following the spill event in some circumstances (refer to Appendix C, Sediment Dispersion Modelling). All substances that comprise drilling muds are screened through a chemical management system in consideration of the OCSG (NEB *et al.* 2009). Previous studies have shown little or no risk of drilling base chemicals to bioaccumulate to potentially harmful concentrations in tissues of benthic animals or to be transferred through marine food chains to fishery species (Neff *et al.* 2000).

8.5.5.2 Mitigation of Environmental Effects

The focus of mitigation is accident prevention; detailed information on Shell's accident prevention and response planning is provided in Section 8.1, including the Oil Spill Response Plan and Well Containment Plan (to address potential for subsea blowout). Specific mitigation to reduce effects from an accidental spill on fisheries also includes compensation for gear loss or damage caused by the spill. Specific measures to be implemented by Shell to mitigate adverse environmental effects on Commercial Fisheries include the following:

- Implementation of a Fisheries Communication Plan which would include procedures for informing fishers of an accidental event and appropriate response. Emphasis is on timely communication, thereby providing fishers with the opportunity to haul out gear from affected areas, reducing potential for fouling of fishing gear.
- Compensation for damage to gear in accordance with *Compensation Guidelines Respecting Damages Relating to Offshore Petroleum Activity* (C-NLOPB and CNSOPB 2002)

In the event of a spill, post-spill environmental effects monitoring would be conducted to measure levels of contamination in fish species with results integrated in a human health risk assessment to inform fishing area closure status. This monitoring program would be developed in consultation with applicable regulatory agencies and may include sensory testing of seafood for "taint" (a smell or taste of oil), as well as chemical analysis for oil concentration. The results of this monitoring program, along with measurable oil sheen observations and scientific predictions for future exposure, would likely inform regulators in the decision to reopen a fishing area.

8.5.5.3 Characterization of Residual Environmental Effects

For the purposes of this effects assessment, a **significant adverse residual environmental effect** on Commercial Fisheries is defined as a residual Project-related environmental effect that results in an one or more of the following outcomes:

- local fishers being displaced or unable to use substantial portions of the areas currently fished for all or most of a fishing season
- local fishers experiencing a change in the availability of fisheries resources (*e.g.* fish mortality and/or dispersion of stocks) such that resources cannot continue to be used at current levels within the RAA for more than one fishing season
- unmitigated damage to fishing gear

Blowout, Batch Spills and Vessel Spill

The significance of spill-related adverse effects depends on the magnitude, location and timing of a spill. A small spill offshore is unlikely to measurably affect fisheries occurring outside the MODU operational safety (fisheries exclusion) zone and therefore would not result in a significant adverse environmental effect on Commercial Fisheries. A spill of the same material and volume occurring in the nearshore environment could have potential effects on nearshore fisheries, potentially displacing fishers from traditional fishing grounds for all or most of a fishing season, depending on the volume, location and timing of the spill.

Because of the widespread nature of the worst-case, unmitigated blowout, a significant effect is conservatively predicted for commercial fisheries for this scenario. The likelihood of this effect occurring is considered low, given the potential for a blowout to occur and given the response measures that would be in place to mitigate potential effects. In addition, while a blowout could potentially affect aquaculture operators on the south shore of Nova Scotia, the likelihood of oil reaching the coast is very low and time required for oil to reach the shore would give Shell and operators time to implement mitigation against oiling of cultivation gear.

SBM Spill

Given the predicted affected area (up to 10 km), temporary period of measurable effect on water quality (up to 30 hours), and the low toxicity of the product, effects of a SBM spill are predicted to be not significant for Commercial Fisheries. A fisheries closure would not likely be necessary, and fouling of gear would be unlikely given the relatively small spatial and temporal footprint of the spill event and limited harvested activity within the LAA.

Summary

Although the probability of a subsea blowout occurring is extremely low (refer to Appendix F), a significant adverse environmental effect could occur if local fishers are displaced or unable to use substantial portions of the areas typically or currently fished for all or most of a fishing season (*e.g.*, implementation of a spill-related fishery closure). Fishers could also experience a significant effect as a result of reduced catches or reduced access to fishing areas. Although significant adverse effects may occur, the likelihood is considered very low given the low probability of an event occurring, and the implementation of response procedures that could reduce the affected area. A medium level of confidence is assigned to the significance determination for 100 bbl batch spills, vessel spills and blowouts in recognition of the variables which could cause the actual significance to be less than predicted (*e.g.*, proximity to fishing area, timing of spill, effectiveness of response and VC-specific mitigation). A high level of confidence is associated with the significance predictions for a 10 bbl spill and a SBM whole mud spill, given the limited spatial and temporal nature of these events and limited potential to interact with Commercial Fisheries. Table 8.5.7. summarizes residual environmental effects on Commercial Fisheries from various accidental event scenarios.

Table 8.5.7 Summary of Residual Project-Related Environmental Effects on Commercial Fisheries – Accidental Events

Project Activities and Components	Mitigation/ Compensation Measures	Nature of Effect	Residual Environmental Effects Characteristics						Significance	Likelihood of Significant Effects	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context				
100 bbl batch spill	• Emergency Response Plan • Spill prevention and response • Fisheries Communication Plan • Compensation for gear damage and other losses	A	H	RAA	MT	S	R	M	S	L	M	Post-spill monitoring of contamination levels in fish species including sensory testing of seafood for "taint", as well as chemical analysis, as deemed necessary by government authorities
10 bbl batch spill		A	L	LAA	ST	S	R	M	N	N/A	H	
Vessel spill		A	H	RAA	MT	S	R	L	S	L	M	
SBM whole mud spill		A	L	LAA	ST	S	R	M	N	N/A	H	
Well blowout		A	H	RAA*	LT	S	R	L	S	L	M	

KEY

Nature of Effect:

P Positive
A Adverse

Magnitude:

N Negligible – no measurable change to commercial fisheries
L Low – very small detectable change to commercial fisheries in low-use areas
M Moderate – measurable change to commercial fisheries in moderate-use areas
H High – measurable change to commercial fisheries in high-use areas

Geographic Extent:

PA – Project Area – effects are restricted to the Project Area and well site.
LAA – effects are restricted to the LAA
RAA – effects are included within the RAA; in certain scenarios, effects may extend beyond the RAA as indicated by an "*".

Duration:

ST Short-Term – effects are measurable for less than one fishing season
MT Medium-Term – effects are measurable for approximately one fishing season
LT Long-Term – effects are measurable for more than one fishing season but are not permanent
P Permanent – effects are permanent

Frequency:

O Once – effect occurs once
S Sporadic – effect occurs sporadically at irregular intervals
R Regular – effect occurs on a regular basis and at regular intervals throughout the Project
C Continuous – effect occurs continuously

Reversibility:

R Reversible – will recover to baseline conditions before or after Project completion (well abandonment)
I Irreversible – permanent

Likelihood of Significant Effect:

L – Low likelihood (*i.e.*, unlikely to occur)
M –Moderate likelihood (*i.e.*, somewhat likely to occur)
H – High likelihood (*i.e.*, very likely or certain to occur)
N/A – effect is not predicted to be significant

Context:

H High Interference – effect occurs within a an area where past or present human activities substantially interfere with commercial fisheries
M Moderate Interference – effect occurs within an area where past or present human activities moderately interfere with commercial fisheries
L Low Interference – effect occurs within an area where past or present human activities do not interfere, or generally do not interfere, with commercial fisheries

Significance:

S Significant
N Not Significant

Prediction Confidence:

Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation

L Low level of confidence
M Moderate level of confidence
H High level of confidence

8.5.6 Current Aboriginal Use of Lands and Resources for Traditional Purposes

Current Aboriginal Use of Lands and Resources for Traditional Purposes refers to communal commercial, and FSC fishing activities by Aboriginal peoples that could potentially interact with the Project. Commercial harvesting by Aboriginal fishers in the RAA targets many of the same species fished by non-Aboriginal commercial fishers, including albacore tuna, bigeye tuna, bluefin tuna, cod, cusk, flounder, haddock, hagfish, hake, halibut, herring, Jonah crab, lobster, pollock, redfish, scallop, shark, shrimp, snow crab, swordfish and yellowfin tuna. Based on interviews conducted for the TUS (Appendix B) as of April 2014, 37 fish species, one mammal (seal), and 9 invertebrate groups were identified as species harvested for FSC purpose.

The TUS states that there is currently no FSC fishing reported as occurring in the Project Area. However, the TUS also acknowledges that this does not imply that FSC fisheries are not occurring in the Project Area or that the Project Area may not be accessed for future FSC fisheries needs. Lobster and herring were identified as currently being harvested within the LAA and several species (cod, herring, halibut, cusk, gaspereau, haddock, monkfish, pollock, red hake, silver hake, white hake, lobster, scallop, Jonah crab, and marine worms) were identified as being harvested for FSC purposes within the RAA (MGS and UINR 2014). A precautionary approach is therefore taken, assuming that FSC fisheries could potentially occur in the Project Area and LAA, as well as the RAA. It is also acknowledged that species fished for FSC purposes could be harvested outside the RAA but could potentially temporarily interact with the Project during migration activities through the Project Area or LAA.

8.5.6.1 Environmental Effects Mechanisms

All accidental scenarios considered in this assessment could have an adverse environmental effect on Current Aboriginal Use of Lands and Resources for Traditional Purposes. An accidental event could have an effect on the fisheries resource (direct or indirect effects on fished species affecting fisheries success) and/or fishing activity (displacement from fishing areas, gear loss or damage) resulting in changes in Traditional Use. Although the TUS indicates that FSC fisheries were not currently identified to occur in the vicinity of the Project Area, in the event of a spill, there could be effects on offshore FSC activities should they be taking place, nearshore fisheries, and/or on FSC species that could be migrating through or otherwise using the affected area. An effect on species fished for traditional (*e.g.*, communal gathering of fish for feasts) or commercial purposes, a change in habitat traditionally fished by Aboriginal peoples, and/or area closures could affect traditional use of marine waters and resources.

In addition to the potential effects on Traditional Use described above, Section 8.5.5 describes the potential environmental effects of the various spill scenarios on commercial fisheries, Section 8.5.1 describes potential environmental effects on fish and fish habitat, and Section 8.5.4 describes potential effects on Special Areas. These sections also help to inform how the accidental release of hydrocarbons to the marine environment may adversely affect Current Aboriginal Use of Lands and Resources for Traditional Purposes.

Hydrocarbon Effects on Current Aboriginal Use of Lands and Resources for Traditional Purposes

For this Project, modelling results indicate that diesel spills from the MODU are not likely to result in effects on fish over a large area. Accidental discharges of marine diesel resulted in limited modelled effects. Around 80% of the spill evaporated within 2–3 days, with only approximately 2 km^2 and 20 km^2 having in-water concentrations of dissolved aromatics in excess of 1 ppb at any time for the 10 bbl and 100 bbl spill, respectively. The effects from a vessel diesel spill would be expected to be of similar magnitude although a spill could also affect nearshore commercial and/or FSC fisheries if an incident were to occur while the OSV was approaching or departing the onshore supply base. Diesel fuel is considered to result in a moderate-to-high risk of seafood contamination because of the relatively high content of water-soluble aromatic hydrocarbons, which are semi-volatile and evaporate slowly (Yender *et al.* 2002). If a fisheries closure was implemented due to the spill, this could result in a temporary loss of access to Aboriginal fishers for commercial or FSC purposes.

As discussed in Section 8.5.5.1, the effects from an unmitigated blowout would be more widespread than for the other spill scenarios. The probability of surface oiling (in excess of 0.4 μm) or dissolved aromatics (concentration in excess of 1 ppb) from an unmitigated 49 150 bpd, 30-day continuous blowout reaching the Scotian Shelf and Georges Bank is between 1 and10%. Predictive modelling (refer to Figures 8.3.2 to 8.3.5) indicates that the length of time for an unmitigated blowout to reach threshold concentrations (0.4 μm for surface oiling, 1 ppb for in-water aromatic concentrations) at the shelf break, where fishing effort is considerably more concentrated, would be approximately 5–10 days, thereby providing an opportunity to notify fishers of the spill and preventing the setting or hauling of gear in the affected area. Fouling of gear and/or catch of contaminated resources would therefore be reduced. As indicated in the mapping included in the TUS (refer to Appendix B), identified fishing areas for demersal and invertebrate fisheries are almost exclusively located on the shelf, whereas pelagic fisheries occur throughout the RAA. Given these low probabilities reflect an unmitigated release, the likelihood of impacts to these traditional use areas is considered very low.

SBM Whole Mud Spill Effects on Current Aboriginal Use of Lands and Resources for Traditional Purposes

Predictive modelling for a spill of SBM whole mud predicts that sediment plumes could travel up to 9.6 km from the release site to a TSS concentration of 1 mg/L and that TSS concentrations above 1 mg/L could persist up to 30 hours following the spill event in some circumstances (refer to Appendix C, Sediment Dispersion Modelling). All substances that comprise drilling muds are screened through a chemical management system in consideration of the OCSG (NEB *et al.* 2009). Previous studies have shown little or no risk of drilling base chemicals to bioaccumulate to potentially harmful concentrations in tissues of benthic animals or to be transferred through marine food chains to fishery species (Neff *et al.* 2000). Given the predicted affected area (up to 9.6 km), temporary period of measurable effect on water quality (up to 30 hours), and the low toxicity of the product, effects of a SBM spill are predicted to be not significant for Current Aboriginal Use of Lands and Resources for Traditional Purposes. A fisheries closure would not likely be necessary, and fouling of gear would be unlikely given the relatively small spatial and temporal footprint of the spill event and limited harvested activity within the LAA.

8.5.6.2 Mitigation of Environmental Effects

The focus of mitigation is accident prevention; detailed information on Shell's accident prevention and response planning is provided in Section 8.4, including the Oil Spill Response Plan and Well Containment Plan (to address potential for subsea blowout.) Specific mitigation to reduce effects from an accidental spill on Current Aboriginal Use of Lands and Resources for Traditional Purposes includes compensation for gear loss or damage, and communication as described in Section 8.5.5.2 (including a Fisheries Communication Plan). In the event of a blowout, appropriate mitigation measures will be identified and implemented to ensure important communications can be made.

8.5.6.3 Characterization of Residual Environmental Effects

For the purposes of this effects assessment, a **significant adverse residual environmental effect** on Current Aboriginal Use of Lands and Resources for Traditional Purposes is defined as a Project-related environmental effect that results in one or more of the following outcomes:

- Aboriginal communal commercial fisheries or FSC fisheries being displaced or unable to use the areas traditionally or currently fished for all or most of a fishing season
- A change in the availability of fisheries resources (*e.g.*, fish mortality and/or dispersion of stocks) such that resources cannot continue to be used at current levels within the RAA for more than one fishing season
- Unmitigated damage to fishing gear

Summary

The significance of spill-related adverse effects depends on the magnitude, location and timing of a spill. A 10 bbl batch spill offshore as well as a SBM spill are unlikely to measurably affect fisheries occurring outside the MODU safety (fisheries exclusion) zone and therefore would not result in a significant adverse environmental effect on Current Aboriginal Use of Lands and Resources for Traditional Purposes. A small batch spill of the same material and volume occurring in the nearshore environment could have greater effects on nearshore fisheries. For example, a diesel spill occurring from an OSV accident in the nearshore, while unlikely, could result in a displacement of Aboriginal fishers for all or most of a season, thereby potentially having a significant adverse residual environmental effect on Aboriginal commercial fisheries and/or traditional use.

A medium level of confidence is assigned to the significance determination for 100 bbl batch spills, vessel spills and blowouts in recognition of the conservative approach to assigning a significant effect determination and the variables which could cause the actual significance to be less than predicted (*e.g.*, proximity to fishing area, timing of spill, effectiveness of response and VC-specific mitigation). A high level of confidence is associated with the significance predictions for a 10 bbl spill and a SBM whole mud spill, given the limited spatial and temporal nature of these events and limited potential to interact with Current Aboriginal Use of Lands and Resources for Traditional Purposes. Table 8.5.8 summarizes residual environmental effects on Current Aboriginal Use of Lands and Resources for Traditional Purposes from various accidental event scenarios.

Table 8.5.8 Summary of Residual Project-Related Environmental Effects on Current Aboriginal Use of Lands and Resources for Traditional Purposes – Accidental Events

Project Activities and Components	Mitigation/ Compensation Measures	Nature of Effect	Residual Environmental Effects Characteristics						Significance	Likelihood of Significant Effects	Prediction Confidence	Recommended Follow-up and Monitoring
			Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Context				
100 bbl batch spill	• Emergency response Plan • Spill prevention and response • Fisheries Communication Plan • Compensation for gear damage and other losses	A	H	RAA	MT	S	R	M	S	L	M	Post-spill monitoring of contamination levels in fish species including sensory testing of seafood for "taint", as well as chemical analysis, as deemed necessary by government authorities
10 bbl batch spill		A	L	LAA	ST	S	R	M	N	N/A	H	
Vessel spill		A	H	RAA	MT	S	R	L	S	L	M	
SBM whole mud spill		A	L	LAA	ST	S	R	M	N	N/A	H	
Well blowout		A	H	RAA*	LT	S	R	L	S	L	M	

KEY

Nature of Effect:
P Positive
A Adverse

Magnitude:
N Negligible – no measurable change from baseline
L Low – very small detectable change from baseline
M Moderate – varies from baseline and may result in noticeable changes to traditional practices, traditional knowledge or community perceptions of traditional territory, practices or knowledge
H High – varies from baseline to a high degree, has serious implication for the continuance of traditional practices and traditional knowledge

Geographic Extent:
PA – Project Area – effects are restricted to the Project Area and well site.
LAA – effects are restricted to the LAA
RAA – effects are included within the RAA; in certain scenarios, effects may extend beyond the RAA as indicated by an "*".

Duration:
ST Short-Term – effects are measurable for less than one fishing season
MT Medium-Term – effects are measurable for approximately one fishing season
LT Long-Term – effects are measurable for more than one fishing season but are not permanent
P Permanent – effects are permanent

Frequency:
O Once – effect occurs once
S Sporadic – effect occurs sporadically at irregular intervals
R Regular – effect occurs on a regular basis and at regular intervals throughout the Project
C Continuous – effect occurs continuously

Reversibility:
R Reversible – will recover to baseline conditions before or after Project completion (well abandonment)
I Irreversible – permanent

Likelihood of Significant Effect:
L – Low likelihood (*i.e.*, unlikely to occur)
M –Moderate likelihood (*i.e.*, somewhat likely to occur)
H – High likelihood (*i.e.*, very likely or certain to occur)
N/A – effect is not predicted to be significant

Context:
H High Interference – effect occurs within a an area where past or present human activities substantially interfere with current Aboriginal use of lands and resources for traditional purposes
M Moderate Interference – effect occurs within an area where past or present human activities moderately interfere with current Aboriginal use of lands and resources for traditional purposes
L Low Interference – effect occurs within an area where past or present human activities do not interfere, or generally do not interfere, with current Aboriginal land and resource use for traditional purposes

Significance:
S Significant
N Not Significant

Prediction Confidence:
Based on scientific information and statistical analysis, professional judgment and effectiveness of mitigation
L Low level of confidence
M Moderate level of confidence
H High level of confidence