6.0 Accidental Spills

6.1. Blowout and Spill Probabilities

Compared with other industries that have potential for discharging petroleum oil into the marine environment, the industry of exploring, developing and producing offshore oil and gas (the offshore E&P industry) has a relatively good record. A recent study on marine oil pollution by the US National Research Council (NRC 2002) indicates that accidental petroleum discharges from platforms contribute only 0.07% of the total petroleum input to the world's oceans (0.86 thousand tonnes per year versus 1,300 thousand tonnes per year - see Table 6.1).

Table 6.1. Best Estimate of Annual Releases [1990-1999] of Petroleum by Source [in thousands of tonnes].

	North America	Worldwide
Natural Seeps	**160**	**600**
Extraction of Petroleum	**3.0**	**38**
Platforms	0.16	0.86
Atmospheric Deposition	0.12	1.3
Produced waters	2.7	36
Transportation of Petroleum	**9.1**	**150**
Pipeline Spills	1.9	12
Tank Vessel Spills	5.3	100
Operational Discharges [Cargo Washings]	na[1]	36
Coastal Facility Spills	1.9	4.9
Atmospheric Deposition	0.01	0.4
Consumption of Petroleum	**84**	**480**
Land-Based [River and Runoff]	54	140
Recreational Marine Vessel	5.6	nd[2]
Spills [Non-Tank Vessels]	1.2	7.1
Operational Discharges [Vessels 100 GT]	0.10	270
Operational Discharges [Vessels <100 GT]	0.12	nd[3]
Atmospheric Deposition	21	52
Jettisoned Aircraft Fuel	1.5	7.5
TOTAL	**260**	**1300**

Notes:
1. Cargo washing is not allowed in US waters, but is not restricted in international waters. Thus, it was assumed that this practice does not occur frequently in US waters.
2. World-wide populations of recreational vessels were not available.
3. Insufficient data was available to develop estimates for this class of vessels.

Source: NRC (2002).

The spill record is particularly good in the US Outer Continental Shelf (OCS) where 32,000 wells were drilled and over 13 billion (10^9) barrels[10] of oil and condensate were produced from 1972 to 2005, yet only 17 blowouts occurred that involved any discharge of oil or condensate. The total oil discharged in the 17 events was only 1,103 barrels.

Two types of environmentally threatening accidents that could occur during the program are blowouts and "batch" spills. Blowouts are continuous spills lasting hours, days or weeks that could involve the discharge of petroleum gas into the atmosphere and crude oil into surrounding waters. Batch spills are instantaneous or short-duration discharges of oil that could occur from accidents on the drilling platforms where fuel oil and other petroleum products are stored and handled. The purpose of this report is to provide estimates on the probability of these spills.

Because this study derives spill and blowout statistics for the Laurentian Sub-basin Project from worldwide statistics, it is assumed that the practices and technologies that will be used by CPC will be at least as safe as those used in other offshore oil and gas operations around the world and will be in accordance with the accepted practices of the international petroleum industry. Because statistics on US and North Sea offshore oil and gas operations are used extensively in this analysis, it is specifically assumed that CPC operations are comparable from a safety viewpoint to operations in US OCS waters and the North Sea.

6.1.1. Sources of Information

Statisticians at the US Minerals Management Service (MMS) have produced a large body of literature on marine oil-spill probability in the US OCS. Because these oil-spill statistics have been extensively peer-reviewed and are updated regularly, they will be used as the primary source for this review. Much of the data discussed in this report is now available on the internet at http://www.mms.gov/stats/index.htm. Another reference is a recent study completed by Scandpower (2000), which analyzes blowout statistics related to activities in the Norwegian and UK sectors of the North Sea, as well as the US Gulf of Mexico OCS region (GOM OCS).

6.1.2. Statistics of Importance to Analysis

CPC expects to drill the first well in mid-2007. Thereafter, additional wells will be drilled subject to exploration success, up to a possible total of seven. Given this uncertainty, for the purposes of this analysis, risk calculations will be performed on a per-well basis and for the base case of two wells. It is also assumed conservatively that the target reservoirs do contain petroleum hydrocarbons.

[10] The petroleum industry usually uses the oil volume unit of petroleum barrel (which is different than a U.S. barrel and a British barrel). There are 6.29 petroleum barrels in one cubic metre (m^3). Most spill statistics used in this report are taken from publications that use the oil volume units of petroleum barrels.

6.1.3. Categories of Spill Size

Five spill size categories are selected and analysed. The first category is for "extremely large" spills, arbitrarily defined as spills larger than 150,000 bbl (23,800 m^3). Good worldwide statistics are available for this size range. The second and third categories are for "very large" and "large" spills, defined by the US Minerals Management Service as spills larger than 10,000 barrels (1,590 m^3) and 1,000 barrels (159 m^3) respectively. The fourth category is for spills in the range of 50 to 999 bbl, and the fifth category is for spills in the 1 to 49 bbl category. The spill size classifications used in this study are summarized in Table 6.2. Note that the top three categories in the table are cumulative; that is, the large-spill category (>1,000 bbl) includes the very large and extremely large spills, and the very large category includes extremely large spills.

Table 6.2. Spill Size Categories.

Spill Category Name	Spill Size Range (in barrels)	Spill Size Range (in m^3 and tonnes)
Extremely Large spills	>150,000 bbl	(>23,850 m^3 or >20,830 tonnes)
Very Large spills	>10,000 bbl	(>1,590 m^3 or >1,390 tonnes)
Large spills	>1000 bbl	(>159 m^3 or >139 tonnes)
Medium spills	50 to 999 bbl	(7.95 m^3 to 158.9 m^3)
Small spills	1 to 49.9 bbl	(0.08 m^3 to 7.94 m^3)

6.1.4. Structure of Analysis

The analysis begins with a review of the probabilities of offshore blowouts that involve the discharge of oil, and those that involve gas only. This is followed by a probability analysis related to other kinds of spills of oil that can happen on the platforms over the course of the drilling project.

A summary table is presented at the end of the report that includes all the key statistics used and derived.

6.1.5. Blowouts During Exploration Drilling

6.1.5.1. Extremely Large, Very Large and Large Oil Spills from Blowouts

The main concern is the possibility of a well blowout occurring and discharging large quantities of oil into the marine environment. In Canada, only one small condensate blowout has occurred on the Scotian Shelf, and in the US, only two moderate-size oil-well blowouts involving oil spills larger than 50,000 barrels have occurred since offshore drilling began in the mid-fifties. One must therefore look beyond North America to find a reasonable database on very large and extremely large oil-well blowouts. Table 6.3 lists all worldwide blowouts involving spills of more than 10,000 barrels each.

Table 6.3. Historical Large Oil Spills from Offshore Oil-Well Blowouts.

Area	Reported Spill Size (bbl)	Date	Operation Underway
U.S.A., Santa Barbara	77,000	1969	Production
U.S.A., S. Timbalier 26	53,000	1970	Wireline
U.S.A., Main Pass 41	30,000	1970	Production
Dubai	2,000,000	1973	Development Drilling
Trinidad	10,000	1973	Development Drilling
North Sea/Norway	158,000	1977	Workover
Mexico (Ixtoc 1)	3,000,000	1979	Exploratory Drilling
Nigeria	200,000	1980	Development Drilling
Iran	100,000	1980	Development Drilling
Saudi Arabia	60,000	1980	Exploratory Drilling
Iran[a]	see note	1983	Production
Mexico	247,000	1986	Workover
Mexico	56,000	1987	Exploratory Drilling
U.S.A., Timbalier Bay/Greenhill	11,500	1992	Production

[a] The Iranian Norwuz oil-well blowouts in the Gulf of Arabia, which started in February 1983, were not caused by exploration or drilling accidents but were a result of military actions during the Iraq/Iran war.

Source: Gulf (1981), updated to present (2005) by reference to the Oil Spill Intelligence Report.

Extremely Large Spills from Exploration Drilling

For this report's definition of "extremely large" spills, that is, oil spills 150,000 barrels in size or greater, it is seen that there have been five such spills in the history of offshore drilling, two of which occurred during development drilling and two of which occurred during production or workover activities. The fifth was from exploration drilling: the Ixtoc 1 oil-well blowout in the Bay of Campeche, Mexico, which occurred in 1979. It is worth noting that this incident, producing the largest oil spill in history, was caused by drilling procedures (used by PEMEX, Mexico's national oil company) that are contrary to US and Canadian regulations and to accepted practices within the international oil and gas industry.

Spill frequencies are best expressed in terms of a risk exposure factor such as number of wells drilled. On a worldwide basis it has been estimated that 36,633 offshore wells were drilled from 1955 to 1980 of which 11,737 were exploration wells (Gulf Canada 1981). The total number of exploration wells drilled up to 1988 has been estimated to be 20,000 (Sharples et al. 1989). It is estimated from a number of sources that the number of exploration wells drilled up to the end of 2005 on a worldwide basis is approximately 39,000. From Table 6.3 it is seen that there was only one extremely large spill (>150,000 bbl) during offshore exploration drilling, so the frequency up to the present has been 2.56×10^{-5} spills per well drilled (1/39,000).

Very Large Spills from Exploration Drilling

A similar analysis can be done for so-called “very large” spills, that is, those larger than 10,000 barrels. Referring again to Table 6.3 it is seen that three exploration drilling blowouts have produced spills in the “very large” spill category (including Ixtoc 1), so the spill frequency for these becomes 7.69×10^{-5} spills per well drilled (3/39,000).

Large Spills from Exploration Drilling

In the entire history of operations in the US OCS or the North Sea there have been no large (>1,000 bbl) spills during exploration drilling. It is difficult to obtain and be confident of data elsewhere in the world. A complete search was made of the records of the Oil Spill Intelligence Report, a weekly newsletter that keeps good track of international spills larger than 1,000 gallons (24 bbl). The search revealed only one exploration-drilling blowout that resulted in a large oil spill, other than the spills listed in Table 6.3 (again noting that the category of large spills includes very large spills and extremely large spills). This occurred in the offshore Ankleshwar field in Gujarat, India, in 1998. The operator was the state-owned Oil and Natural Gas Corporation (ONGC) and the spill size was 100,000 gallons or 2,380 barrels. If it is assumed that this was the only large-spill blowout to occur after the ones accounted for above (and this may be a weak assumption), then the spill frequency for large (>1,000 bbl) spills from exploration drilling becomes $4/39,000 = 1.03 \times 10^{-4}$ spills per well drilled.

Conservative Approach - Ignoring Recent Trends

It must be noted that the above spill frequency calculations are based on the entire offshore experience from 1955 to the present. Most of the spills noted in Table 6.3 occurred over twenty years ago, and, as noted earlier, no large spills from exploration operations have ever occurred in USOCS or North Sea waters. There is an obvious trend over time toward fewer blowouts.

Calculated Frequencies for the Laurentian Sub-basin Project

For the purposes of this assessment, it is assumed that the drilling rate will be two exploration wells per year. On this basis, the

- Predicted annual frequency[11] of extremely large oil spills (>150,000 bbl) from blowouts during a exploration drilling operation, based on an exposure of wells drilled is simply (2 wells drilled/year) x (2.56×10^{-5} spills/well drilled) = 5.13×10^{-5} spills per year. This represents an annual probability of one in 19,500. Another way of expressing this would be to say that, if this drilling rate of two wells per year were to continue forever, one could expect an oil spill larger than 150,000 barrels once every 19,500 years.

[11] In this and other similar calculations in the report, spill frequency rates are kept as three-decimal data, and the probability numbers are rounded off to two decimal points.

- Predicted annual frequency of very large oil spills (>10,000 bbl) from exploration drilling blowouts based on an exposure of wells drilled is 1.54 x 10^{-5}, or a probability of one in 11,600, or, at this drilling rate, one could expect such a spill every 6,500 years.

- Predicted annual frequency of large oil spills (>1,000 bbl) from exploration drilling blowouts based on an exposure of wells drilled is 2.05 x 10^{-4}, or a probability of one in 8,800, or, at this drilling rate, one could expect such a spill every 4,875 years.

6.1.5.2. Exploration Drilling Blowouts Involving Primarily Gas

Gas blowouts from offshore wells that do not involve a discharge of liquid petroleum are generally believed to be harmless to the marine environment. Such blowouts, however, do represent a threat to human life and property because of the possibility of explosion and fire.

Two sources are used for historical statistics on blowouts involving only gas or small oil discharges. A particularly good source for US blowouts is the MMS web page (www.mms.gov) because MMS keeps track of spills down to one barrel in size. This is not the case in other parts of the world. Scandpower (2000) provides good, recent statistics on blowouts in the North Sea and the US GOM, although no information is provided as to whether or not oil spills were involved in the reported blowouts.

Blowout Frequency Based on US OCS Experience

Table 6.4 provides U.S OCS data representing the 34-year period from 1972 to 2005. Note that there are no large spills (>1,000 bbl) in the entire database. If the table had started in 1970, however, two very large blowout spills would have been shown involving 30,000 barrels and 53,000 barrels respectively (see Table 6.3).

The total number of exploration wells drilled in the US Federal OCS from 1972 to 2005 is not shown in Table 6.4, but it is derived from other sections of MMS 1997, from E&P Forum 1996, and current Internet sources; the number is approximately 14,000. The number of blowouts from exploration drilling is shown to be 67; therefore, the blowout frequency is 67/14,000 or 4.79 x 10^{-3} blowouts per well drilled, or one blowout for every 209 wells drilled. Four of the blowouts involved oil spills, one of size 200 bbl, one was 100 bbl, one was 11 bbl, and one was 5 bbl.

Experience in Eastern Canada

It is of interest at this point to compare the statistics in Table 6.4 to those from Eastern Canada. Table 6.5 summarizes the drilling and blowout experience in operations off Newfoundland and Nova Scotia (the data was supplied by the Canadian Association of Petroleum Producers). The exploration well blowout was the Uniacke G-72 gas blowout that happened off Sable Island in 1984. The frequencies in Table 6.5 are consistent with the values derived from Table 6.4 (3.1 x 10^{-3} versus 4.79 x 10^{-3}).

Table 6.4. Blowouts and Spillage from US Federal Offshore Wells, 1972-2005.

Year	Well Starts	Drilling Blowouts				Non-drilling Blowouts								
		Exploration		Development		Production		Workover		Completion		Total Blowouts		OCS Production
		No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	No.	bbl	MMbbl
1972	845	2	0	2	0	1	0	0	0	0	0	5	0	396.0
1973	820	2	0	1	0	0	0	0	0	0	0	3	0	384.8
1974	816	1	0	1	0	4	275	0	0	0	0	6	275	354.9
1975	372	4	0	1	0	0	0	1	0	1	0	7	0	325.3
1976	1,038	1	0	4	0	1	0	0	0	0	0	6	0	314.5
1977	1,064	3	0	1	0	1	0	3	0	1	0	9	0	296.0
1978	980	3	0	4	0	0	0	3	0	1	0	11	0	288.0
1979	1,149	4	0	1	0	0	0	0	0	0	0	5	0	274.2
1980	1,307	3	0	1	0	2	1	1	0	1	0	8	1	274.7
1981	1,284	1	0	2	0	1	0	3	64	3	0	10	64	282.9
1982	1,035	1	0	4	0	0	0	4	0	0	0	9	0	314.5
1983	1,151	5	0	5	0	0	0	2	0	0	0	12	0	350.8
1984	1,386	3	0	1	0	0	0	1	0	0	0	5	0	385.1
1985	1,000	3	0	1	0	0	0	2	40	0	0	6	40	380.0
1986	1,538	0	0	1	0	0	0	1	0	0	0	2	0	384.3
1987	772	2	0	0	0	3	0	1	0	2	60	8	60	358.8
1988	1,007	1	0	1	0	0	0	1	0	0	0	3	0	332.7
1989	911	2	0	[1]5	0	3	0	1	0	0	0	11	0	313.7
1990	987	1	0	1	0	0	0	3	9	1	0	6	9	304.5
1991	667	3	0	[2]3	0	0	0	0	0	0	0	6	0	326.4
1992	943	3	100	0	0	0	0	0	0	0	0	3	100	337.9
1993	717[3]	1	0	2	0	0	0	0	0	0	0	3	0	352.7
1994	717[3]	0	0	0	0	0	0	1	0	0	0	1	0	370.4
1995	717[3]	1	0	0	0	0	0	0	0	0	0	1	0	429.2
1996	921	1	0	1	0	0	0	0	0	2	0	4	0	433.1
1997	1,333	1	0	3	0	0	0	0	0	1	0	5	0	466.0
1998	1,325	1	0	1	0	2	0	3	0	0	0	7	2	490.5
1999	364	1	0	2	0	0	0	1	0	0	0	5	0	534.6
2000	1,061	5	200	4	0	0	0	0	0	0	0	9	200	551.6
2001	1,007	1	0	4	1	2	0	2	0	1	0	10	1	591.5
2002	828	1	0	2	0	2	350	1	1	0	0	6	351	602.1
2003	835	1	0	1	0	2	1	1	10	0	0	5	11	594.7
2004	861	2	16	0	0	0	0	2	1	0	0	4	17	567.0
2005	859[4]	3	0	1	0	0	0	0	0	0	0	4	0	557.3[4]
Total	**32,617**	**67**	**316**	**91**	**1**	**24**	**627**	**38**	**125**	**14**	**60**	**205**	**1,131**	**13520.7**

1. Two of the drilling blowouts occurred during drilling for sulphur.
2. Two of the drilling blowouts occurred during drilling for sulphur.
3. Estimated: cumulative total correct.
4. Forecast.

Table 6.5. Exploration and Development Wells and Blowouts in Eastern Canada.

Region	No. of Exploratory Wells	No. of Development Wells	No. of Blowouts	Exploration Blowout Frequency	Overall Blowout Frequency
Newfoundland	167	127	0	0	0
Nova Scotia	152	49	1 (exploration)	6.6×10^{-3}	5.0×10^{-3}
TOTAL	319	176	1 (exploration)	3.1×10^{-3}	2.0×10^{-3}

Valid to December 2005 for Newfoundland, October 2005 for Nova Scotia.

Current Trends

The above-calculated blowout statistic for the US (4.79×10^{-3}) is based on blowout records of the past 30 years and does not take into account recent improvements in safety and blowout prevention that have tended to reduce blowout frequencies. It is appropriate at this time to analyze current trends and to update predictions of blowout frequency as appropriate. This is done in the following sub-sections, which take into consideration: (1) the differences between "shallow gas" blowouts and "deep" blowouts; (2) special blowout prevention activities that exist for drilling in Canada; and (3) decreases in blowout frequency in recent years due to improvements in blowout prevention. All three issues are covered thoroughly in the Scandpower (2000) publication, which is the primary source for the following analysis.

Shallow-Gas Blowout versus Deep Blowout

A blowout might occur if shallow gas were encountered unexpectedly during drilling operations. This is of particular concern when drilling at depths down to about 1,500 m. Gas that is trapped in the shallow sediments can originate from deeper gas reservoirs, but can also come from biogenic activity in the shallow sediments. Generally, shallow gas blowouts are more likely to occur than deep blowouts, but they do not involve a discharge of oil. Various statistics on shallow and deep blowouts in the North Sea and in the US Gulf of Mexico OCS are shown in Table 6.6, which are derived from Scandpower 2000. It is important to read the notes at the bottom of the table for definitions (from Scandpower 2000) of deep and shallow blowouts and releases.

The statistic of 33 blowouts and releases for the US Gulf of Mexico (US GOM) noted in Table 6.6 is reasonably consistent with the data in Table 6.4, which shows a total of 32 blowouts for the period 1980 to 1997. Note that the US regulator, the Minerals Management Service, classifies "blowouts" in Table 6.4 to include well releases (where no hydrocarbons enter the environment) as well as blowouts. The frequency of blowout and releases from Table 6.6 for the US GOM is $33/5751 = 5.74 \times 10^{-3}$, which is consistent with the value derived earlier from Table 6.4 (4.79×10^{-3}), and with the equivalent Canadian east-coast statistic shown in Table 6.5 (3.1×10^{-3}).

Table 6.6. Exploration Wells and Blowouts in US GOM OCS and North Sea, 1980-1997.

Area	Number of Exploration Wells	Shallow Gas Blowouts	Shallow Gas Releases while Drilling	Deep Blowouts	Deep Well Releases while Drilling	Total Blowouts and Releases
US GOM	5751	13	5	15	0	33
UK	2899	2	0	2	0	4
Norway	680	5	3	0	5	13
TOTALS	9330	20	8	17	5	50

Notes:

- A blowout is as an incident where hydrocarbons flow from the well to the surface, all barriers are non-functional, and well control can only be regained by means that were not available when the incident started.
- A deep blowout is defined as one that occurs after the Blowout Preventer (BOP) is set.
- A shallow gas blowout is a release of gas prior to the BOP being set.
- A well release is an incident where hydrocarbons flow from the well to the surface and is stopped by one or several barriers that were available when the incident started. In this case, hydrocarbons do not enter the environment.

Source: Scandpower (2000).

6.1.5.3. Two-Barrier Philosophy

Deep blowouts are the primary concern and not well releases because releases by definition do not involve a discharge of hydrocarbons into the environment. The frequencies for both shallow and deep blowouts, derived from Table 6.6, are summarized in Table 6.7.

Table 6.7. Exploration Drilling Blowout Frequencies for the US GOM and North Sea, 1980 to 1997.

	Shallow Gas Blowouts		Deep Blowouts	
	US GOM	**North Sea**	**US GOM**	**North Sea**
Blowouts per well drilled	2.26×10^{-3}	1.96×10^{-3}	2.61×10^{-3}	5.59×10^{-4}
Wells drilled per blowout	440	510	380	1800

Although the frequency of shallow gas blowouts is similar for both regions, the frequency of deep blowouts is almost five times higher in the US Gulf of Mexico than in the North Sea. The reason for this, according to Scandpower (2000), is that North Sea operators are required by law to always have two barriers during exploration and development drilling, and this is not the case in the US. In Canada, regulations similar to the North Sea's apply (i.e., two barriers), so it is fair to derive blowout frequencies for Canada on the basis of North Sea statistics.

Decline in Blowouts over Recent Years

It is important to note that blowout frequencies in the North Sea and in the Gulf of Mexico have been on the decline over recent years, as shown in Table 6.8.

Table 6.8. Exploration and Development Drilling Blowout Frequencies over Time.

Time Period	No. of Blowouts	Number of Exp. and Dev. Wells Drilled	Blowout Frequency
18 years (1980 to 1997)	53	22,084	24.0×10^{-4}
10 years (1988 to 1997)	23	13,870	16.6×10^{-4}
5 years (1993 to 1997)	5	7,581	6.6×10^{-4}
3 years (1995 to 1997)	1	4,924	2.0×10^{-4}

Source: Scandpower (2000).

In order to better reflect the obvious decrease in blowout frequency over time, yet not provide too optimistic an outlook based on only the last three or five years data, the authors of the Scandpower study averaged the blowout frequencies for the five periods listed above (average (24.0, 16.6, 6.6, 2.0 = 12.3). Compared with the frequency of the entire period, this yields an adjustment factor of 51% (12.3 / 24.0 = 51%). While the mathematical or statistical justification for this is not clear, it does seem reasonable to reduce the frequency to reflect current trends, and the magnitude of the adjustment also seems reasonable in view of the above data. Based on this, the frequencies derived for the period 1980 to 1997 should be cut in about half for an estimate of frequencies today.

Summary of Results from Trends Analysis

On the basis of the above analysis, the expected frequency of a deep blowout during the Laurentian Sub-basin Project should be predicted on the basis of the North Sea experience and should be rationalized to take into account current falling trends. Accordingly, the prediction yields (from Tables 6.7 and 6.8) a value of $5.59 \times 10^{-4} \times 0.51 = 2.85 \times 10^{-4}$ deep blowouts per well drilled or a probability of one blowout for every 3,500 wells drilled.

Calculated Blowout Frequencies for the Laurentian Sub-basin Project

Considering again a two-well-per-year program, the blowout frequency becomes 2 wells/yr x 2.85×10^{-4} blowout/well drilled = 5.70×10^{-4} blowout per year, or a one in 1,750 chance of a deep blowout occurring over the one-year drilling period.

6.1.5.4. Smaller Platform Spills

Oil spills other than from blowouts can occur during drilling and production activities. These include spills of diesel oil or lubricating oil on the platforms, spills from transfer operations, spills of oil-based drilling muds, and spills from similar accidents involving the handling of oil that is needed to run operations. The overwhelming majority of these spills are very small.

Federal US Outer Continental Shelf

Table 6.9, taken from Anderson and LaBelle 2001, covers oil spills of all sizes from operations on US Federal OCS leases for the period 1985 to 1999. For this report it is not logical to normalize these spill statistics in terms of wells drilled over the period because an unknown proportion of the spills took place during production operations, and the production stage of the Laurentian Sub-basin Project, should it occur, is not considered in this analysis.

In any case, spill data are available for each year over the period 1971 to 1995 (MMS 1997), so if one normalizes the annual data using an exposure of "wells drilled per year", and plots the results, Figure 6.1 is the outcome. Note that the small-spill frequencies in the Gulf of Mexico OCS were relatively high in its early stages, but have decreased by almost a factor of ten over the past 25 years. This is shown in Figure 6.1. The spill statistics in Table 6.9 cover the period following the steep drop in spills that started in the 1975 to 1980 period.

Table 6.9. US OCS Platform Spills[a], Overall Spill Size Characterization, 1985-1999.

Spill Size	Number of Spills
0 to 1.0 bbl	13,000[b]
1.1 to 9.9 bbl	326
10.0 to 49.9	66
50.0 to 499.9	28
500.0 to 999.9	2
1,000 bbl and greater	0

a. Oil spills include crude oil, condensate, and refined petroleum products, including oils in oil-based drilling muds.
b. This number assumes that two-thirds of spills of size 0 to 1.0 bbl are from platforms and one-third from pipelines. Only the total number (19,506) is provided in the source for the table (Table 13 *in* Anderson and LaBelle 2001), but the 2:1 distribution seems reasonable based on the distribution given for the other spill size classifications.

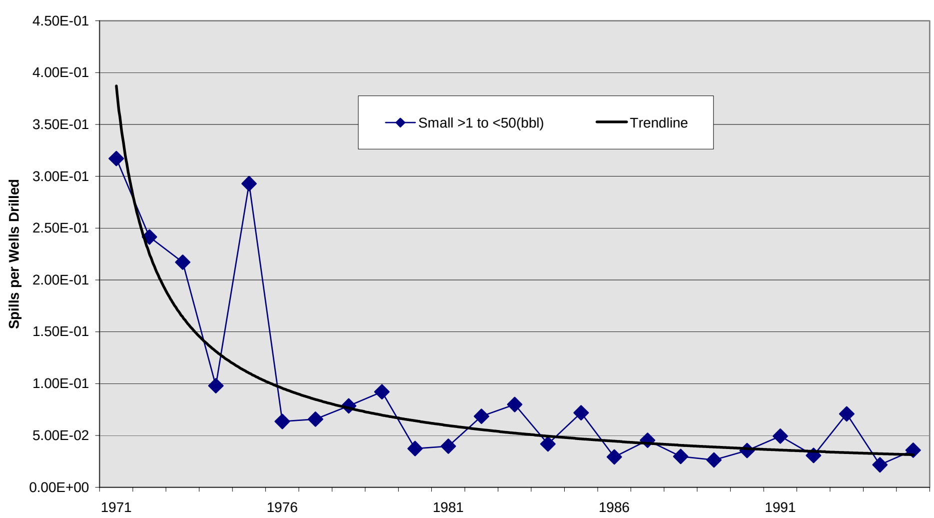

Figure 6.1. Frequency of Small Platform Spills (1 to 49.9 bbl) in the US OCS, 1971 to 1995.

In recent years, MMS has produced a performance measure showing the number of spills in three size ranges. For the spill rate calculation, they use an exposure factor equal to the number of wells spudded (total of exploration, production, and development), plus the number of producing platforms. In other words, the assumption is that each well and each platform produces, on average, a comparable amount of activity that would result in a spill. Unfortunately, they do not use the same size ranges as in the above data, so a direct comparison is not possible. Table 6.10 shows the spill rates for three size classifications, less than 1 bbl, between 1 and 10 bbls, and greater than 10 bbls.

Table 6.10. Spill Rates for US Gulf of Mexico, 2000 to 2004.

	2000	2001	2002	2003	2004	Average
Spills < 1 bbl	0.281	0.264	0.278	0.178	0.218	0.244
Spills 1 to 10 bbls	0.00139	0.00239	0.00280	0.00235	0.00157	0.0021
Spills > 10 bbl	0.00069	0.00048	0.00051	0.00052	0.00131	0.00070

Canada East Coast

Similar data from Nova Scotia from the last five years is provided below for comparison. C-NSOPB maintains a database of oil spills that have occurred as a result of exploration and production activities on the Scotia Shelf. The database shows that, from January 1994 to August 2005, 203 oil spills involving hydrocarbon (including spills of synthetic oil-based mud) have occurred on the Shelf. The database does not include any breakdown of whether the spill was related to exploration or production wells, but a spill rate can be calculated using the same approach as the MMS performance measures, using the total number of wells drilled and platforms. Spill frequencies for drilling activities off Nova Scotia are summarized in Table 6.11, based on the total number of wells in a given year (which ranged from two in 2005 to eight in 2003) and the number of platforms (which ranged from three in 2000 to five in 2005).

Table 6.11. Spill Rates for the Scotian Shelf, 2001 to 2005.

	2001	2002	2003	2004	2005	Average
Spills < 1 bbl	2.111	1.900	2.182	0.857	1.429	1.696
Spills 1 to 10 bbls	0.111	0.000	0.364	0.143	0.000	0.124
Spills > 10 bbl	0.000	0.000	0.000	0.000	0.000	0.000

The rates are clearly higher for the Scotian Shelf than for the Gulf of Mexico. However, there are two reasons to view this with some skepticism. The first is obviously sample size: with the exposure factor so low (between two and eight wells in a given year), a few events will skew the data. A more significant factor is likely that many small spills in the US OCS are under-reported (and rather reported as very small spills) because spills larger than one barrel must undergo a detailed reporting procedure whereas very small spills must still be reported, but not in a rigorous way (for details see http://www.mms.gov/ntls/Attachments/ntl96-2n.htm). It is also likely that in the US OCS database, many very small spills are not reported at all, skewing the calculated rate for spills less than one barrel.

Note that in the C-NSOPB database, there is no minimum volume for spill reporting. Approximately half of the 203 spills listed are less than four litres (one gallon), which has, in the past, been a threshold for reporting in some jurisdictions. There has not been a spill greater than 10 barrels since 1999, a 1,700 litre spill of fuel. For the predictions in this study, we will use the actual spill rates from the Scotian Shelf for the two smaller size ranges, and the US OCS rate for the spills greater than 10 bbl range.

It is worth noting that the C-NSOPB data shows that, for the category of spills less than one barrel, the median spill size is only four litres, and the average 20 litres.

Calculated Frequencies for the Laurentian Sub-basin Project

Three spill size classifications are considered: spills one barrel or less (let us call these very small spills), small spills defined as spills between one and 10 barrel, and medium spills (10 to 999 bbl).

6.1.6. Spills Less Than One Barrel

The statistics in Table 6.11 are used to derive an estimated spill frequency for this spill size range. Considering that two wells will be drilled per year:

- The predicted frequency of spills of size one barrel and less during drilling operations is 2 wells/yr x 1.696 spills/well = 3.4 spills per year.

6.1.7. Small Spills (1 to 10 bbl)

The statistics in Table 6.11 are used to derive an estimated spill frequency for this spill size range. Considering that two wells will be drilled per year:

- The predicted frequency of spills of size one to 10 barrels during drilling operations is two wells/yr x 0.124 spills/well = 0.25 spills per year, or one spill every four years.

6.1.8. Medium Spills (10 to 999 bbl)

No medium spills or larger spills have occurred on the Scotia Shelf since 1999. These are relatively large spills that do not go easily unnoticed, so it is likely that the number of US OCS medium spills identified in Table 6.10 are correct or approximately so. Therefore:

- Based on US OCS experience, the predicted frequency of medium spills (10 to 999 bbl) during exploration drilling is 2 wells/yr x 0.00070 spills/well = 0.0014 spills per year, or one spill every 714 years.

6.2. Summary of Blowout and Spill Frequencies

The calculated oil spill frequencies are summarized in Table 6.12. The highest frequencies are obviously for the smaller, operational spills. Spills less than one barrel in size may occur three times per year, based on recent petroleum development experience off Nova Scotia. Although they may occur with some regularity, they are likely to be quite small, with a median volume of four litres. Oil spills during exploration that are larger than one barrel but less than 10 barrels have about a one-in-four chance of occurring per year. Oil spills of all types in the 10 to 999 bbl range may have about a one-in-700 chance of occurring every year, based on experience in the US OCS.

Table 6.12. Predicted Number of Blowouts and Spills for Laurentian Sub-basin Project (assuming two wells/year).

Event	Historical Frequency (per well drilled)[1]	Predicted No. of Events per year	Frequency (assumes two wells/ year)
Deep blowout during exploration drilling	2.85×10^{-4}	5.70×10^{-4}	One every 1,750 yrs
Exploration drilling blowout with oil spill > 1000 bbls	1.03×10^{-4}	2.06×10^{-4}	One every 4,875 yrs
Exploration drilling blowout with oil spill > 10,000 bbls	7.69×10^{-5}	1.54×10^{-5}	One every 6,500 yrs
Exploration drilling blowout with oil spill > 150,000 bbls	2.56×10^{-5}	5.13×10^{-5}	One every 19,500 yrs
Platform oil spill, 10 to 999 bbls	7.0×10^{-4}	1.4×10^{-3}	One every 714 yrs
Platform oil spill, 1 to 10 bbls	0.124	0.24	One every 4 yrs
Platform oil spill, 0 to 1.0 bbl	1.70	3.4	One every 0.29 yrs

[1] Blowouts and blowout-spills (first four rows of data) are based on worldwide, US OCS, and North Sea experience; Platform-based oil spills (last two rows of data) are based on Nova Scotia experience, 2000 to 2005.

There is about a 1-in-1,750 chance per year of having any sort of deep blowout. Shallow gas blowouts may occur and are three or four times more probable than ones that occur at depth, but these would have virtually no chance of involving an oil spill.

The chances of an extremely large (>150,000 bbl), very large (>10,000 bbl), and large (>1,000 bbl) oil well blowout from exploration drilling are very small: about a 1-in-19,500, 1-in-4,875 and 1-in-1,750 chance per year, respectively. This means that if drilling continued at the rate of two wells per year forever, one could expect (for example) an extremely large spill once every 19,500 years. These predictions are based on worldwide blowout data and are strongly influenced by blowouts that occurred in parts of the world where drilling regulations may be less rigorous. It might also be reasonable to expect even lower frequencies for the Laurentian Sub-basin Project than those calculated above in view of the fact that no exploration drilling blowout spills larger than 10,000 barrels have occurred anywhere in the world since 1987, suggesting a significant improvement of technology and/or practice over the past 19 years.

6.3. Blowout/Spill Behaviour and Fate

This section provides a general description of the behaviour of subsea and surface condensate and gas blowouts and small platform and vessel fuel oil discharges and presents the modeling results of the behaviour of hypothetical spills of these types from the ConocoPhillips exploration drilling project.

The spills of interest from the ConocoPhillips Project include surface well blowouts, both shallow and deep-water blowouts and small platform or vessel releases of marine diesel. In above-surface blowouts the drilling platform maintains its position during the accident (because it is undamaged) and the condensate and gas discharges into the atmosphere from some point on the drilling platform above the water surface and falls on the water surface some distance downwind. Examples of this kind of oil well blowout are the 1977 Ekofisk blowout in the North Sea (Audunson 1980) and the Uniacke blowout on the Scotian Shelf in 1984 (Martec 1984). Shallow water (<500m) subsea blowouts discharge oil and gas from a point on the seabed and the oil and gas rises through the water column to the surface via the influence of the expanding gas bubbles. An example of this kind of oil well blowout was the 1979 Ixtoc 1 blowout in the Bay of Campeche, Mexico. In deep-water subsea blowouts (> 700 to 900 m) the released gas quickly converts to solid hydrates and/or dissolves in the surrounding water and does not influence the rise of the condensate to the surface. The oil rises due to its buoyancy alone. A blowout of this type has never occurred. The three types of blowouts that could occur from the ConocoPhillips exploration operation are discussed in more detail below.

6.3.1. Shallow Water Subsea Blowouts

Oil-well blowouts generally involve two fluids, namely crude oil or condensate and natural gas. The volume ratio of these two fluids is a function of the characteristics of the fluids and the producing reservoir. The natural gas, being a compressible fluid under pressure at reservoir conditions, provides the driving force for an uncontrolled blowout. As the well products flow upwards, the gas expands, finally exiting at the well-head at very high velocities. At this point the oil often makes up only a small fraction of the total volumetric flow.

Oil and gas released from a subsea blowout pass through three zones of interest as they move to the sea surface (Figure 6.2). The high velocity at the well-head exit generates the jet zone that is dominated by the initial momentum of the gas. This highly turbulent zone is responsible for the fragmentation of the oil into droplets ranging from 0.5 to 2.0 mm in diameter (Dickins and Buist 1981).

Because water is also entrained in this zone, a rapid loss of momentum occurs a few metres from the discharge location. In the buoyant plume zone, momentum is no longer significant relative to buoyancy, which then becomes the driving force for the remainder of the plume. In this region the gas continues to expand due to reduced hydrostatic pressures. As the gas rises, oil and water in its vicinity are entrained in the flow and carried to the surface.

Although the terminal velocity of a gas bubble in stationary water is only about 0.25 m/sec, velocities in the center of blowout plumes can reach 5 to 10 m/sec due to the pumping effect of the rising gas in the bulk liquid. That is, the water surrounding the upward moving gas is entrained and given an upward velocity, which is then increased as more gas moves through at a relative velocity of 0.25 m/sec. When the plume becomes fully developed a considerable quantity of water containing the oil droplets is pumped to the surface.

In the surface interaction zone the upward flow of water turns and moves in a horizontal layer away from the center of the plume. The influence of the surface water current causes this radial flow to turn and form a parabolic surface influence as seen in Figure 6.2. This surface influence carries the oil down-current and spreads it over the surface up to the point where this flow no longer affects the surface water motion (between 1 to 1.5 slick widths down-current). At this point the oil moves with the prevailing currents and spreads as any batch spill of oil would behave. The gas exits from the center of the plume and causes a surface disturbance or "boil zone" identified by the arrows in the top view of Figure 6.2. At the surface, the oil coalesces in this outward flow of water and is spread into a slick at a rate much faster than conventional oil slick diffusion or spreading rates.

6.3.2. Above-Surface Blowouts

Condensate released during a blowout from an offshore drilling platform above the water's surface will behave differently than that from a subsurface discharge. The gas and condensate will exit at a high velocity from the well-head and will be fragmented into a cloud of fine droplets. The height that this cloud rises above the release point will vary depending on the gas velocity and the prevailing wind velocity. Atmospheric dispersion processes and the settling velocity of the condensate particles determine the fate of the condensate and gas. Figure 6.3 illustrates a simple Gaussian model of this behaviour that can be used to predict the concentrations of condensate and gas downwind from the release point. Atmospheric dispersion is controlled in part by atmospheric turbulence that is influenced by solar radiation, wind speeds and temperatures. On clear, sunny days, with light winds, solar radiation will create highly turbulent conditions.

Overcast conditions regardless of the winds will result in a neutral atmospheric stability. Low winds will tend to make mixing more prominent whereas high winds tend to reduce the vertical and lateral mixing conditions. The shape of the concentration profile of the plume will vary depending on the atmospheric stability. In very stable conditions the spread both vertically and laterally will be less than in very turbulent conditions.

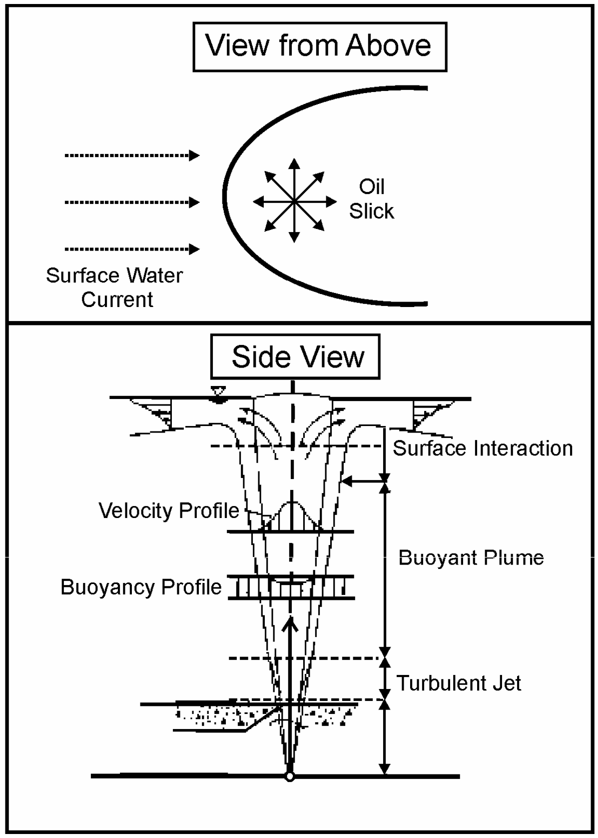

Figure 6.2. Subsea Blowout Schematic.

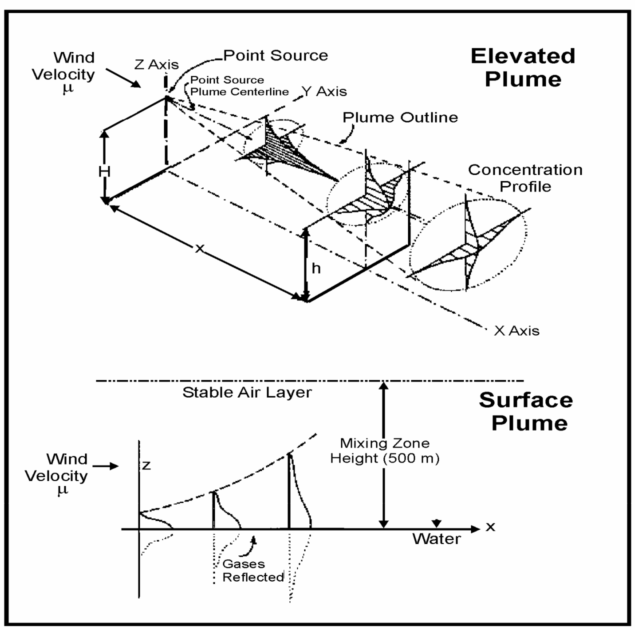

Figure 6.3. Gaussian Plume Behaviour Schematic.

The atmospheric plume representation shown in Figure 6.3 can also be used to illustrate the behaviour of condensate droplets with the following two modifications. The plume centerline is sloped down to account for the condensate droplets' fall velocities and the condensate is not reflected at the water surface. The condensate will "rain" down, with the larger droplets falling closer to the release point. As it falls it will also be spread by the atmospheric turbulence. A portion of the falling condensate evaporates and the remainder eventually lands on the water and is carried down current. As water passes through the area of falling condensate it will be "painted" by the falling condensate and an accumulation of condensate over the width of the fallout zone will occur. Changing wind and water current directions will affect the ultimate distribution of the condensate on the water surface in the fallout zone. If the gas and condensate is blowing through the derrick or some other obstruction, some of the condensate droplets may agglomerate on the obstruction(s) and flow down onto the rig floor and eventually to the water surface. This portion of the condensate will then behave more like a continuous surface release of condensate.

6.3.3. Deep Water Subsea Blowouts

The initial dimensions of condensate slicks from shallow water blowouts are mostly determined by the flow of gas that is released with the condensate. The gas, rising to the surface as a column of bubbles, acts as a large-scale pump to quickly transport condensate droplets to the surface. Because the normal ocean currents are small compared to the vertical rise velocities in the plume, they have little influence on the condensate in shallow water blowouts. This may be different when considering a subsea well blowout in deep water. In this situation the high pressure and low temperatures may cause the natural gas to combine with water to form a solid, ice-like substance known as hydrates. The gas volume may also be depleted through dissolution into the water. With the loss of gas through either or both of these processes, the driving buoyancy of the rising plume may be completely lost, which will result in the condensate droplets rising slowly under gravity forces alone. The movement of the condensate droplets will now be affected by cross currents during their rise. This will result in the separation of the condensate droplets based on their drop size. The large diameter condensate drops will surface first and smaller drops will be carried further down current prior to reaching the surface. Oceanic diffusion processes will result in additional lateral separation of the condensate drops.

The condensate drop size distribution is one of the critical factors that will determine the characteristics of the surface slick that forms above the blowout location. The drop size distribution measured from Dome Petroleum's Oil and Gas Under Sea Ice Experiment (Dickins and Buist 1981) has been used for the condensate rise calculations in this report. This distribution is shown in Figure 6.4. A recent experimental release of oil and gas in deep Norwegian waters recorded oil droplet sizes considerably larger than those identified in the Dome study (SINTEF 2000). This is likely due to the fact that the velocity of the exiting gas in the Norwegian tests was much less than the Dome work and much less than that which would be encountered for the blowout scenarios being considered in this report. Lower exit velocities result in less shearing and larger oil drops. The drop size distribution shown in Figure 6.4 is conservative for the present situation because the blowout scenarios being considered involve higher gas flows than those in the Dome experiment. The higher gas flows could generate smaller drop sizes that would result in thinner surface slicks.

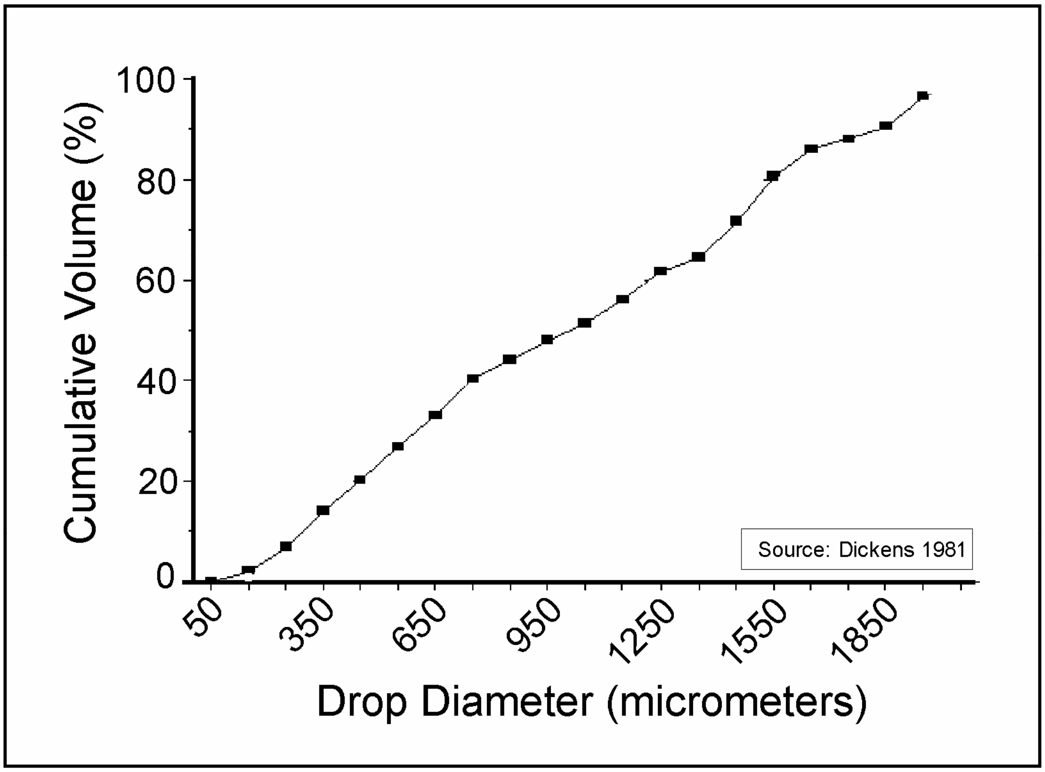

Figure 6.4. Subsea Blowout Oil Drop Size Distribution.

6.3.4. Drilling Platform and Vessel Fuel Oil Spills

Fuel oils are transferred and handled on the drilling platforms and vessels that are used in offshore exploration activities. Past experience in the other areas of the world suggests that small spills of marine fuel oils could occur. The oil spill fate and behaviour model developed at SL Ross (SLROSM) will be used to determine the behaviour and trajectory of these spills.

6.4. Modeling

Modeling has been completed to predict the behaviour and fate of condensate from subsea and surface blowouts for hypothetical blowouts at the exploration platforms and diesel fuel discharges in the vicinity of the drilling platform (SL Ross 2006). Descriptions of the data selected to meet the modeling requirements are contained in SL Ross (2006).

6.5. Discharge Rates and Products

A gas flow rate of 570 MMSCFD and a condensate flow of 10 barrels per MMSCF of gas have been selected for use in the surface blowout modeling exercises. This translates to condensate flows of 906 m^3/day and a gas-to-oil ratio of 17,811 (m^3/m^3). Subsea blowouts are assumed to have gas flows of 850 MMSCFD and a condensate flow of 10 barrels per MMSCF of gas. This translates to condensate flows of 1,351 m^3/day and a gas-to-oil ratio of 17,811 (m^3/m^3). These flow rates have been determined by ConocoPhillips assuming reasonable worst-case spill scenarios. ConocoPhillips geophysicists feel that the geology of these plays is consistent with those in the vicinity of Sable Island - primarily gas with a small amount of liquid condensate.

The fate of 10 and 100 barrel batch spills of diesel fuel have also been modeled. It is highly unlikely that larger volumes of diesel fuel would be spilled from the drilling platforms or support vessels during these operations.

The physical properties of various condensates that have been found on the Scotian Shelf are shown in Table 6.13. Oil property data for a Cohasset condensate, developed by SL Ross in a previous project (SL Ross 1989), have been selected to represent the liquids that might be released from this operation. This is the heaviest condensate found off the east coast of Canada that has been analysed in detail for spill modeling purposes.

Table 6.13. Physical Properties of Scotian Shelf Condensates.

Oil Property	Deep Panuke	Panuke	SOEP	Cohasset
Density (kg/m 3)	750	775	704	790
Viscosity (cP)	1.53	1.895	0.411	2.6
Pour Point (° C)	not known	-36	-117	-30
ASTM Distillation Curve Slope Intercept	 250 390	 271 352	 204 360	 200 443

CPC will submit a comprehensive oil spill response plan to C-NLOPB with the Drilling Program Authorization.

6.6. Potential Effects of Accidental Spills

6.6.1. Oil/Condensate Spill Effects Criteria

ConocoPhillips is considering the Laurentian Sub-basin as a "gas play" as geological conditions appear similar to those off Nova Scotia. Fate and behaviour modeling was conducted by SL Ross in order to assist in predicting the effects of a gas blowout or a fuel spill during the exploratory drilling. While any potential blowout is predicted to be primarily gas it would still contain a heavier petroleum hydrocarbon component (condensate) that has the potential to form a slick on the surface of the water. The scenarios and modeling are described in detail in SL Ross (2006). Surface, slope (750 m) and deepwater (2,300 m) blowouts were modeled within the Project Area.

Any blowouts or spills will form a slick on the surface as well as a subsurface "cloud" of petroleum hydrocarbons suspended in the upper 10 m of the water column. The modeling data presented below is presented in this format with estimates provided for surface slick areas (assumed to be the area affected or geographic extent of effects on surface dwelling animals such as seabirds) and areas influenced by the subsurface clouds (assumed to be the area affected or geographic extent of effects on pelagic animals such as zooplankton). It should be noted that while the zone of influence of the subsurface cloud is potentially quite large, maximum hydrocarbon levels are still quite low (see tables in the following sections). This zone of influence is only for the upper 10 m. In addition, most effects, when they do occur, would be sublethal and temporary, depending upon many biological factors such as species and life stage, and physical factors such as temperature and salinity, and others.

6.6.1.1. Surface Blowout

The salient feature of the surface blowout is that gas and condensate are fragmented into small airborne droplets. The shape of this airborne plume is determined by atmospheric conditions, particularly wind. The droplets then fall out onto the sea's surface to create a slick. The scenario assumed a condensate flow of 906 m^3/d with a gas flow rate of 17,810 m^3 per m^3 of condensate. Characteristics of the slick resulting from a surface blowout are shown in Table 6.14. The summer surface blowout results in a slick width of 131 m and a length based on a visible sheen of 500 m, or a total area affected by the surface slick of <0.1 km^2. The winter surface blowout results in a slick width of 166 m and a length based on a visible sheen of 500 m, or a total area affected by the surface slick of <0.1 km^2. This surface slick has the potential to affect seabirds, sea turtles and marine mammals that use the surface.

For subsurface petroleum hydrocarbon concentrations, a concentration of 0.1 ppm was used as a cut-off point for biological effects on plankton and pelagic fish. This is a more or less standard value used in most east coast EAs (e.g., Grand Banks, Orphan Basin drilling EAs) for effects on sensitive stages such as fish eggs and larvae (e.g., Petro-Canada 1996; Husky 2000; LGL 2005, 2006). The modeling predicted a maximum "cloud" (in winter) of 1.7 x 20 km for a maximum affected area for plankton (including fish eggs and larvae) of 34 km^2 (19 km^2 in summer).

Table 6.14. Surface Blowout Slick and Dispersed Condensate Cloud Characteristics.

Season	In-Air Evaporation %	Initial Slick Width (m)	Initial Slick Thickness (mm)	Slick Survival Time (min)	Final Evaporation %	Final Dispersion %	Max. Cond. Conc. (ppm)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (km)	Distance to 0.1 ppm (km)
Winter	43	166	0.12	8	45	55	11	19	1.7	20
Summer	59	131	0.20	40	63	37	11	20	1.7	11

6.6.1.2. Shallow Subsea Blowout

A "shallow" subsea blowout on the shelf would produce an initial surface slick of width 3.9 km (winter) to 8.1 km (summer) that will immediately dissipate to form a subsurface "cloud" 13.7 km (winter) and 27.2 km (summer) in width and 52 km (winter) to 75 km (summer) in length before achieving a concentration less than 0.1 ppm in the upper 10 m (Table 6.15). For the purposes of assessing a shelf blowout, a surface slick was assumed of area (a circle defined by the initial slick width): 12 km^2 for winter and 51.4 km^2 for summer (R. Belore, SL Ross, pers. comm.). This area would affect surface-using animals, especially seabirds. The subsurface cloud that potentially affects plankton could encompass an area as large as 458 km^2 [winter; (3.9 + 13.7)/2 x 52 km] to 1,324 km^2 [summer; (8.1+27.2)/2 x 75 km)] (Table 6.15).

Table 6.15. Shallow Subsea Blowout Slick and Dispersed Condensate Cloud Characteristics.

Season	Evaporation By Subsea Model (%)	Initial Slick Width (m)	Initial Slick Thickness Φm	Slick Survival Time (hr)	Initial Dispersed Condensate Conc. (ppm)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (km)	Distance from Source to 0.1 ppm (km)
Winter	9.8	3916	13.7	0	1.24	87	13.7	52
Summer	17	8088	13.7	0	1.14	154	27.2	75

6.6.1.3. Slope Blowout (750 m)

A blowout on the slope at a water depth of 750 m would create a surface slick of about 0.4 km^2 in summer and 0.5 km^2 in winter. The subsurface cloud would be about 279 km^2 [(0.56+9.4)/2*59] in summer and about 284 km^2 [(0.56+9.9)/2*57] in winter (see Table 6.16).

Table 6.16. Slick and Dispersed Cloud Characteristics Subsea Slope (750m) Blowouts.

Season	Initial Thick Slick Thickness (mm)	Initial Slick Width (m)	Thick Slick Survival Time (hr)	% Evaporated	% Dispersed	Max. Disp Cond. Conc. (ppm)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (km)	Distance to 0.1 ppm (km)
Summer	2.7	56	1.1	23	77	18	87	9.4	59
Winter	2.1	56	0.4	12	88	19	90	9.9	57

6.6.1.4. Deep Blowout (Channel 2,300 m)

The deep blowout will cause a slick at some distance from the source because of the great distance that the droplets would have to rise; the slick will be thickest near the source because the large droplets will rise faster than small ones. According to SL Ross (2006), the slicks that initially form from the rising droplets from these subsea releases will be about 85 to 90 m wide near source, about 2 to 2.8 km long and about 0.7 km wide at their widest point (location where fresh condensate surfaces in a thickness less than 10 µm). Thus, the area of surface affected by the surface slick would be about 1 km^2 summer or winter.

The subsurface cloud in winter would extend from the source with widths from 0.128 km to 8.1 km, and 54 km in length, for about 222 km^2 in total area [(0.128+8.1)/2*54]. In summer, the area of the cloud would be about 77 km^2 (see Table 6.17).

Table 6.17. Deep Blowout Slick and Dispersed Cloud Characteristics.

Season	Initial Thick Slick Thickness (mm)	Initial Slick Width (m)	Thick Slick Survival Time (hr)	% Evaporated	% Dispersed	Max. Disp Cond. Conc. (ppm)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (km)	Distance to 0.1 ppm (km)
Summer	1.14	124	0.5	23	77	9	69	7.6	20
Winter	0.83	128	0.2	12	88	8	72	8.1	54

6.6.1.5. Batch Spills of Diesel Fuel

Two diesel fuel batch spill scenarios have been considered with spill volumes of 10 and 100 barrels (0.159 m^3 and 1.59 m^3) (Table 6.18). With the exception of the two "Distance To" columns the data in this table apply to spills at all three sites. The "Distance To" values shown in Table 6.18 are the greatest distances estimated by the model from the three sites modeled. These parameters vary due to the different surface water velocities at each site.

Table 6.18. Diesel Spill Characteristics.

Spill Volume (bbl) and Season	Initial Slick Width (m)	Slick Survival Time (hr)	Max. Slick Width (m)	Total Evap. %	Dist. to Loss of Slick (km)	Peak Disp. Cond. Conc. (ppm)	Time to Peak Conc. (hr)	Time to 0.1 ppm (hr)	Cloud Width at 0.1 ppm (km)	Distance to 0.1 ppm (km)
10 Win	10	13	50	27	17	1.9	1.0	16	1.2	18
10 Sum	10	29	55	40	22	0.7	1.0	9	0.64	26
100 Win	32	20	122	27	40	4.0	3.0	43	3.8	26
100 Sum	32	40	132	38	30	1.4	3.0	39	3.4	26

The percentage of the spilled diesel that will evaporate will be 38 to 40% in the summer and about 27% in the winter. The higher winter winds tend to disperse the spills faster even with the colder and slightly more viscous condensate. The diesel fuel from the 10 barrel batch spill scenarios will disperse or evaporate from the surface within about 13 hours in the winter and 29 hours in the summer. These survival times increase to 20 and 40 hours for the 100 barrel spills. The slicks from the 10 barrel spills will dissipate at a maximum distance of 17 to 22 km from the source assuming average wind and water current conditions. The 100 barrel slicks will travel between 30 and 40 km before complete loss of the surface oil. Winds are generally from the south-west in summer, west-north-west in the winter. These winds will tend to push the oil to the north-east (summer) and south-east (winter) of the drilling platforms in the absence of strong water currents.

The peak diesel concentration in the upper 10 metres is estimated to be 0.7 to 1.9 ppm for the 10 barrel spills, 1.4 to 4.0 ppm for the 100 barrel releases. The slightly higher concentrations exist in the winter due to the increased dispersion rate caused by the stronger winter winds.

Within 16 hours the oil clouds from the winter 10 barrel spills will grow to a width of about 1,200 metres and diffuse to 0.1 ppm concentration (assuming a conservative 10 m mixing depth). The summer 10 barrel spill will diffuse to 0.1 ppm within nine hours and have a width of about 640 metres at this point. The dispersed clouds from the 100 barrel spills will diffuse to 0.1 ppm within about 43 hours in the winter and 39 hours in the summer. The dispersed clouds from the 100 barrel releases will reach diameters of about 3.4 km (summer) and 3.8 km (winter).

The dispersed clouds from the winter 10 barrel spills will travel a maximum of about 18 km prior to reaching 0.1 ppm. In the summer the dispersed condensate clouds will travel a maximum of 26 km prior to concentrations dropping below 0.1 ppm. The dispersed clouds from the 100 barrel spills will travel a maximum of 26 km in both the winter and summer.

The estimates used in the effects assessment assume winter surface areas affected by a slick of 0.5 km^2 (0.03 km average width x 17 km) for the 10 bbl spill and 3.1 km^2 (0.077 km average width x 40 km, length) for the 100 bbl spill (see Table 6.18). In the summer, for the 10 bbl spill, the area affected would be 0.7 km^2, and 2.5 km^2 for the 100 bbl spill.

The maximum area affected by the subsurface cloud from the 10 bbl spill would be 8.4 km^2 in summer to 10.9 km^2 in winter. For the 100 bbl spill, the maximum area affected by the cloud is 44.6 km^2 in summer and 49.8 km^2 in winter (see Table 6.18).

It should be noted that while the zone of influence of the subsurface cloud is potentially quite large, maximum hydrocarbon levels are still quite low (e.g., highs of 0.7 to 4.0 ppm—Table 6.18). This zone of influence is confined to the upper 10 m of the water column. In addition, most effects, when they do occur, would be sublethal and temporary, depending upon many biological factors such as species and life stage, behaviour, and physical factors such as temperature and salinity, and others.

6.6.2. Fish and Fish Habitat

The following sections highlight information relevant to the assessment of effects of an offshore oil/condensate spill (i.e., gas blowout or surface release of diesel fuel) at the Laurentian Sub-basin Study Area. The reader is referred to the previous sections for a discussion of spill probabilities of the properties and behaviour of spilled oil/condensate.

A scenario approach was used to evaluate interactions between oil/condensate spills and water quality, plankton, benthos, fish eggs and larvae, juvenile fish, adult pelagic fish, and adult groundfish. Fish and fish habitat VECs were assessed using the same tables (Tables 6.19 to 6.21) because the effects on the fish are directly proportional to the geographic extent of effects on fish habitat.

6.6.2.1. Fish

'Fish' includes all finfish and macroinvertebrate life stages that occur above the ocean substrate within the water column.

Juveniles and Adults

Effects of Exposure to Natural Gas

The impact of natural gas on fish occurs more quickly than the impact of exposure to other dissolved or suspended toxicants (Patin 1999). Gas rapidly penetrates fish, especially via the gills, disturbing various functions including the respiration, the nervous system, blood formation and enzyme activity.

Behavioural disturbances include excitatory behaviour, increased activity, and scattering behaviour. Chronic exposure of fish to natural gas may lead to chronic poisoning, resulting in biochemical and physiological effects. A general effect typical for all fish is the occurrence of gas emboli due to gas oversaturation of water. Symptoms of gas emboli include tissue rupture (e.g., fins, eyes), enlargement of the swim bladder, and circulatory system problems. Specific reported effects of exposure to natural gas on fish include mass mortality and significant pathological changes in the Sea of Asov after accidental gas blowouts in 1982 and 1985 (AzNIIRKH 1986 *in* Patin 1999).

Components commonly found in natural gas include saturated aliphatic hydrocarbons (i.e., methane and its homologues), carbon dioxide, hydrogen sulphide, nitrogen and helium. The saturated aliphatics comprise most of the natural gas. Generally, there are three main degrees of intoxication by methane on vertebrates. These include the following: (1) light – reversible and quickly subsiding effects on the functions of central nervous and cardiovascular systems; (2) medium – deeper functional changes in the central nervous and cardiovascular systems, and an increase in the number of leukocytes in the peripheral blood; and (3) heavy – irreversible disturbances of the cerebrum, heart tissues and alimentary canal, and an acute form of leukocytosis (Patin 1999).

Toxicological studies of the effects of methane and its homologues on aquatic organisms are very limited. Despite the lack of research, particularly under chronic exposure conditions, observations of both fish behavioural responses and fish mortality suggest a relatively low resistance of ichthyofauna to the presence of natural gas in the aquatic environment. The high speed of primary responses, their clear manifestations, and their relatively short latent phases indicate a possible damaging impact on the central nervous system of fish.

Table 6.19. Accidental Spill-Environmental Interaction Matrix for Fish and Fish Habitat VECs.

	Valued Environmental Components								
	Fish Habitat VEC					Fish VEC			
						Pre-Adult Stages		Adult Stage	
	Water Quality	Sediment	Topography	Plankton	Benthos	Eggs/Larvae	Juvenile	Pelagic Fish	Groundfish
	Offshore Blowouts/Spills								
Surface Blowout									
(906 m^3/d condensate)	x			x		x	x	x	x
Sub-surface Blowout (1,351 m^3/d)									
Shelf	x	x		x	x	x	x	x	x
Slope (750 m depth)	x	x		x	x	x	x	x	x
Basin (2,300 m depth)	x	x		x	x	x	x	x	x
Diesel Batch Spill									
Surface (10 bbl or 1.6 m^3)	x			x		x	x	x	x
Diesel Spill									
Surface (100 bbl or 15.9 m^3)	x			x		x	x	x	x

Table 6.20. Accidental Spill/Blowout Effects Assessment for Fish and Fish Habitat VECs.

Valued Environmental Components: Fish and Fish Habitat									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario[a]	Potential Positive (P) or Negative (N) Environmental Effect	Regulatory Mitigation	Project Specific Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Commercial Finfish & Invertebrate Eggs/Larvae									
Surface Blowout									
960 m^3/d condensate	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	3	<1	1	R	1
Subsea Blowout (1,351 m^3/d)									
Shelf	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Slope	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention	0-1	5	<1	1	R	1
Basin	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Diesel Batch Spill									
10 bbl (1.6 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
100 bbl (15.9 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Water Quality									
Surface Blowout									
906 m^3/d condensate	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	3	<1	1	R	1
Subsea Blowout (1,351 m^3/d)									
Shelf	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Slope	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	1	R	1

Table 6.20 (cont'd)

Valued Environmental Components: Fish and Fish Habitat										
Accidental Offshore Oil Spill or Blowout										
				Evaluation Criteria for Assessing Environmental Effects						
VEC and Spill Scenario[a]	Potential Positive (P) or Negative (N) Environmental Effect	Regulatory Mitigation	Project Specific Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Basin	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Diesel Batch Spill									
10 bbl (1.6 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Diesel Spill									
100 bbl (15.9 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Plankton									
Surface Blowout									
906 m^3/d condensate	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	3	<1	1	R	1
Subsea Blowout (1,351 m^3/d)									
Shelf	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Slope	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	5	<1	1	R	1
Basin	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Diesel Batch Spill									
10 bbl (1.6 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1
Diesel Batch Spill									
100 bbl (15.9 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	<1	1	R	1

Table 6.20 (Cont'd).

Valued Environmental Components: Fish and Fish Habitat									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario[a]	Potential Positive (P) or Negative (N) Environmental Effect	Regulatory Mitigation	Project Specific Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Benthos									
Subsea Blowout (1,351 m^3/d)									
Shelf	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	1-2	<1	1	R	1
Slope	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	1-2	<1	1	R	1
Basin	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	1-2	<1	1	R	1

Key:

Magnitude:	Geographic Extent:	Frequency:	Duration:	Reversibility (population level):
0 = negligible	1 = <1 km²	1 = < 11 events/yr	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km²	2 = 11-50 events/yr	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km²	3 = 51-100 events/yr	3 = 13-36 months	
3 = High	4 = 101-1,000 km²	4 = 101-200 events/yr	4 = 37-72 months	
	5 = 1001-10,000 km²	5 = >200 events/yr	5 = > 72 months	
	6 = >10,000 km²	6 = continuous		

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

a Geog. Extent differed during summer & winter but always fell within the same category of Geog. Extent.

Table 6.21. Significance of Predicted Residual Environmental Effects on Fish and Fish Habitat VECs in the Unlikely Event of an Accidental Offshore Oil Spill or Blowout.

Valued Environmental Components: Fish and Fish Habitat				
Accidents	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Oil Blowouts/Spills	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
Surface Blowout				
960 m^3/d condensate	NS	3	-	-
Sub-sea Blowout (1,351 m^3/d)				
Shelf	NS	3	-	-
Slope (750 m)	NS	3	-	-
Basin (2,300 m)	NS	3	-	-
Diesel Batch Spill				
10 bbl (1.6 m^3)	NS	3	-	-
Diesel Batch Spill				
100 bbl (15.9 m^3)	NS	3	-	-

Key:

Residual Environmental Effect Rating:
S = Significant Negative Environmental Effect
NS = Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high Magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence in Impact Prediction:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability:
1 = Low Probability
2 = Medium Probability
3 = High Probability

Scientific Certainty: Based on Scientific Information and Statistical Analysis or Professional Judgement:
1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

N/A = Not Applicable

The potential for impact of natural gas on biota is highest in the immediate vicinity of the blowout. Beyond that high-pressure area proximate to the well, the natural gas ceases to be a real issue in terms of biological effects. Only those fish in or very proximate to the path of the blowout are likely to be impacted. Others in the vicinity will detect and avoid the rapidly rising plume. Therefore, the effects of exposure to gas blowouts on adult and juvenile fish are predicted to be *negligible*.

Effects of Exposure to Oil

There is an extensive body of literature regarding the effects of exposure to oil on juvenile and adult fish. Although some of the literature describes field observations, most refers to laboratory studies.

Reviews of the effects of oil on fish have been prepared by Armstrong et al. (1995), Rice et al. (1996), and numerous other authors. If exposed to oil in high enough concentrations, fish may suffer effects ranging from direct physical effects (e.g., coating of gills and suffocation) to more subtle physiological and behavioural effects. Actual effects depend on a variety of factors such as the amount and type of oil, environmental conditions, species and life stage, lifestyle, fish condition, degree of confinement of experimental subjects, and others. Based on laboratory toxicity studies, pelagic fish tend to be more sensitive (LC_{50}s of 1 to 3 ppm) than either benthic (LC_{50}s of 3 to 8 ppm) or intertidal fish species (LC_{50}s of >8 ppm) (Rice et al. 1979). [An LC_{50} is based upon controlled laboratory experiments using confined fish, usually in a container of standing water. The result is expressed as the concentration of a contaminant that achieves a mortality rate of 50%. There are recognized problems in applying LC_{50} data to the ”real world” but they are useful for “ball park” comparative information, especially in situations where it is very difficult to obtain good controlled field data.]

Reported physiological effects on fish have included abnormal gill function (Sanders et al. 1981 and Englehardt et al. 1981 *in* Brzorad and Burger 1994), increased liver enzyme activity (Koning 1987; Payne et al. 1987), decreased growth (Swatrz 1985 *in* Brzorad and Burger 1994; Moles and Norcross 1998), organ damage (Rice 1985), and increased disease or parasites loads (Brown et al. 1973; Steedman 1991 *in* Brzorad and Burger 1994; Carls et al. (1998); Marty et al. 1999).

Reported behavioural effects include avoidance of contamination by migrating salmon (Weber et al. 1981), and cod in laboratory studies at refined petroleum levels in excess of 100 µg/L (Bohle 1986 *in* Crucil 1989), and altered natural behaviours related to predator avoidance (Gardner 1975; Pearson et al. 1984) or feeding (Christiansen and George 1995).

Juvenile (i.e., those past the egg and larval stages) and adult fish can and probably will avoid any crude oil by swimming from the blowout/spill region (Irwin 1997). Effects of exposure to oil and/or diesel fuel on adult and juvenile fish are predicted to be *negligible*. This conclusion is consistent with the findings in the White Rose EA/Comprehensive Study, the Hibernia and Terra Nova EISs, the Lewis Hill EA, and the Jeanne d'Arc Basin EA. All of these concluded that neither surface spills nor subsea blowouts posed significant risks to either pelagic or demersal fish stocks (Mobil 1985; Petro-Canada 1996; Husky 2000, 2002, 2003).

Eggs and Larvae

Effects of Exposure to Natural Gas

Fish resistance to the presence of gas at the various life stages is not well understood. With many toxicants, the most vulnerable life stages are the early ones. Whether this pattern is true for saturated hydrocarbons remains unclear. However, as indicated in the preceding section, the potential for impact of natural gas on biota is highest in the immediate vicinity of the blowout. If the blowout is subsurface and most of the ichthyoplankton is in the upper water column, impact on them is likely to be minimal.

The gas portion of a surface blowout is quickly evaporated and poses little risk to the ichthyoplankton. Therefore, the effects of exposure to gas blowouts on fish eggs and larvae are predicted to be *negligible*.

Effects of Exposure to Oil

Planktonic fish eggs and larvae (ichthyoplankton) are less resistant to effects of contaminants than are adults because they are not physiologically equipped to either detoxify them or actively avoid them. In addition, many eggs and larvae develop at or near the surface where oil exposure may be the greatest (Rice 1985). It is estimated that sensitivities of fish larvae range from 0.1 to 1.0 ppm of soluble aromatic hydrocarbons, approximately 10 times the sensitivities of adults (Moore and Dwyer 1974). However, an organism's sensitivity to oiling is not simply a function of age.

Generally, fish eggs appear to be highly sensitive at certain stages and then become less sensitive just prior to larval hatching (Kühnhold 1978; Rice 1985). Larval sensitivity varies with yolk sac stage and feeding conditions (Rice et al. 1986). Eggs and larvae exposed to high concentrations of oil generally exhibit morphological malformations, genetic damage, and reduced growth. Damage to embryos may not be apparent until the larvae hatch. For example, although Atlantic cod eggs were observed to survive oiling, the hatched larvae were deformed and unable to swim (Kühnhold 1974). Atlantic herring larvae exposed to oil have exhibited behavioural abnormalities such as initial increased swimming activity followed by low activity, narcosis, and death (Kühnhold 1972). Similarly, Pacific herring (*Clupea pallasi*) eggs and larvae (possibly exposed as embryos) collected from beaches contaminated with *Exxon Valdez* oil in 1989 exhibited morphological and genetic damage (Hose et al. 1996; Norcross et al. 1996; Marty et al. 1997). Marty et al. (1997) indicated that herring larvae collected from oiled sites had ingested less food, displayed slower growth, and had a higher prevalence of cytogenetic damage than those sampled from 'clean' sites. However, these effects were not observed in eggs and larvae collected in later years (Hose et al. 1996; Norcross et al. 1996) and there is no conclusive evidence to suggest that these oiled sites posed a long-term hazard to fish embryo or larval survival (Kocan et al. 1996).

The natural mortality rate in fish eggs and larvae is so high that large numbers could be destroyed by anthropogenic sources before effects would be detected in an adult population (Rice 1985). Oil-related mortalities would probably not affect year-class strength unless >50% of the larvae in a large proportion of the spawning area died (Rice 1985). Herring are one of the most sensitive fish species to oiling. Hose et al. (1996) claim that even though 58% fewer than normally expected herring larvae were produced at a site oiled during the *Exxon Valdez* spill, no effect would be detected at the population level.

Ten-day exposures of large numbers of pink salmon smolt (*Oncorhynchus gorbuscha*) to the water-soluble fraction of crude oil (0.025 to 0.349 ppm) did not result in any detectable effects on their survival to maturity (Birtwell et al. 1999). However, it should be noted that pink salmon may be more resistant to environmental disturbance than other species because they spend so much time in the variable estuarine environment.

Ichthyoplankton occurrence, abundance and distribution are highly variable by season and dependent on a variety of biological (e.g., stock size, spawning success, etc.) and environmental (temperature, currents, etc.) factors. In the unlikely event of a blowout or spill at the Laurentian Sub-basin Project Area, there is potential for individual ichthyoplankters in the upper water column to sustain lethal and sublethal effects following contact with high concentrations of oil. The LC_{50} value at 25°C used by Hurlbut et al. (1991) to predict effects on ichthyoplankton was 0.0143 ppm.

As in the case of fish larvae, the sensitivity of invertebrate larvae to petroleum hydrocarbons varies with species, life history stage, and type of oil. Generally, invertebrate larvae are more sensitive to effects of oil than are adult invertebrates. Sublethal and lethal effects on individual larvae are possible during a spill or blowout at the Laurentian Sub-basin.

American lobster larvae (Stages 1 to 4) showed a 24-h LC_{50} of 0.1 ppm to Venezuelan crude oil (Wells 1972). Larvae exposed to 0.1 ppm of South Louisiana crude oil swam and fed actively while those exposed to 1 ppm were lethargic (Forns 1977). Stage 1 crab larvae (king crab, *Paralithodes camtschatica* and Tanner crab (*Chionoecetes bairdi*)) succumbed to similar concentrations of crude oil (0.96 to 2 ppm; Brodersen et al. 1977) while larval shrimp generally had higher LC_{50} limits (0.95 to 7.9 ppm; Brodersen et al. 1977; Mecklenburg et al. 1977). Anderson et al. (1974) tested a variety of crude and refined oils and found that post-larval brown shrimp (*Penaeus aztecus*) were less sensitive than adult invertebrate species. Also, moulting larvae appear to be more sensitive to oil than intermoult larvae (Mecklenburg et al. 1977). Kerosene affected development of sea urchin embryos at concentrations of 15 ppb or greater, as did gasoline at concentrations of 28 ppb or greater (Falk-Petersen 1979).

Invertebrate larvae exposed to oil may exhibit reductions in food consumption and growth rate, and increases in oxygen consumption (Johns and Pechenik 1980). Despite these physiological changes, deleterious effects on invertebrate populations have not been detected, even after major oil spills (Armstrong et al. 1995). Larval distribution and settlement, fecundity, recruitment and growth of juveniles and subadult crab, pandalid shrimp, clams and scallops were not significantly affected by the *Exxon Valdez* oil spill (Armstrong et al. 1995).

Potential vulnerabilities of important commercial species known to occur in the general area of the Laurentian Sub-basin Study Area are indicated by the spatial and temporal characteristics of their eggs and larvae in Table 6.21.

The eggs and/or larvae of most species indicated in Table 6.22 occur in the near-surface waters. These species' eggs and larvae may account for most of the ichthyoplankton in the area. Three wolffish species are presently listed on Schedule 1 of *SARA*, two as threatened and the third as a species of special concern. The Newfoundland and Labrador population of Atlantic cod is listed as a species of special concern on Schedule 3 of *SARA*. More detail on the life histories of many of the species that likely spawn within or near the Study Area that is available in Section 4.6.

Table 6.22. Important Fish and Invertebrate Species Known or Likely to Reproduce Within or Near the Study Area.

Species	Locations of Reproductive Events	Times of Reproductive Events	Duration of Planktonic Stage
Redfish[1]	Primarily along western slope of St. Pierre Bank and in deeper areas of the Laurentian Channel Slope region from southern St. Pierre Bank to southern Green Bank	Mating in late winter and release of young between April and July (peak in April)	N?A
White hake	Southwestern slope of St. Pierre Bank	June to August	1 month
Snow crab	St. Pierre Bank	Spring and summer	3-4 months
Pollock	NAFO Unit Areas 3Psg, 3Psh	Late summer and fall	
Monkfish	Egg cases found along slope region from southern St. Pierre Bank to southern Green Bank	Late spring/summer	Uncertain
Atlantic cod[1]	Western and southern slopes, and shelf of St. Pierre Bank Deep areas of Laurentian Channel Banquereau Bank Southern Halibut Channel and associated slope region Southern Green Bank and associated slope region	March to June	10 to 12 weeks
Atlantic halibut	Likely at slope of St. Pierre Bank	February to April	3 to 4 months
Skates	NAFO Unit Area 3Ps	Year-round	
Greenland halibut	Laurentian Channel	Winter months	Uncertain
Wolffish	Likely along the slope regions of St. Pierre Bank	September to November	
Cusk	Southwestern slope of Laurentian Channel	May to August	Uncertain

Table 6.22 (cont'd)

Species	**Locations of Reproductive Events**	**Times of Reproductive Events**	**Duration of Planktonic Stage**
Porbeagle shark	St. Pierre Bank Laurentian Channel	Mating in late summer and pupping during the winter	
American plaice[1]	Western and southern slopes, and shelf of St. Pierre Bank Southern slopes of Halibut Channel and Green Bank	April to May	12 to 16 weeks
Atlantic herring	Banquereau Bank	August to November	
Haddock[3]	Western slope of St. Pierre Bank Slope region south of Halibut Channel and Green Bank	March to May	
Mackerel	Southern Laurentian Channel	June to July	1 week
Witch flounder[1]	Slope regions of western and southern St. Pierre Bank, and southern Halibut Channel Halibut Channel	March to May	
Yellowtail flounder[1]	Western slope and shelf of St. Pierre Bank	April to May	

Adapted from Table 3.11 *in* JWEL (2003)

[1] DFO research vessel survey data, 1972-2002 (Ollerhead et al. 2004).

The geographical and seasonal distribution of fish eggs and larvae in the Study Area is highly variable. Generally, there are two peaks in abundance of ichthyoplankton on the Grand Banks. The first typically occurs in April-May and the second in August-September. As already indicated, the eggs and larvae of most of the above species listed in Table 6.22 are distributed in the upper 50 m of the water column. When all of the ichthyoplankton are considered together, the period of their occurrence in the Study Area plankton is year-round, with a peak between April and September. In all five scenarios (Table 6.20), the effects of exposure to gas and/or oil on fish and invertebrate eggs and larvae are predicted to be negative.

Based on fate and behaviour modeling for the ConocoPhillips exploratory drilling Project Area, the area of the subsurface cloud with petroleum hydrocarbon concentrations of at least 0.1 ppm (cut-off point for important biological effects) ranges from 19 (summer surface blowout) to 1,324 km^2 (summer shallow [slope] subsea blowout). The geographic extent of actual measurable effects will likely be much less than the areas shown because concentrations of oil in the water column will likely be lower than those shown to produce demonstrable effects. It should be noted that the 'zone of influence' is considered to occur only in the upper 10 m of the water column. Impacts of exposure to oil and/or diesel on ichthyoplankton are predicted to be *negligible*.

Overall Assessment for Fish

The magnitude of effects on eggs, larvae, juveniles and adults for each finfish and invertebrate species would be *negligible to low* in each blowout/diesel release scenario (Table 6.20). Geographic extent for the five scenarios range from *11-100* km^2 *to 1,001-10,000* km^2. Frequency and duration of these accidental spills are *<11 events/yr* and *<1 month*, respectively. Given these criteria and that all residual impacts are also predicted to be *reversible*, the negative environmental effects on fish are predicted to be *not significant* (Table 6.21).

6.6.2.2. Fish Habitat

For the purposes of EA, 'fish habitat' includes water and sediment quality, phytoplankton, zooplankton and benthos. The Hibernia and Terra Nova EISs and the White Rose and Jeanne d' Arc Basin EAs predicted that environmental (biophysical) effects on water quality and habitat would be *not significant*. Effects of spills on fish habitat during the proposed exploratory drilling program in the Laurentian Sub-basin are also predicted to be *not significant*. As described in the preceding section, the chance of an accidental event is extremely low.

The highest polyaromatic hydrocarbon (PAH) concentration found in Prince William Sound at one and five m depths within the six-week period following the *Exxon Valdez* spill (a much worse case than any plausible spill scenario in the Laurentian Sub-basin) was 0.00159 ppm, well below levels considered acutely toxic to marine fauna (Short and Harris 1996).

Water Quality

Studies on the gas blowouts in the Sea of Asov (AzNIIRKH 1986 *in* Patin 1999) provided some idea about the resultant methane pollution. Methane concentrations in the water at the well location ranged between four and six mg/l, and 0.07 to 3.5 mg/l at 200-500 m from the well. These results suggest that methane and its homologues may remain in the water for a period over considerable distances from the location of an accidental event. Similar conclusions have been made based on observations in the Gulf of Mexico (Patin 1999). However, levels are likely not high enough to cause substantial biological effect. Therefore, the effects of natural gas on the overall water quality would be *negligible to low*.

In terms of oil and diesel in the water, model predictions of maximum concentrations for blowouts and surface releases as well as the predicted times for decrease to a 0.1 ppm hydrocarbon concentration indicate that the effects on water quality would be *negligible to low*.

Plankton

The fish habitat VEC includes plankton because it is a source of food for larvae and some adult fish (i.e., the fish VEC). Thus, effects of a gas and/or oil spill on plankton could affect fish.

Results of field studies around the accidental gas blowout in the Sea of Asov (AzNIIRKH 1986 *in* Patin 1999) suggest that gas affects zooplankton more than the bacterioplankton and phytoplankton. However, high variability of zooplankton parameters and insufficient data prevent the statement of any unqualified conclusions.

Dispersion and dissolution cause the soluble, lower molecular weight hydrocarbons to move from the slick into the water column. Effects of spills on pelagic organisms need to be assessed through examination of effects of water-soluble fractions of oil or light hydrocarbon products. However, gas levels are likely not high enough to cause substantial biological effect. Therefore, the effects of natural gas on the plankton would be *negligible to low*.

Effects of crude oil spills on plankton are short-lived, with zooplankton being more sensitive than phytoplankton. Zooplankon accumulate hydrocarbons in their bodies. The hydrocarbons may be metabolized and depurated (Trudel 1985). Hydrocarbons accumulated in zooplankton during a spill would be depurated within a few days after a return to clean water and thus, there is limited potential for transfer of hydrocarbons up the food chain (Trudel 1985). There is a potential for transfer of hydrocarbons up the food chain in an environment subject to chronic inputs of hydrocarbons, but there is no potential for biomagnification. Celewycz and Wertheimer (1996) concluded that the *Exxon Valdez* spill did not reduce the available prey resources, including zooplankton, of juvenile salmon in Prince William Sound.

Mortality of zooplankton can occur at diesel concentrations of 100 to 10,000 ppm (24 to 48 h LC_{50}, where LC_{50} is the concentration of toxicant that kills 50 percent of the test animals; Trudel 1985).

Diesel oil is much more toxic, but shorter-lived in the open ocean than crude oil. There is great variability among species and some species are relatively insensitive. For example, the 96-h LC_{50} of crude oil for *Calanus hyperboreus*, a common cold water copepod, was 73,000 ppm (Foy 1982). Complete narcotization of copepods can occur after a 15-min exposure to 1,800 ppm of aromatic heating oil and mortality can occur after a 6-h exposure (Berdugo et al. 1979). Exposure to concentrations of 1,000 ppm of aromatic heating oil for three days had no apparent effect on mobility, but exposure for as little as 10 minutes shortened life span and total egg production (Berdugo et al. 1979). No. 2 fuel oil at concentrations of 250 to 1,000 ppm completely inhibited or modified copepod feeding behaviour, while concentrations of 70 ppm or lower may not affect feeding behaviour (Berman and Heinle 1980). Exposure to naphthalene at concentrations of 10 to 50 ppm for 10 days did not affect feeding behaviour or reproductive potential of copepods although egg development was not examined (Berdugo et al. 1979).

In summary, individual zooplankton could be affected by a spill through mortality, sublethal effects, or hydrocarbon accumulation if oil and/or gas concentrations are high enough. However, the predicted maximum concentrations for blowouts and surface releases as well as the predicted times for decrease to a 0.1 ppm hydrocarbon concentration indicate that effects of exposure to oil/diesel fuel on plankton would be *negligible to low*.

Benthos

Under some circumstances, oil spilled in nearshore waters can become incorporated into nearshore and intertidal sediments, where it can remain toxic and affect benthic animals for years after the spill (Sanders et al. 1990). Oil and/or gas from an offshore spill in the Laurentian Sub-basin will not likely become incorporated in the sediments. Oil and gas released from an offshore blowout should quickly rise to the surface. Drilling will occur in open water and because of the depths involved, there is little chance of oil adhering to suspended sediments and being deposited on the bottom. Thus, oil and gas released during an offshore spill in the Laurentian Sub-basin is not likely to interact with the benthos.

Given the model predictions of maximum concentrations for blowouts and surface releases as well as the predicted times for decrease to a 0.1 ppm hydrocarbon concentration, effects of exposure to oil/diesel fuel on benthos would be *negligible to low*.

6.6.2.3. Overall Assessment for Fish Habitat

The magnitude of effects on water quality, plankton and benthos would be *negligible to low* in each blowout/diesel release scenario (Table 6.20). Geographic extent for the five scenarios range from < *1* km^2 (benthos) *to 1,001-10,000* km^2 (water, plankton). Frequency and duration of these accidental spills are *<11 events/yr* and *<1 month*, respectively. Given these criteria and that all residual impacts are also predicted to be *reversible*, the negative environmental effects on fish habitat are predicted to be *not significant* (Table 6.21).

6.6.3. Commercial Fisheries

This assessment has concluded (Section 6.6.2) that the potential effects of an oil/condensate spill (i.e., gas blowout or surface release of diesel fuel during exploratory drilling on the fish and fish habitat VEC will be *not significant*. Therefore, the potential effects of a spill on commercial fisheries as a result of physical effects on fish and invertebrates are considered to be *not significant*. Nevertheless, economic impacts might occur in the event of a spill, if the spill prevented or impeded a harvester’s ability to access fishing grounds (i.e., areas temporarily excluded during the spill or spill clean-up), damaged fishing gear through oiling or if the accident had a negative effect on the marketability of fish products (market perception resulting in lower prices, even without organic or organoleptic evidence of tainting).

The effects caused by exclusion from the spill area would be expected to be short-term, as typical sea and wind conditions would promote fairly rapid evaporation and weathering of the oil slick. As such, fishers would have access to their grounds within a short time following any spill. Fate and behaviour modeling for this EA indicates that the maximum distance from the source of a spill where hydrocarbon concentrations are at least 0.1 ppm is 75 km. Depending on where the drilling site was located within the Project Area, this could be well away from fishing activities. Based on surface wind and current conditions, the hydrocarbons will be carried offshore to the south away from most fishing activities. Also, it should be noted that the area where hydrocarbon levels are high enough to foul gear or cause tainting is much smaller than the area out to 0.1 ppm.

Most of the fisheries activities in or near the Study Area in recent years are pursued with bottom trawl (groundfish), gillnets (groundfish) and crab pots. Moller et al. (1989) *in* Husky (2000) rate the sensitivity of gill nets as “moderate” and that of trawls as “low.” The same would be expected for crab pots, since they rest on the sea floor.

If there were damage to fishing gear, especially to fixed gear, there would likely be some disruption of fisheries activities if fishers were required to cease fishing (though alternate fishing grounds would likely be available in the general area). If harvesting were interrupted, operators might sustain economic impacts as a result of reduced catches, or extra costs associated with having to relocate their harvesting effort.

Effects due to market perception about fish from the area of the spill (no buyers or reduced prices) are more difficult to predict, since the actual (physical) impacts of the spill may have little to do with these perceptions, which might still affect value. It would only be possible to quantify these effects by monitoring the situation if a spill were to occur.

Such economic effects (caused by loss of access, gear damage or changes in market demand) could be considered *significant* to the commercial fisheries. However, with the mitigation of appropriate economic compensation, the impact would be reduced to *not significant*. This mitigation is further discussed below.

Over the past decade, the oil industry has expended considerable effort in the development of programs designed to compensate Atlantic Canada's fisheries industry in situations where offshore exploration and development activities might result in damage to fishing gear and vessels, or in economic loss associated with interference to established fisheries harvesting activities.

These compensation programs (e.g., for the Sable and Hibernia projects), developed in consultation with the fishing industry, include measures and mechanisms to address both attributable and unattributable economic loss associated with offshore oil and gas activities. Their purpose is to provide fair and timely compensation to commercial fish harvesters and processors who sustain actual loss because of damage to fishing gear or vessels, or through the accidental release of oil (spills). One of the basic principles of these programs is to compensate fisheries participants in a fair and timely manner for all actual loss with the aim of leaving them in no worse or better position than before the losses occurred.

These programs have been adopted as an alternative to making a claim through the Courts or to the regulatory boards pursuant to the Accord Implementation Acts and Regulations. Although claims for loss can be made under the laws of Canada, such programs offer a simpler, less expensive process for obtaining appropriate compensation. Thus their purpose is to provide a mechanism for a fair and swift resolution of all legitimate claims, and the opportunity for all parties to minimize costs.

These principles would be an important component of the ConocoPhillips response in the event that a spill has economic consequences, and will ensure that any actual loss to the fisheries industry resulting from any oil spill is fully and adequately addressed.

6.6.4. Seabirds

Seabirds are the marine biota most at risk from oil spills and blowouts. Over 40 million seabirds are estimated to reside or migrate annually through the waters surrounding the island of Newfoundland (Chardine 1995 *in* Wiese and Ryan 2003). The waters around Newfoundland are some of the most productive in the world. The Grand Banks are considered the most important wintering ground for seabirds in the north Atlantic (Wiese and Ryan 2003). The northwest section of the Study Area is on the Grand Banks.

Exposure of seabird feathers to oil causes matting and loss of thermal and buoyancy qualities and often leads to death. Some may initially survive but long-term physiological changes may eventually result in death (Ainley et al. 1981; Williams 1985; Frink and White 1990; Fry 1990). Reported effects vary with bird species, type of oil, weather conditions, time of year, and duration of the spill or blowout (Gorsline et al. 1981). Although oil spills at sea certainly have the potential to kill tens of thousands of seabirds (Clark 1984; Piatt et al. 1990), this is not always the case. The effects of the many toxic compounds in oil when ingested can lead to debilitating or fatal effects as a result of the impact on internal organs (Fry and Lowenstine 1985; Leighton 1993 and Briggs et al. 1997 *in* Wiese and Ryan 2003). Fumes from a gas blowout could also affect the health of seabirds.

6.6.4.1. Immediate Effects

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. The external exposure results in matting of the feathers which effectively destroys the thermal insulation and buoyancy provided by the air trapped by the feathers. Consequently, oiled birds are likely to suffer from hypothermia and/or drown (Clark 1984; Hartung 1995). Most seabird losses occur during the initial phase of oil spills when large numbers of birds are exposed to floating oil (Hartung 1995). Birds living in coldwater environments, such as the Study Area, are most likely to succumb to hypothermia (Hartung 1995).

6.6.4.2. Short-Term Effects

Oiled birds that escape death from hypothermia and/or drowning often seek refuge ashore where they engage in abnormally excessive preening in an attempt to remove the oil (Hartung 1995). The preening leads to the ingestion of significant quantities of oil which, although apparently only partially absorbed (McEwan and Whitehead 1980) can cause lethal effects. Noted effects on Common Murres and Thick-billed Murres oiled off Newfoundland's south coast include emaciation, renal tubular degeneration, necrosis of the duodenum and liver, anemia and electrolytic imbalance (Khan and Ryan 1991). Glaucous-winged Gulls (*Larus glaucescens*) experienced similar effects after they ingested bunker fuel oil during preening (Hughes et al. 1990). Another commonly observed effect is adrenal hypertrophy. This condition tends to make birds more vulnerable to adrenocortical exhaustion (e.g., Mallards [Hartung and Hunt 1966; Holmes et al. 1979], Black Guillemots [Peakall et al. 1980], and Herring Gulls [Peakall et al. 1982]). The adrenal gland maintains water and electrolyte balance that is essential for the survival of birds living in the marine environment. Hartung and Hunt (1966) found that ingested oils can cause lipid pneumonia, gastrointestinal irritation, and fatty livers in several species of ducks. Aromatic hydrocarbons have been detected in the brains of Mallards (Lawler et al. 1978) and are probably associated with observed symptoms (e.g., lack of coordination, ataxia, tremors and constricted pupils) of nervous disorders (Hartung and Hunt 1966).

Birds exposed to oil are also at risk of starvation (Hartung 1995). For example, oiled Common Eiders generally deplete all of their fat reserves and much of their muscle protein (Gorman and Milne 1970). In addition, energy demands are higher because the metabolic rate of oiled birds increases to compensate for the heat loss caused by the reduced insulating capacity of their plumage. This can expedite starvation (Hartung 1967; McEwan and Koelink 1973).

6.6.4.3. Long-Term Effects

It appears that direct, long-term sublethal toxic effects on seabirds are unlikely (Hartung 1995). 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). Birds generally excrete much of the hydrocarbons within a short time period (McEwan and

Whitehead 1980). However, nesting seabirds that are contaminated with oil but still survive, generally exhibit decreased reproductive success.

Nesting seabirds transfer oil from their plumage and feet to their eggs (Albers and Szaro 1978). Very small quantities of oil (1 to 20 µl) on eggs have produced developmental defects and mortality in avian embryos of many species (Albers 1977; Albers and Szaro 1978; Hoffman 1978, 1979a; Macko and King 1980; Parnell et al. 1984; Harfenist et al. 1990). The resultant hatching and fledging success of young appears to be related to the type of oil (Hoffman 1979b; Albers and Gay 1982; Stubblefield et al. 1995) and the timing of exposure during incubation. Embryos are most sensitive to oil during the first half of incubation (Albers 1978; Leighton et al. 1985). Breeding birds that ingest oil generally exhibit 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 (Vangilder and Peterle 1980; Trivelpiece et al. 1984). Similar effects on ducklings occur when they ingest oil directly (Miller et al. 1978; Peakall et al. 1980; Szaro et al. 1981). Oil spills can also cause indirect reproductive failure. Eppley and Rubega (1990) suggest that exposure to an Antarctic oil spill caused changes in the normal parental behaviour of South Polar Skuas (*Catharacta maccormicki*), thus exposing young to increased predation and contributing to reproductive failure in that population. In another case, abandonment of nesting burrows by oiled adult Leach's Storm-Petrels may have contributed to reproductive failure in that population (Butler et al. 1988). Therefore, a spill that occurs during the reproductive period could cause mortality of young even if the adults survived the exposure to oil.

The high chronic oiling rates detected in studies of beached birds in southeast Newfoundland are of concern for the populations of murres and other alcids (Wiese and Ryan 2003). Due to their low reproduction rates, even slightly increased sustained adult mortality can have appreciable population impacts and could threaten long-term population stability. A projected population model shows reduced population growth by 2.5% of Thick-billed Murre in eastern Canada due to oiling mortality from chronic marine oil pollution (Wiese et al. 2004). When combined, mortality from chronic oil pollution and the legal hunting of Thick-billed Murre results in a projected reduced population growth by 4.7% in eastern Canada (Wiese et al. 2004). These results show the Thick-billed Murre population is vulnerable to changes in the environment including additional oil spills.

Some studies have suggested that oil pollution is unlikely to have major long-term effects on bird productivity or population dynamics (Clark 1984; Butler et al. 1988; Boersma et al. 1995; Wiens 1995) while others suggest the opposite (Piatt et al. 1990; Walton et al. 1997). Natural interannual variation in other factors that affect populations (e.g., prey availability and weather) reduces the ability of scientists to assess the full effect of oil spills on bird populations.

6.6.4.4. Species Most at Risk

Seabird species are the most vulnerable and most often affected by exposure to marine oil spills. Diving species such as the alcids; Common Murre, Thick-billed Murre, Atlantic Puffin and Dovekie, are considered to be the most susceptible to the immediate effects of surface slicks at sea (Chardine 1995;

Wiese and Ryan 2003). Murres have the highest oiling rate (70%) of seabirds recovered from beaches along the south and east coasts of the Avalon Peninsula, Newfoundland (Wiese and Ryan 2003). Northern Fulmar, shearwaters, storm-petrels, jaegers, skuas, gulls and Black-legged Kittiwake spend a considerable amount of time on the wing in search of food. However, these species secure prey items at or near the surface of the water and rest on the water making them vulnerable to a surface slick. They feed over a large area increasing the chances of coming into an area contaminated with an oil slick. There is evidence that some birds, especially storm-petrels, are attracted to oily slicks on the surface. Experiments have showed that Wilson's Storm-Petrel located a cod liver oil slick by approaching upwind indicating they were attracted by smell (Grubb 1972 *in* Huntington et al. 1996). Presumably storm-petrels would not identify a hydrocarbon slick as food and would not be as strongly attracted.

Birds are particularly vulnerable to oil spills during nesting, moulting, and prior to young seabirds gaining the ability to fly. Newly fledged murres and Northern Gannets are unable to fly for the first two to three weeks at sea, and are, therefore, less likely to be able to avoid contact with oil during this time (Lock et al. 1994). Before and during moult, the risks of hypothermia and drowning (Erasmus and Wessels 1985) are increased because feather wear and loss reduce the ability to repel water by about 50% (Stephenson 1997). Most of the world population of Greater Shearwater (about five million birds) and smaller numbers of Sooty Shearwater migrate from breeding grounds in the Southern Hemisphere to Atlantic Canada, especially the Grand Banks, to moult their feathers in June and July (Lock et al. 1994). While never flightless during this process, they do spend more time on the water then at other times of the year making them more susceptible to surface slicks.

Close to shore loons, grebes, cormorants Black Guillemots and sea ducks (Common Eider, Long-tailed Duck, the three species of scoters and Red-breasted Mergansers) are species that sit on the water and dive for food making them particularly susceptible to surface slicks. They are also vulnerable to the disturbance and habitat damage associated with oil spill cleanup (Lock et al. 1994). The greatest decrease in use of contaminated habitats immediately following a spill occurs in species that feed on or close to shore, and that either breed along the coast or are full-year residents (Wiens et al. 1996). It is predicted that no condensate or oil spilled in the Project Area will reach shore.

6.6.4.5. Assessment

All of the spills modeled have the potential to negatively affect seabirds (Table 6.23). However, given that the expected hydrocarbons (if present) are primarily gas, the condensate slicks will be relatively small and short-lived, as the slicks will be quickly dispersed by wind and wave, the effects of the modeled spills is assessed as *not significant* (Tables 6.24 and 6.25). However, there is a high degree of uncertainty (Table 6.25) and there is some potential for a significant effect on seabirds depending upon size, timing, and numbers of birds affected.

Table 6.23. Spill-Environmental Interaction Matrix for Seabird VEC.

Accident Scenario	Seabirds
Surface Blowout	**x**
Shelf	**x**
Slope Sub-sea Blowout	**x**
Deep Water Sub-sea Blowout	**x**
Diesel Batch Spill	
10 bbl (1.6 m^3)	**x**
100 bbl (15.9 m^3)	**x**

Table 6.24. Accidental Spill/Blowout Effects Assessment for Seabird VEC.

Valued Environmental Components: Seabirds									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
Spill Scenario[a]	Potential Positive (P) or Negative (N) Environmental Effect	Regulatory Mitigation	Project Specific Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Surface Blowout									
960 m^3/d condensate	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention, Rehabilitation, Enhancement	0-1	6	1	2	R	1
Subsea Blowout (1,351 m^3/d)									
Shelf	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention, Rehabilitation, Enhancement	0-1	6	1	2	R	1
Slope	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention, Rehabilitation, Enhancement	0-1	6	1	2	R	1
Basin	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention, Rehabilitation, Enhancement	0-1	6	1	2	R	1
Diesel Batch Spill									
10 bbl (1.6 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention, Rehabilitation, Enhancement	0-1	4	1	1	R	1
100 bbl (15.9 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention, Rehabilitation, Enhancement	0-1	4	1	1	R	1

Key:

Magnitude:
0 = negligible
1 = Low
2 = Medium
3 = High

Geographic Extent:
1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1,000 km²
5 = 1001-10,000 km²
6 = >10,000 km²

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

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

Reversibility (population level):
R = Reversible
I = Irreversible

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

a Geog. Extent differed during summer & winter but always fell within the same category of Geog. Extent.

Table 6.25. Significance of Predicted Residual Environmental Effects on the Seabird VEC in the Unlikely Event of an Accidental Offshore Oil Spill or Blowout.

Valued Environmental Components: Fish and Fish Habitat				
Accidents	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Oil Blowouts/Spills	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
Surface Blowout				
960 m^3/d condensate	NS	1	-	-
Sub-sea Blowout (1,351 m^3/d)				
Shelf	NS	1	-	-
Slope (750 m)	NS	1	-	-
Basin (2,300 m)	NS	1	-	-
Diesel Batch Spill				
10 bbl (1.6 m^3)	NS	3	-	-
Diesel Batch Spill				
100 bbl (15.9 m^3)	NS	1	-	-

Key:

Residual Environmental Effect Rating:
S = Significant Negative Environmental Effect
NS= Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high Magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence in Impact Prediction:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability:
1 = Low Probability
2 = Medium Probability
3 = High Probability

Scientific Certainty: Based on Scientific Information and Statistical Analysis or Professional Judgement:
1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

N/A = Not Applicable

6.6.5. Marine Mammal VEC

The following sections review information relevant to the assessment of potential impacts of an offshore oil/condensate spill (i.e., gas blowout or surface release of diesel fuel) at the Laurentian Sub-basin Study Area. An interaction matrix for marine mammals (and sea turtles) is provided in Table 6.26. The reader is referred to Section 6.1 for a discussion of spill probabilities, and to Section 6.3 for a discussion of the properties and behaviour of spilled oil/condensate.

Table 6.26 Accidental Spill-Environmental Interaction Matrix for Marine Mammal and Sea Turtle VECs.

Accident Scenario	Marine Mammals	Sea Turtles
Surface Blowout		
(906 m^3/d condensate)	x	x
Sub-surface Blowout (1,351 m^3/d)		
Shelf	x	x
Slope (750 m depth)	x	x
Basin (2,300 m depth)	x	x
Diesel Batch Spill		
Surface (10 bbl or 1.6 m^3)	x	x
Surface (100 bbl or 15.9 m^3)	x	x

Most marine mammals, with the exception of fur seals, polar bears, and sea otters, are not very susceptible to deleterious effects of oil. However, newborn hair seal pups, and weak or highly stressed individuals, may be vulnerable to oiling. Other marine mammals exposed to oil are generally not at risk because they rely on a layer of blubber for insulation and oiling of the external surface does not appear to have any adverse thermoregulatory effects (Kooyman et al. 1976; 1977; Geraci 1990; St. Aubin 1990). Population-level effects are unlikely, as no significant long-term and lethal effects from external exposure, ingestion, or bioaccumulation of oil have been demonstrated.

6.6.5.1. Cetaceans

There is no clear evidence that implicates oil spills, including the much-studied *Santa Barbara* and *Exxon Valdez* spills, with mortality of cetaceans (Geraci 1990). Migrating gray whales were apparently not adversely affected by the *Santa Barbara* spill. There appeared to be no relationship between the spill and mortality of marine mammals. The higher than usual counts of dead marine mammals recorded after the spill was a result of increased survey effort related to the spill (Geraci 1990). The conclusion was that whales were either able to detect the oil and avoid it or were unaffected by it (Geraci 1990).

There was a significant decrease in the size of a killer whale pod resident in the area of the *Exxon Valdez* spill, but no clear cause and effect relationship between the spill and the decline could be established (Dahlheim and Matkin 1994). There were no evident effects on humpback whales in Prince William Sound after the *Exxon Valdez* spill (von Ziegesar et al. 1994). There was some temporary displacement of humpback whales out of Prince William Sound, but oil contamination, boat and aircraft disturbance, or displacement of food sources could have caused this displacement.

Avoidance and Behavioural Effects

Studies of both captive and wild cetaceans indicate that they can detect oil spills. 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). This is consistent with other cetaceans behaving normally in the presence of oil (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). Some evidence exists that indicates dolphins attempt to minimize contact with surface oil by decreasing their respiration rate and increasing dive duration (Smultea and Würsig 1995).

Oiling of External Surfaces

Whales rely on a layer of blubber for insulation and oil has little if any effect on thermoregulation. Effects of oiling on cetacean skin appear to be minor and of little significance to the animal's health (Geraci 1990). It can be assumed that if oil contacted the eyes, effects would be similar to that observed in ringed seals (conjunctivitis, corneal abrasion, and swollen nictitating membranes) and that continued exposure to eyes could cause permanent damage (St. Aubin 1990).

Ingestion and Inhalation of Oil

Whales could ingest oil with water, contaminated food, or oil could be absorbed through the respiratory tract. Species like the humpback whale, right whale, beluga (*Delphinapterus leucas*), and harbour porpoise that feed in restricted areas (for example, bays) may be at greater risk of ingesting oil (Würsig 1990). 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). Only small traces of oil were found in the blubber of a gray whale and liver of a killer whale exposed to *Exxon Valdez* oil (Bence and Burns 1995).

Cetaceans may inhale vapours from volatile fractions of oil from a spill and blowout. The most likely effects of inhalation of these vapours would be irritation of respiratory membranes and absorption of hydrocarbons into the bloodstream (Geraci 1990). Stressed individuals that could not escape a contaminated area would be most at risk.

Fouling of Baleen

In baleen whales, crude oil could coat the baleen and reduce filtration efficiency. However, effects are minimal and reversible. Baleen experimentally fouled with oil did not change enough to alter its filtration efficiency (St. Aubin et al. 1984) and most adherent oil was removed within 30 min after fouling (Geraci and St. Aubin 1985 *in* Geraci 1990). The effects of oiling of baleen on feeding efficiency appear to be only minor (Geraci 1990).

Assessment – Cetaceans

There is no direct evidence that implicates oil spills with cetacean mortality. Both toothed and baleen whales present in the affected area could experience sublethal effects, through oiling of mucous membranes or the eyes if they swim through a slick. As discussed above, these effects are reversible and would not cause permanent damage to the animals. There is a possibility that the baleen of whales could be contaminated with oil, thereby reducing filtration efficiency. However, effects would be minimal and reversible. Some species are likely present in the Laurentian Sub-basin area year round, but most species probably just occur there during summer months. (However, there are no available data for winter time.) For marine mammals, it is probable that only small proportions of populations are at risk at any one time. Based on the marine mammal monitoring program in the Laurentian Sub-basin in the summer of 2005, there is some evidence to suggest that blue whales frequent the slope of the Study Area. Blue whales were the most abundant baleen whale observed during monitoring with the highest sighting rate in August and in deep water (>1,000 m). Although this species is not known to be susceptible to exposure to hydrocarbons, it will be important to implement appropriate monitoring and mitigation measures (see Section 7.0) in the unlikely even of a large gas/condensate blowout or a spill, given the endangered status of this species.

Depending on the time of year, location of toothed and baleen whales within the affected area, and type of oil spill or blowout, the effects of an offshore oil release on the health of cetaceans is predicted to range from a *negligible to low* magnitude over varying geographic extents (Table 6.27). For all spill scenarios considered, the duration is predicted to be 1-12 months and effects are considered reversible (Table 6.27). It is predicted that there will be *no significant* negative effect on cetaceans from an accidental release of oil at the exploratory drilling sites at Laurentian Sub-basin (Table 6.28).

The oil spill countermeasures contained in the Operators' plan and the associated disturbance would likely reduce the number of whales exposed to oil.

6.6.5.2. Seals

Reports of the effects of oil spills and blowouts have shown that some mortality of hair seals may have occurred as a result of oil fouling; however, large scale mortality has never been observed (St. Aubin 1990). The largest effect of a spill was on young hair seals in cold water (St. Aubin 1990).

Effects on seals have not been well studied at most spills because of lack of baseline data and/or the brevity of the post-spill surveys. There is little information about the mortality rate of harp seals exposed to oil from a ruptured storage tank in New Brunswick in 1969. It is believed that 10,000 to 15,000 harp seals were coated with oil but the exact number of dead seals recovered is unknown (Sergeant 1991). The release of fuel oil from the *Arrow* into Chedabucto Bay, Nova Scotia in 1970 resulted in the fouling of 500 seals within the bay and 50 to 60 harbour and 200 grey seals on Sable Island (200 km south of the spill). Twenty-four seals were found dead and some had oil in their mouths and stomachs (Anon. 1970; 1971 *in* St. Aubin 1990). Oiled grey and harbour seals were found on the

Table 6.27. Accidental Spill/Blowout Effects Assessment for Marine Mammal VEC.

Valued Environmental Component: Marine Mammal									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario	Potential Positive (P) or Negative (N) Environmental Effect	Regulative Mitigation	Project Specific Mitigation	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological/ Socio-Cultural and Economic Context
Surface Blowout									
(906 m^3/d condensate)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	3	1	1	R	1
Subsea Blowout (1,351m^3/d)									
Shelf	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1
Slope	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention	0-1	5	1	1	R	1
Basin	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1
Diesel Batch Spill									
10 bbl (1.6 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1
100 bbl (15.9 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1

Table 6.27. (Cont.)

Valued Environmental Component: Marine Mammal										
Accidental Offshore Oil Spill or Blowout										
				Evaluation Criteria for Assessing Environmental Effects						
VEC and Spill Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**	

Key:

Magnitude:	Geographic Extent:	Frequency:	Duration:	Reversibility (population level):
0 = negligible	1 = <1 km²	1 = < 11 events/yr	1 = < 1 month	R = Reversible
1 = Low	2 = 1-10 km²	2 = 11-50 events/yr	2 = 1-12 months	I = Irreversible
2 = Medium	3 = 11-100 km²	3 = 51-100 events/yr	3 = 13-36 months	
3 = High	4 = 101-1,000 km²	4 = 101-200 events/yr	4 = 37-72 months	
	5 = 1001-10,000 km²	5 = >200 events/yr	5 = > 72 months	
	6 = >10,000 km²	6 = continuous		

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

Table 6.28. Significance of Predicted Residual Environmental Effects on Marine Mammal VEC in the Unlikely Event of an Accidental Offshore Oil Spill or Blowout.

Valued Environmental Components: Marine Mammals				
Accidents	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Oil Blowouts/Spills	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
Surface Blowout				
960 m^3/d condensate	NS	3	-	-
Sub-sea Blowout (1,351 m^3/d)				
Shelf	NS	3	-	-
Slope (750 m)	NS	3	-	-
Basin (2,300 m)	NS	3	-	-
Diesel Batch Spill				
10 bbl (1.6 m^3)	NS	3	-	-
100 bbl (15.9 m^3)	NS	3	-	-

Key:

Residual Environmental Effect Rating:
S = Significant Negative Environmental Effect
NS= Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high Magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence in Impact Prediction:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability:
1 = Low Probability
2 = Medium Probability
3 = High Probability

Scientific Certainty: Based on Scientific Information and Statistical Analysis or Professional Judgement:
1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

N/A = Not Applicable

coast of Nova Scotia and Sable Island again in 1979 when the oil tanker *Kurdistan* sank in Cabot Strait. No causal relationship between oiling and death was determined (Parsons et al. 1980 *in* St. Aubin 1990). No mortalities were reported after a well blowout near Sable Island in 1984 and only two oiled grey seals were observed (St. Aubin 1990).

Intensive and long-term studies were conducted after the Exxon Valdez spill in Alaska. There may have been a long-term decline of 36% in numbers of moulting harbour seals at oiled haul-out sites in Prince William Sound (PWS), following the Exxon Valdez spill (Frost et al. 1994). Harbour seal pup mortality at oiled beaches was 23 to 26%, which may have been higher than natural mortality (Frost et al. 1994). However, attributing cause to the decreasing trend in harbour seal numbers since the spill (4.6% per year) is complicated because seal populations were declining prior to the spill (Frost et al. 1999). An analyses of population trends and movements of harbor seals in PWS casts doubt on published findings that 302 seals were killed by the Exxon Valdez oil spill in 1989 (Hoover-Miller et al. 2001). Evidence does not support high unsubstantiated mortality, but is more consistent with seals avoiding or moving away from some oiled haul-outs.

Avoidance and Behavioural Effects

There is conflicting evidence on whether seals detect and avoid spilled oil. Some oiled seals hauled out on land are reluctant to enter the water, even when disturbances from intense cleanup activities occur nearby (St. Aubin 1990; Lowry et al. 1994). In contrast, several thousand grey and harbour seals apparently left Chedabucto Bay, Nova Scotia, after the grounding of the *Arrow* (Mansfield 1970 *in* St. Aubin 1990), although this movement may have been caused by the increased human disturbance during cleanup activities rather than by the presence of oil (St. Aubin 1990). Harbour seals observed immediately after oiling appeared lethargic and disoriented, which may be attributed to lesions observed in the thalamus of the brain (Spraker et al. 1994). Other seals have been observed swimming in the midst of oil spills (St. Aubin 1990). Oiling of both mother and pups does not appear to interfere with nursing (Lowry et al. 1994).

Oiling of External Surfaces

Adult and juvenile hair seals (includes harbour, grey, harp and hooded seals) are at virtually no risk of thermal regulatory effects from oil fouling because their blubber, not their fur, provides insulation (Kooyman et al. 1976, 1977; St. Aubin 1990). It is questionable whether young seal pups, which rely on their birth coat and brown fat stores, could survive the deleterious effects of oiling (St. Aubin 1990). Contact with oil on the external surfaces can cause increased stress and can irritate the eyes of ringed seals (Geraci and Smith 1976; St. Aubin 1990). Harbour seals oiled during the *Exxon Valdez* spill had difficulty keeping their eyes open and experienced conjunctivitis (Spraker et al. 1994). These effects seem to be temporary and reversible, but continued exposure of oil to eyes could cause permanent damage (St. Aubin 1990). Damage to a seal's visual system would likely limit foraging abilities, as vision is an important sensory modality used to locate and capture prey (Levenson and Schusterman 1997). Mucous membranes that line the oral cavity, respiratory surfaces, and anal and urogenital orifices are also sensitive to oil exposure (St. Aubin 1990). Seals fouled externally with heavy oil may also encounter problems with locomotion. The flippers of young harp seals and grey seal pups were impeded by a heavy coating of oil that became stuck to their sides (Davis and Anderson 1976; Sergeant 1991). This led to the drowning of the grey seal pups. The coating of seals and their subsequent deaths were also observed in seals exposed to heavy bunker oil during the *Arrow* and *Kurdistan* spills (Engelhardt 1987 *in* Lowry et al. 1994).

Oil Ingestion and Inhalation

Seals can ingest oil if their food is contaminated or by nursing contaminated milk. Oil can also be absorbed through the respiratory tract (Geraci and Smith 1976; Engelhardt et al. 1977). Some ingested oil is voided in vomit/feces or metabolized at rates that prevent significant bioaccumulation (Neff 1985 *in* Hartung 1995) but some is absorbed and can cause toxic effects (Engelhardt 1981). These effects may include minor kidney, liver and brain lesions (Geraci and Smith 1976; Spraker et al. 1994). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt 1978, 1982, 1985). Seals exposed to an oil spill and especially a blowout are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin 1980; 1982) and any effects are probably reversible (Spraker et al. 1994). There were no significant quantities of oil in the tissues (liver, blubber, kidney and skeletal muscles) of harbour seals exposed during the *Exxon Valdez* spill (Bence and Burns 1995).

Seals are also at risk from hydrocarbons and other chemicals that evaporate from spills and blowout areas. Seals generally keep their nostrils close to the water surface when breathing, so they are likely to inhale vapours if they surface in a contaminated area. Grey seals that presumably inhaled volatile hydrocarbons from the *Braer* oil spill exhibited a discharge of nasal mucous, but no causal relationship with the oil was determined (Hall et al. 1996). Laboratory studies of ringed seals indicate that the inhalation of hydrocarbons may cause more serious effects like kidney and liver damage (St. Aubin 1990). However, exposure conditions were much higher than would be expected in a natural setting.

Factors Affecting the Severity of Oil Exposure

Seals that are under some type of natural stress, such as lack of food or a heavy infestation by parasites, could die as a result of the additional stress of oiling (Geraci and Smith 1976; St. Aubin 1990). Seals that are not under natural stress would most likely survive oiling.

Seals exposed to heavy doses of oil for prolonged periods of time could die. In cases where oil goes ashore, harbour seals may be particularly at risk because they exhibit site fidelity (Boulva and McLaren 1979; Yochem et al. 1987). Prolonged exposure from oil at a preferred haul-out site could cause the death of some seals. However, Jenssen (1996) reported that oil has produced little visible disturbance to grey seal behaviour and there has been little mortality despite the fact that approximately 50 percent of grey seal pups at Norway's largest breeding colony are polluted each year by oil. Based on modeling results for the present EA, none of the gas/oil condensate will reach the shores of Newfoundland and Labrador (or St. Pierre et Miquelon).

Assessment - Seals

Seals are not considered to be at high risk from the effects of oil exposure, but some evidence implicates oil spills with seal mortality, particularly young seals. As previously discussed, seals are likely present on or near Laurentian Sub-basin for at least part of the year. No seals were sighted by observers during ConocoPhillips' 2005 monitoring program in and near EL1081 and 1087. Few seals are expected to be exposed to oil from an accidental release at the drilling sites and most seals do not exhibit large behavioural or physiological reactions to limited surface oiling, incidental exposure to contaminated food, or ingestion of oil.

Depending on the time of year and type of oil spill or blowout, the effects of an offshore oil release on seals could range from a *negligible* to *low* magnitude over varying geographic extents (see Table 6.27). For all spill scenarios considered, the duration is predicted to be 1-12 months and effects are considered reversible (Table 6.27). It is predicted that there will be *no significant* negative effect on seals from an accidental release of oil at the exploratory drilling sites at the Laurentian Sub-basin (Table 6.28). Similar predictions were made in the Hibernia and Terra Nova EIS, White Rose EA, and Orphan Basin EA regarding spills or blowouts at those sites (Mobil 1985; Petro-Canada 1996; LGL 2005).

The oil spill countermeasures contained in the Operators' plan and the associated disturbance would likely reduce the number of seals exposed to oil.

6.6.6. Sea Turtles VEC

It is not known whether sea turtles can detect and avoid oil slicks. Gramentz (1988) reported that sea turtles did not avoid oil at sea, while sea turtles exposed to oil under experimental conditions had a limited ability to avoid oil (Vargo et al. 1986).

Loggerhead sea turtles experimentally exposed to oil had marked gross and histologic lesions present in the skin. Most effects were reversed by the tenth day following cessation of oil exposure (Bossart et al. 1995). Other effects of oil on sea turtles include reduced lung diffusion capacity, decreased oxygen consumption, decreased digestion efficiency, and damaged nasal and eyelid tissue (Lutz et al. 1989).

There are few field observations of sea turtles exposed to oil. After the Ixtoc 1 blowout in 1979, seven live and three dead sea turtles were recovered (Hall et al. 1983). Two of the three carcasses had oil in the gut but no lesions. There was no evidence of aspirated oil in the lungs but hydrocarbon residues were found in kidney, liver, and muscle tissue of all three dead turtles. The authors suggested prolonged exposure to oil may have disrupted the feeding behaviour and weakened the turtles.

Sea turtles are known to occur in the Study Area but are considered uncommon. There is a possibility that sea turtles would be exposed to oil from an accidental release near the proposed drilling area. Effects of oil on sea turtles will likely be reversible, but there is a possibility that foraging abilities may be inhibited by exposure to oil.

Depending on the time of year and type of oil spill or blowout, the effects of an offshore oil release on sea turtles could range from a *negligible* to *low* magnitude over varying geographic extents. For all spill scenarios considered, the duration is predicted to be 1-12 months and effects are considered reversible (Table 6.29). It is predicted that there will be *no significant* negative effect on sea turtles from an accidental release of oil at the exploratory drilling sites at Laurentian Sub-basin (Table 6.30).

The oil spill countermeasures contained in the Operators' contingency plan and the associated disturbance would likely reduce the number of sea turtles exposed to oil.

Table 6.29. Accidental Spill/Blowout Effects Assessment for Sea Turtle VEC.

Valued Environmental Component: Sea Turtle									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**
Surface Blowout									
(906 m^3/d condensate)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	3	1	1	R	1
Subsea Blowout (1,351m^3/d)									
Shelf	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1
Slope	Effects on Health (N)	Contingency Plan; Drilling rig/vessel/equipment certification	Pre-project Planning, Training, Emergency Response Drills, Preparation, Equipment Inventory, Prevention	0-1	5	1	1	R	1
Basin	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1
Diesel Batch Spill									
10 bbl (1.6 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1
100 bbl (15.9 m^3)	Effects on Health (N)	Contingency Plan	Training, Preparation, Equipment Inventory, Prevention	0-1	4	1	1	R	1

Table 6.29. (cont'd)

Valued Environmental Component: Marine Mammal									
Accidental Offshore Oil Spill or Blowout									
				Evaluation Criteria for Assessing Environmental Effects					
VEC and Spill Scenario	**Potential Positive (P) or Negative (N) Environmental Effect**	**Regulative Mitigation**	**Project Specific Mitigation**	**Magnitude**	**Geographic Extent**	**Frequency**	**Duration**	**Reversibility**	**Ecological/ Socio-Cultural and Economic Context**

Key:

Magnitude:

0 = negligible
1 = Low
2 = Medium
3 = High

Geographic Extent:

1 = <1 km²
2 = 1-10 km²
3 = 11-100 km²
4 = 101-1,000 km²
5 = 1001-10,000 km²
6 = >10,000 km²

Frequency:

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

Duration:

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

Reversibility (population level):
R = Reversible
I = Irreversible

Ecological/Socio-cultural and Economic Context:
1 = Relatively pristine area or area not adversely affected by human activity.
2 = Evidence of existing adverse effects.

Table 6.30. Significance of Predicted Residual Environmental Effects on Sea Turtle VEC in the Unlikely Event of an Accidental Offshore Oil Spill or Blowout.

Valued Environmental Components: Sea Turtle				
Accidents	**Significance Rating**	**Level of Confidence**	**Likelihood**	
Oil Blowouts/Spills	**Significance of Predicted Residual Environmental Effects**		**Probability of Occurrence**	**Scientific Certainty**
Surface Blowout				
960 m^3/d condensate	NS	3	-	-
Sub-sea Blowout (1,351 m^3/d)				
Shelf	NS	3	-	-
Slope (750 m)	NS	3	-	-
Basin (2,300 m)	NS	3	-	-
Diesel Batch Spill				
10 bbl (1.6 m^3)	NS	3	-	-
100 bbl (15.9 m^3)	NS	3	-	-

Key:

Residual Environmental Effect Rating:
S = Significant Negative Environmental Effect
NS= Not-significant Negative Environmental Effect
P = Positive Environmental Effect

Significance is defined as a medium or high Magnitude (2 or 3 rating) and duration greater than 1 year (3 or greater rating) and geographic extent >100 km^2 (4 or greater rating).

Level of Confidence in Impact Prediction:

1 = Low Level of Confidence
2 = Medium Level of Confidence
3 = High Level of Confidence

Probability:
1 = Low Probability
2 = Medium Probability
3 = High Probability

Scientific Certainty: Based on Scientific Information and Statistical Analysis or Professional Judgement:
1 = Low Level of Certainty
2 = Medium Level of Certainty
3 = High Level of Certainty

N/A = Not Applicable

6.6.7. Species-at-Risk

As indicated in Section 4.1, eight marine species that potentially occur in the Study Area are listed as either endangered or threatened on Schedule 1 of *SARA* (officially 'at risk' according to Canadian law). They are as follows:

- Blue whale
- North Atlantic right whale
- Northern bottlenose whale (Scotian Shelf population)
- Beluga whale (St. Lawrence Estuary population)
- Leatherback sea turtle

- Atlantic salmon (Inner Bay of Fundy population)
- Northern wolffish
- Spotted wolffish

Details of the potential effects of accidental spills (i.e., natural gas/condensate blowouts and diesel surface releases) associated with exploratory drilling on marine mammals, sea turtles and fish have already been discussed in Section 6.0. Based on the effects assessment for these various animal groups already presented in Section 6.0 (Tables 6.20, 6.21, 6.24, 6.25, 6.27, 6.28, 6.29, and 6.30), the potential effects of accidental spills during the proposed exploratory drilling program on the eight listed species are *not significant*.