hydrocarbons (mostly methane). H_2S will be oxidized in the flare to SO_2. There will also be some minor amounts of products of incomplete combustion such as: carbonyl sulfide; carbon disulphide and mercaptans (from the sulphur); PAH and VOC (from the hydrocarbons). The duration of the testing period for each well will be relatively short (*i.e.*, approximately 12 hours).

EnCana will develop flaring mitigation procedures in the Offshore EPP to reduce, where practical, the temporary and localized emissions and potential effects associated with flaring events. These procedures will specify:

- procedures during perforating/well testing to minimize smoky plumes;
- safe zones for vessels to occupy during the test flares;
- go/no go zones for vessels;
- safety gear and procedures on board platforms and vessels;
- wind direction forecast requirements such as the need to be sure of sustained wind directions during the test;
- visibility and other weather requirements to permit flaring to proceed;
- real-time requirements to monitor the efficiency of the flare and downwind effects;
- reporting requirements to document the safe conduct of the work and potential improvements; and
- notification procedures for shipping, staff and environmental staff.

With the implementation of these procedures, and considering the short duration of the test period, no long or short term significant adverse effects from this procedure is expected.

The flare system is designed to enhance buoyancy of the flared gases, which will promote dispersion in the atmosphere. Although adverse weather conditions can intermittently reduce the efficiency of the flare, an efficiency of 98% is achievable (CAPP 2000). Flaring has been studied extensively in Alberta (Strosher 1996). Improperly operated, or inefficient flares, can result in products of incomplete combustion, which may be of concern if present in high enough concentrations. Low combustion efficiency also results in a visible plume that is aesthetically objectionable. EnCana's flaring procedures will ensure that such potential effects will be reduced. For example, if the flare begins to produce a sooty emission, the gas composition/rate can be modified to enable clean burning. This can be done by source adjustments or by adding additional purge gas to the flare.

Assuming implementation of recommended mitigative measures, no significant adverse effects on air quality during Project construction are anticipated.

Operation

There are a number of sources for the routine emission of air contaminants during the normal operations of the Project, including:

- acid gas management system;
- flare systems;
- turbines for power generators and compressors; and
- glycol dehydrator (to flare).

Table 6.13 shows the air emission modes, probabilities, sources and rates for Project operations. The prediction of effects for these emissions are discussed below.

Acid Gas Management

Acid gases will be managed in this Project by injection into a contained reservoir. The acid gas stream, comprising about 18% H_2S, and the remainder CO_2, is taken directly from the acid gas removal system and compressed for injection through a dedicated piping system. The injection system is expected to operate normally 95% of the time; the acid gas will be sent to flare approximately 5% of the time as required by routine maintenance and occasional malfunctions. Table 6.13 indicates emission rates during routine operation of the injection system.

Flare Systems

Two flare systems will operate on a routine basis (high-pressure and low-pressure). The low pressure flare will handle small volumes of routine emissions (TEG offgas and pilot and purge gas) stabilized with fuel gas as necessary. The purpose of the high pressure flare is to handle flare gas during process upset conditions. These intermittent upsets are a part of normal operations. The flares are also designed to cope with higher gas discharges during certain emergency situations. Table 6.13 indicates estimated emission rates and probabilities associated with routine continuous flaring, and flaring during maintenance and for upset conditions. Intermittent testing, emergency procedures, and process excursions will result in occasional instances of visible emissions. EnCana will continually strive to reduce flaring to optimize process efficiency and to improve environmental performance. Occasional, temporary flare events are not anticipated to cause significant adverse effects on air quality.

Table 6.13 Summary of Air Emissions During Project Operation (Normal and Upset Conditions)

Operating Mode	Plant Status	Emission Mode	Frequency	Approx. Duration	Source	Key Emissions Rates [g/s]			GHG [ktCO$_2$E]
						H_2S	SO_2	NO_X	
Normal	Production (Normal)	Injection of acid gas; TEG waste gas purge and pilot gas to flare; compression and power generation.	95%	347 days/year	Power Generator 1	N/A	0.75	3.4	304 (347 days)
					Power Generator 2	N/A	0.75	3.4	
					Power Generator (spare)	N/A	0	0	
					Main Feed Compressor	N/A	1.5	10.7	
					Export Compressor 1	N/A	2.25	15.8	
					Export Compressor 2	N/A	2.25	15.8	
					Flare	6E-5	0.003	0.3	14 (347 days)
	Equipment Maintenance	Flaring of acid gas; produced water stripper gas, TEG waste gas, purge and pilot gas to flare; power generation.	5%	18 days/year	Power Generator 1	N/A	0.75	3.4	304 (18 days)
					Power Generator 2	N/A	0.75	3.4	
					Power Generator (spare)	N/A	0	0	
					Main Feed Compressor	N/A	1.5	10.7	
					Export Compressor 1	N/A	2.25	15.8	
					Export Compressor 2	N/A	2.25	15.8	
					Flare	12.4	1054	2.5	7 (18 days)

Table 6.13 Summary of Air Emissions During Project Operation (Normal and Upset Conditions)

Operating Mode	Plant Status	Emission Mode	Frequency	Approx. Duration	Source	Key Emissions Rates [g/s]			GHG [ktCO$_2$E]
						H_2S	SO_2	NO_X	
Upset	Emergency Shut down	Inlet separator to flare; power generation.	Twice per year	15 min	Flare	14.8	1272	182	0.3 (15 min)
	Upset requiring flaring	Major injection well/equipment problem requiring repairs or redrilling; production continues.	Extremely unlikely	Momentary up to 5 months (extremely unlikely) for well replacement	As in normal mode, equipment maintenance	12.4	1062	51.6	525 (1 month)
	Upset requiring venting	Flare ignition malfunction during acid gas flaring resulting in venting.	Occasional	Likely to be momentary	Flare vent	436	N/A	N/A	0.003 (30 sec)
	Upset leading to shutdown	Injection well blowout (return of injected acid gas)	Extremely unlikely	Minutes to months (months extremely unlikely)	Subsea or surface release	1614	N/A	N/A	1.0 (1 day)
		Surface blowout of raw gas	Extremely unlikely	Minutes to months (months extremely unlikely)	Broken piping above surface	210	N/A	N/A	73 (1 day)
		Subsea blowout of raw gas	Extremely unlikely	Minutes to months (months extremely unlikely)	Subsea release	210	N/A	N/A	73 (1 day)

N/A = Not applicable or insignificant emissions

Electrical Power Generation System

The electrical load on the platform will vary between 18 and 35 MW over the life of the Project. The capacity will be provided by multiple turbines that will use condensate as the primary fuel source. The turbines will also be designed to burn market-ready gas and diesel fuel as condensate volume fluctuates over the life of the Project, or due to other operational considerations. SO_2 and NO_x emissions from the turbines are estimated based on the 35 MW capacity, which is the most conservative assumption (*i.e.*, worst case) for modeling air emissions. Any surplus will be returned to the condensate injection well. The use of condensate for fuel results in significant Project efficiencies. It results in emissions that are higher than those that would result from the use of sales gas, but similar to a distillate oil such as diesel fuel. One reciprocating diesel engine generator will serve as back-up.

Stack height is currently under design review. Modeling to date for the Project has determined that a minimum stack height of 11 m meets the ambient air quality criteria at sea level and on the accommodations platform. The final determination of the stack height will likely be above 11 m to ensure safe working conditions on the production platform.

Glycol Dehydrator System

Moisture is removed from the gas stream by a circulating system containing TEG which absorbs water. This water is later released when the TEG is recharged. In addition to water, the gas contains an array of other hydrocarbons in small, variable amounts. These compounds, including benzene, may also be absorbed by the TEG and released during the recharge of the TEG. A Canada-wide working group has promulgated criteria for the discharge of contaminants to the atmosphere from these dehydrator units. In this Project, the TEG offgases will be routed to the low-pressure flare system which will ensure thorough destruction of trace hydrocarbons.

Dispersion Modeling Results During Normal Operating Mode

Air dispersion modeling for the normal operating mode takes into account normal production (95%) and routine maintenance (5%). Air emissions (Table 6.13) during the production include:

- low pressure flare loading comprising TEG dehydrator offgases, pilot and purge gas to ensure flare stabilization and complete combustion;
- power turbine emissions; and
- compressors (export and main)

Air emissions (Table 6.13) during maintenance of the acid gas management system include:

- acid gas directed to flare along with routine low pressure gases;
- power turbine emissions; and
- compressors (export and main).

Table 6.14 and 6.15 present the modeling results from the injection mode and flaring mode emissions as maximum ground level concentrations (GLC) compared with Nova Scotia Standards. The results of the air dispersion modeling are shown graphically in Figures 1 to 6 in Appendix C.

Table 6.14 Atmospheric Effects from Normal Production (Acid Gas Injection)

Nova Scotia Criterion	Criterion Concentration [μg/m³]	Predicted Maximum [μg/m³]	Distance to Maximum GLC [m]	Percent of Criterion [%]
1 hour SO_2	900	381	187	42.4
24 hour SO_2	300	300	187	100
Annual SO_2	60	18	100	29.4
1 hour H_2S	42	0.00008	2,500	<0.01
24 hour H_2S	8	0.00001	1,000	<0.01
Annual H_2S	N/A	<0.00001	2,500	N/A
1 hour NO_2	400	395	187	98.6
24 hour NO_2	N/A	319	187	N/A
Annual NO_2	100	100	100	100

Note 98% flare efficiency assumed in conversion of H_2S to SO_2
OLM Method used in estimation of NO conversion.

Table 6.15 Atmospheric Effects from Equipment Maintenance and Upset of Acid Gas System (Acid Gas Flaring)

Nova Scotia Criterion	Criterion Concentration [μg/m³]	Predicted Maximum [μg/m³]	Distance to Maximum GLC [m]	Percent of Criterion [%]
1 hour SO_2	900	900 (1,427)*	2,500	100 (158.5)*
24 hour SO_2	300	10	187	100
Annual SO_2	60	18	100	29.5
1 hour H_2S	42	15	2,500	36.4
24 hour H_2S	8	3	5,000	34.0
Annual H_2S	N/A	0.12	5,000	N/A
1 hour NO_2	400	395	187	98.6
24 hour NO_2	N/A	319	187	N/A
Annual NO_2	100	100	100	100

Note 98% flare efficiency assumed in conversion of H_2S to SO_2
OLM Method used in estimation of NO conversion
* Mitigation applied for the estimated worst case 1.4 hours/year exceedance of 1 hour SO_2 criterion; unmitigated potential maximum is shown in brackets.

The routine operation of the facility (*i.e.*, injection mode) will meet all air quality standards for the parameters modeled. Flaring of the acid gas stream is predicted to occur approximately 5% of total operating time during periods of planned maintenance or shutdown of the acid gas management system. The model predictions of atmospheric discharges during flaring of the acid gas stream show a potential exceedance of SO_2 with respect to the one-hour ground-level criterion of 900 $\mu g/m^3$ for an average of 1.4 hours per year, as a worst case. The only meteorological condition under which this might occur is during a period of thermal inversion which would act to confine the plume below the thermal layer. The maximum hourly exceedance would be about 50% over the standard, occurring at sea level about 2.5 km from the platform where it would not constitute a perceptible impact or a threat to human health or the environment. The actual probability of this exceedance will be reduced by one or more mitigation measures such as: scheduling maintenance activities to avoid adverse weather conditions; reducing the sulphur levels; employing process controls to reduce the flow to the flare; or temporarily adding additional fuel gas to increase the buoyancy of the plume. Using these measures during acid gas flaring under unfavourable meteorological conditions will effectively reduce the ground level concentrations to within criterion levels. In summary, worst-case predicted ground level concentrations of SO_2 during temporary flaring of acid gas has the potential for extremely infrequent, minor exceedances of very short duration of the ground level standard for SO_2. These exceedances, were they to occur, would have no appreciable adverse effect on human or environmental health in the Project area. These concentrations will be reduced through the flaring mitigation procedures noted above, and incorporated in the Offshore EPP.

Greenhouse Gas Emissions

Normal Operation

The Project incorporates significant design elements to reduce GHG emissions, specifically the reinjection of the CO_2 associated with the acid gas stream. Table 6.16 compares Deep Panuke GHG emissions with estimated Nova Scotia GHG emissions.

Table 6.16 Nova Scotia GHG Emissions (1997) by Sector

Greenhouse Gas Source Category	Total CO_2 Equivalent (kilotonnes/yr)	Percent of Total (%)
ENERGY:		
Fossil Fuel Industries	649	3.2
Electricity and Stream generation	7,720	38.6
Mining	41	0.2
Manufacturing	701	3.5

Table 6.16 Nova Scotia GHG Emissions (1997) by Sector		
Greenhouse Gas Source Category	**Total CO_2 Equivalent (kilotonnes/yr)**	**Percent of Total (%)**
Construction	30	0.2
Transportation: Land Vehicle	4,252	21.3
Transpiration: Air/Marine/ Rail	1,090	5.5
Residential	2,100	10.5
Commercial and Industrial	942	4.7
Other Combustion	250	1.3
Fugitive Gases	690	3.5
Energy Total	**18,400**	**92.0**
Industrial Process	270	1.4
Solvent & Other Product Use	14	0.1
Agriculture	580	2.9
Land use Change in Forestry	15	0.1
Waste Total	660	3.3
TOTAL	**20,000**	**100**
Notes: Totals may not always reflect sums of numbers in the table, due to rounding. In order to avoid double-counting, residential energy use excludes residential transportation use (counted under "transportation") as well as the emissions resulting from electricity generation. Source: Neitzert *et al*., 1999 in GPI Atlantic, 2001.		
Deep Panuke Project	**Total CO_2 Equivalent (kilotonnes/yr)**	**Deep Panuke as a percentage of 1997 NS total GHG (20,000 kilotonnes) (%)**
Normal Production Flaring (347 days)	14	0.07
Maintenance Flaring (18 days)	7	0.04
Power Generation and Compression	304	1.52
Support Vessels and Vehicles	10	0.05
Total GHG of Deep Panuke Project	**335**	**1.68**

The Project will emit GHG (including CH_4 and CO_2,) from power generation and other mobile and stationary sources. The GHG emissions from the Project are anticipated to be similar to those generated by other industrial processing facilities of comparable size and scope. The sulphur management option selected for this Project, injection of the acid gas stream, will also inject the CO_2 stripped from the raw gas. The injected CO_2 will amount to approximately 83,400 tonnes/year.

GHG emissions are a global issue; therefore, EnCana manages its GHG emissions at the corporate level. EnCana is a leader in the area of GHG management and is a gold level Voluntary Challenge Registry

(VCR) reporter and a member of the VCR Champions in Action council. A corporate approach to GHG reductions allows EnCana to target the largest and most cost effective reduction opportunities across the organization. Nevertheless, EnCana will consider all reasonable opportunities to reduce GHG emissions from the Deep Panuke Project in the engineering design process within the constraints of the location (*i.e.*, offshore) and facility safety.

The Project has also been analysed against the CAPP "Global Climate Change Voluntary Challenge Guide" (CAPP 2000) for determining the ratio of energy production to greenhouse gas emissions. The Project is predicted to perform significantly better than the industry norm for similar facilities during production.

Abnormal Operation

The extremely unlikely occurrence of a surface or subsurface blowout of a production well represents the greatest potential emission of GHG. The quantity of CH_4 that could be emitted is estimated to be ~4000 tonnes/day (refer to Table 6.13). The immediate repair of blowouts is of the highest priority because of the associated safety and environmental risk. Design measures to minimize the risk of blowouts and GHG releases are presented in Section 2.9. EnCana will develop an AERCP to rapidly respond to and minimize the duration of such a release.

Sound engineering practice will be used to design valves to minimize fugitive emissions. Awareness training will be conducted for employees to supplement the safety program (with respect to CH_4 releases) with knowledge about the cumulative impact of the Project on climate change. EnCana acknowledges the Government of Canada position that reduction of natural gas leaks be a part of the national strategy for greenhouse gas emission reduction.

Decommissioning

The Project activities associated with decommissioning would be similar to those of construction. Specifically, emissions may result from vessel and equipment engines and fugitive leaks and spills. Assuming the same mitigative measures are implemented during decommissioning as are used during construction, no significant adverse environmental effects on air quality are expected.

Malfunctions and Accidents

Upset Condition Resulting in Acid Gas Flaring

As noted for routine operations, acid gases are diverted to the flare during either routine maintenance of the injection system or during certain upset conditions (5% of the time in total).

In the event of a malfunction that takes the acid gas injection compressor out of service, the acid gas will be rerouted directly to the flare. The H_2S will be oxidized to SO_2 in the flare, a conversion estimated to be 98% efficient. Flaring of the bypass gas will provide significant thermal buoyancy to compensate for the increased SO_2 loading. Increased SO_2 emissions would continue until the injection system was returned to service.

The injection compressor is a robust component of production equipment, and a major equipment failure requiring sustained redirection of the acid gas to the flare is thus considered unlikely. The repair time on an outage would likely be three to seven days. Longer repair times are possible if weather conditions delay deliveries of replacement parts to the site. The spare parts inventory will be designed to prevent protracted delays that might otherwise result from adverse weather. Up to five months of flaring could be required in the extremely unlikely event that a new injection well was required and the necessary drilling equipment or vessels were not readily available. EnCana is committed to an immediate response to an unplanned change to flaring mode due to injection well problems. It is proposed that within seven days of the mode shift, a written response would be submitted to the CNSOPB outlining the options, actions, and schedule for resumption of normal operating mode. These procedures will be outlined in the flaring procedures to be included in the Offshore EPP.

Emissions from full acid gas flaring during upset conditions are summarized in Table 6.13. The maximum distance of predicted concentrations exceeding criteria levels for H_2S and SO_2 emissions from the flare are presented in Table 6.17 and 6.18.

Table 6.17 Upset Conditions – Acid Gas Flaring – H_2S

Criterion	Criterion Concentration	Criterion Exceeded
Lower Explosive Limit	4% (40,000 ppm, 56 g/m^3)	not exceeded
Immediate Danger to Life and Health	87 ppm (121 mg/m^3)	not exceeded
Threshold Limit Value – STEL	11 ppm (16 mg/m^3)	not exceeded
Threshold Limit Value - Time Weighted Average	10 ppm (14 mg/m^3)	not exceeded
Air Quality Criterion (1-hour)	30 ppb (42 μg/m^3)	not exceeded
Air Quality Criterion (24-hour)	6 ppb (8 μg/m^3)	not exceeded

Table 6.18 Upset Conditions – Acid Gas Flaring – SO_2		
Criterion	**Criterion Concentration**	**Criterion Exceeded**
Lower Explosive Limit	n/a	n/a
Immediate Danger to Life and Health	87 ppm (228 mg/m^3)	not exceeded
Threshold Limit Value - STEL	3.8 ppm (9.9 mg/m^3)	not exceeded
Threshold Limit Value - Time Weighted Average	2 ppm (5.2 mg/m^3)	not exceeded
Air Quality Criterion (1-hour)	0.346 ppm (900 µg/m^3)	not exceeded
Air Quality Criterion (24-hour)	0.115 ppm (300 µg/m^3)	not exceeded*
n/a = not applicable * with mitigation		

The flare stack is designed to enhance plume dispersion.

Upset Condition – Acid Gas Venting

It is possible, but unlikely, that the flare could be extinguished while acid gas is being redirected to the flare during maintenance or equipment malfunction. A flare failure occurs when the flare does not ignite. A camera system provides continuous visual monitoring of the flare. Although there is a high level of reliability in this design, there are known cases in the industry where the flare pilot flame has extinguished for some reason. If the flare is out, the gas stream will be emitted without combustion, and CH_4 and H_2S levels would be high for a short period of time (Table 6.13). Such an outage would likely last only a matter of seconds due to the redundancy in the system including the continuous ignitors and a pilot. In the event of a failure of these systems, the process safety system would alert operators, and the appropriate action would be taken. The likelihood of a sustained flare failure combined with an acid gas management system bypass is considered extremely remote. The results of modeling of CH_4 and H_2S from acid gas venting are presented in Tables 6.19 and 6.20 respectively.

The modeling results indicate that the Lower Explosive Limit for CH_4 (the only critical level that has been established for this parameter) would not be exceeded in this scenario. The maximum ground-level concentrations for CH_4 and H_2S (10.5 mg/m^3 and 10.1 mg/m^3, respectively) would occur about 1,000 m from the source. The TLV for H_2S would not be exceeded. This scenario would result in an exceedance of the 1-hour criterion for H_2S (odour detection by humans) within a distance of >100 km from the source. This scenario is extremely unlikely and uncombusted emissions would only occur for a very brief period before the flare is re-ignited. This occurrence would likely result in short duration episodes of perceptible to strong odour. The tabulated values correspond to the worst-case meteorological conditions.

Table 6.19 Upset Condition – Acid Gas Venting – CH_4		
Criterion	**Criterion Concentration**	**Criterion Exceeded**
Lower Explosive Limit	5% (50,000 ppm, 35.6 g/m^3)	not exceeded
Immediate Danger to Life and Health	n/a	n/a
Threshold Limit Value - STEL	n/a	n/a
Threshold Limit Value - Time Weighted Average	n/a	n/a
Air Quality Criterion (1-hour)	n/a	n/a
Air Quality Criterion (24 hr)	n/a	n/a
n/a = not applicable; levels not defined for methane.		

Table 6.20 Upset Condition – Acid Gas Venting – H_2S		
Criterion	**Criterion Concentration**	**Criterion Exceeded**
Lower Explosive Limit	4% (40,000 ppm, 56 g/m^3)	not exceeded
Immediate Danger to Life and Health	87 ppm (121 mg/m^3)	not exceeded
Threshold Limit Value – STEL	11 ppm (16 mg/m^3)	not exceeded
Threshold Limit Value - Time Weighted Average	10 ppm (14 mg/m^3)	not exceeded
Air Quality Criterion (1-hour)	30 ppb (42 μg/m^3)	exceeded 100 km
Air Quality Criterion (24-hour)	6 ppb (8 μg/m^3)	not exceeded

System Depressurizing Event

During a one-time testing event, and possibly in response to an emergency, it will be necessary to depressurize all systems to the flare. This blowdown event will result in the supply of 200 MMscfd of gas to the flare for approximately 15 minutes, followed by a flow decreasing to a base level within one hour. This situation does not increase sulphur emissions, but does increase the fuel gas supply to the flare. This results in a further increase in plume buoyancy and reduction of potential impacts during this transient event.

Acid Gas Injection Well Blowout – Subsea Blowout

The acid gas management system involves the construction of an injection well system. During drilling for this well, there is an extremely low probability of pressures in the injection reservoir causing a blowout of the well, accompanied by the release of gas and fluids from the reservoir (refer to Section 3.2). The intended reservoir for disposal of the acid gases does not contain sulphur, therefore it is anticipated that blowout during drilling would not contain significant amounts of H_2S, although the potential concerns with respect to water quality and safety are recognized. A blowout prevention device would limit the potential of a blowout during injection well drilling.

For production, the injection well will have two levels of fail safe valves that will operate in the event of an emergency to avoid release of acid gases from the well back to the surface. In an emergency situation, gas flow would be shut off at the surface on the injection tree, and simultaneously at the subsurface safety valve located 200 to 300 m beneath the sea floor. In the extremely unlikely case of failure of these systems, a release rate based on flow limited by the size of the pipe has been assumed (Table 6.13). The gas would bubble to the surface and be released to the atmosphere. The predicted downwind concentrations are shown in Table 6.21.

Table 6.21 Acid Gas Injection Well Blowout (Production Phase) – H_2S

Critical Level	Criterion Concentration	Criterion Exceeded
Lower Explosive Limit	4% (40,000 ppm, 56 g/m^3)	not exceeded
Immediate Danger to Life and Health	87 ppm (121 mg/m^3)	exceeded within 4,350 m
Threshold Limit Value - STEL	11 ppm (16 mg/m^3)	exceeded within 21,000 m
Threshold Limit Value - Time Weighted Average	10 ppm (14 mg/m^3)	exceeded within 23,500 m
Air Quality Criterion (1-hour)	30 ppb (42 µg/m^3)	exceeded > 100 km
Air Quality Criterion (24-hour)	6 ppb (8 µg/m^3)	exceeded > 100 km

Production Well - Subsea Blowout

A subsea blowout would result in the discharge of compressed gas into the sea. The estimated volume and discharge rate for a maximum credible event is approximately 200 MMscfd, or about 65.5 m^3/s. The atmospheric emissions of a subsea blowout are summarized in Table 6.13 and modeled using SCREEN3. The modeling assumed the maximum credible blowout, and that the gas reached the surface in an area of about 100 m diameter.

The critical conditions and the radius of the zone of influence for CH_4 and H_2S under this scenario are shown in Tables 6.22 and 6.23 respectively. These distances are computed on the basis of 1-hour and 24-hour concentrations. The actual potential consequences may extend to a greater distance because of higher fluctuating concentrations; for example, peak fluctuations may result in instantaneous concentrations ten times higher than the 1-hour average.

Table 6.22 Production Well - Subsea Blowouts – Raw Gas – CH_4		
Criterion	**Criterion Concentration**	**Criterion Exceeded**
Lower Explosive Limit	5% (50,000 ppm, 35.6 g/m^3)	exceeded within 630 m
Immediate Danger to Life and Health	n/a	n/a
Threshold Limit Value – STEL	n/a	n/a
Threshold Limit Value - Time Weighted Average	n/a	n/a
Air Quality Criterion (1-hour)	n/a	n/a
Air Quality Criterion (24-hour)	n/a	n/a
n/a = not applicable; levels not defined for methane.		

Table 6.23 Production Well - Subsea Blowout – Raw Gas – H_2S		
Criterion	**Criterion Concentration**	**Criterion Exceeded**
Lower Explosive Limit	4% (40,000 ppm, 56 g/m^3)	not exceeded
Immediate Danger to Life and Health	87 ppm (121 mg/m^3)	exceeded within 950 m
Threshold Limit Value – STEL	11 ppm (16 mg/m^3)	exceeded within 4,250 m
Threshold Limit Value - Time Weighted Average	10 ppm (14 mg/m^3)	exceeded within 4,800 m
Air Quality Criterion (1-hour)	30 ppb (42 µg/m^3)	exceeded >100 km
Air Quality Criterion (24-hour)	6 ppb (8 µg/m^3)	exceeded >100 km

The modeling results indicate that the Lower Explosive Limit for CH_4 would be exceeded up to a distance of 630 m downwind from the source. For H_2S, the modeling results indicate the Immediate Danger to Life and Health criterion is exceeded within 950 m from the source. Threshold Limit Values, STEL and TWA, would be exceeded within 4,250 m and 4,800 m respectively. One-hour and 24-hour criteria (based in the upper range of odour detection by humans) may be exceeded within a zone extending up to 100 km or greater, from the source.

The nearest permanent installation with workers aboard beyond Deep Panuke is the SOEP platform at Thebaud, approximately 45 km away and slightly closer than staffed locations on Sable Island. The future SOEP platform Alma is closer than Thebaud (23 km); however, workers will only be aboard for temporary work assignments which will not include overnight accommodation. In the extremely unlikely event of a subsea blowout from a production well, and depending on wind direction, an H_2S gas odour might be perceptible at Alma, Thebaud and Sable Island, but it would not pose a risk to safety. The greatest danger would be to persons aboard the platform at Deep Panuke, or aboard vessels within approximately 4 km. In addition to the danger to human health, the plume would represent a risk to seabirds, marine mammals, and other exposed creatures.

In Alberta, typically, emergency response planning zones (EPZ) are based on the 100 ppm isopleth for concentrations of H_2S which would require an emergency response plan for that zone. In this situation, the EPZ would be approximately 4 km, on a worst case basis. Section 2.9.3 describes blowout prevention devices to be incorporated into the Project design. Section 3.2 provides additional information on the low probability of system failures.

The maximum atmospheric emissions from blowouts are predicted to result from low wind speeds (about 1 m/s) that are sometimes observed on the Scotian Shelf. In the event of a blowout, the time of travel of the plume to a potential ignition source or persons on vessels is an important factor in the potential consequences of the event. For example, every kilometer downwind represents a travel time of over 16 minutes at a wind speed of 1 m/s. This time delay affords the opportunity to mitigate the effect through warning and alarm systems. Increased windspeed will reduce the travel time but will also provide additional dilution to the gas. For the annual average windspeed of 25 km/hr, a gas release would travel 1 km in about 2.4 minutes and be diluted to one seventh of the concentration at 1 m/s (3.6 km/hr). Activation of shut off valves would limit the duration of downwind exposure to a period from several seconds to a few minutes.

A detailed Safety Case analysis will be undertaken by EnCana to ensure that appropriate engineering design and materials procurement procedures are incorporated to ensure a safe facility. A comprehensive training program, combined with state-of-the-art detection systems will alert the facility to the occurrence of an accidental release of sour gas and minimize the exposure should a blowout occur. EnCana will develop an AERCP (refer to Section 4); this Plan will include detailed procedures and training to be incorporated during Project operations. The training will cover both the operational staff on the facility and the Emergency Response Team. All safety procedures will be documented and in place prior to the commencement of operations.

Production Well - Surface Blowout

A rupture of piping above the surface is estimated to yield the same raw gas emission rate as that which would result from a subsea event. The atmospheric emissions of a surface blowout are summarized in Table 6.13. A surface blowout would emit a plume from the ruptured pipe somewhere on the structure. The environmental effects beyond a few hundred metres of the platform, would be very similar to a subsea blowout, and the critical distances would be essentially the same, except for small differences due to wind speed and the height of release. A sustained release of more than a few minutes during production is considered extremely unlikely because of the failsafe valve beneath the sea floor and at the production tree; an extended release on the platform is not considered possible. The release would last for a period from several seconds to a few minutes, with the rate of release decreasing rapidly as the gas volume within the piping was exhausted. The critical conditions and downwind distance for CH_4 and

H_2S are shown in Tables 6.24 and 6.25 respectively. It is important to note that instantaneous fluctuations could be a factor of 10 higher than 1-hour averages.

Table 6.24 Production Well - Surface Blowout – Raw Gas - CH_4

Criterion	Criterion Concentration	Criterion Exceeded
Lower Explosive Limit	5% (50,000 ppm, 35.6 g/m^3)	exceeded within 490 m
Immediate Danger to Life and Health	n/a	n/a
Threshold Limit Value – STEL	n/a	n/a
Threshold Limit Value - Time Weighted Average	n/a	n/a
Air Quality Criterion (1-hour)	n/a	n/a
Air Quality Criterion (24-hour)	n/a	n/a
n/a = not applicable; levels not defined for methane.		

Table 6.25 Production Well - Surface Blowout – Raw Gas - H_2S

Criterion	Criterion Concentration	Criterion Exceeded
Lower Explosive Limit	4% (40,000 ppm, 56 g/m^3)	exceeded within <100 m
Immediate Danger to Life and Health	87 ppm (121 mg/m^3)	exceeded within 770 m
Threshold Limit Value - STEL	11 ppm (16 mg/m^3)	exceeded within 4,100 m
Threshold Limit Value - Time Weighted Average	10 ppm (14 mg/m^3)	exceeded within 4,600 m
Air Quality Criterion (1-hour)	30 ppb (42 μg/m^3)	exceeded within >100 km
Air Quality Criterion (24-hour)	6 ppb (8 μg/m^3)	exceeded within >100 km

The modeling results indicate that the Lower Explosive Limit for CH_4 would be exceeded up to a distance of 490 m from the source. The modeling results also indicate that the Immediate Danger to Life and Health criterion for H_2S is exceeded within 770 m from the source. One-hour and 24-hour criteria may be exceeded within a zone greater than 100 km, although the limited duration of the release would prevent the 24-hour average from reaching the criterion.

Because of the significant hazard that these concentrations would pose to the immediate environment and worker health, the engineering design is focused on the reduction of the probability of occurrence. Surface and subsea blowouts would produce similar maximum concentrations downwind; however, a blowout aboard the platform could have more serious consequences to workers aboard compared with a subsea blowout. The multiple levels of blowout prevention controls are designed to minimize the risk; however, emergency operating procedures will also be developed to ensure the protection of platform workers. As discussed above, the time delay associated with the worst-case meteorology (*i.e.,* low wind speed resulting in long travel times) provides an opportunity to warn and thereby protect vessels downwind. EnCana's AERCP is discussed in Section 4.

Acid Gas Piping Rupture

The rupture of acid gas piping on the platform is considered to be an extreme event, resulting in hazards to personnel aboard. Systems to protect worker safety (*e.g.*, emergency shut down devices and H_2S monitors) ensure that any adverse occurrence is of extremely short duration and the release is of low volume. The adequate protection of workers aboard the platform ensures the protection of the environment beyond. The volume of gas that may be released will be limited to the volume and pressure of the segment of piping between the two nearest shutoff valves. The gas volume and pressure that could be released in this emergency scenario are not yet known; therefore, the critical distances cannot be modeled. It is standard practice during detailed engineering design to determine specific risks, and to optimize the design and responses. Because the design will limit the risk to all workers on the platform, the effect on the environment beyond will not be significant.

Pipeline Release

The low probability of an offshore or onshore leak or rupture of the market-ready gas pipeline is discussed in Section 3.3 and 3.4. A pipeline release would consist of methane which would cause a temporary, localized degredation of air quality near (at the surface) of the release. Additional air quality effects could occur in the unlikely event of a rupture of the onshore pipeline with ignition and secondary fire (*i.e.*, vegetation). Large releases of gas from the pipeline would be rapidly detected through process monitoring equipment with shutoff valves triggered. Pipeline integrity measures are described in Section 2.9.

Summary

In summary, routine operations can be conducted with sufficient mitigation to ensure that effects on air quality are not significant. There is potential for significant adverse environmental effects to occur in the extremely unlikely event of blowouts of injection or production wells, or acid gas pipe ruptures; therefore design, inspection, maintenance, and integrity assurance programs will be in place to minimize this risk. Proven engineering techniques are available to prevent these events, and will be employed for the Project. All safety procedures will be documented and in place prior to the commencement of routine operations.

6.3.1.5 Cumulative Effects Assessment

The ambient air quality in the study area, described in Section 6.1.1.2 reflects the influence of emissions from other past and current projects and activities occurring within or outside of the Project area. Other past and current sources of emissions within the study area include emissions from hydrocarbon exploration and production platforms, and engine emissions from vessels engaged in fishing, tourism, hydrocarbon exploration (including seismic and drilling activities), supply of hydrocarbon production facilities (*e.g.*, SOEP), military activities, and domestic and international shipping. It has been estimated that about 80% of Nova Scotia's air pollution originates outside the provincial borders, primarily in the industrial centre of North America (Province of Nova Scotia 2001). Pollutants transported from these industrial areas typically include sulphates, nitrates and ozone precursors. All quantities are significantly lower than the Nova Scotia air quality criteria. It is assumed, for the purposes of this assessment that these existing activities will continue to be carried out and to produce emissions at current levels.

It is anticipated that incremental emissions will result from future seismic and exploration activities that will be carried out in the study area and from the construction of the recently announced Blue Atlantic, Neptune, and Hudson Energy (currently on hold) projects that will traverse the study area. No cumulative interactions with the Sable Island Windpower project affecting air quality are anticipated.

Construction of onshore components of the Project and construction of onshore components of Neptune and Hudson Energy Projects may overlap temporally and spatially. However, the effects of emissions from construction of the Project (*e.g.*, dust, construction vehicle emissions) are small in geographic extent, short in duration, and reversible and will not cause significant cumulative effects with these other proposed projects. The cumulative effect of emissions from Project construction in combination with all existing (and ongoing) emission sources affecting the study area is not expected to be significant. There may be some temporal and/or spatial overlap of the Project construction emissions with emissions from other future exploration drilling activities outside of the Panuke lease but within the study area, and seismic exploration both on and outside the Panuke lease. These other future emissions, however, would be similar in scale to those of the Project construction, and are not expected to result in a significant cumulative adverse effect on air quality. No temporal overlap with construction of the SOEP platform at Alma is expected; therefore, no cumulative effects are anticipated as a result of construction phase activities.

The cumulative effect of operational emissions in combination with all existing (and ongoing) emission sources affecting the study area is not expected to be significant. Emissions from vessel traffic and flaring during Project operation are expected to be similar in extent, duration, and reversibility to those during construction. There may be spatial and temporal overlap between Project operations and construction activities for the Blue Atlantic Transmission System or the Neptune and Hudson Energy subsea cables in the future; however, any cumulative interaction is not expected to result in a significant adverse effect on air quality due to the low scale of the Project emissions. Routine Project air emissions, including those from flaring and power generation on the platform, will be within regulatory limits and generally outside of the zone of influence of air emissions generated by future projects such as hydrocarbon exploration on other leases, and the Blue Atlantic, Neptune and Hudson Energy Projects. In the areas where the Hudson and Neptune projects are expected to generate significant air emissions from operation of gas fired power generation facilities, along with the current operation of the SOEP gas plant (*i.e.*, Goldboro), Deep Panuke Project air emissions will be limited mainly to dust and construction vehicle emissions generated during installation of the onshore portion of the pipeline. The onshore portion of the Blue Atlantic project (*i.e.*, gas processing) is expected to be located at a significant distance from the Deep Panuke Project (*i.e.*, in southwest Nova Scotia). The Neptune and Hudson Energy projects are expected to use gas fired turbines which will minimize the generation of the long range transport of air pollutants (*e.g.*, SO_2) which could interact cumulatively with Deep Panuke Project air emissions. It is expected that Blue Atlantic gas processing operations will be required to meet all current and future emissions requirements (*e.g.*, SO_2 limits) which, in combination with its distance from the Project, will minimize the potential for significant cumulative effects with the Deep Panuke Project.

A visible flare plume from Thebaud has been reported. While quantitative determinations have not been made of the air quality impacts at Thebaud, the "sweet" SOEP gas is not expected to contain large volumes of pollutants (*e.g.*, SO_2) which could interact significantly with Deep Panuke offshore emissions. SOEP Tier II development may result in additional air emissions at Thebaud, however these emissions are not anticipated to overlap spatially with Deep Panuke emissions.

The Project will emit GHG (including CH_4 and CO_2) from power generation and other mobile and stationary sources. The issue of global warming and the role of GHG is an international issue. Canada has been actively involved in developing strategies to limit GHG emissions through mechanisms such as the VCR program. The estimated contribution of the Deep Panuke Project to total estimated GHG by all Canadian human-made sources is extremely small (0.03% of 1995 Canadian totals) (Environment Canada 1997). Since 1994, EnCana has achieved a cumulative reduction in GHG emissions of 2.5 million tonnes of CO_2 equivalent (to the end of 2000). This cumulative reduction amounts to approximately 14% of the total reductions reported by the oil and gas industry to CAPP through the VCR program. EnCana is committed, in the VCR program, to continuous improvement and has implemented a program to reduce GHG emissions throughout its operations through process optimization and technological improvements. The choice of acid gas injection incorporates permanent disposal of a significant quantity of CO_2 that would otherwise be emitted to the atmosphere. EnCana is committed to investigating other GHG reduction opportunities that arise during this Project.

The governments of Canada and Nova Scotia have agreed to an SO_2 emissions cap of 189,000 tonnes annually in Nova Scotia (Canada/Nova Scotia Agreement Respecting Acid Rain Reduction Program). This program is designed to limit sulphur emissions to prevent acid rain damage. A limit of 145,000 tonnes of this cap has been allocated to Nova Scotia Power Inc. in the provincial *Air Quality Regulations* under the *Environment Act*. The SO_2 emissions from the Deep Panuke Project are about 1,596 tonnes per year, or 1% of the cap.

The Government of Nova Scotia has issued an energy strategy for the province, Seizing the Opportunity: Nova Scotia's Energy Strategy (2001), that includes, among other initiatives, the further reduction of SO_2 emissions in the province. The strategy requires a 25% reduction in SO_2 emissions by 2005, and a further 25% reduction by 2010. The EnCana sulphur management strategy results in permanent disposal of sulphur by-products to an underground reservoir, minimizing the release to the atmosphere; this is assumed to be fully compatible with this part of the provincial energy strategy.

The potential environmental effects, including cumulative effects, of decommissioning would be similar to those of construction; no significant adverse effects are anticipated.

The potential future cumulative effects resulting from a malfunction or accident would be the same as those described previously in this section. Other than the extremely unlikely possibility of a significant adverse effect due to a surface or subsurface blowout, or pipe rupture at the platform, no significant adverse cumulative effects on air quality are predicted.

6.3.1.6 Follow-up and Monitoring

Routine atmospheric discharges will be tested on a regular basis to verify the efficiency of the systems. Continuous monitoring systems will be put in place to ensure that fugitive or emergency releases of gas are detected immediately and responded to appropriately. During construction, the process will include test procedures to ensure that the specified equipment is installed and correct tolerances achieved.

In operation, the Project will adhere to proactive maintenance procedures. The effects of corrosion, vibration, mechanical wear and fatigue will be estimated and repair and replacement performed with an adequate margin of safety. During the operation of the facility, environmental monitoring programs are in place to document compliance with environmental standards and reports are submitted to the CNSOPB on a regular basis.

Significant adverse effects on air quality could occur due to emissions of H_2S and CH_4 in the extremely unlikely event of an accidental release of large amounts of raw gas from a production well or acid gas from the injection well. It is therefore critical to the success of the Project that the safety measures, contingency planning, and equipment condition be tested and monitored as a highest priority. In particular, emergency shutdown systems will be tested at routine intervals to ensure that they are functioning properly, and that releases, should they occur, are safely managed to the shortest possible duration.

The EPP will contain procedures for reporting emissions in accordance with regulatory requirements. The EPP will also outline procedures for monitoring of emissions and identification of opportunities for continual environmental improvement. EnCana supports the establishment of a regional EEM framework and has contributed to the establishment of the new Sable Island Air Quality Monitoring Station, which will monitor a wide variety of emission types from regional sources.

EnCana will adhere to provisions of the National Pollution Release Inventory (NPRI) with respect to reporting emissions to the atmosphere. NPRI reporting requirements with respect to East Coast offshore oil and gas industry are currently being addressed in Environmental Studies Research Fund (ESRF) studies on air emissions and pollution prevention opportunities. In conjunction with the Offshore Chemical Selection Guidelines (NEB *et al.* 1999) and the WMP and CMP, EnCana will strive to reduce or eliminate wastes and transfers of NPRI substances throughout the life of the Project.

EnCana submits annual VCR reports, which include detailed descriptions of annual performance, descriptions of GHG reduction projects, projections of future GHG levels, Product Energy Intensity (PEI) and Product Carbon Intensity (PCI) targets, and plans to achieve these targets.

6.3.1.7 Sustainable Use of Renewable Resources

No significant effects on air quality are predicted that would affect the sustainable use of renewable resources. Emissions from a blowout event will dissipate in a short time.

6.3.1.8 Summary of Residual Environmental Effects Assessment

Flaring is necessary for safe operation and testing during Project construction and commissioning; however, to the extent possible, these events will be scheduled to ensure that flaring is carried out safely and in accordance with flaring procedures specified in EnCana's Offshore EPP (refer to Section 4). Other emissions from construction, such as the exhausts of equipment and supply vessels, and dust will be temporary, localized, and not significant. Routine operations will result in the emissions of NO_X and SO_2 from power generation and from normal continuous flaring; these will be within the applicable air quality criteria levels. Some GHG emissions will be produced though injection of acid gas will significantly reduce these emissions. EnCana is committed to continuous improvement in GHG management in its operations.

Acid gas flaring resulting from maintenance or malfunctions of the acid gas management system will result in additional air contaminants. Flaring of acid gas, incorporating mitigative measures when necessary, will cause temporary, but acceptable, increases in emissions. No significant adverse effects from these upset conditions are likely.

A surface or subsurface blowout resulting in the release of large quantities of raw gas from a production well or acid gas from the injection well, would result in significant adverse effects to air quality for several criteria and could result in important consequences affecting the health and safety of workers on the platforms and vessels within 4 km. It is estimated, however, that such an event would be both extremely unlikely (refer to Section 3.2) and of short duration with the probability of occurrence further reduced through good design practices (refer to Section 2.9) and maintenance. Subsea or surface blowouts could last up to several months with the failure of all safety equipment, though a total failure of all safety equipment is considered extremely unlikely. EnCana will develop and implement the AERCP (outlined in Section 4) for all potential malfunctions and accidents to minimize the potential adverse effect on air quality and human health and safety.

Potential adverse residual environmental effects on air quality are predicted to be not significant for construction and operation phases. Significant adverse effects on air quality could occur as a result of an accidental release of large amounts of raw gas or acid gas through a blowout or pipe break; however, such an event would be temporary and is considered extremely unlikely. Cumulative effects with other current or reasonably foreseeable future projects are considered not significant. Tables 6.26 to 6.27 summarize the residual environmental effects on air quality.

Table 6.26 Residual Environmental Effects Assessment Matrix: Air Quality

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		
CONSTRUCTION									
Flaring	• Localized reduction in air quality; visible plume (A)	• Flaring procedures specified in Offshore EPP (*e.g.*, scheduling to avoid adverse weather conditions and presence of vessels)	2	3	3/2	R	2	N	2
Miscellaneous emissions from vessels, power generation, and construction equipment	• Localized reduction in air quality (A)	• Use of energy efficient and low emission technology where appropriate • Dust suppression techniques if required	1	3	2/6	R	2	N	3
OPERATION									
Power generation	• Localized reduction in air quality (A)	• Use of energy efficient and low emission technology where appropriate • Sufficient stack height to minimize platform and ground level concentrations	1	3	5/6	R	2	N	3
Flaring	• Localized reduction in air quality; visible plume (A)	• Manage operations to minimize flaring • Flaring procedures included in Offshore EPP (*e.g.*, adjust operations for adverse weather conditions)	2	3	5/6	R	2	N	3

Table 6.26 Residual Environmental Effects Assessment Matrix: Air Quality

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		
Miscellaneous emissions from vessels	• Localized reduction in air quality (A)	• Use of energy efficient and low emission technology where appropriate	1	3	5/6	R	2	N	3
MALFUNCTIONS AND ACCIDENTS									
Blowout of wells (surface and subsurface) Piping rupture	• Severe reduction in air quality (A)	• Blowout prevention design and equipment • Alert/Emergency Response Contingency Plan • Notification to Mariners	3	6	1/0	R	2	S	2
Acid gas system malfunction	• Increased flaring or venting of H_2S or SO_2 and reduction of air quality (A)	• Spare part inventory • Equipment maintenance program • Asset integrity management	2	4	1/1	R	2	N	2
Pipeline break	• Release of market-ready gas (methane) with reduction of air quality	• Pipeline design to maintain integrity • Leak detection and shutoff valves	2	3	1/0	R	2	N	3

Table 6.26 Residual Environmental Effects Assessment Matrix: Air Quality

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		

KEY

Magnitude: 1 = Low (*e.g.*, within the normal variability of baseline conditions); 2 = Medium (*e.g.*, increase/decrease with regard to baseline but within standards and objectives); 3 = High (*e.g.*, singly or as a significant contribution in combination with other sources causing exceedances or impingement upon standards and objectives)
Geographic Extent: 1=<500 m^2; 2=500 m^2 – 1 km^2; 3=1-10 km^2; 4=11-100 km^2; 5=101-1000 km^2; 6=>1000km^2
Duration: 1=<1month; 2=1-12 months; 3=13-36 months; 4=37-72 months; 5=>72 months
Frequency: 0= unlikely to occur; 1=<11 events/year; 2=11-50 events/year; 3=51-100 events/year; 4=101-200 events/year; 5=>200 events/year; 6=continuous
Reversibility: R=Reversible; I=Irreversible
Ecological/Socio-cultural and Economic Context: 1=Pristine area; 2= Area affected by human activity; 3=Evidence of adverse effects
Residual Environmental Effect Rating: S=Significant Adverse Environmental Effect; N=Nonsignificant Adverse Environmental Effect; P=Positive Environmental Effect
Confidence: 1=Low level of confidence; 2=Medium level of confidence; 3=High level of confidence

Table 6.27 Residual Environmental Effects Summary: Air Quality (All phases)			
Phase	**Residual Environmental Effect Rating**	**Likelihood of Significant Adverse Effects**	
		Probability of Occurrence	**Scientific Uncertainty**
Construction	N	N/A	N/A
Operations	N	N/A	N/A
Decommissioning	N	N/A	N/A
Malfunctions and Accidents	S	1	3

KEY

Residual Effects Rating: S=Significant Adverse Environmental Effect; N=Non-significant Adverse Environmental Effect; P=Positive Environmental Effect
Probability of Occurrence: Based on professional judgement; 1 = Low; 2 = Medium; 3 = High; N/A = Not applicable (effect is not predicted to be significant)
Scientific Uncertainty: Based on scientific information and statistical analysis or professional judgement; 1 = Low level of confidence; 2 = Medium level of confidence; 3 = High level of confidence; N/A = Not applicable (effect is not predicted to be significant)

6.3.2 Marine Water Quality

Marine water quality refers to the physical and chemical condition of the medium that supports all marine life. Marine organisms depend on water for all aspects of their life cycle. Consequently there is an intrinsic link between marine water quality and marine organisms resident in, or transient to, the Project area. Legislation and guidelines regulate industrial discharges to the marine environment in order to protect water quality. Project related discharges to marine waters are discussed elsewhere in this document with respect to potential effects on: marine benthos (Section 6.3.3); marine fish (Section 6.3.4); marine mammals (Section 6.3.5); and marine related birds (Section 6.3.6). Marine water quality in this assessment is therefore addressed primarily in relation to potential effects on key marine biological receptors. Marine water quality is addressed as a separate VEC at the request of regulatory authorities.

6.3.2.1 Boundaries

Temporal boundaries for marine water quality encompass the construction, operation and decommissioning phases of the Project. Malfunctions and accidental events (*e.g.*, well blowout, pipeline rupture, platform spills) may also affect water quality. Temporal boundaries for such events would be dependent upon the nature, duration and magnitude of the accident and its effects.

The spatial boundary for marine water quality includes the entire water column, and encompasses the potential zone of influence of Project related discharges and potential spills.

6.3.2.2 Residual Environmental Effects Evaluation Criteria

A **significant** adverse effect is one that results in the degradation of marine water quality by causing one or more parameters to exceed maximum allowable limits as stipulated in applicable guidelines (*e.g.*, OWTG), such that there is a sustained or repeated exceedance of parameters affecting water quality causing significant adverse effects on other valued environmental components depending on water quality (*i.e.*, benthos, marine fish, marine mammals, marine related birds) as assessed elsewhere in this document.

A **positive** effect is one that measurably improves marine water quality over existing conditions.

6.3.2.3 Potential Interactions, Issues and Concerns

Potential interactions with marine water quality may occur during the Project's construction, operation and decommissioning phases, as well as due to malfunctions and accidental events.

Potential issues and concerns related to marine water quality include:

- temporary and localized increase in suspended particulate matter (SPM) as a result of pipeline and jacket installation;
- discharge associated with hydrostatic testing;
- overboard disposal of WBM and associated cuttings;
- discharge of routine operational discharges (*e.g.*, produced water, cooling water, sewage, *etc.*); and
- accidental release of hydrocarbons following a blowout, pipeline rupture, or platform spill.

The most relevant activity during routine Project operations is the discharge of produced water, which has the potential to affect a number of water quality parameters, including temperature, dissolved oxygen, trace metals, and pH. Marine water quality may also be affected during operations as a result of deck drainage, cooling water discharge, and other Project-related discharges.

6.3.2.4 Analysis, Mitigation and Residual Environmental Effects Prediction

Construction

Pipeline and Platform Installation

Pipeline trenching will result in localized increases in SPM in waters immediately surrounding the trench. The nature and duration of elevated levels of SPM are primarily a function of the physical characteristics of the sediment (*i.e.*, coarse material will settle quickly, and fine grain material over a longer period). SPM concentrations of the fine material may reflect that which naturally occurs during storm conditions and/or levels associated with periods of high primary biological productivity. It is unlikely that the short periods of elevated SPM would affect water quality significantly.

Blasting may be required within 300-500 m of the shoreline. Toxic gas by-products of explosives are primarily carbon monoxide and nitrous/nitric oxides of the detonation reaction. The type of charge used will therefore be an important consideration, as certain compounds produce insignificant toxic gas production, and consequently, little, if any, detrimental effect to the localized water quality (Keevin and Hempton 1997). Both trenching and blasting are short-term, localized events that are unlikely to evoke a prolonged effect on marine water quality conditions. All marine blasting activities will be conducted in accord with the Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters (Wright and Hopky 1998); this will further reduce impacts to marine habitat.

Onshore-related construction activities will be conducted according to DFO and NSDEL guidelines for erosion and sediment control. These control measures, also specified in the Onshore Construction EPP, will minimize or prevent silt-laden surface run-off from entering the marine environment. Land-based construction activities are therefore not anticipated to affect marine water quality.

Mobilization and installation of the platforms may result in an increase in the local concentration of SPM above ambient levels. This activity and any resulting increase in SPM will, however, be short-term, and occur within a small zone of influence. It is unlikely that any resulting increase in concentrations of SPM would exceed natural elevated levels caused by storms or internal waves.

Hydrostatic Testing

Hydrostatic testing of the pipeline may involve discharge of seawater treated with corrosion inhibitors, biocides, and oxygen scavengers (refer to Section 2.3.2). A study, consisting of a toxicity biossay program and plume dispersion modeling, will be undertaken to optimize the method of discharge of hydrostatic water from the pipeline and to identify the chemicals best suited for application and discharge into the environment. The proposed method of discharging the one-time use of hydrostatic water from the pipeline will be to direct the water to the production platform, and mix it with cooling water, prior to discharge through the caisson. It is estimated that the pipeline will contain approximately 47,000 m^3 of hydrostatic test water and that the pipeline will be emptied over an estimated period of 4 to 5 days. The discharge rate will be approximately 470 m^3 per hour. The cooling water discharge at the platform is estimated to be approximately 3,050 m^3 per hour. Therefore, there will be a 7:1 dilution of the hydrostatic test water at the cooling water caisson discharge. The chemicals used in hydrostatic testing will be selected from a list of approved chemicals for use in Canada and subject to the Offshore Chemical Selection Guidelines (NEB *et al.* 1999) and EnCana's CMP (refer to Appendix D).

Development Drilling

Only WBMs and associated cuttings will be discharged into the marine environment. Section 6.3.3 contains drill waste dispersion modeling results and describes predicted effects on marine benthos. The basis of WBM modeling is that WBM can remain in the benthic boundary layer, the thickness of which can range from metres to tens of metres depending on ambient currents (Hannah *et al.* 1995). Modeling results presented in Thomson *et al.* (2000) of WBM on the Sable Bank showed that peak mud concentrations of 10 mg/L could persist in the boundary layer for several days and peak levels of 1 mg/L could persist for a 10-day period (refer to Section 6.3.3 for additional detail).

SBM and EMOBM will either be injected or shipped to shore for treatment and/or disposal. EnCana will also screen all component chemicals of drilling muds to be used, as per the Offshore Chemical Selection Guidelines (NEB *et al.* 1999). EnCana and its Contractors will also comply with all other regulations of the OWTG (NEB *et al.* 1996, and updates) and any other regulatory conditions regarding discharges and waste management (*e.g.*, deck drainage, hazardous and non-hazardous wastes) during the construction phase to minimize potential water quality impacts. EnCana's WMP will be developed and implemented to address these issues for both staff and contractors.

Vessel Discharges

All Project vessels will adhere to applicable regulations (*e.g.*, MARPOL) with respect to discharge of substances affecting marine water quality (*e.g.*, bilge, lubricants, solid waste, fuels, etc.). The WMP will also apply to construction vessels. Project related vessel traffic will therefore not have a significant effect on marine water quality.

In summary, through the use of standard and accepted industry procedures and mitigation measures, adherence to applicable regulations and guidelines, and waste management planning, the construction phase of the Deep Panuke Project will not result in a significant adverse effect on marine water quality.

Operation

Produced Water Discharge

The OWTG (NEB *et al.* 1996, and updates) specify a hydrocarbon limit of 30 mg/L (30-day weighted average) in produced water. EnCana is striving to exceed this guideline, with a dispersed target level of 25 mg/L (30-day weighted average). Treated produced water will be introduced into the cooling water line and discharged from a pipe at a depth of 10 m below the water surface. Discharge at depth will increase effluent dispersion characteristics and reduce interaction with the zone of relatively higher primary productivity nearer to the surface. The total maximum discharge rate will be 3,095 m^3/hr, of which 3,050 m^3/hr will be cooling water (recirculated seawater) and 45 m^3/hr will be produced water. Therefore, an initial dilution of produced water of 68:1 will occur prior to discharge into the marine environment.

Results from produced water dispersion modeling is found in Appendix C. The conclusions of the dispersion modeling are considered conservative as the model assumed a produced water discharge rate of 65 m^3/hr with a dilution rate of 48:1. As the design of the Project has advanced, the produced water maximum discharge rate has been reduced to 45 m^3/hr, with a higher dilution rate of 68:1.

The temperature of the discharge will be about 20^o C, and will provide some buoyancy to the discharge plume. The discharge temperature will however, rapidly decline to within 1^o C of background levels within the immediate vicinity of the platform. Low dissolved oxygen in the produced water will not be a concern since the produced water is mixed with natural seawater (cooling water) from an intake approximately 10 m deep, with dissolved oxygen concentrations near saturation at this depth.

The pH of produced water may be influenced by the H_2S content. However, the design specifications are to treat the produced water to a range of 1 to 2 ppm H_2S prior to mixing with cooling water. Dispersion of low levels of H_2S discharged with produced water has been assessed by modeling of the combined produced water and cooling water discharge. Combination of the produced water stream with cooling water achieves an initial dilution of 68:1 (48:1 dilution was modeled). Modeling shows that after discharge, the total effluent undergoes further dilution of at least 10 to 20 fold within 30 to 100 m of the discharge pipe based on one hour averages within the 20 m x 20 m model grid cells. This results in an overall dilution of produced water H_2S levels by factors of greater than 500:1 to 1,000:1. Based on discharge levels of 1 to 2 ppm, maximum average H_2S levels in the marine environment of less than 0.004 ppm (0.004 mg/L) are predicted at the point of discharge from the Deep Panuke production platform. In addition to rapid dilution, residual H_2S will be rapidly oxidized to sulphate (a common ion in seawater). Significantly higher natural levels have been recorded in waters overlying sediments (20.4 ppm) (Fenchel 1969). Bagarino and Vetter (1989), and Glickman *et al.* (1999), examined H_2S

concentrations at "end of pipe" (95 to 160 mg/L) and at the edge of mixing zone (50 to 96 g/L) at three California offshore sites and predicted no hazard to marine aquatic life. The H_2S levels in routine Project discharges are expected to be significantly lower than those that have been shown to cause harmful effects in marine fish (refer to Section 6.3.4). Consequently no significant H_2S effects are likely from the discharge of produced water.

Although formation waters were not available for testing when the Deep Panuke discovery was made, information on produced water chemistry was adopted from the Musquodoboit Wildcat drill stem tests. It is anticipated that this chemistry is representative of Deep Panuke. Analysis of trace as well as major element concentrations within this produced water indicates that the initial mixing of the produced water with cooling water (dilution of 68:1) and subsequent discharge will not result in a significant impact on water quality with regard to trace metals.

There are no specific data for nutrient concentrations in produced water (NO_2-N, PO_3-P, SiO_2), however, modeling of effluent plume dynamics indicates that the average total dilution of the produced water component in the near-field is from 500:1 to 1,000:1. Any nutrients in the produced water stream would not result in a significant effect on the near-field water quality.

Online oil monitors, backed up with platform based laboratory facilities, are currently proposed for produced water sampling. If online monitoring cannot be provided reliably and economically, a sample laboratory facility approach will be employed. By meeting or improving upon the OWTG (NEB *et al.* 1996, and updates) criteria, it is unlikely that water quality will be significantly affected by hydrocarbons from produced water during Project operation.

Other Operational Discharges

Sanitary and food waste will be macerated to a particle size of 6 mm or less prior to ocean discharge, in accordance with the OWTG. Deck drainage water could contain traces of petroleum hydrocarbons such as lube oils, helicopter fuel, and diesel fuel. Deck drainage will be treated using cartridge-style water polishers and tested prior to discharge. Deck drainage will comply with OWTG (NEB *et al.* 1996, and updates) of 15 mg/L or less of hydrocarbon prior to ocean discharge. Every effort will be made to prevent chemical contamination on decks which could be entrained in deck drainage. Storage areas for totes containing chemicals and petroleum products will have secondary containment to prevent discharge onto deck surfaces. With these procedures in place, under normal operating conditions, marine water quality will not be significantly affected by these operational discharges.

Vessel Discharges

As with construction, all Project vessels will adhere to applicable regulations (*e.g.*, MARPOL) with respect to the use and release of fuel and lubricants and other waste materials (*e.g.*, solid waste, bilge) at sea. EnCana will require all contract vessel operators to adhere to the WMP. Project related vessel traffic during Project operations will therefore not have a significant effect on marine water quality.

In summary, by adhering to applicable regulations and guidelines, implementing mitigation measures, applying standard industry procedures, the operational phase of the Deep Panuke Project will not result in a significant adverse effect on marine water quality. This conclusion is further demonstrated in Sections 6.3.3 to 6.3.6 with regard to potential water quality effects on other VECs during Project operation.

Decommissioning

Decommissioning and abandonment will be performed in accordance with the regulatory requirements applicable at the time of such activities. Requirements for eventual removal of facilities will be taken into account during the detailed design phase. The abandonment/recovery of offshore facilities may result in some minor effects to water quality (*e.g.*, increased SPM due to seafloor disturbance), although any such increase will be localized and of a short-term duration. The potential presence of contaminants that could be encountered during recovery and transportation of the facilities will be taken into account. A Decommissioning Plan will be developed for the Project, which will provide detailed procedures for decommissioning onshore and offshore facilities (refer to Appendix D).

Decommissioning is not predicted to have a significant adverse effect on water quality.

Malfunctions and Accidents

Malfunctions and accidental events which could have implications for marine water quality include platform spills, blowouts, and pipeline ruptures.

Platform Spills

Storage areas for totes containing chemicals and petroleum products will have secondary containment to prevent discharges onto deck surfaces. Drainage from equipment areas on platforms will be directed through a header system to a collection tank to an oil/water separator treatment unit on the production platform. All offshore platforms and drilling rigs will have spill mitigation and clean-up equipment on board to respond to any deck spills. Absorbent pads and dry chemicals will be used immediately in the event of a spill to reduce the potential of spilled material entering the water. Any spills from the platform to the marine environment will likely be small in quantity and frequency and will disperse rapidly (refer to Chapter 3). These small platform spills will be mitigated through development and application of EnCana's Spill Response Plan (refer to Section 4 and Appendix D). The Spill Response Plan will become an integral training component for all offshore EnCana and contractor staff, as applicable.

It is the responsibility of all EnCana employees and contractors to report any accidents, incidents or spills to the Offshore Installation Manager for immediate action. EnCana will report all spills to the CNSOPB. The standby vessel in the field will also be tasked, as part of its regular duties, to observe and report any spills from the facilities. In summary, it is unlikely that platform spills will significantly affect marine water quality.

Well Blowouts

Accidental events which could have the most widespread implications for marine water quality are well blowouts. A production well blowout would release raw gas into the marine environment, and a subsea blowout of the injection well could release liquid hydrocarbon (condensate) as well as H_2S gas into the marine environment. An analysis of the probability of these spills, and fate and behavior modeling, is presented in Section 3. A number of safeguards (*e.g.*, blowout preventors and SC-SSSV) to prevent such accidental events have been incorporated into the Project design (refer to Section 2.9.3). The probability of a blowout is extremely low, with the significance of potential effects dependant upon the nature and magnitude of the event. In addition to design measures to minimize the probability and potential duration of such major releases, EnCana will implement an AERCP and a Spill Response Plan to further reduce the severity of potential environmental effects in the unlikely event a major spill were to occur (refer to Appendix D). These Plans will comply with all applicable regulatory requirements and become an integral part of EnCana's overall environmental management planning structure (refer to Section 4). Potential effects from blowouts on marine environmental receptors are considered in Section 6.3.3 to 6.3.6.

Pipeline Rupture

The release of natural gas (primarily methane) from a subsea pipeline rupture will cause localized, non-significant effects on water quality and associated VECs. In the unlikely event of a pipeline rupture, natural gas (composed largely of methane) will rise to the surface at speeds between 5 to 10 m/s and dissipate into the atmosphere. The toxic potential of natural gas to water column species is expected to be low because worst case concentrations of natural gas constituents (*e.g.*, methane, carbon dioxide, nitrogen and hydrogen sulphide) are below effect concentrations (Howard and Meylan 1997). The probability of a pipeline break is considered very low (refer to Section 3.4).

Summary

Releases containing condensate (*i.e.*, blowouts) or H_2S (injection well blowout) can have relatively widespread adverse effects on VECs potentially affected by reduced water quality (*i.e.*, fish, birds, marine mammals, benthos). However, given the widely distributed nature of VECs in the platform area, the ability of many species to detect and avoid areas of lowered water quality, and likely limited probability and duration of a major release, it is unlikely that VECs will be significantly affected at a population level. Significant adverse effects on VECs that rely on water quality due to malfunctions or accidental events are not considered likely; significant adverse residual effects on water quality are thus also not predicted.

6.3.2.5 Cumulative Effects Assessment

Past and existing projects and activities have, to varying degrees, affected marine water quality on the Scotian Shelf. These include domestic and international vessel traffic, oil and gas exploration and production, and fishing activity. The effects of these other past and present activities are reflected in the description of the existing (baseline) water quality conditions (described in Section 6.1). The existing data for the Project area do not indicate any particular water quality concerns, though occasional events, such as illegal discharges from passing vessels have been reported offshore Nova Scotia.

On-going and future projects and activities in the region which may affect marine water quality include: vessel traffic; the SOEP (existing and future development); offshore petroleum exploration drilling activity and seismic exploration; commercial fishing; and potentially, the future Blue Atlantic, Neptune and Hudson Energy projects. A number of these project activities have or would have similar discharges to the marine environment as the proposed Project, and thus, similar effects on marine water quality. Like the Deep Panuke Project, these other projects and activities will, however, also be subject to specific guidelines and regulations to prevent and minimize their environmental effects. These guidelines and regulations are regularly reviewed and refined to provide ever-increasing protection to the marine environment. In addition, developers are applying new methods and technology to reduce the potential for potential effects on the environment. The potential effects of the Deep Panuke Project on marine water quality are likely to be minor, localized and of relatively short-term duration. Given the widespread spatial and temporal distribution of these future projects and activities, there is limited potential for the effects of these actions to interact with those of the proposed Project. It is therefore not likely that the Deep Panuke Project will result in significant cumulative environmental effects in combination with other projects and activities.

6.3.2.6 Follow-up and Monitoring

Environmental compliance monitoring (ECM) for marine discharges, including toxicity testing of species deemed appropriate by Environment Canada, will be conducted to verify adherence to applicable regulatory requirements and conditions of approval. ECM will primarily involve monitoring for conformance with the discharge limits specified in the OWTG (NEB *et al.* 1996, and updates). The ECM program will be specified in the EPP to be developed by EnCana. EEM for water quality will be undertaken as required and in consultation with regulators. Implementation of ECM will provide early identification of regulatory exceedences to EnCana and regulators (through required reporting), and allow for prompt remedial action. At a minimum, this will include monitoring of water quality after a significant spill, in conjunction with monitoring of various biological components (*e.g.*, birds, fish). The EEM program will be specified in an EEM Plan to be developed by EnCana. EEM will help detect any adverse effects on environmental receptors due to reduced water quality. This may include the monitoring of environmental receptors (*e.g.*, marine biota) which may be affected by Project related changes in marine water quality. These plans will become part of EnCana's overall environmental management planning structure (refer to Section 4).

6.3.2.7 Sustainable Use of Renewable Resources

No significant adverse residual environmental effects on marine water quality are predicted; therefore, further assessment regarding sustainable use of renewable resources is not required.

6.3.2.8 Summary of Residual Environmental Effects Assessment

Project construction, operation, and decommissioning activities are not predicted to have a significant residual effect on marine water quality. Malfunctions/accidents, specifically those related to well blowouts and pipeline ruptures would have an effect on marine water quality, but the effects on VECs dependant on water quality are not likely to be significant. EnCana's design prevention measures and AERCP and Spill Response Plan will reduce the probability of accidental releases and minimize environmental effects. The proposed Project is therefore not likely to result in a significant adverse effect on marine water quality. Tables 6.28 and 6.29 summarize the residual environmental effects on marine water quality.

Table 6.28 Residual Environmental Effects Assessment Matrix: Marine Water Quality

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		
CONSTRUCTION									
Infrastructure installation (pipelines, platforms)	• Sedimentation (A)	• Efficient installation with minimal seabed disturbance (including prefabrication onshore) • Use of silt curtains during nearshore dredging (if required)	1	2	3/3	R	2	N	3
Hydrostatic Testing	• Discharge may contain biocides, oxygen scavengers, and corrosion inhibitors (A)	• Bioassay and plume dispersion modeling • Controlled discharge at platform diluted with cooling water	2	2	1/1	R	2	N	3
Development Drilling	• Increased SPM (A)	• Management of drill waste to minimize discharges • No ocean discharge of SBM/EMOBM • Reduced disposal of bulk WBM through batch drilling • Compliance with CNSOPB disposal requirements • Adherence to Offshore Chemical Selection Guidelines and CMP	2	2	3/6	R	2	N	3

Table 6.28 Residual Environmental Effects Assessment Matrix: Marine Water Quality

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		
Vessel Traffic	• Water quality degredation associated with bilge and ballast discharges (A)	• Compliance with applicable legislation and regulations • Adherence to WMP	1	5	5/6	R	2	N	3
Onshore Construction	• Sedimentation of nearshore waters (A)	• Adherence to the Onshore Construction EPP • Compliance with DFO and NSDEL guidelines	1	2	2/1	R	2	N	3
OPERATION									
Produced Water	• Water quality degradation (A)	• Treatment / testing to meet or exceed OWTG • Dilution of treated produced water with cooling water	2	2	5/6	R	2	N	3
Other Project-related discharges (*e.g.*, deck drainage, sewage, cooling water, etc.).	• Discharge to marine environment (A)	• Treatment in accordance with OWTG • Adherence to WMP	1	2	2/6	R	2	N	3
Vessel Traffic	• Water quality degradation associated with bilge and ballast discharges (A)	• Compliance with applicable regulatory requirements • Adherence to WMP	1	5	5/6	R	2	N	3

Table 6.28 Residual Environmental Effects Assessment Matrix: Marine Water Quality

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		
MALFUNCTIONS AND ACCIDENTS									
Well Blowout	• Release of hydrocarbons from development well and injection well (A) • Release of H_2S from injection well (A)	• Design measures (*e.g.*, BOP and SC-SSSV) • Implement AERCP and Spill Response Plan	3	2	2/0	R	2	N	3
Pipeline Rupture	• Release of methane (A)	• Pipeline design to codes/standards • Design and installation to maintain pipeline integrity (*e.g.*, scour protection, "trawler-proof", burial in depth less than 85 m) • Leak detection and shut off valves • Implement AERCP	2	2	1/0	R	2	N	3
Platform Spills	• Release of hydrocarbons (A)	• Design prevention (*e.g.*, secondary containment, oil/water separation) • Spill prevention procedures/training • Spill monitoring and reporting • Implement AERCP and Spill Response Plan	1	2	1/1	R	2	N	3

Table 6.28 Residual Environmental Effects Assessment Matrix: Marine Water Quality

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		

KEY

Magnitude: 1 = Low (*e.g.*, undetectable or negligible change to existing conditions) ; 2 = Medium (*e.g.*, increase but within standards and objectives; 3 = High (*e.g.*, causing exceedances or impingement upon standards and objectives).
Geographic Extent: 1=<500 m^2; 2=500 m^2 – 1 km^2; 3=1-10 km^2; 4=11-100 km^2; 5=101-1000 km^2; 6=>1000km^2
Duration: 0 = highly unlikely; 1=<1month; 2=1-12 months; 3=13-36 months; 4=37-72 months; 5=>72 months
Frequency: 0= unlikely to occur; 1=<11 events/year; 2=11-50 events/year; 3=51-100 events/year; 4=101-200 events/year; 5=>200 events/year; 6=continuous
Reversibility: R = Reversible; I = Irreversible
Ecological/Socio-cultural and Economic Context: 1=Pristine area; 2 = Area affected by human activity; 3 = Evidence of adverse effects
Residual Environmental Effect Rating: S=Significant Adverse Environmental Effect; N=Nonsignificant Adverse Environmental Effect; P=Positive Environmental Effect
Confidence: 1=Low level of confidence; 2=Medium level of confidence; 3=High level of confidence

Table 6.29 Residual Environmental Effects Summary: Marine Water Quality (All phases)			
Phase	Residual Environmental Effect Rating	Likelihood of Significant Adverse Effects	
		Probability of Occurrence	Scientific Uncertainty
Construction	N	N/A	N/A
Operation	N	N/A	N/A
Decommissioning	N	N/A	N/A
Malfunctions and Accidents	N	N/A	N/A

KEY

Residual Effects Rating: S=Significant Adverse Environmental Effect; N=Non-significant Adverse Environmental Effect; P=Positive Environmental Effect
Probability of Occurrence: Based on professional judgement; 1 = Low; 2 = Medium; 3 = High; N/A = Not applicable (effect is not predicted to be significant)
Scientific Uncertainty: Based on scientific information and statistical analysis or professional judgement; 1 = Low level of confidence; 2 = Medium level of confidence; 3 = High level of confidence; N/A = Not applicable (effect is not predicted to be significant)

6.3.3 Marine Benthos

The marine benthic community is important as a component of the marine ecosystem and also in its connection to commercial fisheries. Environmental effects on benthic fauna may affect the success of finfish and/or shellfish populations in the area. Project discharges may affect benthic habitat and communities on the seabed through deposition of drill cuttings and muds, disturbance of sediments from pipeline installation, and discharge of produced water or hydrocarbons during an accidental event. Resulting changes in sediment quality may affect the quality of habitat for demersal fish species, benthic communities, and commercial species that feed on them. Organic and inorganic contaminants, if present in sediments, may be ingested by benthic organisms or become biologically available if re-suspended into the water column. Presence of pipeline infrastructure on the seabed, as well as the platforms, may also have implications on benthic habitat. Discussions of potential impacts on marine fish are found in Section 6.3.4. Discussions of potential effects on fisheries are found in Section 7.3 and the SEIS (DPA Volume 5). Marine benthos was identified as a VEC based on regulatory and public concern, and professional experience with other petroleum industry projects.

6.3.3.1 Boundaries

The spatial boundaries for the assessment of marine benthos are based on: experience in similar project environments; sediment sampling; sediment dispersion modeling; and, video observations. These boundaries contain a near-field component (*i.e.*, 500 m from platforms) to accommodate potential acute effects such as smothering of benthic organisms, and a far-field component (*i.e.*, 10 km) to accommodate transport of lower concentrations of SPM in the benthic boundary layer. A spatial boundary of 2 km wide has been assigned to the pipeline corridor (zone of influence for anchor locations and cables, if applicable). The temporal boundaries of the assessment are continuous until cessation of the discharges from well development, completion of pipeline installation, and recovery to background conditions. For the case of infrastructure presence in the marine environment, the temporal boundary includes the operational period of the Project and thereafter until the structures are removed.

6.3.3.2 Residual Environmental Effects Evaluation Criteria

A **significant** adverse environmental effect is one that alters valued benthic habitat either physically, chemically, or biologically, in quality or extent, to such a degree that there is a decline in abundance and/or change in composition and distribution of the benthic community beyond which natural recruitment (reproduction and immigration from unaffected areas) would not return that community to its former level of diversity within five years following cessation of Project activities that could interact with the benthos (*i.e.*, pipeline installation, discharge of WBM drill waste).

A **positive** effect may enhance habitat quality or quantity or increase species diversity.

6.3.3.3 Potential Interactions, Issues, and Concerns

Benthic macroinvertebrate organisms live and feed on the seafloor. Because most of these organisms are sedentary or sessile and feed upon particulates raining down through the water column (suspension feeders) or directly upon the sediments (deposit feeders), they can be vulnerable to contaminant accumulation and high suspended particulate loads.

Potential issues and concerns related to marine benthos include:

- displacement and smothering of benthic organisms directly within the footprint area and adjacent areas of sediment deposition during pipeline installation;
- disturbance to the benthos and benthic communities during nearshore blasting, if applicable;
- disturbance to the benthos from pipeline anchors and cables, if applicable;
- smothering of benthic communities from deposition of drill cuttings/drilling muds during well development;
- change in biodiversity from organic enrichment or toxicity from drilling muds;
- change in sediment particle size distribution or physical nature of the sediments due to deposition of drill cuttings/drilling muds during well development;

- contaminant uptake by benthic organisms as a result of drill mud/cuttings and produced water disposal;
- the presence of structures and unburied or settled pipelines may affect movement of benthic invertebrates and increase hard substrate habitat (colonized by local flora and fauna) in otherwise barren sandy or soft bottom areas;
- platforms may attract fish which in turn may increase predation pressure on the benthic community; and
- in the unlikely event of an accidental blowout or pipeline rupture, contamination of the benthos at the point of the breach through adherence of hydrocarbons to particulate matter.

6.3.3.4 Analysis, Mitigation and Residual Environmental Effects

Construction

Installation of Structures

Project interactions with nearshore and offshore benthic habitat and communities will occur during the construction phase. Physical disruption and alteration, of the seabed will occur as a result of placement of the structures on the substrate (*i.e.*, platform legs and pipeline footprints). These activities will displace a limited number of benthic organisms. Settling of suspended sediments may alter habitat adjacent to seabed disturbances. These effects are considered reversible, as disturbed areas will soon recolonize. The species expected to be affected in the intertidal and shallow subtidal zone by landfall trenching include: *Fucus vesiculosis*, *Laminaria* spp., blue mussels, *Corallina officinalis*, barnacles, amphipods, isopods, periwinkles, and sea stars. These are all species ubiquitous to the coastal rocky intertidal zone.

The installation of platforms and pipelines is not anticipated to change sediment chemistry. Trenching the subsea pipeline in shallow water may temporarily alter sediment grain size; however, conditions should revert back to those naturally occurring within months through sediment transport processes. It is predicted that the zone of influence on marine benthos due to trenching activities will be approximately 20 m wide (10 m on either side of the pipeline).

If an anchored pipelay vessel is used, there will be additional disturbance to the marine benthos associated with anchor placement and cable movement. The zone of influence for these effects are limited to 1 km on either side of the pipelay vessel. A maximum of 5 % of the total area within the 2 km wide corridor may be disturbed by anchor handling activities. This disturbance will be reduced through application of an anchor handling plan. Elements of this plan could include: anchor placement to avoid sensitive areas where practical (*e.g.*, inshore lobster and scallop habitat); use of midline cable buoys to reduce the length of cable on the seafloor in sensitive areas where complete avoidance is not practical; and reduction of number of anchors deployed where operating conditions allow. Effects from anchor handling activities will be localized and temporary. Recovery of disturbed benthic communities is predicted to take less than five years and will be assessed as part of an EEM program. No significant effects are predicted from subsea pipeline installation.

Permanent benchmark sites established for the nearshore SOEP EEM demonstrated no change in bottom conditions throughout Stormont Bay from trenching-related activities and that seafloor material typically did not move outside the immediate area of the pipeline route (SEEMAG 2001a). Detailed EEM surveys conducted in the nearshore from shoreline to 1000 m seaward showed kelp and other seaweeds reestablishing shortly after pipeline installation (SEEMAG 2001b). Marine plant life and bottom dwellers recolonized and moved back into disturbed areas. Full recovery of habitat over the pipeline took up to three years. A widespread die-off of sea urchin along the eastern shore over the post construction period was attributable to factors other than construction of the pipeline (Li and Cormick 1982; Scheibling and Hennigar 1997; SEEMAG 2001b).

Blasting, if required, will be conducted within 300 to 500 m of the shoreline and in accordance with the Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (Wright and Hopky 1998). Keevin and Hempton (1997) have reviewed the environmental effects of underwater blasting. The results of all studies reviewed indicated that invertebrates are insensitive to pressure related damage from underwater explosions (apart from direct exposure to pressure wave). This may be attributed to the fact that invertebrates lack a gas containing organ(s). Toxic gaseous by-products of explosions are chiefly carbon monoxide and nitrous/nitric oxides of the detonation reaction. The selection of blasting compound is important since certain compounds produce insignificant toxic gas production and, consequently, little, if any detrimental effect to the environment. No interaction with the nearshore marine benthos is predicted if directional drilling is used to install the pipeline in the nearshore.

No significant adverse effects on the marine benthos are likely to result from pipeline or platform installation, as habitat disturbances will be localized and temporary during construction, and it is anticipated that benthic communities will colonize exposed structures over one to several seasons. Physical effects on the marine benthos will be minimized during construction through the prefabrication of the majority of structures onshore, and topside on the barge. A seabed debris survey will be conducted prior to pipeline and platform installation to provide further data to mitigate effects on marine communities near Project facilities. EnCana will consult with DFO and Environment Canada on HADD and Disposal at Sea permits once engineering design and installation methods have been finalized.

Development Drilling

No SBM or EMOBM and associated cuttings will be discharged to the marine environment during development drilling for the Project. WBM and associated cuttings will be discharged overboard as is permitted by the OWTG (NEB *et al.* 1996, and updates). Bulk releases of WBM will be minimized by batch drilling to the extent possible. Drill waste dispersion modeling presented in the EIS (DPA Volume 4) has been updated below, to reflect the latest worst case drilling scenario, drilling eight wells and using WBM for all hole sections.

WBM cuttings will be released, more or less continuously, from the surface after processing during the drilling phase. Water based cuttings are expected to be in the coarse to fine sand size range with settling rates in the range of 0.3 m/s to 0.03 m/s. Because the discharge rate is low on average, only the dynamic settling of individual particles need be considered.

It is estimated that 412 m^3 of cuttings particles will be generated from each of the six production wells and the additional "contingency" well, plus 270 m^3 from the injection well, for a total volume of 3,154 m^3. The distribution of this material on the bottom will be determined primarily by the advection caused by currents during decent of the particles. Based on the settling rates given above, and a site depth of 40 m, the settling time of particles in the water column will be from 130 to 1300 seconds. The current regime is dominated by tides, which constitute about 90% of the total energy. Tidal currents rotate clockwise and range in strength from about 10 cm/s to about 35 cm/s over the monthly spring/neap cycle. Average tidal current speed is about 25 cm/s. Based on the average tidal current and range of particle settling times, the deposition area will extend to a distance of about 32 m for the fastest settling particles and to about 320 m for the slowest settling particles. On occasion, wind generated currents will oppose the tide with the result that the current will diminish to zero so that material will also be deposited directly below the discharge pipe.

Given the variables involved, it is reasonable for assessment purposes to assume that the material forms a cone with a base radius determined by the range of particle settling rates and average tidal current. This results in a range in base radius of 32 m to 320 m. Smothering of benthic organisms can result if the thickness of the cuttings layer exceeds 1 cm (Bakke *et al.* 1989). If the radius is 32 m, the cuttings mound could attain a maximum height of 2 m under the discharge pipe. The area affected by deposition in excess of 1 cm would extend nearly to the edge of the cone (32 m) (0.32 ha). In the latter case, the maximum height of the mound would be 2 cm and the area of deposition in excess of 1 cm would extend to 160 m, covering an area of approximately 8.04 ha.

Cuttings piles associated with SOEP are lasting longer than predicted as the NovaPlus SBM cuttings are cohesive (SEEMAG 2001b). WBM cuttings do not have that characteristic. Generally, deposits from SOEP have been much smaller and thinner than predicted (500 m), observable within 70-100 m of the platforms (SEEMAG 2001b; 2000a). The cuttings pile at Venture is no longer present following two years cessation of drilling discharges of SBM cuttings. The Thebaud SBM cuttings pile reduces in size annually. Site surveys of drill waste related to the Cohasset Project have indicated that cuttings piles were not evident more than 50 m from the Cohasset and Panuke platforms, or Well H-08 several months following drilling.

In the dynamic and energetic environment of the Sable Bank, WBM cuttings piles from the Project are not expected to persist for more than a year. Experience at other sites in eastern Canada (Hurley 2000; Taylor 2000) shows that WBM discharged cuttings and muds were dispersed by wave action and currents. Following dissipation of the cuttings pile, the benthic community is expected to recover within a further 2 to 3 years through reproduction and migration from other areas.

No permanent change in grain size has been observed at any of the Atlantic Canadian offshore petroleum projects outside of the nearfield (100 m) area. The post drilling monitoring program conducted in 1993 for the Cohasset Project did not show evidence of an adverse effect on benthos biomass or diversity, nor was there an apparent change in sediment grain size in the vicinity of, or directly adjacent, to the rig (John Parsons & Associates 1994).

WBM will be released typically in a bulk discharge when mud types are changed. For the six production wells and the additional "contingency" well, there should be a one-time release of WBM of 1075 m^3 per well. The discharge for the injection well will be 685 m^3. The total volume of WBM released over the well development phase is estimated at 8,210 m^3.

The generic assessment for exploration drilling (Thomson *et al.* 2000) showed that a bulk release of WBM creates a turbulent plume which will sink to a level of neutral density in sufficiently deep water. Model results by Andrade and Loder (1997) for the Cohasset Project indicated that the plume reaches the seafloor when the currents are low (<0.085 m/s) for all mud densities and conditions of stratification except when mud densities are low and stratification is strong. In all cases with typical mud densities, the plume will reach the lower third of the water column, thus interacting with the seafloor.

The basis of WBM modeling is that WBM can remain in a dynamic benthic boundary layer, the thickness of which can range from metres to tens of metres, depending on ambient currents (Hannah *et* *al.* 1995). The boundary layer model is complex; the modeling is further complicated by the fact that, while most of the particles in WBM are small (< 50 µm), they tend to flocculate when discharged in seawater, potentially increasing the settling velocity of the particles by 1-2 orders of magnitude (Gordon *et al*. 2000).

A recent comprehensive treatment of boundary layer dynamics (Thomson *et al.* 2000) focused on WBM releases at several Scotian Shelf sites including Sable Bank. Modeling results for the Sable Bank site showed that peak mud concentrations of 10 mg/L could persist in the boundary layer for several days and peak levels of 1 mg/L could persist for a 10-day period. The area of the bottom affected was shown to have a typical radius of up to approximately 10 km. The location of the center of this area will be advected by tidal and mean currents and can vary with season, spring/neap cycle, etc.

Laboratory research subjecting scallops to chronic exposure (24-72 days) of WBM indicated the following effects.

- A WBM can cause low mortality at concentrations between 0.5 and 10 mg/L (Cranford *et al.* 1999).
- Exposure of scallops to barite in suspended particulate matter (SPM) at low concentrations of 0.5 mg/L caused sublethal effects (cessation of gonad growth) (Cranford and Grant 1990).
- Bentonite concentrations of 1 mg/L were shown to cause sublethal effects on scallops (Cranford and Grant 1990).
- Scallop growth was enhanced by a mixture of WBM and fine cuttings particles at concentrations <10 mg/L due to increased food availability from adsorbed organic matter onto the particles (Cranford *et al.* 1999).

As reported by Gordon *et al.* (2000), no effects on Atlantic sea scallops growth were observed at mud concentrations (bentonite) of 2 mg/L or less, however the "no effects" concentration for barite was estimated to be 0.1 mg/L. These effects were noted based on laboratory trials of 24 to 72 days exposure to WBM. DFO catch and effort data (1996-2000) show some records of scallop catch within 12.5 km from the Deep Panuke site, however large concentrations of scallop beds are located approximately 35 km from the site. No interaction between WBM and commercial concentrations of scallops is anticipated. Lobster and snow crab, which are not filter-feeders, are not common in the shallow sandy sediment of the Deep Panuke area of the Sable Island Bank and are therefore not likely to be affected by discharges of WBM and associated cuttings. No significant adverse effects on the benthic habitat is likely to result from the short duration (worst case of 10 days) of exposure to a bulk release of WBM. This is consistent with EEM observations for the SOEP and Cohasset Project. No effects were noted from WBM discharges related to the SOEP over a three year period (Hurley 2000). On only one occasion was a drill mud plume detected with elevated SPM at 10 m depth, 500 m from the platform

(SEEMAG 1999a). It was therefore concluded that the effects of the WBM discharges did not extend beyond 500 m of the platforms.

At the end of the drilling program, 300 m^3 of completion fluid (for each well) will be pumped to the surface and discharged as a bulk release. This fluid is composed of filtered seawater or freshwater, which may have some added biocide, oxygen scavenger and corrosion inhibitors. Given its near neutral density, it will remain on, or near, the sea surface and is not predicted to impact the benthic community.

No significant adverse environmental effects are therefore predicted on the marine benthos due to Project construction and drilling activities. Further detail on drill waste discharges is found in Section 2.5.4

Operation

Presence of Structures

While the physical presence of Project infrastructure (platforms, protective mattresses, and pipelines) will create a long-term alteration of benthic habitat, the areas will recolonize with local species within one to three years (Scarratt 1968). Concrete mattresses and rocks used to stabilize the pipeline will provide a hard stable substrate that creates benthic habitat in what is otherwise a predominantly sandy mobile environment. These hard surfaces will be colonized by a variety of local marine flora and fauna (creating a "reef" effect). Such an effect was noted on the existing Panuke and SOEP platforms. In particular, EEM surveys of the protective mattresses at Thebaud, Venture and North Triumph show mattresses have been colonized by seaweed, sea cucumbers, snow crabs, Jonah crabs, mussels and fish (SEEMAG 2001a; 2001b). Underwater video surveys around SOEP platforms showed juvenile gadoids, blue mussels and crabs (SEEMAG 2001b). Flounders, sculpins, hermit crabs and Jonah crab were observed on the seafloor in association with mussels which sloughed off the Panuke platform. Species observed to colonize the SOEP pipeline one year after installation included starfish, sea urchins and sea anemones (SEEMAG 2001b). Project structures also create niches on the seafloor and water column in which juvenile demersal and pelagic species can find refuge. This reef effect is anticipated to have a minor positive effect on the benthic community in the Project area. The positive reef and refuge effect associated with the platform structures may be temporarily offset by a localized reduction in sediment quality from WBM discharges.

With regard to concerns of interference of crustacean migration due to the presence of the subsea pipeline, it is anticipated that lobsters and other crustacea will be able to navigate unburied portions of the subsea pipeline. American lobsters have well developed walking legs that also afford great agility in climbing, especially over relatively smooth surfaces such as rock faces in canyon environments. In addition, American lobsters exhibit abdominal flexing which raises the individual off the bottom and propels it through the water column. This flexing may extend for several seconds and propel the lobster in excess of three metres (Scrivener 1971). Concrete coating on the subsea pipeline provides a rough surface which would aid movement of lobster on the pipe. The colonization of the pipeline by other benthic organisms will also increase the roughness of the pipe surface, thereby further facilitating the capability of crustaceans to climb over the pipe. Crab species (including snow crabs) were observed on and along sides of the SOEP pipeline (SEEMAG 2001b) and lobsters have been observed in underwater video negotiating a large diameter subsea discharge pipe for another industrial project (Abitibi-Price 1990). Considering these factors, it is highly unlikely that the proposed subsea pipeline, where unburied, would constitute a significant concern as a physical barrier to migration of crustaceans on the Scotian Shelf.

Concerns have also been identified that noise produced by the subsea pipeline could result in avoidance by crustaceans. Background noise on the Scotian Shelf is strongest at low frequencies, between 50 and 100 Hz (refer to Table 2.7 for typical underwater noise levels for ambient and human generated noise). Detection of such low frequency sound levels by crustacea, such as lobsters and crabs, is not well defined. American lobster, for example, have no specific hearing organs and hearing has not been demonstrated (Cohen and Dijkgraaf 1961); yet this species can detect pressure waves (Offutt 1970). In addition, there is no documented evidence to indicate that chronic low frequency sound induces attraction or avoidance behavior in crustacea, such as crabs or lobsters. Low frequency sound produced within a subsea pipeline is caused by turbulent flow within the pipe. The degree to which this sound would be transferred to the surrounding water and propagate through the water would, in part, be a function of the pressure within the pipe, and pipe diameter, wall thickness and coating. Any external coating or covering of the pipe would further reduce the propagation of low frequency sound. In addition, low frequency sound attenuates rapidly in shallow water (< 50 m) where water depth is shallow relative to wavelength. Considering all of the above factors, the low frequency sound that reaches the surrounding water as a result of turbulent flow within a subsea pipeline, would likely be less than that of background noise levels; it is therefore unlikely to be noticed by crustaceans.

Routine Operational Discharges

Operational discharges generated at the offshore platforms, including produced water, will not significantly affect benthic communities, as they will be treated to comply with the OWTG (NEB *et al.* 1996, and updates), and quantities reaching the seafloor will be negligible, if any (refer to Appendix C for discharge modeling results). Effects of produced water on pelagic eggs and larvae are discussed further in Section 6.3.4.4. While there have been studies on the effects of produced water on pelagic larvae of benthic species (*e.g.*, Raimondi and Schmitt 1992; Krause *et al.* 1992), it is anticipated that these effects would be similar to those predicted for early life stages of pelagic species (*i.e.*, not significant at a population level). It is possible that particles (*e.g.*, trace metals) may separate from the discharge and sink to the benthic boundary layer (Lee 2000), however, this complex pathway is a subject of scientific debate and has not been modeled for this assessment. Modeling shows that produced water discharges will be diluted 500 to 1000 times within the first 20 m from the effluent pipe. This is consistent with monitoring results from SOEP. Produced water was not detected within the immediate vicinity of the discharge caisson (SEEMAG 2001b). Contaminant uptake is therefore not considered to be an issue for marine benthos.

Research is being conducted through the Program of Energy Research and Development (PERD) to investigate the impacts of produced water discharges in the Atlantic Region. EnCana will review results of produced water studies and adapt their EEM program as appropriate.

Based on the above discussion, there are not likely to be any significant adverse environmental effects on the marine benthos from the presence and operation of the Project.

Decommissioning

Decommissioning activities are not expected to interact with the benthic environment, except where structures above the seafloor are removed. In this case, there may be some temporary disruption of sediments and disturbance to organisms. These effects would be similar to the effects of construction. Any reef or refuge effects would be reversed once facilities are removed. No significant adverse environmental effects from decommissioning are predicted.

Malfunctions and Accidents

Any effects on the benthos in the unlikely event of a spill or blowout from a platform would be localized near the area of release, as the raw gas (including condensate) is buoyant and would rise in the water column (refer to Section 3.5.2). Market-ready gas in the pipeline to shore would also rise to the surface in the event of a pipeline break. Any localized effect on the benthos would recover through recolonization by local species. Potential adverse effects of malfunctions and accidents on the marine benthos are not considered to be significant.

6.3.3.5 Cumulative Effects Assessment

Projects and activities in the study area that may interact cumulatively with marine benthos include past and present offshore platforms (Cohasset Project and SOEP), the SOEP pipeline, exploration drilling associated with offshore petroleum exploration and commercial fishing. While it is anticipated that marine benthos may be subject to incremental effects from future exploration activities in the study area, it is not anticipated that ongoing or future projects along the Scotian Shelf edge (including the proposed Blue Atlantic, and Hudson Energy projects) will contribute to cumulative effects.

Land-based sources of pollution were considered as a potential contribution to cumulative effects on benthos, particularly in the nearshore. Results of a survey completed for EnCana in 2001, however, found that in the nearshore Goldboro area, with the exception of one sample, the petroleum hydrocarbon concentrations were under the laboratory detection limit. This survey also found no evidence of contaminated sediments from old mine tailings, reported to possibly occur in the area.

Based on ongoing monitoring programs at SOEP, it is unlikely that any adverse effects due to construction or operation of the SOEP could interact cumulatively with Deep Panuke. The distance between the SOEP and Deep Panuke platforms (45 km to Thebaud and 23 km to the future platform at Alma) will further reduce the likelihood of cumulative effects on marine benthos. Similarly, no significant adverse effects on the benthos have been observed from the installation and presence of the SOEP pipeline, and none are anticipated with the Deep Panuke pipeline; therefore, no significant cumulative effects on benthos from the presence of the two pipelines are predicted.

Exploration drilling activities are generally short term (60 to 90 days) in any one area, are localized and not likely to result in significant effects on marine benthos. In addition to the temporary, localized nature of exploration drilling, the potential for cumulative effects with Deep Panuke are further limited by the widely dispersed nature of these activities and lack of spatial and temporal overlap. Previous development and exploration drilling for the Cohasset Project and Deep Panuke are concentrated closely within the immediate Project area and monitoring has indicated that benthic communities have for the most part returned to their pre-drilling state. Since localized disturbances of the benthos from the current Project are expected to be temporary (one to three years), there is no significant cumulative effect anticipated with regard to past drill waste discharges. Future exploration drilling conducted by EnCana within the Panuke licence will have similar effects as those of the proposed development drilling program and no significant cumulative effects are anticipated.

In conclusion, there is currently no evidence of incremental degradation of benthic communities from oil and gas activities on the Scotian Shelf. Effects from discharges, as evidenced from EEM results, have been relatively localized, temporary and unlikely to overlap spatially or temporally with other projects. EEM conducted for the Deep Panuke Project (including baseline monitoring) has, and will continue, to provide information that will (in conjunction with monitoring data from other projects), begin to detect any widespread, incremental environmental changes. The EEM will detect and assess Project-induced changes in the environment, providing essential feedback to operational managers who can effect any necessary modifications to operational activities or emissions.

Messieh *et al.* (1991) reported that fishing boats have trawled or dredged 4.3 million square km of seabed on the eastern Canadian seaboard from 1985 to 1991. In this context, effects on benthos from drilling operations would result in negligible increases to the perturbation that already exists.

6.3.3.6 Follow-up and Monitoring

EnCana will include benthic habitat/community and sediment quality monitoring in the EEM program to be designed in consultation with stakeholders and the relevant regulatory authorities for both the nearshore and offshore regions. This program, which will be developed based on experience from the Cohasset Project and SOEP EEM programs will include potential toxicity, fate, and environmental effects of WBM and associated cuttings. EnCana will continue to support research initiatives related to the ecological risk of discharges of WBM and associated cuttings and will review the results of the research as they become available. Follow-up programs and mitigation will be adapted as necessary to reflect results of this research. A seabed debris survey will be conducted prior to pipeline and platform installation to provide further data to mitigate effects on marine communities near Project facilities. During ROV inspection of the BOP and riser installation, a survey of the seafloor around the well site for a cuttings mound will verify the prediction of likely effects. Mud logs will be reviewed to verify the volume of mud and cuttings discharged. Colonization of the exposed pipeline will be assessed during a pipeline monitoring survey.

6.3.3.7 Sustainable Use of Renewable Resources

No significant adverse residual environmental effects on benthic habitat are predicted, therefore, further assessment regarding sustainable use of renewable resources is not required.

6.3.3.8 Summary of Residual Environmental Effects

Due to the reversibility and limited duration, magnitude, and geographic extent of the potential adverse environmental effects, including cumulative effects, associated with the Project, no significant adverse residual environmental effects for marine benthos are predicted. A minor positive effect is predicted with regard to the addition of hard substrate associated with the platform structure and unburied portion of the pipeline creating a reef effect. The positive reef and refuge effect associated with the platform structures may be temporarily offset by a localized reduction in sediment quality from WBM discharges. Tables 6.30 and 6.31 summarize the residual environmental effects on marine benthos.

Table 6.30 Residual Environmental Effects Assessment Matrix: Marine Benthos

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects					Residual Environmental Effect	Level of Confidence
			Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context		
CONSTRUCTION									
Offshore platforms installation	• Benthic disturbance and sedimentation (A) • Habitat alteration (A)	• Prefabricate onshore and topside • Efficient installation with minimal seabed disturbance (including seabed debris survey)	1	2	2/6	R	2	N	3
Subsea pipeline installation	• Benthic disturbance and sedimentation (A) • Habitat alteration (A)	• Efficient installation with minimal seabed disturbance (including seabed debris survey) • Adherence to Guidelines for Use of Explosives in or Near Canadian Fisheries Waters and General Blasting Regulations • Implementation of anchor handling plan • Use of silt curtains during nearshore dredging (if required)	1	3	2/6	R	2	N	3
Development drilling	• Discharge of drill waste to displace benthic communities (A)	• No ocean discharge of SBM/EMOBM • Reduce disposal of bulk WBM through batch drilling • Compliance with CNSOPB disposal requirements	2	2	3/6	R	2	N	3

Table 6.30 Residual Environmental Effects Assessment Matrix: Marine Benthos

Project Activity	Potential Positive (P) or Adverse (A) Environmental Effect	Mitigation	Significance Criteria for Environmental Effects: Magnitude	Geographic Extent	Duration/Frequency	Reversibility	Ecological/ Social-cultural and Economic Context	Residual Environmental Effect	Level of Confidence
OPERATION									
Presence of structures	• Habitat loss / alteration (A)	• Minimize footprints of infrastructure	2	4	5/6	R	2	N	3
	• Artificial reef effect and substrate (P)	• No mitigation necessary	2	4	5/6	R	2	P	3
MALFUNCTIONS AND ACCIDENTS									
Well blowout or pipeline rupture	• Disturb benthic habitat in immediate area of subsea blowout or pipeline rupture (A)	• Prevention • Implement AERCP and Spill Response Plan	2	1	1/0	R	2	N	3

KEY

Magnitude: 1= Low: *e.g.*, specific group or habitat, localized, one generation or less, within natural variation; 2 = Medium: *e.g.*, portion of a population or habitat, 1 or 2 generations, rapid and unpredictable change, temporarily outside range of natural variability; 3 = High: *e.g.*, affecting a whole stock, population or habitat outside the range of natural variation.
Geographic Extent: 1=<500 m^2; 2=500 m^2 – 1 km^2; 3=1-10 km^2; 4=11-100 km^2; 5=101-1000 km^2; 6=>1000km^2
Duration: 1=<1month; 2=1-12 months; 3=13-36 months; 4=37-72 months; 5=>72 months
Frequency: 0= unlikely to occur; 1=<11 events/year; 2=11-50 events/year; 3=51-100 events/year; 4=101-200 events/year; 5=>200 events/year; 6=continuous
Reversibility: R=Reversible; I=Irreversible
Ecological/Socio-cultural and Economic Context: 1=Pristine area; 2= Area affected by human activity; 3=Evidence of adverse effects
Residual Environmental Effect Rating: S=Significant Adverse Environmental Effect; N=Nonsignificant Adverse Environmental Effect; P=Positive Environmental Effect
Confidence: 1=Low level of confidence; 2=Medium level of confidence; 3=High level of confidence

Table 6.31 Residual Environmental Effects Summary: Marine Benthos (All phases)			
Phase	Residual Environmental Effect Rating	Likelihood of Significant Adverse Effects	
		Probability of Occurrence	Scientific Uncertainty
Construction	N	N/A	N/A
Operation	N/P	N/A	N/A
Decommissioning	N	N/A	N/A
Malfunctions and Accidents	N	N/A	N/A

KEY

Residual Effects Rating: S=Significant Adverse Environmental Effect; N=Non-significant Adverse Environmental Effect; P=Positive Environmental Effect
Probability of Occurrence: Based on professional judgement; 1 = Low; 2 = Medium; 3 = High; N/A = Not applicable (effect is not predicted to be significant)
Scientific Uncertainty: Based on scientific information and statistical analysis or professional judgement; 1 = Low level of confidence; 2 = Medium level of confidence; 3 = High level of confidence; N/A = Not applicable (effect is not predicted to be significant)

6.3.4 Marine Fish

6.3.4.1 Boundaries

Interactions between marine fish and Project activities may occur at any time of the year, though different species and life cycle components vary seasonally. For example, eggs and larvae are most abundant during the summer and fall, but juveniles and adults of those same species are present year-round. The temporal boundaries for this assessment include the construction, operation and decommissioning phases of the Project.

Spatial boundaries for the assessment of marine fish are generally determined by the stock boundaries, representing the area within which a population is self-sustaining. The stock boundaries of many species considered in this assessment fall roughly within NAFO Division 4W, but may extend to the broader North Atlantic for migratory species such as tunas. Fish, including eggs and larvae, are also distributed spatially within different levels of the water column, ranging from the thin surface layer (neuston) to the ocean bottom (epibenthos). The spatial boundaries were set to the limits of NAFO division 4W to ensure that any effects that might be detectable at the "stock" level would be included.

6.3.4.2 Residual Environmental Effects Evaluation Criteria

A **significant** adverse environmental effect is one in which the abundance of one or more species is reduced to a level from which recovery of the population is uncertain, or more than one season would be required for a locally depleted population or altered community to be restored to pre-event conditions. To be considered significant, Project related mortality would exceed the range of natural mortality experienced by a population as a whole.

A **positive** effect occurs when the abundance of fish within a population is increased, or natural mortality is reduced.

6.3.4.3 Potential Interactions, Issues and Concerns

Pile driving, well development and pipeline construction are Project activities that may interact with marine fish. Other potential issues and concerns related to the effects of the Project on marine fish include:

- contamination of marine fish through discharges of hydrostatic test fluids during pipeline construction, WBM drill cuttings and muds during well development and routine operational discharges (*e.g.*, produced water, cooling water, deck drainage, sewage);
- noise disturbance during construction and operations;
- creation of reef effects from presence of platforms and pipeline structure;
- creation of a refuge area for spawning due to 500 m "no-fishing" safety zone around the platforms;
- accidental release of gas condensate following a blowout, or platform spills, could effect fish eggs and larvae, particularly those in near-surface waters; and
- reduced survival of fish eggs, larvae and other planktonic organisms caused by routine and accidental discharges.

6.3.4.4 Analysis, Mitigation and Residual Environmental Effects

Construction

Subsea Pipeline Construction

Effects associated with pipeline construction are predicted to be localized and temporary and within a limited zone of influence. As discussed in Section 6.3.3, disturbed areas of the marine benthos are expected to be recolonized in less than five years. Excavation or jetting of soft bottom sediments will result in temporary sedimentation. Herring, whose sticky eggs adhere to the bottom and could be smothered by silt would most likely be affected. The subsea pipeline will be laid in the summer and the likelihood that this activity would coincide with herring spawning in time and space is unlikely. Even if it were to coincide, it would not cause significant effects on the herring population.

Blasting, if required, will be conducted in accordance with the "Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters" (Wright and Hopky 1998). Pipeline construction is not expected to have a significant adverse effect on marine fish.

Installation of Structures

Noise from pile driving is of concern because of the magnitude of the noise and vibrations. It is possible that such noise and vibration could interact with fish larvae and adults. Driving the jacket legs (estimated to last 4-7 days) will likely generate up to 135 dB re 1µPa at 1 km distance from the construction vessel (Richardson *et al.* 1995). At source, in 40 m depth, the maximum noise level is estimated to be approximately 180 dB re 1µPa based on standard cylindrical spreading. EnCana will gradually increase pile driving noise, by building up to necessary intensity over a period of time. The distance for this sound level to attenuate to an ambient level of 100 dB is approximately 10 km.

The noise from pile driving may cause fish to move out of the affected areas close to the source. There is considerable variation in the hearing ability of fish, therefore it is difficult to make general statements about behavior of many fish species relative to this activity.

Turnpenny and Nedwell (1994) summarized the following physical effects of noise on fish:

- transient stunning at 192 dB re 1 µPa;
- internal injuries at 200 dB re 1 µPa;
- egg/larval damage at 220 dB re 1 µPa; and
- fish mortality at 230 to 240 dB re 1 µPa.

In addition, Turnpenny (Fawley Aquatic Research Laboratories Ltd., pers. comm. 2002) and Pearson *et al.* (1992) both note that the lower noise threshold that can cause subtle changes in fish behavior is approximately 160 dB. Extrapolating from Richardson *et al.* (1995), as noted above, it was calculated that this lower noise threshold (*i.e.*, 160 dB) would occur out to a radius of approximately 255 m from the Deep Panuke construction site during pile driving.

Based on these anticipated noise levels, no adverse physical effects are expected on adult, juvenile or eggs and larvae of commercial or non-commercial species from pile driving. Regarding a potential behavioral response (*e.g.*, at noise levels above 160 dB) such as disturbance during spawning periods or shifts in migration routes, a 255 m radius from the Project area is considered as the zone of influence. Silver hake are the only commercial species shown to spawn within the Project footprint and this radius accounts for a very small percentage of their spawning area. If the 4 to 7 day pile driving activity occurs within the silver hake spawning period (June to September), the short duration of this activity relative to the extended period of hake spawning and the localized area of potential effect are not likely to result in any significant adverse effects on silver hake.

Hydrostatic Testing

The discharge of hydrostatic testing fluid from the pipeline during construction could have adverse effects on marine fish. Hydrostatic testing fluid may consist of seawater, dye, biocide, corrosion inhibitor and dissolved oxygen scavenger. The chemicals used in this application will be screened through the Offshore Chemical Selection Guidelines (NEB *et al.* 1999). A toxicity bioassay testing program and plume dispersion modeling will be applied to confirm there will be minimal impact to the marine environment from this one time discharge (refer to Section 2.3.2).

Development Drilling

Contamination from drilling discharges may effect bottom dwelling fish, particularly flatfish, however the effects will be highly localized in the vicinity of the discharge (refer to Section 6.3.3 for a discussion on drill waste dispersion and effects). Due to the high-energy environment at the Project site, WBM cuttings piles will likely be dispersed within one year. Therefore, no significant adverse effect on marine fish is predicted from discharges during construction.

Drilling is expected to continue for approximately 450 days. Underwater noise from drilling units (at 119 to 127 dB re 1µPa) is less than that produced by fishing trawlers and other surface vessels (170 to 191 dB re 1µPa) (Buerkle 1975a; 1975b). Received levels at 100 m distance will be approximately 114 dB re 1µPa. Transient stunning of marine fish occurs at noise levels above 192 dB re 1µPa; therefore, no significant effects of noise on marine fish are predicted.

Assuming implementation of the proposed mitigative measures, no significant adverse effect on marine fish is predicted during Project construction.

Operation

Routine Operational Discharges

Effects from produced water and other discharges will likely be undetectable beyond 500 m from the platform. Produced water dispersion modeling results for the Project are included in Appendix C.

A great deal of research has been performed to describe the potential consequences of discharging produced water in the marine ecosystem (*i.e.*, Brendehaug *et al.* 1992; Montgomerry *et al.* 1987; Schiff *et al.* 1992; Sauer *et al.* 1992; Johnsen *et al.* 1994; Querbach *et al.* 2000). These studies showed that there are field variations in the toxicity, but that the acute toxicity of produced water to marine organisms is relatively low. Querbach *et al.* (2000) studied potential effects of produced water exposure on haddock, lobster and sea scallop, and concluded that survival, growth and fertilization success was reduced for these species. The aromatic and phenol fractions appear to be the main contributor to the acute toxicity of produced water (Johnsen *et al.* 1994); this is supported by an experiment which showed that biodegradation of the aromatic and phenol fractions played a dominant role in the decrease of the acute toxicity. Because the toxicity of produced water is relatively low and the dilution high, no measurable effects in marine organisms (in situ) have been reported. Adult fish are not expected to be significantly affected by discharges as they will likely detect and avoid areas of lower water quality (*e.g.*, Zitko and Carson 1974, Wildish *et al.* 1977). The early life stages, or planktonic stages, are particularly sensitive to contaminants due to the inability of these larvae or eggs to actively move from areas of contamination. However, the predicted effect is not considered to be significant since the proportion of the total population that is exposed to these routine discharges at any time is small and any effect caused will be within natural variation for these populations. Sommerville *et al.* (1987) found that cod and herring larvae and phytoplankton appear to be unaffected by produced water.

Studies have been undertaken to investigate potential chronic and sublethal effects of produced water components (*e.g.*, alkyphenols, PAHs) on fish (Meier *et al.* 2002, OLF 1998, Aas *et al.* 2000). However, field studies to date to address these potential effects are too limited to be definitive at this time. This difficulty is compounded by the lack of published information on potential effects with regard to specific species that frequent or reside in the area (*i.e.*, Aas and Klungs yr 1998). More recently however, large research programs have been designed to develop monitoring tools with laboratory experiment (Aas *et al.* 2000, Camus *et al.* 1998, Beyer *et al.* 2001, Baussant *et al.* 2001a; 2001b). EnCana will continue to support similar research initiatives in Canada and will review results of ongoing research as they become available.

EnCana acknowledges the emerging concern with regard to produced water and deck drainage discharges and the difficulty in assessing potential effects in situ (particularly for benthic and pelagic species) given relatively low toxicity and high dilution.

Effects of routine discharge of hydrogen sulphide (H_2S) contained in produced water discharge are expected to be localized, minimal, and not significant. Maximum end of the pipe concentrations will be in the order of 0.004 ppm (0.004 mg/L), and will be both rapidly diluted and rapidly oxidized to sulphate (a common ion in sea water). H_2S toxicity data are lacking for oceanic species, which are generally believed to be intolerant of high concentrations of H_2S. The 2-hour LC50 for the open water flounder

(*Citharichthys stigmaeus*) is approximately 200 µM (6.8 mg/L). Bagarinao and Vetter (1989) and Glickman *et al.* (1999) examined H_2S concentrations at "end of pipe" (95 to 160 mg/L) and edge of mixing zone (50 to 96 µg/L) at three Californian offshore sites and predicted no hazard to marine aquatic life.

Small pelagic and planktonic organisms in the immediate vicinity of the production platform may become entrained in platform water intakes or the zone of discharges. Mortality of organisms will be reduced by intake of water at depth (*i.e.*, minimum 10 m depth) according to DFO guidelines on water intake (*e.g.*, Freshwater Intake End-of-Pipe Fish Screen Guideline (DFO 1995)). This loss of plankton is considered negligible particularly at depth, relative to the widespread distribution of plankton on the Scotian Shelf.

Presence of Structures

Noise from routine operations is not anticipated to have a measurable effect on local fish populations.

The presence of infrastructure (platforms, pipeline) and pipeline protective mattresses may have a minor positive effect in that fish will be attracted to the structure, due to the reef effect. Reef structures not only provide shelter from predation for many species of marine fish, but also contribute to provision of productive feeding grounds. The creation of a 500 m "no-fishing zone" associated with the safety zone around the platforms, can also have a minor positive effect on marine fish by providing further refuge areas for spawning fish. Myers and Barrowman (1996) demonstrated, through meta-analysis of 254 commercial fish stocks, that the highest measures of recruitment occur when the spawning stock biomass is high. Thus, any Project effect that increases the spawning stock biomass of a species can have a positive effect on recruitment into that population.

Various studies in the North Sea and Gulf of Mexico have reported evidence of fish aggregation near offshore platforms and pipelines (AUMS 1987a; 1987b; ICIT 1991; Bohnsack and Sutherland 1985; Picken *et al.* 2000; Soldal *et al.* 1999). Known offshore species attracted to northern reefs include pollock (*Pollachius virens*), cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), ling (*Molva molva*), and mackerel (*Scomber scombrus*) (Soldal *et al.* 1999).

Fish aggregating near platforms will be exposed to produced water and other effluents. Past studies on the health of fish caught near platforms in the North Sea did not demonstrate any major effects of substances discharged in produced water (AUMS 1989; Aas and Klungs yr 1998; Mathers *et al.* 1992a; 1992b). However, a need for insitu research has been identified (Meier *et al.* 2002; Cranford *et al.* 2001).

No significant adverse residual effects on marine fish from Project operations are predicted; a minor positive effect is predicted based on an anticipated reef and refuge effect associated with unburied portions of pipeline and fishing exclusion zone around the platforms.

Decommissioning

Project activities during decommissioning will likely include vessel traffic, equipment and structure removal, and routine discharges. The potential effects of these activities are expected to be similar (or less than) those of construction; therefore, no significant adverse environmental effects are predicted. The removal of structures, and fishing exclusion associated with the platform safety zone will remove the reef and refuge effect thereby returning the area to its pre-Project condition.

Malfunctions and Accidents

Malfunctions and accidents could result in a condensate plume from a well blowout or platform spills. Eggs and larvae would be more at risk than adult fish because they tend to be congregated in the upper water column where released condensate would travel. The risk of a major release of hydrocarbon from a blowout or large spill is considered extremely low (refer to Section 3.2).

Sable Island Bank is an important spawning and nursery area for many species of fish and commercially important invertebrates. Water circulation forms a gyre over the bank during many months of the year, retaining eggs and larvae over the Bank. This retention increases the potential risk of exposure in the event of an accidental release of condensate contained in a blowout of raw gas, or other oil. However, rapid evaporation and dispersion of natural gas and condensate reduces the magnitude of the risk, especially in comparison to heavy oil. During summer there may be localized mortality of fish eggs and larvae close to the blowout site, but evaporation of the condensate would be rapid. Overall concentrations of dissolved hydrocarbons would be well below the lethal level for blowouts and platform spills; mortality of fish eggs and larvae would be within the range of natural population variation for species present on the Scotian Shelf. The likelihood of tainting of fish is extremely remote.

In the extremely unlikely event of a subsea acid gas injection well blowout, H_2S gas could be released into the water column. The chemical reaction of H_2S with seawater will result in the production of H_2SO_4 (aq). In the receiving waters there will be a lowering of the pH, a potential increase in chemical oxygen demand (COD) and an associated increase in water temperature. Fish within the zone of influence will likely detect and avoid abnormal water quality such as low pH, low dissolved oxygen and elevated temperature. Furthermore, fish are known to show a strong avoidance reaction when they detect H_2S, but this information is lacking for indigenous fish species such as cod, haddock, pollock, yellowtail flounder, herring and mackerel. The primary concern of an H_2S subsea blowout is centered on