11 Chemical Oceanography

This section examines the effects of the Program on the chemical characteristics of sea water and sediments of the southern Beaufort Sea. Water and sediment quality are VECS because they could provide pathways for contaminants to move within the food chain, potentially affecting marine biota. Effects of water and sediment quality on other valued ecosystem components (VECs) are discussed in Section 12: Plankton; Section 13: Benthos; Section 14: Fish and Fish Habitat; Section 15: Birds; and Section 16: Marine Mammals. Human health issues related to contaminants are discussed in Section 17.2: Impact Assessment.

11.1 Baseline Conditions

In recent years, several excellent and comprehensive literature reviews of contaminants in the Arctic have been completed (Arctic Monitoring and Assessment Programme [AMAP] 1998; Barrie et al. 1992; CACAR 1997; Macdonald et al. 2000; Muir et al. 1992; Shearer et al. 1991), including contaminants in the ocean environment. These reviews also examine Long Range Transboundary Air Pollution (LRTAP) and deposition in the arctic environment, an issue of importance in estimating the contribution of local or point source activities to environmental impacts and cumulative effects. Indian and Northern Affairs Canada publishes annual 'Synopsis of Research' reports (for example, Kalhok 1999, 2000; Murray and Shearer 1993, 1994) that summarize all projects funded under the Northern Contaminants Program.

Devon conducted a baseline survey of water quality, benthic surficial sediments, and contaminants in plankton, benthic invertebrates and fish tissue in EL 420 (KAVIK-AXYS Inc. 2004f) to provide some site-specific information and to compare local conditions with regional conditions determined from previous studies.

The concentrations of environmental contaminants in the water, sediments and biota of the southern Beaufort Sea are generally regarded as typical of background conditions in the world's coastal oceans. Exceptions are localized areas where site-specific inputs have occurred previously (e.g., Tuktoyaktuk Harbour). To date, no long-term deleterious effects of previous offshore oil and gas activities on the Beaufort Sea chemical environment have been reported.

The baseline data from EL 420 indicate that concentrations of metals in water and fish tissue are within or at the low end of the range reported for the southern Beaufort Sea. Sediment concentrations are also within the range reported for the area. Concentrations of polynuclear aromatic hydrocarbons (PAH) in water are lower than expected in this area, while sediment concentrations are higher than expected for a pristine area. Closer analysis of the sediment data suggested that much of the existing PAH concentrations in sediment are from river-dominated inputs of natural petroleum-based PAHs rather than anthropogenic sources. Concentrations in fish and invertebrate tissues are within the normal range for this area.

11.2 Impact Assessment

Water quality and sediment quality were selected as VECs because they determine the quality of habitat for the various biological VECs such as benthic invertebrates, plankton and fish, and the species that feed on them. Parameters used to evaluate Program effects on water quality are the concentrations of contaminants (major inorganic salts such as KCl, hydrocarbons, potentially toxic mud additives, sewage) and particulates (drill cuttings and mud) in the water column. Those used to evaluate effects on sediment quality include the concentrations of contaminants (hydrocarbons)

and the rate of accumulation (i.e., flux) of these contaminants in the benthic sediments. For the purpose of this assessment, contaminants are defined as any element or chemical compound that is not found naturally in the region or, if found naturally, could (because of the scale of input) become present at concentrations outside the range of natural occurrence and also pose a potential immediate or long-term hazard to human health or the biophysical environment. The general approach to the assessment is:

- definition of the quantity and composition of Program wastes based on previous drilling experience in the area and proposed mud systems
- definition of waste disposal and dispersal scenarios to estimate the rate of introduction of contaminants of concern to the environment under various conditions
- definition of the fate of contaminants from Program wastes in the receiving environment
- quantification of possible contaminant concentrations in the water column and rates of accumulation in benthic sediments
- comparison of these concentrations with baseline values

Criteria used to classify effects of Program waste releases on chemical oceanography as significant are provided in Table 11-1.

Table 11-1 Significance Criteria for Effects on Chemical Oceanography

Potential Effect	Significance Criteria
Reduced water quality	
Naturally occurring substances (e.g., inorganic salts and metals)	• Concentrations occur outside of the range of natural variability and persist at such levels for more than one day[1] at distances beyond 1000 m of the effluent discharge zone[2]
Non-naturally occurring substances (e.g., polymer additives)	• Concentrations persist at values exceeding 1 ppm (Note 3) for more than one day at distances beyond 1000 m of the effluent discharge zone
Reduced sediment quality	
Naturally occurring substances	• Accumulation rate in sediments exceeds the natural sedimentation rate or flux by a factor of two beyond a radius of 1000 m of the discharge zone
Non-naturally occurring substances	• Accumulation rate in sediments exceeds 10 µg/cm^2 (Note 3) beyond 1000 m of the discharge zone

Notes:

1 Generally regarded as a transient time interval

2 Measurable effects from exploration wells are generally confined to a zone of influence within a 500-m to 1000-m radius of the wellsite (Thomas et al. 1983a). Effects in this area (approximately 3 km^2) are considered localized as it represents about 0.005% of available habitat on the Beaufort Sea shelf.

3 Usually considered to be a 'trace' concentration and generally below the level of acute toxic effects for most chemicals for exposure periods of one day

The significance of anthropogenic (human-caused) inputs of chemical contaminants to the receiving environment are assessed by comparing those inputs to baseline conditions and normal cycling processes that influence the spatial and temporal distributions of these contaminants. In the southern Beaufort Sea, key processes affecting contaminant distributions are:

- the annual cycle of the Mackenzie River (i.e., a five-fold annual difference in volumetric discharge and a 3000-fold annual difference in sediment input) (Thomas et al. 1983b)
- ice scouring and associated disturbances of bottom sediments

It is assumed that the waste stream, which will be generated by the Program over the winter drilling season and deposited under the ice, will include:

- drill cuttings, that is, ground up rock from the drill hole (approximately 450 m^3/well)
- water-based drilling mud containing inorganic salts (KCl), barite and inert bentonite clays (approximately 250 m^3/well)
- treated sewage from the on-site camp (approximately 800 m^3/drilling season). Sewage will be treated to meet the *Offshore Waste Treatment Guidelines* (NEB et al. 2002), prior to discharge into the sea. Discharged wastes will be within acceptable BOD limits such that this waste stream will have little inherent toxicity (Topping 1976; Thomas et al. 1983a)
- wash water (e.g., from the kitchen, laundry, showers) (approximately 1320 m^3/drilling season)
- brine from the water treatment system to produce fresh water from sea water (approximately 32 tonnes per drilling season). According to the Offshore Waste Treatment Guidelines (NEB et al. 2002), desalinization brine may be discharged without treatment
- miscellaneous wash water such as deck drainage, rig wash water and miscellaneous low volume routine drainage water (approximately 10 m^3/day according to Thomas et al. 1983b). Wash water will be tested in accordance with a schedule approved by the Chief Conservation Officer to ensure that the oil concentration is 15 mg/L or less (NEB et al. 2002).

The composition of drilling wastes was estimated using a generic water-based KCl drilling fluid and the composition of drilling wastes from Devon's M-18 and B-2 Tuktoyaktuk wells, drilled in the Mackenzie Delta in winter 2001/2002. As per the *Offshore Waste Treatment Guidelines* (NEB et al. 2002), drill cuttings associated with water-based muds can be discharged to sea.

Concentrations of contaminants in the receiving environment are calculated, based on the under-ice disposal scenario and dilution factors described in Section 2.4: Drilling Waste Management and previous studies of the behaviour of drilling mud discharges in the Beaufort Sea. Results are summarized in Table 11-2. These results are in line with historical data for drilling wastes discharges, which indicate that the zone of influence is typically 500-1000 m from the point of discharge.

Furthermore, it should be noted that KCl drilling muds can be tolerated by aquatic biota at very high concentrations without toxic effects. KCl muds have LC50 values for fish, polychaetes, bivalves, crabs, shrimp, isopods and amphipods in the range of 15,000 and 70,000 ppm (Thomas et al. 1983a). Some of the individual components of drilling fluids have LC50 values considerably less than 15,000 ppm and are mostly the additives that are used in very small quantities. As noted earlier, in consultation with the NEB and Environment Canada, Devon will develop a toxicity-testing program for 1) whole drilling muds and 2) the under-ice discharge. These procedures will be followed during the active winter drilling period (Section 11.6: Monitoring).

Table 11-2 Program Effects on Chemical Oceanography

Potential Effect	Interaction with VEC	Level of Effect[1]	Effect Significance[2]	
			Program-related Effect	Cumulative Effect
Pre-operations				
No effects	N/A	N/A	N/A	N/A
Operations				
Under ice waste discharge (whole drilling mud, sewage, desalination brine)	Reduced water quality	• Zones of influence for naturally occurring substances (distance from discharge point within which concentrations are elevated above natural variability: hydrocarbons (100 m); KCl (10 m); sewage (buoyant constituents) (a few hundred metres); suspended particulates (a few hundred metres) • Zones of influence for non-naturally occurring substances (distance from discharge point within which concentrations are elevated above 1 ppm): Alcomer 60RD additive (a few hundred meters). All other additives < 1 ppm within a few hundred metres of discharge zone	Not significant	Not significant
	Reduced sediment quality	• 90% of particulate matter will be deposited within 50 m of the discharge. • Accumulation rates of most naturally occurring contaminants do not exceed natural rates beyond 1000 m from discharge point. The exception is the sedimentation rate for barium, which could exceed natural sedimentation rates as far as 1300 m from the discharge. Deposition rates beyond 1000 m will approach natural rates. Barite is an inert, refractory and non-toxic substance. Subsequent deposition of natural sediments and mixing by ice scour will disperse and dilute barium concentrations to background levels within a number of years. • Accumulation rates for non-naturally occurring substances do not exceed 10 µg/cm^2 beyond 1000 m.	Not significant for all constituents except barium, which will slightly exceed significance criteria for a number of years.	Not significant
Closure				
No effects	N/A	N/A	N/A	N/A

Notes: 1 Based on calculated contaminant concentrations within the zone of influence
2 Based on criteria in Table 11-1

11.3 Mitigation Measures

Potential effects of under-ice waste discharges will be minimized by implementation of management and mitigation measures indicated in Table 11-3.

Table 11-3 Mitigation Measures for Effects on Coastal Oceanography

Potential Effect	Mitigation Measures
• Alteration of water quality and sediment quality from disposal of drilling wastes during operations • Alteration of water and sediment quality from other waste stream disposal (treated sewage, grey water, other wash water and desalinization brine) during operations	• Adhering to the *Guidelines Respecting the Selection of Chemicals Intended to be Used in Conjunction With Offshore Drilling and Production Activities on Frontier Lands* (NEB et al. 1999) to select additives for drilling mud • Fully complying with the *Offshore Waste Treatment Guidelines* (NEB 2004) in regard to waste streams such as drilling muds, drill cuttings, deck drainage, desalinization brine, sewage and grey water • Development of a Waste Management Plan for drilling as part of the DPA process and implementation of this plan during the Program. The plan will address specific waste streams, toxicity testing, specific waste disposal techniques, methods of minimizing potential impacts from waste production, and waste manifest recording. The waste management plan and toxicity testing program will be developed in consultation with DFO and the Environmental Protection Branch of Environment Canada. Drilling operators in Eastern Canada will be contacted as to current waste treatment approaches in the offshore of Newfoundland and Nova Scotia. • Contingency plan for isolation, holding and testing of drilling muds in the event of an upset where muds may become contaminated with hydrocarbons. • Implementing procurement policies that ensure the use of biodegradable soaps, cleaning agents and surfactants • Minimizing volumes of additives • Implementing effective solids control and recycling to minimize drilling mud volumes • Chemical analysis of sediments and benthos following the Program and, based on results, development of appropriate responses (e.g., enhanced mitigation, if necessary) in consultation with DFO and the Environmental Protection Branch.

11.4 Residual Effects and Significance

No significant residual effects on water quality from naturally or non-naturally occurring substances are expected beyond a maximum of 1000 metres from the discharge point. No significant effects on accumulation of naturally or non-naturally occurring contaminants in the benthic sediments are expected beyond a maximum of 1000 metres from the discharge point, except for deposition of barium. In the drilling program, barium occurs in the form of barium sulphate (barite), a chemical compound that is totally non-reactive in the environment (i.e., insoluble and inert). This is the same compound used in digestive track surveys. Deposition rates for barium could exceed natural depostion rates up to 1300 metres from the discharge point (Table 11-2). Although considered a significant effect based on the criteria used for this assessment (Table 11-1), deposition rates beyond 1000 m will approach natural accumulation rates and barite is an inert, refractory and non-toxic substance. Effects on sediment within that zone of influence are limited to a very small proportion of available habitat. Subsequent deposition of natural sediments and mixing by ice scour will disperse and dilute barium and other contaminant concentrations to background levels within a number of years.

Accordingly, residual Program effects on water quality or sediment quality are expected to be not significant, for all waste constituents except barium. Barium deposition will result in a short term, non-toxic but significant effect on sediment quality.

11.5 Cumulative Effects and Significance

There is no expected overlap of the zones of influence for Program wastes among the four exploratory wells to be drilled over the four-year period of the Program. Furthermore, there are no other known existing or reasonably foreseeable future industrial projects that would overlap these zones of influence during the lifespan of the drilling Program.

There is a possibility that residual Program effects could overlap with long-range transport of contaminants via atmospheric deposition, riverine input and ocean currents. The greatest concern regarding LRTAP is the input and bioaccumulation of organochlorine contaminants (e.g., from pesticides). No organochlorine contaminants will be released by Program activities. The magnitude of the input of metals and hydrocarbons from long-range transport will be minor compared with local sources such as the Program, which in themselves are not significant or are non-toxic. Therefore, the cumulative effects of LRTAP with the Program are expected to be not significant.

11.6 Monitoring

In consultation with the NEB and Environment Canada, Devon will develop a toxicity-testing program for waste discharge from the under-ice pipeline. These procedures will be followed during the active winter drilling period. Results will be shared with all interested stakeholders.

Devon will also conduct a monitoring program to assess contaminant levels in benthic sediments, to be completed each year at the location of each previous year's drilling Program (Table 11-4). Results will be used to verify effects prediction and confirm the effectiveness of mitigation measures.

Table 11-4 Monitoring Programs for Chemical Oceanography

Potential Effects	Program Objectives	General Methods	Reporting	Implementation
Toxicity to aquatic life	To confirm effects predictions and enhance mitigation if required	Toxicity testing program for whole drilling muds and the discharge from the under-ice pipeline	To be determined	Devon
Contaminant accumulations in benthic sediments	To confirm effects predictions and enhance mitigation if required	Benthic sediment sampling and contaminant analysis	To be determined	Devon

12 Plankton

Plankton (i.e., phytoplankton, ice algae and zooplankton) are a major part of the food web of the coastal waters of the southern Beaufort Sea. Phytoplankton are floating photosynthesizing organisms (typically microscopic) and are primary producers in aquatic environments. In the arctic estuarine and marine environments, ice algae found on the underside of sea ice also play an important role in primary production. Ice algae production generally begins in March, once there is sufficient light to stimulate photosynthesis. Ice thickness, clarity, snow depth, and salinity all influence the production of ice algae. Zooplankton are floating or weakly swimming animals that are fed upon by fish and whales, providing a critical link between the primary producers (phytoplankton) and the higher trophic levels (Percy et al. 1985; North/South 2001).

12.1 Baseline Conditions

The nearshore waters of the Mackenzie Delta can be categorized into two broad and seasonally variable habitat zones (Figure 12-1):

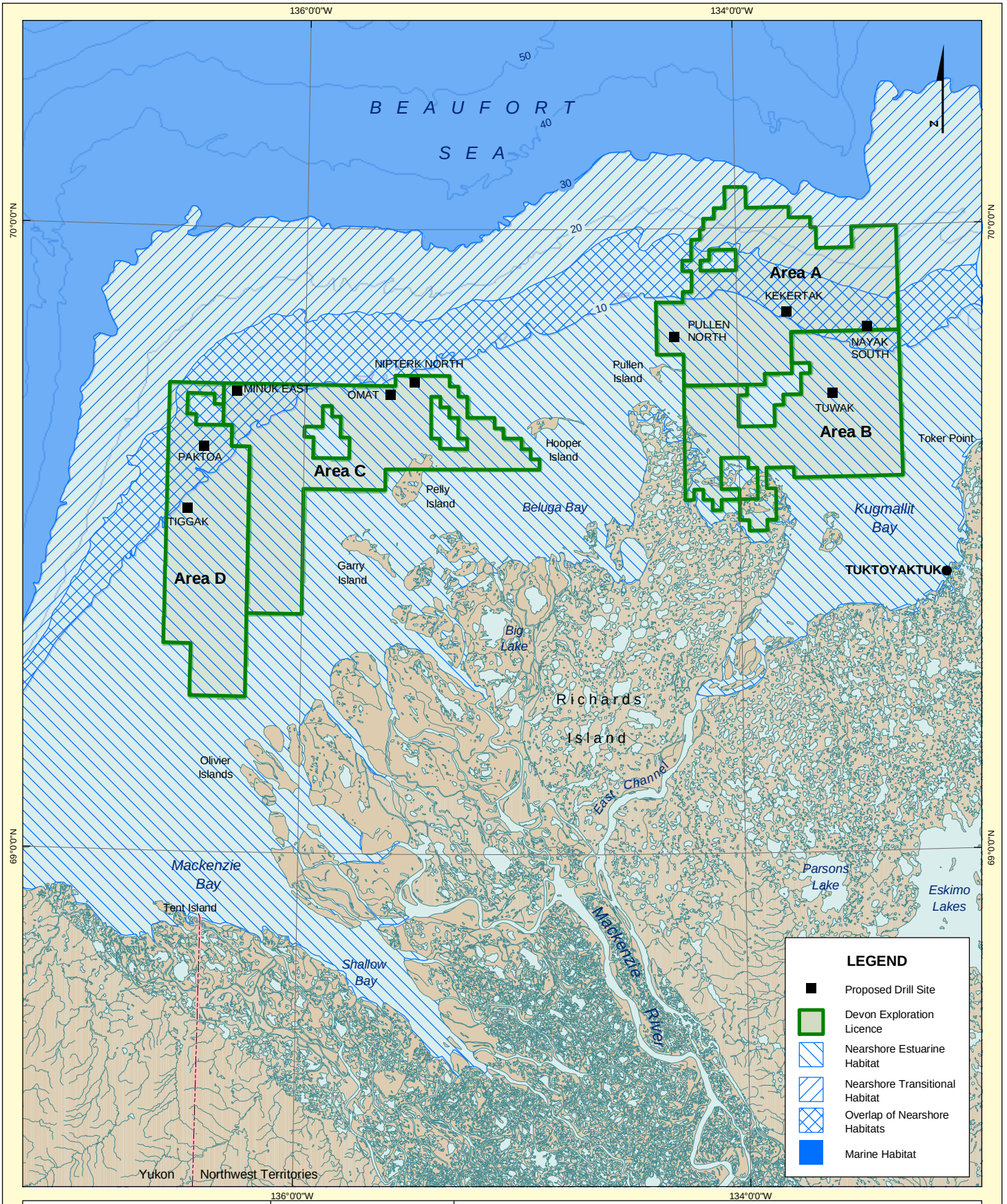
1. estuarine
2. transitional (i.e., between estuarine and offshore marine)

The majority of the LSA and RSA are within the estuarine habitat zone. This zone extends from shore to water depths of 10 to 15 m and has a mix of fresh and brackish water with salinity levels typically less than 20 ppt (Sekerak et al. 1992; Wacasey 1975)

During the summer of 2002, Devon conducted baseline zooplankton studies near EL 420 (North/South and KAVIK-AXYS Inc. 2004) to characterize site conditions and compare findings for EL 420 with data from other studies in the southern Beaufort Sea. Details of the site location, taxonomic identity and density of the zooplankton collected in the LSA are presented in Section 4 of the Baseline Study Reports (North/South and KAVIK-AXYS Inc. 2004).

Zooplankton density and species composition in baseline samples varied spatially according to water depth and salinity. Zooplankton abundance and species composition varies considerably over space and time as a result of the variable influence of the Mackenzie River freshwater plume and resultant localized differences in salinity, water temperature and food availability (Grainger 1975). Further, populations of different species reproduce and develop at different times of the year (North/South and KAVIK-AXYS Inc. 2004). Copepods were dominant in baseline samples, comparable to other studies of the area; however, amphipods (mysis) and Arctic cod larvae were also prevalent.

Few winter surveys of zooplankton distribution and abundance have been conducted because it is difficult to conduct zooplankton tows under the ice. Available data suggest that during March to May, zooplankton abundance may be an order to several orders of magnitude lower than during the more productive open-water period (Horner and Murphy 1985; Evans and Grainger 1980).



devon

KA036 - Map Fig 12-1
August 13, 2004

Area of Detail

0 5 10 15 20
Kilometres

Data Sources:
Devon Canada Corporation
National Energy Board
National Topographic Series
Projection: Universal Transverse Mercator Zone 8 (NAD 27)

Figure 12-1

Devon Canada Corporation Exploration Licence 420 in Relation to Aquatic Habitat Zones

12.2 Impact Assessment

The assessment of Program effects on the plankton community was limited to the winter drilling period. Platform mobilization and demobilization are not expected to impact plankton. Effects on plankton have been considered for both the estuarine (brackish) and transition (marine-brackish) zones. Minor differences in effects that are related to the relative abundance of the communities associated with these habitats were also considered.

The assessment of Program effects on the plankton communities was conducted by examining the potential mechanisms (water quality changes, effects on the ice environment) for changes to those communities and, where possible, quantifying those effects in terms of their magnitude, spatial extent and duration (Table 12-1).

Table 12-1 Effect Attributes for Plankton

Magnitude	
Small	No detectable change but a mechanism for change has been identified
Moderate	A detectable change of less than 50 percent in plankton abundance
Large	A readily measurable change in plankton abundance. Given the high natural variability that exists within the plankton community, a change in the order of greater than 50 percent is considered readily measurable.
Duration	
Short term	Less than one year
Long term	One year or greater
Geographic Extent	
Site - specific	Confined to within a 1-km radius of the drill target
Local	Confined to the LSA (EL 420)
Regional	Confined to the RSA (landfast ice zone from Herschel Island to the northeastern tip of Tuktoyaktuk Peninsula)

Long-term, local effects are considered significant if they are predicted to be moderate or large in magnitude. In other words, detectable changes (i.e., changes beyond natural variability) at the local scale are considered significant.

Other factors that are considered to determine significance include:

- frequency of occurrence of Program impacts because the frequency may influence the duration of effects
- reversibility of an effect either through mitigation or population resilience because that would influence the duration of an effect
- ecological context (e.g., do known thresholds exist? are effects ecologically meaningful?)

The significance of effects was assessed in the context of the LSA because it is only within this geographic context that there is potential for adverse effects to occur. Smaller scale effects (e.g., the footprint of drilling platforms) represent such a minute proportion of available habitat that any effects confined to this area (i.e., within 1-km radius of the drill target) would be so small as to be not significant.

Program effects are summarized in Table 12-2. Waste discharges are predicted to have no significant effects on water quality beyond 1000 m of the discharge point (Section 11: Chemical Oceanography). Given the very small scale of the effect relative to the regionally available habitat in the southern Beaufort Sea region, no measurable and ecologically meaningful effects on the phytoplankton, zooplankton or ice algae communities are expected to occur from waste releases.

During periods of low winter light, nutrients from sewage may flow beyond the LSA and marginally enrich the waters elsewhere on the shelf. In late March and beyond, nutrient enrichment may be expected to result in minor increases in phytoplankton and ice algae abundance. In either event, the addition of nutrients is expected to result in no measurable change in nitrogen and phosphorus values beyond a hundred metres from the platform. Any effects on the plankton community will not be detectable, given the high natural variability in species composition and abundance.

The effects of ice pad and ice road construction on ice algae and associated zooplankton (habitat alienation, increased or decreased light penetration) are summarized in Table 12-2. The effects of ice pad construction on phytoplankton will be similar for all platform options – the ice island platform is the only option that may involve construction of an ice road. In the case of the ice island platform, increased light penetration along the ice road resulting from snow clearing could result in a localized increase in ice algae production, offsetting the loss of production from ice pad construction.

The distance between the potential drilling locations is in the range of tens of kilometres, and only one well will be drilled in each year; therefore, the chance of the drilling and waste disposal activities at one location affecting water quality and plankton at another is extremely remote. Because phytoplankton, ice algae and zooplankton communities are less abundant in the nearshore, low-salinity waters, potential impacts will be of smaller magnitude than those at deeper water sites like Paktoa. Because potential effects are predicted to be small, site specific and short term, effects of the Program on plankton are predicted to be not significant (Table 12-2).

12.3 Mitigation Measures

Because no significant effects on plankton are expected with the waste treatment and disposal procedures to be implemented (Section 11: Chemical Oceanography, Table 11-3), no additional impact mitigation measures are recommended.

12.4 Residual Program Effects and Significance

Residual Program effects on the plankton community (ice algae, phytoplankton, zooplankton) are expected to be not significant.

12.5 Cumulative Effects and Significance

There is no expected overlap of the spatial or temporal zones of influence around the four exploratory wells that will be drilled over the four years of the Program. There are no other known industrial projects planned to take place in the region during the lifespan of the drilling Program. Chemical inputs from long-range transport are described as minor compared with local sources (Section 11.5: Cumulative Effects and Significance). As a result, cumulative effects on plankton are expected to be not significant.

Table 12-2 Potential Program Effects on Plankton

Potential Effect	Interaction with VEC	Level of Effect[1]			Effect Significance[2]	
		Magnitude	Extent	Duration Frequency	Program-related Effect	Cumulative Effect
Pre-operations						
Effect of ice pad and ice road construction on ice algae	• Up to 12 ha (0.004% of the LSA) of ice algae habitat would temporarily be removed by ice pad construction • Snow clearing and increased light penetration on the winter road (approximately 43 ha) are expected to offset this loss for the ice island platform • Effects on nearer-shore locations (e.g., Tuwak and Pullen North) will be less because of lower natural ice algae production in fresher water	Small	Site specific	Short term	Not significant	Not significant
Operations						
Waste disposal affecting water quality with related effects on phytoplankton, zooplankton and ice algae	• No significant changes in water quality are expected (Section 11: Chemical Oceanography, Table 11-2); therefore, no detectable effect on plankton is expected. • Nutrient additions from sewage disposal may cause localized stimulation of algal production for a short period of time but effects are not expected to be ecologically significant	Small	Site specific	Short term	Not significant	Not significant
Closure						
No effect	N/A	N/A	N/A	N/A	N/A	N/A

Notes: 1 Based on criteria in Table 12-1
2 Based on criteria in Section 12.2.

12.6 Monitoring

No monitoring programs are proposed, given the small, site-specific, short-term effects that are predicted and the technical difficulty of sampling the plankton community within the period when those effects may occur (i.e., March through June). Benthic invertebrate sampling (Table 13-3) provides a more practical and useful means of monitoring and determining any additional needs for mitigation.