6 WATER QUALITY

6.1 Introduction

6.1.1 Focus

The section addresses chemical changes in surface water and bottom sediment. Effects on suspended sediment concentrations are evaluated in Section 5, Hydrology, and the effects of changes in suspended sediment concentrations on fish habitat and aquatic life are evaluated in Section 7, Fish and Fish Habitat.

Construction, operations and decommissioning of the project might alter water quality in waterbodies. Project activities and pathways that might cause these effects include:

- acid deposition
- wastewater releases
- leaks and spills
- activities that cause:
  - suspended sediment inputs
  - changes in surface water flow and level
  - changes in groundwater quality

Water quality changes are also used to assess environmental effects in other disciplines, particularly fish and fish habitat.

6.1.2 Summary of Findings

The water quality assessment investigated project effects on:

- water quality
- sediment quality

These features were identified as valued components (VCs) because of their potential to affect other VCs, such as fish, wildlife and use of surface water by people.

Pathways through which the project could affect water and sediment quality include:

- acid deposition
- wastewater releases from:
  - camps
  - pressure testing
  - land-based facilities
  - drilling
  - the Niglintgak gas conditioning facility (barge option only)

- leaks and spills
- suspended sediment inputs from:
  - land disturbance
  - land subsidence
  - frost bulbs
  - disturbance of bottom or bank sediments by barge traffic or because of dredging and pipeline construction at watercourse crossings
- changes in surface water flow and level
- changes in groundwater quality

It was determined from an analysis of potential pathways that the following do not affect water quality:

- disposal of process and drilling wastewater
- management of barge ballast water (barge option only)
- leaks and spills
- suspended sediment inputs from:
  - land subsidence
  - frost bulbs
- changes in surface water flow and levels
- changes in groundwater quality

The effects of acid deposition in the production area and along the gathering pipelines were assessed by evaluating acid sensitivity and by quantitatively analyzing effects for a representative set of lakes with sufficient water quality data. Acid sensitivity is low for most lakes with available data near project components. Critical loads of acidity were calculated for 23 lakes in the northern airshed and compared with modelled acid deposition rates to evaluate effects. The critical load is an estimate of the amount of acid deposition below which there are no significant harmful effects in a specified component of a lake ecosystem (Sullivan 2000). There were no occurrences of acid deposition rates exceeding critical loads and stream sensitivity to acid deposition was considered low. Therefore, no effects from acid deposition were predicted in the production area or along the gathering pipeline route.

Along the pipeline corridor, effects of acid deposition were evaluated separately for each compressor station and the Trout River heater station. Field water quality data indicated that surface waters were not sensitive to acid deposition near the only compressor station, i.e., Little Chicago, where the background level of acid deposition was predicted to be exceeded for a large part of one lake’s drainage area. Therefore, no effects from acid deposition were predicted on lake or stream water quality along the pipeline corridor.

Discharges of pressure test water, domestic wastewater and barge wastewater were predicted to have localized, low-magnitude effects on water quality. This assessment is based on:

- the expected success of wastewater treatment
- criteria for disposal methods
- criteria for size or flow of receiving waters that will ensure that effects on water quality will be, at most, low magnitude and local in extent

Effects of dredging on water and sediment quality are predicted to be low to moderate magnitude and localized. Dredging might be required to maintain barge landings and to allow transport of the Niglintgak gas conditioning facility if the barge option is chosen. Field studies of dredged material disposal have found that chemical releases are transient and localized during dredging and that water quality tends to return to the background condition shortly after dredging. A maximum effect magnitude of moderate was predicted because concentrations of some key indicators (KIs) in the water column could exceed water quality guideline values near the point of dredging.

Effects on water and sediment quality caused by sediment releases during watercourse crossing construction and because of land disturbance and barge traffic were predicted to range from no effects to moderate in magnitude and localized.

Because none of the effects on water quality are expected to persist after decommissioning, the individual and combined effects of the project on water and sediment quality are not significant.

6.1.3 Traditional Knowledge

As described in Volume 1, Section 3, Traditional Knowledge, communities near the project are undertaking traditional knowledge studies. Because these studies are incomplete, the project proponents used existing published traditional knowledge in this assessment. Little traditional knowledge related specifically to water quality has been published, though concerns related to changes in water quality were identified.

Aboriginal people have used the Peel, Aklavik, Husky and West channels of the Mackenzie Delta extensively for subsistence fishing. Because fresh water from the Mackenzie River flows into sea water, the salt content of the delta water varies at different locations. However, local people believe the water has become less salty (Community of Aklavik et al. 2000). Aklavik residents believe Arctic char could be affected by the change in water quality and are concerned that the number of Arctic char might never return to a sustainable harvesting level. They have also noticed that Arctic grayling have become scarce in these waters.

6.2 Assessment Approach

Volume 1, Section 2, Assessment Method, provides information on the assessment approach. The assessment approach for water quality included the following steps:

1. Identify project-related activities and associated physical and chemical changes that might affect water quality, i.e., key issues.
2. Identify VCs and the KIs for measuring potential changes in VCs caused by project activities. Water and sediment quality are the VCs in this assessment.
3. Identify the potential effects and illustrate the linkages between project activities and effects in the form of an effect pathway diagram.
4. Identify mitigation measures to reduce or prevent potential effects.
5. Evaluate the applicability of each pathway, after accounting for mitigation measures.
6. Predict changes in water and sediment quality for the applicable pathways.
7. Evaluate and classify the predicted effects based on weight of evidence, comparison with regulatory guidelines, or site-specific benchmarks.
8. Identify the monitoring programs required to verify effect predictions and to comply with commitments described in Volume 7, Environmental Management.

6.2.1 Key Issues

Key issues included in the assessment were identified through:

- community input, including regional workshops and community-level meetings
- review of environmental assessments in the region
- professional experience

All issues identified by communities were addressed, and several additional issues were identified during the assessment process. The final list of issues, which are relevant to effects on water quality, includes:

- acid deposition

- wastewater releases
  - domestic wastewater
  - pressure test water
  - process wastewater
  - drilling wastewater
  - ballast water and barge wastewater
- leaks and spills
- suspended sediment inputs caused by:
  - land disturbance
  - land subsidence
  - frost bulbs
  - disturbance of bottom or bank sediments
- change in surface water flow and level caused by:
  - change in runoff
  - water withdrawal
  - change in groundwater quantity
  - land subsidence
- change in groundwater quality

6.2.2 Valued Components and Key indicators

6.2.2.1 Valued Components

Water and sediment quality are the VCs selected for water quality. Water and sediment quality are interrelated, so effects on both were evaluated. Changes in each can affect fish and wildlife VCs and the use of surface water by people.

6.2.2.2 Key Indicators

Water and sediment quality were assessed by predicting project effects on the KIs that characterize water and sediment quality. These KIs include individual chemical parameters, such as phosphorus, and physical properties, such as water temperature, that can be measured in the field or in the laboratory.

Changes in KI concentrations affect the suitability of surface waters for aquatic life, wildlife and for use as drinking water, if they exceed regulatory guideline values for particular water uses. Guidelines used to evaluate water quality include water quality guidelines for the protection of aquatic life (CCME 1999) and drinking water guidelines (Health Canada 2001). Sediment quality was evaluated based on sediment quality guidelines for the protection of aquatic life (CCME 1999).

Chemical Parameters

Commonly analyzed chemical water and sediment quality KIs are listed and briefly described in Table 6-1. More detailed descriptions are in Volume 3, Section 6, Water Quality.

Table 6-1: Chemical Water and Sediment Quality Parameters

Parameter Group	Parameter	Description
Water Quality		
Conventional	pH	pH is a measure of the acidic or alkaline nature of water
	Dissolved oxygen (DO)	DO is an important determinant of suitability of a waterbody for aquatic life. Low DO is harmful to aquatic life.
	Total dissolved solids (TDS) and major ions	TDS and major ion concentrations are indicators of dissolved salt concentrations or salinity
	Alkalinity	Alkalinity is an indicator of acid sensitivity
	Hardness	Hardness is a measure of the sum of calcium and magnesium concentrations. Toxicity of several metals depends on the level of hardness.
	Total organic carbon (TOC)	TOC is a measure of the amount of humic substances, i.e., dark-coloured organic material and partly degraded plant and animal material
Nutrients	Phosphorus (P) and nitrogen (N)	Nutrients are chemicals required in small quantities for plant growth. P and N concentrations control biological productivity in fresh water.
Metals	Major and trace metals	Metals occur naturally in small quantities in surface waters. Although many trace metals are essential to life, elevated concentrations of dissolved metals can be harmful to aquatic life.
Organic compounds	Hydrocarbons, phenols, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs)	Organic compounds can occur naturally or originate from human sources. Elevated concentrations of organic compounds can be harmful to aquatic life.
Sediment Quality		
Carbon	TOC	TOC in sediments usually consists of partly degraded plant material
Metals	Major and trace metals	Metals in sediments can occur naturally in the mineral framework of silt and clay particles, or they might originate from human sources. Elevated concentrations of metals can be harmful to aquatic life.
Organic compounds	Hydrocarbons, phenols, PCBs, PAHs	Organic compounds can occur naturally or originate from human sources. Elevated concentrations of organic compounds can be harmful to aquatic life.

Physical Parameters

Commonly analyzed physical water and sediment quality KIs are listed and briefly described in Table 6-2. More detailed descriptions are provided in Volume 3, Section 6, Water Quality.

Table 6-2: Physical Water and Sediment Quality Parameters

Parameter	Description
Water Quality	
Conductance	Conductance is a measure of a solution's ability to conduct electricity. It is also an indicator of salinity.
Water temperature	Water temperature can influence the concentrations of other KIs, e.g., DO. It also controls the development and distribution of aquatic species.
Turbidity	Turbidity is a measure of light scattering by suspended particles. It is an indicator of suspended sediment concentration.
Colour	Colour is a measure of the amount of humic material in the water. Colour is often high in water that flows through muskeg and bogs.
Total suspended solids (TSS)[1]	TSS is a measure of the concentration of suspended material in the water. Concentrations of other KIs, e.g., metals, nutrients and organic compounds, are frequently related to TSS.
Sediment Quality	
Particle size	Particle size refers to the proportions of sand, silt and clay in bottom sediments. It depends on current velocity and turbulence. Metals and hydrocarbons are usually associated with silt or clay particles. The type of aquatic life in sediments is also influenced by particle size.
NOTE: 1 Total suspended solids – commonly referred to as total suspended sediment	

6.2.3 Key Question and Effect Pathway Diagram

The water quality issues can be addressed by answering one key question about the effects of the project:

- How will the project affect water quality?

Table 6-3 shows the relationship between the key question, issues and VCs. An effect pathway diagram was developed to show the various paths by which project activities could affect the VCs. The effect pathway diagram is discussed fully in Section 6.3.1. Effect Pathways.

Table 6-3: Key Question, Related Issues and Valued Components

Key Question	Related Key Issue	Potentially Affected Valued Component
How will the project affect water quality?	Acid deposition	Water quality
	Wastewater releases	Water and sediment quality
	Leaks and spills	Water and sediment quality
	Suspended sediment inputs	Water and sediment quality
	Change in surface water flow and level	Water and sediment quality
	Change in groundwater quality	Water and sediment quality

6.2.4 Effect Descriptions

The project's effects on water quality were described in terms of four effect attributes:

- direction
- magnitude
- geographic extent
- duration

These attributes must be considered in any comprehensive and systematic analysis. They also form a framework for describing effects that is consistent among components of this assessment. These effect attributes are used to determine if an effect is significant and to provide information on the sustainability of the project. Table 6-4 summarizes the categories of effect attributes used to evaluate effects on water quality.

6.2.4.1 Direction

Direction describes whether the effect is adverse or neutral. A positive direction is not applicable to effects on water quality. The categories used for direction were defined as follows:

- adverse – if the quality of water or sediment declines as indicated by increasing KI concentrations. Exceptions include dissolved oxygen and pH, which can also have adverse effects if concentrations decline.

- neutral – if water or sediment quality does not change compared with baseline conditions

Table 6-4: Definition of Effect Attributes

Attribute	Definition	
Direction		
Adverse	Effect is an increase in concentrations[1]	
Neutral	No change in comparison to baseline concentrations	
Positive	Not applicable for water quality	
Magnitude – Protection of Aquatic Life		
Attribute	**Definition**	
No effect	No measurable change in water or sediment quality	No measurable change in water or sediment quality
Low	Measurable change, but KI concentrations would remain below guideline values, except for KIs that exceed guideline values under natural conditions[2]	The magnitude of an effect will be evaluated based on KI and site-specific considerations
Moderate	For KIs that are toxic to aquatic life: an increase in KI concentration such that it exceeds a guideline value, where the guideline value is not previously exceeded under baseline concentrations and where the expected increase is within the factor of safety range of the guideline[3] The moderate category is not applicable for KIs with no inherent safety factor	The magnitude of an effect will be evaluated based on KI and site-specific considerations
High	KI concentrations would increase such that guideline values are exceeded and beyond the factor of safety range, if applicable[3]	The magnitude of an effect will be evaluated based on KI and site-specific considerations
Magnitude – Drinking Water		
No effect	No measurable change in water quality	
Low	Measurable change in water quality, but KI concentrations in waterbody or potable water intake would remain below drinking water guideline values	
Moderate	Measurable change in water quality and KI concentrations in waterbody or potable water intake would increase such that aesthetic drinking water guideline values are exceeded Concentrations would not increase such that non-aesthetic drinking water guideline values are exceeded	
High	Measurable change in water quality and KI concentrations in waterbody or potable water intake would increase such that non-aesthetic drinking water guideline values[3] are exceeded	
Magnitude – Acid Deposition		
No effect	Potential acid input value would remain below critical load for a waterbody, or no acidification is predicted based on weight of evidence	
Potential effect	Potential acid input value would increase such that the critical load is exceeded for a waterbody	

Table 6-4: Definition of Effect Attributes (cont'd)

Attribute	Definition
Geographic Extent	
Local	Effect is limited to the local study area
Regional	Effect is limited to the regional study area
Beyond regional	Effect extends beyond the regional study area
Duration	
Short term	The effect is limited to less than 1 year
Medium term	The effect occurs from 1 to 4 years
Long term	The effect lasts longer than 4 years, but does not extend more than 30 years after decommissioning and abandonment
Far future	The effect extends more than 30 years after decommissioning and abandonment

NOTES:
1 Exceptions include dissolved oxygen and pH, which can also have adverse effects if concentrations decrease beyond the lower guideline values
2 If the natural baseline concentration of a KI exceeds the guideline values and the project is predicted to further increase its concentration, magnitude is evaluated based on KI and site-specific considerations
3 Magnitude of effects also depends on duration of effect, depending on the KI and site-specific considerations. For example, high-magnitude effects that last only a short time, i.e., hours, following the project activity, e.g., dredging, could be reduced to a moderate rating.

6.2.4.2 Magnitude

Approach for Determining Magnitude

Magnitude describes the severity or intensity of the effect. The magnitude of effects on water quality were evaluated in terms of the expected change in the concentration of a KI compared with a benchmark. Guidelines for the protection of drinking water supply and aquatic life were used as the benchmarks.

Health Canada's drinking water guidelines for protecting community drinking water supplies (Health Canada 2001) were used as the benchmarks for evaluating the potential effects on drinking water. Although drinking water guidelines are not normally applied to untreated surface waters, they are used for evaluating effects on surface waters in northern Canada, where drinking minimally treated or untreated water is more common than elsewhere in the country.

Potential effects on aquatic life were assessed relative to water and sediment quality guidelines for the protection of aquatic life (CCME 1999). The 10 provinces, the three territories and the federal government have nationally endorsed these aquatic life guidelines. The guidelines are science-based goals for protecting the quality of aquatic ecosystems. They are defined as numerical concentrations or narrative statements that should result in negligible risk to biota, their functioning or any interactions that are critical to sustaining ecosystem health. In the case of metals and other KIs that can be toxic to aquatic life, the water quality guidelines are intended to protect all forms of aquatic life over the long term in all surface waters. These guidelines are based on the lowest concentration that has been shown to have an adverse effect, the Lowest Observable Effects Level, or LOEL, on the most sensitive life stage of the most sensitive aquatic organism. A safety factor, 10 for most KIs, is then applied to the LOEL as added assurance that the guideline will protect aquatic life. Consequently, an assessment based on compliance with these water quality guidelines is conservative.

The magnitude of an effect also considers the part of a waterbody where concentrations exceed guideline values. Guidelines for chronic effects, such as eutrophication or chronic toxicity, allow for an area of the waterbody to be affected without considering it an effect on the ecological functioning of the system. In large waterbodies, including the Mackenzie River and larger lakes, water releases might not completely mix. Therefore, the magnitude of chronic effects in these waterbodies is usually evaluated after accounting for mixing in up to 10% of the flow or the volume of the waterbody, based on river width and lake volume. For waterbodies where mixing is rapid, as in small streams and lakes, the evaluation of magnitude assumes complete mixing in the waterbody.

Criteria for Aquatic Life

The criteria for defining effect magnitude related to the protection of aquatic life vary depending on the KI. For KIs with available guidelines, the no effect and low-magnitude ratings were defined as follows:

- no effect – no measurable change expected in water or sediment quality
- low – water or sediment quality changes measurably, but KI concentrations remain below guideline values, except for KIs that exceed guideline values under baseline conditions

In some situations, natural baseline KI concentrations exceed guideline values. If the project will increase the concentration of a KI, then a higher-magnitude rating is applied. In these cases, the magnitude would be determined based on KI and site-specific considerations.

The moderate and high effect magnitudes were defined as follows for KIs that are toxic to aquatic life, such as metals:

- moderate – water or sediment quality changes measurably and KI concentrations increase such that the guideline value is exceeded, where a guideline was not exceeded under baseline conditions. However, the increase remains within the guideline’s factor-of-safety range, e.g., a ten-fold safety factor is incorporated into many water quality guideline values

- high – water or sediment quality changes measurably, and KI concentrations increase such that guideline values are exceeded, beyond the factor-of-safety range

The moderate category was not used for KIs with aquatic life guidelines that have no inherent safety factors. A high magnitude in these instances was defined as an expected increase in KI concentration such that the guideline value is exceeded, where the guideline was not exceeded under baseline conditions. In some cases, the magnitude of effects also depends on the duration of effect, depending on the KI and site-specific considerations. For example, high-magnitude effects that last only a short time, i.e., hours, following the project activity, e.g., dredging, could be reduced to a moderate rating.

Criteria for Drinking Water

The criteria for defining effect magnitude related to the protection of drinking water supplies are different from those defined for the protection of aquatic life. The classification system accounts for the difference between aesthetic and non-aesthetic drinking water guidelines by giving a lower weight to concentrations that exceed aesthetic guidelines. Effect magnitudes are classified as follows:

- no effect – no measurable change in water quality
- low – water quality changes measurably, but KI concentrations in waterbody or potable water intake remain below drinking water guideline values
- moderate – water quality changes measurably, and KI concentrations in waterbody or potable water intake increase such that aesthetic drinking water guideline values are exceeded but remain below non-aesthetic guideline values
- high – water quality changes measurably, and KI concentrations in waterbody or potable water intake increase such that non-aesthetic drinking water guideline values are exceeded

Criteria for KIs without Guidelines

There are some KIs, or parameters of potential concern to aquatic life, for which water quality guidelines have not been established. In situations where the project is predicted to increase the concentration of a KI with no guidelines, the magnitude of effect was evaluated based on KI and site-specific considerations.

For evaluating the effects of acid deposition on water quality, magnitude was classified either as no effect or as a potential effect because of uncertainties associated with predicting impacts using critical loads.

The potential for acidification was evaluated by comparing modelled potential acid input (PAI) values to surface waters with lake-specific critical loads. The magnitude was classified as *no effect* where the predicted PAI was below the critical load acidity or where the weight of evidence indicated the lack of an effect, e.g., low lake sensitivity and low acid deposition rate. A *potential effect* was expected if the predicted PAI exceeded the critical load, which was considered an indication that the lake's buffering capacity might be exceeded by acid deposition, with a subsequent drop in pH.

6.2.4.3 Geographic Extent

Geographic extent describes the area within which an effect occurs. Geographic extent was divided into three classes:

- local – the effect is limited to a local study area (LSA)
- regional – the effect is limited to a regional study area (RSA)
- beyond regional – the effect extends beyond the RSA

6.2.4.4 Duration

Duration refers to the temporal extent of an effect. The duration of an effect can be considered an indication of how long the VC is affected by the project and the period required to recover from the effect. Recovery is defined as a return to conditions that would exist if the project had not occurred.

Duration was divided into four classes:

- short term – the effect is limited to less than 1 year
- medium term – the effect occurs from 1 to 4 years
- long term – the effect lasts longer that 4 years, but does not extend more than 30 years after decommissioning and abandonment
- far future – the effect extends more than 30 years after decommissioning and abandonment

6.2.5 Study Areas and Boundaries

Three types of study area were defined to assess the geographic extent of project effects:

- local study areas (LSA)
- regional study areas (RSA)
- an acid deposition study area

6.2.5.1 Local Study Areas

The water quality assessment used seven LSAs, one for each project component or group of components for which project effects were separately assessed. These LSAs were the same as those for the hydrology assessment (see Section 5, Hydrology):

- Niglintgak LSA
- Taglu LSA
- Parsons Lake LSA
- gathering pipelines LSA
- pipeline corridor LSA
- production area infrastructure LSA
- pipeline corridor infrastructure LSA

The geographic extents of these LSAs are described in Table 6-5 and shown in Figure 6-1 for the north part of the project area, Figure 6-2 for the central area and Figure 6-3 for the south.

Table 6-5: Geographic Extent of the Local and Regional Study Areas

Type of Study Area	Study Area	Geographic Extent
Local study area	Niglintgak – land-based option	Lease and 1-km-wide buffer
	Niglintgak – barge option	Lease and 1-km-wide buffer, disturbed riverbed, 1-km downstream
	Taglu	Lease and 1-km-wide buffer, disturbed riverbed, 1-km downstream
	Parsons Lake	Lease and 1-km-wide buffer
	Gathering pipelines	Watercourses within a 1-km-wide right-of-way centred on the gathering pipeline route
	Pipeline corridor	Watercourses within a 1-km-wide right-of-way centred along the gathering pipeline route
	Production area infrastructure	Disturbed land, drainage area from land to receiving waterbodies
	Pipeline corridor infrastructure	Disturbed land, drainage area from land to receiving waterbodies
	Barge-landing dredging activities	Immediate area of disturbance
Regional study area	All areas except barge landings	LSAs and downstream from each LSA to the next major stream or waterbody
	Barge-landing dredging activities	LSAs and downstream until sediment levels drop to less than 50 mg/L in excess of background levels

On these figures, the production area LSAs are delineated by the Significant Discovery Licence area boundaries. Because of the scale of the figures, other project component LSAs fall within the areas covered by symbols or coloured lines representing gathering pipelines.

Figure 6.1 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 6.2 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 6.3 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

6.2.5.2 Regional Study Area

Table 6-5, cited previously, also describes the RSAs for the water quality assessment. These RSAs are the same as for the hydrology assessment (see Section 5, Hydrology).

The locations of RSAs associated with the infrastructure components of the project not draining directly into the Mackenzie River, are also shown in Figure 6-1 (cited previously) for the north part of the project area, Figure 6-2, (cited previously) for the central area and Figure 6-3 (cited previously), for the south.

RSAs for other project components have been similarly defined, but, because of the scale used for these figures, are not shown to avoid cluttering.

The RSAs associated with barge dredging are site-specific and depend on several factors, including:

- location of the river thalweg relative to dredging location
- flow conditions, including flow velocities and depths during dredging
- background sediment concentrations
- time required for dredging

6.2.5.3 Acid Deposition Study Area

The air quality study areas were adopted for evaluating the effects of acidifying emissions on water quality. Effects of emissions from the production area were assessed in the northern airshed, a 150-by-200 km area that includes Niglintgak, Taglu, Parsons Lake and the gathering pipelines and associated facilities. Because emission sources were fewer along the pipeline corridor, effects of acid deposition were evaluated in several smaller, 20-by-20 km study areas around individual compressor stations, which were designated as local study areas in the air quality assessment in Section 2, Air Quality.

The acid deposition study area lakes with available water quality data are shown on the overview map, Figure 6-4. The lakes used to assess acid sensitivity in the production area are provided in Figure 6-5 for Niglintgak and Taglu, in Figure 6-6 for Parsons Lake and Figure 6-7 for the Inuvik area facility.

Study areas along the pipeline corridor are shown in Section 2, Air Quality.

Figure 6.4 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 6.5 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 6.6 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

Figure 6.7 has been removed for the purposes of reducing file size and can be viewed as a graphic separately. This document can be accessed through the link in the Table of Contents reference web page.

6.2.6 Analytical Approach

Baseline data was collected to characterize regional water and sediment quality in rivers, streams and lakes located near facilities or well pads in lease areas or crossed by the gathering system and pipeline corridor. Historical water and sediment quality data was also summarized. Baseline information was used:

- to characterize sensitivity of surface waters to project-related effects
- to evaluate whether existing levels of constituents in sediments might result in an effect if sediments are disturbed by project activities

The baseline data is described in detail in Volume 3, Section 6, Water Quality.

Potential effects were evaluated, taking into account the expected success of mitigation measures. Effects were predicted based on:

- information from other components of this assessment
- the expected success of mitigation measures incorporated in the project
- the level of sensitivity of VCs to the effects considered
- the scientific literature on effects of pathways associated with the project

Potential effects were evaluated based on available weight of evidence in the following situations:

- effects predicted by other components of this assessment were low, e.g., if changes in surface water flow or level resulting from water withdrawals were predicted to be within the natural range of variation, the resulting change in water quality would be undetectable
- mitigation measures were assumed to reduce or eliminate effects, e.g., deep well disposal of process wastewater would reduce contact between surface waters and wastewater, thereby lessening the potential for an effect
- sufficient weight of evidence was available from the scientific literature to evaluate an effect
- analytical methods were not available to support a quantitative analysis

The effect of acid deposition on water quality in lakes was evaluated by comparing critical loads of acidity with acid deposition rates modelled by the air component (see Section 2, Air Quality). The rate of acid deposition was expressed as the PAI, which is an estimate of acid deposition from all sources and accounts for the mitigating effect of base cation deposition. Lake-specific critical loads were compared with predicted rates of acid deposition in 23 lakes selected for detailed analysis. A value of PAI exceeding the corresponding critical load indicated that a lake's buffering capacity might be exceeded by acid deposition, with a subsequent drop in acid neutralizing capacity below a specified threshold value, i.e., 75 μeq/L.

6.3 Effects on Water Quality

6.3.1 Effect Pathways

The effect pathway diagram in Figure 6-8 shows the key and intermediate pathways by which the project could affect water quality. Changes in water column mixing patterns and sediment–water exchange regimes are also an intermediate pathway to effects on water quality. This pathway might result from a change in surface water flow or level, caused by water withdrawals or discharges.

Each pathway was evaluated to determine if it would be applicable given the mitigation measures planned for the project. A pathway was not applicable if mitigation measures would eliminate the potential for effects on water quality. Pathways from other EIS components, e.g., hydrology, were not applicable if they would have no measurable effect on water quality. Key and intermediate pathways from the hydrology assessment were evaluated individually for their effects on water quality.

Each pathway, whether it is applicable or not, is described in the following discussion. Thereafter, only applicable pathways are assessed.

6.3.1.1 Acid Deposition

The project will result in emissions of acid-forming substances, such as oxides of nitrogen (NO_x) and sulphur dioxide (SO_2), from vehicles, construction equipment, generators and facilities including compressor stations, which will be the largest source of acidifying emissions. These emissions might cause an increased rate of acid deposition compared with background rates and might affect pH in acid-sensitive lakes. Although most lakes with available data in the acid deposition study area are not sensitive to acid deposition, a few are moderately to highly sensitive. This pathway is applicable to effects on water quality in lakes during construction and operations. Because the determination of acid deposition applies to the combined effects of all components of the project, it is presented separately in Section 6.3.10, Acid Deposition Study.

A second source of acidification, episodic acidification, or spring acid pulses, is considered for streams. Spring acid pulses occur naturally in streams during snowmelt, usually because of base cation dilution (Sullivan 2000). Acid deposition can contribute to episodic acidification by increasing the amount of acids released during snowmelt. Highly sensitive streams are usually small and at high elevations with steep topography, extensive areas of exposed bedrock, deep winter snowpack and shallow, base-poor soils. Episodic acidification is usually observed in mountainous areas that have deposition from nearby industrialized areas or large population centres and where high NO_x emission rates can cause nitrogen saturation in terrestrial ecosystems.

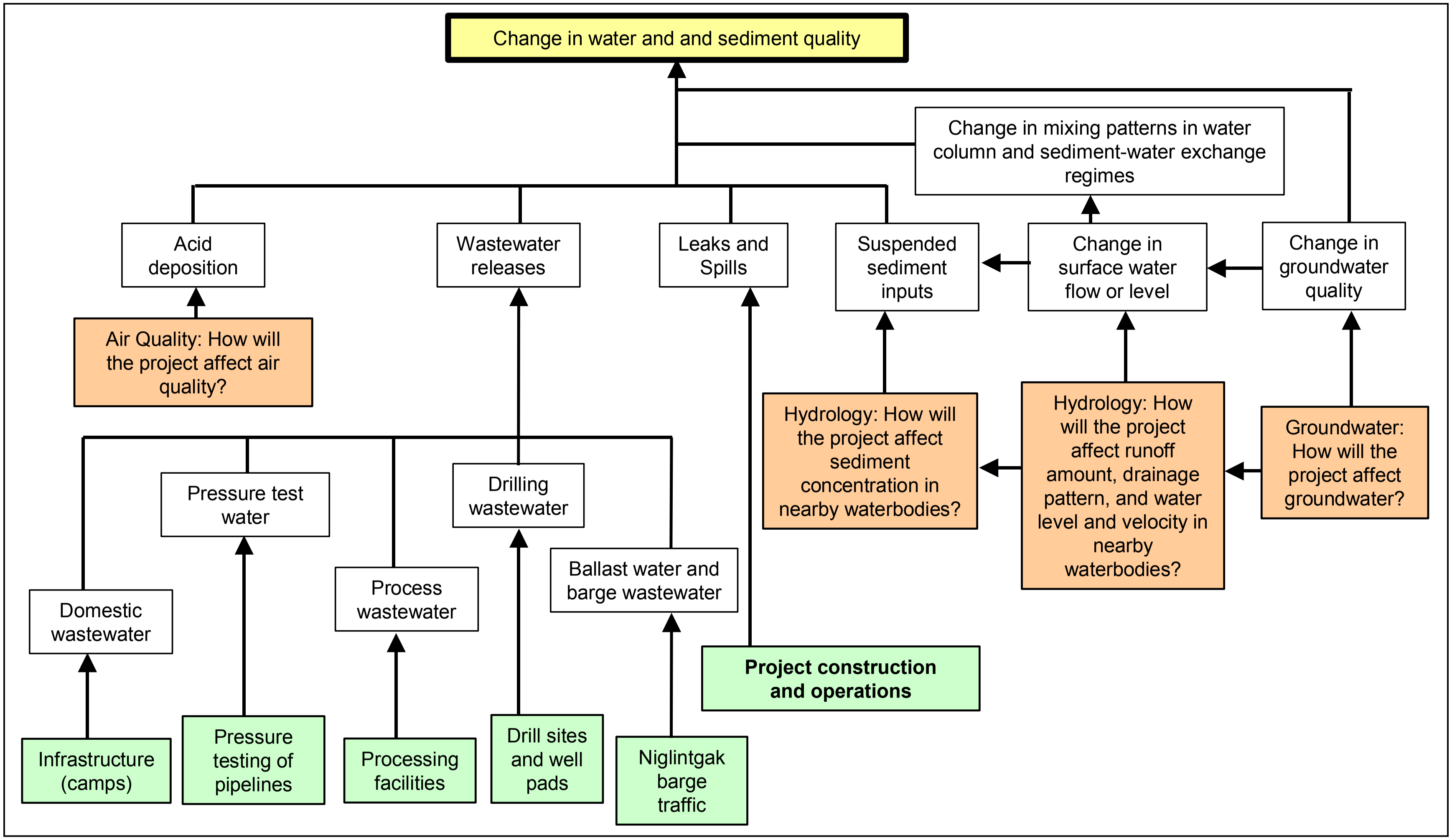

Figure 6-8: Effect Pathways – Water and Sediment Quality

Most streams in the project study area do not share the characteristics listed previously and are unlikely to be sensitive to episodic acidification. Regional water quality data supports this assumption. Some degree of natural pH depression from dilution of stream waters by spring snowmelt is possible, though even during peak operations, acid deposition rates will remain low in absolute terms (see Section 2, Air Quality). Based on low sensitivity to acid deposition in regional streams, combined with low rates of acid deposition, the occurrence and severity of episodic acidification would not change. Therefore, for streams, this pathway is not applicable to effects on water quality.

6.3.1.2 Wastewater Releases

Most domestic wastewater, pressure test water and drilling wastewater will be generated during construction. Smaller amounts of domestic wastewater, along with process wastewater, will be generated during operations.

All project wastewater will be handled and disposed of in a manner that reduces or eliminates potential impacts on the environment, (see Volume 7, Environmental Management). Regulatory requirements, including those defined in site water licences, will be met.

Domestic Wastewater

During construction and operations, domestic wastewater will be generated from camps used to house the project workforce. Construction camps will be temporary, possibly with some being required into the early part of the operations phase. Domestic wastewater release is an applicable pathway for effects on water quality.

Pressure Test Water

Pressure testing refers to the testing of flow lines, the gathering system and pipelines, to detect leaks. This testing will occur during construction.

Regardless of the medium selected, pressure testing will be conducted according to applicable regulatory requirements.

Water used for pressure testing would be withdrawn from nearby surface waters and regulatory criteria for discharge water quality will be met.

Therefore release of pressure test water is an applicable pathway for effects on water quality if pressure testing is the chosen test method.

Process Wastewater and Drilling Wastewater

Wastewater from project facilities and drilling activities might be generated by the project during construction and operations. Process wastewater, produced water and drilling wastewater generated at all locations will be deep-well injected, transported off-site for disposal, or recycled.

At Niglintgak, drilling fluids and cuttings will be disposed of by freezing, burying and covering at an off-site remote sump. A monitoring program will be established to ensure that the material stays frozen and the cap is stable (see Section 4, Groundwater). By maintaining the waste material in a frozen state, it will not provide a source of leachate into surface or ground waters. Therefore, this waste will not be released to surface waters and this pathway does not apply to effects on water quality.

Ballast Water – Barge Option Only

There are two options for the Niglintgak gas conditioning facility location: on land, or on a barge located in a side channel of the Mackenzie River adjacent to Kumak Island. If the Niglintgak gas conditioning facility is located on land, this pathway will not apply to effects on water quality.

Water quality concerns associated with the barge option include:

- the need to carry ballast water in the vessel to maintain draft within the range necessary for navigation
- potential degradation of ballast water quality during operations

Management of ballast water will comply with all applicable regulations, such as the *Guidelines for the Control of Ballast Water Discharge from Ships in Waters Under Canadian Jurisdiction* (Transport Canada 2001), which becomes part of the *Canada Shipping Act* in 2004.

The barge could be transported from the manufacturer to the Arctic via dry tow, on top of a heavy lift vessel; or via wet tow, with ballast tanks filled. If the dry tow option is chosen, transfer of marine ballast water from the barge to fresh water would not occur because ballast tanks would be empty. Under the wet tow option, ballast water would need to be discharged before negotiating the shallow inland coastal waters to bring the barge to its minimum draft. There would be no transfer of marine ballast water to the Mackenzie River under either option.

Once the barge has reached the chosen location in the river, ballast tanks would be filled with fresh water to lower the vessel to the river bottom at the Niglintgak gas conditioning facility location.

The ballast water system would be managed to ensure proper barge stability and operation. There are several options for managing ballast water, each including some degree of contact between ballast water and surrounding river water. However, no effects are expected on the quality of surrounding river water because:

- the source of the ballast water would be the river surrounding the barge

- ballast water would be physically separated from other waters contained on the barge
- the design of the barge would incorporate features to prevent chemical releases to ballast water, and considerations will be given to features such as double-skin enclosures for any liquid storage tanks in contact with ballast water
- the final design of the barge might also incorporate features to treat ballast, if necessary, possibly including:
  - a ballast water cleanup system
  - a treatment system to remove large particles and fine sediments
  - ultraviolet sterilization
- additional ballast water management designs will be evaluated during a subsequent engineering phase to ensure no effects on the environment.

Based on this information, this pathway does not apply to effects on water quality.

Barge Wastewater – Barge Option Only

Wastewater management on the Niglintgak gas conditioning facility barge will conform to applicable regulatory requirements. Process wastewater produced on the barge during operations will be collected and disposed of off site, as planned for conditioning facilities at the other anchor fields, resulting in no effects on water quality.

The barge design will incorporate features that will prevent release of deck drainage water directly to the environment. Deck drainage water will be collected in tanks and managed as for all other wastewater from the barge.

Because operation of the barge will result in releases of treated water to the river, this pathway applies to effects on water quality.

6.3.1.3 Leaks and Spills

This pathway pertains to leaks and small spills during construction, operations and decommissioning and abandonment. Small spills of some substances on land or on barges, including fuel, oil and grease, can reach waterbodies if intercepted by surface runoff or if they enter groundwater. Implementation of management practices, contingency plans, mitigation measures and emergency response plans, as outlined in Volume 7, Environmental Management, will reduce the potential of these substances to reach receiving waterbodies via surface runoff or groundwater.

Small spills could also include the accidental release of drilling mud during installation of pipelines at watercourse crossings where horizontal directional drilling (HDD) techniques are to be employed. HDD mud is more environmentally benign than exploration drilling mud, because it is mostly bentonite clay (Bleier et al. 1993; Hair and Cebo Holland 1994). HDD mud might also include granular materials and water-based spotting fluids, such as glycol or glycerol-based fluids, flocculants and pH control additives to maintain pH between 8 and 9, e.g., soda ash or caustic soda, with low toxicity (Reid and Anderson 1998). Accidental release of HDD drilling mud is not likely to adversely change water quality because it stays bound together in a gel-like suspension when mixed with water and will eventually settle (Reid and Anderson 1998). However, it could change the proportion of clay in bottom sediment in affected areas, without an effect on sediment chemistry.

The potential for small spills to alter surface water or bottom sediment quality is a valid pathway. However, the implementation of management practices, mitigation measures, contingency plans and emergency response plans outlined in Volume 7, Environmental Management, will ensure that the effects of small spills on surface water and bottom sediment quality will be reduced to the lowest possible level. This pathway does not apply to effects on water quality.

6.3.1.4 Suspended Sediment Inputs

Suspended sediment inputs to waterbodies could result from land disturbance, land subsidence at Niglintgak and Taglu, frost bulb formation and disturbance of river bottom and bank sediments by dredging and during pipeline construction at watercourse crossings. Section 5, Hydrology, predicts changes in TSS levels. The direct effects of increased TSS on aquatic life and the effects of sediment releases on fish habitat are evaluated in Section 7, Fish and Fish Habitat.

The evaluation of this pathway in this section is concerned with water quality changes caused by increases in concentrations of sediment-associated parameters and release of chemicals from suspended sediments that have been added to waterbodies, rather than with the effect of sediment addition. Increased TSS concentration might result in higher levels of KIs that are associated with human activities or that are naturally occurring, such as nutrients, metals or organic compounds that bind to particulate material.

The following discussion provides information on potential suspended sediment-related pathways throughout the project.

Land Disturbance

Section 5, Hydrology, predicts changes in TSS levels resulting from land disturbance during construction and operations. Land disturbance will occur during construction activities, clearing of the pipeline right-of-way, borrow site development and use, gravel pad use during operations and decommissioning activities, such as removal of camps.

Predicted effects on TSS concentrations in surface waters were classified by Section 5, Hydrology, as:

- low for anchor fields and common infrastructure in the production area
- low to moderate during construction and low during operations and decommissioning and abandonment for the gathering system, pipeline and pipeline facilities, pipeline corridor infrastructure and for combined effects in both the production area and pipeline corridor

The predicted increases in TSS might result in increased concentrations of sediment-associated water quality parameters, e.g., nutrients and metals, when measured as total concentrations. However, changes in water quality will be limited by the following:

- mitigation measures applied during project-related activities that could generate sediment (see Section 5, Hydrology and Volume 7, Environmental Management) will reduce sediment inputs from construction and operations
- sediment releases are expected to occur over short periods, during and immediately following rain events
- project-related activities will not cause release of sediments from areas that could have elevated levels of chemicals associated with human activities. Implementation of mitigation measures for small-scale leaks and spills will ensure that runoff and suspended sediment does not contain chemicals from human sources.
- under the conditions expected during sediment releases, i.e., from an oxygenated environment to an oxygenated receiving environment, KIs associated with particulate material would remain attached to suspended sediments and would ultimately settle out in depositional areas downstream of the point of input

Because concentrations of some sediment-associated KIs might be affected in surface waters, input of sediments from land disturbance is an applicable pathway for effects on water quality.

Land Subsidence

Subsidence in delta channels and land areas might, from increased rates of bank erosion and seasonal inundation of larger areas, cause increased sediment yield and concentrations in waterbodies (see Section 5, Hydrology). This potential effect might occur during operations and extend into decommissioning until the gas reservoir stabilizes.

Subsidence at Niglintgak and Taglu will occur gradually as the resource is extracted, so changes in erosion and sediment yield will also be gradual. This will likely result in gradual changes in flow velocities and depths, in step with land subsidence, allowing the environment to adjust. Section 5, Hydrology, predicted low effects on sediment yield and concentrations in delta channels during operations and decommissioning.

Additional inputs of sediment associated KIs, e.g., nutrients and metals, caused by subsidence would be nonmeasurable or unlikely to substantially change water quality because:

- sediment inputs from this pathway will be low
- sediments will be released from previously undisturbed areas
- existing high background concentrations are high in the Mackenzie River and delta channels
- conditions resulting in chemical releases are not expected

Input of sediments from land subsidence does not apply to effects on water quality.

Frost Bulbs

As the mean temperature of the gas pipeline will periodically be below 0°C, frost bulbs, i.e., regions of frozen ground, might form around the pipe. The natural gas liquids (NGLs) pipeline will be a smaller diameter line with low flow at ambient temperature, so frost bulb formation will not be a concern for this pipeline.

Frost bulbs that result in frost heave might cause seasonal sediment releases from erosion. If frost heave raises a watercourse substratum, erosion of the raised area could introduce sediments to stream water. Alternatively, if groundwater or surface water flow is blocked in a small stream, ponding and sediment deposition could occur upstream of the crossing. Spring runoff could then mobilize the deposited sediments. Enhanced runoff from ice formed upstream of the crossing might cause erosion and subsequent sediment input to stream water.

The hydrology assessment (see Section 5, Hydrology) predicted low-magnitude effects on sediment concentrations in streams because of frost bulb formation. Increases in sediment releases of this magnitude from previously unaffected watercourses would not result in a measurable change in water or sediment quality. The direct effects of changes in suspended sediment concentrations on fish habitat and aquatic life are evaluated in Section 7, Fish and Fish Habitat.

Input of sediments from frost bulb formation does not apply to effects on water quality.

Disturbance of Bottom and Bank Sediments

Potential Dredging

River bottom and bank sediments might need to be dredged at new and existing barge landings to facilitate landing installation, to allow barge access and as part of routine maintenance. A total of 22 barge landings are proposed, most in the Mackenzie River mainstem. If the barge option is chosen for the Niglintgak gas conditioning facility, dredging might be required in delta channels to allow transport of the Niglintgak gas conditioning facility to its planned location and to remove it during decommissioning. Dredging will likely take place along previously dredged shipping routes, though it is possible that new areas might also need to be dredged. Dredging might also be required at the Niglintgak gas conditioning facility site to prepare it for barge installation.

Dredging can release large amounts of suspended sediments from disturbed bottom sediments into the overlying water. Where required, the shipping channel will be deepened and the material removed will be side-cast along the dredged area. Estimates of the relative amount of sediment brought into suspension during sediment removal range from less than 1 to 5% of the total dredged volume (van Oostrum and Vroege 1994). Return of dredged sediments back to the river along the dredged area would result in additional sediment suspension.

The hydrology assessment in Section 5, Hydrology, predicted localized, low- to high-magnitude effects on sediment concentrations from potential dredging during construction, and decommissioning and abandonment of the Niglintgak gas conditioning facility. The hydrology assessment predicted localized, low- to moderate-magnitude effects on sediment concentrations from potential dredging of barge landings during construction and operations. Effect magnitude considered the high background suspended sediment concentrations in the Mackenzie River and delta channels.

Available sediment quality data suggests that levels of certain KIs could exceed sediment quality guideline levels for the protection of aquatic life. In delta channels and Kugmallit Bay, which are located along one of the barge route options, some KIs were measured at levels that exceed guideline levels. These include arsenic, cadmium and certain polycyclic aromatic hydrocarbon (PAH) levels exceed freshwater sediment quality guideline values in delta channels. Concentrations of chromium, copper, mercury, zinc and certain PAHs exceed the marine sediment quality guideline values in Kugmallit Bay (see Volume 3, Section 6, Water Quality).

Because of the potential for release of metals and organic compounds to the water column during dredging and the occurrence of some KIs exceeding guideline values in sediments, this pathway applies.

Barge Traffic

The effect of disturbance of bottom or bank sediments by barge traffic on TSS levels was predicted to be low (see Section 5, Hydrology). Effect magnitude considered the high background suspended sediment concentrations in the Mackenzie River and delta channels.

Because of the potential for increased levels of sediment-associated KIs caused by barge traffic, this pathway applies.

Watercourse Crossings

Watercourse crossings during pipeline or temporary access bridge construction could release suspended sediments into stream water. The effects on sediment concentrations at watercourse crossings would range from no effect to high during construction, depending on the crossing construction method, but will be no effect during operations and decommissioning and abandonment (see Section 5, Hydrology). Because there is a potential for release of large amounts of sediments at certain crossing locations, this pathway applies to effects on water quality. The effects on water quality are related to increased levels of some KIs, e.g., some metals and PAHs, that occur at naturally high levels in bottom sediments of some waterbodies.

6.3.1.5 Change in Surface Water Flow and Level

Surface water flow or water level might be altered by the following project-related changes:

- change in surface water runoff
- water withdrawal
- change in groundwater quantity
- land subsidence in Niglintgak and Taglu

Change in Runoff

Predictions of changes in surface water runoff in Section 5, Hydrology were based on the amount of land disturbed by project components. The hydrology component predicted low-magnitude effects on surface water flow and level, which represent a nonmeasurable to less than 2% change in mean annual runoff.

Changes in flow and level caused by such small changes in runoff are unlikely to be measurable. Consequently, no effects are expected on water quality from this pathway.

Fertilizer application during reclamation at the pipeline rights-of-way is a minor pathway associated with runoff. Fertilizer might affect the quality of surface runoff and of water in receiving waterbodies. However, as described in Volume 7, Environmental Management, fertilizer use will be minimized. This pathway would not cause measurable effects on water quality and, therefore, does not apply to effects on water quality.

Water Withdrawal

The majority of water for industrial processes, drilling, potable water, pressure testing and winter roads will come from nearby surface waters. Depending on the magnitude of the water withdrawals, the mixing patterns and interactions between bottom sediment and water, referred to as the sediment-water exchange regime, could be altered.

In lakes, the shape and size of the basin can have profound effects on sediment–water interactions and lake productivity (Wetzel 2001). For example, the greater productivity of small, shallow lakes is usually correlated with the higher sediment–water interface area per unit water volume. The sediment–water interface is the site of biological, chemical and physical processes that allow sediment nutrient release to the water column. A study of the predicted change in water levels is required for predicting potential changes in water quality.

Changes in lake or river levels were assessed in Section 5, Hydrology. Potential changes in water level considered the following:

- potable water withdrawals
- winter road withdrawals
- pressure testing withdrawals from the Mackenzie River
- pressure testing withdrawals from lakes

Regulatory limits on water withdrawal volumes and rates would be met at all times. Effects on water levels were predicted to be low to moderate (see Section 5, Hydrology). A low rating corresponds to a change in mean water level that is not detectable, whereas a moderate rating represents a change of 2 to 5% in the natural range. A decline of this magnitude would not affect water quality. Therefore, this pathway does not apply to effects on water quality.

Change in Groundwater Quantity

As outlined in Section 4, Groundwater, the project is not predicted to cause any substantial changes in groundwater quantity. Changes in ground water quantity or flow patterns are expected to be low, i.e., not measurable. Therefore, detectable effects are not expected on surface water quality and this pathway is not applicable to effects on water quality.

Land Subsidence

Land subsidence could occur at both Niglintgak and Taglu because of project development and operations. Section 5, Hydrology, provides details on subsidence effects. The extraction of natural gas and NGLs will reduce reservoir volumes and pressures, leading to compression of the deep gas reservoirs and a lowering of overlying land. The effects of subsidence on surface water drainage are not well understood because of the complex interaction between flow quantity, channel morphology and the changes that inundation could make on sediment supply and movement. The lowering of ground level associated with subsidence might cause increased inundation of land and waterbodies in the affected area, deepening of delta channels and a greater extent of saltwater intrusion into delta channels.

Section 5, Hydrology predicted that subsidence might result in a longer period of seasonal inundation in some areas in Niglintgak and cause a widening of the Middle Channel. Subsidence is unlikely to affect water quality in lakes and ponds, because frequent flooding already controls the water quality in these lakes. Taglu is subject to less flooding and will be affected less by subsidence. Predicted effects on flooding in this area are also lower. Consequently, no effects are expected on lake and pond water quality in Niglintgak and Taglu. The land subsidence pathway is not applicable to effects on water quality in Niglintgak and Taglu.

Saltwater Intrusion

Subsidence could cause an increase in saltwater intrusion into delta channels. Because salt water is denser than fresh water, a saltwater wedge from the ocean frequently extends upstream along the bottom of channels. The extent of saltwater intrusion depends on tides, river flow, bathymetry of the channel bed and possibly other factors and would be greatest at high tide during low river flow. If subsidence deepens a channel in the area of the saltwater wedge, water quality might change near the bottom as the wedge extends farther upstream. However, even if the characteristics of the saltwater wedge change because of subsidence, additional mixing between fresh water and salt water is not expected.

Available information suggests that a saltwater wedge does not extend to the area of predicted future subsidence in the Middle Channel, and, if it does, the wedge is narrow. The following points are relevant to characterizing the likely extent of the saltwater wedge:

- information on channel characteristics (Slaney and Company 1976; Fassnacht 1995) suggests the Middle Channel is shallow from the southern tip of Niglintgak Island to its mouth in the Beaufort Sea. Therefore, there is no potential for a sizeable saltwater wedge in this channel.

- in the Middle Channel, the downstream edge of the predicted zone of subsidence is about 7 km from the mouth. This suggests that there might be several kilometres of potentially shallow water between the channel mouth and the zone of subsidence, which also implies that a saltwater wedge in the zone of subsidence is unlikely.

- near Niglintgak, the Middle Channel is shallow and depositional, with depths of 1 to 1.5 m in the summer, except in a narrow, i.e., less than 100 m, section of the channel that is deeper (Hardy and Associates 1977). The maximum depth in this narrow section ranged from 2.6 to 6.5 m, which suggests limited potential for a saltwater wedge in this channel.

Because it is shallow, it is unlikely that there is a saltwater wedge in the Middle Channel. If present, the wedge is likely to be narrow. If there is no saltwater wedge, this pathway does not apply to effects on water quality. If there is a narrow wedge, saltwater intrusion caused by subsidence would not affect water quality in the Mackenzie River because any change would be too small to influence the quality of river water, especially considering the limited mixing between salt water and fresh water.

Also, because the rate of subsidence will probably be a few centimetres per year, sedimentation might offset any changes in river depth. Therefore, the saltwater intrusion pathway does not apply to effects on water quality.

6.3.1.6 Change in Groundwater Quality

Groundwater interactions with surface water is one of the determinants of water quality, so changes in groundwater quality resulting from the project could affect water quality.

Section 4, Groundwater, predicted low-magnitude effects on groundwater quality for all project components. A change in groundwater quality that is not likely measurable is, by definition, a low-magnitude effect. Therefore, detectable effects are not expected on water quality and this pathway does not apply to effects on water quality.

6.3.2 Overview of Project Design and Mitigation

This section provides an overview of project design features and mitigation measures relevant to potential effects on VCs. The project design features are detailed in Volume 2, Project Description and the mitigation strategies are detailed in Volume 7, Environmental Management. Most potential project effects will be reduced by best management practices during design, construction, operations and decommissioning.

Mitigation strategies for the potential effects on water quality via the pathways discussed previously in Section 6.3.1, Effect Pathways, are described in Table 6-6.

Table 6-6: Mitigation Strategies – Construction

Effect Pathway	Primary Mitigation Strategy
Change in water and sediment quality from release of pressure test water, domestic wastewater from camps and drilling wastewater	Release water to the watershed in a controlled manner such that the effects to the receiving waterbodies are reduced. Meet appropriate water quality discharge criteria for quality of discharge waters. In the event this is not possible, use alternative disposal methods. Dispose of wastewater or drilling waste by deep-well injection, or transport off site when wastewater cannot be appropriately treated for release to the watersheds.
Change in water and sediment quality from release of ballast water	Manage ballast water to comply with applicable regulations.
Change in water and sediment quality from potential dredging activities	Select dredging and sediment-control methods to comply with Fisheries Act authorization.
Change in water and sediment quality from leaks and spills	Implement management practices, contingency plans and emergency response plans to prevent and address leaks and spills. Employ a leak detection system. Use environmentally acceptable hydraulic fluid in hydraulic systems of machinery working in water. For fuel tanks greater than 4,000 L, store fuel in either double-walled tanks, or single-walled tanks with secondary containment systems as required by regulations. Set back storage sites for fuels, lubricating oils, chemicals, or other hazardous materials at least 100 m from any waterbody or protect from flooding, unless approved otherwise. For pipeline activities, wash, maintain and refuel vehicles at least 100 m from any waterbody, unless otherwise authorized. Complete visual inspection to ensure clean facility and work sites.

Table 6-6: Mitigation Strategies – Construction (cont'd)

Effect Pathway	Primary Mitigation Strategy
Change in water and sediment quality from land disturbance	Implement drainage, erosion and sediment controls such as grading and ditching to direct runoff through silt fences, sediment traps, vegetation, berms, or isolation areas, as appropriate for the location. Monitor effectiveness of controls through routine inspection. Install long-term erosion-control measures on slopes and streambanks, where required. Reduce disturbance immediately next to streambanks. Reclaim disturbed areas to reduce sediment transport when horizontal directional drilling is used as a crossing technique. Maintain an undisturbed buffer at the edge of the watercourse. Reclaim bed, banks and approach slopes of the watercourse to stable conditions, grade and contours. Locate borrow sites away from waterbodies, where practical. Develop and implement site-specific erosion and sediment control plans where required.
Change in water and sediment quality from frost bulb formation	Increase burial depth of the pipeline or use insulation at Active I crossing locations that are susceptible to heave and frost bulb growth.

Project activities that could affect water quality will be initiated during construction and will cause changes through the remainder of the project. Decommissioning and abandonment will remove many project components that can generate effects, but some potential effects are long lasting. These effects and those related to project components abandoned in place, would persist after decommissioning.

6.3.3 Niglintgak

Niglintgak will have a gas conditioning facility, six to 12 production wells drilled from three well pads, i.e., north, central and south, associated above-ground flow lines, one or two disposal wells, a remote sump and supporting infrastructure (see Volume 2, Project Description).

Two options are being considered for the location of the Niglintgak gas conditioning facility:

- on a barge in a side channel of Kumak Channel, which is the proposed option
- on land east of Kumak Channel, which is the alternate option

6.3.3.1 Baseline Conditions

In 2002 and 2003, water and sediment samples in the production area were collected from 13 lakes, four rivers and three major channels of the Mackenzie

River. Field water quality data was also collected from another 45 locations. Historical data was available for some locations.

Lakes in Niglintgak and Taglu are low-closure lakes, i.e., lakes that are annually flooded by the Mackenzie River in spring, and are occasionally subject to marine influences. Other lakes in the study area, in the Parsons Lake lease or along the Taglu and Storm Hills laterals, are not likely to be flooded by the Mackenzie River every year.

Baseline water and sediment quality are described in detail in Volume 3, Section 6, Water Quality. A summary of baseline data for the production area is provided in the following discussion.

Water Quality

Water quality is similar throughout the production area. Waterbodies were well oxygenated in summer, and the annual range of pH values was similar throughout, i.e., 6.5 to 9. Except for Yaya Lake in the north basin, and Parsons Lake, most lakes were less than 5 m deep. Lakes were not thermally stratified in the summer of 2002 and 2003.

All waterbodies contained moderately coloured water, often with values exceeding drinking water guideline values. Turbidity and TSS levels were high in delta channels and low in lakes in Niglintgak and Taglu. Turbidity and TSS were low in waterbodies in the Parsons Lake lease and along the gathering system laterals, except for the East Channel of the Mackenzie River and an unnamed stream, which had high levels.

Major ion concentrations varied among sites, as indicated by TDS and conductance levels. Alkalinity data indicates that most lakes are not sensitive to acid deposition.

Total Kjeldahl nitrogen levels were high in most waterbodies, except for three lakes and one stream. Total phosphorus levels were typically low in streams and high in delta channels. The TP-inferred trophic status of lakes ranged from oligotrophic, which are nutrient-poor, to eutrophic, which are nutrient-rich. However, most phosphorus is in the particulate form and is not likely available for biological uptake. Chlorophyll *a* data is available for some lakes and indicates oligotrophic conditions.

Concentrations of total metals were below aquatic life and drinking water guideline values, with some exceptions. Concentrations of total aluminum and iron exceeded aquatic life and drinking water guideline values in delta channels. Other metals that were in delta channels and some lakes at levels exceeding aquatic life guideline values included chromium, copper, lead and zinc. Total manganese levels exceeded drinking water guideline values in delta channels.

Total manganese, selenium and cadmium concentrations occasionally exceed aquatic life guideline values in lakes. Concentrations that exceed guideline values are indicative of naturally elevated concentrations of some KIs, especially aluminum and iron, and are usually associated with elevated TSS levels.

Sediment Quality

Bottom sediment in streams and rivers usually had higher proportions of sand, whereas delta channels had higher proportions of silt. Particle size of lake sediments varied but was often dominated by silt and clay. Total organic carbon concentrations were usually low in streams and delta channels and moderate in lakes. Lakes usually had high levels of total recoverable hydrocarbons, whereas streams and delta channels had low to moderate levels.

Arsenic levels commonly exceeded the interim sediment quality guideline value in streams and rivers, lakes and delta channels, and the values were occasionally in excess of the probable effect level in lakes. Other metals present exceeded guideline values in some lakes and delta channels included cadmium, chromium, copper and zinc. Naphthalene, C_1-substituted naphthalene and phenanthrene were often at levels exceeding the interim sediment quality guideline values in lakes and delta channels. C_1-substituted naphthalene levels also occasionally exceeded the probable effects level in lakes and delta channels. As with water quality, concentrations exceeding guideline values reflect naturally elevated concentrations of certain KIs.

6.3.3.2 Niglintgak Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. Effects on water and sediment quality at Niglintgak are summarized in Table 6-7.

Construction

Discharge of Pressure Test Water

Discharge of pressure test water is predicted to have a low-magnitude effect on water quality. Pressure test water discharge will comply with regulatory requirements. The magnitude rating is based on wastewater treatment, if treatment is necessary, and on the establishment of criteria for the size of receiving waters to ensure that maximum effects on water quality are low magnitude. Pressure test water will be released only if it will cause no more than a low-magnitude effect on water quality in receiving waterbodies.

Table 6-7: Effects on Water and Sediment Quality – Niglintgak

Pathway[1]	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Wastewater Releases					
Discharge of pressure test water	Construction	Adverse	Low[2]	Local	Short term[5]
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	N/A	N/A	N/A	N/A
Discharge of barge wastewater	Construction	Adverse	Low[3]	Local	Medium term
	Operations	Adverse	Low[3]	Local	Long term
	Decommissioning and abandonment	Adverse	Low[3]	Local	Medium term
Suspended Sediment Inputs					
Disturbance of bottom and bank sediments – potential dredging	Construction	Adverse	Low to moderate[4]	Local	Short term
	Operations	N/A	N/A	N/A	N/A
	Decommissioning and abandonment	Adverse	Low to moderate[4]	Local	Short term
Land disturbance	Construction	Adverse	Low	Local	Medium term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	Low	Local	Long term

NOTES:
N/A = not an applicable effect pathway
1 Acid deposition effects are not evaluated for individual project components. They are evaluated for all project components combined, as in Section 6.3.10, Acid Deposition Study
2 Rating assumes that regulatory requirements will be met and that receiving waterbodies will be chosen to eliminate effects or limit them to a low magnitude
3 Rating assumes that regulatory requirements will be met
4 Predicted TSS levels are presented in Section 5, Hydrology – the rating in this table refers to water quality KIs other than TSS
5 Rating refers to the duration of effect for each receiving waterbody

Discharge of Barge Wastewater

Discharge of barge wastewater comprising deck drainage water is predicted to have a low-magnitude effect on water quality. The magnitude rating is based on wastewater treatment, if treatment is necessary; and on the large dilution capacity of the Mackenzie River compared with the expected amount of wastewater discharged. If wastewater treatment is not sufficient to limit effects, barge wastewater will be disposed of off site.

Disturbance of Bottom and Bank Sediments – Potential Dredging

The release of metals, nutrients and organic compounds to the water column during dredging depends on several factors (Augenfeld and Anderson 1982; Lynch and Johnson 1982; Salomons et al. 1987; van Oostrum and Vroege 1994; Degtiareva and Elektorowicz 2001; Schroeder 2001), including:

- concentrations of compounds in dredged sediments
- redox state
- sediment grain size and organic content
- the method of dredging and mitigation measures applied
- the area dredged and flow characteristics in the dredged waterbody
- other factors

Because of the many factors involved, it is difficult to predict the release of chemical constituents during dredging (van Oostrum and Vroege 1994).

Exposure of anoxic sediments to overlying water that is rich in oxygen could cause a release of heavy metals to the aquatic phase under certain conditions (Salomons et al. 1987; Degtiareva and Elektorowicz 2001). Because the oxygen-rich layer of sediments is usually limited to a few centimetres near the surface (Van den Berg et al. 1998), this phenomenon represents a potential pathway for release of chemicals from dredged sediments. Computer simulations have indicated that organic chemical release during dredging can be considerable, depending on the type of chemical and on the environmental conditions during dredging.

Despite the potential for release of chemicals during dredging, the environmental effects of dredging and spoil disposal are believed to be localized and short term, assuming bottom sediments do not already have high levels of chemicals (Lane and Associates Delcan-Stone and Webster 1989). Field studies of dredged material disposal have found that chemical releases are transient and localized and measured levels in water are low (LaSalle et al. 1991). Released metals, and possibly other constituents, would partition to iron oxides and ambient TSS in the water column (LaSalle et al. 1991; Schroeder 2001) and subsequently settle to the bottom.

Available information suggests water quality usually returns to the background condition shortly after dredging is completed. Studies stress that release of chemicals from dredged material is usually limited in time because of patchiness of chemical distribution in sediments, rapid settling and improvements in dredging technology that incorporate mitigation measures such as the use of silt curtains. Burton (1992) and Schroeder (2001) have suggested that concentrations of constituents released from dredged sediments are elevated for a period of hours. Van Oostrum and Vroege (1994) observed that most suspended material re-settled within one hour after dredging during 22 field monitoring events.

Effects of sediment releases from potential dredging done to transport the Niglintgak gas conditioning facility are predicted to be low to moderate magnitude, based on:

- the large amount of bottom sediments disturbed
- the potential for elevated levels of certain KIs in bottom sediments
- chemical processes accompanying sediment disturbances

The maximum rating of moderate for effect magnitude reflects the possibility that concentrations of certain chemicals in the water column near the dredging could exceed water quality guideline values.

This pathway is only applicable if the barge option is chosen for the Niglintgak gas conditioning facility.

Land Disturbance

Effects of land disturbance on water quality are expected to be transient, i.e., limited to increases in concentrations of sediment-associated KIs, e.g., nutrients and metals, during periods of elevated TSS concentration. These periods would occur during and immediately after rain events. Suspended sediments would ultimately settle out in depositional areas, resulting in a return to background concentrations of sediment-associated KIs.

Natural sediment inputs also occur during rain events, implying the likelihood of naturally elevated background levels of sediment-associated KIs. Although changes in KI concentrations caused by land disturbance might be measurable, the incremental increases in concentrations are not expected to be of concern to water quality in terms of nutrient enrichment or toxicity to aquatic life. Therefore, effect magnitude is predicted as low.

Operations

Effects of barge wastewater releases and land disturbance on water quality will be low magnitude during operations.

Decommissioning and Abandonment

Effects during decommissioning will be low to moderate magnitude, resulting from:

- sediment releases during potential dredging required to remove the barge from the anchor field

- releases of barge wastewater
- land disturbance associated with decommissioning and abandonment activities

If the barge option is not selected for the Niglintgak gas conditioning facility, the only applicable pathway for effects on water quality would be land disturbance and the magnitude of the effect would be low.

6.3.4 Taglu

Taglu will include a gas conditioning facility, 10 to 15 production wells (with five initially) on a single well pad, associated short above-ground flow lines, one initial disposal well, and supporting infrastructure including an airstrip (see Volume 2, Project Description). A second disposal well might be added later.

6.3.4.1 Baseline Conditions

Section 6.3.3, Niglintgak, is a summary of baseline water and sediment quality in the production area. Baseline water and sediment quality are described in detail in Volume 3, Section 6, Water Quality.

6.3.4.2 Taglu Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. Table 6-8 summarizes effects of Taglu on water and sediment quality.

Construction

The magnitude of effects of pressure test water discharges and land disturbance will be the same as described for Niglintgak.

Operations

The magnitude of effects of land disturbance during operations will be the same as during construction.

Decommissioning and Abandonment

Effects predicted during decommissioning and abandonment are limited to localized increases in concentrations of sediment-associated KIs, e.g., nutrients or metals, caused by land disturbance. The magnitude of the predicted effect is low, as described for Niglintgak.

Table 6-8: Effects on Water and Sediment Quality – Taglu

Pathway[1]	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Wastewater Releases					
Discharge of pressure test water	Construction	Adverse	Low[2]	Local	Short term[3]
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	N/A	N/A	N/A	N/A
Suspended Sediment Inputs					
Land disturbance	Construction	Adverse	Low	Local	Medium term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	Low	Local	Long term

NOTES:
N/A = not an applicable effect pathway
1 Acid deposition effects are not evaluated for individual project components. They are evaluated for all project components combined in Section 6.3.10, Acid Deposition Study
2 Rating assumes that regulatory requirements will be met and that receiving waterbodies will be chosen to eliminate effects or limit them to a low magnitude
3 Rating refers to duration of effect for each receiving waterbody

6.3.5 Parsons Lake

The Parsons Lake field includes the north and south gas conditioning facilities, associated wells and above-ground flow lines, two disposal wells and supporting infrastructure including an airstrip (see Volume 2, Project Description). The site will be developed in two stages. The north pad, comprising a single well pad with nine to 19 production wells, disposal wells and a gas conditioning facility, will be developed first. The south pad will follow development of the north pad about 5 to 10 years later. The south pad will be a single well pad with three to seven wells. An above-ground flow line will transport product from the south pad to the north pad for conditioning.

6.3.5.1 Baseline Conditions

Section 6.3.3, Niglintgak, provides a summary of baseline water and sediment quality in the production area. Baseline water and sediment quality are described in detail in Volume 3, Section 6, Water Quality.

6.3.5.2 Parsons Lake Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. Table 6-9 is a summary of the effects of the Parsons Lake field on water and sediment quality.

Table 6-9: Effects on Water and Sediment Quality – Parsons Lake

Pathway[1]	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Wastewater Releases					
Discharge of pressure test water	Construction	Adverse	Low[2]	Local	Short term[3]
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	N/A	N/A	N/A	N/A
Suspended Sediment Inputs					
Land disturbance	Construction	Adverse	Low	Local	Medium term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	Low	Local	Long term

NOTES:
N/A = not an applicable effect pathway
1 Acid deposition effects are not evaluated for individual project components, but are evaluated for all project components combined in Section 6.3.10, Acid Deposition Study
2 Rating assumes that regulatory requirements will be met and that receiving waterbodies will be chosen to eliminate effects or limit them to a low magnitude
3 Rating refers to duration of effect for each receiving waterbody

Construction

The magnitude of effects of pressure test water discharges and land disturbance will be the same as described for Niglintgak.

Operations

The magnitude of effects of land disturbance during operations will be the same as during construction.

Decommissioning and Abandonment

Effects predicted during decommissioning and abandonment are limited to localized increases in concentrations of sediment-associated KIs, e.g., nutrients or metals, caused by land disturbance. The magnitude of the predicted effect is low, as described for Niglintgak.

6.3.6 Gathering Pipelines and Associated Facilities

The gathering pipelines connect the three anchor fields to the Inuvik area facility (see Volume 2, Project Description). The gathering pipelines and associated facilities includes the Niglintgak lateral, the Taglu lateral, the Parsons Lake lateral, the Storm Hills lateral, the Inuvik area facility, the Storm Hills pigging facility, two intermediate block valves and pads for the ditchless installation at the East Channel of the Mackenzie River.

6.3.6.1 Baseline Conditions

Baseline conditions described for Niglintgak, Taglu and Parsons Lake (see Section 6.3.3, Niglintgak) also apply to the gathering pipelines and associated facilities. Baseline water and sediment quality are described in detail in Volume 3, Section 6, Water Quality.

6.3.6.2 Gathering Pipelines and Associated Facilities Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. Table 6-10 is a summary of the effects of the gathering pipelines on water and sediment quality.

Table 6-10: Effects on Water and Sediment Quality – Gathering Pipelines

Pathway[1]	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Wastewater Releases					
Discharge of pressure test water	Construction	Adverse	Low[2]	Local	Short term[4]
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	N/A	N/A	N/A	N/A
Disturbance of bottom and bank sediments – watercourse crossings	Construction	Adverse	No effect to moderate[3]	Local	Short term[4]
	Operations	N/A	N/A	N/A	N/A
	Decommissioning and abandonment	N/A	N/A	N/A	N/A
Suspended Sediment Inputs					
Land disturbance	Construction	Adverse	Low	Local	Medium term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	Low	Local	Long term

NOTES:
N/A = not an applicable effect pathway
1 Acid deposition effects are not evaluated for individual project components, but are evaluated for all project components combined in Section 6.3.10, Acid Deposition Study
2 Rating assumes that regulatory requirements will be met and that receiving waterbodies will be chosen to eliminate effects or limit them to a low magnitude
3 Predicted TSS levels are presented in Section 5, Hydrology. The rating in this table refers to KIs other than TSS
4 Rating refers to duration of effect at each affected waterbody

Construction

The magnitude of effects of pressure test water discharges and land disturbance will be the same as described for Niglintgak.

The disturbance of bottom and bank sediments at watercourse crossings was considered to have either no effects or moderate-magnitude effects on water quality. Using a conservative approach, the hydrology assessment (see Section 5, Hydrology) predicted no effects to localized, high-magnitude effects on suspended sediment concentrations during construction, depending on the crossing method and stream classification. The moderate rating for water quality takes into account the fact that sediment will be released from disturbed bed materials that have naturally high levels of some KIs, e.g., metals and PAHs, which are likely associated with particulate material, but that effects on water quality will be of short duration. It is assumed that the crossing methods and mitigation measures selected will ensure that magnitude and duration of TSS releases will be limited.

Operations

Magnitude of effects of land disturbance during operations will be the same as during construction.

Decommissioning and Abandonment

Effects predicted during decommissioning and abandonment are limited to localized increases in concentrations of sediment-associated KIs, e.g., nutrients or metals, caused by land disturbance. The magnitude of the predicted effect is low, as described for Niglintgak.

6.3.7 Pipeline Corridor

The pipeline corridor includes the gas pipeline, the NGL pipeline and pipeline facilities including block valves, compressor stations, a heater station and the NOVA Gas Transmission Ltd. (NGTL) interconnect facility (see Volume 2, Project Description). The 1,220-km natural gas pipeline will transport sweet natural gas from the Inuvik area facility to the NGTL interconnect facility. The gas and NGL pipelines will share a common right-of-way for about 475 km from the Inuvik area facility to a point near Norman Wells.

6.3.7.1 Baseline Conditions

Baseline water and sediment quality were characterized in selected waterbodies along the pipeline route in 2002 and 2003, and available historical data was summarized. Water and sediment samples were collected from 32 rivers and two lakes. Field KIs were also measured at another 101 fish and fish habitat sampling locations.

Baseline water and sediment quality are described in detail in Volume 3, Section 6, Water Quality. A summary of baseline data for the pipeline corridor is provided in the following discussion.

Water Quality

Water was well oxygenated in summer and fall, with most dissolved oxygen concentrations exceeding the minimum aquatic life guideline value of 6.5 mg/L.

Values of pH below 7, or below the minimum aquatic life pH guideline value of 6.5, were measured in early June following the spring freshet. The remaining summer and fall pH values usually exceeded 6.5, with occasional values exceeding the maximum drinking water guideline value of 8.5. Although winter data is sparse, winter pH values were often above 6.5, with occasional values below the minimum aquatic life and drinking water guideline values.

Concentrations of colour, turbidity and TSS are directly related to the discharge regime of rivers in the pipeline corridor and levels are usually lowest in winter and highly variable in spring. Water was usually moderately to highly coloured in all regions, with values exceeding the drinking water guideline value in most waterbodies. Most turbidity and TSS levels were low in summer and fall. Moderate to high turbidity and TSS levels were also observed in some Sahtu Settlement Area and Deh Cho Region waterbodies in summer and fall.

Watercourses along the pipeline corridor usually have total dissolved solids and conductance levels that are highest during winter and that decline over the open-water period. Median total dissolved solids and conductance levels were moderately low in the pipeline corridor, except for many sites in the Sahtu Settlement Area, where levels were more variable, ranging from moderately low to very high, likely because of the influence of groundwater springs at some locations. Alkalinity values indicated that none of the waterbodies sampled were sensitive to acid deposition.

Watercourses in the Mackenzie River sub-basin have variable nutrient levels because of local physical and geologic variations. Total Kjeldahl nitrogen concentrations ranged from moderate to high. Total phosphorus levels in rivers and lakes ranged from levels indicative of oligotrophic, i.e., nutrient-poor, to eutrophic, i.e., nutrient-rich conditions. However, most phosphorus is in the particulate form and is not readily available for biological uptake.

Most metals were present at levels below aquatic life and drinking water guideline values, except for aluminum and iron. Other metals that were occasionally present at levels exceeding aquatic life guideline values in the Sahtu Settlement Area and Deh Cho Region included total cadmium, chromium, copper, lead, selenium and zinc. Total manganese concentrations occasionally exceeded drinking water guideline values in the southern part of the pipeline corridor. Naturally high levels of metals in the pipeline corridor are often associated with suspended solids concentrations.

Sediment Quality

This overview of baseline sediment quality in the pipeline corridor is largely based on bottom sediment data collected in 2002 and 2003. Bottom sediments were collected from depositional areas near where water quality samples were collected.

The relative proportions of sand, silt and clay varied between waterbodies in the corridor. Total organic carbon levels were low in all streams and rivers, except for moderate and high levels in two lakes sampled in 2003. Total recoverable hydrocarbon levels varied between sites, with values ranging from low to high.

Concentrations of metals and PAHs are typically associated with silt and clay particles, so levels varied between sites depending on particle size distribution. Metals and PAHs were usually present at levels below sediment quality guideline values, although there were some exceptions. Exceptions included total arsenic and C_1-substituted naphthalene levels, which often exceeded the interim sediment quality guideline values.

6.3.7.2 Pipeline Corridor Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. Table 6-11 summarizes effects of the pipeline corridor on water and sediment quality.

Construction

Types and magnitude of effects during construction will be the same as described for the gathering system.

Operations

Types and magnitude of effects during operations will be the same as described for the gathering system.

Decommissioning and Abandonment

Types and magnitude of effects during operations will be the same as described for the gathering system.

Table 6-11: Effects on Water and Sediment Quality – Pipeline Corridor

Pathway[1]	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Wastewater Releases					
Discharge of pressure test water	Construction	Adverse	Low[2]	Local	Short term[4]
	Operations	Neutral	No effect	N/A	N/A
	Decommissioning and abandonment	N/A	N/A	N/A	N/A
Disturbance of bottom and bank sediments – watercourse crossings	Construction	Adverse	No effect to moderate[3]	Local	Short term[4]
	Operations	N/A	N/A	N/A	N/A
	Decommissioning and abandonment	N/A	N/A	N/A	N/A
Suspended Sediment Inputs					
Land disturbance	Construction	Adverse	Low	Local	Medium term
	Operations	Adverse	Low	Local	Long term
	Decommissioning and abandonment	Adverse	Low	Local	Long term

NOTES:
N/A = not an applicable effect pathway
1 Acid deposition effects are not evaluated for individual project components, but are evaluated for all project components combined in Section 6.3.10, Acid Deposition Study
2 Rating assumes that regulatory requirements will be met and that receiving waterbodies will be chosen to eliminate effects or limit them to a low magnitude
3 Predicted TSS levels are presented in Section 5, Hydrology – the rating in this table refers to KIs other than TSS
4 Rating refers to duration of effect at each affected waterbody

6.3.8 Northwestern Alberta

The proposed pipeline crosses the boundary into northwestern Alberta where it ties into the NGTL Northwest Mainline (Dickins Lake Section). The NGTL pipeline extends from this tie-in point to about 65 km south of the Alberta and Northwest Territories boundary.

6.3.8.1 Baseline Conditions

Baseline conditions in northwestern Alberta were described previously for the pipeline corridor (see Section 6.3.7.1 Baseline Conditions). Baseline water and sediment quality are described in detail in Volume 3, Section 6, Water Quality.

6.3.8.2 Northwestern Alberta Effects

The types of effects during construction and operation of the proposed pipeline in northwestern Alberta will be the same as that described for the gathering system and pipeline corridor (see Section 6.3.6.2, Gathering Pipelines and Associated Facilities Effects and Section 6.3.7.2, Pipeline Corridor Effects). Table 6-11, shown previously, summarizes the effects of the pipeline corridor on water and sediment quality.

6.3.9 Infrastructure

The project infrastructure for construction and operations includes:

- barge landing sites
- pipe and material stockpile sites
- fuel storage sites
- camps
- potable water supply
- access roads
- airstrips and helipads
- communication centres

Details about the locations, components and footprint areas of the infrastructure sites are in Volume 2, Project Description.

Borrow sites will provide borrow material for the construction of the anchor fields, pipelines, facilities and infrastructure. Seventy primary borrow sites were identified in Volume 2, Project Description. Most of the borrow sites contain surficial deposits such as kames, terraces and ridges. None are in active floodplains. It has been assumed that these sites will be developed with a suitable buffer between the site and nearby waterbodies. There will be no washing of borrow material for the project, so it is presumed that there will be no water withdrawals from or water disposals to local waterbodies.

The project will require considerable materials, supplies and personnel. As a result, extensive transportation of goods by barge, rail, aircraft and truck will be necessary. The transportation of smaller amounts of materials and supplies will be necessary during operations.

6.3.9.1 Production Area Infrastructure

The locations and description of production area infrastructure are in Volume 2, Project Description. A generic assessment is provided in this section.

Baseline Conditions

Volume 3, Section 6, Water Quality gives an overview of regional conditions. Additional details of baseline conditions in the production area are provided in previous discussions where baseline conditions for the anchor fields and gathering pipelines and associated facilities are described.

Production Area Infrastructure Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. Table 6-12 summarizes the effects of production area infrastructure on water and sediment quality.

Table 6-12: Effects on Water and Sediment Quality – Production Area Infrastructure

Pathway[1]	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Wastewater Releases					
Discharge of domestic wastewater	Construction	Adverse	Low[2]	Local	Medium term
	Operations	Adverse	Low[2]	Local	Long term
	Decommissioning and abandonment	Adverse	Low[2]	Local	Medium term
Suspended Sediment Inputs					
Disturbance of bottom and bank sediments – potential dredging	Construction	Adverse	Low to moderate[3]	Local	Short term
	Operations	Adverse	Low to moderate[3]	Local	Short term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Disturbance of bottom and bank sediments from barge traffic	Construction	Adverse	Low[3]	Local	Medium term
	Operations	Adverse	Low[3]	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Land disturbance	Construction	Adverse	Low[3]	Local	Medium term
	Operations	Adverse	Low[3]	Local	Long term
	Decommissioning and abandonment	Adverse	Low[3]	Local	Long term

NOTES:
N/A = not an applicable effect pathway
1 Acid deposition effects are not evaluated for individual project components, but are evaluated for all project components combined in Section 6.3.10, Acid Deposition Study
2 Rating assumes that regulatory requirements will be met and that receiving waterbodies will be chosen to eliminate effects or limit them to a low magnitude
3 Predicted TSS levels are presented in Section 5, Hydrology – the rating in this table refers to KIs other than TSS

Construction

Applicable pathways during construction include discharges of domestic wastewater and sediment inputs from the following:

- land disturbance
- disturbance of bottom or bank sediments by potential dredging
- disturbance of bottom or bank sediments by barge traffic

Concerns about domestic wastewater releases include high concentrations of nutrients and biochemical oxygen demand, which might increase productivity, i.e., eutrophication, and reduce dissolved oxygen concentrations in receiving waters. Wastewater treatment methods are available to reduce nutrient concentrations and biochemical oxygen demand, which will reduce or eliminate effects. Treatment requirements and potential effects on water quality will be assessed as a requirement of the permitting process, once receiving waterbodies have been identified and camp details finalized.

To comply with regulatory requirements, effects resulting from this pathway will be managed using water treatment and disposal techniques that will reduce effects on water quality. Wastewater will be treated and released so that effects on the water and sediment quality of receiving waterbodies will be low. Domestic wastewater discharge is predicted to have a low-magnitude effect on water quality.

The effect of land disturbance on sediment-associated KIs is predicted to be low magnitude and localized, as described for Niglintgak.

Effects of sediment releases during potential dredging to establish and maintain barge landings are predicted to be low to moderate magnitude, based on:

- the amount of bottom sediments disturbed
- the potential for elevated levels of certain KIs in bottom sediments
- chemical processes accompanying sediment disturbances

The maximum effect magnitude rating is moderate in a localized area because concentrations of certain chemicals in the water column could exceed water quality guideline values near dredging. Section 6.3.3.2, Niglintgak Effects, provides a more detailed discussion on the effects of dredging.

The effect of bottom or bank sediment disturbance by barge traffic on TSS levels was predicted to be low (see Section 5, Hydrology). The effects of sediment disturbance because of barge traffic on sediment-associated water quality KIs, i.e., nutrients, metals or hydrocarbons, are expected to be low magnitude.

Operations

Types and magnitude of effects during operations will be the same as during construction.

Decommissioning and Abandonment

Types and magnitude of effects during decommissioning and abandonment will be the same as during construction.

6.3.9.2 Pipeline Corridor Infrastructure

The locations and description of this infrastructure are discussed in Volume 2, Project Description. Site-specific water and sediment quality data is not available for infrastructure components or for waterbodies potentially affected by infrastructure development. A generic effects assessment is provided in this section.

Baseline Conditions

Section 6.3.7.1, Baseline Conditions, provides an overview of regional conditions in the pipeline corridor. Baseline water and sediment quality are described in detail in Volume 3, Section 6, Water Quality.

Pipeline Corridor Infrastructure Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. The effects of the pipeline corridor infrastructure on water and sediment quality are summarized in Table 6-13.

Construction

The magnitude of effects of domestic wastewater discharges and suspended sediment releases will be the same as described for the production area infrastructure.

Operations

Types and magnitude of effects during operations will be the same as during construction.

Decommissioning and Abandonment

Types of effects, and their magnitude, during decommissioning and abandonment will be the same as during construction.

Table 6-13: Effects on Water and Sediment Quality – Pipeline Corridor Infrastructure

Pathway[1]	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Wastewater Releases					
Discharge of domestic wastewater	Construction	Adverse	Low[2]	Local	Medium term
	Operations	Adverse	Low[2]	Local	Long term
	Decommissioning and abandonment	Adverse	Low[2]	Local	Medium term
Suspended Sediment Inputs					
Disturbance of bottom and bank sediments during potential dredging	Construction	Adverse	Low to moderate[3]	Local	Short term
	Operations	Adverse	Low to moderate[3]	Local	Short term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Disturbance of bottom and bank sediments from barge traffic	Construction	Adverse	Low[3]	Local	Medium term
	Operations	Adverse	Low[3]	Local	Long term
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A
Land disturbance	Construction	Adverse	Low[3]	Local	Medium term
	Operations	Adverse	Low[3]	Local	Long term
	Decommissioning and abandonment	Adverse	Low[3]	Local	Long term

NOTES:
N/A = not an applicable effect pathway
1 Acid deposition effects are not evaluated for individual project components, but are evaluated for all project components combined in Section 6.3.10, Acid Deposition Study
2 Rating assumes that regulatory requirements will be met and that receiving waterbodies will be chosen to eliminate effects or limit them to a low magnitude
3 Predicted TSS levels are presented in Section 5, Hydrology – the rating in this table refers to KIs other than TSS

6.3.10 Acid Deposition Study

The effects of acid deposition on lakes are not specific to individual project components because air quality modelling predicted the combined acid deposition from all components simultaneously. Therefore, this pathway was evaluated separately.

6.3.10.1 Baseline Conditions

Baseline conditions relevant to acid sensitivity of lakes are provided in Volume 3, Section 6, Water Quality.

Available water chemistry data and information on flooding frequency in the Mackenzie Delta indicate that most lakes in the northern airshed are not sensitive to acid deposition. Based on water chemistry data, nearly all lakes with available data can be characterized as not sensitive to acid deposition. Exceptions include one unnamed lake in the Parsons Lake lease, which was classified as sensitive, and two moderately sensitive lakes near the Storm Hills lateral. Based on data showing low sensitivity for surrounding lakes, the alkalinity value reported for the single sensitive lake could be erroneous.

Data on acid sensitivity is not available for waterbodies potentially affected by compressor stations along the pipeline corridor, but field water chemistry data at watercourse crossings suggests streams are not sensitive to acid deposition.

6.3.10.2 Acid Deposition Effects

Effect pathways for water quality are evaluated in Section 6.3.1, Effect Pathways. For streams, this pathway does not apply to effects on water quality (see Section 6.3.1.1, Acid Deposition). The combined effects of acid deposition on lakes from all components of the project are summarized in Table 6-14.

Table 6-14: Effects of Acid Deposition on Water Quality

Pathway	Phase When Impact Occurs	Effect Attribute			
		Direction	Magnitude	Geographic Extent	Duration
Acid deposition in lakes	Construction	Neutral[1]	No effect	N/A	N/A
	Operations	Neutral[1]	No effect	N/A	N/A
	Decommissioning and abandonment	Neutral[1]	No effect	N/A	N/A

NOTES:
N/A = there are no applicable pathways for effects on water quality, or the attribute is not applicable because no effect is predicted
1 Direction is neutral because the magnitude was rated as no effect

Although emissions of acid forming substances will begin during construction and extend into decommissioning, peak emissions will occur during operations. Effects of this pathway on lakes were assessed using maximum predicted rates of acid deposition during operations. Because no effects were predicted for operations (see following), no effects were also predicted for construction and decommissioning.

Operations

Acid sensitivity is low in most lakes with available data near the production area, gathering pipelines and associated infrastructure. In the Mackenzie Delta, lakes subject to periodic flooding and marine influences, including most lakes in Niglintgak and Taglu, consistently have a low level of acid sensitivity. No effects are predicted from acid deposition in these areas.

A quantitative analysis of potential effects from acid deposition also indicated no project-related effects. Critical loads of acidity were calculated for a representative set of 23 lakes with sufficient data in the northern airshed. The lakes selected for this analysis were outside the frequently flooded area of the Mackenzie Delta. To evaluate effects, critical loads were compared with modelled acid deposition rates expressed as the PAI. As shown in Table 6-15, there were no occurrences of acid deposition rates exceeding critical loads. Critical loads were eight to 145 times greater than the corresponding PAI values. Therefore, results of the quantitative analysis predicted no effects from acid deposition in the production area or along the gathering pipelines.

In the pipeline corridor, modelled acid deposition rates resulting from project facilities were low and localized. The areas where background acid deposition rates are exceeded near project facilities comprise small proportions of the catchment areas of nearby lakes and ponds, except at the Little Chicago compressor station, where a level exceeding the background level of acid deposition was predicted for a large part of one lake's drainage area. At this location, field water quality data from streams that drain nearby lakes indicates that surface waters near the compressor station are not sensitive to acid deposition. Therefore, based on available information, no effects on lake water quality in the pipeline corridor are predicted.

6.3.11 Significance of Effects

In the previous discussion, the residual effects of the project on water quality were described in terms of the effects' direction, magnitude, geographic extent and duration. These characteristics are used to determine the significance of the effects on water and sediment quality.

Volume 1, Section 2, Assessment Method, provides a discussion about the rationale for determining significance. An adverse residual effect is considered significant if the effect is either:

- moderate or high magnitude and extends into the far future, i.e., more than 30 years after project decommissioning and abandonment
- high magnitude and occurs outside the LSA at any time

In this discussion, the significance of the effects for each project component and for the combined project is presented. Tables show the results of the effects assessment and indicate if an effect is significant.

Effects on water quality range from low to moderate and are local in extent during construction, operations and decommissioning. No significant effects on water quality are predicted.

Table 6-15: Comparison of Acid Deposition Rates with Lake-Specific Critical Loads – Northern Airshed

Lake Name[1]	Lake Identifier[1]	Nearest Project Component	Critical Load (keq/ha/a)	PAI		
				Total (keq/ha/a)	From Project (keq/ha/a)	Background (keq/ha/a)
Parsons Lake	5	Parsons Lake	0.60	0.04	0.01	0.03
Unnamed	6	Parsons Lake	0.72	0.05	0.02	0.03
East Hans Lake	12	Parsons Lake	0.62	0.03	<0.01	0.03
West Hans Lake	13	Parsons Lake	0.70	0.03	<0.01	0.03
Unnamed	19	Parsons Lake	0.53	0.03	<0.01	0.03
Unnamed	22	Parsons Lake	0.63	0.04	0.01	0.03
Unnamed	23	Parsons Lake	0.63	0.04	0.01	0.03
Unnamed	25	Parsons Lake	0.29	0.04	0.01	0.03
Unnamed	27	Parsons Lake	0.99	0.04	0.01	0.03
Unnamed	28	Parsons Lake	0.32	0.03	<0.01	0.03
Unnamed	30	Parsons Lake	0.36	0.04	0.01	0.03
Unnamed	31	Parsons Lake	0.61	0.03	<0.01	0.03
Unnamed	50	Parsons Lake	1.32	0.04	0.01	0.03
Unnamed	51	Parsons Lake	1.55	0.04	0.01	0.03
Unnamed	52	Parsons Lake	1.11	0.04	0.01	0.03
Pullen Lake	40	Niglintgak/Taglu	0.62	0.03	<0.01	0.03
Noell Lake	10	Inuvik	0.34	0.03	<0.01	0.03
Campbell Lake	15	Inuvik	4.46	0.03	<0.01	0.03
Unnamed	21	Inuvik	0.91	0.03	<0.01	0.03
Jimmy Lake	11	Gathering pipelines	0.95	0.03	<0.01	0.03
North Caribou Lake	16	Gathering pipelines	1.05	0.03	<0.01	0.03
Unnamed	26	Gathering pipelines	0.38	0.04	0.01	0.03
Unnamed	17	Other area	0.78	0.03	<0.01	0.03

NOTES:
PAI = potential acid input
1 Lake locations are shown in Figures 6-5 to 6-7, shown previously

6.3.11.1 Niglintgak

Niglintgak will have low-magnitude effects on water quality from releases of pressure test water and sediment releases from land disturbance. Under the barge option for the Niglintgak gas conditioning facility, releases of barge wastewater were also predicted to have a low-magnitude effect, and low to moderate effects were predicted from suspended sediment inputs during dredging. All effects are limited to the LSA and would not persist after decommissioning. Therefore, effects of Niglintgak on water and sediment quality are not considered significant (see Table 6-16).

Table 6-16: Significance of Effects of Niglintgak on Water Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Water and sediment quality – barge option	Construction	Adverse	Low to moderate	Local	Medium term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low to moderate	Local	Long term	No
Water and sediment quality – land-based option	Construction	Adverse	Low	Local	Medium term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Long term	No

6.3.11.2 Taglu

Releases of pressure test water during construction and operations at Taglu would have a low-magnitude effect on water quality. Low-magnitude effects are predicted during all phases because of low sediment inputs from land disturbance. These effects are limited to the LSA and would not persist after decommissioning. Therefore, the effect of Taglu on water and sediment quality is considered not significant (see Table 6-17).

Table 6-17: Significance of Effects of Taglu on Water Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Water and sediment quality	Construction	Adverse	Low	Local	Medium term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Long term	No

6.3.11.3 Parsons Lake

Releases of pressure test water during construction and operations at the Parsons Lake field would, as at Taglu, have a low-magnitude effect on water quality. Low-magnitude effects are predicted during all phases because of low sediment inputs from land disturbance. These effects are limited to the LSA and would not persist after decommissioning. Therefore, the effect of the Parsons Lake field on water and sediment quality is considered not significant (see Table 6-18).

Table 6-18: Significance of Effects of Parsons Lake on Water Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Water and sediment quality	Construction	Adverse	Low	Local	Medium term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Long term	No

6.3.11.4 Gathering Pipelines and Associated Facilities

Water quality effects from pressure test water releases and sediment inputs caused by disturbance of bottom and bank sediments at watercourse crossings and land disturbance were predicted to range from no effects to moderate along the gathering pipelines. Effects are localized and would not persist after decommissioning. Therefore, the effect of the gathering pipelines on water and sediment quality is considered not significant (see Table 6-19).

Table 6-19: Significance of Effects of the Gathering Pipelines on Water Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Water and sediment quality	Construction	Adverse	No effect to moderate	Local	Medium term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Long term	No

6.3.11.5 Pipeline Corridor

Water quality effects from pressure test water releases and from sediment inputs, caused by disturbance of bottom and bank sediments at watercourse crossings and land disturbance, were predicted to range from no effects to moderate along the pipeline corridor. Effects are localized and would not persist after decommissioning. Therefore, the effect of the pipeline corridor on water and sediment quality is considered not significant (see Table 6-20).

Table 6-20: Significance of Effects of the Pipeline Corridor on Water Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Water and sediment quality	Construction	Adverse	No effect to moderate	Local	Medium term	No
	Operations	Adverse	Low	Local	Long term	No
	Decommissioning and abandonment	Adverse	Low	Local	Long term	No

6.3.11.6 Infrastructure

Production area infrastructure and pipeline corridor infrastructure would have effects on water quality ranging from no effect to a moderate-magnitude effect from releases of domestic wastewater and from sediment inputs caused by disturbance of bottom or bank sediments during potential dredging, land disturbance and barge traffic. All effects are limited to the LSA and would not persist after decommissioning. Therefore, effects of infrastructure are considered not significant (see Table 6-21).

Table 6-21: Significance of Effects of Infrastructure on Water Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Water and sediment quality	Construction	Adverse	Low to moderate	Local	Medium term	No
	Operations	Adverse	Low to moderate	Local	Long term	No
	Decommissioning and abandonment	Adverse	No effect to low	Local	Long term	No

6.3.11.7 Acid Deposition Study

No effects were predicted on water quality from acid deposition. Therefore, effects of acid deposition are considered not significant (see Table 6-22).

6.3.11.8 Combined Project Components

No significant effects were predicted for any of the project components. All predicted effects are local and none would persist after decommissioning. Even considering the combined effects of all applicable pathways, the effect on water quality is considered not significant.

Table 6-22: Significance of Effects of Acid Deposition on Water Quality

Valued Component	Phase When Impact Occurs	Effect Attribute				Significant
		Direction	Magnitude	Geographic Extent	Duration	
Water and sediment quality	Construction	Neutral	No effect	N/A	N/A	No
	Operations	Neutral	No effect	N/A	N/A	No
	Decommissioning and abandonment	Neutral	No effect	N/A	N/A	No

NOTE:
N/A = attribute is not applicable because the magnitude of the predicted effect was no effect

6.3.11.9 Prediction Confidence

As with all predictions of future conditions, predictions in the impact assessment have a level of uncertainty. Prediction confidence is a function of several factors:

- available information on details of the project
- data availability and data quality
- understanding of chemical and biological processes that operate in the study area and the effects of stressors on the environment
- level of conservationism applied in the assessment
- effectiveness of mitigation measures to be applied during the project

The assessment addressed uncertainty by being more conservative in predicting effect attribute as uncertainty increased, and by specifying measures to ensure that effect attribute would not be worse than predicted. Provided that proposed mitigation measures are implemented, there is a relatively high degree of confidence that impacts will not be greater than predicted.

Project details regarding air emissions were sufficient for quantitative modelling of acid deposition rates. The understanding of the chemical process associated with acid deposition is well known. Although the historical baseline data is of low spatial resolution and unknown quality in some cases, the data summarized for 122 lakes and field water quality data collected along the pipeline yielded information that is consistent and indicates a low level of acid sensitivity in the production area and along the pipeline corridor. There is uncertainty in lake hydrology data used to calculate critical loads of acidity and the calculation of critical loads is subject to uncertainty. However, both acid deposition modelling and the calculation of critical loads were based on conservative assumptions to account for this uncertainty. Therefore, the confidence in the prediction of no significant effects on water quality from acid deposition is high.

Confidence in predictions of the effects of wastewater discharges is based on the ability to manage effects on water quality through selection of appropriate treatment methods and receiving waterbodies. The effectiveness of various wastewater treatment methods is known and can be controlled through design. Effects of the types of wastewater that could reach surface waters are known and can be characterized using established methods. Once project details are available, detailed assessments can be conducted to ensure the receiving waterbodies are appropriate and effects on water quality are no greater than predicted. Therefore, based on the ability to manage effects from wastewater releases, the confidence in the prediction of no significant effects from wastewater releases on water quality is high.

Effects on water quality related to sediment releases from land disturbance, potential dredging, barge traffic and watercourse crossings were predicted based on conservative predictions of TSS and understanding of chemical processes associated with sediment releases. Predictions of sediment inputs to waterbodies were based on modelling using conservative assumptions and accounted for the known effectiveness of mitigation measures to be applied during project-related activities. Effect magnitudes were assigned based on current understanding of chemical processes associated with sediment inputs to waterbodies. Therefore, the confidence in the prediction of no significant effects on water quality from sediment releases is moderate.

6.4 Monitoring

Volume 7, Section 6, Environmental Compliance and Effects Monitoring Plan, provides an overview of the intent and purpose of the environmental monitoring program to be implemented for the project.

Two types of programs will be developed:

- compliance monitoring
- effects monitoring

6.4.1 Compliance Monitoring

Compliance monitoring will ensure that all environmental mitigation strategies, as outlined in the Environmental Compliance and Effects Monitoring Plan, are implemented. It will also ensure that work proceeds in compliance with regulations and the project proponents' environmental policies. Compliance monitoring will be a component of all phases of the project, from environmental inspection during construction to monitoring required for licences issued by the Mackenzie Valley Land and Water Board.

It includes monitoring specific to the protection of water quality, such as monitoring concentrations of total suspended solids during construction activities in or beside watercourses.

6.4.2 Effects Monitoring

Effects monitoring will be done to confirm the accuracy of effects prediction and to determine the effectiveness of mitigation and enhancement measures. Effects monitoring provides a framework for adopting project practices that address the results of effects monitoring programs. Effects monitoring programs will be established in consultation with communities and regulators.

Table 6-23 summarizes the proposed effects monitoring for water quality and provides details of the parameters likely to be included in the monitoring programs.

Water quality will be monitored to evaluate the effects of domestic wastewater and pressure test water releases. The timing and scope of these monitoring programs will be determined in consultation with communities and regulators.

If the barge option is chosen for the Niglintgak gas conditioning facility, monitoring will be done in the production area to evaluate the effects of potential dredging to transport the barge to its final location in Niglintgak. Monitoring might also be done to evaluate the effects of dredging at selected barge landing sites. Baseline sediment sampling results might be used to select locations where dredging-related effects can be further evaluated.

Table 6-23: Effects Monitoring for Water Quality

Effect to be Monitored	Monitoring Parameters[1]	Sampling Locations
Water quality – domestic wastewater releases	Parameters are likely to include, in water: • conventional KIs[2] • nutrients and chlorophyll *a* • metals • coliforms	Waterbodies affected by domestic wastewater releases
Water quality – pressure test water releases	Parameters are likely to include, in water and potentially in sediment: • conventional KIs[2] • nutrients and chlorophyll a • metals • organic KIs, e.g., hydrocarbons	Waterbodies affected by pressure test water releases
Water quality – disturbance of bottom and bank sediments by potential dredging	Parameters are likely to include, in water and potentially in sediment: • conventional KIs[2] • TSS • nutrients • metals • PAHs, PCBs	Dredging locations in nearshore coastal waters and delta channels, if the barge option is chosen for the Niglintgak gas conditioning facility

NOTES:
1 Specific KIs to be monitored will be determined once site-specific data is available
2 Conventional KIs include conductance, DO, water temperature, pH, colour, dissolved organic carbon, TDS, TOC and TSS

References

Augenfeld, J.M. and J.W. Anderson. 1982. The fate of polyaromatic hydrocarbons in an intertidal sediment exposure system: Bioavailability to *Macoma inquinata* (*Mollusca: Pelecypoda*) and *Abarenicola pacifica* (*Annelida: Polychaeta*). *Mar. Environ. Res*. 7: 31.

Bleier, R., A.J.J. Leuterman and C. Stark. 1993. Drilling fluids: Making peace with the environment. *Journal of Petroleum Technology*. January 1993: 6–10.

Burton, G.A. Jr. (Ed.). 1992. *Sediment Toxicity Assessment*. Lewis Publishers, Boca Raton, Florida. 457 p.

Canadian Council of Ministers of the Environment (CCME).1999 (with updates to 2002). *Canadian Environmental Quality Guidelines.* Winnipeg, Manitoba.

Community of Aklavik, Wildlife Management Advisory Council (NWT) and Joint Secretariat. 2000. *Aklavik Inuvialuit Community Conservation Plan*: A *Plan to Provide Guidance Regarding the Conservation and Management of Renewable Resources and Lands Within the Inuvialuit Settlement Region in the Vicinity of Aklavik, N.W.T*. The Community of Aklavik, Wildlife Management Advisory Council (NWT) and the Joint Secretariat.Aklavik, Northwest Territories.

Community of Inuvik, Wildlife Management Advisory Council (NWT) and Joint Secretariat. 2000. *Inuvik Inuvialuit Community Conservation Plan: A Plan to Provide Guidance Regarding the Conservation and Management of Renewable Resources and Lands Within the Inuvialuit Settlement Region in the Vicinity of Inuvik, N.W.T.* The Community of Inuvik, Wildlife Management Advisory Council (NWT) and the Joint Secretariat. Inuvik, Northwest Territories.

Degtiareva, A. and M. Elektorowicz. 2001. A computer simulation of water quality change due to dredging of heavy metals contaminated sediments in the Old Harbour of Montreal. *Water Quality Resources Journal* 36: (1): 1–19.

Fassnacht, S. 1995. *Mackenzie Delta Channel Stability Investigations At: Niglintgak Island, East Channel Swimming Point*. Prepared for N.W.T. Water Programs, Environment Canada. Yellowknife, Northwest Territories.

Hair and Associates, Inc. and B.V. Cebo Holland. 1994. *Drilling Fluids in Pipeline Installation by Horizontal Directional Drilling: A Practical Applications Manual*. Prepared for the American Gas Association. Pr-227-9321.

Hardy, R.M. and Associates Ltd. 1977. *Evaluation of the Potential Impact of the Shell Niglintgak Gas Project on Hydrology and Water Quality*. Prepared for Shell Canada Resources Limited. Calgary, Alberta.

Health Canada. 2001 (with updates to 2002). *Summary of Guidelines for Canadian Drinking Water Quality.* Prepared by the Federal-Provincial Subcommittee on Drinking Water of the Federal-Provincial-Territorial Committee on Environmental and Occupational Health.

Lane, P. and Associates, Delcan-Stone and Webster. 1989. *Impacts of Dredging and Spoil Disposal*: *Support Document for Question G*. Prepared for Public Works Canada.

LaSalle, M.W., D.G. Clarke, J. Homziak, J.D. Lunz and T.J. Fredette. 1991. *A Framework for Assessing the Need for Seasonal Restrictions on Dredging and Disposal Operations*. Dredging Operations Technical Support Program. Technical Report D-91-1.

Lynch, T.R. and H.E. Johnson. 1982. *Aquatic Toxicology and Hazard Assessment: Fifth Conference*. In J.G. Pearson, R.B. Foster and W.E. Bishop (ed.). American Society for Testing and Materials. ASTM STP 766. 273–287.

Mackenzie Delta – Beaufort Sea Regional Land Use Planning Commission (MDBSRLUPC). 1990. *A Draft Community-based Regional Land Use Plan for the Mackenzie Delta – Beaufort Sea Region. Volume 2: A Comprehensive System of Protected Areas.* Northwest Territories Land Use Planning. Inuvik, Northwest Territories.

Reid, S. and P. Anderson. 1998. *Review of Environmental Issues Associated with Horizontal Directional Drilling at Water Crossings*. Prepared for Interstate Natural Gas Association of America and Gas Research Institute.

Salomons, W., N.M. de Rooij, H. Kerdijk and J. Bril. 1987. Sediments as a Source for Contaminants? *Hydrobiologia* 149: 13–30 (1987). In R. Thomas, R. Evans, A. Hamilton, M. Munawar, T. Reynoldson and H. Sadar (ed.). *Ecological Effects of In Situ Sediment Contaminants.* Printed in the Netherlands.

Schroeder, P.R. 2001. *Estimation of Contaminant Release from Dredging of Clark Fork and Blackfoot River Sediments in Milltown Reservoir*. Memorandum for Mr. Russ Forba, USEPA Region 8 Montana Office. Environmental Processes and Engineering Division. U.S. Army Engineer Research and Development Center. 3909 Halls Ferry Road, Vicksburg, Mississippi. 39180-6199.

Slaney, F.F. and Company Limited. 1976. *1975 Hydrology Survey - Niglintgak, Mackenzie Delta, Northwest Territories*. Shell Canada Limited. Calgary, Alberta.

Sullivan, T.J. 2000. *Aquatic Effects of Acidic Deposition*. CRC Press LLC. Boca Raton, Florida.

Transport Canada. 2001. *Guidelines for the Control of Ballast Water Discharge from Ships in Waters Under Canadian Jurisdiction*. Marine Safety Directorate. Ottawa, Ontario.

Van den Berg, G., G.J.P. Loch, J.J.G. Zwolsman and L.M. van der Heijdt. 1998. Non-steady state behaviour of heavy metals in contaminated fresh-water sediments. *Water Science Technology* 37: 39–46.

van Oostrum, R.W. and P. Vroege. 1994. *Turbidity and Contaminant Release During Dredging of Contaminated Sediments*. In E.C. McNair, J.R. (ed.). *Dredging '94, Proceedings of the Second International Conference on Dredging and Dredged Material Placement*. Volume I. American Society of Civil Engineers. New York, New York.

Wetzel, R.G. 2001. *Limnology - 3rd Edition*. Academic Press. San Diego, California.