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Appendix E-1
Marine Water and Sediment Effects Assessment

Author: **Rescan Environmental Services Ltd.**
Date: **November 2007**

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Bathurst Inlet Port and Road Project Marine Water and Sediment Effects Assessment

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

ARD	acid rock drainage
BIPR	Bathurst Inlet Port and Road
BMP	best management practices
CCME	Canadian Council of Ministers of the Environment
CWQG	Canadian Water Quality Guidelines
DEIS	Draft Environmental Impact Statement
DOJ	Department of Justice
EIS	Environmental Impact Statement
Golder	Golder Associates Ltd.
ISQG	Interim Sediment Quality Guidelines
LSA	local study area
ML	metal leaching
NIRB	Nunavut Impact Review Board
NTCL	Northern Transportation Company Limited
NTKP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
PEL	probable effects levels
RISC	Resources Inventory Standards Committee
RL&L	RL&L Environmental Services Ltd.
RSA	regional study area
STP	sewage treatment plant
the Project	the Bathurst Inlet Port and Road Project
the proponent	Bathurst Inlet Port and Road Joint Venture Ltd.
TOC	total organic carbon
TSS	total suspended solids
VEC	valued ecosystem component
Wolfden	Wolfden Resources Inc.

1. INTRODUCTION

1. Introduction

The Bathurst Inlet Port and Road Project (BIPR) consists of a marine port on Bathurst Inlet and a 211 km all-weather road to Contwoyto Lake. The Project will service existing mines and provide an alternative marine supply route to the mines and local communities in the area.

The proposed port for the Project is located on a peninsula in southwestern Bathurst Inlet (66°33'N and 107°31'W) about 40 km south of the community of Bathurst Inlet. It is located on 159 ha of Federal Crown Land. The wharf will be a sheet pile rock filled structure extending into Bathurst Inlet. It will extend into the marine environment 140 m along approximately 160 m of shoreline; 22,000 m^2 of seabed will be covered by crushed rock required to fill the sheet pile wharf. The surface of the wharf will be 5 m above water level. A small crushed rock jetty will also be built to serve barge traffic between the port and Kitikmeot communities. It will extend 100 m into the marine environment to the 3 m water depth and cover about 4,400 m^2 of seabed.

Marine access to the proposed port site from the northeast will use existing shipping lanes from the eastern Arctic. The route from Barrow Strait will be south through Peel Sound, Franklin Strait, Victoria Strait, cross Queen Maud Gulf, pass through Dease Strait, and enter Bathurst Inlet. The portion of the route from Barrow Strait to Queen Maude Gulf, a distance of approximately 650 km, is currently not a regular shipping route but has been used by summer tourist cruise ships and other vessels "sailing the Northwest Passage." The remainder of the eastern shipping route, through Queen Maud Gulf, Dease Strait and into Bathurst Inlet, is used annually for the sealift re-supply of Gjoa Haven and Taloyoak to the east, and Omingmaktok and Bathurst Inlet in Bathurst Inlet. The final 40 km of the route south of Bathurst Inlet community is new. Barge shipments to the communities will follow commercial shipping lanes used annually by Northern Transportation Company Limited (NTCL) in the re-supply of the coastal communities of Nunavut.

Six key Project components of the port infrastructure have been selected to assess the effects of the Project on marine water and sediment quality. These components include:

- a wharf that can serve vessels up to 50,000 T;
- a dock that will serve barges re-supplying local communities;
- a 220 million L tank farm;
- a 1,200 m airstrip;
- a camp that will support 200 people; and
- a truck shop and diesel maintenance facility.

2. ENVIRONMENTAL SETTING

2. Environmental Setting

The proposed marine port is located on a peninsula on the west side of Bathurst Inlet (66°33'N and 107°31'W) approximately 40 km south of the community of Bathurst Inlet. Vessel access to the port would be from the North Atlantic Ocean via Baffin Bay, Lancaster Sound, Barrow Strait, Peel Sound, Franklin Strait, Larsen Sound, Victoria Strait, Queen Maud Gulf, Dease Strait and Coronation Gulf (Figure 2-1).

The climate of the area is characterized by long cold winters, short cool summers, and minimal precipitation. The length of the open-water season varies along the shipping route, but freezing generally begins in early October and the average date for sea ice melting in Bathurst Inlet is July 6. By the end of July open water is usually present throughout most of the shipping route, allowing a shipping season of approximately 100 days (SNC Lavalin, 2007).

Baseline data were collected for both the physical and chemical characteristics of water and sediment because changes in these variables have the potential to affect the productivity and/or composition of biological communities in the marine environment surrounding the proposed port. Toxic constituents of water and sediment can also enter the food web and accumulate in the tissues of various organisms. Although seawater is not a source of potable water used by the Inuit (Appendix F-5 of the Draft Environmental Impact Statement (DEIS)), good water and sediment quality are important components of marine mammal and fish habitat. As stated in the Naonaiyaotit Traditional Knowledge Project (NTKP), seals are a primary food source for coastal Inuit and are hunted year round for their meat, fat and pelts; fish are also considered an important food source (Appendix F-5 of the DEIS). Seal hunting and traditional fishing grounds occur in Bathurst Inlet and along other parts of the proposed shipping route.

In 2001, five sampling stations were established off the eastern shore of the peninsula on which the port will be built. Stations 01-1, 01-2 and 01-3 were inshore stations that followed a line parallel to the shore, and stations 01-4 and 01-5 were offshore stations directly east of station 01-2 (Figure 2-2). These stations were sampled between August 14 and 16, 2001. Characteristics measured included vertical profiles of water temperature and salinity, Secchi depth, and seawater and sediment chemistry (Appendix E-7 of the DEIS). Sediment quality was again sampled on August 6, 2002 at station 01-2.

In 2007, five additional sites were sampled. Sites were located within the same general study area sampled in 2001. Stations 07-1, 07-2, and 07-3 followed a line parallel to the eastern shore of the peninsula; these stations were sampled for water column structure (temperature, salinity, dissolved oxygen and Secchi depth) and water quality (unpublished data, Rescan). Two stations (07-5 and 07-6) were in the direct location where the port will be built and were sampled for sediment quality. Reference stations located opposite the port site near the eastern shore of Bathurst Inlet were also established. Sampling took place between August 4 and 7, 2007; Ref 1 (deep) was sampled for water column structure and water quality, and Ref 1 (shallow) was sampled for sediment quality. 2007 sampling station locations are shown on Figure 2-2.

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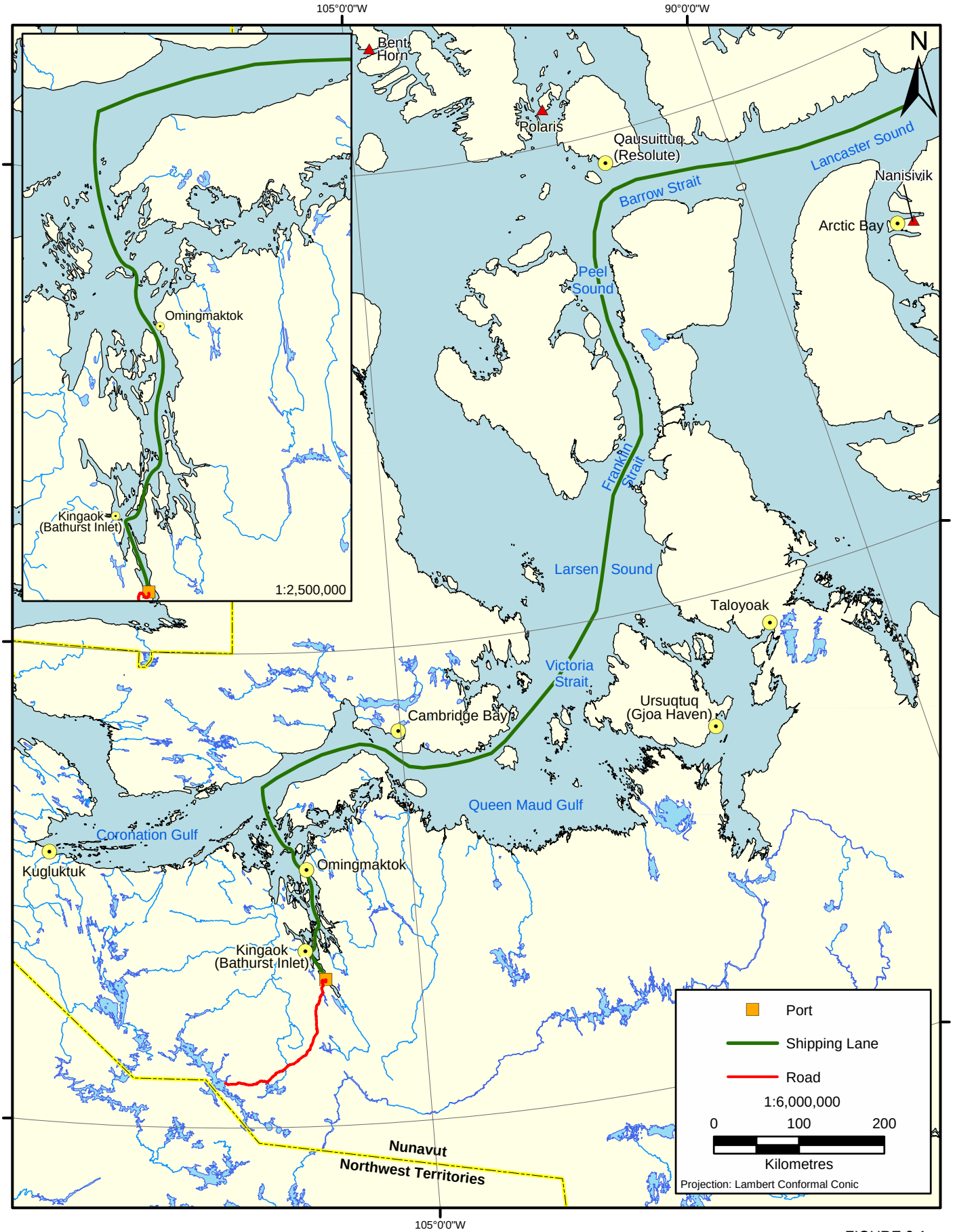

FIGURE 2-1

Proposed Shipping Route

the Bathurst Inlet Port and Road Project

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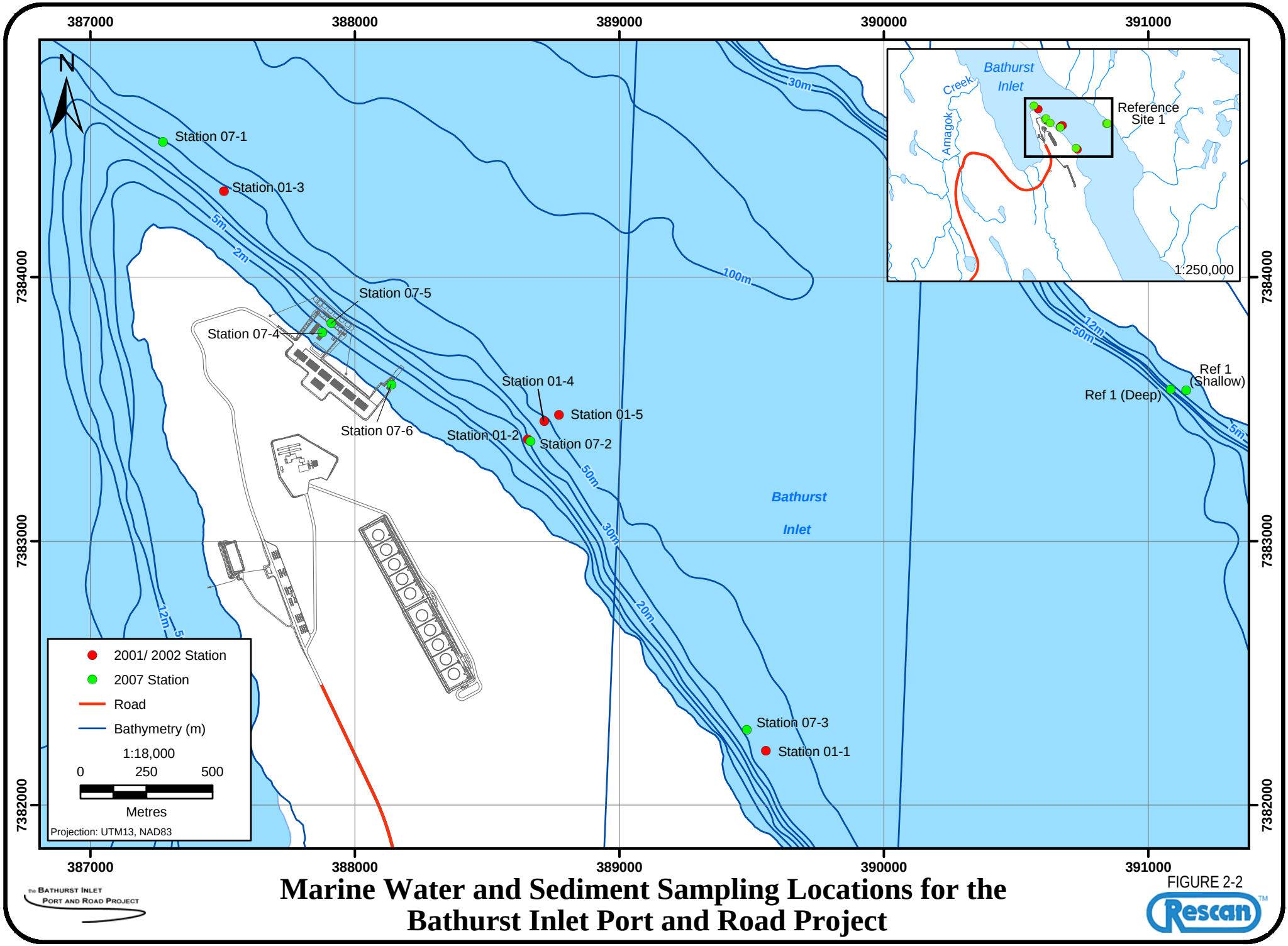


Marine Water and Sediment Sampling Locations for the Bathurst Inlet Port and Road Project

FIGURE 2-2

the Bathurst Inlet Port and Road Project

Rescan™

2.1 Water Column Structure

Secchi depths for 2001 and 2007 surveys were 3.5 m on average, resulting in a calculated euphotic zone depth of approximately 9.8 m. The euphotic depth is an estimate of the maximum depth suitable for primary production by organisms such as phytoplankton.

The water column at sites near the proposed port was highly stratified in August of both 2001 and 2007. The surface layer, to approximately 10 m, was higher in temperature (approximately 11ºC) and less saline (approximately 10-16 PSU) than the bottom layer in both years (0ºC and 22-27 PSU). Vertical profiles of dissolved oxygen collected in 2007 indicated that the water column was well oxygenated, dissolved oxygen decreased from approximately 100% to 70% coinciding with the stratification in temperature and salinity.

Water column stratification is typical in marine Arctic environments following ice melt, which causes the surface layer to become warmer and less saline. This stratification precludes mixing of nutrients throughout the water column and contributes to low primary productivity. Previous sampling at nearby sites in the Grays Bay area of Coronation Gulf indicates water column characteristics similar to the baseline results above (Wolfden, 2006).

2.2 Water Quality

In both 2001 and 2007, water quality near the proposed port site reflected a pristine Arctic environment. The distributions of chemical characteristics were strongly influenced by the vertically stratified nature of the water column.

The upper mixed-layer was characterized by low conductivity, low concentrations of dissolved suspended solids, low acidity and alkalinity, low concentrations of dissolved anions, nitrate, nitrite, phosphates and total and dissolved metals (except for the major constituents of seawater such as calcium, magnesium, potassium, sodium and strontium). This upper layer also consisted of high concentrations of dissolved oxygen and total organic carbon.

With the exception of total suspended solids, turbidity, dissolved oxygen and total organic carbon, the concentrations of all general water quality variables increased dramatically at the pycnocline and continued to increase below this depth. The majority of metals were present in concentrations below their respective analytical detection limits at all depths and stations, and those metals that were above detection limits were generally non-toxic constituents of seawater.

Water quality results collected from within the study area are summarized in Table 2.2-1. Canadian federal water quality guidelines for the protection of marine aquatic life, derived by the Canadian Council of Ministers of the Environment (CCME), are presented alongside analytical results (CCME, 2006a). Analytical detection limits for total arsenic, total cadmium, and total chromium exceeded CCME guidelines in 2001. In 2001, station 01-3 exceeded the CCME guideline for total arsenic in water at the deepest depth sampled (32 m); remaining values were below detection. In 2007, the CCME guideline for hexavalent chromium was exceeded at station 07-3 (at 1 m depth); however, the speciation of existing chromium is unknown. When considering the water column as a whole, no average values exceeded CCME guidelines.

RL&L/Golder (2002) also found total chromium (and total cadmium) to exceed CCME guidelines in nearby Roberts Bay.

Table 2.2-1
Comparison of Average 2001 and 2007 Values for Water Quality Variables with Canadian Guidelines for Selected Variables

	2001	2007	CCME
Parameter	**Mean**	**Mean**	**CWQG (MAL)**
pH	7.79	7.76	7-8.7
Nitrate	0.03	0.03	16
Total Arsenic*	0.0260	0.0010	0.0125
Total Cadmium*	0.01500	0.00004	0.00012
Total Chromium*	0.1500	0.0010	0.0015+
Total Mercury	0.000005	0.000005	0.000016++

All concentrations are in mg/kg.
CWQG (MAL) = Canadian Water Quality Guidelines for the Protection of Marine Aquatic Life.
*** 2001 Analytical detection limits were above CCME guidelines.**
+ The CCME guideline pertains to hexavalent chromium.
++ The CCME guideline pertains to inorganic mercury.

2.3 Sediment Quality

Sediment quality results collected from grab samples within the local study area are summarized in Table 2.3-1. Canadian Interim Sediment Quality Guidelines (ISQG) and probable effects levels (PEL) for the variables discussed in this report are derived from the most current available toxicological data (CCME, 2006b).

Sediment samples from 2001/2002 were composed of soft, loosely bound clay-silt complexes with no organic debris, reflecting the absence of woody debris in the near-shore terrestrial environment. Concentrations of total nitrogen were also low, indicating the absence of significant quantities of organic matter in the sediments. Hydrocarbon concentrations were low, reflecting the absence of industrial activity near the port site. Concentrations of total metals were generally below detection for eight of the 29 metals analyzed. A comparison of the average concentrations of total metals with Canadian guidelines showed that zinc, lead, mercury and cadmium concentrations were below the ISQG, and that arsenic, chromium and copper concentrations were between the ISQG and the PEL, in 2001/2002 (Table 2.3-1). No significant adverse biological effects are expected from these low average metals concentrations. Wolfden (2006) also reported sediment samples with total arsenic, chromium and copper concentrations above the ISQG but below the PEL in the Grays Bay area of Coronation Gulf. Total chromium and copper were also above ISQG in previous years at Roberts Bay (RL&L/Golder, 2002). In general, the marine sediments of southern Bathurst Inlet near the Port are of high quality and reflect a pristine aquatic environment.

Table 2.3-1
Comparison of Average Sediment Metal Concentrations (2001, 2007) with Canadian Guidelines

	2001/2002	2007	CCME	
Parameter	**Mean**	**Mean**	**ISQG**	**PEL**
Arsenic	13.1	1.8	7.24	41.6
Cadmium	0.071*	<0.05	0.7	4.2
Chromium	64	13	52.3	160
Copper	26	7.3	18.7	108
Lead	16	3	30.2	112
Mercury	0.022	<0.05	0.13	0.7
Zinc	62	16	124	271

All values are in mg/kg.
***The analytical detection limit for cadmium in 2001/2002 was 0.1 mg/L (above the CCME guideline).**
ISQG = Interim Sediment Quality Guideline.
PEL = Probable Effect Level.

3. METHODOLOGY

3. Methodology

3.1 Valued Ecosystem Component Selection

Seawater quality was selected as a Valued Ecosystem Component (VEC) because of its direct link to the health of aquatic organisms in the study area. Water quality has the potential to affect all components of the marine food webs from the algal primary producers to higher trophic level consumers such as fish, marine mammals, birds, and polar bears. Many of these higher organisms are of vital importance to the people in the surrounding northern communities. These people would be affected by deterioration in seawater quality through potential population declines of important food sources, such as marine mammals and fish, or through toxic contamination of these resources.

Sediment quality was also selected as a VEC. Sediment quality is especially important to aquatic organisms that are frequently or continuously in contact with sediments (*i.e.*, benthic algae and invertebrates, and many fish species). Changes in sediment quality can directly affect these communities, which then may affect organisms at higher trophic positions that rely on them. As substances are released into the aquatic ecosystem they may adsorb to suspended particles, sink and become part of the sediment, accumulating over time. Further, exchange of nutrients and metals is known to occur between sediments and the overlying water column under various conditions.

The CCME has developed the Canadian Water Quality Guidelines for the Protection of Aquatic Life. These guidelines outline tolerable levels of various water column and sediment constituents, and are derived using the most currently available toxicological data. Their purpose is to protect all life stages of the most sensitive organisms; including both plants and animals.

Water and sediment quality are protected as components of fish habitat by the *Fisheries Act*. The *Fisheries Act* (1985, c. F-14) states that "no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where the deleterious substance or any other deleterious substance that results from the deposit of the deleterious substance may enter any such water;" it also prevents the "harmful alteration, disruption, or destruction of fish habitat" (DOJ, 1985).

3.2 Boundaries

This section supplies rationale and justification for the chosen boundaries to assess potential effects from the Project on marine water and sediment quality. These boundaries were chosen after considering the Project description. Boundaries are discussed in the context of both spatial and temporal aspects.

3.2.1 Spatial Boundaries

The regional study area (RSA) for the water and sediment quality effects assessment consists of the shipping lane from Lancaster Sound to the Bathurst Inlet port site. This includes all waters and shorelines bordering the shipping lane. The local study area (LSA) is defined as the

footprint of the dock and barge landing sites and marine waters, seabed and shorelines out to 2 km from the port site, and the width of the ship along the shipping lane.

3.2.2 Temporal Boundaries

Including all phases, the Project has an approximate planned life of 22.5 years, with construction beginning in 2009. The phases of the Project are as follows:

1. construction (approximately 2.5 years);
2. operation and maintenance (estimated 19 years); and
3. decommissioning and closure (approximately 1 year).

3.3 Approach and Methods

Potential effects of interactions between the Project activities were identified for marine water and sediment quality. This was done for each temporal stage of the Project (*i.e.,* construction, operation, and maintenance, decommissioning, and post-closure).

Assessments use the most current information on both the design of the Project and the environmental conditions at the site, which include baseline data collected in 2001, 2002 and 2007 at the proposed port site. Modelling was not used, but rather issues associated with the construction of the proposed port and operation of the shipping route were assessed using logical discussion of physical and chemical processes and professional judgment. The effects assessment inherently assumes throughout the assessment that activities of road building, transport, storage, and sewage treatment/disposal will use appropriate technology and best management practices (BMPs) to properly mitigate and/or minimize effects. Construction and operating procedures associated with these Project activities are well developed and understood from decades of previous experience. However, all potential effects are examined. Sufficient baseline information are available to monitor for potential future impacts, and no critical data gaps were identified in this assessment.

The effects on each VEC were then summarized on standardized VEC assessment tables. The criteria used for the effects assessment can be found in Appendix A-5 of the DEIS. The potential effects on marine water and sediment quality were assessed in order to recognize mitigation and monitoring needs.

4. EFFECTS ASSESSMENT

4. Effects Assessment

4.1 Description of Potential Project Effects to Water Quality

Potential effects to marine water quality originating from Project activities are discussed in this section. Potential effects to sediment quality are discussed in Section 4.3. The Project components associated with these effects are the port site (including camp and beginning of the all-weather road) and the shipping lane. The construction, operation and decommissioning of the port, as well as the use of the proposed shipping lane have the potential to increase water chemistry variables such as suspended solids, nutrients, major ions and/or metals and organics. Chemical changes to sediment quality may also occur. Areas along the shipping lane may also experience effects due to oil leaks from passing vessels.

4.1.1 Discharges and Accidental Spills

Various direct discharges or potential seepage associated with the Project have the potential to alter water quality including:

- spills of various substances (*e.g.*, fuel, construction materials, sewage sludge); and
- treated sewage effluent from port camp.

Spills in this case are considered to be of relatively low volume. For a discussion of effects from large fuel spills at the port or in the shipping lane, refer to Appendix E-6 of the DEIS.

4.1.2 Tremor Effects

The construction phase of the Project will cause large tremors (blasting and pile driving) that may degrade water quality by disturbing the seabed and sending particulate into the water column.

4.1.3 Airborne Contaminant Loading

During several Project phases, airborne contaminants in the form of dust particles from construction activities (*i.e.*, blasting, crushing) as well as particulates from vehicle/generator emissions and incinerating garbage, and sewage sludge may degrade water quality.

4.1.4 Siltation (Runoff and Erosion)

Project activities have the potential to adversely affect water quality as a result of siltation. These activities involve the installation and dismantling of the port infrastructure, snow removal and the associated runoff and potential erosion.

4.1.5 Metal Leaching/Acid Rock Drainage and Residue Leaching

Blasting activities at the camp and port will produce residues containing nitrogen compounds. Generally, these residues remain on the rock surfaces but travel by surface flow into surrounding waters and alter water quality.

Crushing and moving large quantities of rock can accelerate the natural process of weathering and leaching. The oxidation of sulphide minerals can create acid rock drainage (ARD) if sufficient quantities of neutralizing minerals are not available. The potential exists for acid-generating rock to be used in the construction of the port infrastructure, which may degrade water quality.

4.2 Detailed Effects

Most of the potential Project effects would occur during the construction, operations and decommissioning phases, although the post-closure phase was considered for some effects. A summary of all considered effects to water quality is available in Table 4.2-1.

4.2.1 Construction Phase

Project activities during the construction phase that may affect marine water quality include: accidental spills and the discharge of treated sewage effluent; tremors from blasting and pile driving; airborne transport of particulates; siltation from installing infrastructure, excavating and filling; and leaching of nitrogen residues and ML/ARD.

Various discharges associated with the Project have the potential to alter water quality, including treated sewage from the port camp and materials (*e.g.*, fuel, and explosives*)* used during construction. All sewage and graywater will be treated at the tertiary (removal of solids, dissolved organics, and disinfection) sewage treatment plant (STP) located at the port. Solid waste will be incinerated and the treated effluent will be regularly discharged through an outfall on the west side of the peninsula at the port site. Discharged effluent will be monitored as described in Section 6 and be subject to specific requirements in the water use licence issued by the Nunavut Water Board (NWB). Accidental spills of other substances would likely be more sporadic. During construction, the spills will most likely be low volume spills at the storage and re-fuelling sites. With proper mitigation and management they will not have significant effects on water quality. See Appendix E-6 of the DEIS for an assessment of the effects of potential oil spills. All potential discharges are considered to have local and short-term effects making their significance negligible.

Tremors from blasting and pile driving during construction activity may degrade water quality by sending particulates into the water column. During this phase of the Project there is a moderate probability of this occurring, but as the effect will occur locally and be of short term, its significance is negligible.

Disturbing soil and rock material through blasting, truck transport, and contouring, as well as diesel emissions, has the potential to affect air quality such that atmospheric deposition could subsequently affect water quality. Detailed air quality effects are discussed in Appendix B-2 of the DEIS. Airborne particles during construction are considered to occur locally adjacent to the activity. Dust clouds during dry conditions may be larger, but generally the dust will occur sporadically and be suspended for a relatively short time prior to deposition. Although the deposition of some kind will occur during construction, the effects of dust on water quality are projected to be negligible when considering residual effects after mitigation (as discussed in Section 5).

Table 4.2-1
Summary of Effects Assessment for Marine Water Quality

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	Project Phase (Timing)	Project Component	Direction	Nature	(Design Changes, Management, Monitoring, Compensation, Enhancement)	Description of Residual Effect (after mitigation)	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological Context (Resilience)	Influence on Resource Capacity	Probability of Occurrence	Significance	Confidence Level
Discharge and accidental spills (fuel storage, loading fuel to haul trucks, discharge of wastewater and treated effluent, garbage storage)	Construction	Port Site	Adverse	Direct	Spill Contingency and Emergency Response Plan, spill kits, proper training of staff for handling of hazardous materials Environmental Monitors	Contaminants enter ocean, degrading water quality	Low	Local	Short Term	Sporadic-Regular	Short Term	High	Low	Moderate	**Negligible**	High
Tremor effects (blasting and pile driving) causing sedimentation by disturbing bottom substrates	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; silt curtains if possible	Increased TSS in local marine waters depending on substrate sizes.	Moderate	Local	Short Term	Sporadic	Short Term	High	Low	Moderate	**Negligible**	High
Airborne transport of dust into ocean (from blasting fugitive dust, aircraft traffic, garbage incineration)	Construction	Port Site	Adverse	Direct	Air quality and vegetation monitoring to assess loadings of dust to surrounding areas, dust suppression techniques.	Increased particulate loading in local marine waters.	Low	Local	Short Term	Sporadic	Short Term	High	Nil	Low	**Negligible**	High
Siltation (runoff, erosion) into ocean - from construction of various port components (dock, jetty, airstrip, camp, road, ponds), placing rock fill	Construction	Port Site	Neutral	Direct	Implement onshore drainage and settling ponds, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity.	Increased TSS and associated changes in water chemistry in local marine waters.	Moderate	Local	Short Term	Sporadic	Short Term	High	Low	High	**Low**	High
Seepage from landfill entering ocean	Construction	Port Site	Adverse	Direct	Construct landfill at least 500 m from ocean, Environmental Monitors, Appropriate drainage engineered; landfill will only contain ash from non-hazardous waste	Contaminants seep into ocean, degrading water quality	Negligible									
Potential ML/ARD from quarries - runoff into ocean	Construction	Port Site	Adverse	Direct	Use non-potentially acid-generating rock materials, and monitor areas where ML/ARD potential is higher (Water quality monitoring at selected sites).	ML/ARD resulting in degraded water quality	Low	Local	Medium Term	Regular	Short Term	Neutral	Low	Low	**Negligible**	Low
Nitrogen loading from blasting residues	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines. Drainage ditches and sediment ponds used to collect surface runoff from blasted rock areas.	Increased nitrogenous compounds in local marine waters altering WQ	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Discharge and accidental spills or leeching (loading of fuel and supplies, fuel, ammonium nitrate storage, ship and barge movement, discharge of wastewater and treated effluent, garbage storage)	Operations	Port Site and Shipping Lane	Adverse	Direct	Spill Contingency and Emergency Response Plan, spill kits, proper training of staff for handling of hazardous materials.	Contaminants enter ocean, degrading water quality	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Airborne transport of particulates (diesel exhaust, from incineration, aircraft) into ocean.	Operations	Port Site	Adverse	Direct	Air quality and vegetation monitoring to assess surrounding areas.	Increased particulate loading in local marine waters.	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Siltation (runoff, erosion) into ocean - from snow removal	Operations	Port Site	Adverse	Direct	Implement onshore drainage and settling ponds, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity.	Increased TSS and associated changes in water chemistry in local marine waters.	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Potential ML/ARD from quarries	Operations and Decommissioning	Port Site	Adverse	Direct	Monitor areas where ML/ARD potential is higher (Water quality monitoring at selected sites).	ML/ARD resulting in degraded water quality	Low	Local	Medium Term	Regular	Short Term	Neutral	Low	Low	**Low**	Low
Accidental spills (loading of fuel and supplies, barge movement)	Decommissioning	Port Site and Shipping Lane	Adverse	Direct	Spill Contingency and Emergency Response Plan, spill kits, proper training of staff for handling of hazardous materials.	Contaminants enter ocean, degrading water quality	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Siltation (runoff, erosion) into ocean - from structural removal and contouring	Decommissioning	Port Site	Adverse	Direct	Sediment and erosion control measures and contingency plans; use protective barriers at the site of activity.	Increased TSS and associated changes in water chemistry in local marine waters.	Low	Local	Short Term	Sporadic	Short Term	High	Low	Moderate	**Low**	High
Siltation (runoff, erosion) into ocean	Post-Closure	Port Site	Adverse	Direct	Proper contouring at closure should mitigate siltation problems, monitor each spring for several years after closure	Increased TSS and associated changes in water chemistry in local marine waters.	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Potential ML/ARD from quarries - runoff into ocean	Post-Closure	Port Site	Adverse	Direct	Monitor areas where ML/ARD potential is higher or has become a problem, water quality monitoring at selected sites for several years after closure.	ML/ARD resulting in degraded water quality	Low	Local	Medium Term	Regular	Short Term	Neutral	Low	Low	**Negligible**	High

Disturbance of the terrain during construction will increase surface runoff that could accelerate local erosion rates. If not managed properly, this may result in siltation that could deteriorate water quality. Construction of the dock and jetty will likely increase siltation locally. Best management construction practices, as outlined in Section 5 of this report, will be followed to ensure management plans are implemented throughout the Project area. Environmental monitors will also be on site during construction to ensure water quality is not significantly affected. The probability of such an event is high during the construction phase but is considered to have local, short-term effects, and will therefore have a low significance on water quality.

When exposed to oxygen and water, rock will naturally weather and leach. These processes can be accelerated by crushing, processing and redistributing large quantities of rock. The oxidation of sulphide minerals can create ARD if sufficient quantities of neutralizing minerals are not available. In the event that acidic drainage is formed, the lower pH can create higher rates of metal leaching (ML), but ML can also occur at sites of neutral and alkaline drainage. The study of the geochemistry of surficial samples (Appendix D-6 of the DEIS) indicates potential areas for ARD. However, this report clearly states that because of the uncertainties in the analytical data, deeper rock and granular materials should be sampled before excavation and analyzed for a more complete assessment of ARD potential. The ML/ARD characterization will therefore be conducted prior to construction and adaptive management will be implemented to ensure that excavated rock is properly managed to prevent ML/ARD runoff. However, the confidence in this assessment is low because of the lack of reliable geochemistry results and general significance of ML/ARD to marine waters. This significance rating is due to the current uncertainty regarding quarries and would be "negligible" if quarries can be confirmed to be non ML/ARD rock.

Explosives use and storage at the port could increase nitrogen loading to water as a result of nitrogen residue effects from blasting. The accumulation of these residues (NO_3, NO_2, NH_4^+) on disturbed rock material and the nitrogen load to the marine environment depends on the volume of explosives used. Most nitrogen loading will occur from runoff, although a minor source may be from dust. Increases in nitrogen concentration will likely be low during construction and would be of local and short term scales resulting in a negligible significance.

4.2.2 Operations and Decommissioning Phase

Project activities during operations that may affect marine water quality include loading/unloading of fuel, fuel and garbage storage, ship and barge movement, snow removal, sewage discharge, power generation, incineration and potential ML/ARD. During decommissioning structure removal, surface contouring, as well as accidental spills during barge loading and travel may affect surface water quality.

Discharge of treated effluent will occur during the operations phase. The effluent will be monitored prior to discharge. Some potential exists for fuel spills and leaching from ammonium nitrate to occur, for which a spill contingency plan will be in place (Appendix E-6 of the DEIS). During operations and decommissioning, the significance of discharged contaminants and spills to alter water quality is negligible.

Airborne contaminants from the particle deposition will have a negligible effect on water quality during operations and decommissioning. If water quality is degraded by particles from dust, incineration of garbage and sewage sludge, or diesel emissions, it will likely be on a sporadic basis with short term and local effects. See the Air Quality Effects Assessment for details (Appendix B-2 of the DEIS).

During operations, siltation and surface runoff from the port facilities will be minimal as the drainage and sedimentation ponds will be in place. Depending on the volume of material produced from snow removal, it may contribute to siltation effects during wet periods. However, the probability of this effect is low and has negligible significance. During decommissioning activities, the probability of siltation effects is moderate, but since they will be short term and occur locally they are also considered negligible.

During operations and decommissioning any areas that are characterized as potential ML/ARD will be monitored as described in Section 6. This characterization will result from deep rock and gravel samples. The probability of this effect is considered low, but confidence in this evaluation is also low until stronger analytical results are produced from deeper samples. This significance rating is due to the current uncertainty regarding quarries and would be "negligible" if quarries can be confirmed to be non ML/ARD rock.

4.2.3 Post-Closure Phase

After mitigation plans have been executed during decommissioning, the effect from surface runoff and siltation will be negligible. Where concern exists regarding the potential of future erosion effects, monitoring during freshet could occur after closure.

Upon Project closure, areas may be identified as potential for ML/ARD. After necessary remediation procedures, monitoring may continue as far into the future as required until it is determined that remediation measures are successful. No significant effects are expected.

4.3 Description of Potential Project Effects to Sediment Quality

Potential effects to sediment quality from Project activities associated with the port site, as described in Section 4.1, are discussed in this section. The potential effects to sediment quality are a subset of the water quality effects. The description of each is similar to the list in Section 4.1 and the effects specific to sediment quality are:

- contaminant discharge and spills;
- tremors; and
- siltation and surface runoff contaminant loading.

4.4 Detailed Effects

Project activities that could degrade sediment quality are more likely to occur during construction, although some potential exists for effects during the decommissioning phase. Reduced sediment quality can adversely affect benthic organisms that are in direct contact with

the sediment for extended periods (*i.e.*, four-horned sculpin). A summary of all considered effects to sediment quality is available in Table 4.4-1.

4.4.1 Construction Phase

Project activities during the construction phase that could affect sediment quality include: accidental spills, tremors from blasting and pile driving, and siltation from installing infrastructure, and excavating and filling.

Accidental spills have the potential to reduce sediment quality through the introduction of contaminated materials. This includes deposition of liquids or particulates (*e.g.*, fuels and explosives) containing contaminants. See Appendix E-6 of the DEIS for an assessment of the effects of potential oil spills. Although the effect of spills during construction is considered to be of moderate probability, the magnitude of any spills will be low and localized, making their significance negligible. A Spill Contingency and Emergency Response Plan will be in place and enforced by Environmental Monitors during the construction phase.

Tremors from blasting and pile driving during construction activity may degrade sediment quality by directly disturbing the seabed or slumping of sediments. Since the port infrastructure will be installed during phase of the Project there is a moderate probability of this effect occurring, but since the effect will occur locally and be of short term its significance is negligible.

During construction, there is the potential of physical and chemical sediment degradation due to seabed disturbance. The actual construction of the port and associated infrastructure, with activities such as pile-driving and adding large quantities of rock to the seabed, are the primary sources of the disturbance and siltation. The probability of siltation occurring is high, but since the effect is expected to occur locally over the short term, the significance of such an event is considered low. Environmental Monitors will be on site during construction to ensure that BMPs are in place during construction.

4.4.2 Operations and Decommissioning Phases

Project activities during operations and decommissioning that could affect sediment quality include loading/unloading of fuel and supplies, fuel storage, ship and barge movement, discharge of wastewater and sewage, garbage storage, snow removal, removal of port infrastructure and contouring.

During operations, a tertiary STP will treat all sewage from the camp prior to discharge. The quality of the sewage effluent will be monitored prior to discharge to meet regulations described in the water license issued by the NWB. For this reason, the effect of this discharge is considered to be negligible.

The probability of accidental spills having an effect on sediment quality is low during operations. If they do occur, a Spill Contingency and Emergency Response Plan will be in place and implemented. Contaminated soil will be disposed of (Appendix G-6 of the DEIS), and there will

be a plan implemented specifically for oil spills (Appendix E-6 of the DEIS), making any effect to sediment quality of negligible significance.

Siltation effects to sediment quality during operations will be negligible. However, during decommissioning siltation effects will be of low significance. This is primarily a result of the removal of port structures. Environmental Monitors will oversee decommissioning activities to ensure best management practices.

4.5 Summary of Residual Effects to Water and Sediment Quality

Following the assessment of potential effects to the marine water and sediment quality VECs in light of planned Project design and mitigation, some significant residual effects were identified. Please refer to Tables 4.2-1 and 4.4-1 for a summary of effects with a greater than negligible significance.

All of these effects could act alone or together to degrade water and sediment quality. This could result in effects to other VECs including marine aquatic resources, marine fish species (*e.g.*, Four-horned sculpin), and birds and mammals that inhabit the ocean waters in the Project area.

Table 4.4-1
Summary of Effects Assessment for Marine Sediment Quality

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	Project Phase (Timing)	Project Component	Direction	Nature	(Design Changes, Management, Monitoring, Compensation, Enhancement)	Description of Residual Effect (after mitigation)	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological Context (Resilience)	Influence on Resource Capacity	Probability of Occurrence	Significance	Confidence Level
Accidental spills (fuel barge, loading fuel to haul trucks)	Construction	Port Site	Adverse	Direct	Spill Contingency and Emergency Response Plan,spill kits, proper training of staff for handling of hazardous materials, Environmental Monitors.	Contaminants enter ocean, degrading sediment quality	Low	Local	Short Term	Sporadic	Short Term	High	Low	Moderate	**Negligible**	High
Tremor effects from pile driving or blasting causing sedimentation by disturbing bottom substrates.	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; silt curtains if possible.	Disturb sediment and change physical structure of seabed.	Moderate	Local	Short Term	Sporadic	Short Term	High	Low	Moderate	**Negligible**	High
Siltation (runoff, erosion) into ocean - from construction of various port components (dock, jetty, airstrip, camp, road, ponds), placing rock fill, excavating marine clay	Construction	Port Site	Neutral	Direct	Implement onshore drainage and settling ponds, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity.	Disturb sediment potential contamination and change physical structure of seabed.	Moderate	Local	Short Term	Sporadic	Short Term	High	Low	High	**Low**	High
Discharge and accidental spills (loading of fuel and supplies, fuel storage, ship and barge movement, discharge of wastewater and sewage, garbage storage)	Operations	Port Site and Shipping Lane	Adverse	Direct	Spill Contingency and Emergency Response Plan, spill kits, proper training of staff for handling of hazardous materials.	Contaminants enter ocean, degrading sediment quality	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Siltation (runoff, erosion) into ocean - from snow removal	Operations	Port Site	Adverse	Direct	Implement onshore drainage and settling ponds, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity.	Disturb sediment potential contamination and change physical structure of seabed.	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Accidental spills (loading of fuel and supplies, barge movement)	Decommissioning	Port Site and Shipping Lane	Adverse	Direct	Spill Contingency and Emergency Response Plan, spill kits, proper training of staff for handling of hazardous materials.	Contaminants enter ocean, degrading sediment quality	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Siltation (runoff, erosion) into ocean - from structural removal and contouring	Decommissioning	Port Site	Adverse	Direct	Sediment and erosion control measures and contingency plans; use protective barriers at the site of activity.	Disturb sediment potential contamination and change physical structure of seabed.	Low	Local	Short Term	Sporadic	Short Term	High	Low	Moderate	**Low**	High

5. MITIGATION AND MANAGEMENT PLANS

5. Mitigation and Management Plan

Mitigation and management plans are offered as recommendations and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

This plan details the management of marine water and sediment quality, as well as techniques to mitigate effects to the marine habitat. The objective of this plan is to address potential water quality and sediment quality issues through best management practices. As identified in the effects assessment, the primary potential effects to water and sediment quality requiring mitigation and management include:

- siltation and surface runoff contaminant loading;
- airborne contaminant loading;
- discharge contaminant loading; and
- ML/ARD.

Although mitigation measures have already been incorporated during the engineering and design phase of the Project, some effects are inevitable. In addition to specific mitigation measures, all federal and territorial acts and guidelines relevant to this Project and its activities will be adhered to. They include:

- *Canada Oceans Act*;
- *Nunavut Environmental Protection Act*;
- *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters* (Wright and Hopky, 1998); and
- *Guidelines for the Operation of Tankers and Barges in Canadian Arctic Waters* (Transport Canada, 1997).

5.1 Water Quality and Sediment Management Plan

A number of considerations will be evaluated for environmental protection, especially during construction. BMPs will be implemented as the basis for all work undertaken, particularly when working in or around water. A number of mitigation measures can be put in place to minimize or reduce the spatial extent, magnitude, duration, and frequency of increased contaminant loading. Examples of BMPs to preserve water quality and sediment quality include:

- implementation (where needed) of on-site drainage, sedimentation and erosion prevention and control measures and contingency plans;
- personnel trained in and familiar with prevention and control measures as well as contingency plans;

- use of protective barriers like silt curtains to minimize re-suspension and distribution of material to the surrounding environment;
- install and maintain appropriate erosion control measures like siltation fences, diversion berms, sandbags, or rock, where required;
- continuous inspection, maintenance and repair of all runoff and sediment control works; and
- stabilize disturbed areas as soon as possible, direct sediment laden water to settling ponds or other control structures and monitor/treat sediment and water prior to release.

The implementation of proposed mitigation measures will minimize the risk and adverse effects associated with the accidental spills or inadvertent release of deleterious substances into marine waters. Measures include:

- implementation of Emergency Spill Response and Contingency Plan;
- familiarizing staff with contingency plan and location/content of spill kits as well as in the use of spill containment material;
- area designation for storage, re-fuelling, and application/loading of chemicals away from watercourse and in stable location where run-off from above area will not enter water;
- availability of spill kits where storage, re-fuelling, and application/loading of chemicals takes place;
- use of site isolation techniques to retain all site water in controlled sedimentation ponds;
- installation of lined berms around fuel and ammonium nitrate storage facilities;
- continuous inspection, maintenance and repair of machinery/equipment and all containment units; and
- contaminated water, sludge, spill residue, or other hazardous compounds will be disposed of in appropriate matter.

5.2 Marine Shipping Traffic

Minimal risk to marine aquatic resources is expected to occur with shipping. Mitigation that should be implemented during the life of this Project includes following the federal guidelines for the operation of tankers and barges in Canadian Arctic waters (Transport Canada, 1997). Federal guidelines regarding the management of ballast and bilge will also be followed and be the responsibility of the ship owner (Transport Canada, 2007). The effects and management of spill during shipping are assessed in the Environmental Management Plan (Appendix G-4 of DEIS).

6. MONITORING AND EVALUATION

6. Monitoring and Evaluation

Construction of the port site will occur all year, however, wharf and jetty rockfill will occur during summer. Once complete, the shipping season will run from mid July to October 15th. Six to eight vessels per year are expected to use the port upon completion. Focussed water quality monitoring will occur during construction, and annual water quality and biannual sediment quality monitoring during the shipping season will be ongoing during operations. Figure 6-1 shows proposed sampling station locations.

6.1 Construction Monitoring

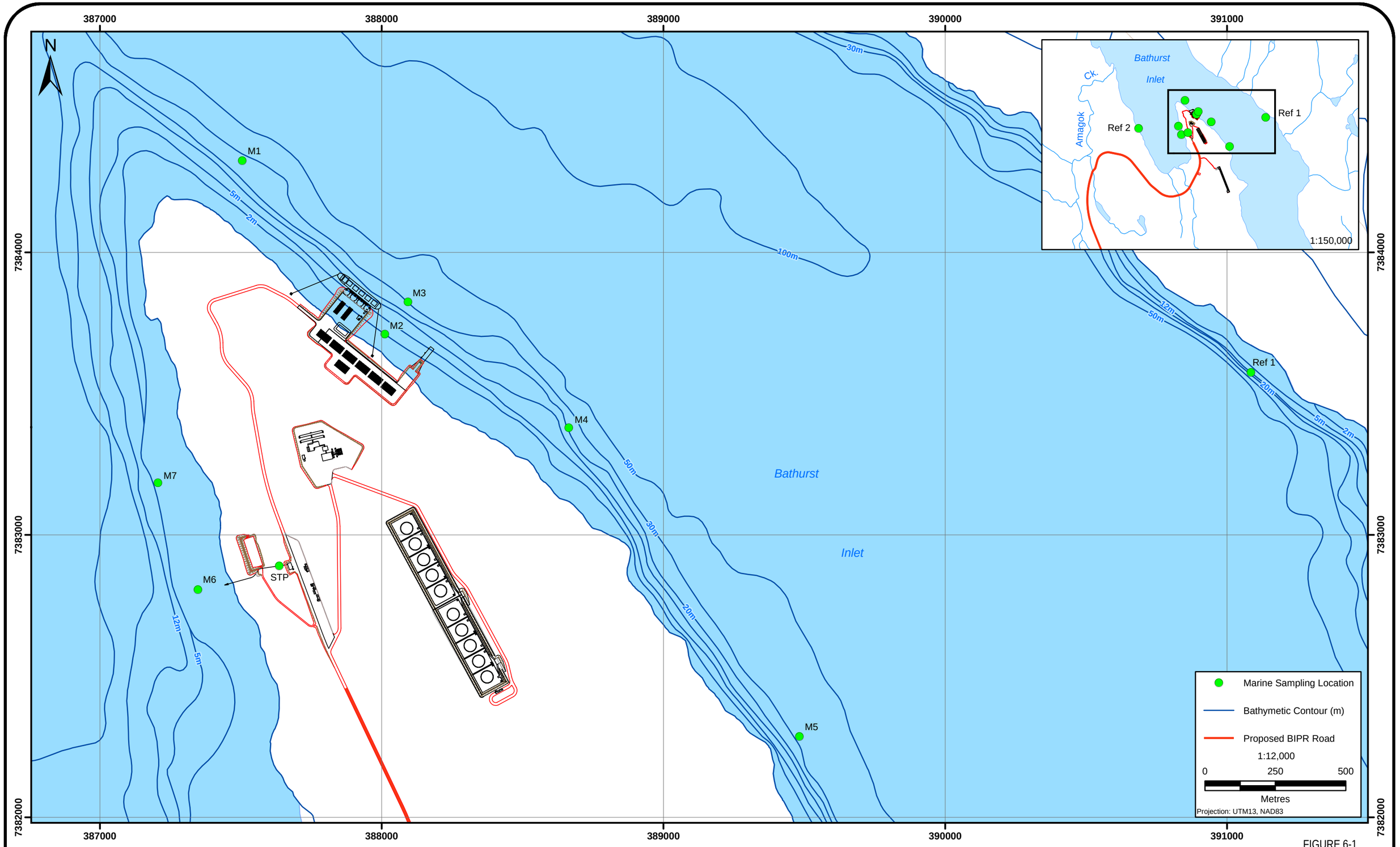
During construction of the port, water quality monitoring will occur regularly in order to document any changes that may result from construction. Duplicate water samples will be collected daily for TSS when building the wharf and from reference sites. Water samples will also be collected from the base of blasted quarries if present. Samples will be collected in pre-cleaned bottles, preserved, kept cool, and shipped to an accredited laboratory for analysis of general parameters, anions, nutrients, total organic carbon, and metals.

6.2 Water Quality

Annual water quality monitoring will occur once throughout the shipping season. Duplicate water samples will be collected from a 1 m depth at each of the five stations, the reference station on the western shore, the sewage treatment plant, two stations near the STP outfall, and the reference station across the bay from the sewage treatment plant. Where there is concern, sedimentation pond water will be monitored for ML/ARD and TSS once per week and before any discharge from pond is allowed. Samples will be collected in pre-cleaned bottles, preserved, kept cool, and shipped to an accredited laboratory for analysis of general parameters, anions, nutrients, total organic carbon, and metals. Treated effluent will be sampled as per the permit received from Nunavut Water Board.

6.3 Sediment Quality

Sediment quality monitoring will occur every two years in August. Samples will be collected from the five stations along the western shore of the peninsula, the reference station on the eastern shore, the two stations at the sewage treatment plant, and the reference station across the bay from the sewage treatment plant. Samples will be collected with an Ekman grab sampler. All samples will be composites of three separate subsamples. Triplicate samples will be collected, kept cool, and shipped to an accredited laboratory for analysis of general parameters, total metals, nutrients, and particle size distribution.



the Bathurst Inlet Port and Road Project

FIGURE 6-1

Locations for Bathurst Inlet Port and Road Project Marine Monitoring Program

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix E-2
Marine Aquatic Resources Effects Assessment

Author: **Rescan Environmental Services Ltd.**
Date: **November 2007**

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

BIPR	Bathurst Inlet Port and Road
CCME	Canadian Council of Ministers of the Environment
DEIS	Draft Environmental Impact Statement
Golder	Golder Associates Ltd.
NTCL	Northern Transportation Company Limited
RL&L	RL & L Environmental Services Ltd
the Project	the Bathurst Inlet Port and Road Project
VEC	valued ecosystem component

1. INTRODUCTION

1. Introduction

The Bathurst Inlet Port and Road (BIPR) Project (the Project) involves the development of a marine port on Bathurst Inlet and a 211 km all-weather road to Contwoyto Lake. The purpose of the Project is to service a number of existing mines and provide an alternative route for re-supply to the mines and local communities in the area. The proposed port for the Project is located on a peninsula in southwestern Bathurst Inlet (66°33'N and 107°31'W) about 40 km south of the community of Bathurst Inlet. It is located on 159 hectares of Federal Crown Land. Terrestrial elements of the port include a 200-person camp, a 220 million litre tank farm, a truck stop and maintenance facility, diesel power plant and a 1,200 meter airstrip. The wharf will be a sheet pile rock-filled structure extending into Bathurst Inlet. It will extend into the marine environment 140 meters along approximately 160 meters of shoreline; and 22,000 m^2 of seabed will be covered by crushed rock required to fill the sheet pile wharf. The surface of the wharf will be 5 m above the high water mark. A small rock jetty will also be built to serve barge traffic between the port and Kitikmeot communities. It will extend 100 m into the marine environment to the three-meter water depth and cover about 4,400 m^2 of seabed.

Marine access to the proposed port site from the northeast will use existing shipping lanes from the eastern Arctic. The route from Barrow Strait will cover a total distance of 650 km through Peel Sound, Franklin Strait, Victoria Strait, cross Queen Maud Gulf, pass through Dease Strait, and enter Bathurst Inlet (Figure 1.1-1). The portion of the route from Barrow Strait to Queen Maud Gulf is currently not a regular shipping route but has been used by summer tourist cruise ships and other vessels sailing the Northwest Passage. The remainder of the eastern shipping route, through Queen Maud Gulf, Dease Strait and into Bathurst Inlet, is used annually for the sealift re-supply of Gjoa Haven and Taloyoak to the east, and Omingmaktok and Bathurst Inlet in Bathurst Inlet. The final 40 km of the route south of Bathurst Inlet community is new. Barge shipments to the communities will follow commercial shipping lanes used annually by Northern Transportation Company Limited (NTCL) in the annual re-supply of the coastal communities of Nunavut.

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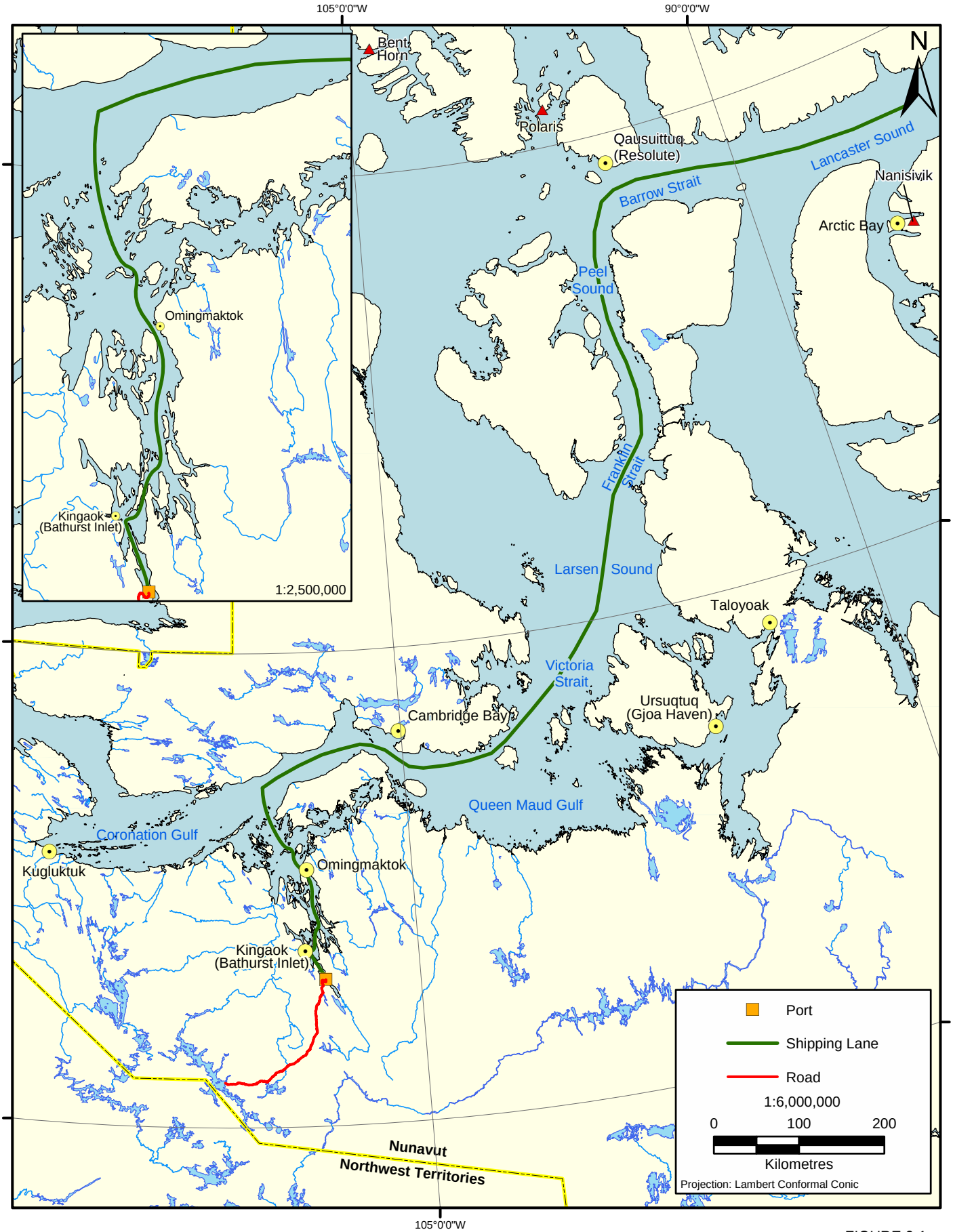

FIGURE 2-1

Proposed Shipping Route

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2. ENVIRONMENTAL SETTING

2. Environmental Setting

2.1 Introduction

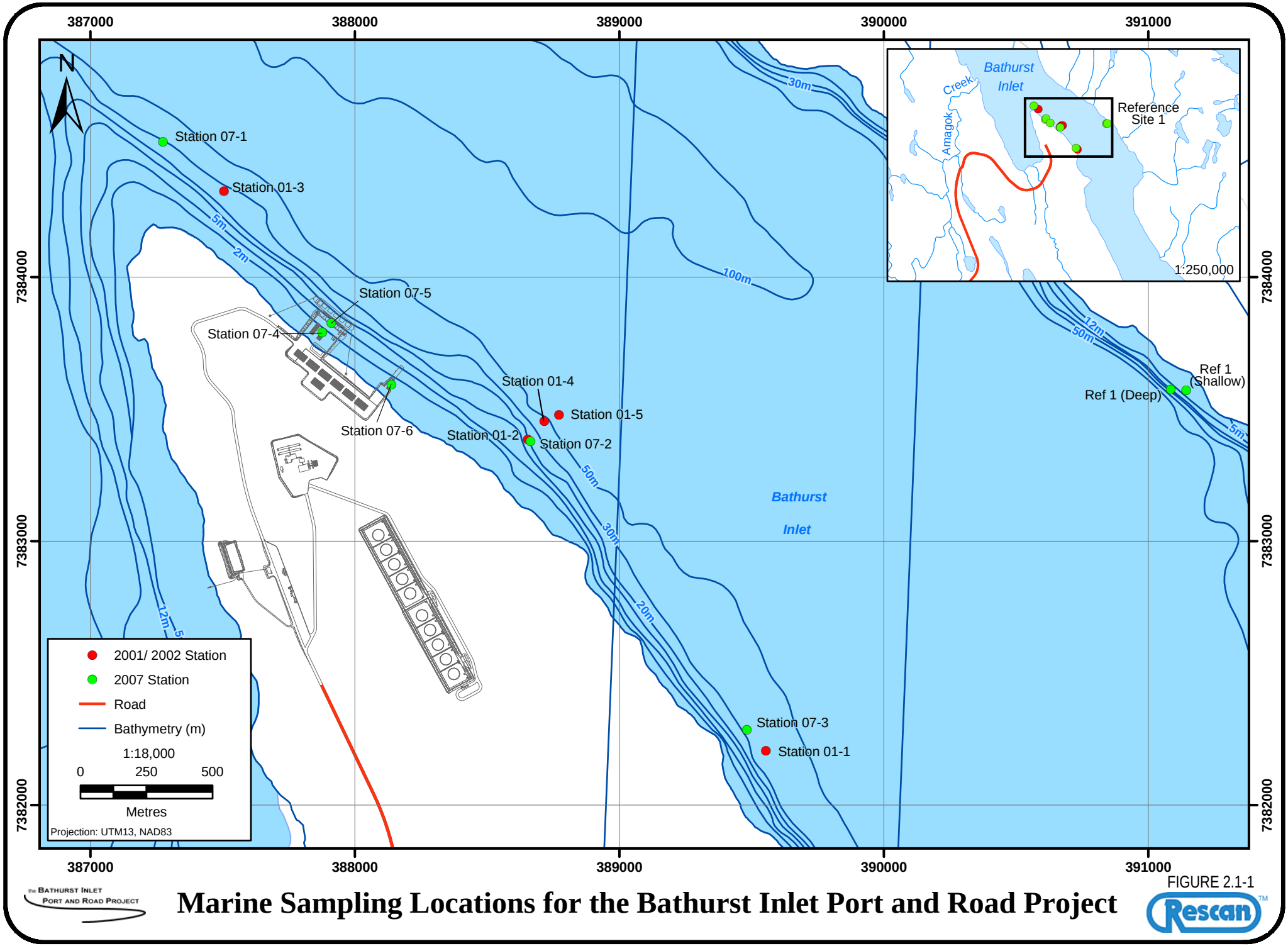
The proposed marine port is located on a peninsula on the west side of Bathurst Inlet (66°33'N and 107°31'W) approximately 40 km south of the community of Bathurst Inlet. The climate of the port area is characterized by long cold winters, short cool summers and minimal precipitation. The length of the open-water season varies along the shipping route, but freezing generally begins in early October and the average date for sea ice melting in Bathurst Inlet is July 6. By the end of July, open water is generally present throughout most of the shipping route. The shipping season is estimated to be 100 days (SNC Lavalin, 2007).

Marine baseline data critical to the assessment of potential environmental effects resulting from the construction, operation and decommissioning of the proposed port were collected during the ice-free seasons of 2001, 2002 (Appendix E-7 of the Draft Environmental Impact Statement (DEIS)) and in 2007 (Rescan, *unpublished data*). Phytoplankton, zooplankton and benthic invertebrates were sampled because changes in the community structure and/or abundance of these organisms could be used to monitor for adverse effects to the marine environment. Also, changes to these producer communities could result in effects at higher trophic levels. Primary producers (*i.e.*, phytoplankton) are at the base of the aquatic food web on which all higher organisms depend. Zooplankton generally feed on phytoplankton, and are in turn a major source of prey for fish and marine mammals. Benthic invertebrates generally feed on algae and other organics in the sediment, but may also be predaceous, and are an important food source for many fish species.

Although the Inuit do not depend on lower trophic levels such as phytoplankton, zooplankton and benthic invertebrates as a food resource, the importance of these organisms relates to the health and abundance of consumers such as fish and marine mammals, on which the Inuit do depend. The *Traditional Knowledge of Wildlife, Fish and Water Quality* report (Appendix F-5 of the DEIS) states that seals were the primary food source for coastal Inuit. Fish were also important for both coastal and inland Inuit, especially in the absence of caribou. Seal hunting and traditional fishing grounds both occurred in Bathurst Inlet and along other parts of the proposed shipping route. Bivalves are part of the benthic invertebrate and are consumed by the Inuit.

In August 2001, five sampling stations were established off the eastern shore of the peninsula on which the port will be built. Stations 01-1, 01-2 and 01-3 were inshore stations that followed a line parallel to the shore, and stations 01-4 and 01-5 were offshore stations directly east of station 01-2 (Figure 2.1-1). Measured biological variables include the density and taxonomic composition of phytoplankton, zooplankton and benthic invertebrates. The benthic community was sampled again in August of 2002.

In August 2007, six stations were sampled in the same study area as those in 2001. Phytoplankton and zooplankton were sampled at three stations following a line parallel to shore. Benthic invertebrates were sampled at three stations in the direct area of the proposed port.



the Bathurst Inlet Port and Road Project

Marine Sampling Locations for the Bathurst Inlet Port and Road Project

FIGURE 2.1-1

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Reference stations were also established opposite the proposed port near the eastern shore of Bathurst Inlet. Phytoplankton and zooplankton were sampled at Ref 1 (deep) and benthic invertebrates were sampled at Ref 1 (shallow). All data collection was carried out according to rigorous design and sampling protocols.

2.2 Phytoplankton

Primary productivity in the Arctic Ocean is limited by the long ice-covered season which reduces or eliminates light availability for photosynthesis. During ice melt in the spring, the surface layer becomes warmer and less saline. This stratification prevents mixing of surface water with deeper, more nutrient rich water. Although there is sufficient light for photosynthesis to occur in the top layer at this time, nutrients may become limited, further contributing to the low primary productivity characteristic of the marine Arctic environment.

Phytoplankton biomass ranged from 0.37 to 0.98 µg/L chlorophyll *a*, and were similar among years. In 2001, abundance ranged from 593 to 980 cells/mL, but in 2007 values were much lower (1 to 3 cells/mL). Richness was also higher in 2001, with 10 to 13 genera per station, compared to only 6 to 8 genera per station in 2007.

In 2001, a large bulk of the algae was represented by an unidentified flagellate (39 to 53%), with chlorophytes (23 to 31%) and cryptophytes (15 to 23%) also being present in large numbers. There were rare members of Bacillariophyceae, Chrysophyta, Pyrrhophyta also observed. Of the identified genera, members of *Plagioselmis* (21%) and *Chlorella* (29%) predominated the five stations. In 2007, only two groups of phytoplankton were observed, including diatoms (Bacillariophyceae) and dinoflagellates (Pyrrhophyta).

Diversity was moderate in 2001, and similar among stations, with Shannon diversity ranging from 1.30 to 1.41 and Simpson diversity ranging from 0.66 to 0.71. Diversity was higher in 2007, with Shannon and Simpson diversity ranging from 1.63 to 1.90 and 0.78 to 0.83, respectively.

2.3 Zooplankton

In 2001, zooplankton abundance ranged from 5,562 to 11,082 organisms/m^3, and were higher in 2007 (22,164 to 43,816 organisms/m^3). Calanoid copepods dominated the zooplankton assemblages in both years. Cyclopoid copepods and cladocerans were present in smaller numbers. The number of genera ranged from 13 to 19 in 2001, and 11 to 15 in 2007. The predominant genera were *Pseudocalanus*, followed by *Acartia* (both are calanoids), and *Podon* (a cladoceran). Simpson diversity indices were similar among stations and slightly higher in 2007 (0.54 to 0.71) than in 2001 (0.34 to 0.66).

Although abundance varied between years, baseline data reflect zooplankton community structure common to the marine Arctic environment. In 2004 and 2005, zooplankton were sampled in the Grays Bay area of Coronation Gulf (Wolfden, 2006). The most dominant genera were again the calanoid copepods *Acartia* and *Pseudocalanus.* Buchanan and Sekerak (1982) sampled zooplankton in eastern Lancaster Sound and western Baffin Bay and also found

zooplankton communities to be dominated by calanoid copepods, with the genera *Calanus* and *Pseudocalanus* being most common.

2.4 Benthic Invertebrates

In 2001, benthos density was 22,752 organisms/m^2 at one site, with nematodes representing 80% of the community, along with annelids, foraminiferans, crustaceans, and rare individuals of other groups. In 2002, four sites were sampled and density was much lower, ranging from 1,515 to 6,276 organisms/m^2, with an overall average of 3,419 organisms/m^2. In 2007, density were slightly lower than those in 2002, ranging from 736 to 3,478 organisms/m^2.

Annelids and foraminiferans were the most abundant groups in 2002, with lesser numbers of crustaceans, and molluscs, and rare arthropods and other groups including nematodes (0 to 14% per station only). Molluscs dominated the benthic assemblages in 2007, followed by arthropods and annelids.

Richness was much higher in 2002 (18 to 39 genera per station) compared to 2007 (2 to 7 genera). In 2002, dominant genera included a polychaete (*Laonice)*, a polychaete (*Aricidea)*, and *Nonion* and *Hippocrepinella* (foraminiferans). In 2007, the mollusc *Astarte borealis* was the most dominant.

Shannon Diversity Index values were much lower and more variable among stations in 2007 (0.15 to 1.50) compared to both 2001 (2.56) or 2002 (2.39 to 2.98). The same pattern was observed for Simpson Diversity Index values.

Wolfden Resources (2007) sampled benthos biomass, densities and species composition at sites in the Grays Bay area of Coronation Gulf in 2004 and 2005. These studies found the benthos community was dominated by *Alagaophamus neotenus* (a polychaete) and *Brachydiastylis resima* (Family Dyastylidae) in this location.

RL&L/Golder (2002) also found that benthic densities in nearby Roberts Bay were highly variable between years, ranging from an average of 1,096 organisms/m^2 in July of 1998 to 41,211 in August of 1997. Polychaetes contributed over 50% of the community numerically at all but the most shallow station (<9 m), where nematodes dominated.

These results demonstrate that the assemblages of primary and secondary producers are highly variable from year to year and therefore may not be appropriate for monitoring of potential effects.

3. METHODOLOGY

3. Methodology

3.1 Valued Ecosystem Component Selection

Phytoplankton, zooplankton, and benthic invertebrates were grouped together and referred to as marine and aquatic resources and selected as one Valued Ecosystem Component (VEC) because they are essential components of the marine food web. Changes in the abundance or composition of these communities may be injurious to higher trophic levels including fish and marine mammals that feed on fish. Seals and fish are also important to the sustenance of local Inuit, and declines in these populations due to lack of food or poor food quality may be detrimental to these people. Additionally, these organisms may be affected by changes in marine water and sediment quality.

The construction, operation and decommissioning of the port as well as the use of the shipping lane have the potential to affect these organisms through changes in water and sediment quality, potentially affecting the availability of light and/or required nutrients, and through the introduction of contaminants. These changes may be introduced through surface runoff or discharge from the port, and accidental chemical or fuel spills. Areas along the shipping lane may also experience effects from ships and ship's cargos.

As these organisms are considered to be a part of fish habitat, they are under protection by legislations such as the *Fisheries Act* (Fisheries and Oceans Canada, 1985). Also, the Canadian Council of Ministers of the Environment (CCME, 2004) has derived water and sediment quality guidelines designed to protect the health of these marine communities.

3.2 Boundaries

This section supplies rationale and justification for the chosen boundaries to assess potential effects from the Project on marine aquatic resources. These boundaries were chosen based on the Project description, location of marine aquatic resources, and through consultation with members of the public and/or technical experts. Boundaries are discussed in the context of both spatial and temporal aspects.

3.2.1 Spatial Boundaries

The spatial boundary for the marine aquatic resources effects assessment includes both a local and regional boundary.

The local study area was defined as the footprint of the dock and barge landing sites and immediate surrounding area, including marine waters, seabed and shorelines. The spatial boundary for the local study area was set at 2 km from the port given that all baseline studies conducted in 2001 on marine aquatic resources were located within 2 km of the port site. It also includes the footprint (width of the ship) of the shipping lane. The potential impact of shipping activities and port activities were limited to these boundaries.

The regional boundary for the marine aquatic resources effects assessment includes the shipping lane from Lancaster Sound to the Bathurst Inlet port site including all waters and shorelines bordering the shipping lane.

3.2.2 Temporal Boundaries

For the purposes of this effects assessment, impacts to marine aquatic resources will be assessed using several temporal boundaries. The temporal boundary for the marine aquatic resources effects assessment includes the Project timelines, as follows:

- **construction:** approximately 2.5 years;
- **operation:** estimated at 19 years; and,
- **decommissioning and closure of the port site:** approximately 1 year.

3.3 Approach and Methods

Potential effects (positive and negative) of any interactions between the Project components, sub-components and/or Project activities were identified for the selected VECs. This was done for each temporal stage of the Project (*i.e.*, construction, operation and maintenance, decommissioning and closure). A detailed description of the Effects Assessment Methodology is presented in Appendix A-5 of the DEIS. A definition of each variable assessed is also included in the same appendix.

In order to ensure all potential effects were identified, a matrix table was used to identify interactions between the identified effects and all aspects of the Project. The potential effects were identified by reviewing the Project components and baseline setting, then determining the potential effects that could occur. The matrix was then used to identify all interactions and influence that a Project component may have on any one effect. If a Project component was considered not to have any interaction (and thus no potential effect), then no further consideration was given to the Project component in the assessment.

This section identifies and assesses the predicted potential effects of each project component on each VEC for the four temporal stages of the Project (*i.e.*, construction, operation and maintenance, decommissioning and closure). Results of this screening process are presented for construction, operation and maintenance, and decommissioning and closure.

Project components that may affect the marine aquatic resources are discussed in relation to mortality (direct), sublethal effects (indirect), and altered productivity of the environment.

4. EFFECTS ASSESSMENT

4. Effects Assessment

4.1 Introduction

Marine aquatic resources may experience adverse effects from various Project activities. Direct effects include: 1) lethal effects or 2) sublethal effects (*e.g.*, increased stress, decreased health or condition and behavioural changes). Sublethal effects do not result in mortality, but may ultimately decrease the growth and development or reproduction of individual organisms, which can lead to population level effects. Indirect effects relate to disruption or altered forage availability for zooplankton or benthic invertebrates due to direct adverse effects at other trophic levels. These could translate into reduced productive capacity at the community level. Therefore, altered productive capacity is included in discussions of mortality and sublethal effects but not as an individual effect on its own. Habitat for marine aquatic resources is not included in this report as it is treated as a separate VEC and is assessed in a report for marine fish habitat (Appendix E-3 of the DEIS).

To assess the potential effects of the Project on the marine aquatic resources, Project activities which could have the potential to affect this VEC were identified. A list of Project components and activities can be found in Table 5.1-2 of Appendix A-5 of the DEIS. Following this initial screening, a detailed evaluation of each activity's potential effect on the marine aquatic resources VEC was conducted. Assessment of each effect considered each group's unique life-history traits, behaviour, and the planned Project design and mitigation strategies. The potential effects to the biological receptors (*e.g.*, zooplankton) are discussed in relation to the physical or chemical stressor (*e.g.*, sedimentation) arising from Project activities (*e.g.*, port construction).

4.2 Potential Effects on Marine Aquatic Resources

Marine aquatic resources may experience both lethal and sublethal effects during the life of the Project. These effects could take place during construction, operation, or decommissioning of the Project. Mortality may result from some proposed activities, such as fuel transport that may lead to spill which would expose marine aquatic resources to deleterious substances.

Sublethal effects to marine aquatic resources may include reduced growth, altered physiological processes or behavioral changes. Although these sublethal effects may not result in mortality, marine aquatic resources could experience effects from decreased productive capacity in the study area at a community level.

Three categories of potential effects were identified, including: release of deleterious substances, sediment and increased turbidity, and marine shipping traffic. Table 4.2-1 assesses each Project activity that may have the potential to affect marine aquatic resources.

4.2.1 Release of Deleterious Substances

The accidental or inadvertent release of deleterious substances into the marine aquatic environment may have the potential to affect marine aquatic resources in the Project area. A deleterious substance is defined by the *Fisheries Act* (Fisheries and Oceans Canada, 1985) as

"any substance that, if added to water, makes the water deleterious to fish or fish habitat or any water containing a substance in such quantity or concentration or has been changed by heat or other means, that if added to water makes that water deleterious to fish or fish habitat." Deleterious substances that could potentially be released include fuel, oil or other hazardous substances, untreated sewage or wastewater, or spills from chemical storage units. Such deleterious substances could potentially impact marine aquatic resources through mortality, physiological stress, contamination, bioaccumulation, behavioural changes, reduced foraging and other sublethal effects. These impacts may directly alter an individual organism's life-history processes with community-wide effects. Oil and diesel fuel spills from ships along the shipping route and at the port site have been assessed in a separate report and can be found in Appendix E-6 of the DEIS.

During the all phases (*i.e.,* construction, operations, or decommissioning) of the proposed Project, the release of deleterious substances may affect marine aquatic resources. Specifically, the construction phase could result in the release of deleterious substances during the following activities: unloading construction materials, fuel, and camp supplies from barges, and during the treating and discharge of wastewater and sewage effluent. During operations, the release of deleterious substances may occur when fuel and cargo are transported, loaded and unloaded, and during the treatment and discharge of wastewater and sewage. Upon decommissioning the port site, deleterious substances could potentially be released by marine barge operations to remove decommissioned structures or when shipping supplies to local communities. All of these potential vectors for the release of deleterious substances will be mitigated by implementing emergency spill response and contingency plans, using spill kits, using containment berms and concrete aprons, using set-back distances for re-fuelling and/or loading and unloading of deleterious substances, and through routine maintenance of equipment and machinery (Appendix G-4 of the DEIS).

Even though the above measures may mitigate effects on marine aquatic resources, there are some potential that activities may cause mortality and sublethal effects. Each of these potential effects were evaluated as low magnitude, local geographic extent, short- to medium-term duration, and with a low to moderate probability of occurrence. The significance of potential effects were assessed as negligible, with a high level of scientific confidence.

4.2.2 Sedimentation and Increased Turbidity

Several Project components may contribute to increased sedimentation of local marine waters close to the proposed port area on Bathurst Inlet. This sedimentation could result in reduced light transmission (turbidity), burial or stress to local biota. Effects include lethal or sublethal effects to local populations of algae and aquatic invertebrates including zooplankton and benthos.

During the construction phase, several Project activities were linked to potential sedimentation effects to marine aquatic resources. These included development of the jetty and dock, preparation of shoreline area for wharf installation, placement of sheet pile, the addition of rock fill between the shoreline and the sheet pile wall, and possible effects from blasting tremors.

Table 4.2-1
Summary of Effects Assessment for Marine Aquatic Resources

Description of Potential Effect						Mitigation and Enhancement	Evaluation of Residual Effect										
Description		Project Phase (Timing)	Project Component	Direction	Nature	Design Changes, Management, Monitoring, Compensation, Enhancement	Description of Residual Effect (after mitigation)	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological Context (Resilience)	Influence on Resource Capacity	Probability of Occurrence	Significance	Confidence
Unload construction materials and camp supplies from marine barges	Accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, equipment and machinery)	Construction	Port Site	Adverse	Indirect	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; maintain equipment and machinery.	No residual effect	Negligible	Local	Short-term	Regular	Short-term	High	Nil	Low	**Negligible**	High
Clear and level (cut and fill) site for on-land facilities	Increased water turbidity and suspended sediments in marine environment (barge landings, onshore construction activites, terrestrial run-off)	Construction	Port Site	Adverse	Indirect	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; maintain equipment and machinery.	Decreased light penetration required for photosynthesis for phytoplankton; Reduced forage ability and displacement of zooplankton; Smothering of benthos	Low	Local	Short-term	One Time	Short-term	High	Nil	Moderate	**Negligible**	High
Construct jetty (100 m into marine environment)	Increased water turbidity and suspended sediments in marine environment (barge landings, onshore construction activites, terrestrial run-off; placement of rock in marine environment)	Construction	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas;use of silt curtains.	Decreased light penetration required for photosynthesis for phytoplankton; Reduced forage ability and displacement of zooplankton; Smothering of benthos	Moderate	Local	Medium-term	One Time	Short-term	High	Low	Moderate	**Low**	High
Prepare the area at tidewater for the wharf	Increased water turbidity and suspended sediments in marine environment (barge landings, onshore construction activites, terrestrial run-off)	Construction	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas.	No residual effect	Low	Local	Short-term	One Time	Short-term	High	Nil	Low	**Negligible**	High
Place rock fill in the space between the shoreline and the sheet piling	Increased water turbidity and suspended sediments in marine environment (barge landings, onshore construction activites, terrestrial run-off; placement of rock in marine environment)	Construction	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas;use of silt curtains.	Decreased light penetration required for photosynthesis for phytoplankton; Reduced forage ability and displacement of zooplankton; Smothering of benthos	Moderate	Local	Short-term	One Time	Short-term	High	Nil	Moderate	**Low**	High
Blasting rock	Tremor effects causing disturbance of sea botom substrate causing increased turbidity and TSS.	Construction	Port Site	Adverse	Direct	Sediment and erosion control measures and contingency plans.	Potential for limited period of sedimentation to marine habitat leading to lethal and sublethal effects.	Low	Local	Short-term	Sporadic	Short-term	High	Nil	Moderate	**Negligible**	Intermediate
Treat waste water and sewage, and discharge effluent to Bathurst Inlet	Accidental or inadvertent release of deleterious substances into the marine environment (e.g., untreated sewage)	Construction	Port Site	Adverse	Direct	Monitor and maintain tertiary sewage treatment facility	Mortality, physiological stress, contamination, behavioural changes, reduced foraging	Low	Local	Medium-term	Regular	Short-term	High	Low	Moderate	**Negligible**	High
Loading and unloading of fuel and supplies between mid-July and mid-October	Accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, equipment and machinery; See Appendix E-6)	Operations	Port Site	Adverse	Direct	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; maintain equipment and machinery.	Mortality, physiological stress, contamination, behavioural changes, reduced foraging, eutrophication	Low	Local	Medium-term	Regular	Short-term	Neutral	Low	Very Low	**Negligible**	Intermediate
Marine shipping between mid-July and mid-October; trips by ice class vessels up to 50,000 tonnes, this includes icebreaker support which may be required in northern end of shipping route	Increased traffic from marine ship and barge operation disrupting marine aquatic resources	Operations	Shipping Lane	Adverse	Direct	Proper training and safety procedures for shipping fuel, Spill Contingency Plan in case of accidents	No direct effect from shipping traffic. Accidental fuel spill would lead to potential lethal and sublethal effects to marine aquatic resources.	Moderate	Local to Landscape	Medium-term	One Time	Short-term	High	Nil	Very Low	**Negligible**	Intermediate
Marine barge operations to serve Nunavut communities; 7 trips by barge from the port during the summer shipping season	Increased traffic from marine ship and barge operation disrupting marine aquatic resources	Operations	Shipping Lane	Adverse	Direct	Proper training and safety procedures for shipping fuel, Spill Contingency Plan in case of accidents	No direct effect from shipping traffice. Accidental fuel spill would lead to potential lethal and sublethal effects to marine aquatic resources.	Moderate	Local to Landscape	Medium-term	One Time	Short-term	High	Nil	Very Low	**Negligible**	Intermediate
Remove imported materials and structures	Increased water turbidity and suspended sediments in marine environment (barge landings, onshore construction activites, terrestrial run-off)	Decommissioning	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas.	Decreased light penetration required for photosynthesis for phytoplankton; Reduced forage ability and displacement of zooplankton; Smothering of benthos	Low	Local	Short-term	One Time	Short-term	High	Nil	Low	**Negligible**	High
Contour surfaces to reduce the possibility of erosion	Increased water turbidity and suspended sediments in marine environment (barge landings, onshore construction activites, terrestrial run-off)	Decommissioning	Port Site	Adverse	Indirect	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas.	No residual effect	Negligible	Local	Short-term	One Time	Short-term	High	Nil	Low	**Negligible**	High

Both direct effects of sedimentation to biota and indirect effects (related to reduced algal production in more turbid sea waters which could reduce secondary production) may be expected. Effects will be mitigated through the use of silt curtains and proper management and monitoring of water quality during activities. However, some localized significant effects were predicted, mainly related to the installation of jetty and marine dock, which are relatively extensive areas of disturbance. Effects were rated of high magnitude but local extent and short duration, therefore the rating of low significant effects was applied.

During decommissioning and post-closure phase, the removal of Project structures and recontouring landscapes to reduce erosion will lead to minimal and localized sedimentation effects to marine aquatic resources. Through proper management, and the use of collection ditches and silt curtains to control of drainage waters in these areas will mitigate effects to biota.

4.2.3 Marine Shipping Traffic

The increased marine ship traffic will not have any direct significant effects on marine aquatic resources. Local marine biota will not be physically affected by the traffic due to their small size. The assessment of fuel spills related to increased traffic is provided in Section 4.2.1. Effects related to marine shipping traffic were rated as negligible significance with a high level of scientific confidence. In addition, the release of ship ballast water may introduce exotic species into Arctic waters. The management of ballast water and its contents is the responsibility of the ship owner to follow regulations made by Transport Canada (1997).

5. MITIGATION AND MANAGEMENT PLANS

5. Mitigation and Management Plans

As detailed in Chapter 4, there are several effects to marine aquatic resources that may arise from the construction, operation and decommissioning of the Project. These include:

- smothering substrates due to sedimentation;
- toxicity related to contamination of marine waters as a result of spills of hazardous substances; and
- alteration to the productive capacity of marine habitat.

Although mitigation measures have already been incorporated during the engineering and design phase of the Project, some effects are inevitable. The following section details mitigation and management plans that are offered as recommendations and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

In addition to mitigation measures specific for the Project, all federal and territorial acts relevant to this Project and its activities will be adhered to. They include:

- *Fisheries Act*; and
- *Nunavut Environmental Protection Act.*

5.1 Sediment and Increase Turbidity

A number of mitigation measures can be put in place to minimize or reduce the spatial extent, magnitude, duration and frequency of increased turbidity and sedimentation. The following mitigation measures can either reduce the increase in suspended material or minimize the area affected. They include:

- implementation (where needed) of on-site drainage, sediment and erosion prevention and control measures and contingency plans;
- personnel trained in and familiar with prevention and control measures as well as contingency plans;
- in water:
    - use of protective barriers like silt curtains to minimize re-suspension and distribution of material to the surrounding environment;
    - continuous inspection, maintenance and repair of all sediment control works;

- on land:
  - minimize areal and temporal extent of disturbance to soil and vegetation on land and substrate in water;
  - install and maintain appropriate erosion control measures like siltation fences, diversion berms, sandbags, or rock, where required;
  - continuous inspection, maintenance and repair of all runoff and sediment control works; and
  - stabilize disturbed areas as soon as possible, direct sediment laden water to settling ponds or other control structures and monitor/treat sediment and water prior to release.

5.2 Release of Deleterious Substances

Mitigating the risk of deleterious substances entering the marine environment is important and subject to federal regulations, including the *Fisheries Act*. The implementation of proposed mitigation measures will minimize the risk of adverse effects associated with the accidental spill or inadvertent release of deleterious substances into marine waters. Measures include:

- implementation of Emergency Spill Response and Contingency Plan;
- familiarizing staff with contingency plan and location/content of spill kits as well as in the use of spill containment material;
- area designation for storage, re-fuelling, and application/loading of chemicals away from watercourse and in stable location where run-off from above area will not enter water;
- availability of spill kits where storage, re-fuelling, and application/loading of chemicals takes place;
- use of site isolation techniques to retain all site water in controlled sedimentation ponds;
- installation of lined berms around fuel and ammonium nitrate storage facilities;
- continuous inspection, maintenance and repair of machinery/equipment and all containment units; and
- contaminated water, sludge, spill residue, or other hazardous compounds will be disposed of in an appropriate manner.

5.3 Marine Shipping Traffic

Minimal risk to marine aquatic resources is expected to occur with shipping. Mitigation that should be implemented during the life of this Project includes following the federal guidelines for the operation of tankers and barges in Canadian Arctic waters (Transport Canada, 1997).

6. MONITORING AND EVALUATION

6. Monitoring and Evaluation

Marine water will be sampled on an annual basis, with marine sediment sampled bi-annually. Sampling of marine aquatic resources will be conducted if significant changes from baseline marine water or sediment quality data are detected. Marine aquatic resources will also be sampled if a spill or other environmental incident should occur.

If sampling is required, a total of nine stations would be used for long-term monitoring and evaluation. These stations are the same as the water and sediment monitoring program. These include five stations on the eastern shore of the port peninsula, a reference station on the eastern shore of Bathurst Inlet, two stations at the sewage treatment plant outfall, and a reference station across the bay from the sewage treatment plant.

Sampling for all marine aquatic resources would occur in August. Phytoplankton and zooplankton will only be sampled if required, determined from the results of water quality monitoring. Monitoring variables and criteria specific to the marine port will be negotiated with regulatory agencies for each proposed activity (*e.g.*, wastewater and sewage effluent). Figure 6.1-1 shows the proposed locations of the sampling stations.

Phytoplankton samples would be collected using a GO-FLO bottle at a depth of 1 m from all stations. Triplicate samples would be collected, and those for taxonomic identification and enumeration will be preserved with iodine solution and sent to a qualified expert for analysis. Samples for phytoplankton biomass (as chlorophyll *a*) will be field filtered and kept frozen until analysis by an accredited laboratory.

Zooplankton samples would be composed of a composite of three separate vertical zooplankton net (118 µm) hauls pooled together. Triplicate samples would be collected from all stations. Zooplankton samples will be preserved in formalin and sent to a qualified taxonomist for identification and enumeration.

Benthic invertebrate samples would be collected from all stations using an Ekman grab sampler. All samples will be composites of three separate subsamples, pooled together following field sieving. Triplicate samples would be collected and preserved in formalin and sent to a qualified taxonomist for identification and enumeration.

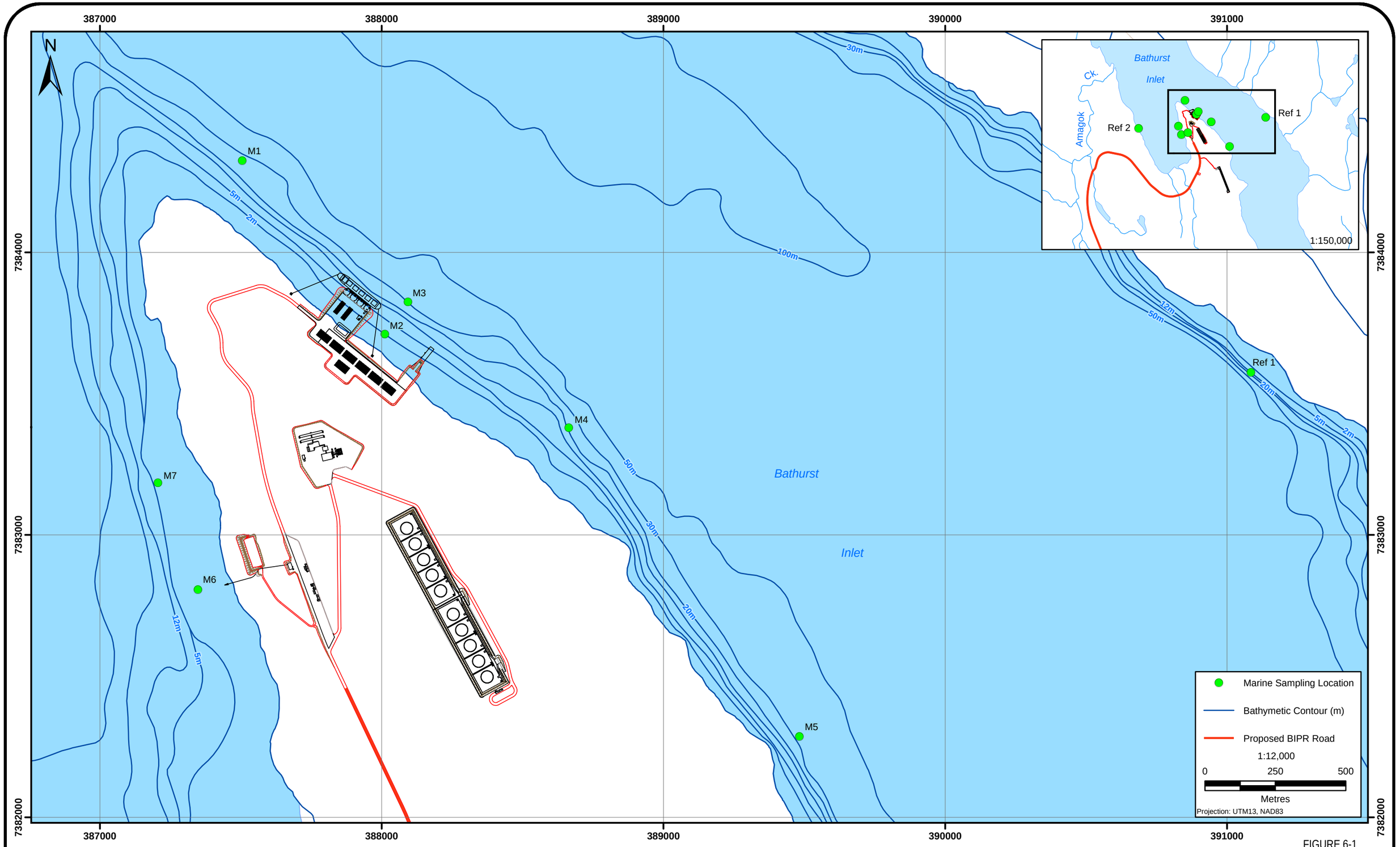

FIGURE 6-1

Locations for Bathurst Inlet Port and Road Project Marine Monitoring Program

the Bathurst Inlet Port and Road Project

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix E-3
Marine Fish and Fish Habitat Effects Assessment

Author: **Rescan Environmental Services Ltd.**
Date: **November 2007**

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ABBREVIATIONS AND ACRONYMS

Abbreviations and Acronyms

AEMP	Aquatic Effects Monitoring Program
AESA	Arctic Environmental Sensitivity Atlas
BOD	biological oxygen demand
BOD5	five-day biological oxygen demand
CMN	Canadian Museum of Nature
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPUE	catch-per-unit effort
DEIS	Draft Environmental Impact Statement
DFO	Department of Fisheries and Oceans Canada
EEM	Environmental Effects Monitoring
EIS	Environmental Impact Statement
Golder	Golder Associates Ltd.
HADD	harmful alteration, disruption or destruction
MMER	Metal Mining Effluent Regulations
NIRB	Nunavut Impact Review Board
NPC	Nunavut Planning Commission
NTCL	Northern Transportation Company Limited
NTKP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
PM	particulate matter
the Project	the Bathurst Inlet Port and Road Project
Rescan	Rescan Environmental Services Ltd.
RL&L	RL&L Environmental Services Ltd.
SARA	*Species at Risk Act* (Canada)
TCWR	Tibbitt-Contwoyto Winter Road
TSS	total suspended solids
WKRLUP	West Kitikmeot Regional Land Use Plan
Wolfden	Wolfden Resources Inc.
VECs	valued ecosystem components

1. INTRODUCTION

1. Introduction

The Bathurst Inlet Port and Road (BIPR) Project (the Project) is located in the Kitikmeot region of Nunavut. The proposed marine port is located on the west side of Bathurst Inlet, about 40 km south of the community of Bathurst Inlet. This effects assessment for the proposed port and shipping lane considers the construction of the port at Bathurst Inlet and the use of the shipping lane during the operation of the Project.

Baseline studies of the proposed port and shipping route were conducted by SNC Lavalin and Rescan Environmental Services Ltd. (Rescan). The port will be used year round as a shipping/receiving site for vessels and barges during the open water season (mid-July to October 15) and by truck traffic from January to April. During operation of the port, round trips from Lancaster Sound to Bathurst Inlet will be made by ice-class vessels supplying fuel and cargo to industry in the area. In addition, barges will be used to re-supply coastal communities within the Kitikmeot region.

1.1 Objectives

To determine environmental conditions prior to development, detailed baseline data on fish and fish habitat were collected in 2001 and 2007 (Appendices E-7 and C-7 of the Draft Environmental Impact Statement (DEIS), respectively). The objective of these baseline studies was to characterize the marine fish community and fish habitat within the local Project area in order to meet the criteria of an Environmental Impact Statement (EIS) as required by the Nunavut Impact Review Board (NIRB). These studies included biological and physical assessments. This effects assessment for the marine fish community and fish habitat will focus on the following components of the marine environment:

- marine fish community at the proposed port location and along the shipping route; and
- marine fish habitat at the proposed port location and along the shipping route.

2. ENVIRONMENTAL SETTING

2. Environmental Setting

2.1 Overview

The Project consists of a marine port on Bathurst Inlet and a 211 km all-weather road to Contwoyto Lake (Figure 2.1-1). The purpose of the Project is to service a number of existing mines and provide an alternative route for re-supply to the mines and local communities in the area.

The proposed port for the Project is located on a peninsula in southwestern Bathurst Inlet (66°33'N and 107°31'W) about 40 km south of the community of Bathurst Inlet. It is located on 159 hectares of Federal Crown Land. Land based elements of the port include a 200-person camp, a 220 million litre tank farm, a truck stop and maintenance facility, diesel power plant and a 1,200 m airstrip (Figure 2.1-2). The wharf will be a sheet pile rock filled structure extending into Bathurst Inlet. It will extend 140 m into the marine environment, along approximately 160 m of shoreline; 22,000 m^2 of seabed will be covered by crushed rock required to fill the sheet pile wharf. The surface of the wharf will be 5 m above water level. A small crushed rock jetty will also be built to serve barge traffic between the port and Kitikmeot communities. It will extend 100 m into the marine environment, to a water depth of 3 m, and cover about 4,400 m^2 of seabed.

Marine access to the proposed port site from the northeast will use existing shipping lanes from the eastern Arctic. The route from Barrow Strait will be south through Peel Sound, Franklin Strait, Victoria Strait, cross Queen Maud Gulf, pass through Dease Strait, and enter Bathurst Inlet (Figure 2.1-1). The portion of the route from Barrow Strait to Larsen Sound is currently not a regular shipping route but has been used by summer tourist cruise ships and other vessels "sailing the Northwest Passage." The remainder of the eastern shipping route, through Queen Maud Gulf, Dease Strait and into Bathurst Inlet, is used annually for the sealift re-supply of Cambridge Bay and Gjoa Haven and Taloyoak to the east, and Omingmaktok and Bathurst Inlet in Bathurst Inlet. The final 40 km of the route south of Bathurst Inlet community is new. Barging to the communities will follow commercial shipping lanes used annually by Northern Transportation Company Limited (NTCL) in the annual re-supply of Kitikmeot communities.

Local Project Area

The local Project area is defined by the footprint of the main Project component, the port. Illustrated in Figure 2.1-2, six key development areas have been defined to describe the physical, chemical and biological setting of the environment:

- wharf that will serve 50,000 tonne vessels;
- dock that will serve barges to re-supply local communities;
- 220 million litre tank farm;
- 1,200 m airstrip;

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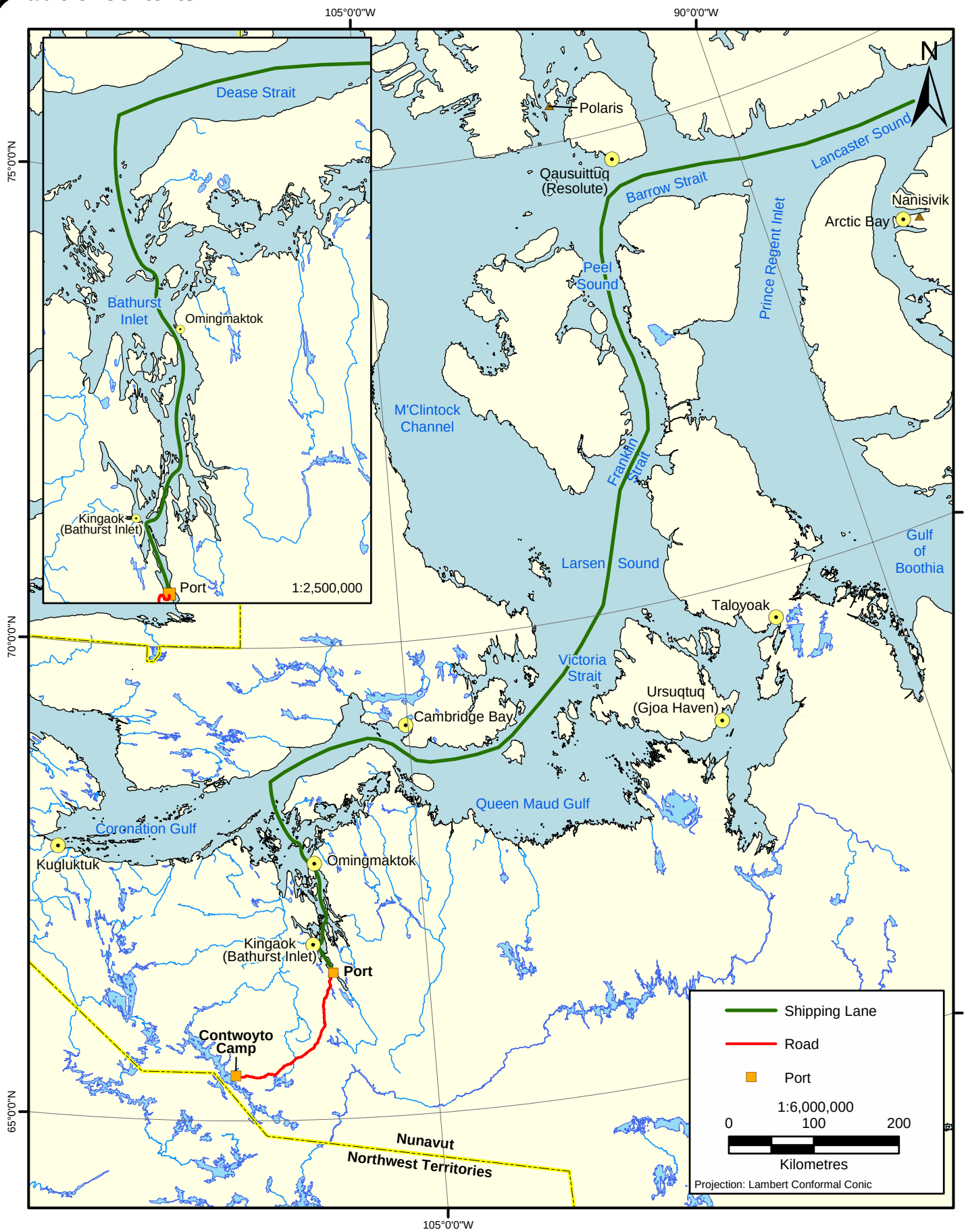
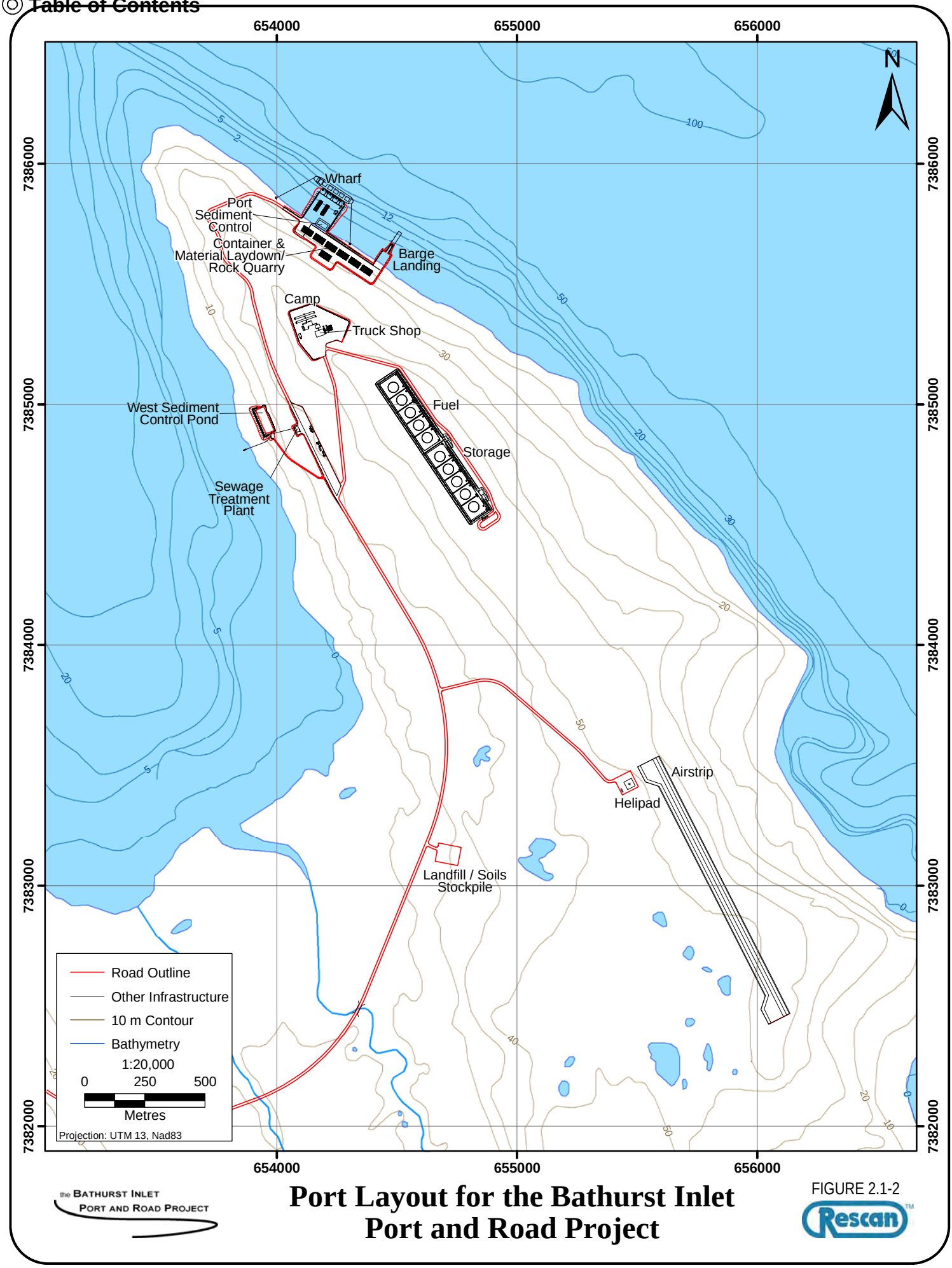


the BATHURST INLET PORT AND ROAD PROJECT

Bathurst Inlet Port and Road Project
Road and Shipping Lane

FIGURE 2.1-1

Rescan™



the Bathurst Inlet Port and Road Project

Port Layout for the Bathurst Inlet Port and Road Project

FIGURE 2.1-2

Rescan™

- a camp that will support 200 people; and
- truck stop maintenance facility and diesel generators.

Regional Project Area

The regional Project area is defined by the Arctic Ocean watershed and associated ecological boundaries near the Project. The regional Project area is bounded from Lancaster Sound west through the Barrow Strait, south through Peel Sound, Franklin Strait, Victoria Strait, across Queen Maud Gulf, through Dease Strait and south through the Bathurst Inlet to the Port (Figure 2.1-1).

2.2 Fish Communities

The marine species and habitat that exist within the Project study area is representative of an Arctic marine ecosystem. Many fish species serve important roles in the ecological, economic and cultural health of the region.

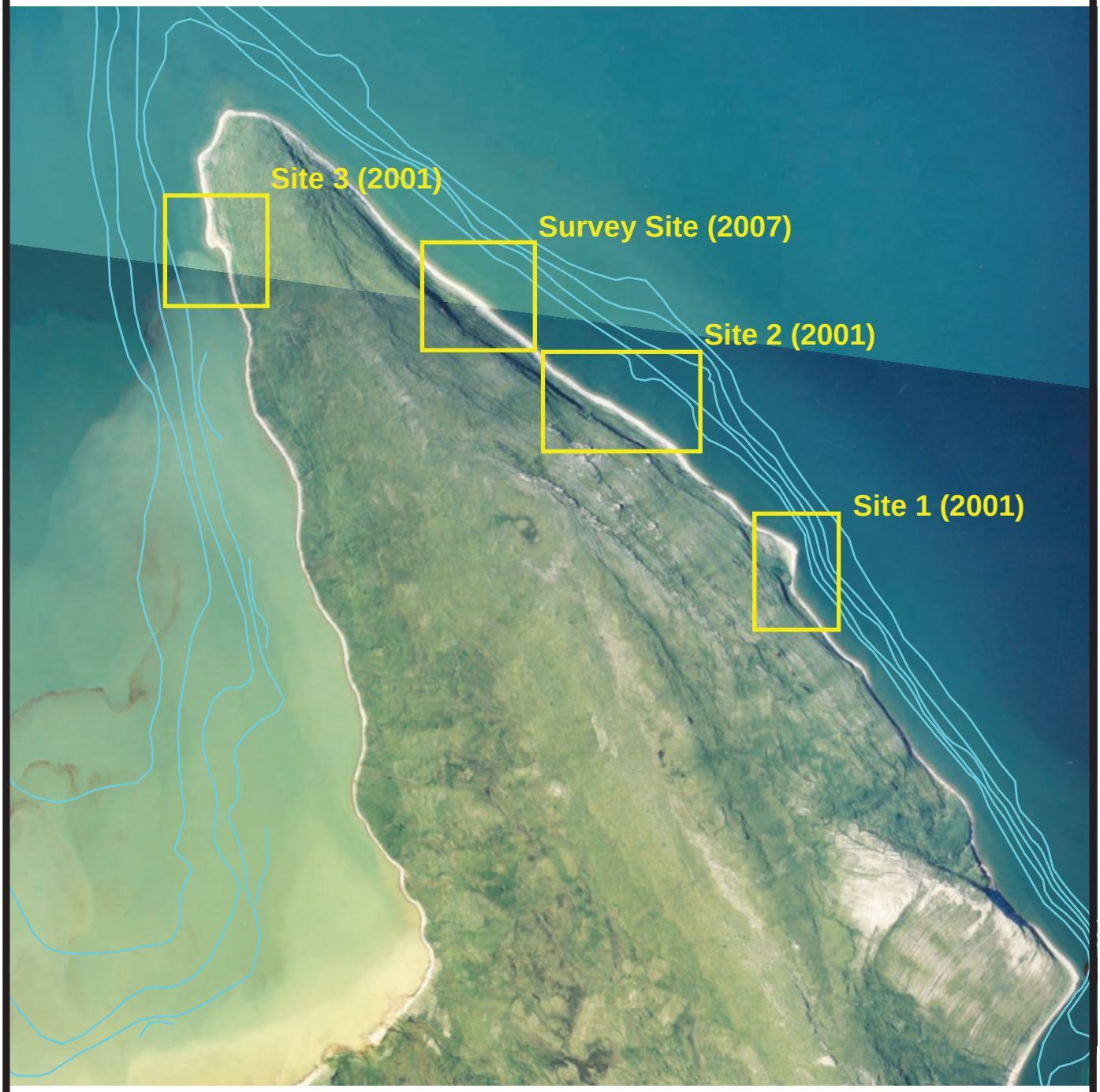
2.2.1 Local Project Area – The Port

The fisheries resources of Bathurst Inlet are not well known because of the remote location of the inlet, small human population, and the absence of significant commercial fisheries. Fish of Bathurst Inlet have been sampled on an opportunistic basis by scientists of the Department of Fisheries and Oceans (DFO) and the Canadian Museum of Nature (CMN) (Hunter *et al.*, 1984; Noel Alfonso, *personal communication*). Other authors have reported fish captured in Bathurst Inlet as part of larger-scale surveys of the fisheries resources of Arctic Canada (Richardson, 1836; Johansen, 1926; Walters, 1953; Boulva and Simard, 1968; Renewable Resources Consulting Services Ltd, 1972; Friesen, 1975; Farquharson, 1976; Stewart and MacDonald, 1978; Sutherland and Golke, 1978; McAllister *et al.*, 1987; Yaremchuk *et al.*, 1989; Kristofferson *et al.*, 1990; Riewe, 1992; McGowan *et al.*, 1993; Stewart *et al.*, 1993; Stewart, 1994).

More recently, detailed baseline marine information on the biology and chemistry, and fish communities and habitat specific to the Project area were collected in 2001 and 2002 (Appendix E-7 of the DEIS and in 2007; Rescan, *unpublished data*).

The objective of the baseline studies was to characterize the physical, chemical, and biological aquatic environment of Bathurst Inlet in order to meet the criteria of an EIS, as required by NIRB. These studies included the assessment of water quality, sediment quality, primary and secondary producers, fish populations and an analysis of fish tissue metal concentrations. Information on fish habitat was also included to satisfy conditions of the DFO's "no net loss" policy (DFO, 1991).

During the 2001 baseline study, marine fish were sampled from three sites along the shoreline of the Bathurst Inlet peninsula (Figure 2.2-1; Appendix E-7 of the DEIS). Sampling gear used included minnow traps, sinking and floating gillnets, sinking and floating longlines and a beach seine. The use of this combination of gear was designed to capture a wide range of fish species and size classes.



the Bathurst Inlet Port and Road Project

Location of Fish and Fish Habitat Sampling Sites in Bathurst Inlet, 2001 and 2007

FIGURE 2.2-1

Rescan™

A total of 177 fish from 11 species were captured during the 2001 fisheries survey (Table 2.2-1). Fourhorn sculpin was the dominant species, followed by Arctic cisco, starry flounder, saffron cod, Arctic flounder, Pacific herring, broad whitefish, rainbow smelt, Arctic char, ogac and lake trout. The fish captured were mainly nearshore, shallow-water species with a relatively large component of anadromous species and species with low tolerance for salinity (compared to the historical records available for Bathurst Inlet). Most fish captured in the nearshore zone were demersal and moved along the sea bottom. All species captured are common fish in Canadian Arctic waters, and none are threatened or endangered.

Table 2.2-1
Species of Fish Captured in Bathurst Inlet in August 2001

Common Name	Scientific Name	Habitat	Spatial Distribution*
Fourhorn sculpin[1]	*Triglopsis quadricornis*	Marine	Demersal
Starry flounder	*Platichthys stellatus*	Marine	Demersal
Saffron cod	*Eleginus gracilis*	Marine	Demersal
Arctic flounder[2]	*Liopsetta glacialis*	Marine	Demersal
Pacific herring	*Clupea pallasi*	Marine	Pelagic
Ogac[3]	*Gadus ogac*	Marine	Demersal
Broad whitefish	*Coregonus nasus*	Freshwater/Brackish	Benthopelagic
Lake trout	*Salvelinus namaycush*	Freshwater/Brackish	Benthopelagic
Arctic cisco	*Coregonus autumnalis*	Anadromous	Pelagic
Rainbow smelt	*Osmerus mordax dentex*[4]	Anadromous	Pelagic
Arctic char	*Salvelinus alpinus*	Anadromous	Benthopelagic

[1]Formerly *Myoxocephalus quadricornis* (Kottelat, 1997).
[2]Formerly *Pleuronectes glacialis* (Cooper and Chapleau, 1998).
[3]Also known as Greenland cod.
[4]Sub-species found in Arctic Canada. Not to be confused with *Osmerus mordax mordax*, the Atlantic rainbow smelt (McAllister, 1990).
Habitat types and spatial distributions were taken from species descriptions shown on Fishbase (Froese and Pauly, 2007).
Demersal = bottom feeders, pelagic = feed in open water, benthopelagic = feed in open water and on bottom.

On the basis of average fork length, adult broad whitefish were the largest fish, followed by adult ogac, Arctic char, saffron cod, lake trout, rainbow smelt, Arctic cisco, starry flounder, Pacific herring, fourhorn sculpin and Arctic flounder. The smallest fish were juvenile fourhorn sculpins.

Average concentrations of mercury, arsenic and lead in starry flounder (resides year-round in the nearshore zone) were below the guidelines established by Canadian Food Inspection Agency. Average concentrations of selenium and cadmium were below the levels known to cause adverse effects. In general, metal concentrations in these Bathurst Inlet fish reflect a pristine environment.

2.2.2 Regional Project Area – The Shipping Lane

A large number of fish have been identified at the regional scale of the Project area. As of 2007, 68 fish species are known to inhabit these waters including marine, anadromous and

freshwater/estuarine species (Table 2.2-2). Most of these fish are demersal, living at or near the sea floor. Dominant fish families include the salmonids, cods, sculpins and eelpouts.

Among the list of 68 fish species found in the regional Project area, three fish species have been identified as regionally important through public scoping: the Bering wolffish (*Anarhichas orientalis*), fourhorn sculpin (*Triglopsis quadricornis*) and Arctic char (*Salvelinus alpinus*). The biology and habitat preferences of these species are described below.

Bering Wolffish

The Bering wolffish is a large member of the blenny family. Based on its distribution in the northwest Pacific Ocean and Bering Sea, it is a demersal species, preferring shallow water among algal-covered rocks, although specimens have been captured in gravel and sand substrate as well (Houston and McAllister, 1990; Fruge and Wiswar, 1991). Adults keep to the shallow coastal area from spring to late fall before moving offshore when the coast becomes ice-bound (Andriyashev, 1954).

Virtually nothing is known about the biology of the Bering wolffish. Spawning may occur in late May as a large female with well developed eggs was reportedly taken from the waters of Avachinskaya Bay in Kamchatka, Russia (Andriyashev, 1954). Another report states that a larva was cast aboard a ship during a storm in the Bering Sea during the month of May, indicating that larvae of this species may be pelagic. Adults, on the other hand, are bottom dwellers, feeding on crabs and mussels (Andriyashev, 1954; Barsukov, 1959).

The Bering wolffish has a confirmed distribution from Hokkaido through the Sea of Okhotsk (Russia) to Alaska but its distribution in the Canadian Arctic is poorly documented. Only three confirmed specimens have been collected in Canadian waters, all from Bathurst Inlet (Figure 2.2-2; Houston and McAllister, 1990; COSEWIC, 2002). Widespread surveys by the DFO, the CMN and various consulting firms have failed to find any Bering wolffish in the Canadian Arctic apart from the individual specimens recorded back in 1964, 1965, and 1969 (COSEWIC, 2002; CMN, 2007). More recently, Fruge and Wiswar (1991) captured Bering wolffish from the Camden Bay area in the Alaskan Beaufort Sea, suggesting that undocumented populations of this species may inhabit Canadian waters outside of Bathurst Inlet. In the summer of 2004, a probable Bering wolffish was caught near Kugluktuk, but there has been no verification as the specimen was not retained and only a photograph was taken (T. Gordanier, *personal communication*).

The Bering wolffish has a unique appearance that should make it easily identifiable. But Inuit fishing on their traditional grounds have not reported catching this fish. Some claim to catch wolffish on a regular basis but cannot distinguish between species, calling them by the name ‘akoak’ or ‘akoaksaluk,’ meaning old woman fish (COSEWIC, 2002).

An assessment and update status report conducted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has changed the status of the Bering wolffish from Special Concern in 1989 to Data Deficient in 2002. Insufficient scientific information was available at the time of assessment to support status designation. The Committee does note that if Bathurst Inlet is truly sustaining the only population of Bering wolffish in Canada, “this unique population is one of national significance” (COSEWIC, 2002).

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Table 2.2-2
Fish Species Found along the Marine Shipping Route Serving the Bathurst Inlet Port and Road Project

Genus	Species	Common Name	Spatial Distribution[2]	Population Resilience[2]	Fish Captured by Rescan at Port site (2001)	Fish in CMN Collection
Amblyraja	*hyperborea*	Arctic skate	bathydemersal	low	--	3
Ammodytes	*dubius*	northern sand lance	demersal	medium	--	1
Ammodytes	*hexapterus*	Pacific sand lance	benthopelagic	medium	--	1
Anarhichas	*orientalis*	Bering wolffish [1]	demersal	very low	--	3
Anisarchus	*medius*	stout eelblenny	demersal	medium	--	76
Arctogadus	*borisovi*	East Siberian cod	demersal	medium	--	42
Arctogadus	*glacialis*	Polar cod	bathypelagic	medium	--	77
Artediellus	*scaber*	rough hookear	demersal	high	--	11
Artediellus	*uncinatus*	Arctic hookear sculpin	demersal	high	--	2
Boreogadus	*saida*	Arctic cod	demersal	medium	--	479
Careproctus	*reinhardt*	sea tadpole	bathydemersal	high	--	3
Clupea	*harengus harengus*	Atlantic herring	benthopelagic	medium	--	1
Coregonus	*artedi*	Cisco	pelagic	low	--	1
Coregonus	*autumnalis*	Arctic cisco	pelagic	low	34	60
Coregonus	*clupeaformis*	lake whitefish	demersal	low	--	25
Coregonus	*nasus*	broad whitefish	demersal	low	10	9
Coregonus	*pallasii pallasii*	Pacific herring	pelagic	medium	11	14
Coregonus	*sardinella*	least cisco	pelagic	medium	--	12
Cyclopteropsis	*jordani*	smooth lumpfish	demersal	high	--	1
Eleginus	*gracilis*	saffron cod	demersal	medium	18	20
Eumesogrammus	*praecisus*	fourline snakeblenny	benthopelagic	medium	--	19
Eumicrotremus	*derjugini*	leatherfin lumpsucker	demersal	high	--	11
Eumicrotremus	*spinosus*	Atlantic spiny lumpsucker	demersal	medium	--	21
Gadus	*ogac*	Greenland cod	demersal	medium	1	90
Gymnelus	*hemifasciatus*	Bigeye unernak	demersal	medium	--	2
Gymnelus	*retrodorsalis*	aurora unernak	demersal	high	--	1
Gymnelus	*viridis*	fish doctor	demersal	low	--	101
Gymnocanthus	*tricuspis*	Arctic staghorn sculpin	demersal	medium	--	206
Hippoglossoides	*robustus*	Bering flounder	demersal	low	--	2
Icelus	*bicornis*	twohorn sculpin	demersal	medium	--	176
Icelus	*spatula*	spatulate sculpin	demersal	medium	--	217
Leptagonus	*decagonus*	Atlantic poacher	demersal	medium	--	25
Limanda	*proboscidea*	longhead dab	demersal	medium	--	1
Liopsetta	*glacialis*	Arctic flounder	demersal	medium	16	14
Liparis	*atlanticus*	Atlantic seasnail	demersal	high	--	2
Liparis	*fabricii*	gelatinous snailfish	bathydemersal	medium	--	165
Liparis	*gibbus*	dusky snailfish	demersal	high	--	6
Liparis	*tunicatus*	kelp snailfish	demersal	medium	--	33
Lumpenus	*fabricii*	slender eelblenny	demersal	very low	--	16
Leptoclinus	*maculatus*	daubed shanny	demersal	medium	--	30
Lycodes	*eudipleurostictus*	doubleline eelpout	demersal	medium	--	1
Lycodes	jugoricus	Shulupaoluk	demersal	medium	--	2
Lycodes	*marisalbi*	White sea eelpout	demersal	medium	--	139
Lycodes	mucosus	Saddled eelpout	demersal	medium	--	29
Lycodes	*pallidus*	pale eelpout	demersal	medium	--	1
Lycodes	*polaris*	polar eelpout	demersal	medium	--	147
Lycodes	*reticulatus*	Arctic eelpout	bathydemersal	medium	--	2
Lycodes	*rossi*	threespot eelpout	demersal	medium	--	42
Lycodes	*seminudus*	longear eelpout	bathydemersal	medium	--	1
Mallotus	*villosus*	capelin	pelagic	medium	--	7
Myoxocephalus	*scorpius*	shorthorn sculpin	demersal	medium	--	76
Myoxocephalus	*scorpioides*	Arctic sculpin	demersal	low	--	21
Oncorhynchus	*keta*	chum salmon	benthopelagic	medium	--	1
Oncorhynchus	*nerca*	sockeye salmon	pelagic	medium	--	2
Osmerus	*mordax*	rainbow smelt	pelagic	medium	2	2
Pholis	*fasciata*	banded gunnel	demersal	high	--	1
Platichthys	*stellatus*	starry flounder	demersal	medium	20	14
Prosopium	*cylindraceum*	round whitefish	demersal	low	--	3
Pungitius	*pungitius*	ninespine stickleback	benthopelagic	medium	--	4
Reinhardtius	*hippoglossoides*	Greenland halibut [2,3]	benthopelagic	low	--	--
Salvelinus	*alpinus*	Arctic char	benthopelagic	low	1	2314
Salvelinus	*namaycush*	lake trout	benthopelagic	low	1	93
Somniosus	*microcephalus*	Greenland shark	benthopelagic	very low	--	11
Stichaeus	*punctatus*	Arctic shanny	demersal	medium	--	1
Triglops	*nybelini*	bigeye sculpin	demersal	medium	--	31
Triglops	*pingelii*	ribbed sculpin	demersal	medium	--	116
Triglopsis	*quadricornis*	fourhorn sculpin [1]	demersal	low	63	93
Ulcina	*orlriki*	Arctic alligatorfish	demersal	medium	--	207

Notes:

Demersal - living at or near the sea floor.

Pelagic - living within mid to upper water column.

Benthopelagic - living and feeding near the bottom as well as in midwaters or near the surface.

Bathydemersal - living and feeding on the bottom below 200 m.

Historical - fish captured in region during previous studies, no numbers provided.

[1]Species identified during public scoping.

[2]Based on FishBase (Froese and Pauly, 2002) distribution (http://www.fishbase.org).

[3]High probability of occuence due to previous capture in area.

Sources: Hart, 1973; Scott and Crossman, 1973; Hunter *et al*., 1984; Jacques Whitford, 2001; Coad *et al* , 1995;

Noel Alfonso and Brian Coad, Research Services Division, Canadian Museum of Nature, P.O. Box 3443, Station "D", Ottawa, Ontario K1P 6P4

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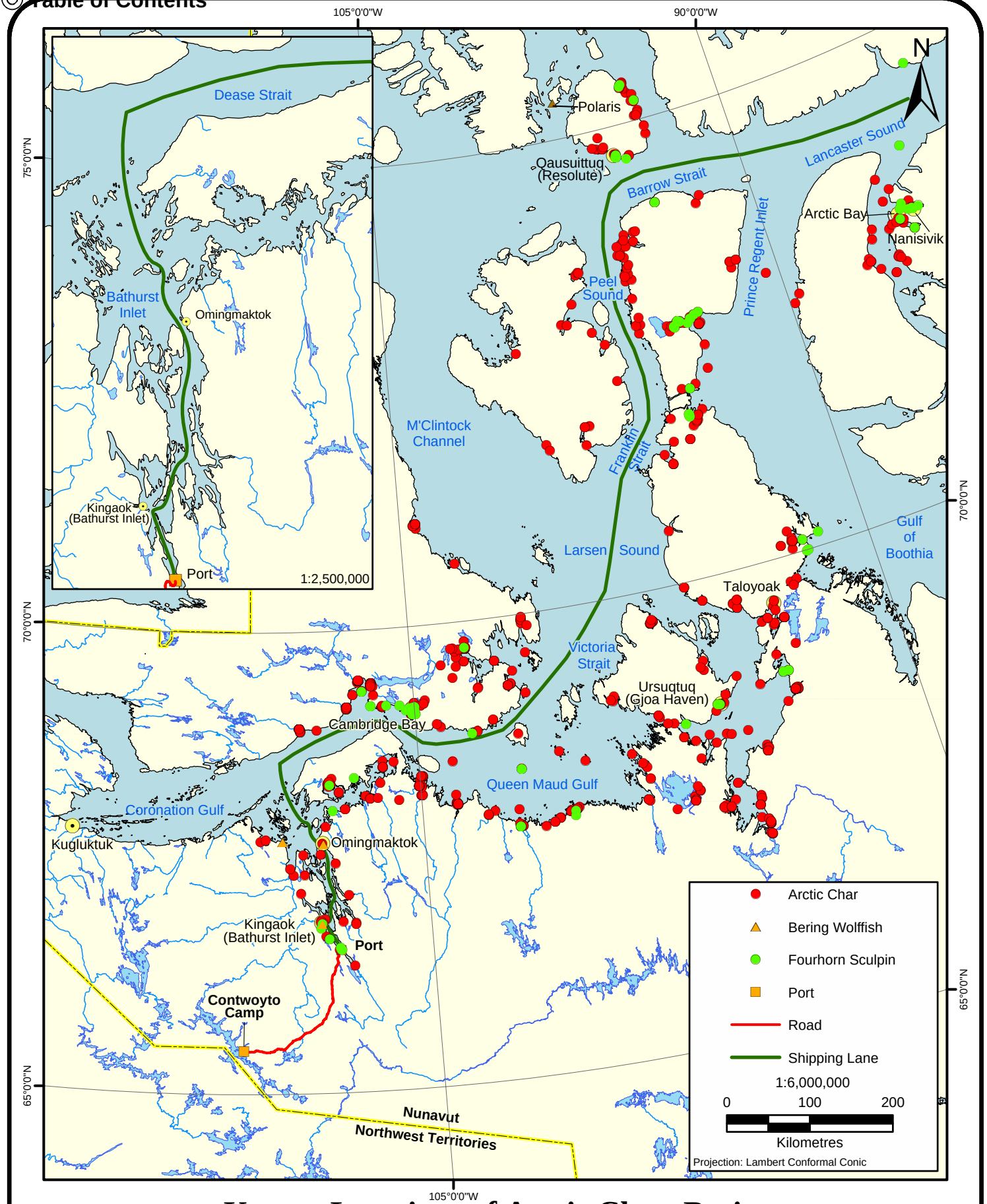


Known Locations of Arctic Char, Bering Wolffish and Fourhorn Sculpin based on Canadian Museum of Nature's Database

the Bathurst Inlet Port and Road Project

FIGURE 2.2-2

Rescan™

Fourhorn Sculpin

The fourhorn sculpin is a member of the family Cottidae. It is a marine fish that is circumpolar in distribution. It is found in both salt and brackish water, usually along the coast in waters from 20 m to the intertidal zone (McAllister, 1980). During the spring, juvenile and adult fourhorn sculpin move from offshore areas to the shallow waters of the coast, returning offshore in the fall. They are benthic, and feed primarily on epibenthic invertebrates such as isopods, amphipods, mysids and plant material (Houston, 1989, 1990). Larvae are pelagic and typically appear along the coast in early spring (Ratynski, 1983). The species overwinters in bays and inlets along the coast, in areas free of landfast ice.

Despite its widespread distribution in the Arctic, not much is known about the fish's ecology or physiology. It is believed to spawn in late winter under the ice, as a ripe and running female specimen was taken from Tuktoyaktuk Harbour in January 1981. Eggs hatch in May to June and larvae are free swimming in shallow pelagic areas along the coast by July (McAllister, 1980; Ratynski, 1983; Houston, 1989, 1990).

The fourhorn sculpin is common in coastal waters of Arctic Canada. The CMN has 93 specimens in its database (Table 2.2-2; Figure 2.2-2; CMN, 2007). Fourhorn sculpin was the most abundant fish species captured during baseline studies for the Project at the proposed port site (Appendix E-7 of the DEIS). They were also collected near Kugluktuk (Jacques Whitford, 2001) and in Melville Sound, near Bathurst Inlet (RL&L/Golder, 2002b, 2003).

Fourhorn sculpin have occasionally been used as food by natives but there is no documented commercial, subsistence or recreational value associated with the fish (Scott and Scott, 1988; Houston, 1989; COSEWIC, 2003). The fourhorn sculpin has been designated a status of "Not at Risk" by COSEWIC (Houston, 1989), as it is widely distributed in the Canadian Arctic.

The fourhorn sculpin is known to be very susceptible to pollutants. A considerable amount of research has been conducted on abnormalities of fourhorn sculpin associated with polluted environments, particularly with metal-ore smelting, pulp mill effluents, and organochlorine contaminants (Bengtsson and Bengtsson, 1983; Bengtsson *et al.*, 1985; Bengtsson, 1991, 1993; Bright *et al.*, 1995; COSEWIC, 2003; Hoekstra *et al.*, 2003). This susceptibility makes the fourhorn sculpin a potential indicator of environmental quality and therefore a key indicator species for monitoring marine systems, specifically in areas of development (Gyllensten and Ryman, 1985; Houston, 1989; Khlebovich, 1997; COSEWIC, 2003).

Arctic Char

One of the most common species of fish found in the study area is Arctic char. It is highly valued by Inuit for subsistence and by commercial and recreational fisheries in the area.

Arctic char is circumpolar in distribution, occupying marine waters, lakes and rivers (Scott and Crossman, 1973). It belongs to the salmonid family and is found as both land-locked and anadromous forms, the latter moving downstream into saltwater in spring and returning to freshwater to overwinter in the fall (Scott and Crossman, 1973). This annual migration into saltwater allows char to take advantage of the more productive marine environment. The diet of

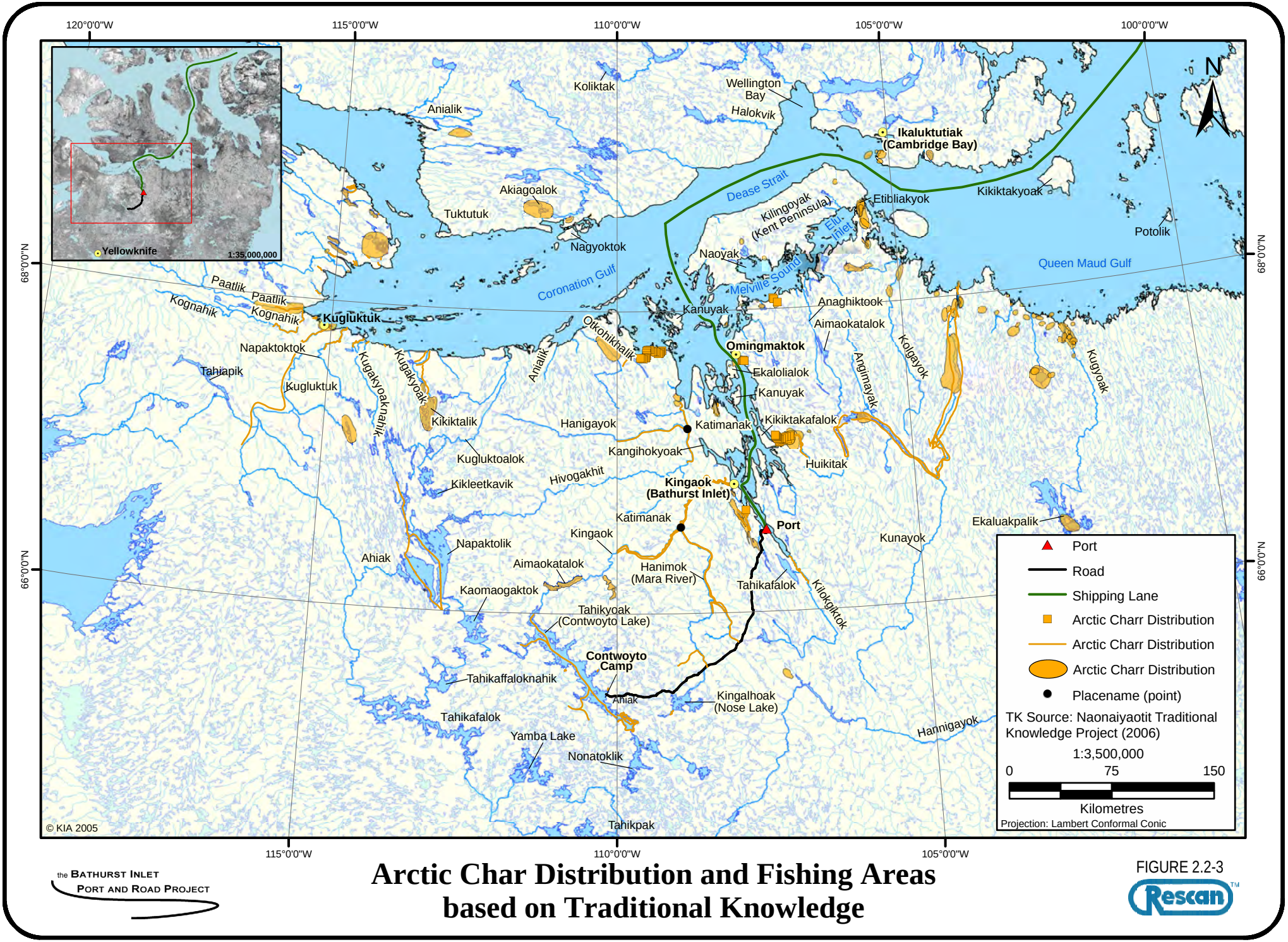
Arctic char includes amphipods and small fish species, including juvenile Arctic char (Scott and Crossman, 1973).

Anadromous Arctic char begin migrating upstream into freshwater from July to September. Spawning takes place in streams and rivers in the fall, usually in areas of groundwater upwelling (McCart, 1980). In the central Canadian Arctic, lake spawning is more prevalent as rivers tend to freeze up in winter (Johnson, 1980). Spawning generally occurs over cobble and gravel substrates in water between 0.5 and 6 m deep. Eggs incubate in gravel substrate over the winter and hatch in early spring but fry emergence does not take place till the break up of ice (Scott and Crossman, 1973). Young Arctic char spend the first stage of their life entirely in freshwater. Those that become sea run make their first migration to sea at about age four or five, returning to freshwater in the fall to escape freezing.

The species is known to be an important food fish to local residents and a key sport fish for the region, supporting local economies, cultures and families (Miramar Hope Bay, 2005; NPC, 2005). Traditional knowledge has shown Bathurst Inlet and the surrounding area to be an important location for subsistence or commercial harvest of Arctic char. It was the key species for Inuit in the area as their movements coincided with the seasonal run of Arctic char (Miramar Hope Bay, 2005; Appendix F-5 of the DEIS; NPC, 2005). People mainly fished at the mouth of major rivers and adjacent to the mainland and island coastlines as documented in NTKP data (Figure 2.2-3; Appendix F-5 of the DEIS).

Arctic char continue to be a valuable fish for subsistence and commercial harvest to many local communities in the Kitikmeot region. These activities enable Inuit to use their traditional knowledge and skills of harvesting while contributing to the local economy (NPC, 2005). The Arctic Environmental Sensitivity Atlas (AESA) lists many locations near the port and along the shipping route as resource (*i.e.,* fish) harvesting locations that are of importance to regional residences (Figure 2.2-4; Environment Canada, 2000). The AESA is a synthesis of environmental information that ranks the relative sensitivity of shoreline and offshore areas of northern regions to the effects of marine oil spills. It incorporates both biophysical and social elements that are important from an oil spill response perspective. Within the Kitikmeot region, the AESA identifies locations for domestic and commercial fishing of Arctic char that are concentrated at the mouth of rivers and along the coastline, similar to regions identified by the Naonaiyaotit Traditional Knowledge Project (NTKP; Figures 2.2-3 and 2.2-4). In Lancaster Sound, the majority of the locations identified as fisheries areas are for domestic purposes, as few commercial fisheries exist in this region (Figure 2.2-4).

The Nunavut Wildlife Harvest Study reports Arctic char as one of the most harvested fish in the Kitikmeot region, which includes Bathurst Inlet, Omingmaktok and Cambridge Bay (Priest and Usher, 2004). It was the most common species recorded in the CMN's database, making up 43% of the specimens collected in the study area (Table 2.2-2; Figure 2.2-2). Arctic char were also collected near Kugluktuk (Jacques Whitford, 2001; Wolfden, 2007) and Melville Sound, near Bathurst Inlet (RL&L/Golder, 2002a, 2003).



the BATHURST INLET PORT AND ROAD PROJECT

Arctic Char Distribution and Fishing Areas based on Traditional Knowledge

FIGURE 2.2-3

Rescan™

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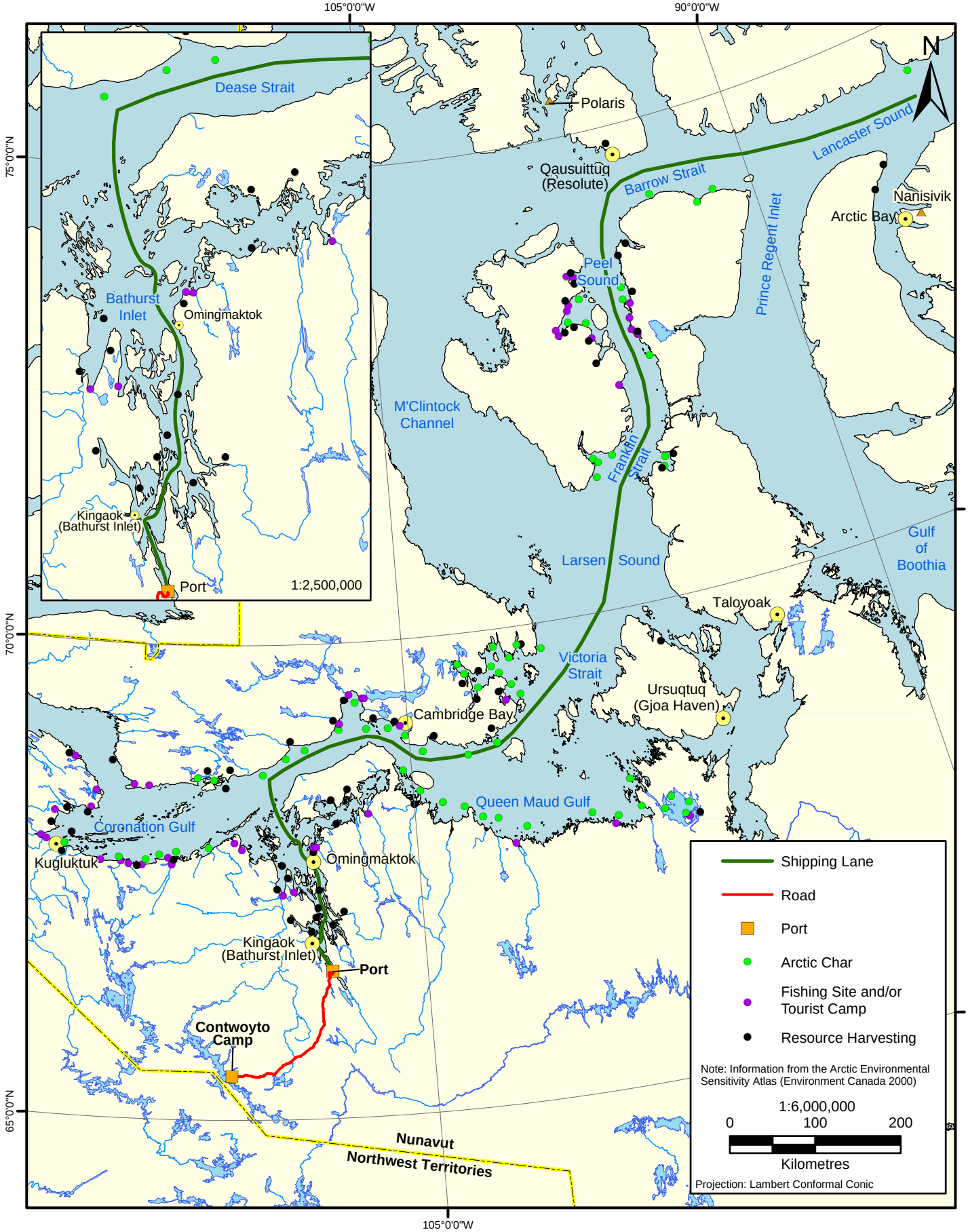


the BATHURST INLET PORT AND ROAD PROJECT

Known Fishing Sites, Important Resource Harvesting Areas and Areas Known to Support Significant Numbers of Arctic Char

FIGURE 2.2-4

Rescan™

2.3 Fish Habitat

2.3.1 Local Project Area – The Port

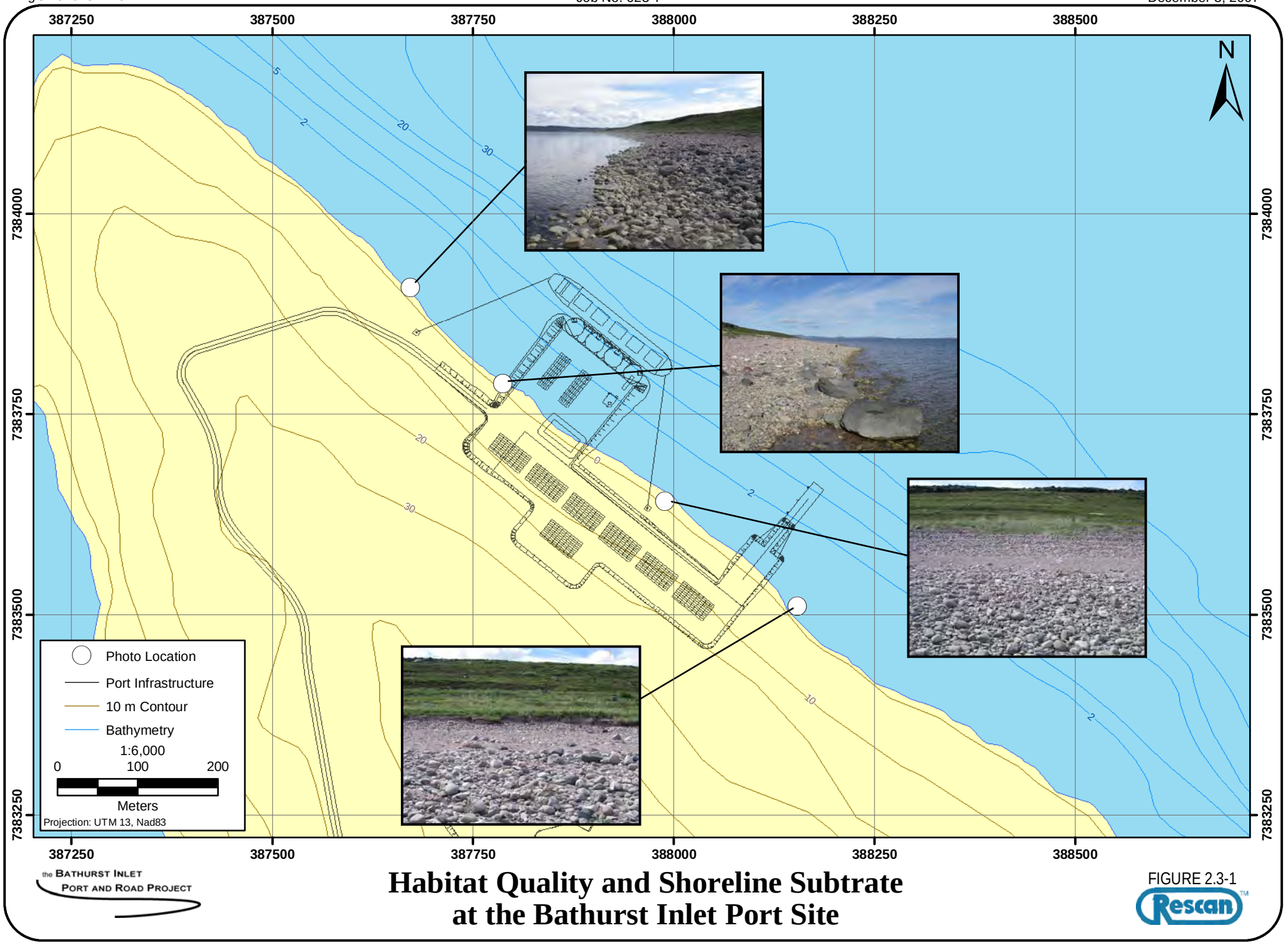
Studies of marine fish habitat were conducted at the port site in 2001 and in 2007, while studies of fish communities were conducted in 2001 only (Figure 2.1-2; Appendix E-7 of the DEIS). In addition, physical marine processes were summarized for Bathurst Inlet and the port site in 2007 (Appendix E-10 of the DEIS).

Shoreline habitat at the port site is dominated by a shallow water shelf which extends at slope of 8% to a depth of approximately 10 m and a distance of 120 m offshore (Appendix E-10 of the DEIS). Beyond this distance, the shoreline drops off steeply at a gradient of 30% to depths greater that 40 m (Figures 2.1-2 and 2.3-1).

Sediment sources in Bathurst Inlet include many watercourses (*e.g.,* Burnside, Hood and Huikitak rivers) and three closer to the port (*e.g.,* Western River, Amagok and no-Name creeks). Western River enters Bathurst Inlet at its southernmost point, and No-Name and Amagok creeks enter Bathurst Inlet on the west side of the peninsula where the port site will be located. Sediment enters the inlet from these sources primarily during freshet in spring (Appendix E-10 of the DEIS). This sediment settles to the bottom of Bathurst Inlet and provides a fine, marine clay substrate that likely supports flatfish, marine bivalves and crustaceans. Sediment may be deposited along the shoreline; however, yearly ice scour prevents significant amounts of fine sediment from occurring in the intertidal zone (Appendix E-10 of the DEIS).

Substrate composition along the shoreline was mapped along zones in 2001 (Appendix E-7 of the DEIS), and along transects in 2007 (Rescan, *unpublished data*). Habitat was mapped up to the high water line in both years. Gravel and cobble dominated the sites closest to the proposed development in 2001, while boulder and cobble dominated a third site on the west side of the peninsula (Appendix E-7 of the DEIS). Marine vegetation was almost non-existent and cover for aquatic organisms was low. In deeper waters, fine clay and silt dominated the substrate, and there was a paucity of organic material in sediment grabs from stations around the proposed development, particularly at depths greater than 40 m. This is reflective of the absence of woody material on shore (Appendix E-7 of the DEIS).

In 2007, substrate composition was determined for evenly spaced quadrats along transects which extended perpendicular to the shoreline from the high water mark to 1 m below the water level. These transects covered the entire length of shoreline that will be altered by the proposed development. All transects were dominated by gravel and cobble substrates; however, a few individual quadrats were composed mostly of fines or boulders. Three distinct habitat zones were present between the high water mark and the terrestrial vegetation, and likely indicate an area of ice scour (Plate 2.3-1). Sandy substrates are considered to be of high value due to their potential for supporting benthic invertebrate communities (RL&L/Golder, 2002a; Urban-Malinga *et al.*, 2005). Such substrates were not common in the intertidal zone at the port site due to ice scour, but were present at depths exceeding 3 m.



the Bathurst Inlet Port and Road Project

Habitat Quality and Shoreline Subtrate at the Bathurst Inlet Port Site

FIGURE 2.3-1

Rescan™

Plate 2.3-1. Substrate zones along the shoreline at the proposed port site, August 2007.

Gravel substrates are preferred by a variety of Arctic marine fishes. Currently, based on habitat preferences, the shoreline habitat at the port site may provide moderate to high quality habitat for fourhorn sculpin, Bering wolffish[1] and Arctic cisco, while deeper areas may provide habitat for starry flounder, Arctic flounder, and saffron cod. In addition, several Arctic char spawning rivers are located near the proposed port site (NPC, 2005). Anadromous Arctic char migrate out of these rivers to the sea where they feed in shallow, coastal areas within 40 to 60 km of their natal stream.

The water column structure near the port site is typical of partially mixed estuaries in that there is a warmer, less saline layer of water over a more saline, colder layer. At the surface, summer water temperatures were approximately 11°C in 2001 and 2007, and salinity ranged from 11 to 16 psu (Appendix E-10 of the DEIS). At depths greater than 30 m, salinity approached 26 psu, and temperature approached 0°C. The estuarine nature of the water column at the port site has led to the capture of some species that normally only inhabit fresh or brackish water (*i.e.*, lake trout and broad whitefish).

[1] Bering wolffish have never been captured at the port site; however, they are known to inhabit Bathurst Inlet, and are thought to prefer gravel/cobble shorelines during the summer months (COSEWIC, 2002).

Summer dissolved oxygen concentrations at the port site reached a maximum at approximately 15 m depth, indicating that colder, highly oxygenated salt water sinks below the fresh water that originates from the rivers (Appendix E-10 of the DEIS).

2.3.2 Regional Project Area – The Shipping Lane

The shipping route from Lancaster Sound to Bathurst Inlet was not examined as part of the baseline studies for this Project. However, data exists for most of the northern portions of the shipping lane because it is regularly used by supply vessels and scientific missions and, increasingly, by commercial traffic.

The AESA lists numerous areas along the shipping route where Arctic char have been observed feeding and/or migrating (Environment Canada, 2000). These areas tend to be concentrated along the south and south-eastern coastlines of Victoria Island, the south shore of Queen Maud Gulf, the south east and northeast coastlines of Prince of Wales Island, and the south shore of Barrow Strait (Figure 2.3-2). Domestic and commercial fishing sites for Arctic char have also been reported for some of these locations, as well as for isolated parts of Melville Sound. Important feeding habitat for Arctic cod has also been reported near Resolute. Whitefish fisheries occur in Foggy Bay (along the western shore of Queen Maud Gulf) and in the Hood River (which empties into Arctic Sound in Bathurst Inlet). The shoreline along much of the shipping route is dominated by gravel/cobble beaches, interspersed with occasional tidal flats and delta complexes (Environment Canada, 2000). Many of the important char habitats listed above occur near these tidal flats and delta complexes, indicating that they are probably highly productive feeding areas for fish.

Fish habitat surveys have been conducted in Roberts Bay, located 187 km northeast of the Project site on the southern shore of Melville Sound as part of the Doris North Project (RL&L/Golder, 2002a). Marine habitat surveys have also been conducted at Grays Bay, 200 km northwest of the Project site on Coronation Gulf, as part of the High Lake Project (Wolfden, 2006). At Grays Bay, the variety and abundance of intertidal biota was low and consisted mainly of encrusted and filamentous algae, as well as a small number of amphipods (Wolfden, 2006). As water depth increased, substrate grain size decreased from bedrock/boulder in nearshore areas to silt/sand substrate at depths greater than 20 m. The abundance of biota also increased with depth. Crabs, sea urchins, sea stars and bivalves were present below the intertidal zone. In general, habitat quality in nearshore areas was poor, and increased in value as depth increased (Wolfden, 2006). This pattern is common in Arctic areas because ice scours the shoreline yearly, making it impossible for most benthic invertebrates to remain in the intertidal zone (Barnes, 1999). At Roberts Bay in Melville Sound, shoreline habitat quality was mostly rated as good due to an abundance of finer grained sediments that support benthic invertebrate communities (RL&L/Golder, 2002a). Throughout the Arctic, habitat quality tends to increase with decreasing substrate grain size because finer sediments support a wider variety of benthic organisms that provide food for fish (Urban-Malinga *et al.*, 2005).

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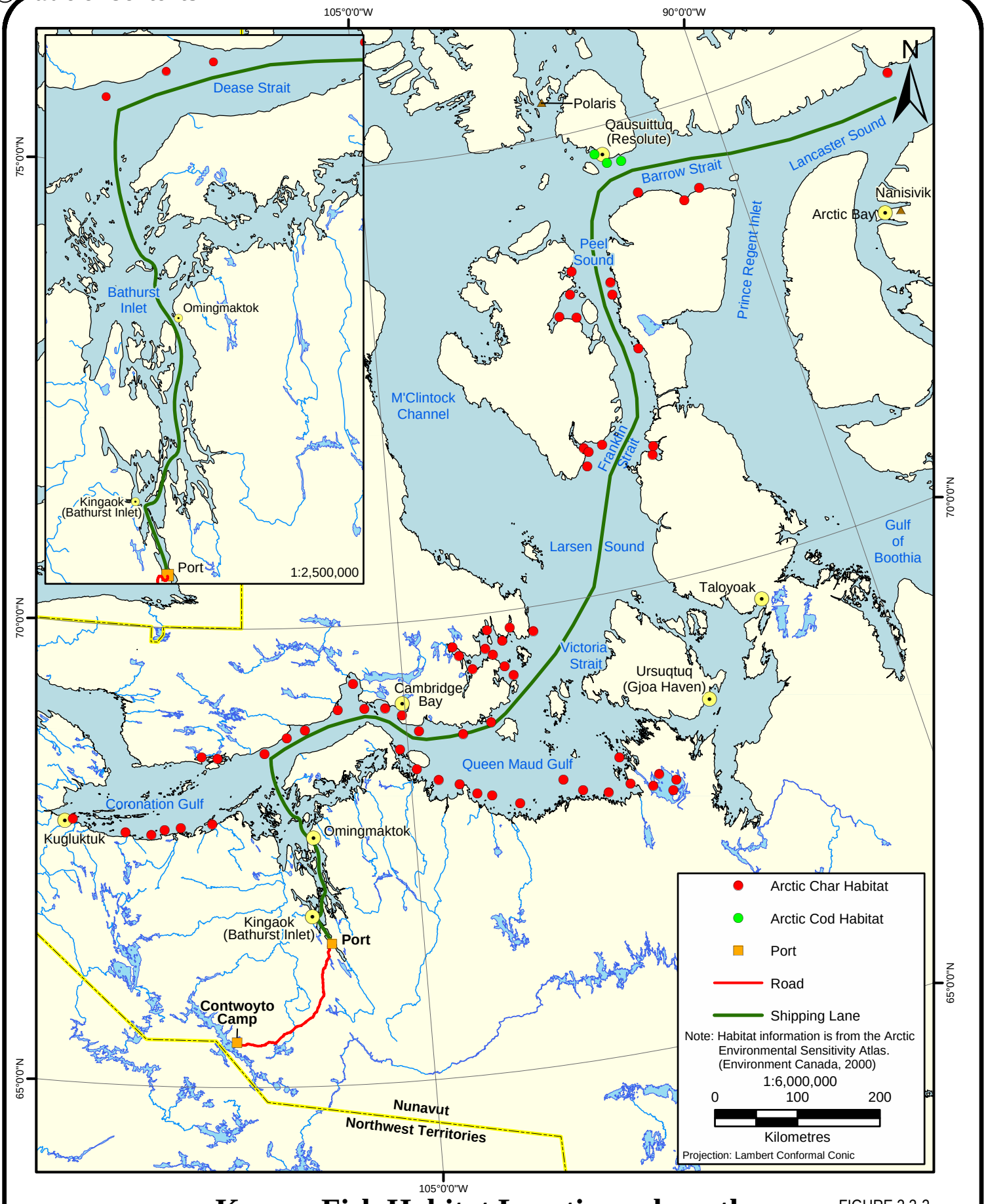


the Bathurst Inlet Port and Road Project

Known Fish Habitat Locations along the Bathurst Inlet Port Shipping Lane

FIGURE 2.3-2

Rescan™

Lancaster Sound, which forms part of the shipping route from Bathurst Inlet, has unusually high primary productivity relative to other Arctic waters (Welch *et al.*, 1992). There is considered to be more than enough primary production to support the current populations of birds and marine mammals (via fish, such as Arctic cod).

Ice edge habitats support a variety of fish species, particularly Arctic cod, which congregate along ice edges to feed (Cohen *et al.*, 1990). The presence of large numbers of Arctic cod also attracts predators such as seals and whales, making the ice edge particularly sensitive o disturbance. Ice may be present year-round in parts of the shipping route, particularly in Peel Sound and Franklin Strait, making the presence of Arctic cod along the shipping lane a real possibility.

Depths along the shipping lane are known to exceed 300 m in places; however, some areas are much shallower. For example, bathymetric soundings around Jenny Lind Island indicate water depths of around 16 m (Appendix E-10 of the DEIS). These shallow shoals may support high populations of fish communities as they are deep enough to be unaffected by shore ice, yet shallow enough to support primary production.

Tidal variation throughout the Project area is low. At Omingmaktok (Bay Chimo Harbour), 129 km north of the port site, the maximum variation between high and low tides is 0.4 m (Canadian Hydrographic Service, 2004). Tides along the northern portion of the shipping route are likely to be larger than those at the port site (Appendix E-10 of the DEIS). The combination of higher tides and stronger winds likely increases the zone of ice scour in the winter, leading to a further impoverished benthic community along the shoreline. Fish habitat in littoral areas is therefore predicted to be of lower quality along the shipping route than in sheltered Bathurst Inlet, where tides and winds are lower.

3. METHODOLOGY

3. Methodology

3.1 Valued Ecosystem Components Selection

Many fish species serve an important role in the ecological, economic and cultural health of Nunavut. Salmonid species in particular are captured for food and sport, supporting local economies, cultures and families, while other species may be used as indicators of environmental health and water quality.

All fish and fish habitat are protected under a variety of federal and provincial regulatory acts and principles. The *Fisheries Act* states that no one is permitted to cause a harmful alteration, disruption or destruction (HADD) of fish habitat without prior authorization from the DFO. In addition, the National Policy for the Management of Fish Habitat also dictates that no net loss of productive capacity of fish habitat should occur at any phase of a Project.

The Project has the potential to affect fish species and their habitat both directly and indirectly during construction, operation and decommissioning of the port and use of the shipping lane. As a result, individual species and their habitats were isolated for further study as valued ecosystem components (VECs) due to their conservation status, commercial value, cultural importance and ecological significance.

The following sources were consulted to identify species at risk and of conservation concern:

- *Species at Risk Act* (SARA);
- COSEWIC; and
- DFO.

In addition to information obtained from the above noted sources, baseline marine fish community and habitat data were acquired by sampling three locations at the proposed port location. In addition, public scoping was performed by NIRB. This process included holding public meetings involving local interest groups from regional and local government offices, community representatives, outfitters and the general public. NTKP interviews also highlighted valuable fish species and habitat in this region.

VECs of the marine fish community and fish habitat were selected using the information collected. Fish listed as VECs for the Project have been identified as regionally important through public scoping for their commercial, cultural and ecological importance, abundance, potential use as a bio-indicator species and/or unique presence to the surrounding area. The fish species identified as regionally important share biology and/or habitat with other fish found in the area. Therefore, potential impacts and associated mitigation for these fish species covers and protects other fish in the area. Fish listed as VECs are Arctic char, Bering wolffish and fourhorn sculpin. Marine fish habitat was also selected as a VEC due to its importance to marine fish species (Table 3.1-1).

Table 3.1-1
Fish and Fish Habitat Valued Ecosystem Components

VEC	Source	Reason for Inclusion
Arctic char	NTKP (Appendix F-5 of the DEIS), West Kitikmeot Regional Land Use Plan (WKRLUP)	Harvested in domestic fishery, and of economic and social importance
Bering wolffish	COSEWIC, WKRLUP, Public scoping	Identified through public scoping; only known Canadian population occurs in Bathurst Inlet, Nunavut
Fourhorn sculpin	Public scoping	Identified through public scoping; highly abundant and can be used as bio-indicator species for the area
Fish habitat	DFO	*Fisheries Act* and National Policy for the Management of Fish Habitat prohibit HADD of fish habitat, and/or loss of productive capacity of fish habitat

Potential impacts to the marine fish community and fish habitat could occur during the construction, operation, and/or decommissioning of the Project. Potential impacts can be direct or indirect and include: sub-lethal effects and mortality; loss or alteration of aquatic habitat; and altered productive capacity at a community level.

3.2 Boundaries

Boundaries are defined to give both a spatial and temporal extent of the impacts that are potentially expected from the Project.

3.2.1 Spatial Boundaries

The spatial boundary for the fish habitat and community effects assessment includes both a local and regional boundary. The local study area is defined as the footprint of the dock and barge landing sites and immediate surrounding area, including all marine waters, seabed, and shorelines. The spatial boundary for the local study area was set at 2 km from the port. This boundary also includes data collected during the 2001 baseline studies on marine fish communities (Appendix E-7 of the DEIS).

The regional boundary for the marine fish habitat and community effects assessment includes the shipping lane from Lancaster Sound to the port site. The boundary includes all waters and shorelines bordering the shipping lane. The impact of shipping activities on fish species is expected to be limited to this boundary. The impact of shipping activities on fish habitat will depend on the distance of the shipping lane from the nearest shore, as the shorelines comprise the most limiting habitat for most fish species in the study area.

3.2.2 Temporal Boundaries

3.2.2.1 Fish Communities

Effects on the marine fish community may be expected at the Port site year-round as some fish species overwinter along the coast. Effects on the marine fish community along the shipping

lane are restricted to the open water season, when shipping occurs. Therefore, for the local study area, the temporal boundary for effects assessment must include year-round activities for the life of the Project. Effects assessment for the regional setting can be confined to the open-water season (July through October).

The temporal boundary for the marine fish community effects assessment includes:

- construction (approximately 2.5 years);
- operation (estimated at 19 years);
- decommissioning and closure of the port site (approximately 1 year); and
- post-closure (approximately 10 years).

The time period considered for the post-closure phase takes into account that some effects have the potential to extend past decommissioning and into the post-closure. The assignment of ten years for post-closure accounts for two generations of fourhorn sculpin or two life spans of Arctic char.

3.2.2.2 Fish Habitat

Effects on fish habitat may be expected at the port site year-round, especially during construction. Along the shipping lane, effects on fish habitat are only expected during the open water season when shipping occurs. Thus, for the local study area, the effects assessment must consider year-round activities for the life of the Project. For the regional study area, the effects assessment is limited to the open-water season from July through October.

The temporal boundary for the marine fish habitat effects assessment will be the same as for the marine fish communities.

3.3 Approach and Methods

The environmental assessment approach used in this assessment is similar to that described for the Project as a whole (Appendix A-5 of the DEIS). Assessments use the most current information on both the design of the Project and the environmental conditions at the site, which includes baseline fish community data collected in 2001 and baseline fish habitat data collected in 2001 and 2007 at the proposed port site. Modelling was not used, instead issues relating to various Project activities associated with the construction of the proposed port and operation of the shipping route consisted of logical discussion of physical and chemical processes in relation to biological receptors, based on professional judgement.

It is assumed throughout the assessment that activities associated with the Project will use appropriate technology and best management practices to properly mitigate or minimize effects. Procedures associated with these Project activities are well developed and understood from decades of experience. However, all potential effects are examined, including unlikely impacts like spills and structural failures.

3.3.1 Limitations

Research on fish communities and fish habitat in the Arctic are sparse in comparison to research in southern areas. Sources of information for this region include: the baseline reports conducted for this Project in 2001 and 2007 (Appendices E-7 and E-10 of the DEIS); baseline reports and environmental assessments conducted for other projects in the region, for example the Doris North Project (RL&L/Golder, 2002a) and the High Lake Project (Wolfden, 2007); and information collected during scientific and exploratory investigations in the region, for example the AESA (Environment Canada, 2000).

4. EFFECTS ASSESSMENT

4. Effects Assessment

4.1 Introduction

The marine fish community and fish habitat may experience adverse effects from various Project activities. Direct effects to the fish community include: 1) mortality (*i.e.,* immediate or near immediate death of fish) or 2) sub-lethal effects (*e.g.,* increased stress, decreased health or condition and habitat avoidance). Sub-lethal effects do not result in mortality, but may ultimately decrease the fecundity or reproductive success of individual fish, and may affect population health in the long term. Indirect effects relate to disruption or altered forage and/or habitat availability for the fish which could translate into reduced productive capacity at the community level. Therefore, altered productive capacity is included in discussions of mortality and sub-lethal effects but not as an individual effect on its own. Fish habitat in marine systems may be adversely affected by sedimentation or spills of hazardous substances, or may be lost altogether as new undersea structures are built.

This chapter will assess the potential impacts of the construction, operation, and decommissioning of the Project on marine fish communities and fish habitat in Bathurst Inlet and along the proposed shipping lane as far as Lancaster Sound.

The environmental effects assessment is designed to address the potential effects of the Project on individual VECs. The scope of the environmental impact assessment is detailed in guidelines produced by NIRB (2004).

To assess the potential impacts, Project activities which have the potential to affect VECs were identified. A list of Project components and activities can be found in Table 5.1-2 of Appendix A-5 of the DEIS. Once the scoping of the Project activities was completed, a detailed evaluation of each activity's potential effect on each VEC was conducted. Evaluations took into consideration the species' biology and life history, the planned Project design, and the mitigation strategies. For fish communities, the potential effects to the biological receptors (*i.e.,* fish) are discussed by physical or chemical stressor (*e.g.,* noise) arising from Project activities (*e.g.,* port construction).

4.2 Potential Effects

4.2.1 Fish Community

Marine fish species may experience both lethal and sub-lethal effects during the life of the Project. These adverse effects can be either direct (*e.g.,* mortality) or indirect (*e.g.,* reduced forage availability) and take place during construction, operation, or decommissioning of the Project.

Fish mortality may result from certain proposed Project activities. Mortality may occur from noise during construction related activities like blasting, drilling, pile driving or seismic waves. Mortality may also be caused by the exposure of fish to deleterious substances that may be introduced into marine waters accidentally. Sources of potential contaminants include sewage or

waste water discharge from camps, discharge from sedimentation ponds or a chemical/fuel spill from storage containers or the on-site equipment and machinery.

Sub-lethal effects to fish may include reduced growth, altered physiology/biology or behavioural changes. Although these sub-lethal effects may not result in mortality, fish could experience effects from decreased productive capacity in the study area at a community level.

Following is a discussion on how stressors related to Project activities may act as a source of biological effects on marine fisheries VECs. Each stressor will be discussed with regard to its source and its direct and/or indirect effect on each fisheries VEC to give an overall assessment of potential impacts. Tables 4.2-1 to Table 4.2-3 present the issue scoping matrices for each fish VEC.

Given the very limited information available on the Bering wolffish there is uncertainty surrounding the assessment of Project related stressors. Assessments have been based on professional judgement on what is known of this species as well as fish species having similar life history, habitat and biological traits. As Bering wolffish were not captured during baseline studies, the likelihood of their presence at the port site is minimal.

4.2.1.1 Construction

Construction of the port may have an impact on the marine fish community. Activities may result in the direct mortality of fish, including the infilling of sheet pile cells and construction of a causeway to the steel sheet pile cells. As rock fill is placed on the soft sediment substrate at the port location, fish may be crushed and/or smothered if not able to escape the area. Although it is expected that fish will be displaced prior to rock placement, there is a possibility that some may not have time or the chance to remove themselves from the zone of impact. Refer to Appendix A-3 of the DEIS for a detailed review of construction activities at the port site.

Arctic Char

Although it is possible that a small number of Arctic char may be killed by direct impact of port construction, it is more than likely that the fish will avoid the area once construction commences. Any fish that remain near the port site and/or stranded inside the silt curtain barrier will likely be saved during fish salvage efforts prior to construction. After mitigation, the residual effect of direct mortality by construction is considered to be low in magnitude and local in extent, and the significance of the impact on Arctic char will be **negligible**.

Bering Wolffish

Bering wolffish present in the port location at the time of construction may be directly affected by construction activities. Wolffish are demersal species, preferring shallow water along algal-covered rocks as well as gravel/sand substrate: habitat that will be directly affected by construction (Section 2.2.2). It is highly possible that placement of rock fill to create a causeway at the port location may kill Bering wolffish. Mitigation, specifically fish salvage in the area, prior to construction will minimize the impact. Therefore, the residual effect after mitigation is

Table 4.2-1
Summary of Effects Assessment for Arctic Char

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
	Project Phase (Timing)	**Project Component**	**Direction**	**Nature**			**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence Level**
	Construction Operations Decommissioning Post-Closure	Port Site All-Weather Road Shipping Lane Human Resources	Beneficial Adverse Neutral	Direct Indirect Cumulative Synergistic			Negligible Low Moderate High	Local Landscape Regional Trans-Boundary	Short Term Medium Term Long Term Far Future	One Time Sporadic Regular Continuous	Short Term Long Term Irreversible	High Neutral Low	Nil Low Moderate High Unknown	Low Moderate High	**Negligible Low Moderate High**	High Intermediate Low
Description					**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Residual Effect (after mitigation)** [1]										
Mortality or sublethal effects due to construction (dumping of rock fill, infilling of sheet pile)	Construction	Port Site	Adverse	Direct/Indirect	Fish salvage	Mortality; reduced or altered forage availability; displacement of Arctic char	Low	Local	Short Term	Sporadic	Short Term	Low	Low	Low	**Negligible**	High
Mortaility due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods; setbacks during char migration.	Mortality	High	Local	Short Term	Sporadic	Short Term	Low	Low	Low	**Negligible**	High
Sublethal effects due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods; setbacks during char migration.	Auditory (hearing hair) and/or internal damage (ruptured swim bladder, internal bleeding)	Moderate	Local	Short Term	Sporadic	Short Term	Low	Low	Low	**Negligible**	High
Sublethal effects due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods; setbacks during char migration.	Behavioural changes	Low	Local	Short Term	Sporadic	Short Term	High	Low	Moderate	**Negligible**	High
Sublethal effects due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Indirect	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods; setbacks during char migration.	Reduced forage availability	Low	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Construction	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; inspection, maintenance and repair of all runoff and sediment control works.	Physiological stress; immune system breakdown; and/or increased disease	Moderate	Local	Medium Term	Sporadic - Regular	Short Term	Neutral	Low	Low	**Low**	Intermediate
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Operation, Decommissioning	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; inspection, maintenance and repair of all runoff and sediment control works.	Physiological stress; immune system breakdown; and/or increased disease	Moderate	Local	Medium Term	Sporadic - Regular	Short Term	Neutral	Low	Low	**Negligible**	Intermediate
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; inspection, maintenance and repair of all runoff and sediment control works.	Reduced forage ability; displacement of Arctic char	Low	Local	Short Term	Sporadic - Regular	Short Term	High	Low	Moderate	**Negligible**	Intermediate
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Construction, Operation, Decommissioning	Port Site	Adverse	Indirect	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; inspection, maintenance and repair of all runoff and sediment control works.	Reduced forage availability	Low	Local	Short Term	Sporadic - Regular	Short Term	High	Low	Moderate	**Negligible**	Intermediate
Mortality due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Mortality	High	Landscape	Short Term	One Time	Short Term	Low	Low	Low	**Negligible**	High
Sublethal effects due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Physiological stress; immune system breakdown; contamination and/or increased disease	High	Landscape	Medium Term	One Time	Short Term	Neutral	Low	Low	**Negligible**	High
Sublethal effects due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Indirect	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Reduced forage availability	Low	Landscape	Short Term	One Time	Short Term	High	Low	Low	**Negligible**	High
Elevated dust emissions (blasting, crushing, power generation, waste incinerating, traffic)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct/Indirect	Dust suppression (*e.g.,* water) at source	No residual effect										
Sublethal effects due to increased traffic from marine ship and barge operation	Operations, Decomissioning	Shipping Lane	Adverse	Direct	Modify timing of shipping/barge operations to avoid critical/sensitive time periods;	Displacement of fish	Low	Landscape	Short Term	Regular	Short Term	High	Low	Moderate	**Negligible**	High

[1] **If there is NO residual effect after mitigation there is no need for further evaluation.**

Table 4.2-2
Summary of Effects Assessment for Bering Wolffish

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
	Project Phase (Timing)	**Project Component**	**Direction**	**Nature**			**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence Level**
	Construction Operations Decommissioning Post-Closure	Port Site All-Weather Road Shipping Lane Human Resources	Beneficial Adverse Neutral	Direct Indirect Cumulative Synergistic			Negligible Low Moderate High	Local Landscape Regional Trans-Boundary	Short Term Medium Term Long Term Far Future	One Time Sporadic Regular Continuous	Short Term Long Term Irreversible	High Neutral Low	Nil Low Moderate High Unknown	Low Moderate High	**Negligible Low Moderate High**	High Intermediate Low
Description					**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Residual Effect (after mitigation) [1]**										
Mortality or sublethal effects due to construction (dumping of rock fill, infilling of sheet pile)	Construction	Port Site	Adverse	Direct/Indirect	Fish salvage	Mortality; reduced or altered forage availability; displacement of Bering wolffish	Low	Local	Short Term	Sporadic	Short Term	Low	Unknown	Low	**Negligible**	Low
Mortality or sublethal effects due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods.	Mortality; auditory (hearing hair); internal damage (ruptured swim bladder, internal bleeding); and/or damage to incubating eggs	High	Local	Short Term	Sporadic	Short Term	Low	Unknown	Low	**Negligible**	Low
Sublethal effects due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods.	Behavioural changes	High	Local	Short Term	Sporadic	Short Term	Low	Unknown	Moderate	**Negligible**	Low
Sublethal effects due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Indirect	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods.	Reduced forage availability	Moderate	Local	Short Term	Sporadic	Short Term	Low	Unknown	Low	**Negligible**	Low
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Construction	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas.	Physiological stress; immune system breakdown; increased disease; and/or damage to incubating eggs	High	Local	Medium Term	Sporadic - Regular	Short Term	Low	Unknown	Low	**Low**	Low
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Operation, Decommissioning	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas.	Physiological stress; immune system breakdown; increased disease; and/or damage to incubating eggs	High	Local	Medium Term	Sporadic - Regular	Short Term	Low	Unknown	Low	**Negligible**	Low
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas.	Reduced forage ability; displacement of Bering wolffish	High	Local	Short Term	Sporadic - Regular	Short Term	Low	Unknown	Moderate	**Negligible**	Low
Sublethal effects due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff, remediation/contouring of surfaces)	Construction, Operation, Decommissioning	Port Site	Adverse	Indirect	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; inspection, maintenance and repair of all runoff and sediment control works.	Reduced forage availability	Moderate	Local	Short Term	Sporadic - Regular	Short Term	Low	Unknown	Moderate	**Negligible**	Low
Mortality due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, sedimentation ponds, fuel and prill storage, sewage sludge, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Mortality	High	Landscape	Short Term	One Time	Short Term	Low	Unknown	Low	**Negligible**	Low
Sublethal effects due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, sedimentation ponds, fuel and prill storage, sewage sludge, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Physiological stress; immune system breakdown; contamination; increased disease; and/or damage to incubating eggs	High	Landscape	Medium Term	One Time	Short Term	Low	Unknown	Low	**Negligible**	Low
Sublethal effects due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, sedimentation ponds, fuel and prill storage, sewage sludge, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Indirect	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Reduced forage availability	Moderate	Landscape	Short Term	One Time	Short Term	Low	Unknown	Low	**Negligible**	Low
Elevated dust emissions (blasting, crushing, power generation, waste incinerating, traffic)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct/Indirect	Dust suppression (*e.g.*, water) at source	No residual effect										
Sublethal effects due to increased traffic from marine ship and barge operation	Operations, Decommissioning	Shipping Lane	Adverse	Direct	Modify timing of shipping/barge operations to avoid critical/sensitive time periods;	Displacement of fish	Low	Landscape	Short Term	Regular	Short Term	Low	Low	Moderate	**Negligible**	Low

[1] **If there NO residual effect after mitigation there is no need for further evaluation**

Table 4.2-3
Summary of Effects Assessment for Fourhorn Sculpin

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	**Project Phase (Timing)** Construction Operations Decommissioning Post-Closure	**Project Component** Port Site All-Weather Road Shipping Lane Human Resources	**Direction** Beneficial Adverse Neutral	**Nature** Direct Indirect Cumulative Synergistic	**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Residual Effect (after mitigation)** [1]	**Magnitude** Negligible Low Moderate High	**Geographic Extent** Local Landscape Regional Trans-Boundary	**Duration** Short Term Medium Term Long Term Far Future	**Frequency** One Time Sporadic Regular Continuous	**Reversibility** Short Term Long Term Irreversible	**Ecological Context (Resilience)** High Neutral Low	**Influence on Resource Capacity** Nil Low Moderate High Unknown	**Probability of Occurrence** Low Moderate High	**Significance** **Negligible** **Low** **Moderate** **High**	**Confidence Level** High Intermediate Low
Mortality or sublethal effects due to construction (dumping of rock fill, infilling of sheet pile)	Construction	Port Site	Adverse	Direct/Indirect	Fish salvage	Mortality; reduced or altered forage availability; displacement of fourhorn sculpin	Low	Local	Short Term	Sporadic	Short Term	Low - High	Low	Low	**Negligible**	High
Mortality due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods.	Mortality	High	Local	Short Term	Sporadic	Short Term	Low	Low	Low	**Negligible**	High
Sublethal effectsa due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods.	Auditory (hearing hair); internal damage (ruptured swim bladder, internal bleeding); and/or damage to incubating eggs	Moderate	Local	Short Term	Sporadic	Short Term	Low	Low	Low	**Negligible**	High
Sublethal effectsa due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Direct	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods.	Behavioural changes	Moderate	Local	Short Term	Sporadic	Short Term	Neutral	Low	High	**Negligible**	High
Sublethal effect due to increased noise (blasting, drilling, pile driving, seismic waves)	Construction	Port Site	Adverse	Indirect	Follow federal blasting guidelines; adopt measures designed to minimize effects of noise (e.g. use detection/deterring, sound sources); modify work window to avoid critical/sensitive time periods.	Reduced or altered forage availability; displacement of fourhorn sculpin	Moderate	Local	Short Term	Sporadic	Short Term	High	Low	Low	**Negligible**	High
Sublethal effect due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff)	Construction	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; maintenance and repair of all runoff and sediment control works.	Physiological stress; immune system breakdown; increased disease; and/or damage to incubating eggs	Moderate	Local	Medium Term	Sporadic - Regular	Short Term	Neutral	Low	Low	**Low**	Intermediate
Sublethal effect due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff)	Operation, Decommissioning	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; maintenance and repair of all runoff and sediment control works.	Physiological stress; immune system breakdown; increased disease; and/or damage to incubating eggs	Moderate	Local	Medium Term	Sporadic - Regular	Short Term	Neutral	Low	Low	**Negligible**	Intermediate
Sublethal effect due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; maintenance and repair of all runoff and sediment control works.	Reduced forage ability; displacement of fourhorn sculpin	Moderate	Local	Short Term	Sporadic - Regular	Short Term	Neutral	Low	Moderate	**Negligible**	Intermediate
Sublethal effect due to increased water turbidity and suspended sediments in marine environment (rock filling, barge landings, onshore construction activites, terrestrial runoff)	Construction, Operation, Decommissioning	Port Site	Adverse	Indirect	Implement onshore drainage, sediment and erosion control measures and contingency plans; use protective barriers at the site of activity or in sensitive areas; maintenance and repair of all runoff and sediment control works.	Reduced or altered forage availability; displacement of fourhorn sculpin	Moderate	Local	Short Term	Sporadic - Regular	Short Term	High	Low	Moderate	**Negligible**	Intermediate
Mortality due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, sedimentation ponds, fuel and prill storage, sewage sludge, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Mortality	High	Landscape	Short Term	One Time	Short Term	Low	Low	Low	**Negligible**	High
Sublethal effect due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, sedimentation ponds, fuel and prill storage, sewage sludge, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Physiological stress; immune system breakdown; contamination; increased disease; and/or damage to incubating eggs	High	Landscape	Medium Term	One Time	Short Term	Neutral	Low	Low	**Negligible**	High
Sublethal effect due to accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, sedimentation ponds, fuel and prill storage, sewage sludge, equipment and machinery)	Construction, Operation, Decommissioning	Port Site	Adverse	Indirect	Implement Emergency Spill Response and Contingency Plan; use of spill kits, containment berms and concrete apron; setback distances for re-fueling and/or loading deleterious substances; monitor and maintain tertiary sewage treatment facility; maintain equipment and machinery.	Reduced or altered forage availability; displacement of fourhorn sculpin	Moderate	Landscape	Short Term	One Time	Short Term	High	Low	Low	**Negligible**	High
Elevated dust emissions (blasting, crushing, power generation, waste incinerating, traffic)	Construction, Operation, Decommissioning	Port Site	Adverse	Direct/Indirect	Dust suppression (*e.g.,* water) at source	No residual effect										
Sublethal effect due to increased traffic from marine ship and barge operation	Operations, Decommissioning	Shipping Lane	Adverse	Direct	Modify timing of shipping/barge operations to avoid critical/sensitive time periods;	Displacement of fish	Moderate	Landscape	Short Term	Regular	Short Term	Neutral - High	Low	Moderate	**Negligible**	High

[1] **If there NO residual effect after mitigation there is no need for further evaluation.**

considered to be low in magnitude and local in extent. The significance of the impact to the Bering wolffish community is **negligible** although the lack of data on this fish species results in an assessment with low confidence.

Fourhorn Sculpin

The creation of a causeway and the infilling of sheet pile cells may affect fourhorn sculpin inhabiting the port area. The life history and biology of this fish species, specifically that it is benthic, inhabiting coastal waters from 20 m to the intertidal zone, and found in abundance at the port site, makes the fourhorn sculpin directly and indirectly susceptible to this stressor (Section 2.2.2). Fish may be crushed or smothered by rock fill if still in the location of boulder placement during the construction of the causeway. Fish salvage in the area prior to the commencement of construction will minimize this impact. Therefore, the residual effect of construction activities will be low in magnitude and local in extent. The significance of the impact to fourhorn sculpin will be **negligible**.

Indirect effects of construction may arise as a result of mitigation measures put in place to minimize mortality. As fourhorn sculpin are the most common species captured at the port location, any fish salvage that occurs will likely result in increased competition for food and habitat with neighbouring sculpin. This may have an indirect effect on the growth and survival of the fish as it is more susceptible to predation through displacement from preferred habitat and/or its forage availability has been reduced or altered. Therefore, after mitigation is considered, the residual effect of construction is considered to be moderate in magnitude and local in extent. The significance of this impact will be **negligible**.

4.2.1.2 Noise

High noise levels and shock waves may result from various activities associated with the construction phase of the Project. Sources may originate on land (*e.g.*, blasting and/or drilling on land) or for the sea bed (*e.g.*, pile driving), each possibly affecting fish in the area. Direct effects include mortality or internal injury (*e.g.*, hearing, bleeding, ruptured swim bladder) to juvenile and adult fish or behavioural changes which may result in avoidance of the dock area, changes in swimming patterns (*e.g.*, swimming speed and directional orientation) or a change in vertical distribution (Wright, 1982; DFO, 1992; Wright and Hopky, 1998; DFO, 2004). In addition, developing eggs may experience mortality or damage as a result of the substrate shaking (Wright, 1982; Faulkner *et al.*, 2006; Faulkner *et al.*, In press). Indirectly, the mortality of prey organisms in the area may cause a reduction in the food available to fish species.

Some specific details associated with noise and/or sound wave producing activities (such as timing and frequency) are not available at the time of writing this assessment. The timing, frequency, and duration of events can be altered to have the least effect on fish. These, in addition to other mitigation measures, are discussed in Chapter 5. Monitoring noise related activities is discussed in Chapter 6.

Arctic Char

Although it is possible that a small number of Arctic char may be killed or injured if near the elevated noise and shock waves (*i.e.*, while migrating past dock site) it is more than likely that

the fish will avoid the area once construction commences. Forage species may be affected in the local study area; however, given the large area available, it is unlikely to affect Arctic char and effects on char will be **negligible**.

Bering Wolffish

It is possible, if it is present, that Bering wolffish will be affected by increased noise in and around the proposed port area. Juvenile and adult Bering wolffish may experience mortality or injuries associated with elevated noise and shock waves if inhabiting rock-covered and/or gravel/sand substrate in the shallow, coastal waters around the proposed port. Following mitigation, the residual effect is considered to be low in magnitude and local in extent. The significance of the impact to the Bering wolffish community is **negligible** although the lack of data on this fish species results in an assessment with low confidence.

Eggs incubating in the area may be directly affected by elevated noise levels. Studies have documented the sensitivity of fish eggs to physical disturbances (*e.g.*, shaking of substrate) as a result of out-of-water blasting-induced peak particle velocity (Faulkner *et al.*, 2006). These studies have mostly focused on species of cultured fish like Pacific salmon (*Oncorhynchus* spp.), Dolly Varden (*Salvelinus malma*) and rainbow trout (*O. mykiss*) eggs. A study recently conducted in the Canadian Arctic found incubating eggs exposed to blasts more than double the current maximum allowable limit set by the DFO (Wright and Hopky, 1998) produced mortality similar to reference levels (Faulkner *et al.*, 2006). Although the study suggests existing guidelines provide ample protection under similar blasting conditions because it did not result in reduced survival of eggs, the margin of this protection remains unknown. Also unknown is how the sensitivity to peak particle velocity varies among species. Given this uncertainty, as well as the ambiguity associated with the life history of Bering wolffish, caution should be taken when conducting any activity associated with elevating noise levels and all existing guidelines followed (Wright and Hopky, 1998).

Assuming Bering wolffish are spring spawners (based on limited information available in the literature) and that construction is likely to occur in open water season, implementation of proposed mitigation measures and adherence to guidelines set forth by the DFO (Wright and Hopky, 1998) should result in a minimal effect on Bering wolffish.

Forage may be affected by elevated noise levels in the area of the proposed port. However, given the large area available for foraging, it is assumed that Bering wolffish can disperse to other regions for appropriate forage and are therefore unlikely to be affected by a localized reduction in forage availability.

Fourhorn Sculpin

Effects of noise on fourhorn sculpin are expected to be similar to those experienced by other fish species. Refer to the effects of noise on the egg and larval stage of Bering wolffish that are discussed above.

Juvenile and adult fourhorn sculpin may experience adverse effects associated with elevated noise levels. Although direct effects (*e.g.*, mortality and injury) are similar to Arctic char and Bering wolffish, indirectly this fish species may be more susceptible to impacts. As a small-bodied

species, their home range is smaller than that of Arctic char and Bering wolffish. Therefore, they are less likely to be able to avoid disturbances by simply moving up or down the coastline. This is exacerbated by the fact they are the most common species captured at the port site. Any mitigation implemented at the port site to avoid disturbance will likely result in increased competition for food and habitat with neighbouring sculpin. This could have an indirect effect on growth and survival (*e.g.,* increased susceptibility to predation through displacement from preferred habitat, reduction or alteration in forage availability) of the species. Therefore, the residual effect of increased noise after mitigation is considered to be moderate in magnitude and local in extent, and the significance of the impact on the marine fish community will be **negligible**.

4.2.1.3 Sedimentation

Increased water turbidity and sedimentation in the marine environment could occur as a result of activities taking place in or near waters during construction (*e.g.,* blasting, sheet pile driving), operation (*e.g.,* barge landing and terrestrial run-off), and decommissioning (*e.g.,* infilling of structural elements). Direct effects on fish include physiological stress, immune system breakdown, increased disease, damage to incubating eggs and behavioural changes like displacement and reduced ability to forage. Indirectly, fish may be affected through the reduction or loss of forage items available to them in the area.

Arctic Char

Incidental sedimentation and increased water turbidity are expected to occur during the construction phase of the Project. With the implementation of proposed mitigation measures, the effect will be minimal and temporary. Sediment is unlikely to accumulate in the local area due to tidal currents displacing material over a much larger area. Although most fish will avoid the area during construction, those that do remain in the direct vicinity of water with elevated levels of suspended sediments are likely to suffer minimal effects. Anadromous Arctic char are likely resilient to changes in suspended sediment levels as they consistently expose themselves to sediment-laden, brackish waters near river outlets and deltas during coastal movement and migration. The significance of this impact during construction will be low.

Limited sedimentation is also expected to occur from barges landing at the port during operation, uncontrolled site runoff and from remediation and/or contouring of surfaces during decommissioning; however, sediment and erosion control plans will minimize this effect. The significance of this impact on char will be negligible.

Sedimentation may also alter forage density and result in a decrease in the ability of the area to support fish. However given that it is a local effect with limited duration, and that forage habitat is not limiting in Bathurst Inlet, Arctic char will likely not be affected. Overall, the effect of increased turbidity and sedimentation over the life of the Project will have a **negligible** effect on Arctic char.

Bering Wolffish

As mentioned above for Arctic char, increased water turbidity and sedimentation associated with various activities of the Project are expected to occur. Sediment is unlikely to accumulate in the rocky habitat preferred by Bering wolffish because of tidal currents displacing material over a larger area, and because of ice scour, which removes fine sediment from the rocky intertidal zone

on a yearly basis. In addition, Bering wolffish are likely to vacate the area once construction commences. However, implementation of the proposed mitigation measures should minimize any effect of increased water turbidity and sedimentation on juvenile and adult Bering wolffish. During construction, the significance of this impact will be low. During operation and decommissioning, the significance of increased water turbidity and sedimentation will be negligible. Over the life of the Project, this impact will have a **negligible** effect on Bering wolffish. The lack of data on this fish species though results in an assessment with low confidence.

While juvenile and adult fish are capable of avoiding or temporarily leaving a hostile environment, this is not the case for eggs and larvae. Studies have found early life stages of fish to be less tolerant to turbid waters. Eggs blanketed in sediment, or having insufficient oxygen supply, may lead to a delay in hatching and increased mortality (Isono *et al.*, 1998). Larvae that are less advanced in their swimming abilities can also be affected by increased turbidity and sedimentation. Studies indicate that the larval stage is less tolerant to high suspended particle concentrations than eggs (Isono *et al.*, 1998). It is believed that morphological changes from the egg to the larval stage are associated with the tolerance differences. Eggs have a tough capsule that can give protection from physical attrition. Larvae, on the other hand, have a larger and more delicate body surface relative to body mass compared to spherical eggs.

Assuming Bering wolffish in the Canadian Arctic have a similar life history to those found in the Bering Sea (Section 1.1.1.2), larvae may be present in the pelagic waters near the proposed port location. Since sediment is unlikely to accumulate in the area due to tidal currents displacing material over a much larger area, and if proposed mitigation measures are implemented and adhered to, residual effects should be minimal and short lived.

The availability of forage may be affected by increased water turbidity and sedimentation in the area of the proposed port. However, the large area available to forage, and the fact that sediment is unlikely to accumulate in the area, this stressor is unlikely to have an effect on Bering wolffish.

Fourhorn Sculpin

Increased turbidity and sedimentation as a result of various activities associated with the Project may have an effect on the fourhorn sculpin population near the port site. Fourhorn sculpin lay eggs under the ice during the winter when everything is frozen, there is no construction and there is a low potential of terrestrial run-off. Therefore, following mitigation there is expected to be no residual effect to fourhorn sculpin eggs as a result of sedimentation and/or increased water turbidity.

As eggs hatch in spring, larval fourhorn sculpin may be present near in waters near the proposed port location during construction, operation, and decommissioning activities: activities that may result in increased water turbidity and sedimentation. As mentioned above with Bering wolffish larvae, sediment is not expected to accumulate in the area due to tidal currents displacing material over a much larger area. Therefore, the residual effect of increased turbidity and sedimentation after mitigation is considered to be low in magnitude and local in extent, and the significance of the impact on fourhorn sculpin will be negligible.

Juvenile and adult fourhorn sculpin may experience adverse effects associated with increased water turbidity and sedimentation. Direct effects (*e.g.*, physiological stress, immune system breakdown and/or increased disease) are similar to Arctic char and Bering wolffish. Indirectly, fourhorn sculpin may be more susceptible to impacts associated with this stressor. As discussed in Section 4.2.1.2, with the effects of noise on fourhorn sculpin, this small-bodied fish species may not easily move away from the stressor as easily as Arctic char and Bering wolffish. The effect is intensified by the fact that it is the most abundant fish caught in the area. Any mitigation implemented at the port site will likely result in increased competition for food and habitat in the neighbouring areas. This could have an indirect effect on growth and survival of fourhorn sculpin. Therefore, the residual effect of increased turbidity and sedimentation after mitigation is considered to be moderate in magnitude and local in extent. The significance of this impact will be low during construction and negligible during operation and decommissioning. Over the life of the Project, increased water turbidity and sedimentation will have a **negligible** effect on fourhorn sculpin.

4.2.1.4 Aerial Deposition of Dust and Contaminants

Marine fish may be directly or indirectly affected by the potential aerial transport and deposition of fine particles into the marine environment. Sources are strictly from terrestrial activities during the construction, operation, and decommissioning phase of the Project.

Arctic Char

Blasting during construction will produce dust particles that, depending on their size and prevailing wind currents, may be transported to the marine environment. Direct and/or indirect effects include the alterations of water quality, suspended sediments and depending on the amount deposited, the smothering of eggs and benthic prey. The implementation of proposed mitigation measures will suppress dust on-site and therefore limit or omit any residual effect. The diminutive amount of dust that may enter marine waters will be low in amount and therefore have a **negligible** effect on Arctic char (Appendix B-2 of the DEIS).

In addition to blasting, air emissions from construction, operation and decommissioning activities will consist primarily of diesel emissions from trucks, construction equipment engines, power generators, rock crushing, and waste incinerating. These emissions release carbon monoxide/dioxide, nitrogen oxides, sulphur dioxide, particulate matter (PM) and residual unburned fuel vapors into the air and may potentially make their way into the marine environment. The implementation of proposed mitigation measures (Appendix B-2 of the DEIS) will limit the amount of material entering the system. PM that does make its way into the marine environment will be minimal in amount and be quickly and efficiently diluted with the marine current (Appendix E-1 of the DEIS). Air emissions are expected to have **no effect** on Arctic char.

Bering Wolffish

It is possible that Bering wolffish will be affected by aerial deposition into the marine environment. The effects of aerial deposition on Arctic char discussed above are expected to be consistent with effects to juvenile and adult Bering wolffish.

With the implementation of mitigation measures, the amount of dust particles and harmful emissions produced and transported to the marine environment are expected to be negligible. Bering wolffish eggs and larvae are expected to experience **no residual effects**.

Fourhorn Sculpin

The effects of aerial deposition on the egg, larval, juvenile, and adult stage of Bering wolffish are predicted to be similar to the effects on fourhorn sculpin. Suppression of dust and airborne emissions at the source should omit any residual effect of aerial deposition to fourhorn sculpin.

4.2.1.5 Accidental Spills

Accidental events that result in the spill or release of deleterious substances into the marine environment have the potential to harm marine fish. Materials that could be released include fuel, oil or other hazardous substances, untreated sewage or wastewater, discharge, water from sedimentation ponds and run-off from chemical storage units. Direct effects include mortality, physiological stress, immune system breakdown, disease, contamination, or damage to incubating eggs. Indirectly, spills could affect the availability of forage to fish, either through mortality or contamination.

The probability and behaviour of an oil spill from shipping vessels or barges along the shipping route and at the port site have been assessed in a separate report and can be found in Appendix E-6 of the DEIS.

Arctic Char

Although it is possible that spills could occur during the life of the Project, the likelihood is low. Given that Arctic char present in the proposed port area will be either juveniles or adults, they are capable of avoiding or temporarily leaving a hostile environment. Although it is possible that any deleterious substance that enters the marine water may be spread over a large area due to tidal currents, the effect will not expected to increase in magnitude as the deleterious substance will be diluted. In addition, implementation of proposed mitigation measures, as well as training for on-site personnel in emergency response procedures, will minimize impacts that result from accidental spills. Camp sewage will undergo tertiary treatment prior to release therefore the effects from sewage release are expected to be negligible. As the facility treating sewage will be permitted by the Nunavut Water Board, variables that will be monitored will be determined by regulators. The significance of accidental spills to Arctic char will be **negligible**.

Bering Wolffish

It is possible that Bering wolffish will be affected by the accidental or inadvertent release of deleterious substances into the marine environment. Although accidental spills may occur during the life of the Project, the likelihood of this event is low. Given that Bering wolffish are believed to inhabit shallow coastal waters, there is a probability that they could be directly or indirectly affected. For more detail, refer to the section above which discusses the effects of accidental spills on Arctic char. The implementation of proposed mitigation measures and monitoring there after will minimize the risk and adverse effects on Bering wolffish distribution and populations.

Fourhorn Sculpin

The effects of accidental spills on Arctic char and Bering wolffish are predicted to be similar to the effects on fourhorn sculpin. Analogous to discussions in Section 4.2.1.2 and Section 4.2.1.3 with fourhorn sculpin, competition may indirectly have an effect on this fish species. Any mitigation implemented at the port site may result in increased competition among neighbouring fourhorn sculpin, indirectly affecting their growth and/or survival. However, habitat such as that located at the port site is common throughout Bathurst Inlet. Therefore, the residual effect of an accidental spill after mitigation is considered to be moderate in magnitude and landscape in geographic extent. The significance of this impact will be **negligible**.

4.2.1.6 Coastal Shipping – Barge and Vessel Traffic

Apart from the increased risk of oil spills, which is dealt with in a separate report (Appendix E-6 of the DEIS), increased ship and barge traffic should have a minimal effect on marine fish communities. During operation of the Project, vessels will make round trips from Lancaster Sound to Bathurst Inlet. In addition, barges will re-supply communities along the coast. Marine access to the proposed port site from the northeast will use existing shipping lanes from the eastern Arctic. Only the final 40 km of the route south of Bathurst Inlet community is new.

It is widely believed that fish elicit patterns of avoidance when ships pass: vessel traffic may elicit a general precautionary response by fish to an unknown danger or the fish may interpret the noise stimuli from the vessel as a large predator and therefore bring about a behavioural or avoidance response (Vabø *et al.*, 2002; Skaret *et al.*, 2006). Avoidance reactions are energy intensive but studies have shown that the motivational state of the fish influences their reactions. For example, fish may trade off predatory avoidance for other activities like spawning or feeding (Ryer and Olla, 1998). The trade-offs are coherent to maximizing fitness: fish typically minimize their risk to predation prior to spawning to maximize reproduction. On the other hand, they may allow for higher predation risk when they are focused on essential activities like spawning and later on, feeding (Nøttestad *et al.*, 1996). Studies of herring (*Clupea harengus*) in Norwegian fjords found that shallowly distributed pre-spawning fish showed moderate avoidance reactions to survey vessels that manifested as a deeper depth distribution during vessel passage (Skaret *et al.*, 2006). But despite clear indications of avoidance, measured reactions varied among studies (Vabø *et al.*, 2002; Røstad *et al.*, 2006; Skaret *et al.*, 2006).

Contrary to the above, recent studies in Norway have found that fish are actually attracted to vessels rather than being repelled by them (Røstad *et al.*, 2006). Accumulations of various fish assemblages were recorded during various seasons and both day and night. Fish have even been observed to swim towards vessel paths (Handegard and Tjøstheim, 2005). Evidently, the response of fish to vessel traffic is not simply an avoidance reaction and the direct impacts are not fully known. Given that traffic will be limited, the effect on fish in the area should not change greatly to what they are exposed to currently.

In addition to above, coastal traffic increases risks associated with the release of ship ballast water into the marine environment. The management of ballast water and its contents is the responsibility of the ship owner and federal guidelines set forth by Transport Canada (2007) are expected to be adhered to.

Arctic Char

Arctic char may be affected by increased traffic along the shipping route. Fish may be displaced for a short period of time as the vessel moves through a given area. The residual effect of increased traffic along the shipping route after mitigation is considered to be low in magnitude and landscape in geographic extent. The significance of this impact will be **negligible**.

Bering Wolffish

Bering wolffish may be affected by increased traffic along the shipping route. During the summer when vessel and barge traffic will be active, Bering wolffish are believed to inhabit the shallow coastal waters of the marine environment. Given that the port site will have a steep shoreline to a water depth of 15 m and that the proposed shipping route will be along water depths equal to or much greater than this, coastal shipping activities should not have an effect on Bering wolffish. Bering wolffish may be displaced for a short period of time as the vessel moves through a given area however, this effect is expected to be **negligible** and short-lived.

Fourhorn Sculpin

Given that fourhorn sculpin inhabit similar regions in marine waters during the summer, the effects assessment is similar to that of Bering wolffish. This could have an indirect effect on the growth and/or survival of fourhorn sculpin. Therefore, the residual effect of increased traffic after mitigation is considered to be low in magnitude and landscape in geographic extent. The significance of this impact will be **negligible**.

4.2.2 Fish Habitat

Fish habitat is protected under the federal *Fisheries Act*, which prohibits the HADD of habitat that is used either directly or indirectly by fish for any part of their life cycle (DFO, 1985). Additional federal policies promote a net gain of fish habitat through the principle of "no net loss of productive capacity" (DFO, 1991). The productive capacity of fish habitat is defined as "the maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend" (DFO, 1991). Productive capacity may be altered by physical or chemical changes to fish habitat, or by direct loss of fish habitat.

Preliminary scoping of the potential effects of activities associated with construction, operation, and decommissioning on the port site is presented in Table 4.2-4. A detailed summary of the effects of the Project on marine fish habitat at the port site and along the shipping lane is presented in Table 4.2-5.

4.2.2.1 Habitat Alteration

Construction

During construction of the jetty and wharf complexes, sheet pile cells will be driven into the substrate using a pile driver, and quarried blast rock will be used to fill the cells and the area behind the cells. These activities will result in the mobilization of fine sediments in the water column. Sediment may be carried by currents, and may settle upon fish habitat throughout the local study area. Such sedimentation may cause a decrease in the productive capacity of the

Table 4.2-4
Identification of Effects for Marine Fish Habitat

Project Component	Project Activity		Potential Environmental and/or Socio-economic Effects Marine Fish Habitat
	A.	**Construction Phase**	
Port Site	1	Construct barge ramp (rock fill with steel pile dolphins)	- direct loss of habitat - sedimentation and potential undersea slope failure
	2	Unload construction materials and camp supplies from marine barges	- spillage of hazardous materials
	4	Store fuel in a NTCL fuel barge that will be "tied up" and allowed to "freeze in" at the port site cargo staging area	- Spillage of fuel
	11	Construct temporary shallow draft dock: to facilitate unloading material and equipment for building the permanent dock and other infrastructure	- direct loss of habitat - sedimentation during construction - spillage of hazardous materials
	12	Install sheet pile cells for the wharf during summer off barges, or from rock fill approaches or from winter ice platform (~150 m from shore)	- direct loss of habitat - sedimentation during construction
	13	Place rock fill behind the sheet pile cells to complete the wharf (~160 m along shore line)	- direct loss of habitat - sedimentation and potential undersea slope failure
	14	Construct rockfill causeway to connect the shore with the wharf	- direct loss of habitat - sedimentation and potential undersea slope failure
	15	Treat waste water and sewage, and discharge effluent to Bathurst Inlet. Treatment plant will have a maximum capacity of 65 m^3/day; effluent quality will not exceed 10 mg/L BOD5 and 10 mg/L TSS	- increased productivity in Bathurst Inlet
All-Weather Road	25	Construct road base: push quarried rock and granular materials over the tundra, after being laid down by 90 tonne "end dump" mine trucks. Work will run continuously all year, with 2 shifts working 24 hrs/day	- sedimentation into Bathurst Inlet
	26	Construct bridges and other stream crossings (proposed 28 modular steel bridges, 25 arch culverts, and 51 rockfill fords)	- sedimentation into Bathurst Inlet
	B.	**Operation and Maintenance Phase**	
Port Site	1	Unload approximately 284,000 tonnes of fuel and supplies between mid-July and late October (six or more voyages per year depending on vessel capacity)	- spillage of fuel or other hazardous materials
	2	Load fuel and supplies onto marine barges between mid-July and late October	- spillage of fuel or other hazardous materials
	9	Treat waste water and sewage, and discharge effluent to Bathurst Inlet	- increased productivity in Bathurst Inlet
Shipping Lane	34	Marine shipping between mid-July and late October; six or more round trips by ice class vessels up to 50,000 tonnes	- scoured shoreline due to ship wake
	35	Marine barge operations to serve Kitikmeot communities; 19 trips by barge from the port during the summer shipping season	- scoured shoreline due to ship wake
	36	Icebreaker support may be required in northern end of shipping route	- increased area of ice edge habitat

habitat by killing crustaceans and bivalves, especially those which are sessile (Thrush *et al.*, 2004). Increased sediment may also decrease light penetration through the water column, resulting in a smaller euphotic zone (the area of the water column in which photosynthesis may take place) and therefore less productive waters. Less significant, land-based construction and operation activities as well as airborne dust may result in sediment being transported to the marine environment. However, all areas in this vicinity will be contoured so that runoff will be directed towards the sediment ponds at the port site.

To control and limit the effects of sediment on surrounding fish habitat, a sediment and erosion control plan will be developed and implemented during all phases of the port Project. In the marine environment, this will include the use of boom-mounted silt curtains around all construction activities occurring in or near the water. These silt curtains will limit the area of impact to an area slightly larger than the construction footprint. All rock that is introduced to the marine environment will be clean and relatively free of dirt, and rock used in construction will be placed on a layer of geotextile for added stability. On land, sediment and erosion control measures will include settling ponds, silt fences, geotextile and revegetation of disturbed soil. Water that is released from settling ponds will be monitored for total suspended solids (TSS).

Habitat types that are found at the port site are common and probably do not limit fish production in Bathurst Inlet. Therefore, the residual effect of sedimentation after mitigation is considered to be low in magnitude and local in extent, and the significance of the impact on marine fish habitat will be **negligible**.

The construction of the jetty and wharf extending over 100 m into the marine environment may disrupt shoreline processes and long shore transport (the movement of sediment along the shoreline by marine currents). The placement of new structures in the marine environment may cause a disruption in marine currents whereby new eddies form on the down current side of structures, scouring away sediment. Conversely, “dead zones” may occur on the up-current side, resulting in the deposition of fine sediment. Effects such as these are common along shoreline areas where man-made structures have disrupted ocean currents (Fredsøe and Deigaard, 1992). Long shore transport mechanisms have not been fully described in upper Bathurst Inlet. The absence of fine sediment along the shoreline does not necessarily indicate of an absence of long shore transport because fine sediments are likely scoured away by ice on a yearly basis (Appendix E-10 of the DEIS). Only one feature that may indicate coastal sediment transport is evident along the Bathurst Inlet shoreline near the port site. This spit is located approximately 15 km south of the port site and is evident on satellite imagery (Appendix E-10 of the DEIS). In the satellite imagery, it appears as a finger of sediment from which fine sediments appear to be eroding.

Port structures within the marine environment are expected to have a low magnitude of impact on fish habitat as it is unlikely to create habitat that differs from that already present at the site. The deposition of fine sediments may actually act to replace habitat that will be lost under the footprint of the port structures. Build-up and erosion of sediments will be monitored through aerial photography and bathymetric surveys every two years. This monitoring will determine if long-shore transport processes are resulting in the alteration of fish habitat around the port site. It is unlikely that habitat alteration alone will require remediation; however, if build-up of

Table 4.2-5
Summary of Effects Assessment for Marine Fish Habitat

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	**Project Phase (Timing)**	**Project Component**	**Direction**	**Nature**	**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Residual Effect (after mitigation) [1]**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence Limit**
Accidental or inadvertent release of deleterious substances into the marine environment (fuel, oil or other hazardous material, equipment and machinery)	All	Port site	Adverse	Direct	- Spill management plan will be developed and implemented - Spill kits will be located on site, including absorptive materials and booms	Mortality of primary and secondary producers Decreased productive capacity of habitat	Moderate	Landscape	Short to Medium	Sporadic	Reversible Short-term	High	Low	Low	**Negligible**	Intermediate
Increased sediment from land-based construction and operation of roads and buildings	All	Port site	Adverse	Direct	- Sediment and Erosion Control will be developed and implemented - Sediment control measures will include the use of silt fences, sediment ponds, and geotextile	Increased turbidity Increased fine sediment in substrate	Low	Local	Short to Medium	Sporadic	Reversible Short-term	High	Low	Moderate	**Negligible**	High
Disruption of longshore transport processes, causing erosion downstream of port and build-up of sediments upstream of port, could have effect on fish habitat adjacent to port site	All	Port site	Adverse	Direct	- Management plan for changes in port site bathymetry would be developed and implemented. - Effects on fish habitat would be mitigated through the implementation of the fish habitat compensation plan - Regular monitoring of sediment build-up and erosion	Increased or decreased depth around port structures due to erosion or deposition of sediment	Low	Local	Long Term	Continuous	Reversible Long-term	High	Low	Low	**Low**	Low
Increase in productivity due to discharge of waste water and treated sewage to Bathurst Inlet	All	Port site	Positive	Direct	- Waste water will be treated	Potential increase in productivity	Low	Local	Long Term	Continuous	Reversible Short-term	High	Low	Moderate	**Negligible**	Intermediate
Direct loss of habitat under the proposed rock jetty	Construction	Port site	Adverse	Direct	- Fish habitat compensation plan to be implemented; - Outer flanks of jetty will be armoured with large boulders to provide cover for fish	Net gain or no net loss of productive capacity of habitat	Low	Local	Permanent	One time	Not Reversible	N/A	Low	High	**Low**	High
Direct loss of habitat due to the preparation of the wharf site for construction	Construction	Port site	Adverse	Direct	- Fish habitat compensation plan will be implemented to replace lost habitat	Net gain or no net loss of productive capacity of habitat	Low	Local	Permanent	One time	Not Reversible	N/A	Low	High	**Low**	High
Increased sediment and undersea slope failure due to wharf construction, jetty construction, sheet pile installation and placement of rock fill at wharf site	Construction	Port site	Adverse	Direct	- Sediment and Erosion Control Plan to be developed and implemented - Sediment control measures will include the use of silt curtains to limit spread of suspended sediment	Increased turbidity Increased fine sediment in substrate	Moderate	Local	Short	Sporadic	Reversible Short-term	High	Low	Moderate	**Low**	High
Shore disruption due to ship wakes, causing erosion	Operations	Shipping Lane	Neutral	Direct	- No mitigation required.	No Residual Effect										N/A
Increased ice-edge habitat due to ice-breaker activities in the shipping lane	Operations	Shipping Lane	Neutral	Direct	- No mitigation required	No Residual Effect										N/A

[1] **If there NO residual effect after mitigation there is no need for further evaluation.**

sediment creates hazards to navigation, dredging may be required to maintain water depth near the docking locations. In the unlikely event that dredging is necessary, the impacts of those activities will be assessed at that time.

Loading and unloading of fuel and other goods to and from ships and barges may result in some inadvertent spills of hazardous materials at the port site. Spills of hazardous materials may decrease the productive capacity of habitat if they smother benthic substrates and kill primary and secondary producers, which are an important food resource for fish (Sergy and Blackall, 1987). Spills that go unattended or unnoticed may be spread a long distance by ocean currents and wind. The potential impacts of oil and fuel spills are further investigated in Appendix E-6 of the DEIS.

A detailed spill management plan will be developed and adhered to at the port site, and spill kits will be readily available in the event of inadvertent releases of hazardous materials (Appendix G-4 of the DEIS). All staff will be trained to avoid, identify and manage accidental releases of hazardous materials. Spills in the Arctic are considered to have limited biological effects due to the paucity of organisms in the intertidal zone – the area that is usually impacted most by spills (Sergy and Blackall, 1987). Events such as these are predicted to be sporadic in frequency and, if managed correctly, the magnitude is predicted to be low and the significance is predicted to be **negligible**.

Operation

During operation of the port site, round trips from Lancaster Sound to Bathurst Inlet will be made by ice-class vessels up to 50,000 tonnes (SNC Lavalin, 2007). Wave erosion from passing ships may contribute to erosional processes on the coastline bordering the shipping route. However, wave action from wind is likely to have a greater effect on shoreline erosion than the wakes from a small number of ships. In addition, ice scour limits the accumulation of fine sediments in the intertidal zone of Arctic water, leaving behind coarse, less erodible substrates. As a result, these processes are not predicted to have a significant impact on the shoreline due to the low magnitude of the effect (within baseline conditions), and the lack of fine, erodible soils in the Arctic intertidal zone.

In the northern reaches of the shipping lane, ice-breaker support may be required for some early season trips in some years. Some fish species (such as Arctic cod) are found in greater densities near ice-edges in the Arctic, where they forage for food and use the ice for cover (Cohen *et al.*, 1990). By using ice-breaking ships, the area of ice-edge habitat is increased, increasing the amount of habitat available. If air temperatures are cold, water in the shipping lane may refreeze, eliminating the newly created habitat. Ice edge habitat is not thought to be limiting, especially during the months that the shipping lane will be active (summer through fall). During the shipping months, Arctic cod are typically moving to nearshore areas to spawn (Cohen *et al.*, 1990), and are therefore unlikely to be attracted to the ice-edge habitat created by ice-breakers. Because Arctic cod are not predicted to be present at the ice-edge habitat during the shipping season, and the duration of the impact will be temporary (*i.e.*, shipping will only occur for the life of the Project), the significance of the impact on fish habitat is predicted to be **low**.

The port site will be used to store fuel and ammonium nitrate for use by mines served by the Tibbitt-Contwoyto Winter Road (TCWR). Accidental spills of these materials may have toxic effects on benthic invertebrates and fish, and contaminants could be stored in organic sediment and be transferred to benthic organisms including invertebrates and fish. While the magnitude of an accidental spill of hazardous substances may range from low to high (based on the size of the spill), the likelihood of a major spill occurring at the port site is considered to be low (Appendix E-6 of the DEIS). Spill response and management plans will be developed to ensure that all employees are trained in the avoidance, identification and management of accidental spills to ensure the lowest possible impact on the environment (Appendix G-4 of the DEIS). Vehicles used on the wharf will be inspected regularly for leaks and deficiencies that may result in spills. Thus, after mitigation, the projected significance of the impact of spills on marine fish habitat is **negligible**.

A small camp will be located adjacent to the port site in Bathurst Inlet. Treated sewage will be regulated by the Nunavut Water Board (NWB). Effluent quality discharged directly into Bathurst Inlet is expected to not exceed 10 mg/L BOD5 (five-day biochemical oxygen demand) and 10 mg/L TSS. Sewage effluent has the potential to increase productivity by increasing the amount of nutrients available for primary and secondary producers; however, excessive nutrients may cause an increase in the biological oxygen demand (BOD) that outstrips availability, resulting in the depletion of benthic organisms in sheltered waters (O'Sullivan, 1971). Effluent that is treated has a minimal effect on fish habitat, resulting in minor nutrient enrichment that can lead to greater localized productivity (Savage *et al.*, 2002). Provided that treatment of sewage is effective, the predicted magnitude of sewage effluent disposal in Bathurst Inlet is predicted to be low and local in extent. Sewage treatment will be monitored on a regular basis to ensure the continued success of the process, and effluent will be monitored for TSS and BOD. Other parameters will be monitored as outlined in the water license. If the TSS or BOD5 exceeds the guidelines for effluent discharge, discharge will be halted until effluent quality is improved. The significance of the impact of treated sewage effluent on fish habitat in Bathurst Inlet is predicted to be **negligible**.

Sediment from road beds and other disturbed soil sites may be transported to the marine environment through runoff, or through airborne dust, this may affect fish habitat in the local area. The effects of sedimentation on fish habitat are described in the previous subsection. A sediment and erosion control plan will be developed and implemented to aid in the management of sediment throughout the life of the Project. Sediment control structures such as settling ponds and silt fences will be employed to prevent the introduction of fine sediment to adjacent waterbodies. Disturbed areas will be revegetated, where possible, with native seed mix to decrease erosion potential.

Fish habitat may also be disturbed at the barge jetty when barges are beached at the loading ramp. The area of impact would be relatively small, and would occur entirely in the intertidal zone. Production in the Arctic intertidal zone is low due to yearly scouring by ice, and habitat quality is therefore low. No mitigation is planned for the effects of barge beaching on fish habitat, but due to the limited geographic area and low habitat quality at the barge landing, the residual impact on fish habitat is predicted to be of low significance.

Decommissioning

During the decommissioning stage of the Project, impacts to marine fish habitat are predicted to be similar to the operational impacts. Sedimentation may arise from the decommissioning of roads and structures, and will be managed through the sediment and erosion control plan. Spills of hazardous materials (especially fuel) may occur as they are loaded or unloaded from ships and barges. These will be managed and prevented through the proposed spill management and spill response plans. Alterations to the productive capacity of fish habitat due to the discharge of treated sewage effluent will continue as long as there are people living at the port site; however, the impact of the effect is predicted to diminish as the population of the camp decreases. No effects arising from the decommissioning of the port site are predicted to have a significant impact on marine fish habitat.

4.2.2.2 Habitat Loss

Construction

During construction, marine fish habitat will be lost under the footprint of the crushed rock jetty and ship-loading pier. The crushed rock jetty will extend approximately 100 m into the marine environment and will cover approximately 4,400 m^2 of undersea habitat. The wharf structure will extend approximately 140 m out into the marine environment, and 160 m along the shoreline, resulting in a loss of 22,400 m^2 of marine fish habitat (SNC Lavalin, 2007).

The impacts of the jetty and wharf on fish habitat are mixed. Construction of the jetty and wharf will result in the alteration of habitat from fine, silt/clay substrates and gravel beaches to coarse boulder and rock surface. This will create cover and shelter from predators for Arctic char, coregonids and fourhorn sculpin, while destroying habitat for bottom-dwelling flatfish such as starry flounder. Habitat in the intertidal zone is primarily made up of gravel/cobble beaches that are regularly scoured by ice in the winter. These beaches provide moderate quality feeding, migration, and rearing habitat for a variety of marine and brackish water fish species. Deeper waters at the jetty and port site are dominated by fine silt and sand substrates that provide high quality feeding habitat for benthic and demersal fish species. Fine sediments provide good habitat for a variety of invertebrates that support higher trophic levels, such as bivalves and crustaceans. Shallow, nearshore areas are important feeding habitats for species such as Arctic char (*Salvelinus alpinus*), which utilize marine areas within 40 to 60 km of their natal streams.

The shoreline habitat at the port site is rated as highly sensitive to environmental disturbances such as oil spills (Environment Canada, 2000). This rating was applied based on the importance of that area of Bathurst Inlet to grizzly bears, caribou and other Arctic mammals. No mention of critical fish habitat was cited. Habitat such as that which will be lost under the footprint of the port site is not limiting in Bathurst Inlet. The AESA shows that the shoreline of Bathurst Inlet is dominated by similar gravel beaches (Environment Canada, 2000). The extent of predicted habitat loss due to construction of the port site is relatively small when compared to the area of similar habitat available in Bathurst Inlet. All habitat loss will be compensated for in accordance with the *Fisheries Act* and the National Policy for the Management of Fish Habitat (DFO, 1985, 1991). Compensation and mitigation plans are presented in Chapter 5.

While the magnitude of this event is high (permanent loss of habitat), the geographic extent of the disturbance is minimal, and the influence of the habitat loss on the resource capacity of Bathurst Inlet is low. Therefore, the significance of the residual effect on marine fish habitat is **low**.

No construction activities will result in the loss of marine fish habitat along the proposed shipping lane.

Operation

The operation of the port is not expected to result in any incremental loss of marine fish habitat at the port site, or along the proposed shipping lane.

Decommissioning and Closure

The decommissioning and closure of the port will not result in any additional loss of fish habitat in the marine environment.

5. MITIGATION AND MANAGEMENT PLANS

5. Mitigation and Management Plans

Mitigation and management plans are offered as recommendations and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

5.1 Introduction

As detailed in Chapter 4, there are several effects that may arise from the construction, operation and decommissioning of the Project. These include:

Marine Fish Communities

- physical, biological and/or behavioural changes to fish due to noise production;
- smothering substrates due to sedimentation and/or aerial deposition;
- contamination of marine waters as a result of spills of hazardous substances;
- alteration to the productive capacity of fish habitat; and
- displacement and/or disturbance of fish due to coastal shipping activities.

Marine Fish Habitat

- direct loss of fish habitat under the footprint of the port structures;
- loss of productive capacity of fish habitat due to spills from re-fuelling structures;
- sedimentation from pile driving at the port site;
- sedimentation arising from onshore construction activities; and
- disturbance of fish habitat due to the beaching of barges and other vessels.

Although mitigation measures have already been incorporated into the engineering and design phase of the Project, some effects, such as the loss of habitat under the wharf footprint, are unavoidable. The following section details the mitigation strategies that may be employed to reduce or eliminate the effects of the Project resulting from port-site infrastructure construction, operation and decommissioning. Where mitigation is not possible (*i.e.*, due to habitat loss), compensation plans have been developed to ensure no net loss of fish habitat. Proposed compensation plans are found in Section 5.3 of this report. In addition, an environmental effects monitoring (EEM) program (detailed in Chapter 6) will be implemented to evaluate the effectiveness of environmental protection measures and to monitor the health of marine ecosystems associated with the Project site.

The environmental policy of the Project is consistent with the National Policy for the Management of Fish Habitat (DFO, 1991). The guiding principle of the DFO policy is “no net loss of fish habitat productive capacity” and a net gain if possible for all industrial developments in Canada affecting surface waters. Management of the port Project will include stringent environmental protection policies and plans. Staff and management will work towards no net

loss in fish resources through a wide range of impact avoidance and mitigation measures, site reclamation/rehabilitation techniques, and habitat enhancement methods.

5.2 Fisheries Management Plan

5.2.1 Objectives

5.2.1.1 HADD Avoidance

Section 35 of the *Fisheries Act* states that no one is permitted to cause a HADD of fish habitat without authorization by DFO. Section 36 states that no one shall permit the introduction of substances deleterious to fish in waters frequented by fish.

The primary objective of the fish and fish habitat management plan for the Project is to avoid HADDs during all phases of the Project. Fish habitat, as defined by the *Fisheries Act*, includes "the spawning grounds, nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes," including both fish-bearing and non-fish-bearing waterbodies.

To avoid and prevent HADDs and the introduction of deleterious substances to waterbodies, and to minimize the adverse effects of any unavoidable disturbances to fish habitat, a range of specific and generally accepted techniques for sediment control, site isolation, reclamation and rehabilitation will be used. They are detailed in this management plan and in related environmental protection plans for the Project. The sediment control plan, reclamation plan, and habitat compensation plans will also apply to the objectives for the protection of fish habitat.

5.2.1.2 No Net Loss Policy

The main policy objective of the federal government with respect to fish populations and fish habitat is that human activities should cause no net loss of fish productive capacity in Canadian waters. Productive capacity refers to the capability of fish habitat, including all of its physical, chemical and biological characteristics, to produce fish. In practice, productive capacity is generally measured in terms of aquatic habitat area, which includes both the aquatic ecosystem and the associated riparian areas and vegetation.

5.2.1.3 Protection of Sensitive Species and Species at Risk

Particular attention will be paid to fish habitat supporting regionally and locally sensitive species, including any rare or endangered species or locally threatened species. Bering wolffish are a species of concern in Bathurst Inlet. While they have never been captured in the immediate vicinity of the port site, they have been captured further north in Bathurst Inlet and are thought to be rare. Bering wolffish have a known distribution that extends from Japan to the Russian coastline. Specimens have also been collected from Alaska, and three isolated specimens were collected from Bathurst Inlet (COSEWIC, 2002). Little is known of their distribution, biology, or habitat preferences in Bathurst Inlet and their official status is "Data Deficient" as of 2002 (COSEWIC, 2002) Because of their seemingly specialized and localized habitat, Bering wolffish are a species of concern for the Nunavut Planning Commission (NPC) and special management is warranted (NPC, 2005).

Arctic char are also a species of concern in Bathurst Inlet due to their importance to local subsistence and sport fishermen (NPC, 2005). All activities that may have an impact upon Arctic char habitat must be carefully managed.

5.2.2 Fisheries Protection

Numerous acts, guidelines and recommendations exist to aid in the protection of fish-habitat in freshwater and marine ecosystems in Canada. By following the federal and territorial guidelines and others noted below, no significant residual impacts will occur to the marine fisheries resources in the Project area. These guidelines include:

- *Fisheries Act (DFO, 1985)*: federal act governing potential impacts to fish and fish habitat;
- *Nunavut Environmental Protection Act* (Government of Nunavut, 1988): territorial act governing impacts to the environment, including contaminants;
- *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters* (Wright and Hopky, 1998): important for construction and operational guidance;
- *Guidelines for the Operation of Tankers and Barges in Canadian Arctic Waters* (Transport Canada, 1997): guidelines for the operation, including loading and unloading, of tankers and barges;
- *Spill Contingency Planning and Reporting Regulations, N.W.T.* (Environmental Protection Service, 1988): guidelines to spill reporting regulations; and
- *Guidelines for Ships Operating in Arctic Ice-covered Waters* (International Maritime Organization, 2002): includes guidelines for environmental protection and damage control.

Qualified and experienced staff will be employed to direct and supervise the impact avoidance and environmental protection procedures during construction and provide quality assurance that Project environmental management commitments are being achieved.

Prior to the onset of construction, the following preparations will be made:

- detailed design drawings will be prepared and approved by the various regulatory agencies, including locations of the wharf, causeway, crushed rock jetty, and onshore structures such as fuel tanks, roads, and buildings;
- a qualified environmental monitor will be employed to ensure that regulations and guidelines are being followed with respect to environmental protection. The monitor will be familiar with federal and territorial guidelines and regulations regarding marine habitat, sediment and erosion control, and spill protection/prevention. The monitor will advise project management with respect to impact avoidance and mitigation measures on site;
- detailed environmental protection plans will be prepared and implemented, including the use of silt fences, silt curtains, site isolation and fish salvage at each construction location; and

- approvals for marine work and HADD authorization will be sought from the DFO and Nunavut Department of the Environment.

5.2.2.1 All Phases

Some effects are not limited to one stage of the Project, and have the potential to affect fish or fish habitat at all times. Mitigation measures for these effects will be implemented during construction and will continue through decommissioning to the post-closure phase. These include spill management and many aspects of sediment and erosion control.

Activities that could result in spills of hazardous materials or contamination will be mitigated through the following measures:

- development and implementation of spill response and management plans to ensure that spills of hazardous materials (*i.e*. fuel, oil, de-icing fluids, *etc*.) are first avoided, or identified and managed appropriately;
- designating an area for storage, re-fuelling, and application/loading of chemicals away from watercourse and in stable location where run-off from above area will not enter water;
- monitoring the sewage treatment plant regularly to ensure proper functioning, and ensuring that discharge from the plant meets NWB license requirements for BOD and TSS prior to discharge to Bathurst Inlet.
- providing spill kits throughout the Project site, and training crews in their appropriate use;
- storage of fuel in tanks surrounded by lined berms; and
- appropriate disposal of contaminated water, sludge, spill residue, or other hazardous compounds.

Sedimentation and erosion control are ongoing challenges at remote Project sites. Some aspects of sediment and erosion control must be applied at all stages of the Project. These include:

- drainage ditches will be excavated around all on-shore construction sites and disturbed areas. Runoff will drain directly into one of two settling ponds, and discharge from the settling ponds will be monitored;
- the areal and temporal extent of disturbance to soil and vegetation on land and substrate in water will be minimized;
- appropriate erosion control measures like siltation fences, diversion berms, sandbags, or rock will be installed and maintained where required; and
- environmental construction monitors will be employed to oversee construction activities and advise on potential impacts to fish and fish habitat.

Wind can contribute to the contamination of marine habitat and fish by transporting dust and other fine particulate arising from land-based activities to the marine environment. Mitigation

measures that can potentially lower or omit the amount of air borne particles entering the marine environment include:

- suppressing dust at source by using water to control the distribution of finer particles; and
- minimizing emissions through regular maintenance of equipment and vehicles, limit idling and speed limits of vehicles.

5.2.2.2 Construction

The port site includes a number of structures that will be built on land and in the water. Specifically, a wharf supported by steel, sheet-pile cells and accessed by a rock fill causeway will be constructed on the shoreline (SNC Lavalin, 2007). A barge-landing jetty will also be constructed of crushed rock, and will extend from the shoreline into the marine environment. Construction of these features may have numerous impacts on fish and fish habitat. Mitigation measures for these impacts are presented here.

Sedimentation and erosion during construction of the port site will be managed through a sediment and erosion control plan. This plan will incorporate the following measures to protect fish and fish habitat:

- a boom-mounted silt curtain will be installed in the water surrounding the construction site, which will limit the spread of suspended sediment in the water column. Water quality outside of the silt curtain will be monitored during construction; and
- fill for the jetty and wharf will be composed of clean, non-acid-generating material with low metal-leaching potential.

Noise and blasting effects will be mitigated by following federal guidelines for the use of explosives around fish-bearing waters (Wright and Hopky, 1998). These include:

- setting timing, frequency, and duration of blasting and noise to minimize impact;
- using devices like bubble curtains, air blankets, acoustic curtains or noise reduction blankets to reduce noise levels and shock waves from blasting activities. Sound sources can also be used to scare fish away from site prior to commencement of activity; and
- minimize the release/scattering of debris from blasting activities around the area to minimize scatter of debris into the marine environment.

5.2.2.3 Operations

The port site will receive bulk goods and fuel between July and October. The port site will also act as a storage and transhipping facility for fuel destined for the various mine sites and local communities, ammonium nitrate for construction, and other goods that may be required at mines along the TCWR. Spill avoidance is therefore one of the most significant environmental tasks that will be required during the operational phase of the port.

Mitigation and environmental protection measures that will be employed at the port site include:

- continued implementation of the spill management and response plan. All crews will be trained in the proper avoidance, identification, and management of spills, including spills of fuel, and oil; and
- continued implementation of the sediment and erosion control plan.

Minimal risk to marine fish species is associated with coastal shipping as the route selected is along an existing shipping lane. Mitigation that should be implemented during the life of this Project includes:

- following federal guidelines for the operation of tankers and barges in Canadian Arctic Waters (Transport Canada, 1997); and

5.2.2.4 Decommissioning

At the closure of the port, most of the imported structures and buildings will be removed, and the land recontoured to pre-Project conditions. Some of the specific measures that will be undertaken to protect marine fish habitat at this stage include:

- removal of structures and rehabilitation of ground contours. Disturbed areas will be planted where soil available with native vegetation to reduce erosion potential. Ditches and settling ponds will be maintained until erosion and sedimentation issues no longer occur;
- maintenance of the spill management and response plans and spill kits. Spill response and management plans will be maintained as long as hazardous materials remain on site. Contaminated soil will be treated or removed from site; and
- removal of steel from the sheet-pile cells for burial or removal from site. The jetty surface will be regraded below the water level to allow sufficient passage for fish.

5.3 Fish Habitat Compensation

5.3.1 Introduction

Fish and fish habitat are protected under a variety of federal and provincial regulatory acts and principles, including the *Fisheries Act*, which prevents the "harmful alteration, disruption, or destruction of fish habitat" through physical, chemical or biological means, and the Policy for the Management of Fish Habitat (DFO, 1991), which puts forth the principle of "no net loss of productive capacity" of fish habitat.

Under Section 35 of the *Fisheries Act*, any Project or activity that causes a HADD requires an authorization from DFO (1985). The *Fisheries Act* defines fish habitat as "spawning grounds, nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes." Under the *Fisheries Act*, the term "fish" includes

a) parts of fish;

b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine mammals; and

c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine mammals (sections 2a, 2b and 2c of the *Fisheries Act*).

In addition, DFO's *Policy for Management of Fish Habitat* promotes the objective of a "net gain of productive capacity of fish habitat" (DFO, 1991). This policy is to be achieved through the replacement and/or restoration of damaged or lost habitat through compensation.

The principle of no net loss is achieved through a hierarchy of preferences:

- avoidance of a HADD through the redesign of the Project (if and where possible);
- compensation by replacing lost habitat with natural habitat on site (*i.e.*, like-for-like compensation);
- compensation by increasing the productive capacity of existing habitat on site (*i.e.*, compensating lost habitat with new habitat of a different type);
- compensation by replacing lost habitat with natural habitat in another watershed; and
- compensation by using artificial production (*i.e.*, building hatcheries or fertilizing lakes).

Where a HADD may occur to fish habitat, compensation will be completed to ensure that there is no net loss of potential fish production. The planned compensation measures will be monitored to ensure that habitat losses are offset and a marginal net gain in fish production is achieved over the long term.

5.3.2 Residual HADD of Fish Habitat

The port site at Bathurst Inlet is comprised of two structures: the permanent dock structure will consist of an area developed by rock filling behind steel sheet pile cells, and the smaller barge docking site, located south of the wharf, will be constructed of rock fill extending out from shore to a depth of approximately 3 m.

The permanent wharf will measure approximately 160 m across the face, and extend approximately 140 m out into the water to a depth of 13.5 m. This will result in the permanent loss of approximately 22,400 m^2 of marine fish habitat (Table 5.3-1). Sheet pile cells will be placed by driving them from the surface of the ice in the spring, from a barge in the summer or from a rock filled approach. The structure will then be backfilled with crushed rock. The surface of the wharf will be 5 m above the water level. During operation of the port, no dredging of the seafloor is expected to be required to maintain the water depth at a sufficient level for the size of ships to be served.

The crushed rock jetty will extend approximately 100 m out into the marine environment, and will cover approximately 4,400 m^2 of the seabed. Geotextile will be placed under the rock fill to provide a stable base for construction and to prevent rock from sinking into the substrate.

Table 5.3-1
Area of Fish Habitat Lost at the Port Site

Project Component	Area (m^2)
Ship-loading wharf	22,400
Barge jetty	4,400
Total	**26,800**

Habitat at the port site is mainly comprised of cobble/gravel beaches which extend out to a depth of approximately 5 m (Appendices E-7 and E-10 of the DEIS). At depths greater than 5 m, the seafloor is dominated by very soft clay and silt with low organic content (SNC Lavalin, 2007). Algae are present on rocks below the high water mark; however, no macroalgae was observed near the Project site.

Based on habitat preferences (Appendix E-7 of the DEIS), the gravel/cobble beaches likely provide spawning habitat for fourhorn sculpin, and saffron cod, while the fine sediments on the seabed provide habitat for flatfish (family Pleuronectidae) and other demersal species. Salmonids such as whitefish, cisco and char may use the shoreline areas for feeding on benthic invertebrates and small fish (Table 5.3-2). The rare Bering wolffish has not been captured near the proposed port development; however, limited information regarding habitat preferences indicates that they prefer rocky shorelines or gravel and sand substrates, and only sparse populations are found in Bathurst Inlet (COSEWIC, 2002).

Table 5.3-2
Habitat Use by Species at the Port Site

Species	Habitat Use	Habitat Value
Fourhorn sculpin	S, R, F	M
Arctic cisco	F	L
Starry flounder	R, F	H
Saffron cod	S, R, F	M
Arctic flounder	R, F	H
Broad whitefish	F	L
Arctic char	F	L

Habitat value based on habitat preferences (Appendix E-7 of the DEIS).
Habitat Use: S = spawning, R = rearing, F = feeding.
Habitat Value: H = high, M = moderate, L = low.

5.3.3 Conceptual Fish Habitat Compensation Plan

5.3.3.1 Introduction

This section presents a conceptual marine fish habitat compensation plan (the "Plan") for the proposed Project, located on Bathurst Inlet, Nunavut. A detailed plan will be prepared in

conjunction with DFO, other federal and territorial agencies and local Inuit associations to meet the requirements of DFO's "no net loss" policy for the management of fish habitat.

Surveys of fish and fish habitat undertaken in 2001 and 2007 at the port site have shown that the entire site is dominated by a gravel/cobble beach. The beach has low habitat complexity. Upper reaches of the beach are subjected to ice scour each year, and as such are particularly devoid of structural features that would provide high quality habitat.

5.3.3.2 Site Selection

Any compensation work undertaken in Arctic environments must account for the presence and influence of sea ice. Ice in Bathurst Inlet freezes fast to the shore; however, ocean currents and wind, combined with the effect of water expansion during freezing may push large blocks of ice up the shoreline (SNC Lavalin, 2007). These processes cause extensive ice scour along the shores, limiting habitat complexity and the abundance and distribution of benthic organisms (Barnes, 1999; Gutt, 2001). These processes also limit the types of habitat compensation that may be undertaken in Arctic marine environments. Sea ice thickness in Bathurst Inlet typically measures up to 2 m in winter (SNC Lavalin, 2007). Thus, compensation works must be undertaken at depths greater than 2 m in order to avoid the influences of ice scour.

Accidental spills and accumulation of debris in the immediate vicinity of the port site may have a negative impact on the success of compensation habitat. Most compensation sites will therefore be located at least 100 m from the port site. The only exceptions will be the riprap and boulders applied to the outer surface of the jetty to enhance habitat quality.

Currents and sediment transport mechanisms are poorly understood in Bathurst Inlet, but can have an impact on fish habitat compensation projects. Swift currents and ice may dislodge reef structures or rocks, and currents may deposit sediment in slack-water zones, smothering or filling in fish habitat structures. In addition, placing heavy structures on soft substrates may cause them to sink and become ineffective. Further studies will be conducted prior to the construction of habitat.

Long-term monitoring of compensation projects, including comparison of constructed habitat to existing habitat, is essential to determine the success of the constructed habitat. Reference sites will be chosen to compare the productivity of new habitat to existing habitat. References sites will be located in areas where impacts from port operations are not expected. Possible sites include the bay on the west side of the port peninsula, as well as locations further south in Bathurst Inlet or on the east side. Efforts will be made to select reference sites that are similar in terms of habitat type and species composition to the habitat that will be lost at the port site.

Compensation habitat will be limited to the local study boundary. Replacing habitat lost with new habitat at the Project location is preferred to replacing habitat in other locales because it is most likely to be used by fish that are displaced during construction. Furthermore, consideration must be given to the selection of the site with respect to accessibility of equipment and material to create habitat enhancements.

5.3.3.3 Compensation Methods

Mitigation

The impact of the crushed rock jetty on fish habitat will be mitigated by armouring the outer surface of the jetty with large, non-acid generating rock sourced from the immediate vicinity of the port site. This will provide cover and feeding habitat in the crevices and interstitial spaces for juvenile and adult fish. Similarly, the causeway leading out to the ship-loading wharf will be lined with large-sized boulders and riprap to provide habitat for resident fish species.

A comprehensive spill-management plan will be developed to ensure that harmful substances are not introduced to the marine environment. This plan will include installing spill kits at appropriate locations, and developing a spill-response and clean-up plan.

A sediment control and erosion plan will be established to ensure that fine sediments are not introduced to the marine environment from land-based or sea-based construction activities. Typical mitigation measures will include the installation of boom-mounted silt curtains around marine construction activities, and the use of sediment and erosion control structures and practices (*i.e.*, silt fences, straw bales and revegetation) on land. Regular monitoring of turbidity and suspended sediment concentrations will be undertaken to ensure that impacts on marine fish habitat are minimized.

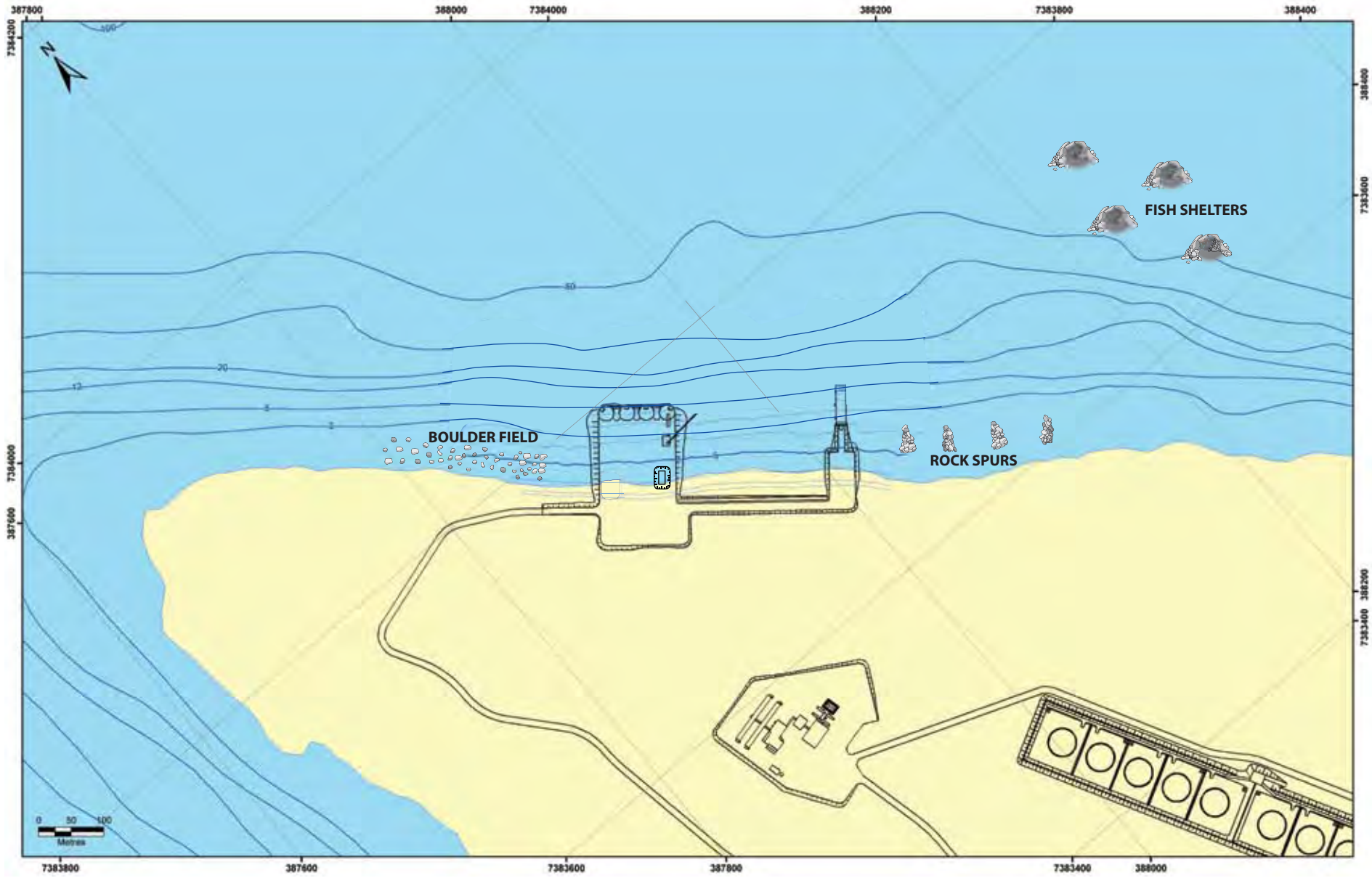
Mitigation measures are further discussed in the Fisheries Management Plan (Section 5.2 of this report).

Compensation

Approximately 26,800 m^2 of marine fish habitat will be lost under the footprint of the wharf and jetty at the port site. Mitigation will assist in moderating the impact of this loss; however, compensation habitat must be created in order to meet the requirements of DFO's "no net loss" policy.

A schematic of various compensation techniques is presented in Figure 5.3-1. Potential compensation projects include:

- creating underwater "rock spurs" to enhance habitat quality along the shoreline. These rock spurs would be installed at depths greater than 3 m, and would be constructed of large boulders and riprap to increase habitat complexity and provide cover;
- installing boulder fields along the shoreline. Similar to the idea of rock spurs, boulders would be spread at depths from 3 to 10 m along the shoreline to increase habitat complexity;
- installing artificial reefs. Reefs can be installed in various depths and may be constructed of rock bundles, crushed concrete, or other materials.



the BATHURST INLET PORT AND ROAD PROJECT

Marine Fish Habitat Compensation Options at the Bathurst Inlet Port and Road Project

FIGURE 5.3-1

Rescan™

Each of these compensation techniques has benefits and disadvantages that may make them more or less desirable depending on the circumstances. Table 5.3-3 presents the pros and cons of each compensation technique, as well as examples where each technique has been applied. A detailed review of the compensation techniques is provided in the following sections.

Table 5.3-3
Benefits and Disadvantages of Proposed Compensation Options

Compensation technique	Benefits	Disadvantages	Examples
Rock spurs	• Inexpensive and easy to install • Provide habitat for a variety of demersal fish species	• Similar to the rock jetty itself, rock spurs replace one type of habitat (sand/silt) with another (boulder/cobble) • Subject to ice scour if installed in water that is too shallow • Need to determine the depth of soft substrates where they will be installed. Installing on deep, soft substrates may result in rocks sinking into the substrate	• Doris North Project (Melville Sound, Nunavut) • Deltaport Expansion Project (Delta, BC)
Boulder fields	• Inexpensive and easy to install • Provide habitat for a variety of demersal fish species	• Similar to the rock jetty itself, rock spurs replace one type of habitat (sand/silt) with another (boulder/cobble) • Subject to ice scour if installed in water that is too shallow • Need to determine the depth of soft substrates where they will be installed. Installing on deep, soft substrates may result in rocks sinking into the substrate	• Proposed High Lake Project (Grays Bay, Nunavut)
Artificial reefs/Fish shelters	• Inexpensive and easy to install • provide habitat for a variety of demersal fish species	• need to determine the depth of soft substrates where they will be installed. Installing on deep, soft substrates may result in structures sinking into the substrate • may only attract fish from other areas rather than increase the productive capacity of habitat. • similar to the rock jetty itself, rock spurs replace one type of habitat (sand/silt) with another (boulder/cobble) • untested in Arctic waters	• White Point Quarry (Digby, Nova Scotia) (fish shelters)

Rock Spurs

Rock spurs are underwater structures similar to artificial reefs that are installed perpendicular to the shoreline. In the Arctic, these must be constructed at depths greater than 3 m to avoid ice scour. Rock spurs can be constructed of large, angular boulders, crushed concrete, or riprap randomly stacked to create large crevices and a large surface area for sessile organisms. Rocky habitat in the Arctic tends to be less productive than sandy habitat because it supports fewer benthic organisms for fish to feed upon; however, rocky areas do provide cover and shelter from predators, and are uncommon along the shoreline in upper Bathurst Inlet (Environment Canada, 2000). The creation of rock spurs will take up space previously occupied by sandy substrates; however, by using large rock (0.9 m average diameter), the functional surface area of the spur is increased by approximately 2.5 times (Williams and Millar, 2005). Thus, the functional surface area of the constructed habitat will be greater than that of the habitat that was previously there. Examples of other projects using rock spur construction for habitat compensation include the Deltaport Expansion Project (Williams and Millar, 2005) and the Doris North Project (Golder, 2005).

Construction of rock spurs may require work to be conducted in the water, and will therefore require sediment and erosion control measures to prevent impacts to adjacent habitat. Boom-mounted silt curtains will be installed around the compensation site during construction, and only

clean, non-acid generating rock with low metal-leaching potential will be used for construction of rock spurs. Fish salvage will be undertaken within the boundaries of the silt curtain to prevent unnecessary mortality of resident fish. Rocks may be placed using an excavator operating from a barge or from the shore. Boulders and rocks will be carefully stacked to ensure minimal disturbance of the seafloor. Alternatively, the construction of rock spurs could be done in the winter by placing rock on ice and therefore minimizing disturbance of the seafloor and to adjacent habitat.

Boulder Fields

Boulder fields are another method of creating habitat complexity in structurally simple habitats. In this method, boulders are placed randomly along the seafloor in areas that are devoid of large rock. This serves to increase the functional surface area of the substrate to provide cover for fish. One disadvantage of this method is that it may require maintenance as boulders sink into soft substrates over time. It is best suited for areas where the substrate is hard but homogeneous in texture, where maintenance will not be required to maintain the function of placed rocks. This method also does not provide as much useable habitat area as rock spurs because it does not create crevices for fish to hide in. This method of habitat compensation is proposed for the Grays Bay dock at the High Lake Project (Gartner Lee, 2007).

Boulders may be installed via two methods along the shoreline. They can be placed strategically during the open water season using a long-armed excavator, or they can be placed on the ice surface during winter and allowed to settle to the bottom when the ice melts. Boulders should be placed in water that is between 3 and 10 m in depth. In water less than 3 m deep, ice scour could move the rocks and disturb the compensation site, while in deeper water, boulders are more likely to sink into the deep, soft substrate. Only clean, non-acid-generating rock with low metal-leaching potential will be used. This rock will be locally sourced from quarries used at intervals along the proposed road. A silt curtain would be used during open-water placement of boulders to limit the extent to sedimentation.

Artificial Reefs and Fish Shelters

Artificial reefs and fish shelters are man-made structures that are designed to be sunk in place to provide habitat for a variety of fish species. These structures can have a variety of shapes and sizes; examples of artificial reefs range from piles of tied down tires to sunken, decommissioned ships and airplanes. Purpose-built structures, such as Reef Balls™ can also be purchased ready-made and sunk in place to create reef colonies (Sherman *et al.*, 2002; Reef Ball Foundation, 2007). Advantages to artificial reefs are that they can be constructed from a variety of materials to a variety of sizes and shapes depending on the fish species and size classes of interest. Silt-curtains may be employed to limit the spread of sediment arising from the placement of reef structures. Diving may also be required to ensure the adequate placement and functionality of reef structures.

The effectiveness of artificial reefs (and rock spurs) has been called into question. It is possible that these habitat enhancement techniques act as fish attractants, but do not actually increase the productive capacity of habitat (Bohnsack, 1989; Grossman *et al.*, 1997). Some studies have

found that artificial reefs have deleterious effects on fish populations because they concentrate fish around a central point where they are more easily fished by recreational fishermen (Grossman *et al.*, 1997).

Fish shelters similar to Reef Balls™ were used to compensate for habitat loss at the White Point Quarry in Digby, Nova Scotia (Bilcon of Nova Scotia Corporation, 2005), as well as at several smaller habitat enhancement sites throughout Canada (Reef Ball Foundation, 2007). No known examples of artificial reef or fish shelter construction have been undertaken in Arctic waters.

5.3.3.4 Monitoring of Compensation Projects

Monitoring, evaluation, maintenance and remediation are necessary to ensure the long-term success of constructed fish habitat. Each compensation site will need to be monitored for a period of time to prove its effectiveness. This will be a requirement under the Fisheries Authorization that will be obtained from DFO, and the period will be determined by consultation with regulatory agencies.

Monitoring of compensation projects will include fish community and habitat assessments, and each site will be compared to reference sites to gauge the relative success of the compensation works. Fish habitat will be monitored to ensure the ongoing functionality of the constructed habitat. Key habitat variables that will be monitored are substrate composition and depth. Substrate will be monitored to ensure that compensation habitat is not being covered by fine sediment. For most of the proposed compensation projects, the functionality of the habitat is dependent upon the complexity supplied by interstitial spaces between rocks and within artificial reefs. If these spaces become filled with silt and clay, the habitat will not function as designed. Therefore, substrate composition and habitat complexity will be evaluated periodically to ensure that the functionality of constructed habitat is maintained.

Depth around habitat compensation sites will also be monitored. Ocean currents erode and deposit sediment around features along the shoreline. Man-made structures such as islands and artificially hardened shorelines may result in the creation of shoals in places where they did not previously exist.

Fish communities will also be monitored at the compensation sites and in the surrounding area. Uncertainty exists regarding the value of artificial reefs and rock spurs to fish communities. There is some evidence to suggest that these structures may not increase the productive capacity of habitat; rather, they simply attract fish from other areas. Therefore, it will be important to collect baseline and monitoring information on fish communities in the area surrounding the compensation sites as well as at the sites themselves in order to determine if fish production on artificial reefs is enhanced, or if any increase in the fish community is due to immigration.

Following the initial two-year period after compensation projects are complete, monitoring could occur on a five-year cycle. In the event that constructed habitat compensation sites do not function properly, remedial actions will include improvements to the existing compensation areas, or establishment of additional sites. Once it is determined that productivity around the compensation sites has reached its target level and is stable, long-term monitoring may cease. The final decision on the compensation option will be decided with DFO and other agencies or associates.

6. MONITORING AND EVALUATION

6. Monitoring and Evaluation

6.1 Introduction

An environmental effects monitoring (EEM) program will be established as a requirement of the permits and licenses under which the Project will operate. The frequency, duration and geographic extent of monitoring will be determined by the regulators. The proposed program will be implemented to:

- ensure regulatory compliance with respect to discharge limits and other criteria to be set at the permitting stage;
- verify the predictions of environmental effects assessments;
- detect any unforeseen impacts as measured against the baseline established as part of the initial environmental assessment; and
- help identify cause-effect relationships between Project activities and environmental impacts.

The approaches and methods used to analyze the monitoring data will be the same as those used in the baseline studies. The monitoring program outlined below should not be considered final; the program will be adaptive and will change in response to permitting requirements and monitoring results.

6.2 Fish and Fish Habitat

Fish habitat assessments have been conducted in 2001 and 2007. Additional work will be conducted prior to construction to verify fish habitat values and to provide baseline information for the compensation plan. Marine fish habitat is not expected to change drastically in the vicinity of the port site. The primary fish habitat variables to monitor following port construction will be changes in substrate and bathymetry changes in the vicinity of the port structures. These can be evaluated through aerial photographs, underwater photographs and periodic sediment surveys. Aerial photographs of the fish habitat surrounding the port site will be obtained during the course of other monitoring programs (*i.e.*, water quality, wildlife), and photographs will be compared to previous years. If the aerial photographs suggest that the marine habitat around the port site is changing in terms of substrate types, shoreline shape (could indicate erosion), or bathymetry, then a fish habitat survey will be conducted on the ground to quantify and describe the changes, and to propose mitigation if necessary. Dedicated fish habitat surveys will therefore be conducted on an “as needed” basis once baseline studies are complete.

In addition to fish habitat surveys, water quality will be collected and presented every year and sediment quality every second year during the operational phase of the Project. If a spill occurs, both water and sediment monitoring will take effect. The monitoring program for these variables is presented in Appendix E-1 of the DEIS.

The probability of major spills contaminating fish and fish habitat in Bathurst Inlet is low, and water and sediment quality monitoring will detect contamination before it can be detected in fish tissues. Therefore, fish community monitoring will not occur unless a major spill occurs, or sampling of water or sediment detects contaminants that may affect fish.

As discussed in Section 4.2, sounds produced during construction related activities, namely pile driving and blasting may adversely affect marine fish species. A detailed monitoring program will be developed to ensure that mitigation measures included in the DEIS are fully implemented to reduce environmental impacts.

Best management practices for pile driving, blasting and other related operations that may produce noise will include biological monitoring of effects during construction. The development of these practices incorporated guidelines and policies from the following sources: Best Management Practices for Pile Driving and Related Operations (Vagle, 2003); and Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters (Wright and Hopky, 1998).

Noise levels will be monitored prior to the onset of construction (baseline) as well as during construction. A trained environmental monitor will use hydrophones to collect noise levels underwater. Measurements will be taken along two transects, one running parallel to the shore and at a reasonably consistent depth and the other perpendicular to the shore line.

If during monitoring, construction related activities generate shock waves in excess of 30kPa (the often-used threshold level for observable impacts on fish) or a fish kill is visibly observed, effective mitigation measures will be introduced. These methods include the deployment of attenuation devices (*e.g.,* bubble curtain, acoustic curtain or noise reduction blanket) to absorb and reduce the shock wave and a fish fence (*e.g.,* curtain) to keep fish out of the affected area. If shock waves continue to exceed 30kPa despite the introduction of preventative measures, work will cease and methods will be reviewed and corrected.

For blasting related activities, refer to guidelines set forth by Fisheries and Oceans Canada (Wright and Hopky, 1998) for setback distances and/or burial depths that will ensure explosive charges do not exceed guidelines.

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix E-4
Polar Bear and Seabird Effects Assessment

Author: **Rescan Environmental Services Ltd.**
Date: **November 2007**

Photo credit: Bruce Mactavish, LGL Limited

Photo credit: Michelle Gilders, LGL Limited

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Bathurst Inlet Port and Road Project Polar Bear and Seabird Effects Assessment

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

BIPR	Bathurst Inlet Port and Road
CESCC	Canadian Endangered Species Conservation Council
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWS	Canadian Wildlife Service
DEIS	Draft Environmental Impact Statement
EIS	Environmental Impact Statement
EMMC	Environment Management, Monitoring and Compliance
FEARO	Federal Environmental Assessment Review Office
IBA	important bird area
the Project	the Bathurst Inlet Port and Road Project
the proponent	Bathurst Inlet Port and Road Project Joint Venture Ltd.
SARA	*Species at Risk Act*
SPBEMP	Seabirds and Polar Bear Effects Monitoring Program
SPBMMP	Seabirds and Polar Bear Mitigation and Management Plan
VEC	valued ecosystem component
WKRLUP	West Kitikmeot Regional Land Use Plan
WWF	World Wildlife Fund

1. INTRODUCTION

1. Introduction

This effects assessment is divided into the following sections:

- **Chapter 2 (Environmental Setting):** a description and contextualization of the seabird and polar bear populations along the shipping lane of the proposed Bathurst Inlet Port and Road (BIPR) Project (the Project);
- **Chapter 3 (Methodology):** a description of the environmental assessment process and the methodology used to assess the potential effects of the Project on seabirds and polar bears and their habitat;
- **Chapter 4 (Effects Assessment):** an assessment of potential effects of Project phases and components on seabirds and polar bears and their habitat;
- **Chapter 5 (Mitigation and Management Plans):** a mitigation and management strategy to minimize potential negative effects of the proposed Project seabirds and polar bears; and
- **Chapter 6 (Monitoring and Evaluation):** a monitoring program to evaluate, and adaptively adjust suggested mitigation and management programs, based on measures of program success.

Wildlife considered in the environmental setting are species known or suspected to occur along the shipping lane. Data sources for the environmental setting are from Traditional Knowledge, government, literature reviews, baseline research and expert opinion. When knowledge gaps were identified, they were highlighted.

Second, an effects assessment was conducted for wildlife species that were determined to be valuable ecosystem components (VECs). Selection was based on wildlife conservation statutes, socioeconomic importance and/or role in ecosystem functioning. A detailed methodology of the effects assessment is located in Appendix A-5 of the Draft Environmental Impact Statement (DEIS).

Third, a series of mitigation and management strategies were developed in order to minimize the negative effects of the Project on VECs, as determined from the effects assessment.

Finally, a monitoring plan was developed in order to assess the success of the management and mitigation plans at achieving their objectives. Information from the monitoring program will be integrated back into the Project design such that management and mitigation strategies can be adaptively managed to maintain the integrity of the wildlife populations that may interact with the Project.

2. ENVIRONMENTAL SETTING

2. Environmental Setting

This environmental setting presents information on polar bears and seabirds in the areas of the proposed shipping lane for the Project. This setting also identifies critical wildlife habitat associated with polar bears and seabirds along the shipping lane. The information presented in the present chapter has been compiled from a literature review on ecological conditions, range distributions, and existing pressures on wildlife in the region and from baseline data collected in 2004 by LGL Ltd. (LGL Limited, 2005). Traditional Knowledge was also included as a source of wildlife information whenever possible (Keith *et al.*, 2005; Appendix F-5 of the DEIS).

2.1 Polar Bears

2.1.1 Traditional Knowledge Data

Polar Bears are found in many areas along the shipping lane year-round and are typically found close to land masses. Polar bears are of significant cultural value to Inuit people and hunting of polar bears is a tradition that has been passed down through generations. Inuit people venerate the polar bear for the sustenance and the spiritual significance of the animal (Keith *et al.*, 2005). As such, Traditional Knowledge provides valuable information on polar bear ecology and the cultural significance of various areas of the Canadian Arctic.

2.1.2 Field Data

Marine mammal baseline surveys conducted in 2004 confirmed the presence of polar bears along the shipping lane (LGL Limited, 2005). There were only two sightings of polar bears during the surveys; one was a single individual off the west coast of the Boothia Peninsula south of Weld Harbour and the other was an adult and two cubs, which were seen northwest of Gateshead Island in southern M'Clintock Channel. Both sightings were in areas of heavy ice cover (95 to 99%). In addition, five kill sites (presumed to be from polar bears) and two observations of polar bear tracks were recorded. Polar bears are widely distributed and could occur along all northern portions of the shipping lane during August and September, but would more likely be encountered where there is moderate to heavy ice cover (LGL Limited, 2005).

2.1.3 Population Trends

According to Traditional Knowledge, polar bear numbers in the southern portion of the shipping lane have declined in recent years (Keith *et al.*, 2005). Population estimates for polar bears in M'Clintock Channel is approximately 240 (LGL Limited, 2005). Population estimates of polar bears in Lancaster sounds is around 1,700 (Zinifex, 2007); however there is variability in estimates from different studies (Schweinsburg *et al.*, 1982).

2.1.4 Habitat Use and Diet

Polar bear breeding occurs from April to the end of May. Denning occurs in late November to early December and lasts until April when bears with cubs emerge. Female bears den close to land and exhibit site fidelity for denning areas (Messier *et al.*, 1994). Males and solitary bears, however, are not constrained to den during the winter, although they may build temporary

shelters to avoid the cold and during unfavourable seal hunting conditions (Messier *et al.*, 1994). Key denning sites have been identified using Traditional Knowledge and include areas on King William sound and Jenny Lind island along the southern portion of the lane (Keith *et al.*, 2005). Studies conducted in Lancaster Sound located denning sites along Devon and Baffin Islands using inferences from sightings of females with cubs (Schweinsburg *et al.*, 1982). Polar bears are found in several areas along the proposed shipping lane, including Victoria Strait, Larsen Sound, Barrow Strait and Lancaster Sound (Environment Canada, 2000; Keith *et al.*, 2005; LGL Limited, 2005).

Polar bears mainly rely on marine mammals for sustenance and their primary prey item is the ringed seal. Ringed seals give birth in April and are raising pups on through to July (Parks *et al.*, 2006) and this period is critically important for polar bears to gain fat stores used during fasting periods later in the year. Polar bears fast when seal hunting conditions are unfavourable (*i.e.*, when sea ice is frozen up or completely absent (such as in Hudson Bay) (COSEWIC, 2002). Polar bears are frequently seen on sea ice and areas of pressure ice along the coasts of islands, which are prime habitats that have thinner ice, which is better for seal hunting (Keith *et al.*, 2005). Traditional Knowledge highlighted areas where bears hunt for seals, which occurred near land in Victoria Strait, Larsen Sound and off the coast of King William Island further north. Polar bears using the northern portion of the shipping lane select for coastal habitats similar to those identified in the southern portion of the lane where there are cracks and holes in the sea ice, which are used by seals for breathing (Schweinsburg *et al.*, 1982; COSEWIC, 2002).

2.2 Seabirds

2.2.1 Introduction

The northern reaches of the shipping lane contain important breeding areas for marine birds. The coastal areas within the vicinity of Barrow Strait/Lancaster Sound support thousands of breeding seabirds during the summer. Migratory seabirds generally arrive in the area of the northern shipping lane by mid May and continue to occupy those areas until September to October (Mallory and Fontaine, 2004). Many avian families are represented along the shipping lane, including Laridae (*e.g.*, gulls, jaegers and kittiwakes), Diomedidae (*e.g.*, fulmars), Anatidae (*e.g.*, eider ducks) and Alcidae (*e.g.*, murres and guillemots). The southern reaches of the shipping lane in the Queen Maud gulf and Bathurst Inlet support populations of marine waterfowl as well (Mallory and Fontaine, 2004; Zinifex, 2007); these areas would be occupied during ice-free months and would be used during migration staging in late summer.

2.2.2 Population Trends

Many breeding seabird colonies along the shipping lane are composed of very large numbers of individuals. The Canadian Arctic breeding pair estimates for thick-billed murres, black-guillemots, black-legged kittiwakes and northern fulmars are 1,446,00, 60,000, 95,000 and 235,000, respectively (Mallory and Fontaine, 2004). In the Barrow Strait/Lancaster Sound area, thousands of seabirds can be observed in the summer. The Barrow Strait/Lancaster Sound area supports 27% of the thick-billed murre population, 57% of the northern fulmar population, and 35% of the black-legged kittiwake population (Mallory and Fontaine, 2004). Common and King eiders nesting in the Arctic have declined by more than 50% in the last few decades (Goudie *et*

al., 2000; Suydam *et al.*, 2000). Common and king eider populations in the western and central Canadian Arctic are estimated at 37,000 and 200,000 individuals, respectively (Dickson *et al.*, 1997; CWS Waterfowl Committee, 2006). Ivory and Ross' gulls have reached critically low population numbers in the Canadian Arctic; 1,200 pairs of ivory gulls breed in the northern shipping lane and only an estimated 10 pairs of Ross' gulls (Mallory and Fontaine, 2004). The *Species at Risk Act* (SARA) lists these two species on Schedule 1 as endangered (ivory gull) and threatened (Ross' gull) (SARA, 2006). However, additional breeding colonies of ivory and Ross' gulls occur outside of Canada in Russia and Greenland (Haney and MacDonald, 1995; Mallory and Fontaine, 2004; SARA, 2006).

2.2.3 Breeding

The northern shipping lane passes by many identified breeding seabird colonies. Breeding colonies of endangered ivory gulls occur on Seymour Island, north of Bathurst Island. Seymour Island hosts the largest known colony of Ivory Gulls in Canada (Mallory and Fontaine, 2004). Ivory gulls also nest on the northwestern Brodeur peninsula. Only one breeding colony of Ross' Gull has been identified, which occurs on the Cheyne islands off the coast of Bathurst Island (Mallory and Fontaine, 2004). Other important areas for birds include: Prince Leopold Island, Cape Hay, Cape Liddon, Hobhouse Inlet and Lancaster Sound, which support large colonies of thick-billed murres, black-legged kittiwakes and northern fulmars (Mallory and Fontaine, 2004). As mentioned, the southern shipping lane supports colonies of marine waterfowl as well. Victoria Island, Bathurst Inlet, Elu Inlet and the central Queen Maud Gulf supports more than 80% of the Canadian population of Pacific common eiders, which breed in these and nearby areas (Dickson *et al.*, 2005). Creswell Bay on eastern Somerset Island, the Queen Maud Gulf Important Bird Area (IBA) and Victoria Island are all identified nesting areas for king eiders (Mallory and Fontaine, 2004). Jenny Lind Island, located in the Queen Maud Gulf, is also an important nesting and moulting area for lesser snow geese and Ross's geese (Latour *et al.*, 2006). Identified IBAs , territorial and federally protected areas are shown in Figure 2.2-1.

2.2.4 Habitat Use and Diet

Near the northern reaches of the shipping lane, there are polynyas that are of particular importance for marine birds. Polynyas are areas where the sea ice opens up before the formal ice break-up in the summer and that are important feeding areas for marine birds. Three polynyas occur in Lancaster Sound between Baffin and Devon Islands, on the central eastern coast of Somerset Island and north of Bathurst Island in Penny Strait. The Lancaster Sound polynya is an important feeding area for thousands of marine birds that nest in the Lancaster Sound/Barrow Strait area, while the Somerset Island polynya is an important feeding resource for several hundred king and common eiders (Mallory and Fontaine, 2004). The Penny Strait polynya is an important feeding area for the ivory gull, which breeds nearby (Mallory and Fontaine, 2004).

Nest site selection varies with species. Marine waterfowl (*i.e.*, eider ducks) tend to nest near water (predominately seawater) on low tundra or bare rock microhabitats (Kellett and Alisauskas, 1997). Nests are rarely more than a scrape in the ground, lined with vegetation in the immediate vicinity of the nest (Goudie *et al.*, 2000; Suydam, 2000). Ivory and Ross' gulls nest

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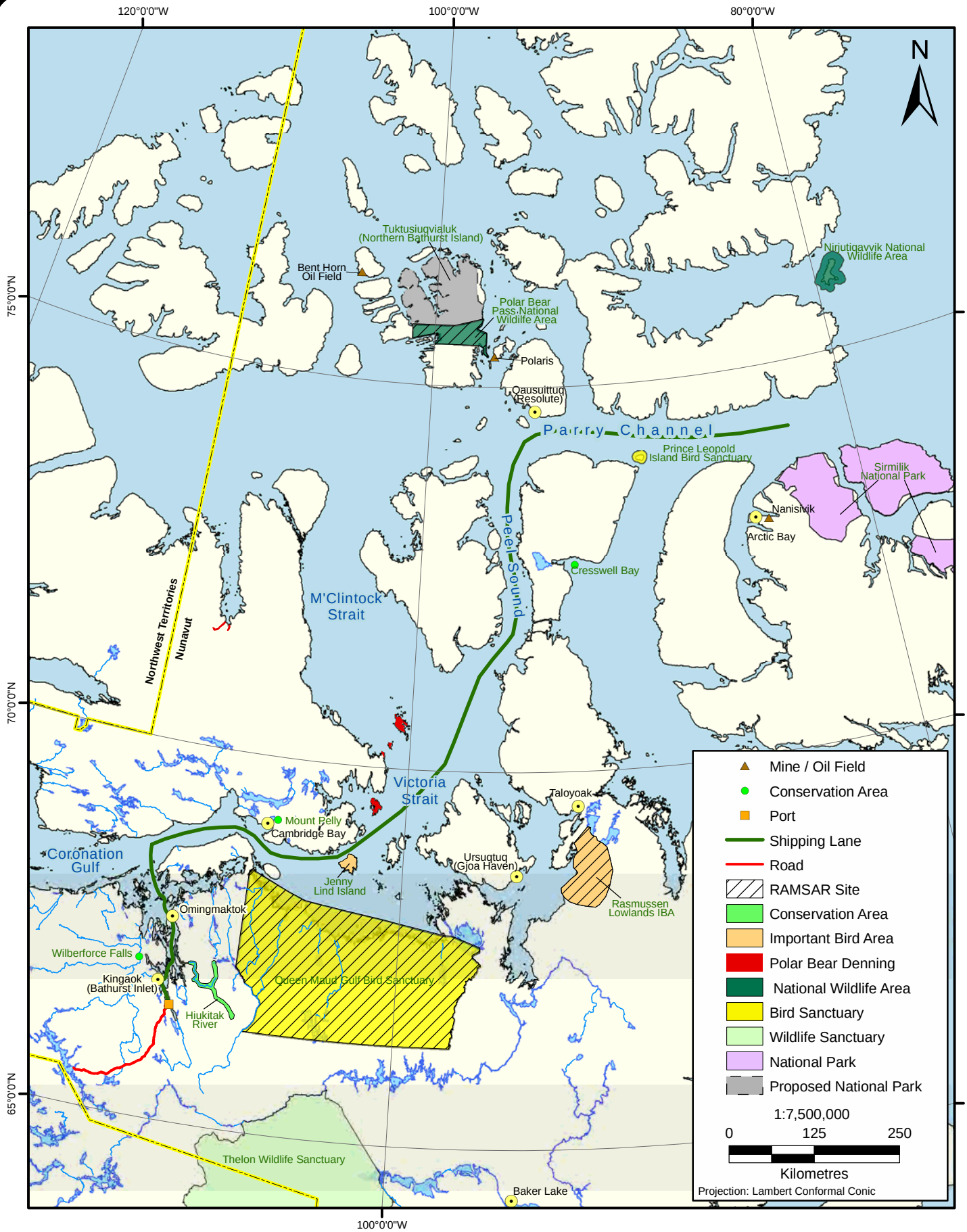

Areas of Federal, Territorial and Conservation Concern along the BIPR Shipping Lane

FIGURE 2.2-1

the Bathurst Inlet Port and Road Project

Rescan

in more rugged terrain than marine waterfowl, selecting hummocks in tundra or ledges in rocky outcrops or reefs, often at varying distances from seawater (Haney and MacDonald, 1995; SARA, 2006). Nests are built out of vegetation and woody debris; some ivory gulls may also usurp nests of Eider ducks (Haney and MacDonald, 1995). Cliffs act as nesting structures for a wide variety of seabirds of the Canadian Arctic; for instance, fulmars, murres, guillemots and kittiwakes all select ledges on cliff faces as nesting sites. Nests built on cliffs range from scantily lined scrapes on ledges (Hatch and Nettleship, 1998) to rudimentary nest cups built with mud and vegetation (Baird, 1994). Fishes and aquatic invertebrates are primary prey items of seabirds (Baird, 1994; Haney and MacDonald, 1995; Hatch and Nettleship, 1998; Gaston and Hipfner, 2000; Goudie *et al.*, 2000; Suydam, 2000; Butler and Buckley, 2002). Aquatic vegetation is included in the diets of eider ducks while they are nesting (Goudie *et al.*, 2000; Suydam, 2000); eider ducks move to coastal areas post-breeding for migration staging, during which time aquatic invertebrates are the largest component of their diet.

3. METHODOLOGY

3. Methodology

3.1 Valued Ecosystem Component Selection

Each potential VEC was screened for inclusion in the effects assessment through an evaluation of the results of baseline studies, conservation status, biological, regulatory, cultural, social, or economic significance and the potential for each to be affected by the shipping lane component of the Project. The VECs that were chosen for the shipping lane component of the Project and the rationale for their inclusion are presented in Table 3.1-1.

Table 3.1-1
Wildlife Valued Ecosystem Components Included in the Environmental Assessment

VEC	Scientific Name	Reference	Rationale for Inclusion
Polar Bear	*Ursus maritimus*	• COSEWIC • Public scoping • Inuit Knowledge • Draft WKRLUP • Scientific Literature	• Species of special concern under COSEWIC • Listed as sensitive in Nunavut • Culturally significant to the Inuit • Potentially at risk from changing ice conditions associated with climate change
King Eider	*Somateria spectabilis*	• CESCC • CWS • Inuit Knowledge • Scientific Literature	• Listed as sensitive in Nunavut • Declining population, significant information available • Potentially at risk from changing ice conditions associated with climate change • Source of food for coastal Inuit
Thick-billed Murre	*Uria lomvia*	• CWS • Scientific Literature	• Biodiversity indicators of environmental health • Relatively high numbers enable statistical detection of changes in populations or communities in relation to development/activity • Undergoes large sea-borne migration through Barrow Strait/Lancaster Sound • Potentially at risk from changing ice conditions associated with climate change

COSEWIC = Committee on the Status of Endangered Wildlife in Canada.
CWS = Canadian Wildlife Service.
WKRLUP = West Kitikmeot Regional Land Use Plan.
CESCC = Canadian Endangered Species Conservation Council.

Although ivory and Ross' gulls were identified through public scoping as being important species, the King eider and thick-billed murre were chosen as an avian marine umbrella species because they occur in throughout the shipping lane, whereas these gulls are in much lower numbers and occur in isolated areas.

3.1.1 Identification of Potential Effects on VECs

The effects assessment for wildlife focused on the following potential effects:

- habitat loss;
- disruption of movements;
- disturbance to feeding, nesting, denning or breeding habitats;
- features acting as an attractant;

- mortality (direct and indirect); and
- reduction in wildlife productivity.

The terrestrial Wildlife Effects Assessment describes the VEC-based assessment approach and the nature and extent of potential effects (Section 3.2.1 in Appendix D-3 of the DEIS). The effects that were assessed/relevant to each VEC are summarised in Table 3.1-2.

Table 3.1-2
Summary Table of Potential Effects Assessed for Wildlife VECs

VEC	Habitat Loss	Disruption of Movements	Disturbance	Features Acting as Attractants	Direct Mortality	Indirect Mortality	Reduction in Reproductive Productivity
Polar bears		X	X			X	X
King eider			X	X	X	X	X
Thick-billed murre		X	X	X	X	X	X

3.2 Boundaries

3.2.1 Spatial Boundaries

To assess the significance of Project effects on VECs, spatial boundaries were established based on considerations of home range size, distribution, and densities.

3.2.1.1 Local Study Area

The local study area (LSA) for seabirds and polar bears includes the direct footprint of shipping traffic along the BIPR shipping lane (*i.e.* areas directly underneath vessels) and extends from the entrance of ships in the lane (Lancaster Sound) to the Bathurst Inlet Port site. The port site is included in this study area.

3.2.1.2 Regional Study Area

The regional study area (RSA) includes the gulfs and straits that encompass the shipping lane as surveyed in the Marine Mammal Baseline (Figure 2 in Appendix E-8 of the DEIS), including Bathurst Inlet, Dease Strait, Queen Maud Gulf, Victoria Strait, Franklin Strait, Peel Sound, Franklin Strait and Barrow Strait. Lancaster Sound was not surveyed but is included in the RSA for the purposes of this effects assessment.

For the purposes of this effects assessment, most effects occur within the RSA. Those effects that specifically occur within the LSA are features that act as attractants (ship and port site lighting) and direct mortality of VEC species (from ships strikes).

3.2.2 Temporal Boundaries

Temporal boundaries for this assessment begin with construction of the port facility and extend when the Project is decommissioned after 22.5 years (2032) and into the far future (>100 years).

4. EFFECTS ASSESSMENT

4. Effects Assessment

This section evaluates the potential effects of the Project shipping lane on three VECS: polar bears, king eiders and thick-billed murres. Potential effects resulting from shipping traffic is evaluated for each VEC for the life of the project as described in Chapter 3 (Methodology) and are summarized at the end of this section in Table 4-1.

4.1 Polar Bears

Polar bears (*Ursus maritimus*) were selected as a VEC due to expressed concern for their conservation during public scoping. Polar bears are also listed by COSEWIC as a species of special concern, and they have strong socio-economic and cultural ties to the Inuit people (Appendix F-5 of the DEIS). The primary threats to polar bears in the Arctic that could potentially result from shipping traffic (WWF, 2007) are:

- pollution and oil spills (addressed in Appendix E-6 of the DEIS);
- extent of the sea ice used for hunting; and
- mortality and reduced productivity.

These issues correspond to four possible effects outlined in the methodology section (as defined by potential wildlife issues raised in Section 4.7.3 of the Final Environmental Impact Statement (FEIS) Guidelines), which are:

- disruption to movement;
- disturbance to feeding, denning or breeding;
- direct and indirect mortality; and
- reduction in productivity.

Detailed background information on polar bears is available in the Environmental Setting (Section 2.1). Important points required for the effects assessment are summarized from this background information in the following sections as required and the potential effects of shipping and alterations to sea ice are evaluated for polar bears along the shipping lane.

Oil spill modelling was done for the shipping lane (Appendix E-6 of the DEIS). Mitigation measures for diesel and oil spills can be found in Appendix G-4 of the DEIS. Oil spills can affect polar bears in numerous ways. Spills can effect prey distribution and contaminants could enter the food web, which would eventually filter up to the larger carnivores. Direct contact with oils could also reduce the isolative properties of polar bears fur, which could lead to hypothermia.

4.1.1 Potential Effects

4.1.1.1 Disruption of Movement

Polar bears occupy large home ranges, which include extensive areas of sea ice where they conduct the majority of their hunting activities. Ship traffic along the shipping lane may increase ice breakup. This section provides background on polar bear movements and assesses potential impacts of shipping on these movements.

Polar bears may move hundreds of kilometres per year (Amstrup, 2000). Annual polar bear movement patterns are influenced by sea ice distribution. Studies have shown that polar bears movements in the Beaufort Sea are correlated with annual movements of the sea ice edges, which polar bears stay nearby to hunt for seals (Amstrup, 2000). Shipping may change their movement pattern between land and the sea ice or between patches of sea ice if shipping increases the break-up of sea ice or alters annual sea ice distribution.

Sea Ice Distribution and Break-up

Shipping may increase the breakup of sea ice. Studies have assessed that current sea ice conditions facilitate the passage of vessels through the shipping lane without having to break ice (Appendix E-10 of the DEIS). Howell and Yackel (2004) identify the proposed shipping lane as the easiest for ship passage due to milder ice conditions, allowing for Type A through E vessels to transit with less difficulty. However, ice conditions are not expected to remain static, however, and there is considerable variability in the extent of ice cover and timing of break- and freeze-up among years (Howell and Yackel, 2004; Appendix E-9 of the DEIS). A review of ice condition study conducted for Wolfden Resources Inc. noted considerable difficulty for vessels transiting through the proposed shipping lane, and the likelihood of encountering multiyear ice in Peel sound (DF Dickins Associates Ltd., 2004). To date, there have been studies showing that shipping can affect ice cover and increase break up, and studies have reported that reductions in sea ice caused by climate change could have had serious consequences for polar bears (FEARO, 1984; Stirling and Derocher, 1993; Derocher *et al.*, 2004; Stirling and Smith, 2004).

Ringed seal utilize areas of active ice throughout the year, such as pressure ridges along island coastlines or sea ice edges (Amstrup, 2000; Keith *et al.*, 2005). They maintain breathing holes during the winter and create birthing and haul out lairs in the spring and summer. Habitat use varies with location and prevalent annual ice conditions (Moulton *et al.*, 2002). During the summer, ringed seals are found more in open waters as landfast ice recedes. Hence, local ice conditions influence seal distribution and abundance, which often then dictates annual polar bears movements (Amstrup, 2000). Thus seals, as ice begins to break-up in summer, will be found closer to sea ice edges and polar bears will likely be found in these areas as well. Any alterations of sea ice distribution that may negatively affect ringed seal distribution may cause polar bears to increase energy expenditure by having to travel longer distances to reach optimal seal hunting areas, or travel further distances annually from near shore habitat (used by females for denning) to sea ice edges (Stirling and Derocher, 1993; Stirling and Smith, 2004). However, effects of shipping potentially altering ringed seal distribution is expected to be negligible (Appendix E-5 of the DEIS). Furthermore, polar bears are aquatic mammals and often cross

large areas of open water (COSEWIC, 2002), thus they would likely cross channels produced by shipping traffic unless these open water segments are extremely wide.

Mitigation and Management

Mitigation for the effects of the shipping on the movement of polar bears is discussed in the Seabirds and Polar Bear Mitigation and Management Plan (Section 5.2). Mitigation measures that can be applied include:

- adhere to proposed shipping season outlined in the Project description; and
- avoid wildlife sensitive areas.

Residual Effects

The disruption of movement patterns in polar bears from shipping is expected to be ***Direct*** and ***Adverse***. The magnitude of this effect is ***Low***, and is a ***Regular*** effect for polar bears. The spatial extent after mitigation is the ***Regional*** scale. The duration is ***Medium Term*** for the life of the Project and is ***Reversible*** in the ***Short Term***. Polar bear populations are likely ***Neutrally Resilient*** and the effect has a ***Low-Moderate*** probability of occurrence. Hence, the significance of residual effects is rated as ***Negligible***, but the potential effect is poorly understood and therefore has a ***Low*** confidence of assessment. Refer to Table 4-1 for full description of effects assessment on polar bears.

4.1.1.2 Disturbance of Feeding, Denning or Breeding

This section addresses the potential effects of disturbance due to shipping on polar bear feeding. Noise or visual interaction with passing ships may cause temporary disturbance to polar bears. Denning and breeding occurs during the winter and early summer, hence ship traffic is not likely to affect these life history stages.

Noise disturbance

Polar bear feeding behaviour may be affected by noise emanating from shipping vessels passing through foraging areas. Auditory disturbance events may lead to greater energy expenditures used for activities such as fleeing, being vigilant, shifting habitats and less time may be spent hunting. However, polar bears are known to habituate to certain stimuli, particularly if the disturbance event occurs without negative repercussions (Perham, 2005).

Given the large tracts of sea and pack ice over which polar bears forage, shipping activities are localized within the polar bear range and are unlikely to have a direct impact on feeding. Therefore the effect of noise disturbance on polar bear feeding and feeding habitat is expected to be negligible**.**

Mitigation and Management

Mitigation for the effects of the shipping lane on the noise disturbance of polar bears is discussed in the Seabirds and Polar Bear Mitigation and Management Plan (Section 5.2). Mitigation measures that can be applied include:

- minimizing use of ship horns in wildlife sensitive areas; and
- minimizing use of ship horn during wildlife sensitive periods.

Residual Effects

Disturbance for polar bears is expected to ***Direct*** and ***Adverse***. The magnitude of this potential effect is rated as ***Negligible***. All ratings are given in Table 4-1, yielding a residual significance level of ***Negligible***. Confidence in this assessment is ***Intermediate***.

4.1.1.3 Mortality

Direct Mortality

Polar bears are strong swimmers and have been observed in open waters (Monnett and Gleason, 2006). However, there has been no documentation of mortality of polar bears being caused by collisions with ships. The incidences of encounters causing direct mortality along the shipping lane are assumed to be rare. At this time the potential effect of direct mortality of shipping on polar bears is expected to be negligible.

Indirect Mortality

Polar bears depend on sea ice for survival (Derocher *et al.*, 2004). Modifications of sea ice coverage and thickness of ice potentially caused by shipping may lead indirectly to reductions in foraging and survival of individuals (Section 4.1.1.1). However, since polar bears are strong swimmers and the shipping is not expected to create large gaps in otherwise continuous ice, effects are expected to be negligible.

Given the large tracts of sea and pack ice over which polar bears forage, shipping activities occur within a small portion of the polar bear range and is unlikely to have a direct impact on feeding behaviour. Therefore, the effect of noise disturbance on polar bear feeding and feeding habitat is expected to be negligible**.**

Mitigation and Management

No Management is planned for this potential effect.

Residual Effects

Mortality for polar bears is expected to be ***Direct*** (direct mortality) or ***Indirect*** (indirect mortality) and ***Adverse***. The magnitude of this effect is rated as ***Negligible***. Residual effect ratings are provided in Table 4-1, yielding a residual significance level of ***Negligible***. Confidence in this assessment is ***Low***.

4.1.1.4 Reduction in Reproductive Productivity

The possibility that shipping will reduce reproductive productivity of polar bears depends on several factors, including the degree of disturbance from shipping activities and the extent of changes to the population demographics.

Noise disturbance during the important late summer foraging season could divert a proportion of time and energy away from resource acquisition, which may lead to a deterioration of body condition, survival, and reproductive success of individual polar bears.

Changes in seal habitat and abundance could significantly affect female polar bears (Derocher *et al.*, 2004; Stirling and Smith, 2004). Female polar bears, in particular, rely in seal meat for building up fat stores for the winter when food acquisition is more difficult. Lower fat stores in summer could reduce female body condition and her ability to produce milk for newborn cubs, reducing cub survival (Derocher *et al.*, 2004). Polar bear cubs are dependent on their mothers for up to two years, and females expend more energy during this time (Amstrup, 2000). Therefore shifts in prey abundance and distribution could potentially lead to larger effects on both females and cubs.

Since the effects of shipping on the reproductive productivity of polar bears are a synergy of other possible effects of shipping on polar bears is expected to be low, but cannot be rated with certainty.

Mitigation and Management

See Section 4.1.3.1.

Residual Effects

Reduction in productivity for polar bears is expected to be ***Cumulative*** and ***Adverse***. The magnitude of this effect is expected to be ***Low.*** Residual effect ratings are provided in Table 4-1, yielding a residual significance level of ***Negligible***. Confidence in this assessment is ***Low***.

4.2 Seabirds

Two seabird species have been identified as important VECs along the shipping lane; the king eider, a representative sea duck and the thick-billed murre, a representative colony-nesting sea bird. The relevant potential effects of the Project are evaluated for these VECs in the following sections.

4.2.1 King Eiders

Since all seabirds could not be included in the effects assessment, the king eider (*Somateria spectabilis*) was selected as a representative VEC for marine waterfowl inhabiting the shipping lane. The king eider was chosen as a representative sea duck, because population data indicates it is a sensitive species with declining population numbers (Suydam *et al.*, 2000) and this species is relatively well studied in the western Arctic; providing more detailed ecological information than any other marine waterfowl in the region. Hence, the king eider can be viewed as an umbrella species for marine waterfowl. The primary threats to king eiders are:

- pollution and oil spills (addressed in Appendix E-6 of the DEIS);
- disturbance during migration staging;
- ship lighting acting as an attractant during inclement weather; and
- mortality and reduced productivity.

These issues correspond to four of possible effects outlined in the Methodology section (as defined by potential wildlife issues raised in Section 4.7.3 of the Final EIS Guidelines). These include:

- disturbance to feeding, nesting or breeding;
- features acting as an attractant;
- direct and indirect mortality; and
- reduction in productivity.

Detailed background information on king eiders is available in the Environmental Setting (Section 2.2) and in section 4.2.2. This information is summarized in the following sections as required and the potential effects of shipping and alterations to sea ice are evaluated for king eiders breeding along the shipping lane.

Oil spill modelling was done for the shipping lane (Appendix E-6 of the DEIS). Mitigation measures for diesel and oil spills can be found in Appendix G-4 of the DEIS. Oil spills can affect seabirds in numerous ways, such as ingestion of contaminants and reduced insulation and buoyancy due to oiling of feathers.

4.2.2 King Eiders in the Study Area

King eiders have a circumpolar distribution and undergo seasonal migrations. Within North America, wintering areas for the king eiders include: the Aleutian Islands in Alaska, southern Greenland and the Atlantic regions of Canada and northern United States. The breeding range for the king eider occurs throughout most of the Canadian Arctic, but also includes northern Alaska and Greenland (Suydam, 2000). Specifically, king eiders breeding and migration staging areas within the shipping lane have been identified around Kent Peninsula, in the Queen Maud Gulf and on Victoria, Somerset, Devon and Baffin Islands (Suydam, 2000; Mallory and Fontaine, 2004; Conant *et al.*, 2006). King eiders are present along the shipping lane from May to early October (Suydam, 2000). Therefore, king eiders will be exposed to disturbances from vessels during the shipping season as ships travel from Bathurst Inlet into Lancaster Sound.

4.2.3 Potential Effects

4.2.3.1 Disturbance to Feeding, Nesting or Breeding

Disturbance to feeding habitat and behaviour of king eiders may occur along the shipping lane. The primary source of disturbance to this species will be noise emanating from marine vessels during the shipping season. Since king eiders utilize different habitats during the breeding season, this section provides a background on breeding of king eiders and outlines possible effects of the shipping lane where it is applicable.

King eiders utilize two principal habitats during the breeding season: inland tundra and coastal. Inland tundra is used for nesting and rearing of young, while coastal habitats are used for migration staging. Males arrive in coastal habitats before females, as males do not take part in rearing of the young (Suydam, 2000; Conant *et al.*, 2006). Since king eiders nest and rear their broods on inland

tundra habitats, they will not be affected by ships using the proposed shipping lane. Areas where noise disturbance may affect king eiders occurs on coastal habitats outside of identified nesting areas (Section 2.2.3), primarily around the northern portion of Bathurst Inlet and the Queen Maud Gulf and Dease and Victoria Straits (Suydam, 2000; IBA, 2004; Conant *et al.*, 2006). Common eiders (*Somateria mollissima*) are far more common in coastal habitats in Bathurst Inlet than king eiders (Dickson *et al.*, 2005). King eiders that breed further north and outside the shipping lane may enter the shipping lane during their fall migration on their way to Greenland or Atlantic Canada and the United States. Stopover points used during fall migration for king eiders have been identified on eastern Baffin Island (Mallory and Fontaine, 2004); however, they could be encountered in coastal habitat around Barrow Strait and Lancaster Sound (McLaren and Alliston, 1985). Congregations on coastal habitats could occur as early as June in the southern shipping lane (Conant *et al.*, 2006) and would likely occur by late July to August in the northern shipping lane if king eiders pass through Barrow Strait/Lancaster Sound during fall migration.

Noise and Visual Disturbance

King eiders are known to be sensitive to disturbance (Mallory and Fontaine, 2004). Two studies have documented dramatic reactions of king eiders to sounds of distant airplanes and boats (Frimer, 1994; Mosbech and Boertmann, 1999). In response to this stimulus, the eiders ceased feeding, swam offshore in alert posture and dove to escape the disturbance. The majority of birds did not return to feeding for six to eight hours after the disturbance (Frimer, 1994; Mosbech and Boertmann, 1999). Mallory and Fontaine (2004) identified key marine areas within 15 km of breeding colonies as the primary areas in which common eiders (a closely related species of the king eider) forage for aquatic invertebrates and fishes post breeding; king eiders would likely follow the same trend. Therefore, foraging king eiders (and common eiders) could be encountered by ships during the summer (July to August), particularly in the southern shipping lane.

Mitigation and Management

Mitigation for disturbance effects on king eiders as an umbrella VEC will focus on avoidance of sensory (noise) disturbance in sensitive areas and during sensitive periods, specifically during migration when seabirds are using shoreline areas (Sections 5.2.3.1 and 5.2.3.2). Where possible, ships will try to maintain as much distance from coastal areas identified as migration staging areas (*i.e.*, key marine areas surrounding these staging locations) for eiders when the lane occurs close to shore.

Residual Effects

Although eiders have been observed to display dramatic avoidance reactions in response to passing boats (Frimer, 1994), the infrequency and far proximity of ship traffic to areas utilized by king eiders and the availability of undisturbed feeding habitat will likely lessen this effect.

Disturbance of king eiders is expected to be ***Direct*** and ***Adverse***. The magnitude of this effect is rates as ***Low*** and is a ***Sporadic*** effect for king eiders**.** The spatial extent is likely on the ***Landscape*** scale. The duration will be ***Short Term*** and is ***Reversible*** in the ***Short Term***. Populations likely have ***Neutral Resiliency*** to this effect and the probability of occurrence is rated as ***Moderate***. Hence, the significance of the residual effects is ***Negligible***. Confidence in this assessment is ***Intermediate*** due to supporting scientific literature.

4.2.3.2 Features Acting as an Attractant

Artificial lights at night attract many species of migratory birds. Ginter and Desmond (2004) reported that aircraft lights on radio towers attracted migrating songbirds, particularly during foggy conditions when lights reflect off of the cloud layer. Red lights in particular have been shown to cause a significant amount of disturbance/disruption (Erickson *et al.*, 2005). Lights on ships could cause migrating eiders to become lost or disoriented and waste valuable energy reserves. This may be of particular significance during inclement weather, *i.e.*, fog or low cloud. As mentioned, common eiders are present in Bathurst Inlet and may be attracted to constant lighting during the night at the port site; however given that the port site is localized within the common eiders range, the potential effects of lighting on this species is expected to be low. For further assessment of effects of lights on migratory birds, see Appendix D-3 of the DEIS.

Mitigation and Management

No mitigation is planned for effects of shipping lights on king eiders. Mitigation measures for port site lighting affecting birds species is described in Appendix D-3 of the DEIS.

Residual Effects

The effects of shipping lights attracting king eiders are expected to be ***Indirect*** and ***Adverse***. The effects of the port site lights attracting common eiders are expected to be ***Indirect*** and ***Adverse.*** The magnitude of these effects are rated as ***Low,*** however the magnitude of the effect of shipping lights may be reduced by the infrequent and ephemeral nature of shipping traffic and the prevalent light conditions of the Arctic summer. These effects are rated in Table 4-1. Hence, the significance of the residual effects is ***Negligible***. Confidence in this assessment is ***Intermediate*** due to supporting scientific literature.

4.2.3.3 Mortality

Mortality of king eiders could occur directly or indirectly. Direct mortality would result from encounters of birds with ships. Indirect mortality could be the result of disruption to feeding and avoidance of feeding habitat, which is addressed in Section 4.2.3.1.

Direct Mortality

Frimer (1994) documented that a common response by king eiders to ship disturbance was diving and flight, suggesting that while in the water, bird-ship strikes would be low. Hatchling king eiders are precocial (young are able to fend for themselves soon after hatching) and behave like adult eiders. Thus, young king eiders, despite their age, may not be at an elevated risk of collisions with ships.

Mitigation and Management

No mitigation is planned for this potential effect.

Residual Effects

The potential for king eiders to collide with shipping vessels is unlikely and the effect is expected to be ***Direct*** and ***Adverse***. The magnitude of this effect is rated as ***Negligible***. All other

ratings are listed in Table 4-1, yielding a ***Negligible*** residual effect. Confidence in this assessment is ***Intermediate*** due to supporting scientific literature.

4.2.3.4 Reduction in Reproductive Productivity

Suitable king eider habitat is found in some areas in the shipping lane, including the northern coasts of Bathurst Inlet. King eider feeding areas and behaviours may be altered by noise disturbances and the presence of ships, leading to habitat avoidance and abandonment of areas for relatively short periods of time. Moulting requires significant body resources to complete (Lindström *et al.*, 1993; Schieltz and Murphy, 1995). Any changes in foraging success could affect the ability of king eiders to prepare for the fall moult. These changes may manifest as lower individual fitness, thus reducing reproductive success. However, disturbance events are expected to be infrequent.

Hence, the effect of shipping on king eiders as an umbrella VEC species for other sea ducks is expected to be ***Cumulative*** and ***Adverse***. The magnitude of this effect is rates as ***Low***. Residual effects rating and confidence of assessment are given in Table 4-1. Hence, the significance of the residual effect is ***Negligible*** and the confidence in this assessment is ***Low***. This evaluation is based on the effects of shipping only on this VEC. The effects of oil spills and other marine accidents are likely a larger potential effect on this VEC and are evaluated in Appendices E-6 and G-4 of the DEIS.

4.2.4 Thick-billed Murres

Since all seabirds could not be included in the effects assessment, the thick-billed murre (*Uria lomvia*) was selected as a representative VEC for marine seabird species in the shipping lane. Their designation as a VEC was to address the possible effects of the shipping lane on cliff nesting colonies of seabirds, which are the most common type occurring in the northern shipping lane. The thick-billed murre is one of the most abundant seabirds in the Canadian end of the Arctic, with large colonies observed in the Barrow Strait/Lancaster Sound Area (Mallory and Fontaine, 2004). Seabirds have also been proposed to be indicator species of Arctic ecosystem integrity (Mallory *et al.*, 2006). The thick-billed murre could be a focal species for monitoring changes in the Arctic ecosystem and be used as a future umbrella species for cliff nesting seabirds. The potential effects of the shipping lane on thick-billed murres are:

- pollution and oil spills (addressed in Appendix E-6 of the DEIS);
- disruption of fall migration from shipping traffic;
- disturbance from noise during foraging and migration;
- ship lighting acting as an attractant during inclement weather; and
- mortality and reduced productivity.

The issues correspond to four of the possible effects outlined in the methodology section (as defined by potential wildlife issues raised in Section 4.7.3 of the Final EIS Guidelines). These are:

- disruption of movement;

- disturbance to feeding, nesting or breeding;
- features acting as an attractant;
- direct and indirect mortality; and
- reduction in productivity.

Detailed background information on thick-billed murres is available in the Environmental Setting (Section 2.2) and in section 4.2.5. This background information is summarized in the following sections as required and the potential effects of shipping and alterations to sea ice are evaluated for thick-billed murres breeding along the shipping lane.

Oil spill modelling was done for the shipping lane (Appendix E-6 of the DEIS). Mitigation measures for diesel and oil spills can be found in Appendix G-4 of the DEIS. Oil spills can affect seabirds in numerous ways, such as ingestion of contaminants and reduced insulation and buoyancy due to oiling of feathers.

4.2.5 Thick-billed Murres in the Study Area

During the summer, thick-billed murres occupy areas in western and eastern North America, breeding on coastal cliffs in Alaska and the eastern Arctic in the Lancaster Sound Area; they are absent in the central Arctic (Gaston and Hipfner, 2000). The winter range of this species includes the marine environments off the coasts of Newfoundland and Labrador and southern Greenland. Within the shipping lane, the thick-billed murre breeds in coastal habitat off Baffin (Bylot) and Somerset Islands. Thick-billed murres arrive in the Lancaster Sound area (where Cape Hay on Bylot Island is the primary nesting site) by mid May and to Somerset Island (where Prince Leopold Island is the primary nesting site) by the end of May. During the late summer (August), thick-billed murres undergo a lengthy sea-borne migration with the young of the year, when they swim through Lancaster Sound into Baffin Bay either, where they continue on to Newfoundland. However, some birds will winter off the coasts of Greenland (Gaston and Hipfner, 2000).

4.2.6 Potential Effects

4.2.6.1 Disruption of Movement

Shipping traffic through Barrow Strait and Lancaster Sound could have the potential to disrupt daily and annual movements of thick-billed murres. Their spring migration to the Arctic is done primarily by flying from wintering areas in Newfoundland and Greenland. Their fall migration through Barrow Strait/Lancaster Sound, on the other hand, is undertaken almost entirely by swimming (Gaston and Hipfner, 2000). Thus, there is potential for disruption by ships during fall migration. Disruption of daily movements, such as feeding trips by adults, is covered in Section 4.2.6.2.

Thick-billed murres are powerful swimming and diving birds. The fall migration for the thick-billed murres begins in August when chicks are around three weeks old (CWS, 2005). Adult thick-billed murres moult during this migration as well and are unable to fly for a month and half after initiating migration (CWS, 2005). Timing of migration is synchronized within colonies

(Gaston and Nettleship, 1981), yet colonies do not move as a whole, but as fragmented groups of up to 30 individuals (adults and chicks) (Gaston and Hipfner, 2000; CWS, 2005). Thick-billed murres have been documented to swim 10-20 km offshore during fall migration (Gaston and Hipfner, 2000). Shipping traffic may disrupt these large-scale movements and potentially separate adults and chicks, as migrating individuals would dive in response to large ships. To date, there is no evidence of effects of shipping on migrating thick-billed murres; however, there has not yet been much traffic through the Northwest Passage.

Mitigation and Management

No mitigation is planned for this potential effect.

Residual Effects

Disruption of migratory movements in the thick-billed murre is expected to be ***Direct*** and ***Adverse***. The magnitude of the effect for this species is rated as ***Low*** and of ***Sporadic*** frequency. The magnitude of this effect may be reduced by the infrequent and ephemeral nature of shipping traffic**,** but cannot be rated with certainty. The spatial extent is likely on the ***Landscape*** scale. The duration will be ***Medium Term*** and is ***Reversible*** in the ***Short Term***. Populations likely are ***Neutrally Resilient*** to this effect and the probability is rated as ***Moderate***. Hence, the significance of the residual effect is ***Low***. The potential effect is poorly understood and therefore has a ***Low*** confidence of assessment. Effects are summarized in Table 4-1.

4.2.6.2 Disturbance to Feeding, Nesting or Breeding

The primary source of disturbance of the Project on thick-billed murres will occur from noise emanating from marine vessels and the physical presence of ships during the shipping season. Since thick-billed murres forage at varying distances from colonies and are sensitive to disturbance, it is likely that thick-billed murres will be affected by ships travelling in Barrow Strait/Lancaster Sound. The following section provides necessary background on the activities of breeding thick-billed murres and outlines the possible effects therein.

Feeding

Thick-billed murres forage over large areas. Mallory and Fontaine (2004) designated areas within 30 km of breeding colonies as the key marine areas utilized by this species (*e.g*. primary areas where murres forage for fishes and invertebrates). Key marine areas for migratory birds as designated by the CWS are shown in Figure 4.2-1 (A. Fontaine, Canadian Wildlife Service, *unpublished data*). These areas were delineated using current species biology and ecology to identify the key marine habitat utilized by migratory bird populations. Key marine areas in Figure 4.2-1 also include those for black-legged kittiwakes (*Rissa tridactyla*), which also occur within 30 km of breeding colonies. Key marine areas for common eiders and northern fulmars (*Fulmarus glacialis*) occur within 15 km of breeding colonies (Mallory and Fontaine, 2004). Other gull or alcid species likely fall within the illustrated key marine areas as colonies are often mixed. As shown in Figure 4.2-1, the inlets connected to Barrow Strait and Lancaster Sound around Devon, Baffin and northern Somerset Islands (around Prince Leopold Island) are valuable sites used by murres (and other seabirds) for foraging. Thick-billed murres have also

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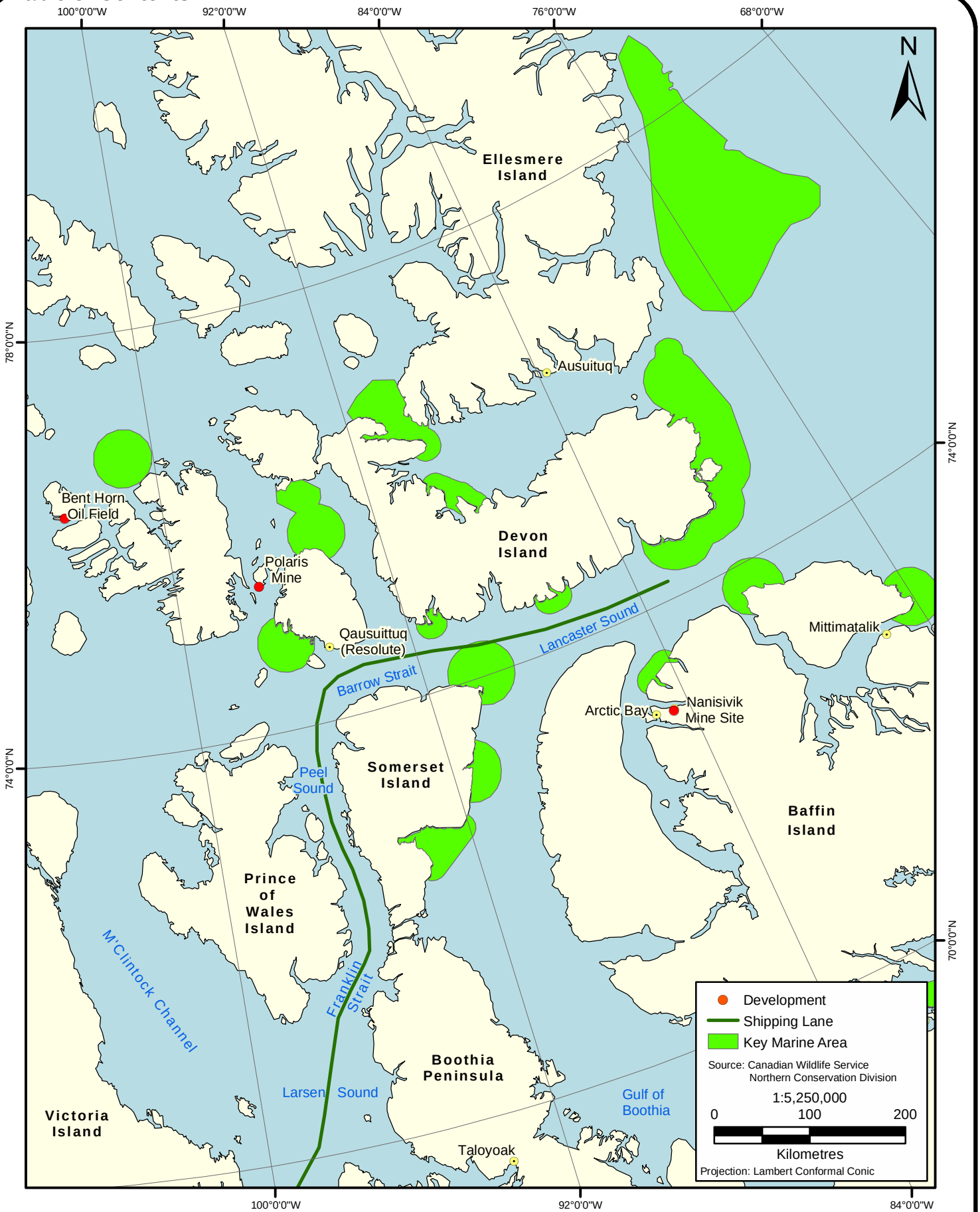

the Bathurst Inlet Port and Road Project

Key Marine Areas of Colony Nesting Seabirds

FIGURE 4.2-1

Rescan™

been observed making longer range foraging trips of up to 170 km (Gaston and Hipfner, 2000). The noise and presence of ships has been shown to adversely affect thick-billed murres (Chardine and Mendenhall, 1998) and may result in altered distributions or reduced population sizes.

Nesting

Thick-billed murres species utilizes rugged and isolated cliffs for breeding in colonies. Various sources of disturbance affecting nesting colonies have been documented for thick-billed murres (Chardine and Mendenhall, 1998). Adults flush from nests at when approached (*e.g.*, by a perceived predator) within a distance of approximately 5 m (Gaston and Hipfner, 2000). Since predators are a problem for all birds within the colony, colonies often act gregariously and a few flushing events may stimulate all birds to respond to the stimuli in a similar way. Noise from passing ships has the potential to flush nesting thick-billed murres at distances greater than 5 m, due to sound carrying over water. However, ships will likely not pass within many kilometres of identified colonies. Thick-billed murres incubate their eggs on their feet, so flushing responses could result in the loss of eggs. Similar effects may be observed with chicks later in the breeding season, although the frequency of flushing may be low (Curry and Murphy, 1995).

Mitigation and Management

As with the king eider, mitigation for disturbance effects on thick-billed murres as an umbrella VEC will focus on avoidance of sensory (noise) disturbance in sensitive areas and during sensitive periods, specifically during the nesting period (Sections 5.2.3.1 and 5.2.3.2). Where possible, ships will try to maintain as much distance from identified breeding colonies and key marine areas around breeding colonies if and where the lane occurs close to these areas.

Residual Effects

The area of the shipping lane is a small proportion of the foraging habitat used by thick-billed murres, which are largely confined to Lancaster Sound and the northeast coast of Baffin Island. In addition, shipping traffic is infrequent and ships will not be passing close to identified colonies. Disturbance of feeding and nesting in thick-billed murres is expected to the ***Direct*** and ***Adverse***. The magnitude of the effects of shipping on the foraging and nesting of thick-billed murres is rated as ***Low***. This effect is rated in Table 4-1. The significance of residual effects is ***Negligible***. Confidence in this assessment is ***Intermediate*** due to supporting scientific literature.

4.2.6.3 Features acting as an Attractant

Shipping lights may act as attractants to thick-billed murres. Migrating passerines have been documents being attracted and disoriented by light towers in foggy weather (Ginter and Desmond, 2004). Similar effects could be observed in thick-billed murres but have not been reported.

Mitigation and Management

No mitigation is planned for this potential effect.

Residual Effects

Lights attracting thick-billed murres are expected to be ***Indirect*** and ***Adverse***. The magnitude of this effect is rates as ***Low***; however, the magnitude of this effect may be reduced by the infrequent and ephemeral nature of shipping traffic lights. This effect is rated in Table 4-1. Hence, the significance of residual effects is ***Negligible***. Confidence in this assessment is ***Intermediate*** due to supporting scientific literature.

4.2.6.4 Mortality

Direct and indirect mortality of thick-billed murres could occur. Direct mortality could occur due to strikes of murres by ships. Indirect mortality may result from lowered body condition, which may occur if shipping induces stresses in thick-billed murres and causes avoidance of feeding habitat.

Direct Mortality

The shipping lane will pass through foraging habitat and the fall migration lane used by thick-billed murres and possible collisions with ships could occur. However, adult thick-billed murres are able to sustain dives for several minutes and for up to 200 m in depth (Gaston and Hipfner, 2000). Therefore, this species would most likely be able to avoid ships when they pass by. Hatchling murres encountered during the fall migration may be more vulnerable as they are unable to sustain long dives (Gaston and Hipfner, 2000) and could possibly be struck by passing ships. In addition, chicks rely on parental care during the early stages of this migration period and separation events could affect survival rates of young murres. Since the fall migration is localized in time, possible effects of the shipping lane on the direct survival of thick-billed murres is expected to be low.

Indirect Mortality

Possible sources of disturbance leading to indirect mortality of thick-billed murres could arise from disruption of daily and annual movements, which result in elevated stress and decreased body condition. These effects are covered in Sections 4.2.6.2, and 4.2.6.3.

Mitigation and Management

Mitigation will focus on avoidance of sensory (noise) disturbance in sensitive areas and during sensitive periods, specifically during the nesting period (Sections 5.2.3.1 and 5.2.3.2).

Residual Effects

Mortality for thick-billed murres is expected to be ***Direct*** (direct mortality) or ***Indirect*** (indirect mortality) and ***Adverse***. The magnitude of this effect is rates as ***Low***. These effects are rated in Table 4-1. The significance of residual effects is ***Low-Negligible***. Confidence in the assessment of this potential effect is not well understood and is therefore ***Intermediate***.

Table 4-1
Summary of Effects Assessment for Seabirds and Polar Bears

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
Description	**Project Phase (Timing)**	**Project Component**	**Direction**	**Nature**	**(Design Changes, Management, Monitoring, Compensation, Enhancement)**	**Description of Residual Effect (after mitigation) [1]**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence Limit**
Polar bear																
Disruption of Movement	Operations	Shipping Lane	Adverse	Direct	adhere to proposed shipping season and documentation of activities in wildlife sensitive areas	limited or no breaking-up of ice	low	Regional	Medium-term	Regular	Reversible Short-term	Neutrally Resilient	Low	Low-Moderate	**negligible**	low
Disturbance of Feeding, Denning or Breeding	Operations	Shipping Lane	Neutral	Direct	limiting the use of ship horns	less potential for disturbing hunting polar bears	negligible	Regional	Medium-term	Regular	Reversible Short-term	Neutrally Resilient	Low	Low-Moderate	**negligible**	intermediate
Direct Mortality	Operations	Shipping Lane	Adverse	Direct	no mitigation planned	polar bear-ship encounters are expected to be low	negligible	Regional	Medium-term	Regular	Reversible Short-term	Neutrally Resilient	Low	Low	**negligible**	low
Indirect Mortality	Operations	Shipping Lane	Adverse	Indirect	no mitigation planned	low impact on polar bear populations	negligible	Regional	Medium-term	Regular	Reversible Short-term	Neutrally Resilient	Low	Moderate	**negligible**	low
Reduction of Reproductive Productivity	Operations	Shipping Lane	Adverse	Cumulative	adhere to proposed shipping season and documentation of activities in wildlife sensitive areas	low impact on polar bear populations	low	Regional	Medium-term	Medium-term	Reversible Long-term	Neutrally Resilient	Low	Moderate	**negligible**	low
King Eider																
Disturbance of Feeding, Nesting or Breeding	Operations	Shipping Lane	Adverse	Direct	adhere to proposed shipping season, limiting the use of ship horns	less potential for disturbing foraging king eiders	low	Landscape	Short-term	Sporatic	Reversible Short-term	Neutrally Resilient	Nil	Moderate	**negligible**	intermediate
Features acting as an Attractant	Operations	Port	Adverse	Indirect	See Wildlife Effects Assessment (Appendix D-3) Table 4-1 for mitigation measures on lighiting acting as an attractant	low to negligible attraction rates of common eiders to port site	low	Landscape	Short-term	Sporatic	Reversible Short-term	High Resilience	Nil	Moderate	**negligible**	intermediate
Features acting as an Attractant	Operations	Shipping Lane	Adverse	Indirect	no mitigation planned	low to negligible attraction rates of king eiders to ships	low-negligible	Landscape	Short-term	Sporatic	Reversible Short-term	High Resilience	Nil	Low	**negligible**	intermediate
Direct Mortaility	Operations	Shipping Lane	Adverse	Direct	no mitigation planned	bird-ship encouters expected to be low	negligible	Landscape	Short-term	Sporatic	Reversible Short-term	Neutrally Resilient	Nil	Low	**negligible**	intermediate
Reduction of Reproductive Productivity	Operations	Shipping Lane	Adverse	Cumulative	avoiding disturbance (i.e. excessive noise) in migration staging areas	low impact on king eider populations	low	Landscape	Medium-term	Sporatic	Reversible Long-term	Neutrally Resilient	Nil	Moderate	**negligible**	intermediate
Thick-billed Murre																
Disruption of Movement	Operations	Shipping Lane	Adverse	Direct	no mitigation planned	less potential for disturbing migrating thick-billed murres	low	Landscape	Medium-term	Sporatic	Reversible Short-term	Neutrally Resilient	Nil	Moderate	**low**	low
Disturbance of Feeding, Nesting or Breeding	Operations	Shipping Lane	Adverse	Direct	adhere to proposed shipping season, avoidance of seabird colonies, limiting the use of ship horns	less potential for disturbing foraging and breeding thick-billed murres	low	Landscape	Short-term	Sporatic	Reversible Short-term	Neutrally Resilient	Nil	Moderate	**negligible**	intermediate
Features acting as an Attractant	Operations	Shipping Lane	Adverse	Indirect	no mitigation planned	low to negligible attraction rates of thick-billed murres to ships	low	Landscape	Short-term	Sporatic	Reversible Short-term	High Resilience	Nil	Low	**negligible**	intermediate
Direct Mortaility	Operations	Shipping Lane	Adverse	Direct	adhere to proposed shipping season, avoidance of seabird colonies, limiting the use of ship horns	low-no adult or hatchling murre interactions with ships resulting in	low	Landscape	Short-term	Sporatic	Reversible Short-term	Neutrally Resilient	Nil	Low-Moderate	**low-negligible**	low
Indirect Mortality	Operations	Shipping Lane	Adverse	Indirect	adhere to proposed shipping season, avoidance of seabird colonies, limiting the use of ship horns	low impact on thick-billed murre populations	negligible	Landscape	Short-term	Sporatic	Reversible Short-term	Neutrally Resilient	Nil	Low-Moderate	**negligible**	low
Reduction of Reproductive Productivity	Operations	Shipping Lane	Adverse	Cumulative	adhere to proposed shipping season, avoidance of seabird colonies, limiting the use of ship horns	low impact on thick-billed murre populations	low	Landscape	Medium-term	Sporatic	Reversible Long-term	Neutrally Resilient	Nil	Moderate	**low-negligible**	low

[1] **If there NO residual effect after mitigation there is no need for further evaluation**

4.2.6.5 Reduction in Reproductive Productivity

Reductions in reproductive productivity of murres may occur as a result of synergistic effects that culminate from disruptions of movements, feeding and disturbances from ships (*e.g.*, noise and presence). These synergistic effects may lead to reduced parental and chick body conditions (Section 4.2.7.2). Disruption of movement during fall migration could also lead to the disruption and separation of migrating groups and could decrease chick survival (Section 4.2.7.1). However, shipping traffic encountering thick-billed murres is expected to be low and shipping traffic is ephemeral (passing through an area in a matter of minutes), hence the effects on reduction in reproductive productivity is expected to be low-negligible**.**

Mitigation and Management

Mitigation will focus on avoidance of sensory (noise) disturbance in sensitive areas and during sensitive periods, specifically during the nesting period (Sections 5.2.3.1 and 5.2.3.2).

Residual Effects

Reduction in productivity in thick-billed murres is expected to be ***Cumulative*** and ***Adverse***. The magnitude of this effect is rates as ***Low***. Residual effects are rated in Table 4-1**.** Hence the significance of the residual effect is ***Low-Negligible*** and the confidence in this assessment is ***Low***. This evaluation is based on the effects of shipping only on this VEC. The effects of oil spills and other marine accidents are likely a larger potential effect on this VEC and are evaluated in Appendices E-6 and G-4 of the DEIS.

5. MITIGATION AND MANAGEMENT PLANS

5. Mitigation and Management Plans

5.1 Introduction

5.1.1 Overview and Objectives

Mitigation and management directives are offered as recommendations and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

This Seabirds and Polar Bear Mitigation and Management Plan (SPBMMP) focuses on developing mitigation and management directions which will reduce the impacts of the Project on identified wildlife issues; it is intended to direct the actions of Bathurst Inlet Port and Road Joint Venture Ltd. (the proponent) in maintaining wildlife habitats and populations in areas influenced by shipping traffic, while taking into account operational requirements and safety of Project employees. The wildlife issues raised in Section 4.7.3 of the Final EIS Guidelines include:

- disruption of movement;
- disturbance to feeding, nesting, denning or breeding habitats;
- mortality (direct);
- mortality (indirect); and
- reduction in wildlife productivity.

Habitat loss was not identified as a potential effect for the selected VECs and was therefore not considered in the effects assessment (Chapter 4) and will not be considered here. Mitigation strategies for potential oil spills are considered in Appendix G-4 of the DEIS.

Unless otherwise indicated, measures described in the SPBMMP apply to the shipping lane for the life of the Project. This plan is designed to be adaptive, effective and achievable in both the short and long term and includes measurable objectives which will be evaluated in the Monitoring Plan (Section 6).

5.1.2 Adaptive Management Approach

Wildlife management for the Project will be undertaken using an adaptive management approach. The mitigation and management procedures discussed here have been formulated in order to consider potential effects of Project development on wildlife, as well as best management practices. Management strategies will need to be reviewed periodically, due to the changing nature of the Project over time, and will be adapted based on the outcome of initial management practices. This review process will be guided by further research findings and best management guidelines. An adaptive management approach will allow the proponent to respond to concerns as they arise throughout the life of the Project.

5.2 Seabirds and Polar Bear Management Plan

5.2.1 Issues

Assessment of Project activities identified the following potential effects and concerns for polar bears and seabirds found along the shipping lane:

- disruption of movement for both polar bear during the shipping season from mid July to mid October, and disruption of migrating thick-billed murres from August through to the end of shipping;
- disturbance of feeding, denning and breeding through potential alteration of optimal polar bear hunting areas and displacement of foraging king eiders and thick-billed murres, as well as disturbing nesting thick-billed murres;
- a potential for VEC-ship interactions resulting in direct mortality and physical presences and sound of ships elevating VEC stress levels and decreasing body condition (indirect mortality); and
- reduction in VEC productivity due to synergistic effects from a combination of above effects.

Climate change is one of the greatest concerns threatening the integrity of Arctic ecosystems. Numerous studies have started studying ice trends in recent years and how alteration in ice conditions could have multiple detrimental effects on Arctic wildlife, especially polar bears (Stirling and Derocher, 1993; Stirling, 1997; Derocher *et al.*, 2004). Climatic changes may complicate assessing the effects of the shipping lane on identified VECs, which reduces the confidence in assessing Project effects and necessitates further study and monitoring of VEC species in the future.

5.2.2 Goals and Objectives

The goal of the SPBMMP is to minimize and mitigate the effects of the shipping lane on polar bears, king eiders and thick-billed murres. This plan will focus on the shipping lane during the months of mid July to mid October and the round trips through the area undertaken by ships during that time (Appendix A-3 of the DEIS). Objectives of the Polar Bear and Seabird Management Plan are to:

- maintain the functional integrity of the landscape and wildlife sensitive areas to support healthy populations of wildlife VECs;
- avoid unnecessary disturbance or harassment of wildlife species in the shipping lane;
- avoid direct and indirect mortality of wildlife as a result of shipping traffic; and
- prevent hunting by workers or contractors.

5.2.3 Mitigation and Management

Mitigation and management directives to address potential effects of the shipping lane on polar bears, King eiders and thick-billed murres, as identified in the effects assessment (Sections 4.1.1, 4.2.3, and 4.2.6), are described in the following sections and include:

- avoidance of wildlife sensitive areas;
- documentation of VECs in wildlife sensitive periods;
- minimization of sensory disturbances;
- a no hunting policy; and
- an employee education program.

5.2.3.1 Avoidance of Wildlife Sensitive Areas

It is recognized that there are areas that are particularly sensitive for wildlife within and adjacent to the shipping lane. Wildlife habitats that are sensitive to shipping traffic include bird colony nesting sites (in particular those used by cliff nesting seabirds) and wildlife movement corridors.

Key marine areas around nesting colonies for thick-billed murres and common eiders (applied to king eiders) include habitats extending 30 and 15 km from colonies, respectively (Mallory and Fontaine, 2004). However, specific federal regulations regarding distance of closest approach (buffer zones) around seabird colonies do not exist for commercial ship traffic. Canada has recommended a 100 m distance restrictions for motorized boats in Newfoundland around common murre colonies (Chardine and Mendenhall, 1998). This distance, however, is not feasible for larger industrial vessels, whose presence and sound emissions are not comparable to smaller commercial or recreational boats. The North Baffin Regional Land Use Plan (NBRLUP) stipulates that ships passing through Lancaster Sound shall remain 20-25 km off shore wherever it is practical and safe to do so, as well as remain at least 10 km from all coastlines within the North Baffin region (NPC, 2005). To minimize potential effects of physical presence and sound transmission, sensitive areas will be avoided by ships where possible and should adhere to policies outlined in the NBRLUP in the northern shipping lane. A map of sensitive areas will be given to ship captains. The Project must also take into consideration operational feasibility, economics and employee safety.

5.2.3.2 Wildlife Sensitive Periods

Individuals or populations of some wildlife species are more sensitive to disturbances during certain seasons and life stages. Sensitive periods may include seasonal migrations, dispersal movements, breeding period, periods when young are vulnerable, denning and wintering periods. Project activities (*e.g.*, noise) that may disturb wildlife VECs should be avoided during sensitive periods (Table 5.2-1). These periods represent times when wildlife VECs are within the Project area and sensitive to disturbance. The dates for sensitive periods may change with global warming and Project activities. Wintering activities for year round residents, *i.e.*, denning by polar bears, is a sensitive life history period but occurs outside of the shipping window and is not considered below. Sensitive periods of wildlife along the shipping lane will be given to ship captains.

Table 5.2-1
Wildlife Sensitive Periods Applicable to the Shipping Lane

VEC	Activity	Sensitive Period[1]		
Polar Bear	Den Emergence/Breeding	March	–	July
	Food Acquisition	March	–	November[2]
King Eider	Nesting / fledging	May	–	July
	Post breeding moult and migration	June[3]	–	September
Thick-billed Murre	Nesting / fledging	May	–	August
	Post breeding moult and migration	August	–	November[4]

[1]Sensitive period that interacts with the Project. For complete life history stages, see Environmental Setting (Chapter 2).
[2]End date based on den entrance for female polar bears, male, solitary females and females with cubs would forage throughout the year (maximal food acquisition is during the Den Emergence/Breeding period when ringed seals are rearing seal pups).
[3]Male King eiders will arrive on post breeding/migration staging areas earlier than female eiders.
[4]End date for migrating thick-billed murre is unknown for the Lancaster Sound area, date is based on earliest arrival in wintering areas.

5.2.3.3 Minimize Sensory Disturbance

Thick-billed murres are known to be sensitive to noise while nesting, and King eiders can be disturbed by noise while on coastal habitats used for migration staging (Frimer, 1994; Gaston and Hipfner, 2000). However, it is unknown to which degree polar bears are sensitive to noise while hunting along the sea ice edges. While ship noises are a novel disturbance that could potentially cause elevated stress levels, polar bears may be able to habituate to ship disturbance (Perham, 2005).

Mitigation and management directives have been created that will aid in minimizing or eliminating potential sound disturbance and their effects on wildlife. These directives include:

- minimizing use of ship horns in wildlife sensitive areas;
- minimizing use of ship horns in wildlife sensitive periods; and
- maximum feasible distances between shipping activities and breeding seabird colonies will be maintained.

5.2.3.4 No Hunting Policy

A no hunting policy will be in effect throughout the life of the Project, for both the terrestrial and marine components (Section 5.5.3.7 in Appendix D-3 of the DEIS). This policy will be in place to minimize human-caused harassment and death of wildlife in the shipping lane. Management directives for this policy are to:

- prohibit all employees/contractors from carrying personal firearms on marine vessels as per Transport Canada regulations;
- prohibit hunting by employees;

- report any poaching or evidence of illegal hunting/trapping to government authorities; and
- enforce this policy by supervisors and regulatory authorities.

5.2.3.5 Aerial Flight Restriction

Pilots flying helicopters and fixed wing aircraft used for Project construction and operation will adhere to wildlife-recommended guidelines designed to:

- maintain established minimum flight altitudes recommended by Environment Canada (aircraft used in conducting project activities maintain a vertical distance of 1,000 m and minimum horizontal distance of 1,500 m from any observed concentrations (flocks/groups) of birds, unless closer distances are required to complete wildlife surveys);
- prevent harassment of wildlife;
- avoid low-level aircraft overflights near wildlife concentration areas;
- develop pre-determined flight paths to provide buffer distances between flight paths and sensitive habitats; and
- re-route flight paths to avoid wildlife sensitive areas or periods.

5.2.3.6 Employee Education Program

An employee education program has been developed for Wildlife Effects Assessment (Appendix D-3 of the DEIS) and could be adapted for staff on board ships serving the BIPR port. This program will be supported by standard operating procedures, reporting forms, information sheets, educational posters and signage. These documents would be given to ship captains. The education program will include, but not be limited to:

- awareness of wildlife-sensitive locations (*e.g.*, movement corridors, breeding areas) and sensitive times of year;
- education on local wildlife species of concern and threats to native biodiversity;
- no-firearms and no-hunting policies;
- wildlife incidental observation reporting; and
- wildlife incident/accident reporting and response procedures.

The program will be reviewed annually and updated as necessary. A training program for environmental staff that implement and monitor the recommended mitigation measures may also be required, depending on personnel education and expertise.

6. MONITORING AND EVALUATION

6. Monitoring and Evaluation

6.1 Introduction

6.1.1 Overview

Marine shipping in Canada is beyond the control of the proponent. As part of the environmental monitoring program for the Project, a Seabirds and Polar Bear Effects Monitoring Program (SPBEMP) has been developed to serve as environmental guidelines for shipping companies serving the BIPR port.

6.1.2 Goals and Objectives

Environmental guidelines proposed for shipping companies will serve to:

- assess the adherence to mitigation measures proposed in the SPBMMP (Section 5.2);
- identify opportunities for adaptive management; and
- continuously reduce uncertainty of Project effects on wildlife.

6.1.3 Approach and Monitoring Plans

The SPBEMP could potentially assess Project-related effects through an informal monitoring program that focus on wildlife behaviour, mortality, population dynamics, and distribution. The effects of Project activities on wildlife will be assessed through incidental observations (*e.g.*, movements, activities, injury and mortality). Implementation of the SPBEMP will involve the integration of tasks, where possible, to achieve increased efficiency and cost effectiveness

Wildlife management for the Project will be undertaken using an adaptive management approach. Review of management will be guided by the SPBEMP and by further research findings and best management guidelines from international organizations as they become available. An adaptive management approach will allow the proponent to respond to concerns as they arise throughout the life of the Project. The results of the monitoring programs under SPBEMP may be compiled in an annual report that will be distributed to regulatory agencies and neighbouring communities.

6.2 Shipping Lane Monitoring

6.2.1 Objectives

Shipping companies serving the port will be provided with environmental guidelines developed for the protection of marine wildlife.

Potential objectives developed for the shipping lane monitoring are to:

- monitor adherence of shipping activities to those designated in the Project description;

- monitor behaviour and species presence, particularly species of concern and identified wildlife VECs (Chapter 4), to evaluate potential effects of the Project on local biodiversity.

6.2.2 Monitoring Activities

Monitoring of initiatives with the cooperation of ship's captains and crews will focus on evaluating potential effects through:

- monitoring of ice conditions;
- on board monitoring of polar bear and seabirds; and
- the creation of a employee wildlife education program that will allow employees on ships to document observations and encounters, movements and activities of VECs.

6.2.3 Reporting and Responsibilities

Contingent of the implementation of environmental guidelines and monitoring activities by shipping companies serving the BIPR port, a summary of the data collected will be included in an annual report. Future collaboration/cooperation between BIPR Joint Venture Ltd. and government/non government agencies may aid in gaining knowledge on selected VEC species.

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix E-5
Marine Mammals Effects Assessment

Author: **LGL Limited**
Date: **November 2007**

Photo credit: W.R. Koski, LGL Limited

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Bathurst Inlet Port and Road Project Marine Mammals Effects Assessment

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

APP	Arctic Pilot Project
ASPPR	Arctic Shipping Pollution Prevention Regulations
AWPPA	*Arctic Waters Pollution Prevention Act*
BIPR	Bathurst Inlet Port and Road
BLM	Bureau of Land Management (US)
CEA Agency	Canadian Environmental Assessment Agency
CI	confidence interval
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
dB	decibel
DEIS	Draft Environmental Impact Statement
DWT	Dead Weight Tons
EA	Environmental Assessment
EIS	Environmental Impact Statement
ESA	*Endangered Species Act* (US)
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
km	kilometre
min	minute
MMO	Marine Mammal Observer
ms	millisecond
NAMMCO	North Atlantic Marine Mammal Commission
NIRB	Nunavut Impact Review Board
NMFS	National Marine Fisheries Service (US)
NOAA	National Oceanic and Atmospheric Administration (US)
OCS	Outer Continental Shelf
OCSEAP	Outer Continental Shelf Environmental Assessment Program (US)
the Project	the Bathurst Inlet Port and Road Project

Acronyms and Abbreviations

the proponent	Bathurst Inlet Port and Road Joint Venture Ltd.
rms	root-mean-square
SARA	*Species at Risk Act*
TTS	Temporary Threshold Shift
µPa	micro Pascal
VEC	valued ecosystem component

1. INTRODUCTION

1. Introduction

The Bathurst Inlet Port and Road (BIPR) Project (the Project) consists of a port on Bathurst Inlet connected to mines and mineral deposits in Nunavut and Northwest Territories by a new 211 km all-weather road to Contwoyto Lake, and the existing Tibbitt to Contwoyto winter road. The port will include a wharf to serve large ice-class vessels delivering fuel and bulk cargo to the port; a dock to handle barges serving the Kitikmeot communities of Kugluktuk, Kingoak (Bathurst Inlet), Ikaluktutiak (Cambridge Bay), Omingmaktok, Gjoa Haven, and Taloyoak; a 200-person construction camp and services; a 220-million litre diesel fuel tank farm; a truck and trailer maintenance shop; and a 1,200 m airstrip. Noise, other disturbances, habitat alterations, and various types of discharges from Project activities at the port and elsewhere along the shipping route during the construction and operations phases may disturb marine mammals. In winter and spring, ringed seals and possibly some bearded seals are expected to occur in Bathurst Inlet near the proposed port. In summer, belugas and some pinnipeds may occur in Bathurst Inlet. During the shipping period (mid-July to October), bowhead whales, belugas, narwhals, walruses, ringed seals, bearded seals, and harp seals may occur along the shipping route.

This report first presents and reviews background information on marine mammal abundance, distribution, movement patterns, and natural history in Bathurst Inlet and along the proposed shipping route to the east. The report includes a review of the literature and other background information, and the results of original field surveys conducted for this Project during September 2004 and June 2007 (Appendices E-7 and E-8 of the Draft Environmental Impact Statement (DEIS)). It then presents the effects assessment methodology (including selection of valued ecosystem components (VECs) and spatial and temporal boundaries), assesses the effects of port construction and operation and Project-associated shipping on marine mammal VECs, and discusses plans to mitigate, manage, and monitor adverse effects.

2. ENVIRONMENTAL SETTING

2. Environmental Setting

During winter and spring, when virtually the entire Canadian arctic archipelago is icebound, only ringed seals and bearded seals could occur in Bathurst Inlet or along the shipping route. Ice begins to break up in June, and the open water period usually lasts throughout July, August, and September or October. The open water allows several other species of marine mammal to migrate into and summer in the archipelago. Beluga could occur and ringed seals and bearded seals likely would occur in Bathurst Inlet, whereas those and a number of other species could be encountered along the shipping route including bowhead whales, narwhals, and harp seals.

2.1 Bowhead Whale (*Balaena mysticetus*)

2.1.1 Range and Population Status

The bowhead whale is a large, slow-moving Arctic baleen whale that is well-adapted for living in ice-covered waters. It is rare; all stocks were severely reduced in numbers by intensive commercial whaling during the 1800s and early 1900s. One stock is found in the Canadian arctic archipelago, the Davis Strait-Baffin Bay stock, which ranges throughout the eastern and central northern Canadian arctic archipelago (Davis and Koski, 1980; Finley, 2001). Previously, it was thought that there were two stocks, but recent satellite-tracking studies of bowhead whales in West Greenland and the eastern Canadian Arctic suggest that there is only one stock of eastern bowhead whales, and that Hudson Strait is an important wintering area for that population (Heide-Jørgensen et al., 2006). Based on surveys of Hudson Strait and the West Greenland coast conducted during March 1981 and 1982, and an assumed population growth rate of 3.4% per year (George et al., 2004), Koski et al. (2006) derived a projected population estimate of 3633 animals for the overall eastern bowhead whale population in 2004. The stock is listed under Schedule 2 of the Species at Risk Act (SARA) as Endangered and designated Threatened by COSEWIC (2007). Prior to commencement of commercial exploitation in the early 19th century, the Davis Strait stock may have numbered about 11,000 individuals (IWC, 1992).

2.1.2 Distribution and Seasonal Movements

The wintering areas, summering areas, and migration routes of eastern arctic bowheads are not understood completely. Bowheads apparently winter primarily in Hudson Strait, and in smaller numbers in Baffin Bay, such as along the coast of western Greenland (Koski *et al.*, 2006) . Bowheads are known to summer in northern Hudson Bay-Foxe Basin, and in the central High Arctic. Recent satellite tracking studies have indicated that some bowheads use both summering areas (Heide-Jørgensen et al., 2006). Bowhead whale migration into the eastern and central High Arctic is via Lancaster Sound and Fury and Hecla Strait. The migration through Lancaster Sound can extend from early to mid May through early August, with a peak in late June (Davis and Koski, 1980). During May to early July, bowheads are found at the floe edge and in the pack ice off Lancaster Sound and Pond Inlet (Reeves *et al.*, 1983; Moore and Reeves, 1993). When the pack ice melts, they quickly migrate through Lancaster Sound to the channels of the

Arctic Archipelago. In 2002 and 2003, 8 of 13 bowheads tagged in northern Foxe Basin entered Prince Regent Inlet through Fury and Hecla Strait in mid July (Dueck *et al.*, 2006).

About half of the existing Davis Strait-Baffin Bay stock summer in the bays and passages of the central and eastern High Arctic islands during August and September (Davis and Koski, 1980; Koski and Davis, 1980). Principal summering areas include Isabella Bay (eastern Baffin Island), Eclipse Sound (northern Baffin Island), Milne Inlet, Admiralty Inlet, and Prince Regent Inlet (Figure 2.1-1), with the last area considered to be a major nursery area (Lubbock, 1937). A few bowheads occur in the Peel Sound/Franklin Strait area and in Barrow Strait (Davis *et al.*, 1980; Davis and Koski, 1980). They are present in the region from late June through September.

The fall migration out of the eastern Arctic Archipelago occurs during late August through October. In late August and September, whales that summer in Prince Regent Inlet and areas to the west migrate to the north coast of Baffin Island, at which point the migration occurs close to shore. Whales that summer in Eclipse Sound and Milne Inlet proceed north through Navy Board Inlet and then east along Bylot Island (Koski and Davis, 1980), then migrate along the east coast of Baffin Island to Isabella Bay where they join whales that have summered in that area (Finley, 1990, 2001). The migration along Bylot Island and NE Baffin Island is within 1.5 km of the coast and the migration is quite rapid, with the whales averaging 5 km/hr (Koski and Davis, 1980).

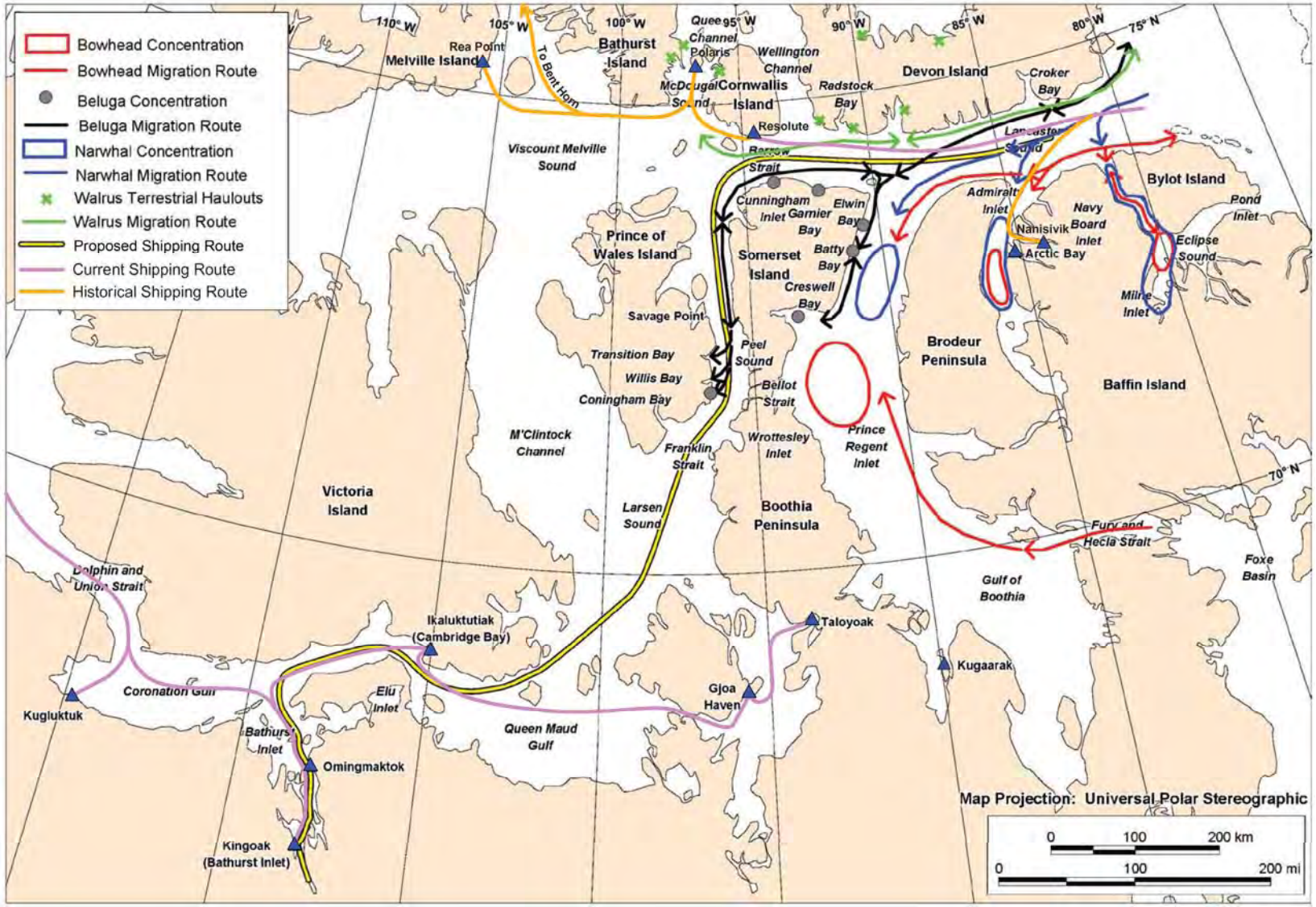
2.2 Beluga (*Delphinapterus leucas*)

2.2.1 Range and Population Status

The beluga has a northern circumpolar distribution, ranging south into the subarctic. Two populations of beluga in the Canadian Arctic are of potential concern to the Project: the Eastern Beaufort Sea and Eastern High Arctic–Baffin Bay stocks (Davis and Finley, 1979; Finley *et al.*, 1987; COSEWIC, 2004). The Eastern Beaufort Sea population, probably the source of the belugas that have been recorded in Coronation Gulf and Bathurst Inlet, summer in the eastern Beaufort Sea and Amundsen Gulf (Finley *et al.*, 1987); their distribution is not discussed further here. The Eastern High Arctic–Baffin Bay stock summers in the Canadian central High Arctic and winters in Baffin Bay.

The Eastern High Arctic–Baffin Bay population is listed under Schedule 3 of SARA as a species of Special Concern. COSEWIC (2007) also has designated that population as of Special Concern (*i.e.*, the population may become threatened or endangered because of a combination of biological characteristics and identified threats). The Eastern Beaufort Sea population is not listed under SARA, and is designated as Not at Risk by COSEWIC (2007).

Innes *et al.* (2002) provided an estimate of abundance for the Eastern High Arctic–Baffin Bay population, corrected for submerged animals, of 21,213 (95% CI = 10,985–32,619). That estimate is based on aerial and photographic surveys of Prince Regent Inlet, Barrow Strait, and Peel Sound between July 31 and August 3, 1996.



2.1-1 Proposed Shipping Route, Migration Routes, and Main Summering Areas of Marine Mammals

Although that area does not include all belugas summering in the Canadian High Arctic, it does encompass the core summering range and includes the estuaries and bays used by large congregations of belugas (*e.g.*, Creswell Bay on Somerset Island).

2.2.2 Distribution and Seasonal Movements

The Eastern High Arctic–Baffin Bay population winters in loose pack ice along the west coast of Greenland south of Disko Island (Davis and Finley, 1979; McLaren and Davis, 1983), and in the North Water Polynya in northern Baffin Bay (Finley and Renaud, 1980; Richard *et al.*, 1998; Heide-Jørgensen *et al.*, 2003b). Belugas from the smaller population wintering in the North Water begin entering Lancaster Sound in late April or early May (Finley and Renaud, 1980), and the peak movement of Greenland-wintering animals occurs later, in late June and July (Davis and Finley, 1979; Koski *et al.*, 2002). During the migration into the central High Arctic, the westward passage of whales is often blocked by fast ice edges across channels such as Lancaster Sound. In such circumstances, large congregations of belugas can occur along the ice edges (Finley *et al.*, 1984a; Finley *et al.*, 1984b). For example, 1800 belugas were found along a 60 km portion of the fast ice edge across eastern Lancaster Sound on July 11, 1978 (Koski and Davis, 1979).

The core summering range of the eastern high arctic beluga whale population is in offshore and coastal waters around Somerset Island: in Prince Regent Inlet, Barrow Strait, and Peel Sound (Koski *et al.*, 2002). Some range north and west of Barrow Strait, around Cornwallis Island and eastern Bathurst Island. Very few belugas summer in eastern Lancaster Sound. During the early open-water period (mid July to mid August), belugas concentrate in large herds of up to several thousand in a few shallow estuaries along the northern and eastern coasts of Somerset Island (Finley, 1976; Smith *et al.*, 1985; Koski *et al.*, 2002). The estuaries regularly used during that period are Creswell Bay, Batty Bay, Elwin Bay, Garnier Bay, and Cunningham Inlet (Figure 2.1-1). Belugas appear to be persistent in their use of estuaries, and use of the estuaries may be site-traditional and critical to the life scheme of the species (Finley *et al.*, 1987). The warm, brackish waters in estuaries are thought to enhance the skin moult; apparently little feeding occurs in estuaries (Koski *et al.*, 2002).

Most belugas abandon the estuaries along northern and eastern Somerset Island by mid August, and a large proportion shift to Peel Sound and northern Franklin Strait until fall migration begins in early to mid September (Richard *et al.*, 2001; Koski *et al.*, 2002). During surveys in August and September 1976, most belugas were observed offshore in southern Peel Sound and along the southeastern coast of Prince of Wales Island, in Coningham Bay and north to Savage Point (Koski *et al.*, 2002). An estimated 2340 individuals were present in Peel Sound on 4 September 1976 (Koski *et al.*, 2002).

Belugas satellite-tagged during July 1996 in estuaries around Somerset Island used several bays on Prince of Wales Island (Transition/Kennedy Bay, Willis Bay, and Coningham Bay) and made daily trips to a deep-water area offshore in Peel Sound called the Franklin Trench (Richard *et al.*, 2001; Heide-Jørgensen *et al.*, 2003b; P. Richard 2005, pers. comm.). There they frequently dove to the seabed. Some also occasionally used the eastern side of Peel Sound/Franklin Strait, including Wrottesley Inlet on the Boothia Peninsula, where Smith and Martin (1994) have also

reported belugas. Belugas are also known from an estuary on the west coast of Somerset Island north of Wadworth Island (Smith and Martin, 1994).

Belugas cross Bellot Strait, between Somerset Island and the Boothia Peninsula (Finley and Johnston, 1977; Smith and Martin, 1994; Richard *et al.*, 2001). Following aerial and ground surveys of Bellot Strait in August and September 1976, Finley and Johnston (1977) concluded that "Bellot Strait does not appear to be an important migration route for marine mammals." Of eleven belugas radio-tagged in estuaries of Somerset Island in 1996, three travelled to Peel Sound through Bellot Strait, and eight through Barrow Strait (Richard *et al.*, 2001).

Satellite-tagged belugas departed southern Peel Sound in late August and early September and quickly swam to the southern coast of Devon Island (Smith and Martin, 1994; Richard *et al.*, 2001; Heide-Jørgensen *et al.*, 2003b). Smith and Martin (1994) reported similar findings. The rapid fall migration of belugas out of the central High Arctic occurs in mid to late September and is concentrated close along the south coast of Devon Island (Davis and Finley, 1979; Koski and Davis, 1979, 1980; Heide-Jørgensen *et al.*, 2003b). The fall migration is almost exclusively along the northern margin of Lancaster Sound and within 400 m of shore, and most of the population passes through Lancaster Sound in less than a week (Koski *et al.*, 2002). The whales then turn north along the eastern coast of Devon Island. Some enter Jones Sound, and others swim directly on to southeastern Ellesmere Island and northern Baffin Bay (Koski *et al.*, 2002). Tagged beluga whales moved along the southern and eastern coasts of Devon Island, arriving in Jones Sound and northern Baffin Bay from late September to early October (Richard *et al.*, 2001; Heide-Jørgensen *et al.*, 2003b). Seventeen of 20 tagged individuals travelled to the North Water and were recorded there until the last of the tags ceased transmitting, from mid October to late November. Three animals continued on to coastal waters of southwestern Greenland (Richard *et al.*, 2001; Heide-Jørgensen *et al.*, 2003b).

During aerial surveys of the proposed BIPR shipping route in September 2004, belugas were observed in Peel Sound and Radstock Bay on southwestern Devon Island, but were not seen between Bathurst Inlet and southern Peel Sound (Appendix E-8 of the DEIS).

During both spring and fall migrations, belugas are found regularly in large groups of up to several hundred (Koski and Davis, 1979, 1980). The timing and extent of spring, summer, and autumn movements in the central High Arctic varies from year to year, sometimes dramatically, in response to ice conditions (Koski *et al.*, 2002).

Belugas usually do not penetrate the area between Dolphin and Union Strait, and Victoria Strait (Stewart and Burt, 1994). However, in some years, probably because of favourable ice conditions, they have been observed or harvested. Stewart and Burt (1994) noted that only one beluga was harvested at Kugluktuk between 1962 and 1971, none were taken there between 1988 and 1993, and one beluga was sighted at Ikaluktutiak (Cambridge Bay) in 1977. In late July 1989, two belugas were sighted in the southeast area of Bathurst Inlet (Stewart and Burt, 1994). Indirect evidence of the presence of belugas is found in the Nunavut Wildlife Harvest Study (Priest and Usher, 2004). Between 1996 and 2001, belugas were harvested in Coronation Gulf only from Kugluktuk, and only in one year: two were taken on July 16, 1996, approximately 30 km east of Kugluktuk, and one was taken on July 21, approximately 120 km east of

Kugluktuk. Belugas were also harvested in Gjoa Haven in 1999/2000. Inuit of the western Kitikmeot reported that belugas were captured only occasionally, and that Elu Inlet was an area where they occur (Appendix F-5 of the DEIS).

2.3 Narwhal (*Monodon monoceros*)

2.3.1 Range and Population Status

Narwhal inhabit deep marine waters of the eastern Canadian Arctic from northern Hudson Bay and Davis Strait west to the central Arctic Archipelago (Reeves *et al.*, 2002). They do not usually occur in the Beaufort Sea or elsewhere in the western Canadian Arctic. Those that summer in the Canadian High Arctic winter in Baffin Bay.

Davis *et al*. (1978b) estimated that the entire narwhal population in the Canadian High Arctic numbered between 20,000 and 30,000. Smith *et al*. (1985) estimated that approximately 13,200 to 18,000 summered in Lancaster Sound and adjoining waterways. Up to 10,000 may summer in Admiralty Inlet, 3,000 in Eclipse Sound, 10,000 in Prince Regent Inlet, 2,000 in Peel Sound, and 1,000 in Barrow Strait. Numbers in each area vary from year to year (Fallis *et al.*, 1983; Smith *et al.*, 1985; Koski and Davis, 1994; Richard *et al.*, 1994). Innes *et al*. (2002) provided a more recent estimate of 45,358 individuals (95% CI 23,397–87,932) for the narwhal population summering around Somerset Island. That estimate was based on 1996 surveys of western Lancaster Sound, Barrow Strait, Prince Regent Inlet, and Peel Sound, and thus did not include all areas in the Canadian High Arctic where narwhals are known to concentrate (*e.g.*, Gulf of Boothia, Admiralty Inlet, and Eclipse Sound).

The narwhal is not listed under SARA, but is designated as a species of Special Concern by COSEWIC (2007).

2.3.2 Distribution and Seasonal Movements

Narwhal winter in very heavy pack ice throughout northern Davis Strait and southern Baffin Bay (McLaren and Davis, 1982). In spring, they move north through the loosening pack ice and appear near and in Lancaster Sound in April. They enter Pond Inlet and Lancaster Sound in late June and July after break up of the ice edge, en route to summering areas farther west (Koski and Davis, 1979; Koski, 1980b). Large congregations can develop in Lancaster Sound during those years when the entrance to the Sound is blocked by fast ice (Finley *et al.*, 1990a). The peak movement of narwhals westward into the central High Arctic, from Baffin Bay via Lancaster Sound, occurs in late June and July.

In summer, narwhals do not frequent shallow waters or estuaries (as do many belugas), but prefer deep-water fiords, inlets, and channels. They also occur in inshore areas (Born *et al.*, 1994; Dietz *et al.*, 1994; Kingsley *et al.*, 1994; Richard *et al.*, 1994; Heide-Jørgensen *et al.*, 2003a). In larger bays, narwhal are strongly associated with ice during summer, but use narrow fiords only when ice-free (Kingsley *et al.*, 1994). Most narwhals summer in the fiords of northern Baffin Island, such as Admiralty Inlet, Navy Board Inlet, and Eclipse Sound (Figure 2.1-1). Other important summering areas are Prince Regent Inlet and the Gulf of Boothia. Smaller numbers summer in Barrow Strait and Peel Sound (Fallis *et al.*, 1983; Smith *et*

al., 1985; Koski and Davis, 1994; Richard *et al.*, 1994; Heide-Jørgensen *et al.*, 2003a). Two thousand narwhal may summer in Peel Sound (Finley and Johnston, 1977; Smith *et al.*, 1985). Narwhals are present in the north-central High Arctic through September.

During the ice-free season, narwhals do not move great distances. Narwhals tagged with satellite transmitters in Tremblay Sound on the northeastern coast of Baffin Island were sedentary (Dietz *et al.*, 1994). Individuals tagged in August in Creswell Bay on Somerset Island remained within 200 km of that locality. Transmitters on two of the animals continued transmitting until the following summer, allowing them to be tracked back to Somerset Island. This suggests that at least some individuals are faithful to summering grounds (Heide-Jørgensen *et al.*, 2003a). Narwhal cross Bellot Strait, between Somerset Island and the Boothia Peninsula (Finley and Johnston, 1977; Smith and Martin, 1994). Following aerial and ground surveys of Bellot Strait in August and September 1976, Finley and Johnston (1977) concluded that "Bellot Strait does not appear to be an important migration route for marine mammals."

Narwhals exit the central High Arctic during their autumn migration back to Baffin Bay via Lancaster Sound. The outbound migration occurs at a much slower pace than that of belugas (Finley and Johnston, 1977). During fall migration, narwhals are dispersed in open water and remain there as long as open water permits. Thus, they are present after the belugas have departed. At that time, most are found in offshore waters of the passages among the central Arctic islands (Koski and Davis, 1980). By mid to late September most satellite-tagged narwhals have moved out of most of those passages and into Lancaster Sound (Heide-Jørgensen *et al.*, 2003a). During aerial surveys of the proposed shipping route in September 2004, narwhal were observed only in Barrow Strait, north of Prince Leopold Island off the northeast coast of Somerset Island and in Radstock Bay on southwestern Devon Island (Appendix E-8 of the DEIS).

Outbound migration becomes concentrated near the north and south coasts of Lancaster Sound during at least the first part of the migration (Koski and Davis, 1980). On their way out of Lancaster Sound and into northern Baffin Bay, the pace of outbound migration speeds up and becomes very rapid. Some animals remain in Lancaster Sound and Pond Inlet into mid October, but most have left by the middle of the month (Heide-Jørgensen *et al.*, 2003a).

Narwhal are social and are usually seen in small groups (Strong, 1988). They can be encountered in groups of up to hundreds during migration, and concentrations do occur along some fast ice edges (Strong, 1988).

Narwhal do not usually occur in the Beaufort Sea or elsewhere in the western Canadian Arctic. Inuit of the western Kitikmeot reported that narwhals were captured only occasionally, and that Elu Inlet was an area where they occur (Appendix F-5 of the DEIS). The only narwhal harvests reported in Kitikmeot Region during 1996–2001 were in the eastern communities of Kugaaruk and Taloyoak (Priest and Usher, 2004).

2.4 Walrus (*Odobenus rosmarus*)

2.4.1 Range and Population Status

Walruses are widespread in the eastern Canadian Arctic, but largely absent in Canadian waters west of there. The Atlantic subspecies, the only population that occurs regularly in the Canadian Arctic, is widely distributed from approximately Barrow Strait, Bathurst Island, and Devon Island east to Baffin Bay and south into Foxe Basin and Hudson Bay. The western Arctic subspecies of walrus winters in the Bering Sea and undertakes an annual summer migration into the western Beaufort Sea (Fay, 1982). Very few of those western walruses are found east of Barrow, Alaska, in summer, and even fewer are found as far east as the Canadian Beaufort Sea.

The walrus population in the Canadian central High Arctic is small, estimated to be 1000–2000 (Davis *et al.*, 1978a). There are records of extralimital occurrences of walrus in the central Arctic Archipelago. Stewart and Burt (1994) listed records for Kugluktuk, Taloyoak, and Bathurst Inlet. The Canadian walrus population is not listed under SARA, but is designated as a species of Special Concern by COSEWIC (2007).

2.4.2 Distribution and Seasonal Movements

Walruses cannot overwinter in areas of solid ice, and must make seasonal movements to areas of broken pack ice. Consequently, the Canadian high arctic population evacuates most of the central Arctic Archipelago and winters in Baffin Bay and in polynyas at the west end of Jones Sound, in Penny Strait, and in Queens Channel (Davis *et al.*, 1978a; Kiliaan and Stirling, 1978).

Most walruses that winter in Baffin Bay migrate from there to summering areas in the central High Arctic via Lancaster Sound. The summer range is centred on Cornwallis Island, Bathurst Island, and western Devon Island. The timing of migration westward into the central Arctic through Lancaster Sound depends on ice break up but usually peaks in July. The movement occurs primarily along the south coast of Devon and Cornwallis islands. About 300–500 animals are involved (Davis *et al.*, 1978a; Koski, 1980b). Numbers of walruses in Lancaster Sound decrease after mid August (Johnson *et al.*, 1976), as most apparently migrate farther west to summering areas. Approximately 200 to 300 may follow another route to the central High Arctic from Baffin Bay via Jones Sound (Davis *et al.*, 1978a; Koski, 1980b). Most walruses reach their summering areas by late July or early August. Between 100 and 150 summer in eastern Lancaster Sound (Johnson *et al.*, 1976; Koski and Davis, 1979). A few are found in the vicinity of the Wollaston Islands at the northeast corner of Navy Board Inlet, but densities are much lower on the south side of Lancaster Sound than on the north side (Johnson *et al.*, 1976; RRCS, 1977). Very few walruses use the offshore waters and south shores of Barrow Strait, the west shores of Prince Regent Inlet and the Gulf of Boothia, or Peel Sound (Davis *et al.*, 1978a).

Most walruses retrace the spring route back to Baffin Bay at the time of freeze-up. Fall migration out of the central High Arctic in eastern Lancaster Sound begins at the end of September and may peak in mid October (Koski and Davis, 1980). As freeze-up continues, some walruses that summered in Queen's Channel and McDougal Sound migrate to overwintering areas in polynyas at Hell Gate/Cardigan Strait and Penny Strait between Devon and southwestern Ellesmere islands.

Although widely distributed in the eastern Arctic, walruses tend to be abundant only in a few areas that provide suitable habitat. They prefer shallow waters (usually <100 m), where they can most easily reach their preferred benthic food sources; they prey on many species of benthic animals, but mainly consume clams (Fay, 1982). They also prefer areas where they have access to ice pans on which to haul out (Lowry, 1985). If sea ice is unavailable during summer, walruses use traditional terrestrial haul-out sites (Salter, 1979). They are gregarious, foraging and migrating in herds, and hauling out in densely packed groups on the ice or shore. Summer terrestrial haul-out sites have been reported along northwest and southwest Devon Island, southwest Ellesmere Island, and in the Crozier Strait area between Bathurst and Cornwallis islands (Figure 2.1-1; Davis *et al.*, 1978a).

Walruses have a low birth rate, at best giving birth to one calf approximately every two years. The calves are born on the ice flows in May or June, and are dependent on the female for approximately 18 months to two years (Mansfield, 1958; Fay, 1982).

Walruses are largely absent in Canadian waters west of the eastern Canadian Arctic. However, there are records of extralimital occurrences of walrus in the central Arctic Archipelago. Stewart and Burt (1994) listed records for Kugluktuk, Taloyoak, and Bathurst Inlet. Inuit of the western Kitikmeot reported that walrus were not common, and that Elu Inlet was an area where they occur (Appendix F-5 of the DEIS).

2.5 Ringed Seal (*Pusa hispida*)

2.5.1 Range and Population Status

Ringed seals have a continuous northern circumpolar distribution. In Canada, their distribution is centred in the Arctic Archipelago, but they range from Newfoundland to the Beaufort Sea. Canadian populations are not listed under SARA and are designated as Not at Risk by COSEWIC (2007).

Ringed seals are the most abundant marine mammal in the Canadian Arctic, but accurate population estimates are difficult to obtain. Canadian researchers have estimated the numbers of visible seals hauled out on the ice in spring; but those estimates may substantially underestimate the actual size of the populations. Some of the estimates are:

- at least 40,000 ringed seals in the Canadian Beaufort Sea (Stirling *et al.*, 1981);
- 50,000 in northern Amundsen Gulf (Kingsley, 1990);
- 49,000 in Prince Albert Sound (Kingsley, 1990); and
- 90,000 in the Canadian High Arctic (Kingsley, 1985, 1990).

There can be large natural variations in the numbers of ringed seals in an area over a period of a very few years (Stirling *et al.*, 1977). In 1974/1975, there was a marked decrease in the abundance and productivity of seals in the Canadian Beaufort Sea and Amundsen Gulf (Stirling *et al.*, 1977; Smith and Stirling, 1978). There was another such decrease between 1982 and 1985 (Harwood and Stirling, 1992).

No population estimates are available for Bathurst Inlet, but the uncorrected density on landfast ice in Bathurst Inlet in late June 2007 (0.3/km^2; Appendix E-9 of the DEIS) was well within the normal range of densities for ringed seals seen on landfast ice during studies in other areas in the Canadian and US Arctic (Table 2.5-1). Ringed seals were observed in most parts of the inlet, but density was considerably lower in the southern part of the inlet.

Table 2.5-1
Observed Ringed Seal Densities on Landfast Ice from Other Studies in the Alaskan and Canadian Arctic

Year	Country	Location	Number /km^2	Citation
1975	Canada	Central Arctic (early June)	1.32	Finley (1976)
1975	Canada	Central Arctic (late June)	0.67	Finley (1976)
1978	Canada	Baffin Island Fiords	1.72	Finley *et al*. (1983)
1979	Canada	Northwest Baffin Island	1.31	Finley *et al*. (1983)
1980, 1981	Canada	Central Arctic	0.27, 0.41	Kingsley *et al*. (1985)
1981 to 1984	Canada	Beaufort, Amundsen, Prince Albert Sound	0.06 to 0.41	Kingsley (1986)
1985 to 1999	US	North Slope, Alaska	0.58 to 1.67	Frost *et al*. (2002)
1997	Canada	Barrow Strait Fiords	8.70	Finley (1979)
1997 to 2002	US	Prudhoe Bay Area	0.39 to 0.83	Moulton *et al*. (2005)
2004	Canada	Coronation Gulf	0.69	LGL Ltd., *unpubl. data*

There are few estimates in the literature based on open water surveys, likely because ringed seals are only visible during aerial surveys over open water in ideal conditions (low sea state, no forward glare). Densities estimated under such conditions are lower than those in spring, and variable. Estimated densities in the Beaufort Sea were 0.42, 0.15, 0.08, and 0.19 in 1982, 1984, 1985, and 1986, respectively (Harwood and Stirling, 1992).

2.5.2 Biology, Distribution, and Seasonal Movements

Ringed seals are year-round residents in the Arctic and are highly adapted for living in arctic conditions. Ice conditions influence ringed seal distribution and abundance (Smith and Stirling, 1975, 1978; Moulton *et al.*, 2002), and densities have been shown to vary with ecological circumstances such as biological productivity (Kingsley *et al.*, 1985; Stirling and Øritsland, 1995).

Ringed seals do not haul out on land, but haul out on sea ice to moult and rest. They also give birth to young on the ice, in subnivean (below snow on ice) lairs. In winter and spring, ringed and bearded seals are the only marine mammals that inhabit areas covered by fast ice. As the ice forms in autumn, ringed seals open and then maintain breathing holes in the sea ice throughout the ice-covered period using the claws of their front flippers (Vibe, 1950). Each seal maintains numerous breathing holes because it must breathe every 15 min or so (Riedman, 1990). As snow drifts over their breathing holes, seals excavate lairs in the drifts. There are two types of lairs; the haul-out lair and the breeding lair. Haul-out lairs are made as early as January, and ringed

seals frequently begin to haul out in the open air on top of the ice to undergo moult from mid-May through early June.

Breeding or birth lairs are constructed in mid-March at the earliest (Smith *et al.*, 1991). Ringed seals prefer to breed on landfast ice in all areas within the study area (McLaren, 1958; Kelly, 1988), but they also breed in the pack ice (Finley *et al.*, 1983; Kelly, 1988). Ringed seal pups are born in the birth lairs in April. They nurse for 38 to 44 days (Smith *et al.*, 1991). Newborn pups do not have a layer of blubber to protect them from the cold. They rely on their white fur, high metabolic rates, and the birth lair for protection from the cold. Newborn pups can and do enter the water to escape predation, but they must return to the birth lair to prevent hypothermia (Smith *et al.*, 1991). Pups are subject to intense predation by foxes and polar bears (Smith, 1976; Kingsley, 1990). In some areas, mortality from fox predation may be as high as 40% (Smith, 1976).

During summer, ringed seals are dispersed throughout open-water areas. Some disperse to offshore areas after the landfast ice breaks up in summer (Heide-Jørgensen et al., 1992); in some regions, they move into coastal waters. Ringed seals encountered in the Alaskan Beaufort Sea during open-water seismic exploration were broadly dispersed as individuals or small groups (Harris et al., 1997; Harris et al., 1998; Lawson and Moulton, 1999; Moulton and Lawson, 2000; Lawson and Moulton, 2001; Moulton and Lawson, 2001; Moulton et al., 2002). Seasonal concentrations related to food sources are known in offshore waters of the Canadian Beaufort Sea off the Tuktoyaktuk Peninsula and off Cape Dalhousie (McLaren and Davis, 1982; Harwood and Stirling, 1992). Ringed seals feed primarily on fish (especially arctic cod) and large crustacean zooplankters such as amphipods, euphausiids, epibenthic mysids, and decapods (Bradstreet et al., 1986; Smith, 1987).

Ringed seals are capable of moving distances of 1,000 km or more during the summer (Heide-Jørgensen *et al.*, 1992; Kapel *et al.*, 1998; Teilmann *et al.*, 1999), although they tend to show site fidelity (Teilmann *et al.*, 1999).

There is very little existing information on marine mammals in the area between Bathurst Inlet and Peel Sound. As noted above, ringed seals were distributed throughout Bathurst Inlet in June 2007. Indirect evidence of the presence of ringed seals is found in the Nunavut Wildlife Harvest Study (Priest and Usher, 2004). Ringed seal harvests were reported for all four communities on Coronation Gulf (Kugluktuk, Ikaluktutiak, Kingoak, and Omingmaktok) from 1996 to 2001. The numbers of seals harvested were small in the small communities of Kingoak and Omingmaktok. Kugluktuk recorded the highest harvest, an average of approximately 280 seals per year for the five years. Most (76%) were harvested in August and September, but smaller numbers were harvested in every other month. The harvest in Cambridge Bay increased from 38 in 1996/1997 to 277 in 2000/2001, with a five-year average of approximately 96 seals per year. Most were harvested in July to September (68%) and May and June (26%) with small numbers taken in November, December, March, and April. (The numbers above include some unidentified seals, most of which are thought to be ringed seals.) Coastal Inuit of the western Kitikmeot Region reported that ringed seals were hunted year round for their meat, fat, and pelts, and that they were the most important marine mammal (Appendix F-5 of the DEIS).

2.6 Bearded Seal (*Erignathus barbatus*)

2.6.1 Range and Population Status

Bearded seals have a northern circumpolar distribution. They are distributed throughout the Canadian Arctic in relatively low densities. Uncorrected estimates of the number of bearded seals in eastern Lancaster Sound and western Baffin Bay ranged from 7400 to 9500 (Koski and Davis, 1980). Maximum densities of bearded seals in that region ranged from 0.05 to 0.24 seals/km^2 (Finley, 1976; Koski and Davis, 1979; Koski, 1980a, 1980b; Koski and Davis, 1980; Kingsley *et al.*, 1985). Canadian populations are not listed under SARA and are designated Not at Risk by COSEWIC (2007).

2.6.2 Distribution and Seasonal Movements

During winter, bearded seals are primarily restricted to areas of moving, broken pack ice. Because they have only a limited capability to maintain breathing holes in ice, most bearded seals are excluded from areas of fast ice during winter (*e.g.*, many of the channels in the Arctic Archipelago), although some use ice holes made by ringed seals. Most bearded seals undertake seasonal migrations in response to the advance and retreat of fast ice (Martell *et al.*, 1984). Limited numbers of bearded seals overwinter in polynyas (Cleator *et al.*, 1989).

The bearded seal is a benthic feeder that is most abundant in areas where it can reach the bottom to feed, usually in waters less than 200 m deep (Burns and Frost, 1983; Finley and Evans, 1983). Its preferred habitat is areas with thin, broken or rotten ice, or the floe edge (Kingsley, 1985). This species also prefers less stable ice during break-up, and tends to avoid areas heavily used by walruses (Cleator and Stirling, 1990). Throughout the year, bearded seals typically occur alone or in small groups.

There is very little existing information on marine mammals in the area between Amundsen Gulf and Peel Sound, including Coronation Gulf and Bathurst Inlet. Small numbers of bearded seals were sighted during surveys in Bathurst Inlet in June 2007 (Appendix E-9 of the DEIS). Indirect evidence of the presence of bearded seals is found in the Nunavut Wildlife Harvest Study (Priest and Usher, 2004). Bearded seal harvests were reported for all communities on Coronation Gulf except Ikaluktutiak between1996 and 2001. The numbers of seals harvested were small in all communities. Kugluktuk recorded the highest harvest, an average of two bearded seals per year for the five years. Bearded seals were taken from May to September, with the majority (50%) harvested in July. Coastal Inuit of the western Kitikmeot Region reported that bearded seals were captured only occasionally (Appendix F-5 of the DEIS).

2.7 Harp Seal (*Phoca groenlandica*)

2.7.1 Range and Population Status

Harp seals summer in the eastern and central Canadian Arctic and in European Arctic waters. They do not occur in the western Canadian Arctic. The Newfoundland stock of harp seals whelps and moults in the Gulf of St Lawrence and on the ice front in the Strait of Belle Isle during February through May. They migrate north from those areas in April and May to summer

in arctic waters. They are found in summer from northern Hudson Bay, Hudson Strait, and Davis Strait north to northern Baffin Bay and Jones Sound, west to offshore southwestern Greenland, and east through Lancaster Sound to Prince Regent Inlet, Barrow Strait, and Peel Sound. Numbers of harp seals occurring in various parts of the Canadian Arctic in summer are poorly known (Davis *et al.*, 1980).

Canadian populations of the harp seal are not listed under SARA or by COSEWIC (2007).

2.7.2 Distribution and Seasonal Movements

Harp seals are present in the High Arctic from June through October. The most important route for harp seals migrating into the central Arctic is via Lancaster Sound. Harp seals may concentrate at the southern end of the Lancaster Sound ice edge until leads open up, when they migrate westward through the leads. A steady movement of seals occurs along the northeastern coast of Baffin Island from mid June to late August with stragglers noted as late as mid September (Koski and Davis, 1979). Most of the animals that enter Lancaster Sound are adults (Davis *et al.*, 1980).

Most of the estimated 150,000 harp seals that may enter Lancaster Sound do not move as far west as Barrow Strait (Finley, 1976). Most summer in the eastern portions of the arctic archipelago, especially in Croker Bay, Admiralty Inlet, and northern Navy Board Inlet (Johnson *et al.*, 1976; Koski and Davis, 1979; Fallis *et al.*, 1983). However, in some years several thousand travel as far west as Barrow Strait and Peel Sound (Finley, 1976; Finley and Johnston, 1977). Ice permitting, they can appear in the Barrow Strait area in early July. They also occur in Wellington Channel (Johnson *et al.*, 1976; Koski and Davis, 1979; Fallis *et al.*, 1983). Harp seals may concentrate at the Peel Sound ice edge and then migrate south into the sound as ice breaks up. They cross Bellot Strait, between Somerset Island and the Boothia Peninsula (Finley and Johnston, 1977; Smith and Martin, 1994), although Bellot Strait likely is not an important migration route for marine mammals (Finley and Johnston, 1977). Harp seals have been harvested much further south, in Gjoa Haven, King William Island (Priest and Usher, 2004).

Harp seals migrate out of Barrow Strait during August and most have departed by late August (Finley, 1976), although some were found in Peel Sound as late as mid and late September. They were swimming north, presumably migrating out of the sound (Finley and Johnston, 1977). Harp seals may leave the Bellot Strait area in Prince Regent Inlet in early September.

Harp seals are gregarious and often travel in groups of up to 100 (Koski and Davis, 1979), or even up to 500 when on the summer range (Fallis *et al.*, 1983). Large congregations can be found almost anywhere within their summer range. Harp seals will concentrate to feed on their principal prey, the arctic cod, which itself congregates in large numbers (Finley *et al.*, 1990b). Harp seals will haul out on ice pans while on their summer range.

Harp seals depart the Lancaster Sound region in late September. They remain along the coasts until the outbound migration, which coincides with the formation of pan ice in offshore waters in mid to late September (Koski and Davis, 1980). There can be large numbers in offshore waters, but they are widely dispersed (Koski and Davis, 1980). The outbound movement along the north

shore of Lancaster Sound is protracted, lasting from spring through summer to fall. The outbound migration along the south shore of Lancaster Sound can be approximately two weeks in duration in late September (Koski and Davis, 1980). Most harp seals have departed the region by October.

2.8 Other Species

Project interactions with the following two species are possible but unlikely.

2.8.1 Killer Whale (*Orcinus orca*)

The killer whale ranges from the Atlantic Ocean up into Davis Strait as far north as Lancaster Sound, and there are a few known areas where killer whales are regularly sighted: in Cumberland Sound, Lancaster Sound, and Pond Inlet (Baird, 2001). Killer whales avoid areas of heavy ice, so do not penetrate far into the arctic archipelago (Davis *et al.*, 1980); they are uncommon in northern Baffin Bay and Lancaster Sound from August to October (Koski and Davis, 1979). They are found only rarely along or within pack ice (Reeves *et al.*, 2002), so they probably remain in northern areas until forced south by pack ice formation (APP, 1982). Killer whales prefer coastal areas, but also occur in deep water (Dahlheim and Matkin, 1994).

2.8.2 Hooded Seal (*Crystophora cristata*)

Hooded seals are sometimes seen in Lancaster Sound during the summer. Western Atlantic hooded seals whelp and breed in March on ice floes off northern Newfoundland and southern Labrador and in Davis Strait (Sergeant, 1976). Most migrate north to western Greenland and then to the Denmark Strait to moult, but small numbers reach the eastern Lancaster Sound-western Baffin Bay area in summer. Their routes into (and out of) the area are unknown.

3. METHODOLOGY

3. Methodology

3.1 Valued Ecosystem Component Selection

An essential element in preparing an Environmental Impact Statement is to identify the environmental components that could be affected by, or have an influence on, the proposed development. It is necessary to focus the assessment on those components that will have the greatest relevance to the particular circumstances of the Project. These will include components that are of particular value or sensitivity and that have a meaningful potential to be affected by the development, or VECs. A VEC is defined by CEA Agency (1999) as:

> *Any part of the environment that is considered important by the proponent, public, scientists and government involved in the assessment process. Importance may be determined on the basis of cultural values or scientific concern.*

For the Project, the determination of VECs was guided by the public scoping undertaken during preparation of the *Final EIS Guidelines* (NIRB, 2004), Traditional and Community Knowledge, community consultation, results of baseline studies, and issues and concerns raised by environmental specialists. To be considered a VEC, a component must be known to occur in, or be applicable to, the Project study area and there must be a reasonable likelihood that it would be affected by the Project.

Marine mammal VECs, and their reason for selection, are as follows:

The **bowhead whale** could be affected by vessel traffic along the shipping route. The stock that occurs there, the Davis Strait-Baffin Bay stock, is listed under Schedule 2 of the *Species at Risk Act* (SARA) as Endangered (*i.e.*, facing imminent extirpation or extinction). They are designated Threatened by COSEWIC (2007) (*i.e.*, likely to become endangered if limiting factors are not reversed).

The **beluga** could be affected by vessel traffic along the shipping route and by activities during construction and operation of the port in Bathurst Inlet. The stock that occurs along the shipping route, the High Arctic–Baffin Bay stock, is listed under Schedule 3 of SARA as Special Concern and designated Special Concern by COSEWIC (2007) (*i.e.*, may become a threatened or an endangered species because of a combination of biological characteristics and identified threats). There are known important concentration areas and migration routes along the shipping route. The beluga is also a subsistence harvest species.

The **narwhal** could be affected by vessel traffic along the shipping route. The narwhal is not listed under SARA, but is designated as a species of Special Concern by COSEWIC (2007). Narwhal migrate offshore along part of the shipping route.

The **walrus** could be affected by vessel traffic along the shipping route. The Canadian walrus population is not listed under SARA but is designated as a species of Special Concern by COSEWIC (2007).

The **ringed seal** could be affected by vessel traffic along the shipping route and by activities during construction and operation of the port in Bathurst Inlet. Canadian populations are not listed under SARA and are designated Not at Risk by COSEWIC (2007). However, the subsistence harvest of the ringed seal is of great importance to the coastal Inuit of the western Kitikmeot Region.

3.2 Boundaries

3.2.1 Spatial Boundaries

3.2.1.1 Local Study Area

For the purposes of this environmental assessment, the local study area for marine mammals will include:

1. the marine area from the water surface to the seabed that will be developed for port operations; and
2. the shipping route from Lancaster Sound (north of Arctic Bay) to the proposed Port location, which has not been used previously for the regular shipping of fuel.

3.2.1.2 Regional Study Area

For the purposes of this environmental assessment, the regional study area boundaries were determined on the basis of the potential impacts of Project-generated noise on marine mammals. The regional study area is defined as:

1. the area within 5 km around the port site; and
2. the area within 5 km to either side of the shipping route from Bathurst Inlet to Lancaster Sound.

Many, if not all, marine mammals will certainly hear sounds from the construction activities in Bathurst Inlet and ships on the shipping route far beyond 5 km, but disturbance effects are not likely to extend much (if any) beyond 5 km in open water. There will be some masking of low-frequency sounds out to greater distances, so some masking effects on baleen whales are theoretically possible beyond 5 km from the shipping route. However, this would be transient and not very severe at $\geq$5 km.

3.2.2 Temporal Boundaries

The temporal boundaries for effects on marine mammals are the anticipated lengths of the various Project phases:

1. construction (30 months);
2. operation and maintenance (estimated 19 years); and
3. decommissioning and closure (approximately 1 year).

There are no anticipated effects on marine mammals during the post-closure phase.

3.3 Approach and Methods

The assessment is based on the results of previous studies and professional judgment. Considerable research on marine mammals in the Canadian Arctic has been carried out, particularly since the 1970s, both on behalf of the oil and gas industry and by government researchers. The professionals who conducted this assessment have more than 30 years experience in environmental assessment, and conducted much of the research pursuant to oil and gas development in the 1970s. Areas for which little or no information were available were surveyed as a part of this assessment: Bathurst Inlet in summer 2004 (Appendix E-8 of the DEIS) and spring 2007 (Appendix E-9 of the DEIS), and the shipping route from Bathurst Inlet to Franklin Strait in summer 2004 (Appendix E-8 of the DEIS).

4. EFFECTS ASSESSMENT

4. Effects Assessment

4.1 Port Construction

Port construction will occur mostly during the open-water season. The only construction activities that could affect marine mammals are aircraft overflights, small oil spills during fuel transfer, and pile driving. Port construction will not involve marine blasting or dredging.

4.1.1 Pile Driving

Pile driving the steel sheet pile cells into the bottom sediment at the face of the dock could be carried out from the ice in spring, from a barge in open water months, or from the land side using a fill-approach method. Pile drivers include a heavy weight placed between guides so that it is able to slide freely up and down in a single line. The weight is raised and dropped onto the pile, driving it into the sediment. The diesel pile driver used to construct the pile footings for an aviation fuel receiving facility in 6 to 8 m of water near the Hong Kong International Airport consisted of a 6-tonne diesel hammer that fell by gravity between 1.0 and 1.5 m during each stroke, detonating a fuel-air mixture to drive down the piling. Blow heights and detonation explosions varied with substrate hardness (and other mechanical features), and maximum blows corresponded to approximately 90 kJ of energy. Rates of blows were between 57 and 81/min (Würsig *et al.*, 2000). At the Northstar artificial island off Prudhoe Bay, Alaska, in June and July 2000, the diesel pile driver used to drive 51- and 107-cm diameter pipes consisted of a 13-tonne diesel hammer that fell by gravity approximately 3.4 m. Rates of blows were between 36 and 50/min, and blows produced approximately 224 kJ of energy (Blackwell *et al.*, 2004).

Pile driving transmits most of its considerable noise energy into air and water during a 40-ms period per blow (Würsig *et al.*, 2000). The underwater noise created by pile driving has its highest energy at lower frequencies, from ~20 Hz to 1 kHz (Green Jr., 1987). The received broadband sound pressure levels for pulses from the pile driver used in Hong Kong were between 160 and 170, between 150 and 160, and approximately 148 dB re 1 μPa_{rms}[1] at distances of 250 m, 500 m, and 1,000 m from the pile-driver, respectively (Würsig *et al.*, 2000). During July (the open-water period) at Northstar, mean received broadband sound pressure levels for pulses from the pile driver were 157 and approximately 130 dB re 1 μPa_{rms} at distances of 63 m and 1110 m from the pile driver, respectively (Blackwell *et al.*, 2004).

The only marine mammal likely to be present in Bathurst Inlet during pile driving is the ringed seal. Pile driving during the ice-covered period and the open-water period has the potential to impact ringed seals. During the sensitive periods of birth and pup dependence from April to mid-June, pile-driving noise could cause adult seals close to the port site to abandon lairs or pups, or

[1] Sound measurements are ratios of pressures, which requires a standard reference pressure for use in the denominator of the ratio; the underwater sound community has adopted 1 µPa as the reference pressure. The rms (root mean square) pressure is an average over the pulse duration.

startle pups to the extent that they enter the water and suffer hypothermia. During the open-water period, pile-driving noise could cause avoidance reactions or hearing damage in ringed seals.

As noted above, pile-driving noise in spring could startle pups to the extent that they enter the water and suffer hypothermia. Newborn pups can and do enter the water to escape predation, but they must return to the birth lair to prevent hypothermia. If hypothermia did cause mortality in seal pups, only very small numbers would be involved, especially given the low number of seal holes near the port site (see Appendix E-8 of the DEIS). It is very unlikely that such mortality, if it occurred, would have effects at the population level; in some areas, mortality from fox predation may be as high as 40% (Smith, 1976), and the ringed seal is the most abundant marine mammal in the Arctic. Studies conducted prior to and during the construction and operation of an offshore artificial drilling island (NorthStar) in the Alaskan Beaufort Sea, which included pile driving from March to May, found that seal densities during spring were not significantly affected by proximity to Northstar (Moulton *et al.*, 2005). Active seal structures (breathing holes and lairs) were found within ~1 km of Northstar, and one pupping lair was located between two ice roads, as close as 140 m from the nearest road (Williams *et al.*, 2001).

During 55 h of observation at Northstar in 2000, none of the 23 observed ringed seals appeared to react adversely to acoustic or visual stimuli arising from construction activities on the island, which included pile driving, and most appeared either indifferent or curious. Ringed seals swam in open water near the island throughout construction activities and as close as 46 m from the pile-driving operation (Blackwell *et al.*, 2004). There was no clear indication that sound and vibration from industrial activities at Northstar in 2000 and 2001 reduced the density of ringed seals near Northstar; in fact, in 2001 significantly higher densities of ringed seals occurred close to Northstar than farther away (Moulton *et al.*, 2003).

Belugas likely will not be in Bathurst Inlet during port construction, but the possibility exists, as it seems that a few beluga reach Coronation Gulf or farther east every few years. There have been no reports of the reactions of belugas to pile driving, but their hearing sensitivity, like other small odontocetes whose hearing has been tested, is quite poor at frequencies where pile-driving noise has its highest energy, <1 kHz (Richardson *et al.*, 1995). Würsig *et al*. (2000) tracked Indo-pacific hump-backed dolphins that occurred between 300 and 500 m of the pile-driving in Hong Kong. The dolphins did not change patterns of general orientation between pile-driving and no pile-driving conditions, but they travelled at speeds over twice as rapidly with than without pile driving. During the construction of an offshore wind farm in the Baltic Sea that involved intermittent pile driving for 25 days, harbour porpoises either largely avoided the construction area or did not avoid it but used their echolocation signals much less often (Carstensen *et al.*, 2006).

Based on existing literature and given the mitigation measures described in Section 5.1, there likely would be no effects of pile driving on ringed seals during port construction in the ice-covered or the open-water period. If belugas are present, which is doubtful, the only likely effects would be transitory disturbance. The residual direct and adverse Project-specific effects of pile driving during port construction are predicted to be of negligible significance (Table 4.1-1) because they would have or be:

Table 4.1-1
Summary of Effects Assessment for Marine Mammals

Description of Potential Effect					Mitigation and Enhancement	Evaluation of Residual Effect										
	Project Phase (Timing)	**Project Component**	**Direction**	**Nature**			**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological Context (Resilience)**	**Influence on Resource Capacity**	**Probability of Occurrence**	**Significance**	**Confidence Level**
	Construction	Port Site	Beneficial	Direct			Negligible	Local	Short Term	One Time	Short Term	High	Nil	Low	Negligible	High
	Operations	All-Weather Road	Adverse	Indirect			Low	Landscape	Medium Term	Sporadic	Long Term	Neutral	Low	Moderate	Low	Intermediate
	Decommissioning	Shipping Lane	Neutral	Cumulative	**(Design Changes, Management,**	**Description of Residual Effect**	Moderate	Regional	Long Term	Regular	Irreversible	Low	Moderate	High	Moderate	Low
Description	Post-Closure	Human Resources		Synergistic	**Monitoring, Compensation, Enhancement)**	**(after mitigation) [1]**	High	Trans-Boundary	Far Future	Continuous			High		High	
Noise from pile driving	Construction	Port Site	Adverse	Direct	None required	Disturbance	Negligible or low	Landscape	Short Term	One Time	Short Term	High	Nil	Low	Negligible	Intermediate
Small fuel spills during transfers	Construction, Operations	Port Site	Adverse	Direct	Oil spill response plan	Disturbance	Negligible or low	Local	Short Term	Sporadic	Short Term	High	Nil	Low	Negligible	Intermediate
Aircraft disturbance	Construction, Operations	Port Site	Adverse	Direct	Route and altitude restrictions	Disturbance	Negligible or low	Local	Short Term	Sporadic	Short Term	High	Nil	Low	Negligible	Intermediate
Collisions on shipping route	Operations	Shipping Lane	Adverse	Direct	Vessel speed, route, precautions	Injury or mortality	Negligible or low	Local	Short Term	Sporadic	Short Term	High	Nil	Low	Negligible	Intermediate
Disturbance, displacement on shipping route	Operations	Shipping Lane	Adverse	Direct	Vessel speed, route, precautions	Disturbance	Negligible or low	Landscape	Short Term	Sporadic	Short Term	High	Nil	Low or moderate	Negligible	Intermediate
Major oil spill	Operations	Shipping Lane	Adverse	Direct	Oil spill response plan	Disturbance (whales and seals), injury or mortality (seals)	Negligible or low	Landscape	Short Term	Sporadic	Short Term	High	Nil	Low	Negligible	Intermediate

1. If there NO residual effect after mitigation there is no need for further evaluation

- low probability of occurrence for beluga and ringed seals;
- of negligible or low magnitude;
- of landscape spatial extent (<5 km);
- short term (two months) and only once; and
- reversible in the short term.

4.1.2 Aircraft Overflights

During the Construction and Operations phases, there will be two Dash 8 aircraft flights a week for staff shift changes. Aircraft overflights during winter and spring could disturb ringed seals to the extent that they enter the water. During the spring birthing and pupping period, adult seals could abandon lairs or pups, or pups could enter the water and be exposed to hypothermia. During the open water period, overflights could disturb ringed seals and belugas near the flight paths.

Ringed seals hauled out on the ice may dive when approached by a low-flying aircraft or helicopter (Burns and Harbo Jr., 1972; Alliston, 1981; Burns and Frost, 1983), although they do not always do so (Burns *et al.*, 1982). Specific details on aircraft altitude and distance from the seals were not reported. Finley (Finley, 1976) flew over ringed seals hauled out along a 10.8-km long aerial survey transect in Barrow Strait 31 times at an altitude 91 m, and was unable to detect any decline in seal numbers that could be attributed to the aircraft disturbance. During aerial surveys of Bathurst Inlet in June 2007 from a single-engine Beaver flying at 91 m, most ringed seals did not exhibit any obvious negative response to the aircraft as it flew overhead. Almost half (43.8%) showed no obvious response, 37.2% looked up at the aircraft, 9.5% moved on the ice, and 8.7% dove into their holes or cracks in apparent response to the aircraft (Appendix E-9 of the DEIS). The noise received by a seal in a subnivean lair is reduced by the snow, especially at high frequencies (*e.g.*, ~10 kHz) (Cummings and Holliday, 1983).

The reactions of swimming ringed seals to aircraft overflights have not been documented. Swimming seals are generally considered to be less susceptible to airborne disturbance than are seals that are hauled-out (Richardson *et al.*, 1989).

Reactions of whales to aircraft have been reported less often than reactions of pinnipeds. Bel'kovich (1960) and Kleinenberg *et al.* (1964) reported that belugas did not react to an aircraft flying at 500 m, but when it descended to 150–200 m, they dove for longer periods, had shorter surface intervals, and sometimes swam away. Feeding belugas were reportedly less prone to disturbance, whereas lone animals dove even when the aircraft was at 500 m.

Belugas in shallow summering areas also react to aircraft, often by swimming away (Fraker and Fraker, 1979; Finley, 1982; Finley *et al.*, 1982; Gales, 1982). When Inupiat hunters concluded that low-flying aircraft were preventing belugas from entering Eschscholtz Bay, Alaska, the timing of aircraft traffic was adjusted to reduce the suspected interference (Burns and Seaman, 1985). Aerial surveys of the Mackenzie estuary in a Cessna 185 aircraft (single engine, piston) at 300 m provoked only occasional mild responses from belugas (Fraker and Richardson, 1980). However, when the aircraft circled or repeatedly flew over at the same height, the whales swam away from the area.

Because of the mitigation measures described in the next section, the likelihood of an aircraft flying at low altitude over ringed seals or belugas would be very low. The residual direct and adverse Project-specific effects of aircraft overflights are predicted to be of negligible significance (Table 4.1-1) because they would have or be

- low probability of occurrence for beluga and ringed seals;
- of negligible or low magnitude;
- of local spatial extent (<1,000 m);
- short term (<1 day) and sporadic (two times per week); and
- reversible in the short term.

4.1.3 Oil spills

Small oil spills could occur while fuel is being transferred from the tankers to the dock and from the dock to barges. As discussed in more detail below for large oil spills, marine mammals, especially cetaceans, are not very susceptible to oil. Given the mitigation measures mentioned in the following section, effects of small, fuel-transfer related spills in the port are predicted to be of negligible significance because they would have or be

- low probability of occurrence belugas and ringed seals;
- of negligible or low magnitude;
- of local spatial extent (<1000 m);
- short term (<1 day) and sporadic; and
- reversible in the short term.

4.2 Shipping Route

Vessel traffic associated with the Project includes barges and large (up to 50,000 DWT) tankers capable of carrying oil/bulk/ores and ice strengthened to Type B to CAC 2 Ice Class. All vessel traffic will be during the summer open-water period. Tug-assisted, 1,000- to 2,000-tonne capacity ocean barges will carry construction materials and camp supplies from Hay River to Bathurst Inlet during the construction phase, and will make 7 trips annually to deliver supplies to Kitikmeot communities during the operations phase. The tankers will carry cargo and diesel fuel to Bathurst Inlet an estimated six to eight times per year during the operations phase, and carry away non-combustible and hazardous waste (if any).

In keeping with the final EIS guidelines for this Project (NIRB, 2004), only the shipping route from Lancaster Sound to the proposed port location, which has not been used previously for the regular shipping of fuel, is included in this assessment. In keeping with the West Kitikmeot Land Use Plan, the shipping season will end on 15 October.

Populations of marine mammals potentially could be affected by shipping activities associated with the Project on the shipping route between Bathurst Inlet and Lancaster Sound during the operations phase. Specific concerns include

- risk of collisions with vessels;
- alteration of movement patterns and distributions as a result of disturbance by vessels;
- increased potential for exposure to contaminants as a result of spills (*e.g.*, fuel).

4.2.1 Likelihood of Interactions

Most of the marine mammals in the study area likely would not come into close contact with vessels on the shipping route during the shipping season because of their distribution or preferred habitats, as summarized below and discussed in more detail in Chapter 2. The shipping route is located well offshore or in mid-channel except in Bathurst Inlet itself, whereas many of the marine mammals are coastal, and some are found only in low numbers along the shipping routes.

- Very few, if any, cetaceans or walruses would be encountered between Bathurst Inlet and Franklin Strait, about half of the shipping route.
- Only a few bowhead whales occur in the Peel Sound/Franklin Strait area and in Barrow Strait; most bowheads between Bathurst Inlet and Lancaster Sound summer in Prince Regent Inlet, Admiralty Inlet, and Eclipse Sound. When they migrate in and out through Lancaster Sound, they remain very close to shore.
- Belugas are coastal during the early open-water period (mid July to mid August), generally congregating in shallow estuaries on the north and east coasts of Somerset Island. By mid August, most abandon the estuaries, and a large proportion shift to Peel Sound and northern Franklin Strait until fall migration begins in early to mid September. There, they use several bays on eastern Prince of Wales Island, western Boothia Peninsula, and western Somerset Island, making daily trips to a deep-water area offshore in Peel Sound called the Franklin Trench. They begin to depart in late August and early September, and a rapid fall migration occurs in mid to late September and is concentrated close along the south coast of Devon Island. In the west, belugas rarely enter Coronation Gulf, but occasionally have been seen or taken in Bathurst Inlet and near Kugluktuk, Ikaluktutiak, and Gjoa Haven.
- Narwhal prefer deep-water fiords, inlets, and channels, and most summer away from the shipping route, in Prince Regent Inlet, Admiralty Inlet, Navy Board Inlet, and Eclipse Sound. Only small numbers of narwhals summer in Barrow Strait and Peel Sound.
- During fall migration back to Baffin Bay via Lancaster Sound, narwhals are dispersed in open water and remain there as long as open water permits.
- Migration of walrus westward into the central Arctic through Lancaster Sound usually peaks in July and occurs primarily along the south coast of Devon and Cornwallis islands. Walrus are bottom feeders, largely restricted to water depths <200 m. Their summer range is centred on Cornwallis Island, Bathurst Island, and western Devon Island, north of the shipping route. Very few walruses use the offshore waters and south

shores of Barrow Strait, the west shores of Prince Regent Inlet and the Gulf of Boothia, or Peel Sound. Fall migration out of the central High Arctic in eastern Lancaster Sound begins at the end of September and may peak in mid October, and occurs along the south coast of Devon Island.

- During summer, ringed seals are dispersed throughout open-water areas singly or in small groups.

The relatively few times and locations when marine mammals could occur near the shipping route during the shipping season are as follows:

- A few bowheads occur in the Peel Sound/Franklin Strait area and in Barrow Strait during August and September.
- Belugas occur in deep-water area offshore in Peel Sound called the Franklin Trench from mid August to early to mid September.
- Narwhal occur only in small numbers in Barrow Strait and Peel Sound during August and September. During fall migration back to Baffin Bay via Lancaster Sound, narwhals are dispersed in open water and remain there as long as open water permits.
- Very few walruses occur in Peel Sound or the offshore waters and south shores of Barrow Strait.

4.2.2 Collisions

The probability of collisions between vessels and marine mammals is very low, but on infrequent occasions whales and ships do collide, resulting in injury or death to the whale (Laist *et al*., 2001; (Moore and Clarke, 2002). Most of the marine mammals near the shipping route are relatively small and agile, and likely would avoid vessels. The bowhead whale and other baleen whales are large, slow-moving whales, and are more susceptible to collisions. Of large whale strikes that have been documented, fin whales are struck most frequently, and right, humpback, sperm, and gray whales are hit commonly (Laist *et al.*, 2001; Jensen and Silber, 2004). There are no records, to our knowledge, of mortality from collisions involving bowhead whales, which is probably attributable at least in part to their avoidance reactions. Examination of 236 subsistence-harvested bowhead whales between 1976 and 1992 for scarring revealed two or three animals with lacerations attributed to a large ship's propeller, indicating that the incidence of ship collisions with bowheads was quite low (~1%). It was suggested that the low level was probably largely attributable to the comparatively small amount of vessel traffic, but also to the possibility that many do not survive the collision (George *et al.*, 1994). Philo *et al.* (1992) concluded that the number of animals succumbing to such injuries is likely very low, based on the rarity of beach-cast animals bearing such injuries. Very few (if any) bowheads would occur on the shipping route, and only between Franklin Strait and Lancaster Sound.

The residual direct and adverse Project-specific effects on marine mammal populations of collisions with vessels on the shipping route are predicted to be of negligible significance (Table 4.1-1) because they would have or be:

- low probability of occurrence;

- of negligible or low magnitude;
- of local spatial extent;
- short term and sporadic, if at all; and
- reversible in the short term.

4.2.3 Disturbance

In general, bowhead whales react strongly to a variety of types and sizes of approaching vessels, interrupting their normal activities and swimming rapidly away; they can be displaced by as much as a few km when fleeing from vessels, but have been observed to return to feeding locations within a day after being displaced (Richardson and Malme, 1991; Richardson *et al.*, 1995). Bowheads are more tolerant of vessels moving slowly or in directions other than toward the whales. Bowheads actively engaged in social interactions or mating may be less responsive to boats (Wartzok *et al*., *unpublished data*). The only effect that could occur at distances greater than 5 km from the shipping route would be masking effects of low-frequency sounds on bowhead whales. However, this would be transient and not very severe at greater than 5 km.

In most situations, belugas are quite tolerant of vessels. Noise from large vessels such as the 50,000 DWT tankers proposed for this Project is predominantly low frequency (<1 kHz), where beluga hearing is poor; belugas hear best at frequencies 10–15 kHz (Richardson *et al.*, 1995). Belugas that are hunted from power boats in traditional estuarine concentration areas return each summer, even though hunting causes rapid movement away from approaching boats and short-term displacement, and can change local distribution (Fraker, 1980; Caron and Smith, 1990; Lerczak *et al.*, 2000). They are also tolerant of the frequent passages by larger vessels travelling in consistent directions in summering areas (Pippard, 1985; Sergeant, 1986), and they feed amid hundreds of salmon fishing boats in Bristol Bay, Alaska (Frost *et al.*, 1984). On the other hand, decreased abundance of belugas in Norton Bay, Alaska during summer has been attributed to the noise from processor ships and the increase in quantity and frequency of boat traffic associated with the commercial herring fishery that started in the 1970s (Huntington, 1999).

Belugas are known to be sensitive in two situations. When approached by fast, erratically moving small boats, as is typical during the subsistence hunt, belugas flee towards shore (Savelle, 1995). Belugas are also sensitive when exposed to noise from ships and icebreakers in deep channels of the Canadian High Arctic in spring. In studies carried out at ice edges in Lancaster Sound and Admiralty Inlet in 1982, 1983, and 1984, belugas detected an approaching ship over 80 km away, at which point they made “alarm” calls; they showed strong avoidance reactions at distances of 30 to 50 km, formed into herds with a loss of pod integrity, and moved rapidly along ice edges away from approaching ships (Finley *et al.*, 1990b). The Inuit recognize this combination of behaviours as *ardlingayuk*, fear of killer whales, the only significant natural predator of belugas in the Arctic. The degree of displacement appeared to depend on the proximity of coastal waters; animals on the side of the ship closest to the shore stopped fleeing when they reached shore 18 km from the ships, whereas those on the offshore side travelled as much as 80 km until they reached the opposite shore (Finley *et al.*, 1990b).

In the same study as that discussed immediately above, narwhals reacted very differently than did beluga. Narwhals did not form large herds, their movements were slow or they were motionless near the ice edge, and they huddled together in pods. They ceased vocalizing temporarily, and dispersed slowly along the ice edge or offshore as the ships approached. Narwhals returned to disturbance areas much faster than did belugas, and showed little or no change in vocal activity or surface behaviour when received levels from ice-breaking were as high as 120 dB re 1 μPa (Finley *et al.*, 1990b). Savelle reported similar behaviour during subsistence hunting; their immediate response to a perceived threat was to lie motionless below the surface of the water, and when they did flee, they fled toward deeper water.

Seals do not appear to respond as strongly to vessels and, in some areas, are commonly observed close to vessels (Harris *et al.*, 2001; Miller and Davis, 2002; Miller and Moulton, 2003). Some seals are likely to avoid approaching vessels by a few metres to tens of metres, whereas some curious seals are likely to swim toward vessels. Any disturbance of ringed seals would be transitory.

Given the distribution of marine mammals along the shipping route, the transitory disturbance that would be the only likely effect of any encounter, and the mitigation measures described in the next section, the residual direct and adverse Project-specific effects of vessel traffic along shipping routes are predicted to be of negligible significance (Table 4.1-1) because they would have or be:

- low probability of occurrence for bowheads and walrus or moderate probability of occurrence for beluga, narwhal, and ringed seals;
- of negligible or low magnitude;
- of landscape spatial extent (<5 km or, for masking in bowhead whales, <10 km);
- short term (<1 day) and sporadic (six to eight times per open-water season); and
- reversible in the short term.

4.2.4 Oil Spills

The most serious accident that could occur would be one that released a large amount of oil into the marine environment, *e.g.*, a hull breach. A detailed discussion of oil spill modeling, fate and behaviour impacts are presented in Appendix E-6 of the DEIS. There will be no cargoes of crude oil, only diesel fuel. In cold water, about 50% of spilled diesel oil would be left on the surface after about 12 h (Smith and McIntyre, 1971; Birchard and Nancarrow, 1986). About 50% of the oil lost from the surface is dispersed in the water and 50% is lost through evaporation.

Marine mammals that rely on fur rather than a layer of blubber for insulation are most vulnerable to effects of oil spills. The only marine mammal VECs in the study area that do so are new-born seal pups less than 3–4 weeks old, which are born in April, mostly on landfast ice. There will be no vessel traffic at that time of year.

Marine mammals that do not rely on fur for insulation are much less vulnerable because oiling of the external surface does not appear to have any adverse thermoregulatory effects (Kooyman *et al.*, 1976; Kooyman *et al.*, 1977; Geraci, 1990; St. Aubin, 1990). Contact with oil on the external surfaces can, however, cause increased stress and can irritate the eyes of ringed seals (Geraci and Smith, 1976; St. Aubin, 1990). These effects seem to be temporary and reversible, but continued exposure to eyes could cause permanent damage (St. Aubin, 1990). Effects of oiling on cetacean skin appear to be minor and of little significance to the animals' heat balance (Geraci, 1990).

Marine mammals can ingest oil if their food is contaminated, and oil can also be absorbed through the respiratory tract (Geraci and Smith, 1976; Engelhardt *et al.*, 1977). Some of the ingested oil is voided in vomit or faeces or metabolized at rates that prevent significant bioaccumulation (Neff, 1985 *in* Hartung, 1995), but some is absorbed and can cause toxic effects (Engelhardt, 1981). These effects may include minor kidney, liver, and brain lesions (Geraci and Smith, 1976; Spraker *et al.*, 1994). When returned to clean water, contaminated animals can depurate this internal oil (Engelhardt, 1978, 1982); marine mammals extensively metabolize aromatic compounds in their livers and metabolites are excreted. Whales or seals exposed to an oil spill are unlikely to ingest enough oil to cause serious internal damage (Geraci and St. Aubin, 1980, 1982). Only small traces of oil were found in the blubber of a gray whale and liver of a killer whale, and there no significant quantities of oil in the tissues (liver, blubber, kidney, and skeletal muscles) of harbor seals exposed to *Exxon Valdez* oil (Bence and Burns, 1995).

In baleen whales, oil could coat the baleen and reduce filtration efficiency, but effects can be reversible within a few days (Richardson *et al.*, 1989; Geraci, 1990). Effects of oiling of the baleen on feeding efficiency appear to be only minor (Geraci, 1990). Light diesel oil is not likely to cause much reduction in efficiency.

There is no clear evidence that implicates oil spills, including the much-studied *Santa Barbara* and *Exxon Valdez* spills, with mortality of cetaceans (Geraci, 1990). Migrating gray whales were apparently not adversely affected by the *Santa Barbara* spill. There appeared to be no relationship between the spill and mortality of marine mammals. The higher than usual counts of dead marine mammals recorded after the spill was a result of increased survey effort related to the spill (Geraci, 1990). The conclusion was that whales were either able to detect the oil and avoid it or were unaffected by it (Geraci, 1990). There was a significant decrease in the size of a killer whale pod resident in the area of the *Exxon Valdez* spill, but no clear cause and effect relationship between the spill and the decline could be established (Dahlheim and Matkin, 1994). There was no apparent change in abundance, movement out of Prince William Sound, or other evident effects on humpback whale resulting from the *Exxon Valdez* spill (von Ziegesar *et al.*, 1994; Loughlin *et al.*, 1996).

Reports of the effects of oil spills and blowouts have shown that some mortality of hair seals may have occurred as a result of oil fouling; however, large-scale mortality has never been observed (St. Aubin, 1990). The largest effect of a spill was on young hair seals in cold water (St. Aubin, 1990). It is believed that 10,000 to 15,000 harp seals were coated with oil from a ruptured storage tank in New Brunswick in 1969, but the exact number of dead seals recovered is unknown (Sergeant, 1991). The release of fuel oil from the *Arrow* into Chedabucto Bay, Nova

Scotia, in 1970 resulted in the fouling of 500 seals within the bay and 50–60 harbor and 200 gray seals on Sable Island, 200 km south of the spill. Twenty-four seals were found dead and some had oil in their mouths and stomachs (St. Aubin, 1990). Oiled gray and harbor seals were found on the coast of Nova Scotia and Sable Island again in 1979 when the oil tanker *Kurdistan* sank in Cabot Strait. No causal relationship between oiling and death was determined (Parsons *et al.* 1980 *in* St. Aubin 1990). No mortalities were reported after a well blowout near Sable Island in 1984 and only two oiled gray seals were observed (St. Aubin, 1990). Frost *et al*. (1999) estimated that at least 302 harbor seals likely died as a result of the *Exxon Valdez* spill, but a subsequent reassessment of the impact on harbor seals concluded that available evidence did not support high mortality but was more consistent with seals avoiding some oiled haul-out sites. Only 14 dead seals (11 pups) were recovered following the spill, and the cause of death in most cases could not be determined nor could the natural rate of mortality. Analysis of all pre- and post-spill trend count data for harbor seals strongly suggest that effects of the spill were limited and transitory (Hoover-Miller *et al.*, 2001).

Studies of both captive and wild cetaceans indicate that they can detect oil spills. Captive bottlenose dolphins (*Tursiops truncatus*) avoided most oil conditions during daylight and darkness, but had difficulty detecting a thin sheen of oil (St. Aubin *et al.*, 1985). Wild bottlenose dolphins exposed to the *Mega Borg* oil spill in 1990 appeared to detect, but did not consistently avoid contact with, most oil types (Smultea and Würsig, 1995). This is consistent with other cetaceans behaving normally in the presence of oil (Harvey and Dahlheim, 1994; Matkin *et al.*, 1994). Humpback whales were not observed swimming in oil from the Exxon Valdez spill whereas killer whales were observed swimming in oiled water (Loughlin *et al.*, 1996). It is possible that cetaceans swim through oil because of an overriding behavioural motivation (for example, feeding). Some evidence exists that indicates dolphins attempt to minimize contact with surface oil by decreasing their respiration rate and increasing dive duration (Smultea and Würsig, 1995).

With the exception of ringed seals, marine mammals likely would not be encountered along approximately half of the eastern shipping route, from Bathurst Inlet to Franklin Strait. An oil spill along the rest of the route likely would have only minor and transient effects on cetaceans unless the spill occurred near whale concentrations, especially in confined situations. A number of ringed, bearded, and harp seals could become oiled with consequent mortality, but evidence from other spills indicates that numbers would be small.

Given the mitigation measures mentioned in the following section, effects of a large oil spill on the shipping route are predicted to of negligible significance (Table 4.1-1) because they would:

- have a low probability of occurrence;
- be of negligible or low magnitude;
- be of landscape spatial extent (<5 km);
- be short term (<1 year) and sporadic (if at all); and
- be reversible in the short term.

5. MITIGATION AND MANAGEMENT PLANS

5. Mitigation and Management Plans

Mitigation and management plans are offered as recommendations and will be refined during the environmental assessment process leading to the Final Environmental Impact Statement (FEIS) and Project Certificate.

5.1 Port Construction and Operations

The only requirements for mitigation measures for marine mammals during port construction and operation are the oil spill response plan (Appendix G-4 of the DEIS) and those for aircraft overflights and timing of construction, as follows:

If pile driving takes place on the ice, the sensitive periods of birth and pup dependence from April to mid-June should be avoided.

All aircraft should:

- follow designated flight corridors over land when within 5 km of the port;
- fly at or above 600-m altitude; and
- be prohibited from flying low over marine mammals for observation or photographs.

5.2 Shipping

Vessels will use caution and operate at safe speeds consistent with weather and sea state conditions so as to be able to avoid collision with marine mammals.

Vessels will maintain a straight course and a constant speed whenever possible. These types of vessel operations provide marine mammals with an opportunity to move away from the direction of approach, while also being less disturbing to the animals.

Vessels will stay well offshore or in mid-channel unless it is unsafe to do so, and will avoid areas where marine mammals congregate. Such areas will be identified in a Marine Environmental Management Plan, which will incorporate, as a minimum, the areas identified in DFO's Marine Environmental Handbook for the Arctic Northwest Passage (DFO, 1999).

While scanning the surrounding ocean for ice and other hazards to navigation, watchstanders on the vessels will also watch for marine mammals.

If a marine mammal is detected within 500 m of the vessel and, based on its position and the relative motion, is likely to enter that area, the vessel's speed and/or direct course may, when safe, be changed to avoid the marine mammal. The marine mammal activities and movements relative to the vessel will be closely monitored to ensure that the animal does not approach within the 500 m radius.

When a mammal sighting is made, the following information about the sighting will be recorded, if possible:

- species, group size, behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from vessel, and apparent reaction to vessel (*e.g.*, none, avoidance, approach, paralleling, *etc.*).
- time, location, heading, speed, sea state, visibility, cloud cover, and sun glare.
- whether an animal approaches within 500 m of the vessel, and is so, what measures was taken to address the sighting issue.

5.3 Oil Spills on the Shipping Route

Prevention of an oil spill begins with the *Arctic Waters Pollution Prevention Act* (AWPPA), which deals with shipping in Canadian waters that lie north of 60° North latitude. The controlling regulation made under the AWPPA is called the Arctic Shipping Pollution Prevention Regulations (ASPPR). The ASPPR provides for construction and machinery standards for various classes of ice-strengthened vessels and establishes when and where in the Canadian Arctic such vessels can navigate based on their class and ice conditions in the area.

Project-specific oil spill modeling, fate and behaviour impacts are presented in Appendix E-6 of the DEIS. Mitigation measures to minimize the number of marine mammals exposed to spilled oil are to:

- have oil spill contingency plans and equipment on the vessels that transport fuel to Bathurst Inlet; this will be the responsibility of the vessel owners or operators, and the proponent will review the spill plans to ensure they are in line with the Project's environmental policy.
- navigate well clear of concentrations of marine mammals (*e.g.*, belugas moulting in estuaries on Somerset Island or congregating in bays on eastern Prince of Wales Island, terrestrial walrus haul-out sites, and coastal migration routes of belugas, bowheads, and harp seals); these concentrations are described in Chapter 2, mapped in Figure 2.1-1, and will be identified in a Marine Environmental Management Plan (see further in Section 5.2, above).

6. MONITORING AND EVALUATION

6. Monitoring and Evaluation

The only monitoring that would happen would be for marine mammals and carried out by the watchstanders on the vessels, as described in Section 5.2.

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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Appendix E-6
Marine Oil Spill Fate and Behaviour and Assessment of Effects

Author: **SL Ross Environmental Research Ltd.**
Date: **November 2007**

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Bathurst Inlet Port and Road Probability, Fate and Behaviour, and Potential Impact of Accidental Oil Spills from Marine Tankers Associated with the Project

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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

AOI	area-of-impact
bbl	billion barrels
Bbbl	10^9 bbl
EA	environmental assessment
IFO	intermediate fuel oil
MMS	U.S. Minerals Management Service
PAH	polycyclic aromatic hydrocarbon
SLROSM	SL Ross Oil Spill Model
ULSD	ultra low sulphur diesel
VEC	valued ecosystem component

1. OVERVIEW

1. Overview

This report investigates the probability, fate and behaviour, and potential impact of accidental oil spills from marine tankers associated with the Project.

The probability of spills related to the oil handling and transportation aspects of the marine component of the Project are estimated using a method developed by the U.S. Minerals Management Service (MMS) for determining the probability of large, crude oil tanker spills.

The behaviour and trajectory of oil spills that might occur during the marine shipping activities being proposed for the Project have been modeled. The spills of concern considered are vessel-based batch spills of the diesel cargo and the intermediate fuel oils used to power the tankers. A number of hypothetical oil spills that cover the main spill types and areas of concerns have been modeled and their behaviour and trajectory described in detail.

Potential impacts of the oil spills from the Project have been assessed by identifying a limited number of specific spill scenarios (oil types, spill sizes and conditions, spill locations and seasons); modeling fate and movement of spills; estimating areas of impacts (the toxic footprint) of these spills on particular types of receptors (marine birds, bare-skinned mammals, local hunting and fishing activities); and estimating the proportion of the target stock contacted by oil using information on each species vulnerability (*e.g.*, spatial distribution, level of aggregation and habits).

2. PROBABILITY OF OIL SPILLS

2. Probability of Oil Spills

2.1 Introduction

The Bathurst Inlet Port and Road Project will involve the development of a marine terminal for receiving fuel shipments by tanker through the summer shipping season. Detailed information on project components is provided in Appendix A-3 of the DEIS. Of relevance to the analysis provided in this report are the following:

- The terminal facility will have an average annual throughput of 213,070 tonnes (1.6×10^6 barrels).
- The marine terminal will be serviced by tankers with capacities up to 50,000 deadweight tonnes.

2.2 Study Objective

The objective of this portion of the study is to estimate the probability of spills related to the oil handling and transportation aspects of the Bathurst Inlet marine terminal. This will include spills related to tanker transits, and tanker unloadings and fuel barge loadings at the facility.

2.3 Tanker Related Spills

2.3.1 Study Approach

Canada has not experienced many large marine oil spills, so for spill prediction purposes one must look elsewhere for a good database on large spills. There is indeed a good database on large tanker spills that have taken place on a worldwide basis, and this can be used as a basis for estimating Canadian large spill frequencies. Because worldwide statistics are used in the analysis, the assumption is that tanker safety and navigational risks associated with the Bathurst Inlet facility are no better (or no worse) than those in the rest of the world. This is likely a conservative assumption. Current generation tankers will likely have far more safety and spill-control features than conventional crude oil tankers. However, because there are very few such tankers in the world, and because these have been in service for only a limited number of years, there is an insufficient database on spills from such ships. Therefore, spill statistics from worldwide conventional tanker operations will be used to predict spill frequencies for the Bathurst Inlet facility-related tankers.

For relatively small spills, the situation is reversed: whereas worldwide small-spill statistics are unreliable, the Canadian government maintains a database on small spills, and it is used in this study.

The approach used here is very simple. It assumes that there is a direct correlation between spill frequency and the amount of oil moved by vessel. This means, for example, that a system that has twice the oil traffic as another system will be expected to have twice as many spills.

The approach is adopted directly from a method developed by the MMS for analyzing large, crude oil tanker spills. Since 1983, MMS has analyzed worldwide tanker spills of crude oil in depth to determine the best risk exposure to use in normalizing spill data. After analyzing spill frequencies in terms of voyage length, ship size, oil volumes transported, spill location, *etc.*, it was concluded that a simple exposure of oil volumes transported (*e.g.*, billions of barrels) is as good as any in predicting risk. The most recent detailed report from MMS on the subject is Anderson and LaBelle (2000). Because the oil spill statistics of the MMS have been extensively peer-reviewed, they are used as the primary source for this analysis of large spills.

Of specific interest here is a study by Anderson and LaBelle (2000), which compared spill frequency data from the period 1985 to 1999 to data from 1974 to 1992, and proved that there is a significant trend toward lower tanker spill frequencies. We recognize this trend in this report, and consider the period of 1985 to 1999 for calculation purposes in estimating spill probability. In the same report, statistics are given for U.S. coastal waters, and for the tanker movements related to the movement of Alaskan North Slope oil. These latter statistics are shown to compare spill rates for what might be thought of as a more comparable situation in terms of both a relatively modern tanker fleet and regulatory scrutiny.

Finally, it is assumed for the purposes of this analysis that there is no fundamental difference between the transportation risks presented by the shipment of diesel fuel versus that of crude oil, which seems like a fair assumption. Databases on the shipment of oil do not generally distinguish between different types of oil, so an analysis based solely on diesel fuel shipments is not likely possible. In any case, the use of the much broader statistics relating to the shipment of all types of crude oil should produce the most reliable estimate of historical spill frequency.

2.3.2 Spill Size Classification

Initially, only major spills in three spill size categories are considered. The first category is for "extremely large" spills, arbitrarily defined as spills larger than 100,000 bbl (13,300 tonnes). The second and third categories are for "very large" and "large" spills, defined by the MMS as spills larger than 10,000 barrels (1,330 tonnes) and 1,000 barrels (133 tonnes) respectively. In summary, the spill size classifications used in this study are:

Extremely large spills:	>100,000 bbl	(13,300 tonnes or 15,900 m^3)
Very large spills:	>10,000 bbl	(1330 tonnes or 1,590 m^3)
Large spills:	>1,000 bbl	(133 tonnes or 159 m^3)

The large-spill category includes the very large and extremely large spills, and the very large category includes extremely large spills.

Spill frequencies are best expressed in terms of a risk exposure factor, such as billions of barrels of crude oil transported. It is known that about 239.7 billion barrels of crude oil were transported on a worldwide basis from 1974 to 1999, as shown in Table 2.3-1. Table 2.3-1 also shows the number of extremely large (>100,000 bbl), very large (>10,000 bbl) and large crude oil spills (>1,000 bbl) that have occurred during this 26-year period, both "in port", meaning in harbours or at piers, and

"at sea," meaning away from ports either in restricted waters or in open waters. Note in Table 2.3-1 the dramatic decrease in spill frequency when comparing spills in the 1970s to spills in the 1980s and beyond.

Using the statistics in Table 2.3-1 and other statistics, Anderson and LaBelle (2000) calculated oil spills frequencies for the three different spill categories, and these are shown in Table 2.3-2 for the worldwide situation. Note that both "average" and "median" size spill statistics are provided in Tables 2.3-3 and 2.3-4.

Table 2.3-1
Number of Worldwide Crude Oil Spills Greater than or Equal to 1,000 Barrels from Tankers, and Crude Oil Movements, 1974 to 1999

		Spills in Port			Spills At Sea				
Year	All Spills	1,000-9,999 bbl	10,000-99,999 bbl	100,000 bbl or greater	1,000-9,999 bbl	10,000-99,999 bbl	100,000 bbl or greater	Crude Oil Movements (Bbbl)	Spills Per Bbbl
1974	21	7	2	1	6	3	2	10.17	2.07
1975	21	2	2	2	6	6	3	9.33	2.25
1976	19	6	2	1	2	2	6	10.51	1.81
1977	16	2	2	1	3	3	5	10.69	1.50
1978	17	3	2	1	3	4	4	10.48	1.62
1979	23	4	2	3	4	5	5	10.96	2.10
1980	11	1	1	1	3	2	3	9.66	1.14
1981	8	3	1	0	4	0	0	8.54	0.94
1982	8	3	1	1	3	0	0	7.32	1.09
1983	13	4	1	0	1	4	3	6.86	1.90
1984	8	2	3	0	1	2	0	6.84	1.17
1985	6	1	2	0	0	2	1	6.35	0.95
1986	6	2	0	0	1	3	0	7.19	0.83
1987	15	5	1	0	5	4	0	6.76	2.22
1988	9	3	3	0	2	0	1	7.41	1.22
1989	13	2	1	0	1	6	3	8.04	1.62
1990	11	5	0	0	2	4	0	8.71	1.26
1991	9	3	0	1	2	1	2	9.18	0.98
1992	7	3	0	1	1	2	0	9.30	0.75
1993	6	0	1	0	2	1	2	9.87	0.61
1994	6	1	1	1	1	0	2	10.08	0.60
1995	6	3	0	0	3	0	0	10.29	0.58
1996	7	3	0	1	3	0	0	10.62	0.66
1997	6	1	0	1	2	2	0	11.32	0.53
1998	3	3	0	0	0	0	0	11.62	0.26
1999	3	1	0	0	1	1	0	11.57	0.26
Total	278[1]	74	28	16	62	57	42	239.67	1.16

Bbbl = 10^9 bbl.
[1]278 spills totaling 26,091,500 bbl spilled; excludes inland spills.
Largest tanker spill 1,869,000 bbl.
Sources: BP Amoco 2000; BP 1998; MMS 2000.
(Note: 28 spills were added to 1974 to 1992 data since Anderson & LaBelle, 1994).

Table 2.3-2
Worldwide Tanker Spill Rates

Spill Source	Old Rate, 1974 to 1992[1]			Updated Rate, 1974 to 1999			Last 15 Year Rate, 1985 to 1999		
	Volume (Bbbl)	Number of Spills	Spill Rate	Volume (Bbbl)	Number of Spills	Spill Rate	Volume (Bbbl)	Number of Spills	Spill Rate
Spills Greater than or Equal to 1,000 bbl									
All Spills	164.40	213	1.30	239.67	278	1.16	138.31	113	0.82
In Port		77	0.47		117	0.49		50	0.36
At Sea		136	0.83		161	0.67		63	0.46
Spills Greater than or Equal to 10,000 bbl									
All Spills	164.40	119	0.72	239.67	143	0.59	138.31	51	0.37
In Port		31	0.19		44	0.18		14	0.10
At Sea		88	0.53		99	0.41		37	0.27
Spills Greater than or Equal to 100,000 bbl									
All Spills	164.40	52	0.31	239.67	58	0.24	138.31	16	0.12
In Port		12	0.07		16	0.07		5	0.04
At Sea		40	0.24		42	0.17		11	0.08

Spill Rate = Spills per Bbbl handled; Bbbl = 10^9 bbl.
Crude oil spills only, excludes barges and inland spills.
[1]Anderson and LaBelle (1994).
Sources: BP Amoco 2000; BP 1998; MMS 2000.

Table 2.3-3
Worldwide Tanker Spill Sizes, Spills Greater than 1,000 bbls, 1985 to 1999

Tanker spills[a]	Number of spills	Average spill size (bbl)	Median spill size (bbl)
In Port	117	56,300	3,600
At Sea	161	81,000	14,300
All Spills	278	70,100	7,900

[a] Crude oil spills only, excludes barge and inland spills (1 bbl = 0.159 m^3).
Source: Anderson and LaBelle (2000).

Table 2.3-4
Worldwide Tanker Spill Sizes, Spills Greater than 10,000 bbls, 1985 to 1999

Tanker spills[a]	Number of spills	Average spill size (bbl)	Median spill size (bbl)
In Port	14	192,300	43,000
At Sea	37	135,000	60,000
All Spills	51	150,800	56,900

[a] Crude oil spills only, excludes barge and inland spills (1 bbl = 0.159 m^3).
Source: Anderson and LaBelle (2000).

The average size spill is derived by simply dividing the total volume spilled by the total number of spills. The median spill size in a given category means that 50% of the spills were smaller than the

median size and 50% were larger. The average size is much larger than the median size because the former number is heavily skewed by the small number of historical supertanker spills that have resulted in a total loss of cargo, say in the range of 100,000 tonnes (720,000 barrels) and more.

It is of interest for scenario development to refine Table 2.3-2 in terms of the "at sea" statistics. In the late 1970s and early 1980s MMS used to break the "at sea" statistics into the two categories of spills in "restricted waters," defined by MMS as waters less than 50 nautical miles from land (93 kilometres) and spills in the "open sea," that is, beyond 50 n. miles of land. In these earlier studies it was shown that spills in the open sea represented about 10% of the total number of large spills. This low percentage is understandable because most tanker spills occur during loading and unloading operations in port, or as a result of collision and grounding accidents, which mostly take place in harbours and restricted waters. Large tanker spills in the open sea are most likely to result from hull failures during poor weather, or fires and explosions. Table 2.3-5 shows that spills resulting from such accidents represent about 9% of total spills, similar to the MMS-calculated statistic.

Table 2.3-5
Incidence of Tanker Spills[a] by Cause, 1974 to 2004

	<50 barrels (<7 tonnes)	50 to 5000 bbl (7 to 700 tonnes)	>5000 bbl (>700 tonnes)	Total
OPERATIONS				
Loading/discharging	2,817	327	30	3,174
Bunkering	548	26	0	574
Other operations	1,177	55	1	1,233
ACCIDENTS				
Collisions	167	283	95	545
Groundings	232	214	117	563
Hull failures	573	88	43	704
Fires & explosions	85	14	30	129
OTHER/UNKNOWN[b]	2,176	144	24	2,344
Total	7,775	1,151	340	9,266

a. Database includes crude oil spills and product oil spills.
b. "Other" includes spills, "for which the relevant information is not available or where the cause was not one of those given". Note that 93% of the spills in this category are less than 50 barrels.
Source: International Tanker Owners Pollution Federation Ltd. (2006).

In any case, it is of interest to break down the "at-sea" statistics in Table 2.3-2 into the categories of "restricted waters" and "open sea." Table 2.3-2 shows that 136 "large" spills occurred "at sea" (restricted waters and open sea) during the time frame of 1974 to 1992. In Anderson and Lear (1994) spill locations are noted for all spills in the database. (This breakdown is no longer made, so the data cannot be updated to 1999, as with the overall record.) The data show that of the 136 spills, 26 (19% of the "at-sea" spills) can be said to have occurred in the open sea, beyond 50 n. miles of land. Assuming the same percentage for the more recent record of 1985 to 1999, an

estimated 12 of the 63 "at-sea" spills occurred in the open sea, and 51 occurred in restricted waters. Table 2.3-6 summarizes the reworked version of Table 2.3-2 including an estimated breakdown of "restricted waters" and "open sea" spills, and average spill sizes for all location categories. With the available data, the analysis is only possible for "large" spills, that is, spills larger than 1,000 barrels. It does not seem reasonable to extend the assumed breakdown between "restricted" and "at sea" spills to the large spill categories because these categories involve a different distribution of failure modes.

Table 2.3-6
Worldwide Tanker Spill Rates for Large Spills (>1,000 bbl) in Port, Restricted Waters (< 50 nm) and Open Sea (>50 nm), 1985 to 1999

Location	Number of spills	Spill rate (spills per 10^9 bbl)
In Port	50	0.36
Restricted Waters	51	0.37
Open Sea	12	0.088
All Locations	113	0.82

2.3.3 Tanker Size and Distance Traveled

One can legitimately use the MMS spill rate statistics expressed in terms of "spills per billion barrels transported" to calculate expected spill frequencies for a given industrial situation only if (a) the tanker sizes in the situation are about the same as the worldwide average, and (b) the average voyage length is about the same. From data on worldwide shipments of oil (Smyth and Purdon, 1991), the average crude oil tanker size in the world (or more exactly, the average oil delivery per voyage) is 110,114 tonnes or about 826,000 barrels (based on traffic from 1974 to 1989). This is about twice the maximum size of tanker that will be used to transport diesel fuel to the Bathurst Inlet terminal, so the MMS spill statistics should be generally valid for an order of magnitude estimate.

For voyage length, it has been calculated (Bercha *et al.* 1983) that the average voyage length of a crude oil tanker operating worldwide is about 8,000 kilometres. For the proposed Bathurst Inlet project, the length of the shipping route within the study area is estimated to be 1,600 km through Lancaster Sound to Bathurst Inlet to the port. The total voyage length would be an additional 4,500 km from refineries in eastern Canada. The total is similar to the worldwide average, so the MMS spill statistics should be generally valid.

2.3.4 Spill Rates for U.S. Coastal Waters and the Alaskan North Slope Trade

It is interesting to compare spill rates from the U.S. trade and Alaska in particular. This data is of interest to compare spill rates for a more comparable situation than worldwide data in terms of the tanker fleet, navigation risks, and regulatory scrutiny. Tables 2.3-7 and 2.3-8 show this data, with the same breakdown of years illustrating the much reduced frequency of spills in the last 15 years reported. The data show, in recent years, comparable spill rates, as summarized in

Table 2.3-9. When compared with worldwide data, spills greater than 1,000 have occurred slightly less frequently in U.S. waters as a whole, and slightly more frequently in the movements of Alaskan oil. Spills of greater than 10,000 bbls have occurred at a significantly lower rate in U.S. waters as a whole, but at an almost identical rate for the Alaskan trade. Based on this, worldwide data will be used for Bathurst Inlet calculations given the much broader database and exposure factor.

Table 2.3-7
Spill Rates for Tankers in U.S. Coastal and Offshore Waters

	Old Rate, 1974 –1992[1]			Updated Rate, 1974 -1999			Last 15-Year Rate, 1985-1999		
Spill Source	**Volume (Bbbl)**	**Number of Spills**	**Spill Rate**	**Volume (Bbbl)**	**Number of Spills**	**Spill Rate**	**Volume (Bbbl)**	**Number of Spills**	**Spill Rate**
Spills Greater than or Equal to 1,000 bbl									
Tankers U.S. Waters	31.24	38	1.21	44.50	46	1.03	27.57	20	0.72
In Port		22	0.70		30	0.67		12	0.43
At Sea		16	0.51		16	0.36		8	0.29
Spills Greater than or Equal to 10,000 bbl									
Tankers U.S. Waters	31.24	18	0.58	44.50	19	0.43	27.57	7	0.25
In Port		8	0.26		9	0.20		2	0.07
At Sea		10	0.32		10	0.23		5	0.18

Spill Rate = Spills per Bbbl handled; Bbbl = 10^9 bbl.
Crude oil spills only, excludes barges and inland spills.
[1]Anderson and LaBelle (1994).
Sources: COE, 2000; MMS Worldwide Tanker Spill Database, October 2000.

Table 2.3-8
Alaska North Slope Crude Oil Tanker Spill Rates

	Old Rate, 1977 –1992[1]			Updated Rate, 1977 -1999			Last 15-Year Rate, 1985-1999		
Spill Source	**Volume (Bbbl)**	**Number of Spills**	**Spill Rate**	**Volume (Bbbl)**	**Number of Spills**	**Spill Rate**	**Volume (Bbbl)**	**Number of Spills**	**Spill Rate**
Spills Greater than or Equal to 1,000 bbl									
Alaska North Slope Oil Tankers	9.08	10	1.10	12.60	11	0.88	8.72	8	0.92
In Port		3	0.33		4	0.32		4	0.46
At Sea		7	0.77		7	0.56		4	0.46
Spills Greater than or Equal to 10,000 bbl									
Alaska North Slope Oil Tankers	9.08	3	0.33	12.60	3	0.23	8.72	3	0.34
In Port		0	–		0	–		0	–
At Sea		3	0.33		3	0.23		3	0.34

Spill Rate = Spills per Bbbl handled; Bbbl = 10^9 bbl.
[1]Anderson and LaBelle (1994).
Dash (–) indicates zero spills observed; spill rate not calculated.
Sources: DOC, 2000; MMS Worldwide Tanker Spill Database, October 2000.

Table 2.3-9
Comparison of Spill Rates, Spills per 10^9 barrels, 1985 to 1999

	Worldwide	U.S. Coastal Waters	Alaskan Trade
Spills > 1,000 bbls	0.82	0.72	0.92
Spills > 10,000 bbls	0.37	0.25	0.34

2.3.5 Small and Medium Spills

Smaller spills occur much more frequently than do spills larger than 1,000 barrels. Often referred to as "operational" spills, these events are the result of such things as leaking or broken pipes or hoses during transfer operations, leaking fittings, ill-timed opening of valves, and overfilled tanks. Spill frequencies for small and medium size oil spills can be calculated by considering Canadian spill statistics, which are available from the National Environmental Emergency System (NEES formerly NATES, the National Analysis of Trends in Emergencies System), maintained by the Environmental Emergency Program Division, Management and Emergencies Branch, Environment Canada, Ottawa. Complete reports of NEES data are published approximately every ten years, with the most recent publication covering the eleven-year period to 1996. Data from that and the other most recent report, covering a total of 24 years, are shown in Table 2.3-10.

Table 2.3-10
Medium and Small Crude Oil Spills from Tankers in Canadian Waters (1973 to 1996)

Spill Size Range (bbl)	Number of Spills	Average Spill Size (bbl)
1 to 49	31	10.4
50 to 999	6	233

The statistics in Tables 2.3-10 can be transformed into spill frequencies in terms of spills per billion barrels transported by considering the oil volumes transported in Canada. The volume of crude oil traffic in Canada over the time period was about 22 million tonnes per year or about 0.165 billion barrels per year. This crude oil was generally imported to (the East Coast) or exported from (the West Coast) of Canada by tanker; there were virtually no crude oil tanker shipments from a Canadian port to another Canadian port. The spill frequency results are shown in Table 2.3-11.

Table 2.3-11
Frequencies (per billion bbl transported) of Medium and Small Crude Oil Spills from Tankers in Canadian Waters (1973 to 1996)

Spill Size Range (bbl)	Spills/Billion Barrels Transported
1 to 49	15
50 to 999	3.0

2.3.6 Predictions for Bathurst Inlet

The above frequencies derived from worldwide and Canadian statistics are now used to predict the probability of spills from the handling and transportation of diesel fuel at the Bathurst Inlet facility. The predicted spill rates are based on the appropriate historical spill frequency per size category, and multiplying with the estimated annual throughput of the project, namely of 213,070 tonnes per year (1.6×10^6 bbl/year) of diesel fuel. The predicted frequency for each size range and location category is reported as "spills/year," the statistical average number of spills that would occur in a given year, and "years/spill," the statistical average number of years between spills.

Table 2.3-12
Predicted Frequency of Tanker-Related Diesel Fuel Spills

Size Category (bbl)	Location Category	Historical Rate, Spills per 10^9 (bbl)	Average Spill Size (bbl)	Median Spill Size (bbl)	Predicted Frequency for Bathurst Inlet	
					spills/year	years/spill
1 to 49	--	15	10.4	-	2.39×10^{-2}	42
50 to 999	--	3.0	233	-	4.79×10^{-3}	209
> 1,000	All	0.82	70,100	7,900	1.31×10^{-3}	764
	Port	0.36	56,300	3,600	5.74×10^{-4}	1,740
	Restricted	0.37	--	--	5.90×10^{-4}	1,690
> 10,000	All	0.37	150,800	56,900	5.90×10^{-4}	1,690
	Port	0.10	192,300	43,000	1.60×10^{-4}	6,300
	At Sea	0.27	--	--	4.31×10^{-4}	2,320
>100,000	All	0.12	--	--	1.91×10^{-4}	5,220

2.3.7 Discussion

Spills in the smallest size category are predicted to occur once every 42 years, making them a possibility within the lifetime of the project. Spills in the 50 to 999 barrel category are predicted to occur every 209 years, somewhat beyond likelihood but within the realm of possibility. Spills in larger size ranges are unlikely events, and increasingly unlikely as the size range increases.

The predicted spill rates are a direct reflection of the volume of diesel fuel being handled in the Bathurst Inlet facility, and on the historical spillage rates in the international shipping industry. In fact, the record in Canada has been relatively good with regards to large tanker spills: only two large (>1,000 barrels) crude oil spills have ever occurred in Canadian waters: the *Imperial Sarnia* tanker spill off Brockville, Ontario in 1974, which involved 2100 barrels of oil, and the *Czantoria* tanker spill in the port of Québec in 1988 involving about 3300 barrels. The Athenian Venture tanker spill (200,000 barrels or 27,000 tonnes) of crude oil spilled in the northwest Atlantic far off Canada in late 1988 occurred during an inbound journey to Come by Chance and thus might be considered a "Canadian" spill. Even in this case, Canada has "experienced" only three large crude oil spills (larger than 1,000 barrels) in the past 25 years.

Implicit in the approach used in this analysis is that there is no consideration given to the particular navigational risks of one port or one shipping route versus another. This assumption may be debatable. However, some comfort should be taken from the fact that the spill rates for two smaller data sets (U.S. coastal waters and the Alaskan trade) had, over the period of 1985 to 1999, similar spill rates as those in the larger worldwide database.

Finally, it should be reiterated that the spill frequencies calculated in this study were based on the assumption that the tankers used in conjunction with the Bathurst Inlet facility would be as safe, but no safer, than the average tankers that have been used internationally over the past 15 years. In fact, the tankers will be much safer, and this should have the effect of reducing the calculated spill frequencies to even lower values.

3. MARINE OIL SPILL FATE AND BEHAVIOUR MODELING

3. Marine Oil Spill Fate and Behaviour Modeling

The objective of this Modeling is to assess the behaviour and trajectory of oil spills that might occur during the marine shipping activities being proposed for the Bathurst Inlet Port and Road Project. The spills of concern are vessel-based batch spills of the diesel cargo and intermediate fuel oils used to power the tankers. The approach is to select a number of hypothetical oil spills that cover the main concerns and to describe their behaviour and trajectory in detail. These spill scenarios, involving various spill types and sizes, serve subsequently as the basis for impact assessment and countermeasures analyses.

3.1 General Oil Spill Behaviour

All of the oil spills being considered are surface releases due to hypothetical tanker accidents or fuel transfer incidents. As such, the oil is assumed to be released directly onto the water surface over a short time period and then be influenced by the prevailing environmental conditions. When oil is spilled at sea it is subject to several weathering processes. The processes of importance to spill impact assessment and spill countermeasures assessment are drifting (advection), spreading, evaporation, natural dispersion of oil in water, and water-in-oil emulsification.

3.1.1 Drifting

Drifting or advection is the process of surface slicks moving away from the site of a spill by water currents and winds. The vector combination of water currents and winds determines the final slick drift. If the surface oil is not dispersed it will be influenced by wind as well as water current forces, and thus can be driven ashore by onshore winds. On the other hand, if the oil is dispersed, the movement of the oil droplets in the water will only be influenced by the water current. Hence, the trajectory of surface oil can be different than the trajectory of dispersed oil.

3.1.2 Slick Spreading

Numerous models are available for predicting oil spreading behaviour and its dependence on oil properties and environmental conditions. All models relate the properties of the oil (density, viscosity and interfacial tension) to its spreading on calm water. Marine spills do not spread uniformly but are composed of thick patches (usually thicker than 1 mm) that contain about 90% of the spill's volume that are surrounded by sheens (about 1 to 10 μm or 0.001 to 0.01 mm thick). The thick patches spread and thin over time and feed oil into the surrounding sheen.

3.1.3 Evaporation

Evaporation is one of the most important processes that affect oil properties and therefore the behaviour of spilled oil. Fortunately, it is also one of the better understood and modelled oil fate processes. Most evaporation models use the approach of determining an overall mass transfer coefficient as a function of environmental conditions. The volume or mass fraction of oil evaporated is related to an exposure coefficient (combining time, oil volume and area, and the mass transfer coefficient to the atmosphere) and to the pressure-concentration behaviour of the

oil. The unique aspect of this approach is that it permits the results from a variety of laboratory evaporation experiments to be extrapolated to actual environmental conditions.

3.1.4 Natural Dispersion

The dispersion of oil into the water by natural forces is an important process controlling the long-term fate of oil slicks at sea. In conjunction with evaporation, this process reduces the volume of oil on the water surface, thereby influencing the potential extent of surface and shoreline contamination. In slick dispersion, oil droplets are dispersed from the slick into the water by oceanic mixing. The larger of these droplets, which are buoyant, resurface quickly and rejoin the slick. The smaller droplets remain in suspension in the water column. Lighter, more water soluble hydrocarbons partition from these droplets into the water phase. Clouds of the entrained dissolved and particulate oils then spread horizontally and vertically by diffusion and other long-range transport processes.

Although natural dispersion is a poorly understood process, it is known that oil/water interfacial tension, oil viscosity, oil buoyancy and slick thickness each inversely affect the ability of a particular oil to disperse naturally. Sea state is also an important factor controlling the rate and amount of dispersion. Even light, non-viscous oils do not rapidly disperse under calm conditions. On the other hand, even the heaviest, emulsified oils can disperse over a period of time in heavy seas with frequent breaking waves. The net dispersion rate of oil from a slick into the water will vary greatly depending on the properties of the spilled oil and mixing energy.

3.1.5 Emulsification

When spilled at sea, most crude oils tend to form water-in-oil emulsions. Emulsification occurs in the presence of mixing energy such as that provided by wave action. During emulsification, seawater is incorporated into the oil in the form of microscopic droplets. This water intake results in several undesirable changes to the oil. First, there is a significant increase in the bulk volume of the oil (usually up to a four- or five-fold increase), greatly increasing the amount of oily material that can contaminate shorelines and biological resources. Secondly, there is a marked increase in fluid viscosity. The much higher viscosities greatly inhibit the chemical or natural dispersion of oil.

Most experts believe that precipitates of asphaltenes and resins in the oil act as surface-active agents to stabilize the water droplets in the forming emulsion. Without such stabilizing agents the small water droplets in the oil layer would tend to coalesce into larger droplets that would sink through and leave the oil phase. Spills of some crude oils start to form emulsion within a few minutes of environmental exposure, and will form a highly viscous and stable emulsion within hours. This has been recorded many times during actual and experimental spills. On the other hand, a few crude oils and most refined petroleum products do not easily emulsify at all.

Both diesel fuel and IFO 180 are unlikely to form water-in-oil emulsions when spilled at sea. Diesel fuels do not contain sufficient surface-active agents to permit stable emulsion formation so these oils will not emulsify when spilled. The high viscosity of IFO 180 fuel oil at low temperatures prevents the mixing of water into the oil thereby preventing the formation of water-in-oil emulsions.

3.2 Spill Fate Modeling Methods

The fate of the oil in the spill scenarios considered in this study has been modelled using the SL Ross Oil Spill Model (SLROSM). This model has undergone continuous development and use at SL Ross since the early 1980s and has been used in spill scenario Modeling for clients world-wide. The following is a brief description of the sources of the main spill process algorithms used in SLROSM. The spreading model relies on the work of Fay (1971) and Mackay *et al*. (1980a) but includes modifications to account for oil viscosity changes and the development of a yield stress in the oil (*i.e*., pour point). Longer term spreading takes into account oceanic diffusion processes according to relationships developed by Okubo (1971). Evaporation models use the work of Stiver and Mackay (1983) with modifications developed by SL Ross and Mackay (1988). Natural dispersion is modelled using either Audunson's (1980) natural dispersion model modified to account for oil density, viscosity, interfacial tension and pour point or Delvigne's (1985, 1987) oil entrainment model. In this project Delvigne's algorithms were selected for the Modeling. Emulsification is modelled using the relationship developed by Mackay and Zagorski (1982) with modifications by Bobra (1991) and SL Ross and Mackay (1988).

SLROSM estimates the movement of slicks through the vector addition of the local surface water current and 3% of the prevailing wind speed. Wind forecasts are entered by the user for each spill scenario of interest based on the best available data. Surface water currents are provided, in map form, to identify the spatial variation in the water velocities.

3.3 Spill Modeling Inputs

The oil property data, spill flow rates and volumes, air and water temperatures, winds and water currents used in the spill behaviour and trajectory model are described in the following sections.

3.3.1 Oil Properties

The two oil types of concern in this project are the bulk oil being transported: Ultra Low Sulphur Diesel (ULSD) and the fuel oil used to power the tankers: Intermediate Fuel Oils (IFO) 180 or 380. Properties for diesel oil and IFO 180 and 300 fuel oils have been obtained from Environment Canada's online oil property database (www.etc-cte.gc.ca/databases/spills/oil_prop_e.html) for use in this Modeling exercise. Detailed fresh and weathered oil properties for IFO 380 are not readily available. The fresh and weathered properties of these oils have been processed to provide the parameters necessary for SL Ross's oil spill model to predict oil evaporation, dispersion, emulsification and property change as a function of spill size and environmental conditions. Preliminary Modeling identified that the IFO 180 and 300 grade fuel oils have similar long-term persistence with minimal dispersion making it unnecessary to model both oils for the requirements of this study. The properties of the IFO 180 fuel oil were chosen to represent the intermediate fuel oils used by the tankers in this project. The basic physical properties of the oils selected for use in the Modeling are provided in Table 3.3-1.

Table 3.3-1
Diesel and IFO Fresh Oil Physical Properties

Oil	Density @ 0 °C (kg/m^3)	Viscosity @ 0 °C (cP)	Pour Point (°C)
Diesel	838	11	-36
IFO 180	978	12,300	-10
IFO 300	996	128,400	-6

3.3.2 Discharge Volumes

The tankers that will be used in this operation typically have individual storage compartments on the order of 4,000 to 5,000 m^3. It has been assumed that a maximum credible spill of the diesel fuel would be two, full compartments or a maximum of 10,000 m^3 of oil. It also has been assumed that the diesel will spill over a 10-hour period and the fate of 10 discrete parcels of 1,000 m^3 of diesel have been modelled for spill impact and countermeasures assessments. These tankers typically have intermediate fuel oil storage capacity of about 300 m^3. One hundred and fifty cubic metre spills of intermediate fuel oil have been modelled. The fuel oil releases have been assumed to last over a ten hour period and the fate of ten discrete parcels of 15 m^3 of intermediate fuel oil have been modelled.

At the port facility, 15 m^3 diesel fuel spills have been modelled as the maximum credible spill from a loading operation at this Level 3 oil handling facility. The diesel is discharged instantaneously in a single batch.

3.3.3 Water Currents

A surface water current field developed by combining very basic surface water current information from a variety of sources was used in the spill trajectory Modeling. The sources used to identify the basic surface water flow included Canadian Hydrographic Service sailing directions (DFO 1994, 1985), an old arctic atlas (Fenco 1978), the Arctic Environmental Sensitivity Atlas System (Environment Canada 2000), and moored current meter observations in Barrow Strait (Pettipas *et al.* 2006). Surface water velocities reported in these various sources were entered into the SLROSM's water current mapping utility. The utility was then used to interpolate between known velocities, while conforming the velocities to shoreline topography, to provide an approximation of the surface water velocity field. Figure 3.3-1 shows the resulting surface water flow representation. It must be stated that this water velocity representation is very approximate and is likely incorrect in many locations. While this information is adequate for spill behaviour Modeling for use in spill impact and countermeasures assessment, it must be used with caution for other applications. These water currents were combined with 3 % of the average winds to determine the movement of oil slicks.

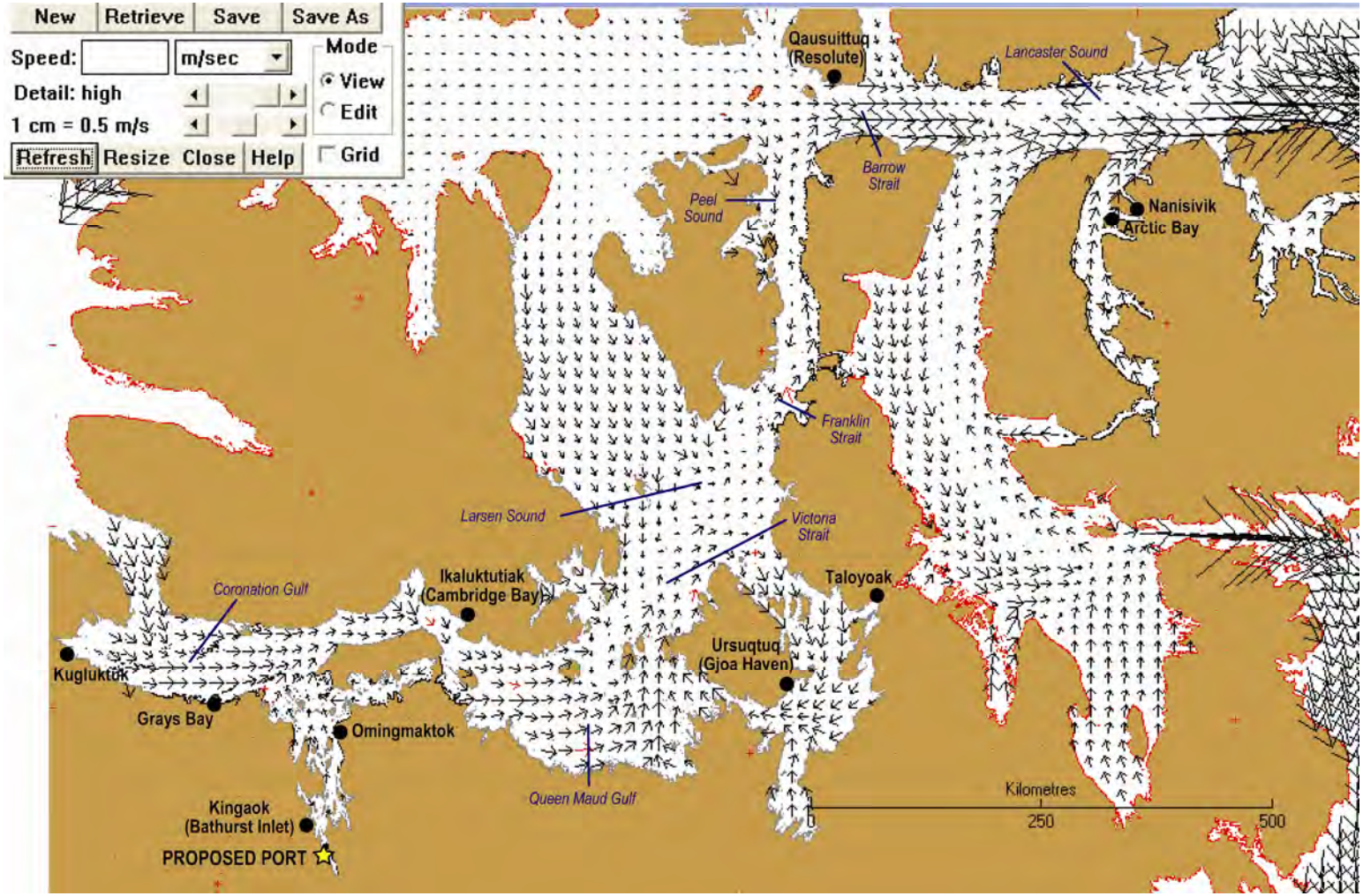

Figure 3.3-1 Approximate Arctic Surface Water Currents

3.3.4 Air and Water Temperatures

The monthly average air and water temperatures for key sites in the study area are shown in Table 3.3-2. The average water temperatures recorded throughout the region and over the months of concern have a narrow range (-2 to 5 °C). Average air temperatures have a greater range (-14.9 to 12.1°C).

Table 3.3-2
Monthly Air and Water Temperatures used in Spill Modeling

	Average Temperatures (°C)							
	July		August		September		October	
Location	Air	Water	Air	Water	Air	Water	Air	Water
Bathurst Inlet	12.1	4	9.7	5	2.5	5	-8.2	0
Jenny Lind Island	6.1	1	4.5	2	-0.9	2	-10.4	-2
Resolute	4.3	2	1.5	1	-4.7	1	-14.9	-2

Source: Environment Canada (air temperature), USA Government PODAAC (water temperature).

3.3.5 Winds

The likely fate of the diesel and IFO fuel oils (property change, dispersion, evaporation, *etc*.) in the various spill scenarios considered has been summarized using average wind data from the weather stations nearest the spill location. Table 3.3-3 shows the average monthly wind speeds determined from the Canadian Climate Normals maintained by Environment Canada. Because the average winds do not vary significantly from month to month or from location to location a single average wind speed of 21.5 km/hr has been used to model the typical fate of the spill scenarios considered in this study.

Table 3.3-3
Average Wind Speeds

	Average Wind Speeds (km/hr)			
Location	July	August	September	October
Bathurst Inlet	19.4	20.1	21.8	21.2
Cambridge Bay	19.7	21.5	22.4	23
Resolute	20.8	20.7	23.9	23

Source: Environment Canada.

Historical hourly wind records available online from the weather office of Environment Canada (http://climate.weatheroffice.ec.gc.ca/climateData/canada_e.html) were used in the spill scenario trajectory Modeling. Historical records from Resolute were used for the Barrow Strait/Lancaster Sound spill release. Data from Cambridge Bay were used for the Jenny Lind Island release and the Bathurst Inlet scenarios. The Cambridge Bay data was the closest location available for detailed hourly wind data for these two sites. The 2005 hourly data for the months of July, August, September, and October and the 1995 and 2000 data for August were downloaded from the weather office database and converted to the format used in the SLROSM. Spill scenarios were

run using these wind datasets to provide an indication of the realistic trajectory of spills in the study area based on actual hourly wind records for use in spill impact and countermeasures assessments.

3.3.6 Spill Locations

Spill scenarios were modelled at eight locations along the shipping route as seen in Figure 3.3-2. Six of the scenarios were located in Bathurst Inlet or the approach to the Inlet due its complex structure. The Jenny Lind Island release point was selected because of the potential grounding sites along this section of the shipping route and its proximity to resources in the south central section of the shipping route. The Barrow Strait / Lancaster Sound site was selected to provide maximum possible impact on the unique resources of the northern portion of the shipping route.

3.4 Oil Fate Modeling Results

3.4.1 Diesel Spills

Two diesel fuel spill volumes have been considered: 10,000 m^3 discharged in ten 1,000 m^3 spillets released over a 10-hour period and a 15 m^3 instantaneous fuel transfer spill at the port. Table 3.4-1 shows the fate of these batch spills for warm, average and cold conditions (within the bounds presented in Table 3.3-2) to demonstrate the influence of temperature on the likely fate of the oil. An average wind speed of 21.5 km/h was used in the Modeling; the average of the wind speeds shown in Table 3.3-3. From the standpoint of spill impact and countermeasures assessment there is not a significant difference in the behaviour of the spills at the different temperatures. Spills in warmer temperatures will evaporate more leaving less to disperse. A 1,000 m^3 spillet of diesel that does not travel to shore will disperse or evaporate from the surface within about 95 to 104 hours. A 15 m^3 spill of diesel from a port transfer operation would last on the surface for 43 to 47 hours. The average surface oil coverage will drop to 1 μm within less than 92 hours for the large spillets and 27 hours for the small transfer spills. The distance that these slicks will travel will be a function of the prevailing water currents, wind velocity, and the local topography.

The peak diesel concentration in the upper 10 m is estimated to be 3.5 to 4.9 ppm for the 1,000 m^3 spillets and 1.3 to 1.8 ppm for the 15 m^3 release. Higher concentrations will occur in the colder conditions because less oil evaporates. Within 60 to 84 hours the oil clouds from the 1,000 m^3 spillets will grow to a width of 6.6 to 9.3 km and diffuse to 1.0 ppm oil concentration (assuming a conservative 10 m mixing depth). The concentration of 1.0 ppm of total petroleum hydrocarbon is the exposure concentration below which no significant biological effects are expected. The dispersed oil clouds from the 15 m^3 spills will diffuse to 1.0 ppm within five to seven hours and reach a diameter of 425 to 500 m.

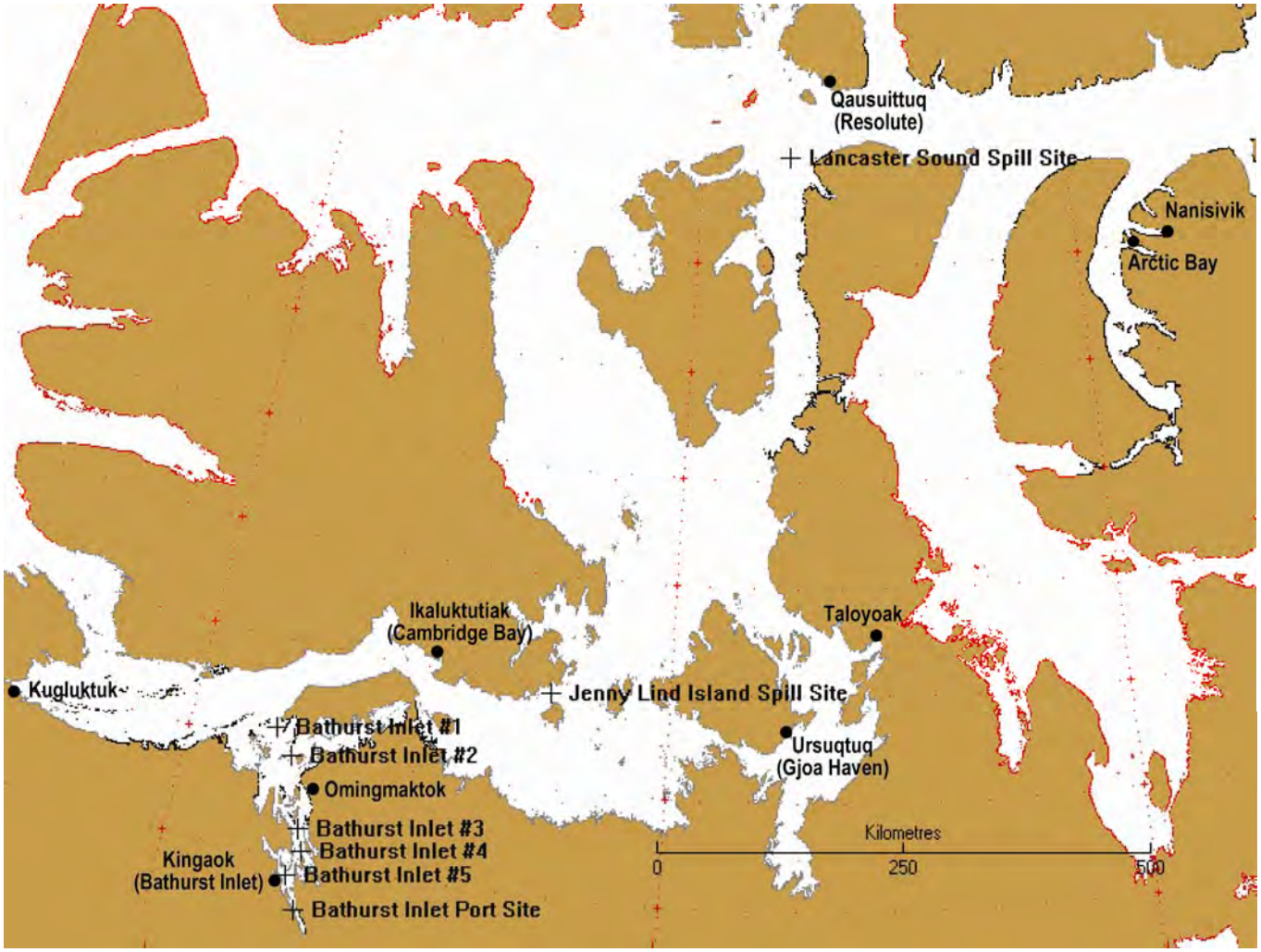

Figure 3.3-2 Spill Scenario Locations

3.4.2 IFO Spills

A 150 m^3 spill of IFO 180 occurring over a ten hour period has been modelled to account for the possible accidental spill of the ship's operating fuel. The release has been modelled using ten discrete 15 m^3 parcels, or spillets, with one spillet released each hour. The fate of these spills has been modelled for a 30-day period but it is likely that the oil will come to shore within this time. Table 3.4-2 shows the fate of these persistent spills for warm, average and cold conditions. There will be very little difference in the behaviour of these spills over the range of temperatures expected throughout the study area. The only significant difference will be the amount of oil evaporated. In the warmer periods up to 18% of the oil will evaporate. This will reduce to 13% in the colder conditions. In all cases, the IFO will be very viscous and persistent and will remain on the water surface, in some form, for an extended time unless it contacts shore. After 48 hours the oil will have diffused over the water surface such that the average oil coverage will be below one micron thick or less than one gram of oil per square metre of water surface. After an extended period (several weeks), the oil will likely be in the form of widely diffused bits of relatively benign tar. Very little of this oil will disperse and in-water oil concentrations will be well below those needed to cause impact.

3.5 Spill Trajectories

3.5.1 Introduction

Once spilled, oil will be moved by currents and wind until it evaporates, disperses into the water, contacts land, or diffuses on the surface to low concentration. As noted in the previous sections, spills of IFO will tend to be highly persistent, and survival times of months are conceivable. Diesel oil will evaporate and disperse much more quickly and surface oil will likely persist only for about four days under average environmental conditions. SLROSM estimates the losses of oil through evaporation, dispersion and shoreline retention. The shorelines along the shipping route have been classified into two categories (steep rock face and gravel/cobble/sand beaches) based on data provided in the Arctic Environmental Sensitivity Atlas System (Environment Canada 2000). Oil retention values of 0.7 m^3/m and 0.01 m^3/m have been assigned to the beach and steep rock classes, respectively. When an oil slick contacts land a portion (or all) of the oil is retained on shore based on the slick width and shoreline retention value. If more oil is present in the slick than can be retained by the shore, the slick is moved back offshore and allowed to move under the influence of the wind and water currents until it dissipates. Rock shores are shown in black, beaches in grey and unclassified shores in red on the maps provided.

3.5.2 Typical Slick Trajectories: Lancaster Sound

Oil slick trajectories have been modelled from a spill site at the western end of Lancaster Sound at the entrance to Prince Regent Inlet. Six scenarios have been modelled using historical winds as described in section 2.2.5. The extents of the travel of the surface diesel oil slicks from these diesel spills are shown in Figure 3.5-1. The trend for the movement of these slicks is generally to the east but movement to the west is possible as seen in the August 1995 trajectory.

Table 3.4-1
Diesel Spill Characteristics

Spillet Volume (m^3)	Air Temp (°C)	Water Temp. (°C)	Initial Slick Width (m)	Slick Survival Time (hr)	Max. Slick Width (m)	Time to 1 µm Oil Coverage (hr)	Total Evap (%)	Total Disp (%)	Peak Disp. Oil Conc. (ppm)	Time to Peak Conc. (hr)	Time to 1.0 ppm (hr)	Cloud Width at 1 ppm (m)
Tanker accident along shipping route												
1,000	10	5	250	95	670	84	36	64	3.5	6	60	6,600
1,000	5	0	250	104	700	90	32	68	3.8	6	72	7,900
1,000	-10	-2	250	102	730	92	26	74	4.9	12	84	9,300
Port transfer spill												
15	10	5	31	43	132	27	36	64	1.33	3	5	425
15	5	0	31	47	138	27	32	68	1.45	3	6	500
15	-10	-2	31	45	144	27	26	74	1.77	3	7	576

Table 3.4-2
IFO 180 Spill Characteristics

Spillet Volume (m^3)	Air Temp. (°C)	Water Temp. (°C)	Initial Slick Width (m)	Slick Survival Time (hr)	Max. Slick Width (m)	Total Evap (%)	Time to 1 µm Oil Coverage (hr)	Total Disp (%)	Peak Disp. Oil Conc. (ppm)	Time to Peak Conc. (hr)
Tanker accident along shipping route										
15	10	5	31	>720	77	18	48	0.3	0.03	6
15	5	0	31	>720	72	15	48	0.25	0.02	15
15	-10	-2	31	>720	84	13	48	0.6	0.02	12

The extents of the IFO 180 spills for the same winds are shown in Figure 3.5-2. The longer travel times for some of these spills when compared with the diesel spills is due to the significantly higher persistence of the IFO 180. Over the long travel distances shown the oil from these spills can be expected to break up into bits and pieces of tar that diffuse over a relatively large area.

3.5.3 Typical Slick Trajectories: Jenny Lind Island

Oil slick trajectories have been modelled from a spill site in Icebreaker Channel between Jenny Lind Island and Victoria Island. Six scenarios have been modelled using the historical winds described in section 2.2.5 . The extents of travel of the surface diesel oil slicks from diesel spills are shown in Figure 3.5-3. The trend for the movement of these slicks is generally to the north and east and contact with nearby land is highly likely.

The trajectories for the IFO 180 spills are shown in Figure 3.5-4. The higher persistence of the IFO 180 results in longer trajectories for these spills.

3.5.4 Typical Slick Trajectories: Bathurst Inlet

Trajectories for the diesel spill scenarios are provided in Figures 3.5-5 through 3.5-10. The IFO 180 releases follow the same trajectories as the diesel spills and make the same landfalls in the tight confines of Bathurst Inlet and its approach. The trajectories shown for the diesel transfer spill at the port site (Figure 3.5-10) have a spill origin offshore from the dock to illustrate where the spilled oil would go if initially blown away from the port. If the trajectories are started at port next to land their trajectories are confined to a very small area adjacent to the port. Spills within Bathurst Inlet will generally be confined within the Inlet and contaminate the shores within a 50 to 75 km radius of the spill site as shown in Figures 3.5-5 through 3.5-10.

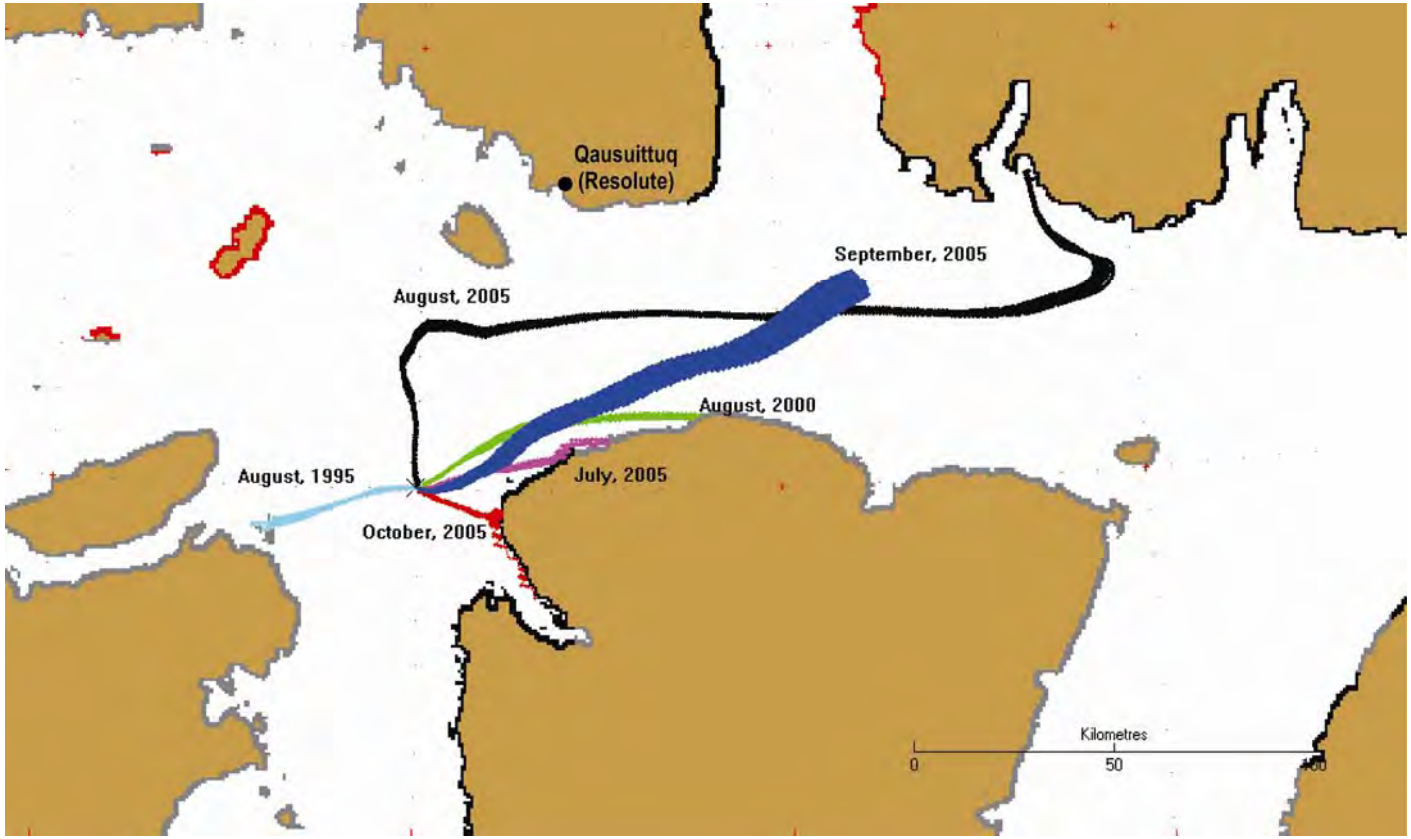

Figure 3.5-1 Example Diesel Spill Trajectories: Lancaster Sound (spill origin-X)

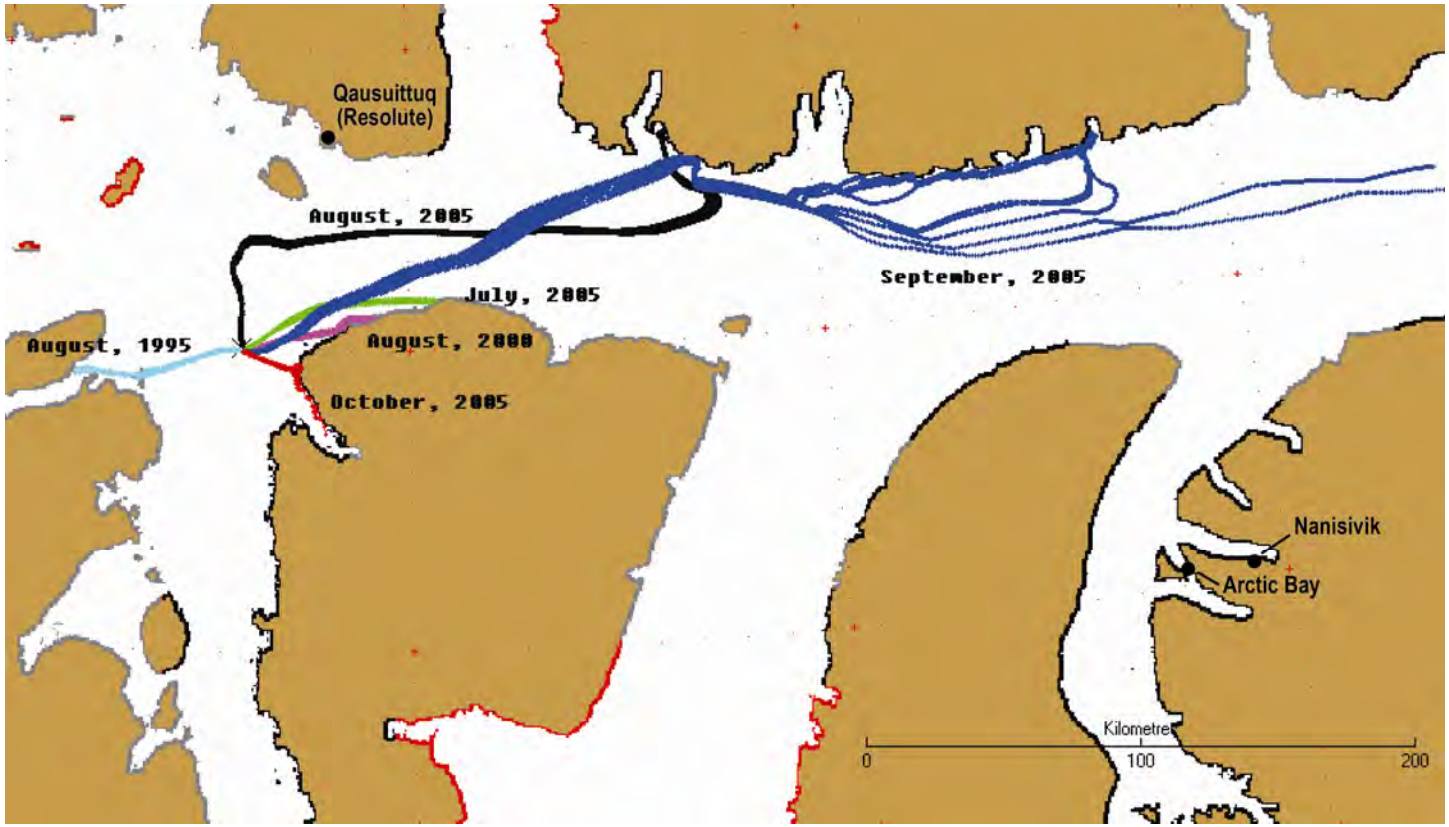

Figure 3.5-2 Example IFO 180 Spill Trajectories: Lancaster Sound (spill origin-X)

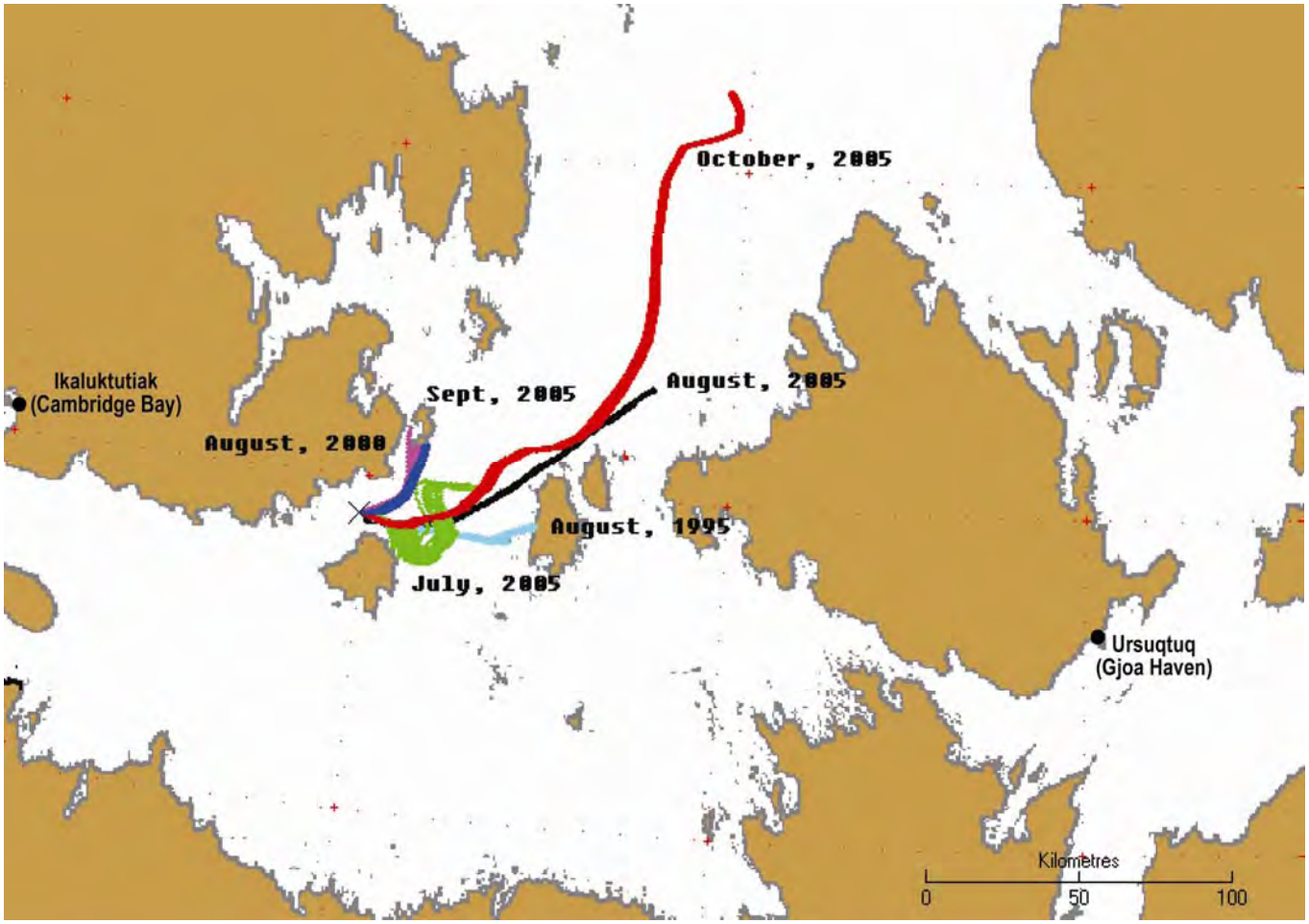

Figure 3.5-3 Example Diesel Spill Trajectories: Jenny Lind Island (spill origin-X)

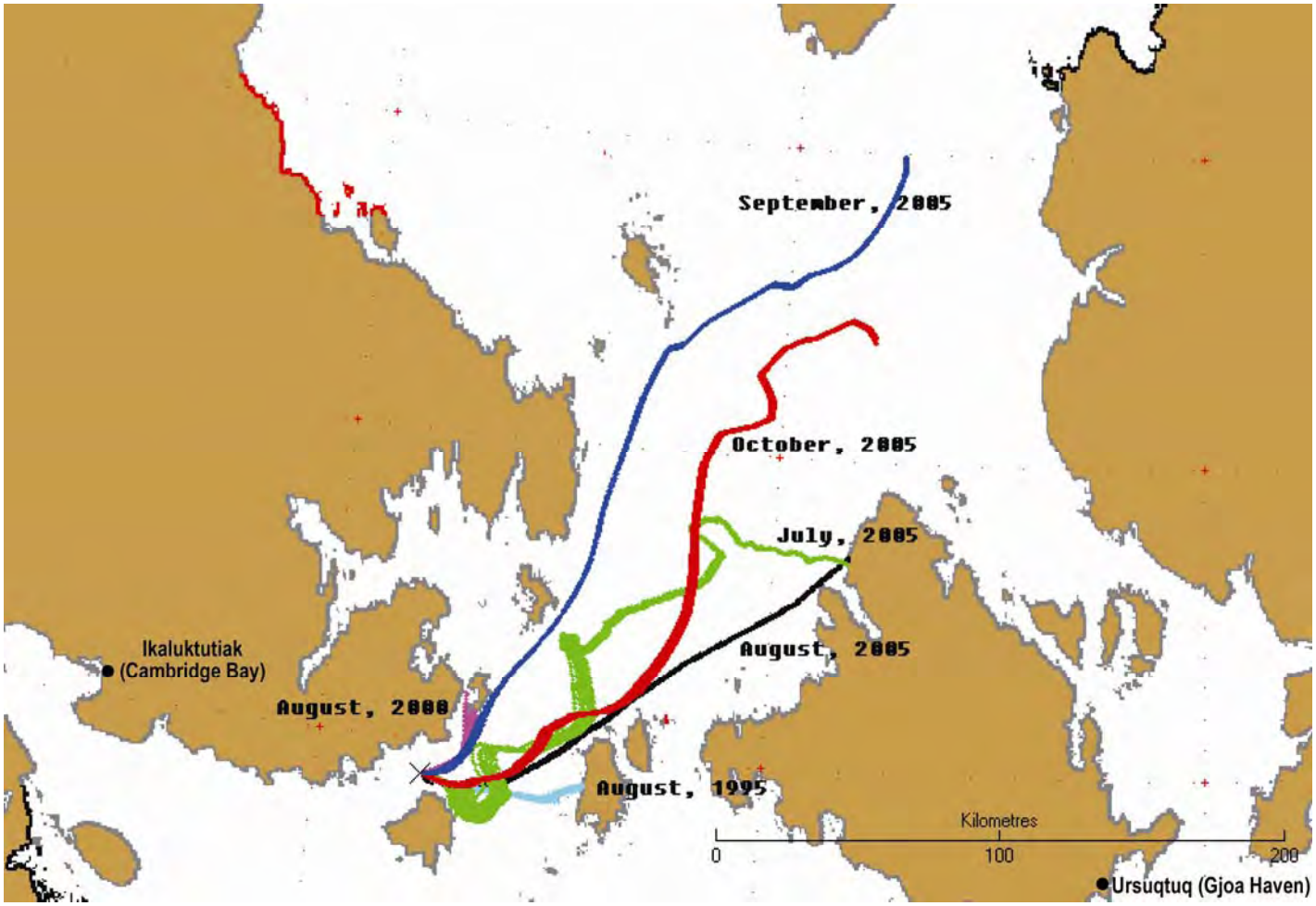

Figure 3.5-4 Example IFO 180 Spill Trajectories: Jenny Lind Island (spill origin-X)

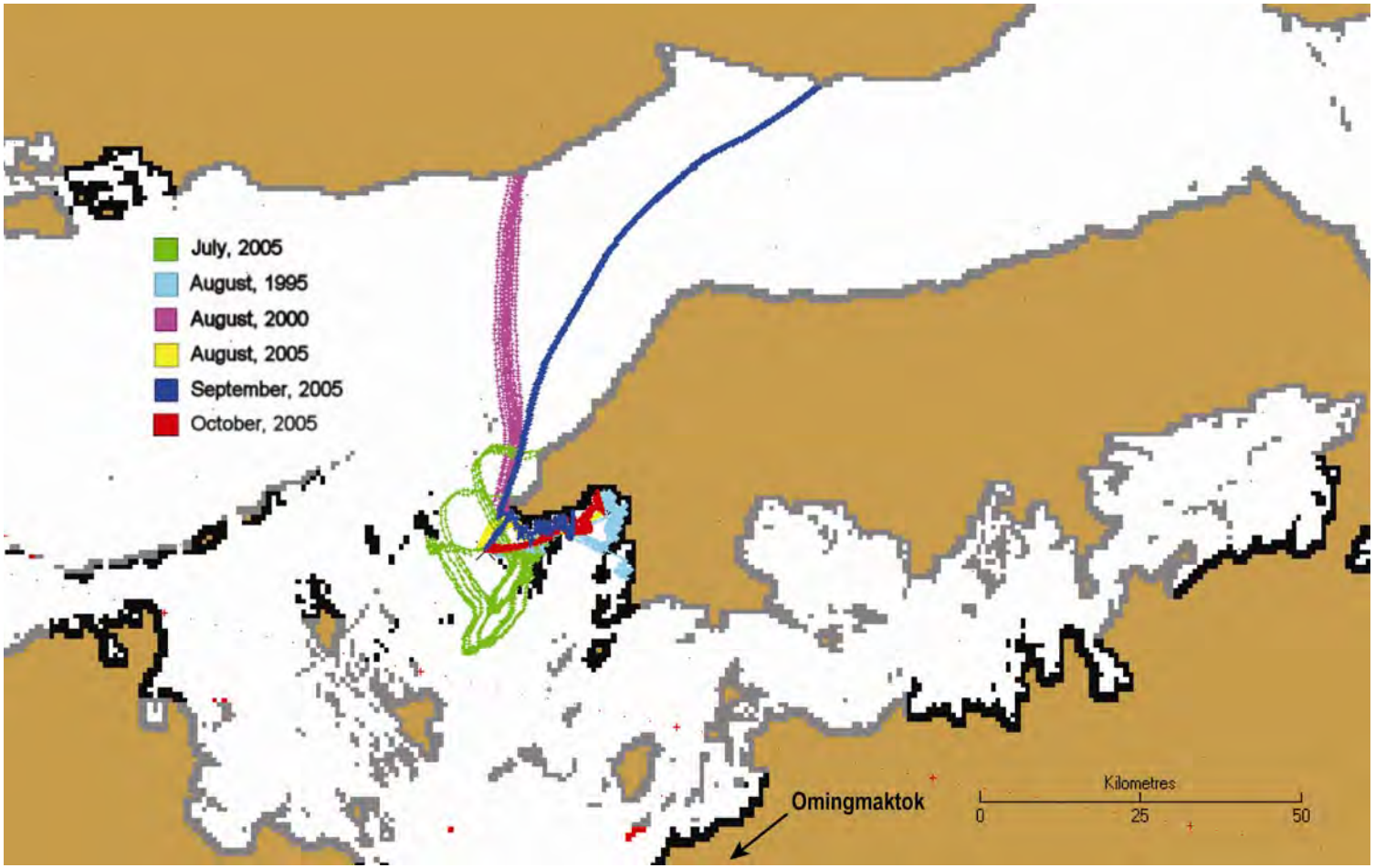

Figure 3.5-5 Example Diesel Spill Trajectories: Bathurst Inlet #1 (spill origin-X)

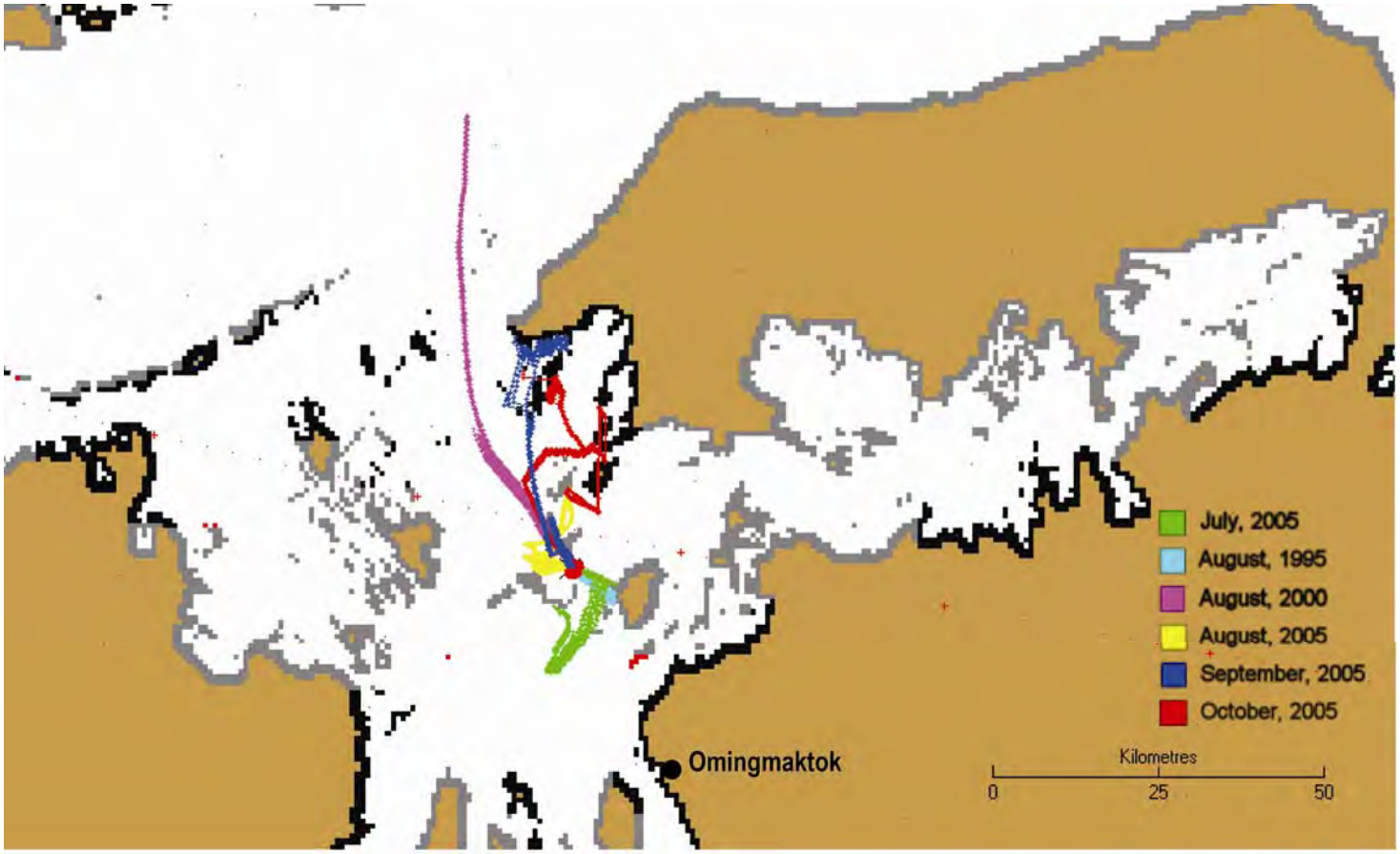

Figure 3.5-6 Example Diesel Spill Trajectories: Bathurst Inlet #2 (spill origin-X)

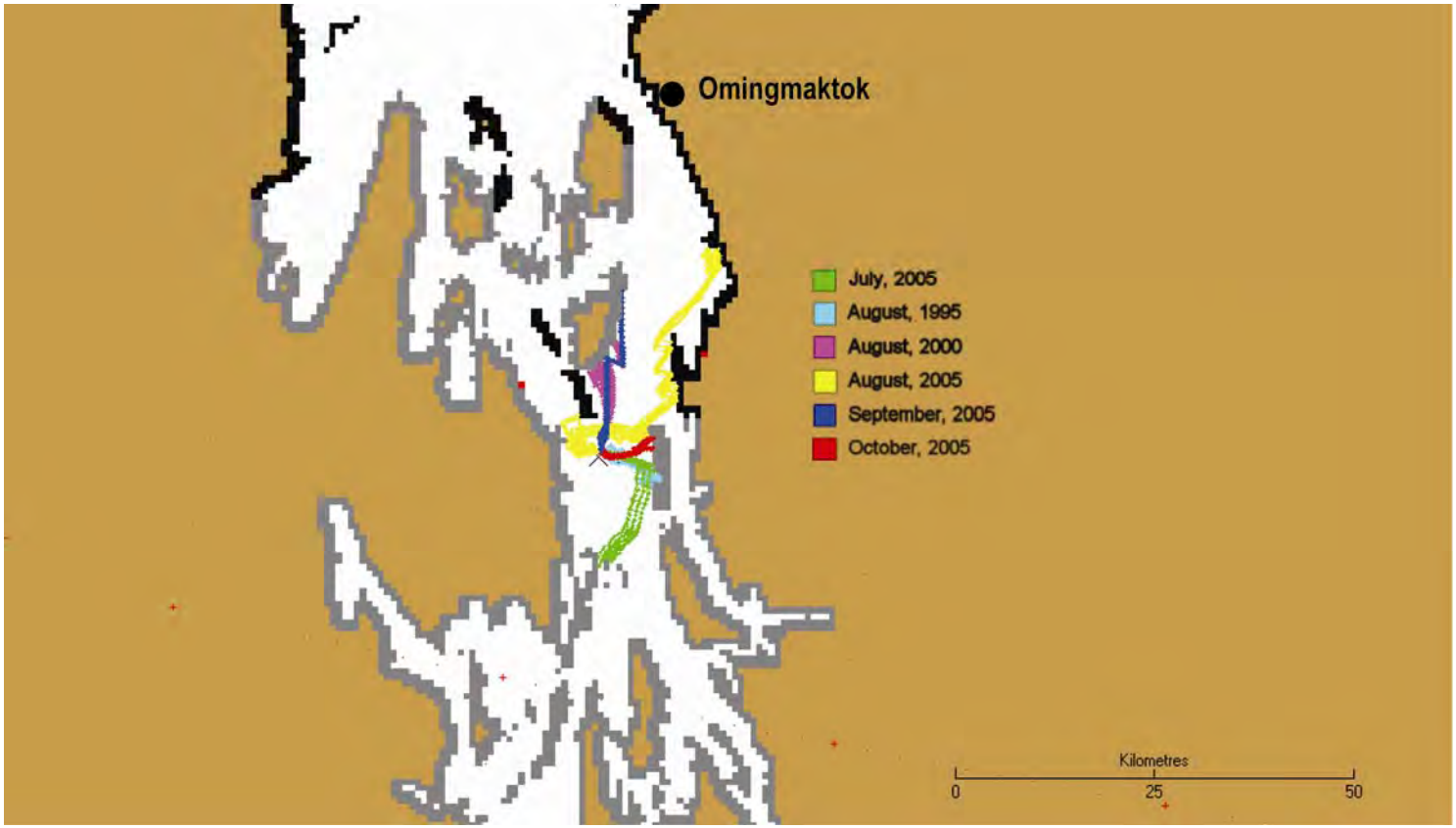

Figure 3.5-7 Example Diesel Spill Trajectories: Bathurst Inlet #3 (spill origin-X)

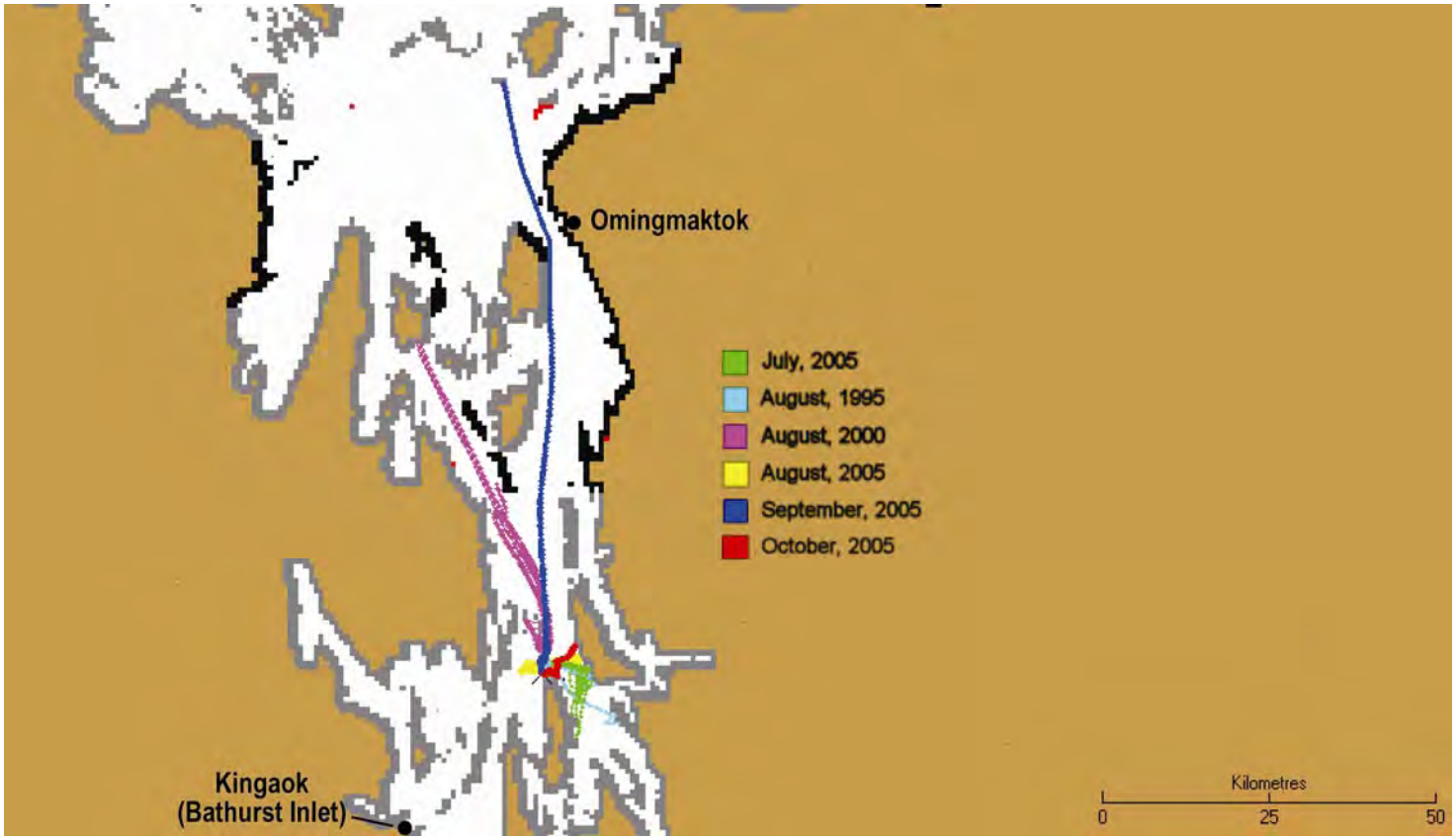

Figure 3.5-8 Example Diesel Spill Trajectories: Bathurst Inlet #4 (spill origin-X)

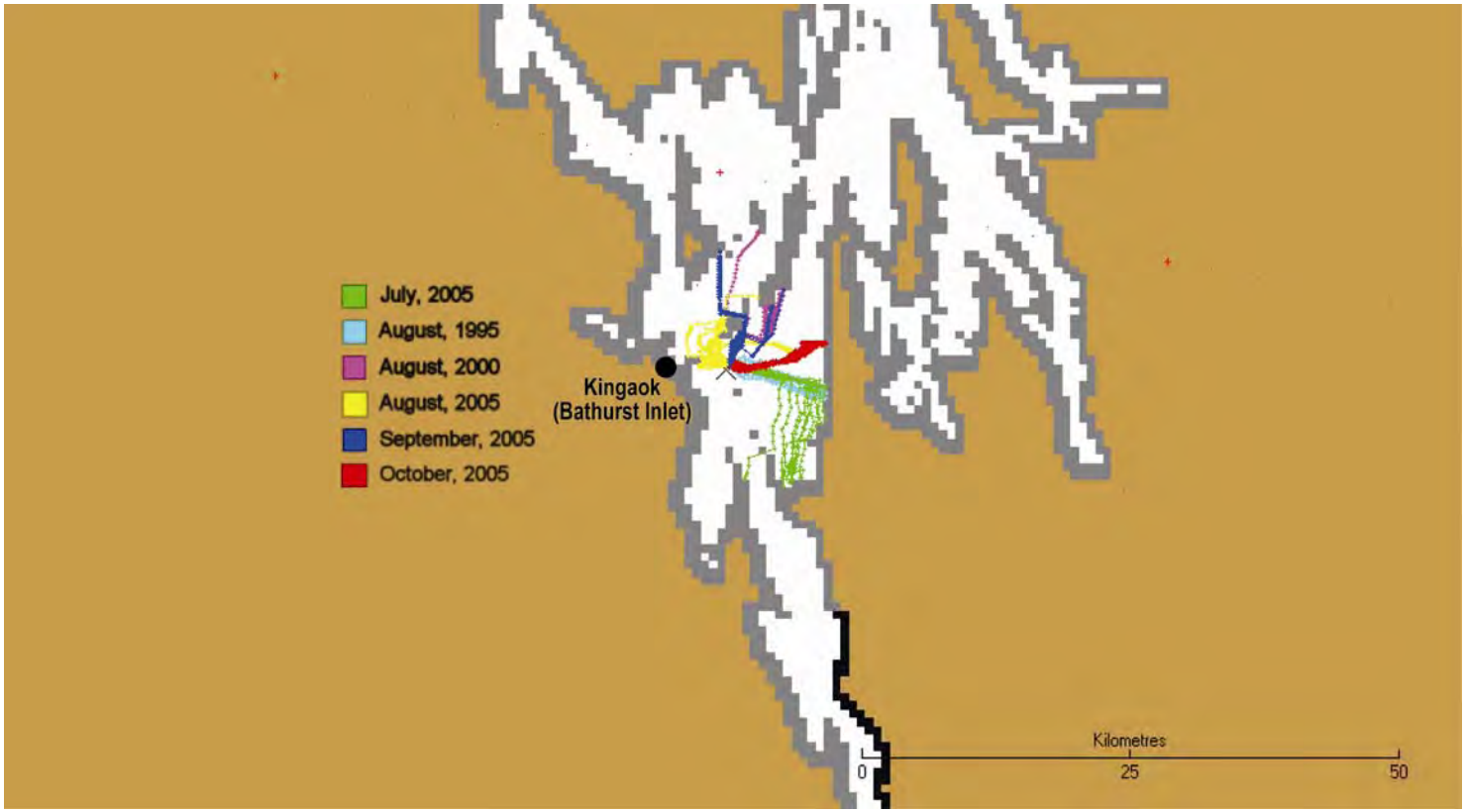

Figure 3.5-9 Example Diesel Spill Trajectories: Bathurst Inlet #5 (spill origin-X)

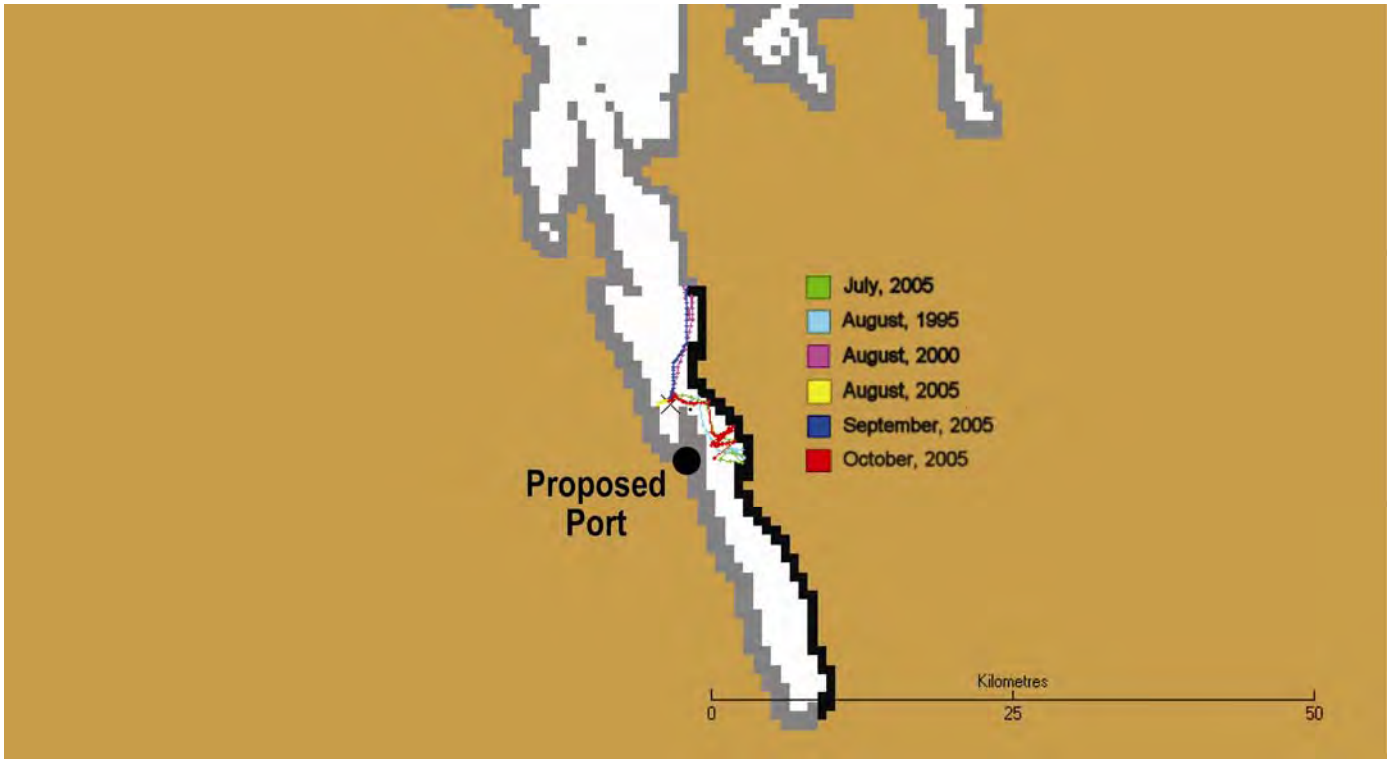

Figure 3.5-10 Example Diesel Spill Trajectories: Bathurst Inlet Port Site (spill origin-X)

4. IMPACT OF ACCIDENTAL MARINE OIL SPILLS

4. Impact of Accidental Marine Oil Spills

This section addresses the potential for environmental damage from oil spills resulting from transportation of diesel fuel into the proposed Bathurst Inlet port. The following chapters deal with fate and movement of spilled oil and the potential for damage from the spills to both environmental (birds, mammals, fish) and socioeconomic receptors (hunting and fishing activities). Impact assessments are made based on specific spill scenarios involving accidental discharges of specific types and volumes of cargo and ship fuel. Analyses consider discharges (scenarios) occurring at a limited number of selected specified locations along the shipping route and at selected times during the shipping season. For each scenario, a spill is launched from a specified location and the fate and movement of the spilled oil are estimated using oil fate and trajectory models. The size and location of areas of environmental oiling and "areas-of-impact" (AOI) are estimated by combining the predicted oil fate data and information concerning spill vulnerability and sensitivity of valued ecosystem components (VECs). Examples of VECs are target receptor populations and socio-economic features, such as hunting activities for specific communities.

4.1 Methodology

Potential impacts of oil spills from tankers have been assessed using specific spills scenarios employing established impact assessment practices (Trudel *et al.*, 1988). Impacts have been assessed by identifying a limited number of specific spill scenarios (oil types, spill sizes and conditions, spill locations and seasons); Modeling fate and movement of spills; estimating AOIs (the toxic footprint) of these spills on particular types of receptors (marine birds, bare-skinned mammals, local hunting and fishing activities); and estimating the proportion of the target stock contacted by oil using information on each species vulnerability (*e.g.*, spatial distribution, level of aggregation and habits). Results of these assessments were reported using standard terms.

4.2 Spatial Boundaries

The study area for this work includes the shipping lane and adjacent areas extending from Lancaster Sound (north of Arctic Bay) to the proposed port location. Based on assessments of potential fate of spills, discussed below, the study area includes a corridor at least 120 km on either side of the shipping lane. This is the maximum distance to which toxic conditions will extend from the spill scenarios considered in this analysis.

4.3 Spill Fate and Movement

The level of spill impact will vary with spill conditions (*e.g.*, oil type, spill volume, spill location, wind direction, and speed). For purposes of this environmental assessment (EA), a number of spill scenarios have been examined spanning the range of spill conditions that might occur as a result of the proposed ship activity. Specific spill scenarios considered here were defined using the following.

1. spill locations:

a) Lancaster Sound;

b) central part of Northwest Passage (Jenny Lind Island);

c) Bathurst Inlet; and

d) proposed port location in Bathurst Inlet.

2. oil types:
   a) diesel (cargo); and
   b) intermediate fuel oil (IFO) 180.
3. spill size:
   a) diesel: 10,000 m^3 spill released over ten hours (ten spillets of 1,000 m^3);
   b) IFO 180: 150 m^3 released over ten hours (ten spillets of 15 m^3); and
   c) port transfer spill of 15 m^3 of diesel as a single batch spill.
4. Winds used for spill trajectory assessment were once-hourly historical data from Cambridge Bay and Resolute for July, August, September and October 2005 and August 1995, 2000 and 2005. Average winds (21.5 km/hr) were used to characterize typical oil fate (property change, evaporation and dispersion, *etc*.) All scenarios begin on the first of the month and winds used in the trajectory assessments change hourly as per the historical records. Scenarios were run for a maximum of 30 days.
5. In all cases, scenario analyses were conducted for the open water season (ice-free season), the time of year to which the fate and trajectory Modeling apply best.

A summary of the typical fate of the three basic spills being considered is provided in Table 4.3-1. Average winds, air, and water temperatures were used in this fate Modeling. Of primary interest for impact assessment is the duration that these slicks will remain in a form that might cause resource impacts. Two criteria that have been used to determine the likely extent of the impact from these spills: the time to loss of surface oil (slick survival time), and the time for the surface oil to diffuse to concentrations below 1 g/m^2 or 1 μm average oil coverage. The in-water oil concentration from these spills is not significant due to the relatively low peak concentrations and small footprints. For the large diesel spills, the time to loss of slick and time to insignificant average coverage due to diffusion are similar: 90 to 100 hours. Under average wind conditions, the large diesel slicks will travel about 65 to 100 km prior to dissipation, depending on the prevailing currents, and thus may cause impacts to resources over such distance from the release point.

The surface slicks from the small diesel transfer spills at port will survive only for about 48 hours and will exist on the surface in significant concentration only for about 27 hours, if they do not hit shore prior to these times.

The oil from the IFO 180 spills will be persistent, but surface oil concentrations from these relatively small spillets will drop below 1 g/m^2 or 1 μm average oil coverage within about 48 hours. These spills could potentially affect resources 40 to 50 km from the spill site.

Table 4.3-1
Spill Characteristics

	Diesel		IFO 180
	Tanker Accident along Shipping Route	Port Transfer Spill	Tanker Accident along Shipping Route
Spillet Volume (m^3)	1,000	15	15
Air Temperature (°C)	5	5	5
Water Temperature (°C)	0	0	0
Initial Slick Width (m)	250	31	31
Slick Survival Time (hr)	104	47	>720
Max. Slick Width (m)	700	138	72
Time to 1.0 µm Oil Coverage (hr)	90	27	48
Total Evaporation (%)	32	32	15
Total Dissipation (%)	68	68	0.25
Peak Dissipation Oil Concentration (ppm)	3.8	1.45	0.02
Time to Peak Concentrations(hr)	6	3	12
Time to 1.0 ppm (hr)	72	6	n/a
Cloud Width at 1 ppm (m)	7,900	500	n/a

Because large diesel spills have a potentially wider resource impact zone, the following descriptions of potential resource impacts due to oil spills focus on the large diesel spill scenarios.

The possible spill impact zone is further investigated by running a number of spill trajectories based on historical wind records. One of these spill trajectories has been selected at each spill site to discuss possible resource impacts. The scenario selected has generally been the one likely to cause the greatest impact.

4.4 Valued Ecosystem Component (VEC) Selection

Target receptors considered for inclusion in this analysis are listed in Appendix 1. These include all of the marine hunting and fishing activities, marine mammals, birds and fish identified in current environmental sensitivity atlases for the study area prepared by Fisheries and Oceans Canada (1999) and Environment Canada (2000).

In each risk assessment, risks to all socio-economic resources (hunting and fishing activities), targets of major local hunting and fishing activities (beluga whales, polar bears) and living receptors covered by national and territorial species-at-risk legislation were considered. For the remaining living resources, risks to groups of target species were addressed by considering model species.

Information concerning the hunting and fishing activities, areas of special environmental concern and habits of living environmental receptor species (mammals, birds, and fish) are provided in Appendices F-6, F-7, E-3, E-4 and E-5 of the DEIS.

4.5 Effects Assessment

The following describes the fate of oil spills at sea, their interaction with target receptors, effects of spills on receptors and exposure-effect thresholds.

4.5.1 Behaviour of Spills of Diesel Fuel and Marine Fuel Oil at Sea

The behaviour of fuel oil spills at sea is determined by the fact that the hydrocarbons are only slightly miscible with water and less dense than water. As a result, spilled oil floats on the sea surface, where it spreads to form thin oil slicks. Slicks move under the influence of winds and ocean currents and, with the passage of time following a spill, some hydrocarbons are lost from the slick by evaporation and some disperse into the water column. The weathered oil slicks break up into patches or slicklets that become separated by stretches of open water. If diesel spills do not strand on shorelines they will dissipate completely by evaporation or dispersion. If IFO 180 slicks do not become stranded on shore, these patches ultimately break up into persistent, but widely dispersed tar balls that remain in the water column until they aggregate with suspended sediments and sink, are ingested by a suspension feeder and sink, become stranded on shorelines, or become degraded microbially. If oil is spilled into ice-infested waters the oil can be expected to mix with the broken ice and spread and move with the ice.

If slicks encounter shores, the oil will become stranded in the intertidal zone and above, depending on the sea state at the time of the stranding. The oil may penetrate into the shoreline substrate, depending on the porosity and water content of the sediment and the viscosity of the oil. In successive tidal cycles, the oil in the intertidal zone may be remobilized as slicks or as an oil/sediment mixture deposited in the shallow nearshore littoral zone. If not cleaned, the oil that deposits on shores may be persistent.

In open-water diesel spills, some oil from diesel slicks becomes entrained into the upper water column immediately under slicks by direct solution or by entrainment of small oil droplets by wave action. Oil concentrations in this cloud of oil-contaminated water depend on the oil properties and the level of mixing energy (winds/waves) and in theory may greatly exceed the toxic thresholds for species present. The cloud moves under the influence of ocean currents and spreads outward and downward by turbulent diffusion, engulfing organisms nearby. As the cloud spreads the hydrocarbon concentrations within it are reduced by dilution. With the passage of time these oil concentrations fall below concentrations that cause toxicity and ultimately decline to background levels. Some of the hydrocarbons become associated with the suspended sediments in the water column and begin to sediment out. These oil-sediment aggregates arrive at the seabed in the form of light flocculent material that accumulates in depressions in the sea floor, can be redistributed by seabed currents, and can ultimately be incorporated into the sediments by the action of burrowing organisms. In this relatively low wave-energy environment, there will be little dispersion of the more viscous IFO 180 into the water column.

4.5.2 Risks to Hunting and Fishing Activities

Hunting and fishing activities are traditionally sensitive to the presence of marine oil slicks in the local environment for a number of reasons. When commercial fisheries are involved, closures may be imposed by the harvesters or regulators in order to maintain long-term consumer

confidence in local products. When subsistence hunting/fishing are involved, harvesting may be suspended in contaminated areas to: a) avoid consuming tainted products or avoid health risks associated with consuming hydrocarbon-contaminated food; b) avoid contaminating gear used in hunting or fishing; and c) avoid unnecessarily stressing target stocks that are already under stress from effects of spills.

4.5.3 Risks to Marine Birds from Oil Spills

Marine birds are one of the more vulnerable and sensitive of marine species to oil spills in that some species have a strong likelihood of contacting oil slicks if oil is spilled in their vicinity and all birds suffer adverse effects from exposures to small amounts of spilled oil. Historical spills have caused significant impacts on local species populations in the past. These impacts have been well-documented (Vandermuelen, 1982; National Research Council, 1985; Trudel, 1986b; Trudel, 1986a; Murphy *et al.*, 1997; National Research Council, 2003) and accepted exposure effect thresholds have been established (Table 4.5-1).

Table 4.5-1
Summary of Group-Specific Vulnerabilities and Sensitivities to Marine Spills

Group	Exposure-Effect Threshold	Probability of Effects (%)
Dabbling waterfowl	10 g oil/m^2	99
Surface divers	10 g oil/m^2	35
Aerial divers	10 g oil/m^2	35
Surface seabirds	10 g oil/m^2	99
Aerial seabirds	10 g oil/m^2	5
Waders	10 g oil/m^2	35
Shorebirds	10 g oil/m^2	35
Other marine-associated birds	10 g oil/m^2	35
Cetaceans	10 g oil/m^2	0.1
Pinnipeds	10 g oil/m^2	1
Furbearing mammals	10 g oil/m^2	75
Finfish, adult form	1 ppm, oil in water	100
Finfish, larva	0.1 ppm, oil in water	100
Pelagic invertebrates, adult form	1 ppm, oil in water	100
Pelagic invertebrates, larvae	0.1 ppm, oil in water	100
Epibenthic invertebrates, adult form	1 ppm, oil in water	100
Epibenthic invertebrates, larvae	0.1 ppm, oil in water	100
Intertidal and infauna, larvae	0.1 ppm, oil in water	100
Intertidal and infauna adult form	1 ppm, oil in water	1

Revised from French-MacCay (2004).

Adults, juveniles, and fledglings are exposed to spilled oil either directly through exposure to slicks at sea or via ingestion of oil or oil-contaminated prey. Most marine birds have waterproof plumage. Direct exposure to oil slicks on the surface results in oiling of plumage and the

resultant loss of waterproofing. This in turn leads to a loss of insulating properties of plumage causing death by hypothermia. Oiling also leads to loss of buoyancy leading to death by drowning or reduction in swimming ability. Ingestion of hydrocarbons during preening or ingestion of contaminated food can lead to death or a variety of sub-lethal effects.

The risk or vulnerability to oiling by spills appears to vary with birds' habits. Marine species that sit on the sea surface appear to be the most vulnerable; soaring birds, aerial divers, shorebirds and waders less so (French-MacCay, 2004). Once oiled, risk may vary with the birds' ability to leave the water and roost until the oil can be preened off and waterproofing restored. The dosage required to cause damage to birds is low; as little as one gram of oil per kilogram of body weight may be sufficient to cause death in seabirds (Trudel, 1986b). The analytical work of French-MacCay (2004) suggest an exposure standard for Modeling seabird impacts during spills of 10 mL of oil per m^2 of sea surface as a target.

Eggs and nestlings can be affected indirectly by spills. Empirical evidence has shown that eggs or nestlings suffer toxicological effects if contaminated by an oiled parent carrying oil back to the nest on their plumage (Albers, 1977). Obviously, nestling birds are unlikely to survive if a parent is lost at sea due to oiling.

4.5.4 Marine Mammals

Marine mammals in the study area include whales, seals, walrus, and polar bears. The impact of marine oil spills on some marine mammals is well-documented, while those to some groups have just recently been recognized. Some experimental studies have been conducted; all of this material has been extensively reviewed and predictive impact models have been developed (Trudel *et al.*, 1988; Geraci and D.J. St. Aubin, 1990; Loughlin, 1994; French-MacCay, 2004). During historical spills, oiling of mammals and oil-related mortality have been observed, as have sub-lethal effects ranging from mild irritation to severe distress and life-threatening conditions. Mammals are exposed to slicks at sea and to oiled shorelines when they haul out. Significant routes of exposure are surface contamination of pelage and skin, ingestion of oil and inhalation of liquid oil and hydrocarbon vapour. Surface oiling is important for hairy mammals like polar bears. As with marine birds, the hair of some mammals provides thermal insulation, protecting them form the rapid loss off heat to air and sea. Oil acts directly to disrupt the thermal insulation leading to distress and death from hypothermia. Surface oiling also leads to ingestion of oil while grooming, which also leads to systemic effects and possibly death from chemical toxicity. Inhalation of liquid oil leads to toxic damage to lung tissue.

There are very important differences among taxa in terms of sensitivity to oiling. Species like polar bears that derive all of their thermal insulation from their pelage are highly sensitive and have suffered significant and visible impact from spills in the past. On the other hand, bare-skinned mammals like whales appear to be relatively insensitive to the presence of oil slicks in their environment. These species are only exposed to oil slicks at sea, and because they derive their insulation solely from layers of blubber, are insensitive to oiling. An intermediate group of mammals, including pinnipeds, derive their insulation from a combination of hair and blubber. These species are sensitive to exposure to oiling either at sea or on shorelines, if their haulout areas are oiled. These differences among taxa are reflected in the sensitivity/vulnerability

criteria established by modellers like French-McCay (2004). As summarized in Table 4.5-1, the latter suggested that a realistic exposure-effect threshold is an oil slick coverage of 10 g oil/m^2 of sea surface and a sensitivity index 75% mortality of fur-bearing mammals (polar bears), 1% mortality of pinnipeds, and 0.1% risk of mortality in cetaceans.

4.5.5 Finfish

Marine finfish and the fisheries that they support have been impacted by spills in the past. Fish kills and impacts of spills on fish populations are well documented (Wells *et al.*, 1995; Rice *et al.*, 1996). There is also an extensive body of research dealing with acute and sublethal toxicity of hydrocarbons to fish and the potential for contamination of fish tissues by hydrocarbons during spills. This material has been extensively reviewed (National Research Council, 1985; Trudel, 1986b; Trudel, 1986a). Direct impacts of major spills on commercial fisheries are well documented (Tidmarsh *et al.*, 1986; Wells *et al.*, 1995; Rice *et al.*, 1996; Law and Hellou, 2000).

Of interest in this report are the potential risks from spills to both the biological populations and the fisheries based on them. Measurable effects on fish species from hydrocarbon exposure include sub-lethal effects (*e.g.*, embryonic and larval malformation, failure to hatch, reduced size at hatching, reversible physiological conditions), lethality, and tissue contamination. Of interest here are only the effects that have implications at the population level, which include mortality and certain sub-lethal effects that can compromise survivorship or reproduction. These population level effects have implications for fisheries if the population of harvestable life stages is significantly reduced. Impacts of spills on fisheries more commonly arise from environmental or tissue contamination (presence of slicks, elevated concentrations of hydrocarbons in the water column or sediments or off-flavour in fish flesh or contamination with cancer-related polycyclic aromatic hydrocarbon (PAH) rather from damage to the stocks themselves.

5. POTENTIAL ENVIRONMENTAL IMPACTS FROM SPILLS

5. Potential Environmental Impacts from Spills

The following sections present the potential impacts on a spill scenario basis and then consider risks from spills along the shipping lane in general. As mentioned above, this report focuses on the diesel spills at each location, as these are likely to have the largest impacts.

5.1 Lancaster Sound Scenario

5.1.1 Slick Behaviour and Persistence

The persistence of diesel and IFO 180 spillets, respectively, in all scenarios modeled are described above. In the diesel scenarios where the slicklet does not hit shore, the 1000 m^3 slicklets dissipate by evaporation and dispersion within about 100 hours. Based on this, despite their large size, these diesel spills pose significant risks of environmental damage only within about 100 km of the spill site but not beyond.

In IFO 180 scenarios, where the slicklet does not hit shore, the model suggests that surface oil is very persistent, with significant amounts of oil remaining on the surface for up to 720 hours, more than four weeks. Even though the oil is on the surface for a long time, the slicklets will break up into smaller and smaller patches that diffuse over a large area so that in about 48 hours each spillet will have spread to an effective coverage of 1µm. The small patches of oil and tar balls that persist will pose no threat to even the most oil-sensitive species. For this reason, effects of these marine fuel oil spills will likely be restricted to within 40 to 50 km of the spill site, much less than the zone of influence of the larger diesel spill.

5.1.2 Spill Movement

Trajectories of diesel spillets, modeled using six different historical wind records for the Lancaster Sound scenarios, are shown in Figure 5.5-1. These show that most trajectories track to the north and east with only one of six moving west and none moving to the south. Two of the six scenarios dissipate offshore in Barrow Strait without touching land. Four of the six sweep through offshore and nearshore areas, before stranding on shore within 100 hours, where they would clearly cause oiling, sometimes heavy oiling, of potentially sensitive shorelines. Spills could potentially travel in any direction from the spill site, and environmental risks would vary depending on the direction. The August 2000 case, in which the slick travels northwest, contacting shore on the northwest corner of Somerset Island within 48 hours, was selected for analysis because the oil moves in the most common direction, strands on-shore, and causes the highest level of shoreline oiling and environmental impact.

5.1.3 Scenario 10,000 m^3 Diesel Spill with August 2000 Winds: Oil Fate and Movements

In this scenario, diesel slicklets move northeast from the spill site, grounding on the northwest corner of Somerset Island within 72 hours. At the time of grounding, approximately 400 m^3 of oil remains of the 1,000 m^3 originally in each slicklet, and the area covered by each slicklet is approximately 8.5 km in width. A total of approximately 4,000 m^3 of oil lands on the shoreline.

The shoreline in this area is largely beach (cobble), so much of the stranded oil is retained and is not re-mobilized to be transported along the shore by winds and current.

5.1.4 Scenario 10,000 m^3 Diesel Spill with August 2000 Winds: Potential Environmental Impacts

Environmental risks from this spill in late August or September are summarized in Table 5.1-1. The oil would pose limited toxicological risk to the beluga population of northwest Somerset Island, because biological sensitivity of these mammals to thin slicks is low. However, this much oil in the hunting area in hunting season would certainly disrupt the hunt for the season.

Archaeological sites on shore would be at risk from both the oil contamination and the cleanup activities. Damage from the oil is unavoidable, but potential damage from cleanup activities can be minimized if they are conducted with care.

The presence of many thick oil slicks in the foraging areas of the black guillemot colonies at Limestone Island and Pressure Point could contaminate a large proportion of the birds from that colony and kill a large proportion of the birds. On the other hand, these colonies contain a relatively small proportion of the regional breeding stock of black guillemots, so the risk to the population as a whole is very modest.

These spills could cause oiling of pelagic thick-billed murres, northern fulmars and black-legged kittiwakes. However, the proportion of the regional population potentially impacted is very small.

5.2 Jenny Lind Scenario

5.2.1 Slick Behaviour and Persistence

The persistence of the 10,000 m^3 diesel and IFO 180 spill are described above. In diesel scenarios where slicklets do not hit shore, the spillets dissipate in about 100 hours and will not pose any environmental risk beyond 100 km from the spill site.

5.2.2 Spill Movement

The trajectories of diesel spillets for the Jenny Lind scenarios are shown in Figure 3.5-4. These show that oil spills in this area track to the north, northeast and east. None track to the south. Two of the six scenarios track to the northeast, dissipating offshore M'Clintock Channel or Larsen Sound. Two track to the north stranding on Taylor Island, with some oil possibly bypassing the island and dissipate at sea in M'Clintock Channel. In two cases, the spill tracks to the east towards King William Island. As discussed above, spills could potentially travel in any direction from the spill site and environmental risks would vary depending on the direction. For purposes of this analysis, the trajectory analysed is September 2005, in which the slick travels north, stranding on Taylor Island after approximately 60 hours. For impact assessment purposes, a conservative assumption has been made that some oil persists beyond Taylor Island to pass near Admiralty Island before moving offshore and dissipating in M'Clintock Channel.

Table 5.1-1
Impact Summary for Scenario Lancaster Sound, August 2000, 10,000 m^3 of Diesel

Criteria	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological Context	Influence on Resource Capacity	Probability	Mitigation	Significance[a]	Confidence Count[a]
Hunting/Fishing												
Hunting (Resolute) • Beluga northwest Somerset Island	Disrupt hunt	High	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	Low	Prevention effective. Containment offers limited protection. Shoreline cleanup limits disruption lto one year.	High	High
Archaeology												
Archaeological sites on shoreline	Damaged by contamination and cleanup	High	Local	Short-term	One time	Short-term to irreversible	Low	Low	Moderate	Some damage if shoreline oiled. Damage minimized with careful cleanup.	High	High
VECs												
Beluga Whales • (Canadian Low Arctic) Area of concentration (2,000 individuals) contacted, little risk of mortality as slicks are very thin (<10 µ)	Mortality	Negligible	Regional	Medium-term	One time	Reversible short-term	High Resilience	Low	Low	Prevention effective. Containment offers limited protection. Shoreline cleanup limits disruption lto one year.	Negligible to Low	High
Black Guillemot • Limestone Island (200 pairs) • Pressure Point (100 pairs) Slicks briefly contaminate all foraging area for these colonies killing major proportion occupants	Mortality	High	Local	Medium-term	One time	Reversible short-term	High Resilience	High	Low	Attempt at containments will have limited effect,	Moderate	High
Thick-billed Murres (pelagic) • East Canadian Arctic population (2.4 M birds)	Mortality	Low	Regional	Medium-term	One time	Reversible short-term	High Resilience	Nil	Mod	Attempt at containments will have limited effect.	Low	High
Northern Fulmar (pelagic) • East Canadian Arctic breeding population (0.6 M individuals)	Mortality	Low	Regional	Medium-term	One time	Reversible short-term	High Resilience	Nil	Mod	Attempt at containments will have limited effect.	Low	High
Black-legged Kittiwakes (pelagic)	Mortality	Low	Regional	Medium-term	One time	Reversible short-term	High Resilience	Nil	Mod	Attempt at containments will have limited effect.	Low	High

a. See Section 3.5.2 below.

5.2.3 Scenario 10,000 m^3 Diesel Spill with September 2005 Winds: Oil Fate and Movements

The September 2005 scenario is assumed to occur in the ice-free period in late August and early September. The spill occurs in Icebreaker Channel between Jenny Lind Island and Victoria Island, tracks north past De Haven Pt., oiling Taylor Island, and possibly Admiralty Island and the lower end of Collinson Peninsula near Cape Alfred. By the time Cape Alfred is reached, oil concentrations on the sea surface may be visible as sheen, but are nearing innocuous levels from a toxicological perspective. In this scenario, some oil strands on Taylor Island after approximately 60 hours, while some passes near Admiralty Island before moving offshore and dissipating in M'Clintock Channel. Some may strand on Admiralty Island.

5.2.4 Scenario 10,000 m^3 Diesel Spill with September 2005 Winds: Spill Impact

Environmental risks from an open-water spill of diesel in late August or September are summarized in Table 5.2-1. The presence of oil or sheens in areas like Cape Adelaide or Cape Alfred where char fishing is done would disrupt fishing activity for as long as sheens are present and as long afterward as would be required to test for tissue contamination (probably for the remainder of the open-water season). There would be negligible toxicological risk for char in these areas as oil concentrations in the water column generated by these thin slicks would be low. Slicks would affect harvesting of ringed seals, sea ducks and polar bear in a similar way.

Slicks of diesel in these areas might pose toxicological risks to local polar bear populations on the Admiralty Islands. Risks posed to less sensitive ringed seals would be less.

The fact that oil threatens areas adjacent to the Albert Bay Key Marine Bird Terrestrial Area flags this spill as being of higher concern. The presence of oil slicks in the foraging areas of sensitive and vulnerable sea ducks (oldsquaw and eiders) and loons puts significant numbers of the local populations at risk. These conditions would pose less of a threat to the less vulnerable geese and swans and limited risk to shorebirds and waders.

5.3 Bathurst Inlet Scenario

5.3.1 Slick Behaviour and Persistence

Spills launched from a number of locations along the shipping lane through Bathurst Inlet were considered in the oil spill modeling completed for the project. Details of the results of this analysis are reported in Section 1.5.4 of this report. Because Bathurst Inlet is a large estuary containing numerous islands, spills launched from virtually all locations in the Inlet will strand on islands, usually within a few hours, long before the spills can travel any distance. The scenarios considered for impact assessment here were launched north of the Breakwater Islands in northern Bathurst Inlet. These scenarios were selected for analysis because they were more persistent than most, and impacted a larger area than spills originating from other sites. The persistence of the diesel spill is described above. Generally most slicklets from all spills strand on offshore islands within a few days, seldom persisting more than a few tens of kilometres from the spill site.

5.3.2 Spill Movement

The trajectories of diesel spillets for the Bathurst Inlet spills are shown in Figures 3.5-5 to 3.5-10 and show that in general, trajectories track to the north, but strand quickly on islands.

5.3.3 Scenario 10,000 m^3 Diesel Spill, September 2005: Oil Fate and Movements

The September 2005 scenario was analysed in this scenario. In this scenario the slicklets travel north, from the Breakwater Islands toward Walker Bay on the Kent Peninsula, stranding on the Kent Peninsula and Cockburn Islands.

5.3.4 Scenario 10,000 m^3 Diesel Spill, September 2005: Spill Impact

Environmental risks from an open-water spill of diesel in September in northern Bathurst Inlet are summarized in Table 5.3-1. The presence of oil slicks or sheens in an active hunting/fishing area in Bathurst Inlet will disrupt harvesting activity in the immediate vicinity of the contaminated area for the length of time that contamination persists (in the present case for one season).

The presence of oil slicks in the foraging areas of sensitive and vulnerable sea ducks (oldsquaw and eiders) and loons, puts significant amounts of the local populations at risk. These conditions would pose less of a threat to the less vulnerable geese and swans and little risk to shorebirds and waders.

5.4 Bathurst Port Scenario

5.4.1 Slick Behaviour and Persistence

The persistence of the 15 m^3 diesel spills in the Bathurst Inlet port spill scenarios is reported above. In all scenarios the oil slicks contact shorelines quickly, in most cases within 24 hours and very near the spill site. As long as oil persists at sea thicknesses are great enough to pose a risk to sensitive biological VECs. In two scenarios, the slick tracks to the northeast transiting north along the inlet for nearly 48 hours (Figure 3.5-10). During this period in both scenarios, small amounts of oil are deposited on rocky shores or beaches along the length of the inlet.

5.4.2 Scenario 15 m^3 Diesel Transfer Spill in Port: Potential Environmental Impacts

Environmental risks from an open-water spill in late August or September are summarized in Table 5.4-1. In short, much of the area is used for hunting waterfowl and seals during the summer months and these spills would disrupt this hunting over part, but not all of the area. If oiled shorelines are cleaned, this impact can be limited to a single season.

The presence of many thick oil slicks in the coastal foraging areas of moulting red-breasted mergansers could oil and kill some birds. However, these birds represent a small proportion of the regional breeding stock of red-breasted mergansers, so the risk to the population as a whole is very modest.

Table 5.2-1
Impact Summary for Jenny Lind, August to September, 10,000 m^3 Diesel Spill

Criteria	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological Context (Recovery)	Influence on Resource Capacity	Probability	Mitigation	Significance[a]	Confidence Count[a]
Hunting/Fishing												
Char • Cape Adelaide • Cape Alfred	Disruption	Moderate	Local	Short-tem	One time	Reversible short-term	High Resilience	Nil	Low	Prevention needed. Containment will have limited effect. Shoreline cleanup ensures disruption limited to 1 year.	Low	High
Ringed Seals • De Haven Point	Disruption	Moderate	Local	Short-tem	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Low	High
Sea Ducks • De Haven Point	Disruption	Moderate	Local	Short-tem	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Low	High
Polar Bear • De Haven Point	Disruption	Moderate	Local	Short-tem	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Low	High
Archaeology												
None												
VECs												
Polar Bear (AI)[b]	Mortality	High	Local	Medium-term	One time	Reversible short-term	Neutral	Mod	Mod	Same as above	High	High
Ringed Seals (AI)	Mortality	Low	Local	Medium-term	One time	Reversible short-term	High Resilience	Mod	Mod	Same as above	Low	High
Oldsquaw (JL,AI) • Canadian Arctic population	Mortality	Moderate	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	High	Same as above	Moderate	High
King Eider (JL, AI) • East Canadian Arctic population	Mortality	Moderate	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	High	Same as above	Moderate	High
Pacific Loon (AI)	Mortality	Moderate	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	High	Same as above	Moderate	High
Ruddy Turnstone	Mortality	Negligible	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	Nil	Same as above	Negligible	High
White-front Goose (AI)	Mortality	Low	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Low	High
Canada Goose (AI)	Mortality	Low	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Low	High
Tundra Swan (AI)	Mortality	Low	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Low	High
Arctic Char	Mortality	Negligible	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Negligible	High
Albert Edward Bay KMBTS[c]	Bird Mortality	Negligible to Moderate	Local	Short-term	One time	Reversible short-term	High Resilience	Nil	Low	Same as above	Negligible	High

a. See Section 3.5.2 below b. AI=Admiralty Islands, c. KMBTS = Key Marine Bird Terrestrial Habitat Site

Table 5.3-1
Impact Summary for the Bathurst Inlet, August to September 10,000 m^3 Diesel Spill

	Nature	Magnitude	Geographic Extent	Duration	Frequency	Reversibility	Ecological Context (Recovery)	Influence on Resource Capacity	Probability	Mitigation	Significance[a]	Confidence Count[a]
Hunting/Fishing												
Hunting (Bathurst Inlet, Bay Chimo) • seals	Disrupt hunt	Moderate	Local	Short-tem	One time	Reversible short-term	Neutral	Nil	Mod	Prevention effective. Containment offers limited protection. Shoreline cleanup ensures disruption limited to one year.	Moderate	High
Archaeology												
None[b]												
VECs												
Ringed Seals (BI)	Mortality	Negligible	Local	Medium-term	One time	Reversible short-term	Highly Resilient	Nil	Moderate	Prevention effective. Containment offers limited protection. Shoreline cleanup ensures disruption limited to one year.	Negligible	High
Pac. Eiders • North Bathurst Inlet	Mortality	Moderate	Local	Short-term	One time	Reversible short-term	Highly Resilient	Nil	High	Same as above	Moderate	High
Oldsquaw (BI) • Canadian Arctic population	Mortality	Moderate	Local	Short-term	One time	Reversible short-term	Highly Resilient	Nil	High	Same as above	Moderate	High
King Eider (BI) • East Canadian Arctic population	Mortality	Moderate	Local	Short-term	One time	Reversible short-term	Highly Resilient	Nil	High	Same as above	Moderate	High
Pacific Loon (BI)	Mortality	Moderate	Local	Short-term	One time	Reversible short-term	Highly Resilient	Nil	High	Same as above	Moderate	High
White-front Goose (BI)	Mortality	Low	Local	Short-term	One time	Reversible short-term	Highly Resilient	Nil	Mod	Same as above	Low	High
Brant (BI)	Mortality	Low	Local	Short-term	One time	Reversible short-term	Highly Resilient	Nil	Mod	Same as above	Low	High
Sandhill Cranes (BI)	Mortality	Low	Local	Short-term	One time	Reversible short-term	Highly Resilient	Nil	Mod	Same as above	Low	High

a. See Section 3.5.2 below. b. No archaeological sensitivities shown in sensitivity maps in areas at risk from this spill scenario.

Table 5.4-1
Impact Summary for Scenario Bathurst Inlet Port Spill, August to September, 15 m^3 Diesel Spill

Criteria	Nature	Magnitude	Geographic Extent	Frequency	Duration	Reversibility	Ecological Context	Influence on Resource Capacity	Probability	Mitigation	Significance	Confidence Count
Hunting/Fishing												
Hunting (Bathurst Inlet) • Ringed seals • Red-breasted mergansers	Disrupt hunt	Mod	Local	One time	Short-term	Reversible short-term	Neutral	Nil	Moderate	Prevention effective. Containment offers limited protection. Shoreline cleanup ensures disruption limited to one year.	Mod	High
Archaeology												
None[b]												
VECs												
Red-breasted Mergansers • Tinney Hills	Mortality	Low	Local	One time	Short-term	Reversible short-term	Highly Resilient	Nil	Moderate	Prevention is effective. In the event of a spill, containment will have limited effectiveness, but shoreline cleanup will minimize persistence	Low	High

a. See Section 3.5.2 below b. No archaeological sensitivities shown in sensitivity maps in areas at risk from this spill scenario.

5.5 Overview/Summary

5.5.1 Oil Fate and Movement

The fate and effects of spills along the shipping lane will depend on a variety of factors including the location and season of the spill, the nature of the spill itself (type and volume of oil spilled) and the conditions in the receiving environment at the time of the spill (winds, ice cover). The oil fate Modeling and trajectories demonstrated consistent patterns. The 1,000 m^3 spillets of diesel transiting open water will persist for only a matter of days in thicknesses great enough to do damage to biota. As a result, these spills pose environmental risks only within 100 to 120 km from the spill sites. The smaller but more persistent spills of the IFO 180 posed risks only within 40 to 50 km from the sites. These distances were somewhat reduced for scenarios in confined waters or waters with numerous islands.

5.5.2 Impacts

The analyses of impact in the scenarios lead to the following conclusions.

Spills in hunting/fishing areas will cause localized short-term disruptions (one season) to hunting and fishing activities. The magnitude/importance of the disruptions will depend on the relative sizes of the hunting/fishing area and areas contaminated by spills. For very large hunting/fishing areas even sizable spills can cause disruptions in only a small proportion of the hunting/fishing areas. However, the above analysis showed that when small hunting/fishing areas are involved, larger spills could potentially disrupt harvesting throughout the area in question for the season.

In general, risks to bare-skinned mammals (whales) from spills of the type considered here are very limited because the mammals themselves are relatively insensitive to effects of oil. On the other hand the threat to hairy mammals like polar bears must be considered significant. The bears themselves have been shown to be sensitive to oil and would suffer adverse effects if oiled. Oiling could reasonably occur and significant numbers of animals might be impacted should a spill occur near a high use area, such as a denning area. However, because the persistence of these spills is limited, impacts of even large spills would be limited only to the immediate area of the spill.

Similarly, risks of impacts to relatively invulnerable bird species like shorebirds will be modest. Risks to more vulnerable marine bird species like seabirds and seaducks might be significant. Risks will obviously depend on spill size and location. For the spill locations selected in the analyses above, predicted spill impacts on birds were generally modest. In most cases, spill trajectories contaminated areas where birds were present, but in only modest bird concentrations. Concentrations were low because the populations as a whole were broadly distributed across large areas in the study area and beyond. As a result, though some bird mortalities might occur, the proportions of populations as a whole that would be impacted are small. This situation is indeed true through much of the study area. However, spills in some specific locations, such as near the major seabird concentration areas on Prince Leopold Island in Lancaster Sound or the Queen Maud Bird Sanctuary, would have larger and more significant impacts.

Risks from the spills to fish populations (char) must be considered limited for several reasons. First, the IFO 180 fuel oil will not mix into the water column and hence poses negligible

toxicological risk to in-water species. Most important, however, the mapped sensitivity data for the study area reported in Fisheries and Oceans Canada (1999) and Environment Canada (2000) show few important concentration areas for fish populations. Generally, significant risks to fish populations from spills occur only under conditions where populations concentrate in limited areas for all or part of the season.

In short, environmental risks from spills will vary from negligible to high depending on the size of spill and its location and timing (seasonality). Based on the assessment of spill probability above, small spills (few litres to a few tenths of a tonne) involving diesel or marine fuel oil are likely to occur. When they do, their impact will be negligible and they can be readily cleaned up. On the other hand, very large spills of diesel (thousands of tonnes) are highly unlikely. However, if one were to occur its impact would be moderate to high depending on its location and timing. The potential for mitigation of impacts of the large spill would be problematic and would vary depending on location and timing. The level of confidence in these assessments is high as a result of experience with thousands of marine spills in arctic, temperate and tropical environments over the last five decades.

5.6 Mitigation and Management Plans and Monitoring

Mitigation and management plans are dealt with in Appendix G-4 of the DEIS (Environmental Management Plan for Camp, Road, Port and Shipping).

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Appendix E-7
Marine Environment Baseline Studies 2001-2002

Author: **Rescan Environmental Services Ltd.**
Date: **October 2007**

the BATHURST INLET PORT AND ROAD PROJECT

Bathurst Inlet Port and Road Project

Nunavut, Canada

Bathurst Inlet Port and Road Project Marine Environment Baseline Studies, 2001-2002

Prepared by:

Rescan™ Environmental Services Ltd.
Vancouver, British Columbia

October 2007

EXECUTIVE SUMMARY

Executive Summary

This report describes the marine environment during the ice-free season of a proposed Port site in southern Bathurst Inlet, and is a component of the overall baseline studies for the Bathurst Inlet Port and Road Project. Five oceanographic stations were established in August 2001: three along the eastern shore of the Port site and two offshore. At each station vertical profiles of water temperature, salinity and light extinction were taken, samples of water and sediment were collected for chemical analyses, and the abundance and taxonomic composition of phytoplankton, zooplankton and benthic invertebrates was measured. In addition, a survey of the nearshore zone adjacent to the proposed port was conducted to provide baseline information on fish and their habitat. In August 2002, the five oceanographic stations were sampled again: all five for benthos taxonomy and one station for sediment chemistry.

The water column near the proposed Port was highly stratified during the summer it was sampled. The upper mixed-layer was 5 to 7 m and the euphotic zone extended to about 9 m depth. The water quality at all stations reflected a pristine environment. The marine sediments near the Port were of high quality and also reflected a pristine aquatic environment. The sediments were soft, loosely bound clay-silt complexes with no organic debris, reflecting the absence of woody debris from the near-shore terrestrial environment. Concentrations of total nitrogen were also low, indicating the absence of significant quantities of organic matter in the sediments. Hydrocarbon concentrations were low, reflecting the absence of industrial activity near the proposed Port site.

Chlorophyll *a* concentration (an index of phytoplankton biomass) ranged from 0.05 to 1.18 µg/L. Average cell densities of phytoplankton collected at the sea surface ranged from 590 to 989 cells/mL, with three or four genera dominating the phytoplankton assemblage. Average numerical abundance of zooplankton in vertical hauls ranged from 5,562 to 11,082 ind./m^3. Calanoid copepods predominated, making up between 81 and 90% of average abundance. Average benthos density was 22,752 ind./m^2 in August 2001, and 3,419 ind./m^2 in August 2002. The average number of genera ranged from 18 to 39, with the most numerous organisms identified as nematodes, annelids and foraminiferans.

A total of 177 fish from 11 species were captured. Fourhorn sculpin was the predominant species, followed by Arctic cisco, starry flounder, saffron cod, Arctic flounder, Pacific herring, broad whitefish, rainbow smelt, Arctic char, ogac and lake trout. The fish captured were mainly nearshore, shallow-water species with a relatively large component of anadromous species and species with low tolerance for salinity (compared to the historical records available for Bathurst Inlet). Most fish captured in the nearshore zone were demersal and moved along the sea bottom. All species captured were common fish in Canada's Arctic waters, and none are threatened or endangered.

On the basis of average fork length, adult broad whitefish were the largest fish, followed by adult ogac, Arctic char, saffron cod, lake trout, rainbow smelt, Arctic cisco, starry flounder, Pacific herring, fourhorn sculpin and Arctic flounder. The smallest fish were juvenile fourhorn sculpins.

Condition (the ratio of weight to length cubed) was highest for short, broad fish such as Arctic flounder and starry flounder, and lowest for long, narrow fish such as rainbow smelt and saffron cod.

Average concentrations of mercury, arsenic and lead in starry flounder (resides year-round in the nearshore zone) were below the guidelines established by Canadian and British Columbia food inspection agencies. Average concentrations of selenium and cadmium were below the levels known to cause adverse effects. In general, metal concentrations in these Bathurst Inlet fish reflect a pristine environment.

Nearshore habitat was primarily composed of gravel, cobble and sand, with a narrow band of small gravel intersecting the middle of the exposed shore. This is likely the preferred habitat for starry flounder, Arctic flounder, and fourhorn sculpin. At one of the three sites examined, boulder was the dominant substrate.

In general, the physical, chemical and biological characteristics of the marine environment of Bathurst Inlet near the proposed Port are typical of those expected of a pristine Arctic marine environment.

ACKNOWLEDGEMENTS

Acknowledgements

Dr. Michael McGurk (R.P.Bio.), François Landry (M.Sc.), Jonathan Olsen (B.Sc. Hons.), and Marc Wen (M.Sc.) wrote this report. Marc Wen was the principal oceanographer, and was assisted in the field by John Chételat (M.Sc.) of Rescan and Alan Kapolak of the community of Bathurst Inlet. François Landry, Michael McGurk and Shane Uren of Rescan, along with Allen Kapolak of the community of Bathurst Inlet, and George Hitolok of the Kugluktuk Hunters and Trappers Association conducted the fisheries field work. John Tost of North Shore Environmental Services Ltd. aged the fish. ALS Environmental performed the chemical analyses on water, sediment and fish tissue. Brian Coad and Noel Alfonso of the Research Services Division of the Canadian Museum of Nature provided an unpublished key to Arctic marine fish of Canada and historical records of fish collected in Bathurst Inlet. The Rescan staff that produced the report included Jackie van der Eerden, Joanna Lerner, Guylaine Cachard, Francine Alford and Ping Lee.

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1. INTRODUCTION

1. Introduction

1.1 Background

The proposed Port for the Bathurst Inlet Port and Road Project is located on a peninsula in south-western Bathurst Inlet (66°33'N and 107°31'W) about 40 km south of the community of Bathurst Inlet (Figure 1.1-1). Marine environmental studies were conducted in 2001 to provide the baseline information needed to assess the potential environmental effects of the construction and operation of the Port. This marine environment baseline report describes the objectives, methods, and results of the studies.

There is limited information available on the physical, chemical and biological characteristics of the water column and the sea floor in Bathurst Inlet. This report is intended to provide site specific information on the marine environment. Physical characteristics measured include vertical profiles of water temperature, salinity and light extinction. Measured chemical characteristics include seawater quality and sediment quality, and biological characteristics include the density and taxonomic composition of phytoplankton, zooplankton and benthic invertebrates. These basic biological characteristics of the local marine environment were included in the baseline study because of their general importance to the marine food web.

Phytoplankton (single-celled plants) are a food source for all trophic levels of the marine ecosystem. Zooplankton consume phytoplankton and are prey for higher trophic levels, thereby acting as a vector for transferring pollutants to fish and other planktivorous organisms. Benthic invertebrates are animals that live on or in close association with the sea bottom. They can live either in the sea floor (infauna) or on the sea floor (epifauna). These organisms have a limited capacity to move, and are susceptible to local disturbances to the sediment. Benthic invertebrates are an importance food resource for many species of fish, and some planktonic stages contribute seasonally to the pelagic food web as consumers and as prey.

The fisheries resources of Bathurst Inlet are not well known because of the remote location of the inlet, small human population, and the absence of significant commercial fisheries. Fish of Bathurst Inlet have been sampled on an opportunistic basis by scientists of the Department of Fisheries and Oceans and the Canadian Museum of Nature (Hunter *et al*., 1984; Noel Alfonso, Canadian Museum of Nature, P.O. Box 3443, Station "D", Ottawa, K1P 6P4, personal communication). Other authors have reported fish captured in Bathurst Inlet as part of larger-scale surveys of the fisheries resources of Arctic Canada (Richardson, 1836; Johansen, 1926; Walters, 1953; Boulva and Simard, 1968; Renewable Resources Consulting Services Ltd., 1972; Friesen, 1975; Farquharson, 1976; Stewart and MacDonald, 1978; Sutherland and Golke, 1978; McAllister *et al*., 1987; Yaremchuk *et al*., 1989; Kristofferson *et al*., 1990; Riewe, 1992; McGowan *et al*., 1993; Stewart, 1994; Stewart *et al*., 1993).

the BATHURST INLET PORT AND ROAD PROJECT

Bathurst Inlet Port and Road Project
Port Location

FIGURE 1.1-1

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1.2 Objectives

There were four objectives for this component of the marine environmental study:

- Describe the physical structure of the water column near the Port;
- Describe water quality and sediment quality;
- Describe the abundance and taxonomic composition of phytoplankton, zooplankton and benthic invertebrates near the Port; and
- Describe the taxonomic composition, relative abundance and biological characteristics of the nearshore fish community and to describe the nearshore and intertidal fish habitat near the Port.

2. METHODS

2. Methods

2.1 Marine Vessel

All sampling was conducted from an 18 foot-long aluminum motor boat with a 60 hp outboard engine. All instruments were lowered and raised over the side of the boat by hand using a metered rope. A Differential Global Positioning System (DGPS) (Trimble ProXRS) receiving differential corrections from a LandStar satellite was used to accurately measure the Northing and Easting of each sampling station.

2.2 Sampling Locations and Dates

Five sampling stations were established off the eastern shore of the peninsula of the proposed Port site. Stations 1, 2 and 3 were inshore stations that followed a line parallel to the shore, and stations 4 and 5 were offshore stations directly east of station 2 (Table 2.2-1 and Figure 2.2-1). The five stations were sampled from August 14 to 16, 2001. Selected parameters (sediment quality and benthos taxonomy) were again sampled ion August 6, 2002.

Table 2.2-1
Locations of Sampling Stations, Bathurst Inlet, August 2001 and 2002

Station	Northing (m)	Easting (m)	Depth (m)
1	7382206	389554	40
2	7383386	388654	17
3	7384325	387505	34
4	7383455	388716	47
5	7383478	388772	70

Note: UTMs (Northing and Easting) are defined using the NAD-83 datum, grid 13N.

2.3 Physical Structure of the Water Column

The depth at each of the five stations was measured with a Sci-Tex 200 kHz depth echo-sounder prior to sampling. Vertical profiles of temperature, salinity and density were performed at stations 1, 2, 3 and 5 using an *in situ* Applied Microsystems Ltd. model STD-12 Conductivity, Temperature and Depth (CTD) probe. The CTD probe was calibrated prior to the field survey. The instrument provided measurements of temperature, salinity and density at approximately 1 m intervals from the surface to the sea bottom. The temperature sensor had an accuracy of ±0.01°C over the range of –2 to 38°C. The conductivity meter had an accuracy of ±1 mS/m over the range of 0.02 to 6.5 S/m. Salinity was calculated from conductivity and reported as Practical Salinity Units (PSU). Density was calculated from temperature and salinity and was reported as units of σ_t (or "sigma-t" where σ_t = density (kg/m^3) – 1,000 kg/m^3).

The CTD was also equipped with an optical transmissivity sensor (manufactured by SeaTech Inc.) that measured light transmission. The sensor consisted of a 25 cm long water path illuminated by a modulated light emitting diode. The diode produced a monochromatic red light that was detected by a synchronous detector. The instrument measured the degree of light

attenuation, as a percentage of unobstructed light transmission, resulting from the presence of suspended solids in the water path. The sensor had a range of 0 to 100% (corresponding to an approximate range of 0.004 to 20 mg/L of suspended solids) and an accuracy of ±0.5%. Percent transmissivities cannot be converted readily to concentrations of suspended solids because the relationship between the two variables is dependent on particle size.

A vertical profile of dissolved oxygen concentration was measured at each station at 1 m intervals with a YSI dissolved oxygen meter (Model 85). The meter had an accuracy of 0.3 mg/L over the range of 0 to 20 mg/L of dissolved oxygen.

Finally, a Secchi depth was measured at each station to calculate the depth of the euphotic zone, a key variable used to calculate sampling depths for phytoplankton biomass. A marine Secchi disk (30 cm diameter, solid white) was attached to the end of the sampling wire and lowered on the shaded side of the boat until it disappeared from sight. The depth of disappearance was identified as the Secchi depth or D_s (m). The extinction coefficient (k', m^{-1}) was calculated as:

$$k' = 1.7/D_s ,$$

where 1.7 is a constant (Parsons *et al*., 1984). In turn, the depth of the base of the euphotic zone, $Z_{1\%}$ (m), defined as the depth at which only 1% of the surface irradiation reaches (Falkowski and Raven, 1997), was calculated as:

$$Z_{1\%} = 4.6/k' ,$$

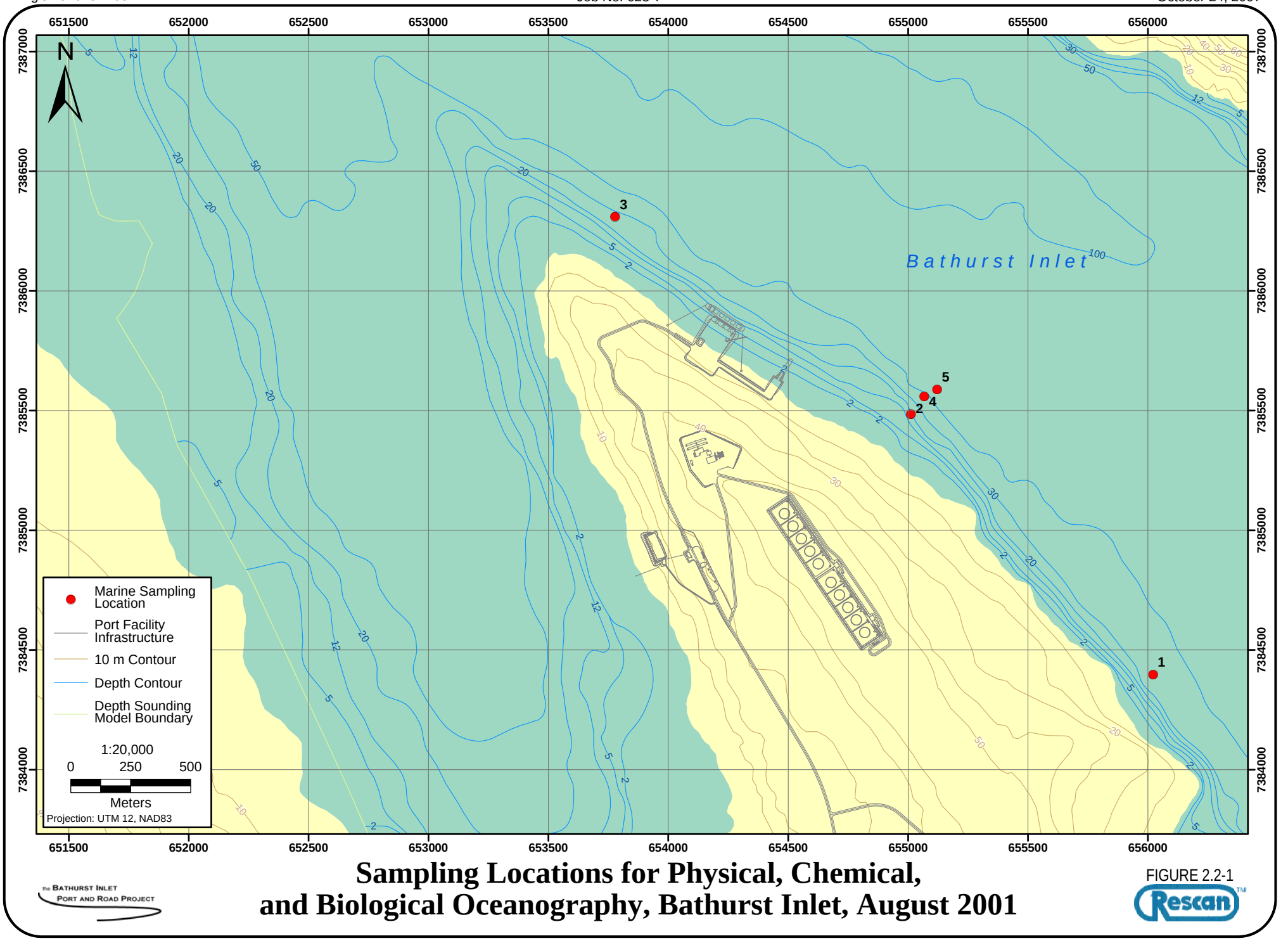
where 4.6 was a constant derived from Beer's Law.

2.4 Water Quality

Water quality samples were collected at all five sampling locations near the proposed Port location.

2.4.1 Sample Collection

Samples of seawater were collected from five depths at each of the five stations: near surface, above the thermocline, below the thermocline, in the middle of the stable layer and about 1 m from the sea bottom. Sampling at each station was preceded by a CTD cast to identify the depth of the thermocline. Each sample was collected in a Teflon-lined General Oceanics GO-FLO sampling bottle suspended on a wire (Figure 2.4-1). A GO-FLO bottle is specially designed for sampling waters with low metals concentrations because there is no rubber or other contaminating material inside the apparatus. The bottle is designed to pass through the air-water surface without collecting any of the oil, dust and contaminants that tend to accumulate as a micro-layer on the water surface. The bottle has a hydrostatic valve that is designed to release at a pressure of about 10 m of water. Hence, the bottle was sealed at the surface and dropped to a depth of 10 m where it automatically opened. Then, the bottle was raised or lowered to the sampling depth. After a wait of about 1 minute to allow the bottle to equilibrate with its surroundings, a Teflon-coated messenger was sent down the wire to close the bottle. Then, the bottle was raised to the surface and water samples were drawn off and stored in prepared sample bottles.



Sampling Locations for Physical, Chemical, and Biological Oceanography, Bathurst Inlet, August 2001

the Bathurst Inlet Port and Road Project

FIGURE 2.2-1

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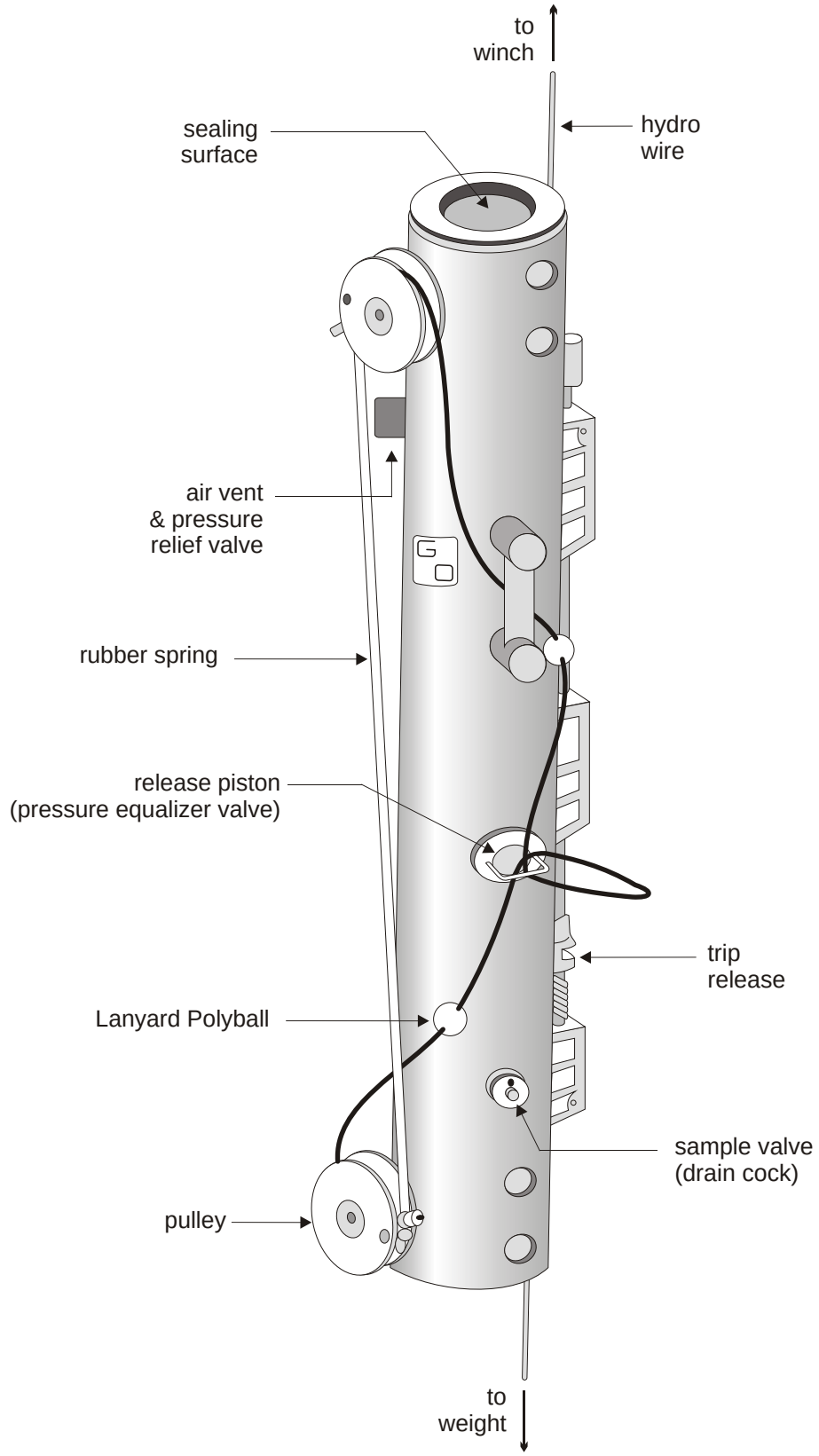

FIGURE 2.4-1

GO-FLO Water Sampler

2.4.2 Methods of Analysis

All water sample bottles were individually stored in ziplock bags and transported on ice in coolers to ALS Environmental Ltd. in Vancouver, British Columbia, for analysis. To ensure sample integrity, proper clean trace-metal sampling protocols were followed (Environment Canada, 1994; US EPA, 1986-1991). All analyses were in accordance with "Standard Methods for the Examination of Water and Wastewater" (APHA, 1998) or adapted from "Test Methods for Evaluating Solid Waste" (US EPA, 1986). Six groups of variables were measured:

1. physical variables including conductivity (S/cm), pH, total dissolved solids (mg/L), total suspended solids (mg/L), hardness (mg/L of CaCO3) and turbidity (NTU);
2. concentrations of dissolved anions including acidity (mg/L CaCO3), alkalinity (mg/L CaCO3), bromide (mg/L Br), chloride (mg/L Cl), fluoride (mg/L F), silicate (mg/L SiO2) and sulphate (mg/L SO4);
3. concentrations of nutrients including ammonia-nitrogen (mg/L NH4-N, i.e., the total amount of nitrogen in the form of ammonia), nitrate-nitrogen (mg/L NO3-N), nitrite-nitrogen (NO2-N), dissolved ortho-phosphate (mg/L of dissolved P), and total phosphate (mg/L of total P including particulate P and dissolved P);
4. concentrations (mg/L) of 33 dissolved metals including aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), bismuth (Bi), boron (B), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), lithium (Li), magnesium (Mg), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), phosphorus (P), potassium (K), selenium (Se), silicon (Si), silver (Ag), sodium (Na), strontium (Sr), thallium (Tl), tin (Sn), titanium (Ti), uranium (U), vanadium (V) and zinc (Zn);
5. concentrations (mg/L) of 33 total metals (the same metals measured in the dissolved state); and
6. concentration (mg/L) of total organic carbon (TOC).

Conductivity and pH were measured with electronic probes. Total dissolved solids and suspended solids were measured gravimetrically after filtering and drying samples at 103°C.

Turbidity was measured by nephelometric method and was reported in units of NTU (nephelometric turbidity units). Acidity was measured by potentiometric titration to a specific endpoint, and alkalinity by the methyl orange colourimetric method. Both were reported in units of mg/L $CaCO_3$. Dissolved anions were measured by ion chromatography. Ammonia was measured by phenate colourimetric method, nitrate by cadmium reduction colourimetric method, nitrite by azo dye colourimetric method, and phosphate by ascorbic acid colourimetric method. Trace metals in seawater were extracted using a suspended particulate resin consisting of immobilised iminodiacetate on a divinylbenzene polymer. Instrumental analysis was by inductively coupled plasma-mass spectrometry (ICP-MS), graphite furnace atomic absorption spectrophotometry (GFAAS) or cold-vapour atomic absorption spectrophotometry (CVAAS). Total organic carbon was measured by the combustion-infrared method.

Detection limits for each water quality variable are shown in Table 2.4-1. The detection limits were higher than the theoretical minimum for some variables because dilution was required to compensate for high concentrations of dissolved solids.

2.4.3 Quality Control and Quality Assurance

A quality assurance and quality control program (QA/QC) was included in the design of the study. It included the use of blanks, replicates, standard reference materials and chain of custody forms. QA/QC samples made up at least 20% of all water quality samples taken. All sample bottles were new and cleaned. Bottles used for dissolved nutrients and total and dissolved metals were acid-cleaned by ALS before use. Sample bottles were clearly labelled prior to collecting samples to avoid sample misidentification. ALS is an accredited and certified analytical laboratory.

2.5 Sediment Quality

2.5.1 Sample Collection

In August, 2001, bottom sediments were collected from each of the five oceanographic stations with a Petite Ponar grab sampler (Figure 2.5-1). A single sediment grab sample was also taken at station 2 in August, 2002, to provide a simple comparison of sediment quality for the 2002 benthos work (see Section 2.8). The Ponar sampler is one of the most widely used grab samplers in oceanographic research (Murdoch and McKnight, 1994). It consists of a pair of weighted, tapered metal jaws held open by catch bars. The sampler was lowered to the sea bottom at a steady velocity with the jaws open. When it was 5 m from the sea bottom its speed was reduced to about 0.5 m/sec to minimize disturbance to the sediments. On contact with the bottom, the tension on the catch bar was released by spring action to close the jaws, capturing sediment to a depth of about 15 cm. As the sampler was raised to the surface, tension from the wire kept the jaws closed. Once raised to the deck, the sampler was examined to ensure that water was present (indicating the seal was intact), that the water was not turbid (indicating minimal disturbance to the sample), and that the sediment surface was flat (also indicating minimal disturbance to the sample).

If these criteria were violated, then the sample was rejected and the Petite Ponar was cleaned and another sample was collected.

The characteristics of each sediment sample were noted once it was brought to the surface. Texture and grain size were estimated using the Wentworth classification scheme (*e.g.*, Boggs, 1987). Colour was determined using a standardized Munsell colour-coding scheme (Geological Society of America, 1988). Any strong odours (*e.g.*, hydrogen sulphide, oil, creosote) were noted. The presence of biological materials (*e.g.*, shells, tubes, macrophytes) and debris (*e.g.*, wood chips, human artefacts) were noted. A photograph of each sediment sample was taken.

Table 2.4-1
Detection Limits of Marine Water Quality Variables

Variable	Units	Detection Limit
Physical		
Conductivity	µS/cm	2
pH	log units	0.01
Total suspended solids	mg/L	3
Total dissolved solids	mg/L	10
Hardness	mg/L $CaCO_3$	1
Turbidity	NTU	0.1
Dissolved Anions		
Acidity (to a pH of 8.3)	mg/L $CaCO_3$	1
Total alkalinity	mg/L $CaCO_3$	1
Bromide (Br)	mg/L	0.5
Chloride (Cl)	mg/L	0.5
Fluoride (F)	mg/L	0.02
Silicate (SiO_2)	mg/L	0.1
Sulphate (SO_4)	mg/L	1
Nutrients		
Dissolved ammonia-N (NH_4-N)	mg/L	0.005
Dissolved nitrate-N (NO_3-N)	mg/L	0.005
Dissolved nitrite-N (NO_2-N)	mg/L	0.001
Dissolved ortho-phosphate (D-P)	mg/L	0.001
Total phosphate (T-P)	mg/L	0.002
Total and Dissolved Metals		
Aluminum	mg/L	1
Antimony	mg/L	0.05
Arsenic	mg/L	0.05
Barium	mg/L	0.03
Beryllium	mg/L	0.3
Bismuth	mg/L	0.3
Total and Dissolved Metals (continued)		
Boron	mg/L	5
Cadmium	mg/L	0.03
Calcium	mg/L	0.01
Chromium	mg/L	0.3
Cobalt	mg/L	0.05
Copper	mg/L	0.05
Iron	mg/L	0.3
Lead	mg/L	0.03
Lithium	mg/L	3
Magnesium	mg/L	0.1
Manganese	mg/L	0.03
Mercury	mg/L	0.00001
Molybdenum	mg/L	0.03
Nickel	mg/L	0.3
Phosphorus	mg/L	3
Potassium	mg/L	2
Selenium	mg/L	0.5
Silicon	mg/L	0.5
Silver	mg/L	0.005
Sodium	mg/L	2
Strontium	mg/L	0.001
Thallium	mg/L	0.05
Tin	mg/L	0.05
Titanium	mg/L	0.1
Uranium	mg/L	0.005
Vanadium	mg/L	0.5
Zinc	mg/L	0.5
Organics		
Total organic carbon	mg/L	0.5

Sampled Area: 152 x 152 mm
Weight: Approximately 6.8 kg
Maximum Sample Volume: 2.4 L

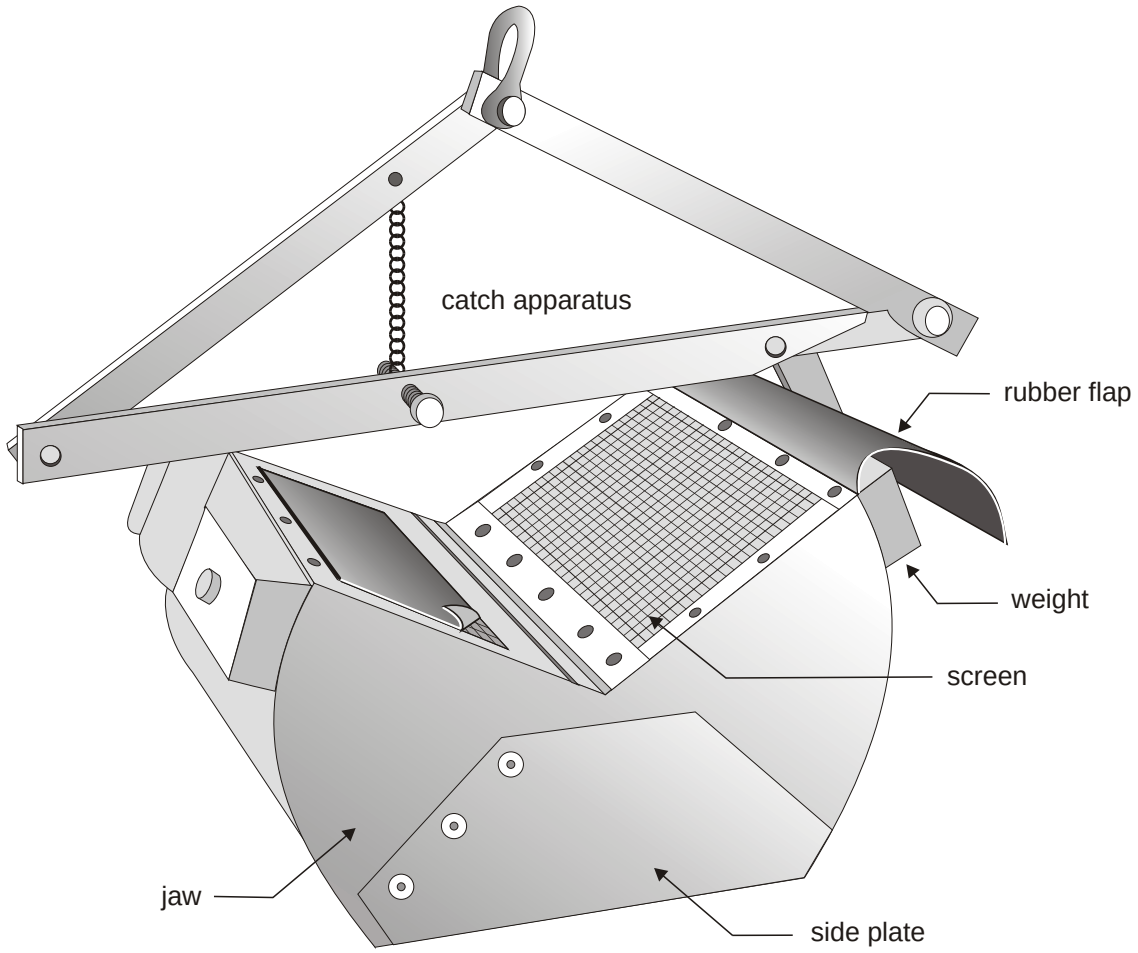

FIGURE 2.5-1

Petite Ponar Grab Sampler

The undisturbed surface of each grab sample was subsampled to a depth of 2 cm for chemical and grain size analyses. Subsamples were placed in pre-cleaned and pre-labelled jars. The jars were sealed with tape and stored on ice until delivery to ALS in Vancouver. There, they were analyzed for five groups of parameters:

1. physical parameters, including percent moisture and percent particle size. Particles were divided into four classes based on average size: clay (<4 m), silt (4 to 63 m), sand (0.063 to 2.000 mm) and gravel (>2 mm);
2. nutrients: total nitrogen and available phosphorus;
3. solid phase metals: the same metals analyzed for water quality with the exception of boron, silicon, sodium and uranium;
4. inorganics: total sulphur; and
5. extractable petroleum hydrocarbons (EPH): EPH10-19 and EPH19-32.

Total organic carbon of sediments was not measured because there was no reason to expect significant organic carbon content in sediments from a pristine Arctic embayment.

Table 2.5-1 shows the detection limits for each variable.

2.5.2 Methods of Analysis

Moisture content was determined gravimetrically after drying the sample at 103°C for at least 6 hours. Particle size distribution was carried out by oven-drying a sample and then weighing the fractions that were retained on a series of standard sieves. Nutrient concentrations were measured using methods described by the Soil Science Society of America. Total nitrogen was measured colourimetrically on a semi-micro Kjeldahl digest. Total metal concentrations were measured by first digesting a sample over a hotplate using a 1:1 ratio of nitric and hydrochloric acids, and then using inductively coupled plasma-mass spectrometry (ICP-MS) or graphite furnace atomic absorption spectrophotometry (GFAAS) to measure metals in the digested sample. Extractable hydrocarbons were carried out according to the British Columbia Ministry of Environment Lands and Parks (BC MELP) analytical method for contaminated soils (BC MELP, 1999).

2.5.3 Quality Control and Quality Assurance

All analyses were in accordance with “Standard Methods for the Examination of Water and Wastewater” (APHA, 1998) or adapted from “Test Methods for Evaluating Solid Waste” (US EPA, 1986). Replicate samples were collected at each station to measure the degree of heterogeneity among samples. Approximately 20% of all samples taken were replicates. Subsamples taken from a single grab were used to measure the degree of heterogeneity within samples. Before use, the Petite Ponar sampler was cleaned with acetone to remove any residual organic material. Between grabs, the Petite Ponar was cleaned with copious amounts of seawater. Sediment samples were collected in prepared contaminant-free containers supplied by ALS. Containers were stored in cool, dark coolers until they were shipped to ALS. Chain of custody forms were used to document the shipment of sediment samples from the sampling vessel to the analytical laboratory.

Table 2.5-1
Detection Limits of Marine Sediment Quality Variables

Variable	Units	Detection Limit
Physical		
Grain size classification	percent	0.1
Moisture	percent	0.1
Nutrients		
Total nitrogen	percent	0.01
Available phosphorus	mg/kg	0.1
Total Metals		
Aluminum	mg/kg	50
Antimony	mg/kg	20
Arsenic	mg/kg	0.05
Barium	mg/kg	1
Beryllium	mg/kg	0.5
Bismuth	mg/kg	20
Cadmium	mg/kg	0.1
Calcium	mg/kg	NA
Chromium	mg/kg	2
Cobalt	mg/kg	2
Copper	mg/kg	1
Iron	mg/kg	50
Lead	mg/kg	2
Lithium	mg/kg	2

Variable	Units	Detection Limit
Total Metals (continued)		
Magnesium	mg/kg	50
Manganese	mg/kg	1
Mercury	mg/kg	0.005
Molybdenum	mg/kg	4
Nickel	mg/kg	5
Phosphorus	mg/kg	50
Potassium	mg/kg	200
Selenium	mg/kg	50
Silver	mg/kg	2
Strontium	mg/kg	0.5
Thallium	mg/kg	50
Tin	mg/kg	10
Titanium	mg/kg	1
Vanadium	mg/kg	2
Zinc	mg/kg	1
Inorganics		
Total sulphur	percent	0.01
Extractable Petroleum Hydrocarbons		
EPH10-19	mg/kg	100
EPH19-33	mg/kg	100

NA = not available

2.6 Phytoplankton

2.6.1 Sample Collection and Methods of Analysis

2.6.1.1 Phytoplankton Biomass (Chlorophyll a)

Samples of seawater were collected in triplicate at four sampling depths at each of the five stations. Samples were collected with a GO-FLO bottle at the same time as were samples for water quality. The sampling depths were determined from the depth of the euphotic zone at each station, which was estimated from Secchi depth for that station. Samples were taken from four evenly-spaced depths within the euphotic zone and just below the euphotic zone. Samples were stored on ice in coolers until they were brought back to the George Lake camp each night. There, the water samples were filtered through nitrocellulose filters with a 0.45 µm pore size. The filters were folded, wrapped in aluminum foil, and frozen until they could be shipped to ALS for analysis. At ALS, the filters were analyzed for their concentrations of chlorophyll *a*, a photosynthetic pigment that is the conventional index of phytoplankton biomass. The standard spectrophotometric technique described by APHA (1998) was used.

2.6.1.2 Phytoplankton Taxonomy

For taxonomic analysis, a single water sample was taken at the surface at each station and preserved with Lugol's solution. The preserved samples were sent to Fraser Environmental Services Ltd., an experienced consultant in taxonomic identification. Samples were examined, identified, and enumerated.

Diversity of phytoplankton taxa was estimated using five indices that have been widely used in phytoplankton research. The first index was the number of genera (G) per station. The second was the number of genera contributing to 90% (G (90%)) of the abundance. The third was the maximum dominance by a single genus, expressed as the percentage of total number of cells contained within the dominant genus. The fourth was the Shannon-Wiener index of diversity (H')

$$H' = -\Sigma\, p_i \ln(p_i)\ ,$$

where p_i = the proportion of the taxa in a sample that belongs to the i^{th} genera (defined as the number of organisms in the i^{th} genera divided by the total number of organisms in a sample). The product of p_i and its natural logarithm was summed over all genera. The Shannon-Wiener index represents the total amount of information contained in a phytoplankton sample. The fifth index was the Simpson index (D)

$$D = 1 - \Sigma\, (p_i)^2\ ,$$

where the square of pi was summed over all genera in a sample. The Simpson index represents the probability that two individuals selected at random from the population belong to different genera.

2.6.2 Quality Control and Quality Assurance

US EPA-approved protocols were used to collect and process phytoplankton samples. All sampling bottles were new and clean. Acid was not used to clean bottles because any residual acid would have degraded chlorophyll *a*. Chain of custody forms were used to document the shipment of samples from the sampling vessel to the analytical laboratories. All analyses were in accordance with "Standard Methods for the Examination of Water and Wastewater" (APHA, 1998). Both Fraser Environmental Services Ltd. and ALS Environmental Inc. have in-house quality assurance programs.

2.7 Zooplankton

2.7.1 Sample Collection and Methods of Analysis

Zooplankton samples were collected with a 1.5 m-long, Birge-style, conical plankton net with 200 μm mesh, a plastic cod-end, and a General Oceanics flowmeter (model 2030R) to measure the volume of filtered water. The net was towed vertically from the sea floor to the sea surface. The flowmeter reading was recorded and the net was lowered to about 2 to 5 m from the sea bottom, then the net was retrieved at a speed of 0.5 to 1.0 m/sec. The flowmeter reading was recorded as the net exited the water. The net was washed down from the outside and the contents of the cod-end were poured into a clean, pre-labelled sample bottle. Buffered formalin was added to the bottle to make up a 5% formalin-seawater solution. Triplicate tows were made at each of the five stations. The preserved samples were sent to Applied Technical Services Ltd. of Victoria for taxonomic identification and enumeration.

At Applied Technical Services Ltd., samples were examined by an experienced taxonomist with a dissecting microscope, and all organisms were identified to the lowest possible taxonomic level and counted. Samples with high zooplankton densities of organisms were split before identification and counting. Counts of each taxa were divided by the filtered volume, derived from flowmeter revolutions, to obtain abundances (ind./m^3).

2.7.2 Quality Control and Quality Assurance

Chain of custody forms were used to document the shipment of zooplankton samples from the sampling vessel to the analytical laboratory.

2.8 Benthos

2.8.1 Sample Collection and Methods of Analysis

Samples of benthic invertebrates were collected in triplicate at one of the five stations (station 3) in August, 2001, using a Petite Ponar sampler. Difficulties in the marine program hampered sampling in 2001, and delayed the benthic sampling until August, 2002. In August, 2002, all five stations were sampled in triplicate for benthos abundance and taxonomy. In all cases, the samples were taken in the same manner as the sediment samples, but were not subsampled. The contents of the sampler were washed through standard 0.5 and 1 mm mesh tubs to remove sediment and divide benthic organisms into two size classes. The organisms retained on the sieves were transferred to plastic jars and preserved in a 10% buffered formalin-seawater

solution. The jars were labelled, sealed and sent to Applied Technical Services Ltd. for taxonomic analysis and enumeration. The density of benthic invertebrates was calculated by dividing the number of organisms by the surface area of the Petite Ponar grab sampler.

2.8.2 Quality Control and Quality Assurance

Chain of custody forms were used to document the shipment of benthic invertebrate samples from the sampling vessel to the analytical laboratory.

2.9 Fish Community

2.9.1 Study Design

Sampling of fish populations was conducted between August 17 and August 20, 2001. Three fish sampling sites were established along the shoreline of the peninsula (Figure 2.9-1). Each site required about 1.3 days of sampling effort by a four-person crew. Site 1 was established southeast of the proposed Port site on the east shore of the peninsula (Figure 2.9-1). Site 2 was established further north close to the site of the proposed Port. Site 3 was established on the west shore of the peninsula slightly north of site 2. UTM coordinates are presented in Table 2.9-1.

Table 2.9-1
Location of Fish Sampling Stations, Bathurst Inlet, August 2001

Site	Northing (m)	Easting (m)
1	7382785	388938
2	7383415	388257
3	7383735	387284

2.9.2 Sampling Gear and Locations

Locations of all sampling gear sets are presented in Figure 2.9-2. Gear was set and retrieved with the assistance of a 5.5 m power boat. Times of installation and retrieval were recorded for each set of each type of gear to calculate fishing effort. Northing and Easting of each set (both inshore and offshore ends of each net or longline) were recorded with a handheld GPS unit. Average depths at which gear was fished were estimated from the length of rope let out as the gear was installed.

2.9.2.1 Minnow Traps

Minnow traps were designed to catch juvenile fish and small forage fish that live in shallow water. Each conical metal trap was 40 cm long and 22 cm in diameter with 7 mm mesh. Traps were baited with dry dog food or pieces of fresh raw fish, and then set in a line along the shoreline in water between 0.5 and 1.0 m deep about 20 m from each other. A plastic buoy was attached to each trap to mark its location. Traps were set overnight and were usually retrieved before noon on the following day. Six traps set at each of the three sites plus an additional brief set at site 2 meant there were 24 separate minnow traps sets numbered MT1 to MT24.

2.9.2.2 Sinking Gillnet

The sinking gillnet was designed to catch fish of a wide range of body sizes that move along the sea bottom. The net measured 137 m (450 ft) long by 1.83 m (6 ft) deep and were comprised of six panels of 22.8 m long of monofilament each with a different mesh size: 38 mm (1.5“), 51 mm (2“), 76 mm (3“), 95 mm (3.75“), 108 mm (4.25“) and 127 mm (5“). The total surface area of each sinking net was 250 m^2. The upper (or “float”) line had small plastic buoys that allowed it to float in the water column, but the lower (or “lead”) line was weighted and rested along the sea bottom. Nets were generally set perpendicular to the beach and anchored with rocks and marked with buoys. They were retrieved after approximately 2 hours to reduce fish mortalities. One sinking gillnet set at each of the three sites meant there were three separate sinking gillnet sets numbered GN1 to GN3.

2.9.2.3 Floating Gillnet

The floating gillnet was designed to catch fish that move near the water surface. The net was composed of three panels each 15.2 m (50 ft) by 1.83m (6 ft), with mesh sizes of 25 mm (1”), 38 mm (1.5”), and 51 mm (2”). The surface area of the floating nets was 84 m^2. The float line was buoyed but the lead line lacked weight, allowing the net to float at the surface. Nets were generally set perpendicular to the beach and anchored with rocks and marked with buoys. They were retrieved after approximately two hours. One floating gillnet at each of the three sites meant there were three separate floating gillnet sets numbered FN1 to FN3.

2.9.2.4 Sinking Longline

The sinking longline was designed to capture actively-feeding bottom-dwelling fish. The line was 50 m long with 15 hooks clipped onto the line at 3 m intervals. The hooks were baited with pieces of raw fish. The line was weighted along its length with lead weights so that it rested on the sea bottom. Longlines were generally set perpendicular to the beach, and anchored with rocks and marked with buoys. They were retrieved after several hours of soaking. One sinking longline at each of the three sites meant there were three separate sinking longline sets numbered SLL1, SLL4 and SLL6.

2.9.2.5 Floating Longline

The floating longline was designed to capture actively-feeding surface-dwelling fish. The line was 17 m long with 7 hooks clipped onto the line at 2.5 m intervals. Hooks were baited with pieces of raw fish. The line floated at the water surface with the hooks dangling about 0.20 m below the line. The line had plastic buoys placed along its length. The line was usually set perpendicular to a beach and its ends were weighted with rocks and marked with buoys. The line was first set for 2 hours with zero catch, and thereafter was left in the water overnight. One floating longline at each of the three sites meant there were three separate floating longline sets numbered FLL2, FLL3 and FLL5.

2.9.2.6 Beach Seine

The beach seine was designed to capture fish of all sizes that live in shallow water near the surf line.

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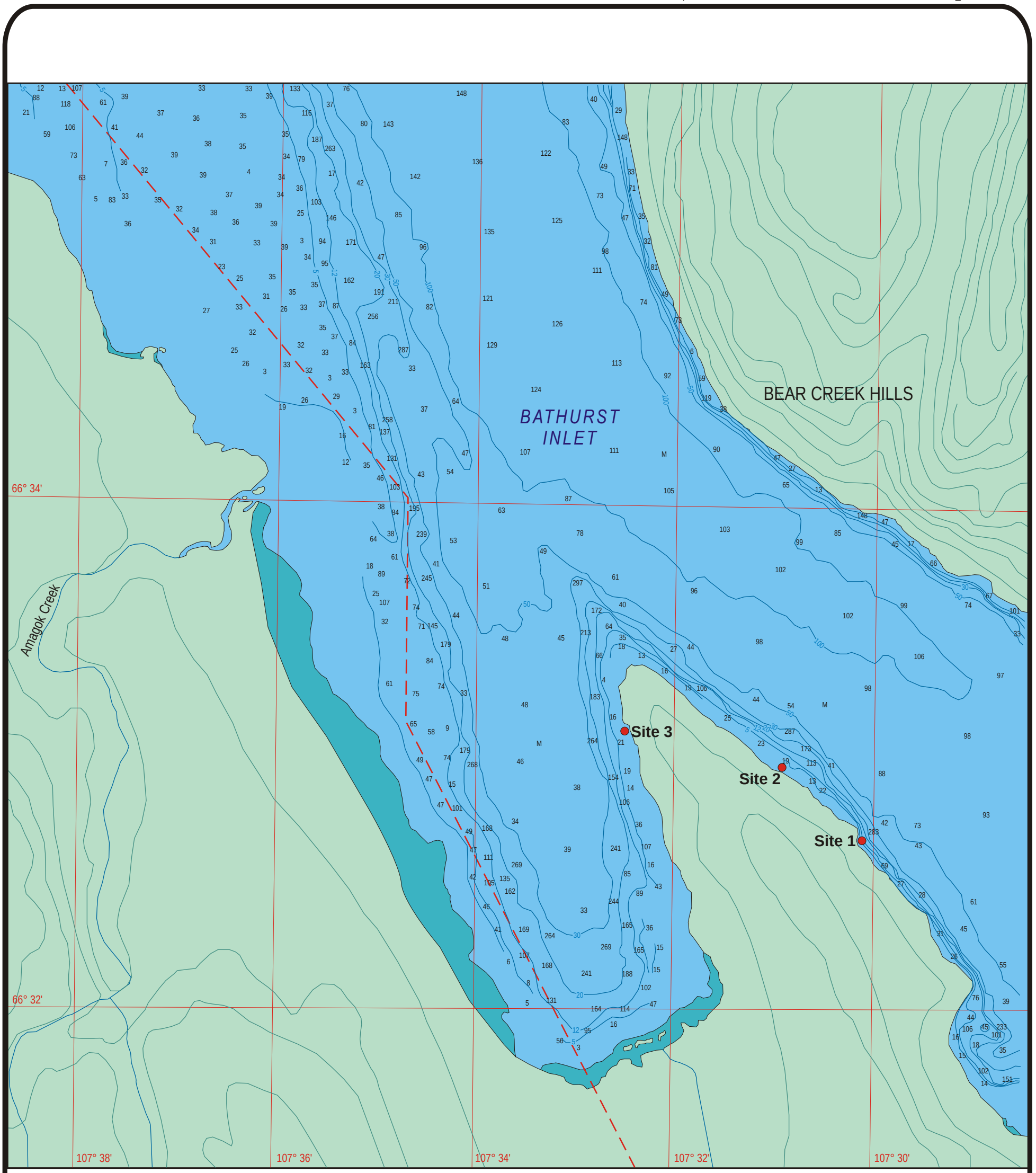

Nautical Miles (66°34'N)

1 0 1

Metres (66°34'N)

1000 0 3000

Scale 1 : 20 000 (66°34'N)
Magnetic Variation 022½°E 1999) (24'W)
Magnetic Compass Erratic

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Map of Bathurst Inlet Showing the Fish Community and Fish Habitat Sampling Sites, August 2001

FIGURE 2.9-1

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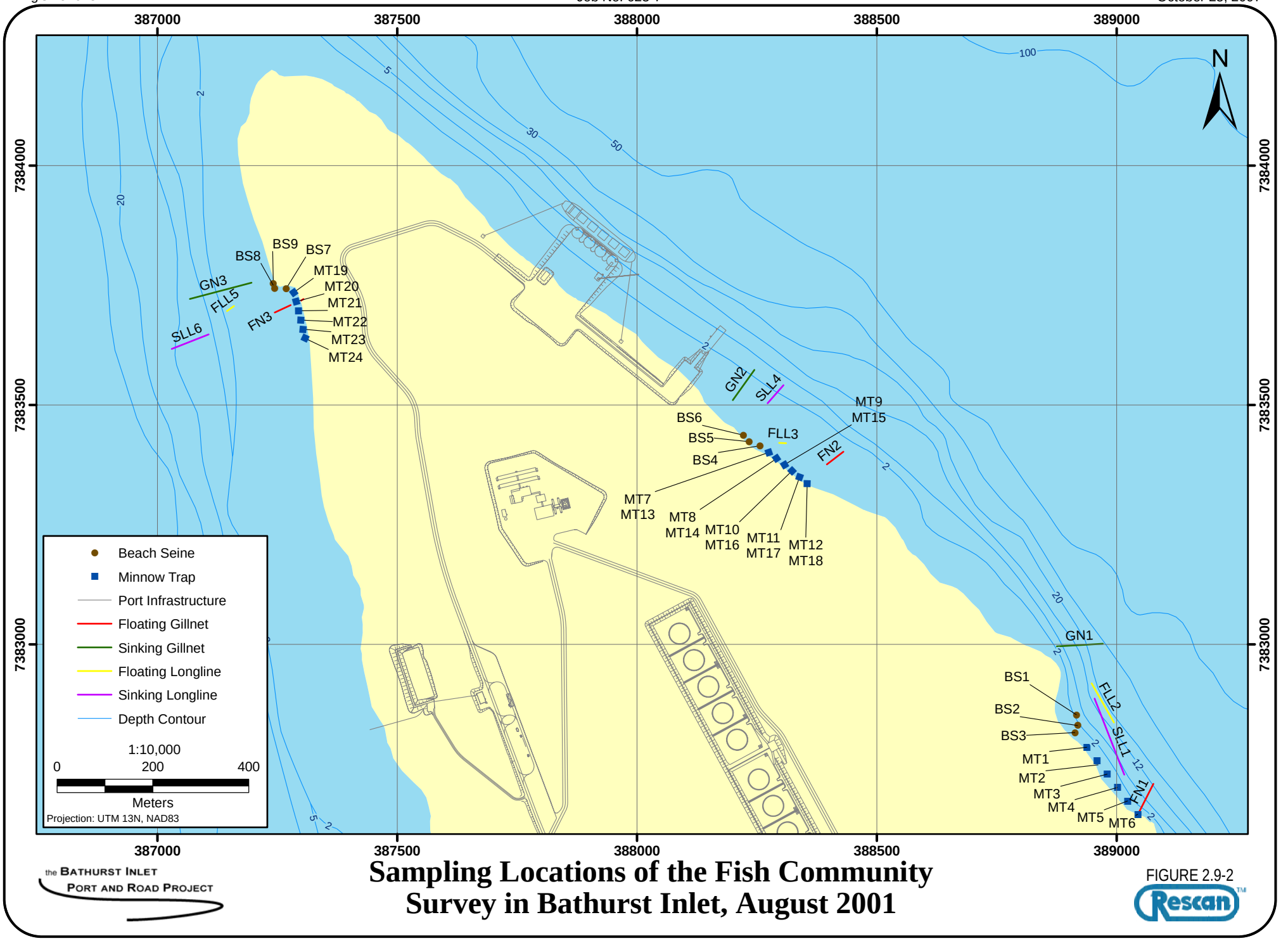

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Sampling Locations of the Fish Community Survey in Bathurst Inlet, August 2001

FIGURE 2.9-2

Rescan™

The seine was 27 m long, 2.2 m deep with 3-mm mesh. One end of the seine was held on the shoreline, and the other end was drawn by a boat in a horseshoe shape so that it enveloped a portion of the shoreline. The two ends were then quickly drawn onto the beach keeping the lead line on the sea bottom and forcing fish into the bunt of the seine. Fish were picked out of the bunt with dipnets. The seine was used in series of three at each of the three sites, giving nine separate beach seine sets numbered BS1 to BS9.

2.9.3 Sample Processing

Captured fish were immediately placed in a water-filled plastic tub to keep them alive until they could be processed and then released. Fish were counted and identified to species using a marine fish key (Coad and Reist, 2001) and fish photographs shown in Hart (1973), Scott and Crossman (1973), and Coad *et al*. (1995).

Once identified to species, fish were anaesthetized by dissolving several tablets of Alka-Seltzer in a tub. Then, each fish was assigned a unique sample number, fork length was measured to the nearest 1 mm with a measuring board, and weight was measured to the nearest 0.01 g with an electronic balance for fish less than 10 g, to the nearest 25 grams for fish less than 200 g and to the nearest 25 g with a mechanical balance for fish heavier than 250 g. Scales were taken for aging purposes by scraping the left side of each fish below the dorsal fin with a sharp knife (except for those species with no scales, *e.g*. sculpins, and juvenile fish that were too small to be scraped). Scales were put on Write-in-Rain paper and stored in individual envelopes with the sample number and species abbreviation written on the outside. A few pectoral fin rays (also used as aging structures) were snipped from one of the pectoral fins close to the pectoral girdle and placed in the same numbered envelope (except for juveniles whose pectoral fins were too small to be clipped). The fish was then placed in a tub with clean seawater and allowed to recover. Once the fish recovered, it was returned to the sea.

Despite the short set times (~2 hours) for the sinking gillnets (the most effective of the fishing gear used), 13% of the fish captured by that gear died. For those mortalities, additional information and structures were collected such as otoliths (also aging structures) were removed from the otic capsule in the head, wrapped in paper and placed in the numbered envelopes that held scales and pectoral fin rays. The body cavity was opened and sex (male, female or unknown), sexual maturity (mature, immature or unknown) and reproductive status (undeveloped, green, ripe, running, spent or unknown) was assessed from the colour, texture and size of the gonads. Undeveloped was synonymous with immature, green referred to a fish that was in the process of maturing, ripe referred to a mature fish that was ready to spawn, and running was a mature fish in which eggs and sperm were loose in the body cavity and could be easily squeezed from the fish. Finally, the stomach was opened and contents were described visually. Contents were described in general terms only (*e.g.*, clams). Stomach contents were not preserved for taxonomic analyses.

All data were recorded on paper data sheets and then entered into Excel spreadsheets in the office.

2.9.4 Aging

Age was estimated from the number of annuli (or year rings) counted in aging structures. Otoliths were broken in half, one piece was burned to enhance zonation, and annuli in the burned part were counted with a dissecting microscope. Fin rays were sectioned and the sections were attached to glass slides and examined with a compound microscope. Scales were attached to plastic fiches, and annuli were counted with a microfiche reader. Age readers assigned an index of confidence ranging from 0 (no confidence) to 10 (absolute confidence) to each age estimate. For fish with more than one age structure, the best estimate of age was based on the estimate(s) with the highest confidence. Not all structures were read, only those required to provide a reliable age estimate. To avoid bias, age readers were not provided with information on fish length, weight, sex or sexual maturation.

2.9.5 Tissue Metals Sampling

One of the objectives of the survey was to measure baseline metal concentrations in fish muscle tissue (also called myomere). Samples were collected from a single species to avoid intra-species variation in metal concentrations. Starry flounder (*Platichthys stellatus*) was selected because it was abundant in the catches and a wide range of body sizes were available. This species is a resident of the nearshore environment of Bathurst Inlet for its entire life history. A large volume of information about starry flounder life history and tissue contaminant residues exists because starry flounder is used as a contaminant sentinel species in Pacific coast estuaries of Canada and the United States (McCain, 1982; Mark *et al*., 1994; Nelson, 1995).

Seventeen starry flounder of a wide range of lengths were selected from catches at the three sites, and processed as described in Section 2.9.3 with the exception that each fish was filleted and a 1 to 10 g piece of muscle tissue was taken, stripped of bones and skin, rinsed in clean seawater and placed in individual numbered Whirl-Pak plastic bags. Samples were frozen at the end of the day and kept frozen until they were delivered to ALS Environmental in Vancouver.

Analyses of tissue metal concentrations were carried out according to procedures adapted from EPA (1995). Percent moisture was measured gravimetrically by drying the sample at 103°C for a minimum of 6 hours. Dried tissue samples were homogenized either mechanically or manually and then digested with nitric acid on a hotplate followed by repeated additions of hydrogen peroxide. Concentrations of 29 metals were measured from the digested samples using atomic absorption spectrophotometry (EPA Method 7000 series), inductively coupled plasma – mass spectrometry (EPA Method 6020) and/or inductively coupled plasma – optical emission spectrophotometry (EPA Method 6010B). Results were expressed as mg/kg dry weight (DW).

2.9.6 Data Sources

FishBase (www.fishbase.org), a global on-line database of fish biological information, was used as the source for the life history characteristics of fish captured in August, 2001, and in previous studies of Bathurst Inlet. FishBase is supported by a consortium of seven research institutions including the United Nations Food and Agriculture Organization and the University of British Columbia Fisheries Centre. FishBase was used as a data source because much of the life history information on Canadian Arctic fish is not available in standard reference texts such as Scott and Crossman (1973) and Hart (1973). The only text that describes life history information of fish

known only from Canada's Arctic is the *Encyclopedia of Canadian Fish* by Coad *et al*. (1995), but that text is out of print. *Arctic Marine Fish of Canada* by Brian Coad and James Reist is currently in press and was not available at the time of the survey.

The Canadian Museum of Nature in Ottawa maintains a comprehensive list of records on fish species of the Canadian Arctic, based on the collections of Canada's national museums and on literature sources. Alfonso Noel and Brian Coad of the Research Services Division of the Canadian Museum of Nature provided Rescan with their records for Bathurst Inlet, current as of September 2001. The majority of littoral and sublittoral collections were taken by beach seine and gillnet; and those in deeper water principally by otter trawl. Specimens were also occasionally collected by midwater trawling, jigging, angling and longlining. The majority of collections were made in July and August during the open water season.

2.9.7 Data Analysis

To compare fish abundance among sites, catches were standardized as catch-per-unit-effort (CPUE), an index of relative abundance. Gillnet catches were standardized using:

(1) $CPUE = C(T/t)(X/x)$,

where CPUE has units of number of fish/net area/24 hours or of kilograms of fish/net area/24 hours, C = catch (number or kg), T = 24 hours for all sets, t = the number of hours that a specific net was set, X = 100 m^2 of gillnet, and x = the area of a specific gillnet. Setting X to 100 m^2 for both floating and sinking gillnets allowed a comparison of gillnet CPUE between the surface and the sea bottom. Longline catches were also standardized with equation (1), but CPUE had units of fish/line/24 hours or of kg of fish/line/24 hours, T = 24 hours for all sets, t = number of hours the line was set, X = 15 hooks/line, and x = the number of hooks of a specific long line. Beach seine catches were not standardized for effort because effort was constant among sets.

Weight-length regressions were calculated for each species using the standard formula (Ricker, 1975):

(2) $\ln(W) = \ln(a) + b \ln(L)$,

where W = wet body weight (g), L = fork length (mm), a is a coefficient, b is an exponent, and both weight and length were ln-transformed to meet the statistical requirements of linear regression (mainly homogeneity of variance).

All regressions in this report cite the r^2 statistic – an index of the amount of variation in the dependent variable that is explained by the independent variable. The r^2 statistic has a range from 0 to 1. For example, an r^2 of 0.9 indicates that 90% of the variation in the dependent variable has been explained by a regression. All r^2 were adjusted for the number of degrees of freedom of the regression. All regressions also cite the P statistic – the probability of significance of the regression. Only regressions that were significant at the 1% level ($P<0.01$) were reported.

Condition of fish was assessed using the standard assumption that the weight-length exponent of most fish has a value close to 3 (Ricker, 1975):

(3) Condition = $Wx10^5/L^3$,

where condition has units of g/mm^3 and weight was multiplied by a factor of 10^5 to avoid fractional values of K (growth coefficient, year $^{-1}$).

The von Bertalanffy growth model was used to described length-age relationships of fish species. The von Bertalanffy model is the standard model used in fisheries science (Ricker, 1975):

(4) $L = L_\infty(1 - \exp(-K(t - t_0)))$,

where L = length-at-age (mm), L_∞ = asymptotic length (mm) (years) (*i.e.*, length at infinite age), K = growth coefficient (year $^{-1}$), and t_0 = age at L = 0 mm. The model was fit to length-at-ages with non-linear regression (SYSTAT, 1998).

All of the 29 metals analysed from starry flounder muscle tissues were expressed as total metals. To calculate average tissue concentrations, concentrations that were less than the detection limit were replaced with values of one half the detection limit.

2.10 Fish Habitat

The objective of the habitat assessment was to classify fish habitat types along the shoreline near the proposed Port site location (Figure 2.9-1).

Nearshore fish habitat was characterized on August 19, 2001, using a combination of methods. First, the littoral zone was delineated into zones while walking on the shoreline and substrate composition of each zone was recorded as percent coverage (*e.g.*, 70% gravel and 30% sand). The habitat types were classified as boulder, cobble, gravel, sand, and grass. Following the ground survey, the sites were videotaped and photographed from a helicopter at low altitude. In the office a combination of notes from the field with video and photographic records were used to create habitat maps and to verify and make any modifications (if needed) to the composition of each zone. Habitat data collected were then compared with habitat preference from the seven species captured. In this baseline report, a summary of the habitat preferences obtained from Scott and Crossman (1973) and FishBase (2002) is provided as text for seven species captured during this study. This information was used to assess the habitat at the three sites.

3. RESULTS AND DISCUSSION

3. Results and Discussion

3.1 Water Column Structure

Profiles of the water column at four of the five stations sampled showed an upper mixed-layer defined by a pycnocline between 5 and 7 m depth (Figures 3.1-1 and 3.1-2). Surface temperatures averaged about 11.5ºC in the upper mixed-layer. Salinity in the mixed-layer was between 10 and 12 PSU, except at station 1 (the eastern-most station) where the surface water was much fresher. Transmissivity in the mixed-layer ranged from 10 to 75%. The deepest profile was taken furthest from shore at station 5, which showed a gradual gradient in temperature, salinity, density and transmissivity below the pycnocline.

Secchi depths ranged from 3.0 to 3.5 m at the five stations and averaged 3.4 m (SD = 0.2, n = 5) (Table 3.1-1). The calculated euphotic zone ranged from 8.1 to 9.5 m and averaged 9.2 m (SD = 0.6, n = 5). Hence, the sampling depths for phytoplankton were set at equally-spaced intervals within the euphotic zone and just below it, *i.e.*, at 1, 5, 10 and 14 m.

Table 3.1-1
Secchi Depth and Depth of the Euphotic Zone, Bathurst Inlet, August 2001

Station	Date	Secchi Depth Ds (m)	k' (m-1)	Euphotic Zone Depth Z1% (m)
1	14-Aug-01	3.5	0.49	9.5
2	14-Aug-01	3.5	0.49	9.5
3	14-Aug-01	3.5	0.49	9.5
4	15-Aug-01	3.0	0.57	8.1
5	15-Aug-01	3.5	0.49	9.5

Note: $k' = 1.7/D_s$ and $Z_{1\%} = 4.6/k'$.

3.2 Water Quality

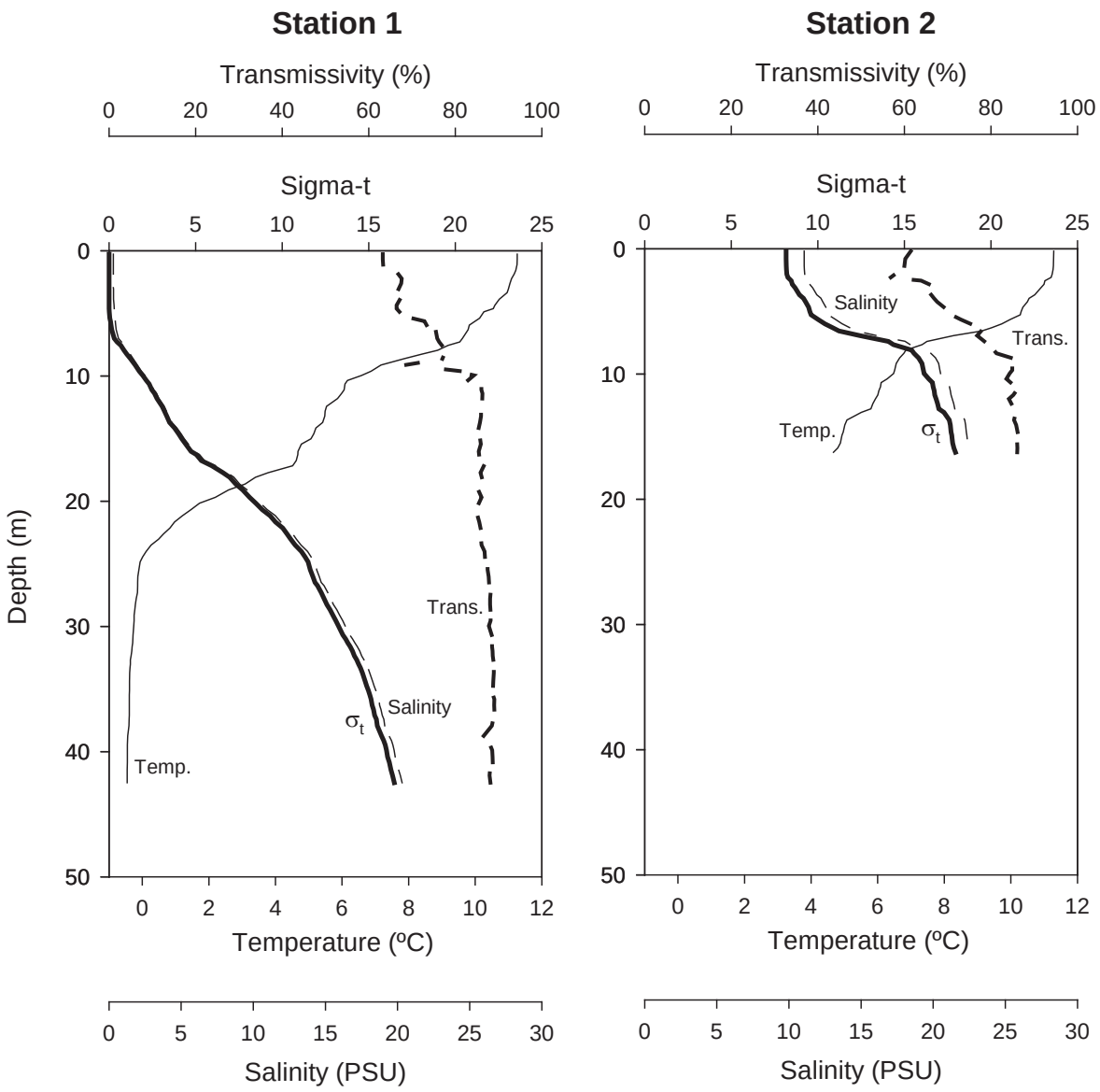
Appendix 3.2-1 shows the water quality data collected at stations 1 to 5.

3.2.1 Physical Parameters

Profiles of physical parameters are presented in Figures 3.2-1 through 3.2-4.

Values of pH ranged from 7.7 to 7.9 at the five stations. There were no consistent trends with depth. The average pH over all depths and stations (calculated from log-transformed values) was 7.8 (SD = 0.1, n = 26).

The concentration of total dissolved solids (TDS) increased with depth at all five station with the greatest change in concentration occurring near the pycnocline between depths of 5 and 10 m (Figure 3.2-1).



Vertical Profiles of Temperature, Salinity, Density and Transmissivity at Stations 1 and 2 in Southern Bathurst Inlet, August 2001

FIGURE 3.1-1

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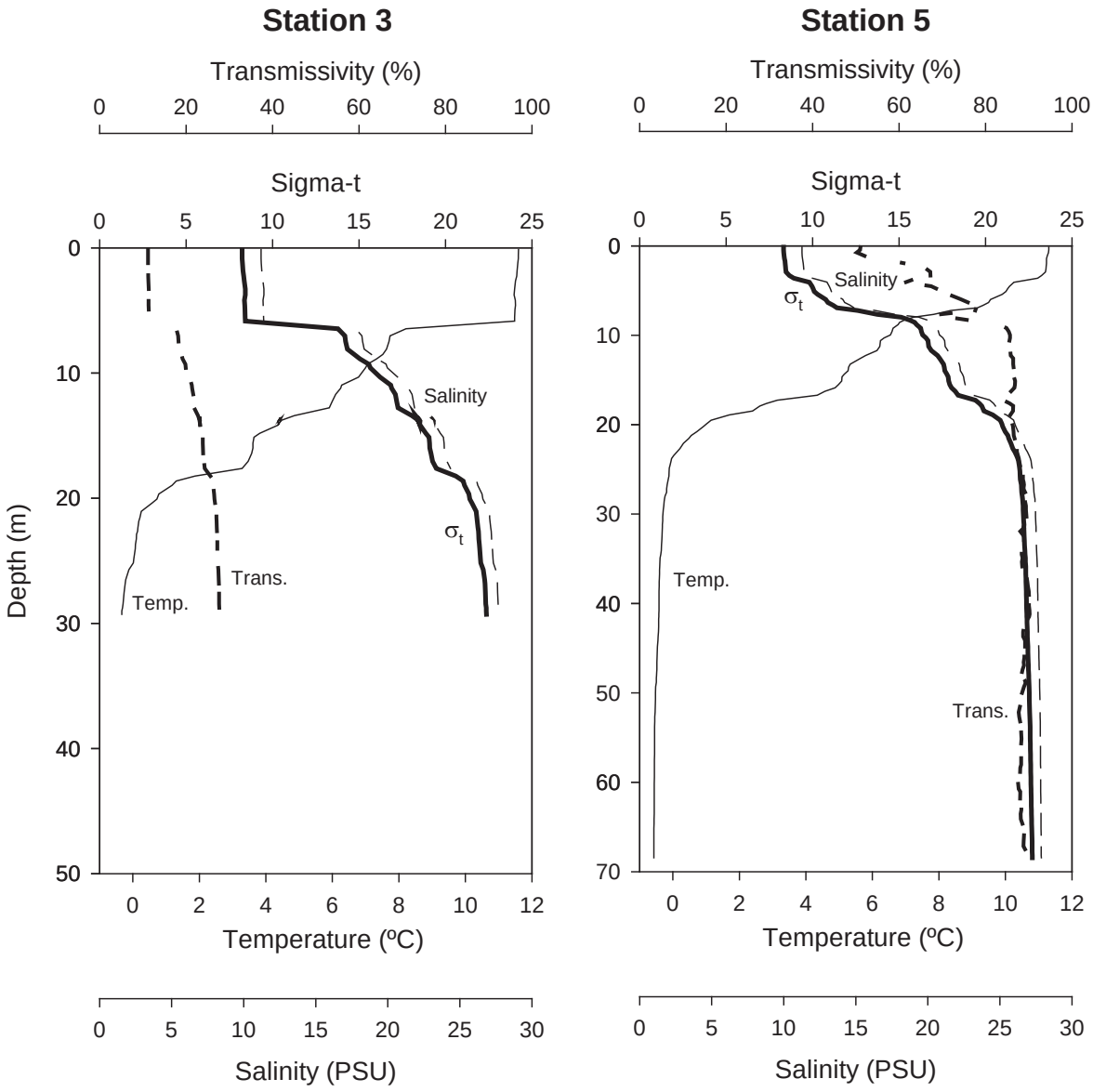

Vertical Profiles of Temperature, Salinity, Density and Transmissivity at Stations 3 and 5 in Southern Bathurst Inlet, August 2001

FIGURE 3.1-2

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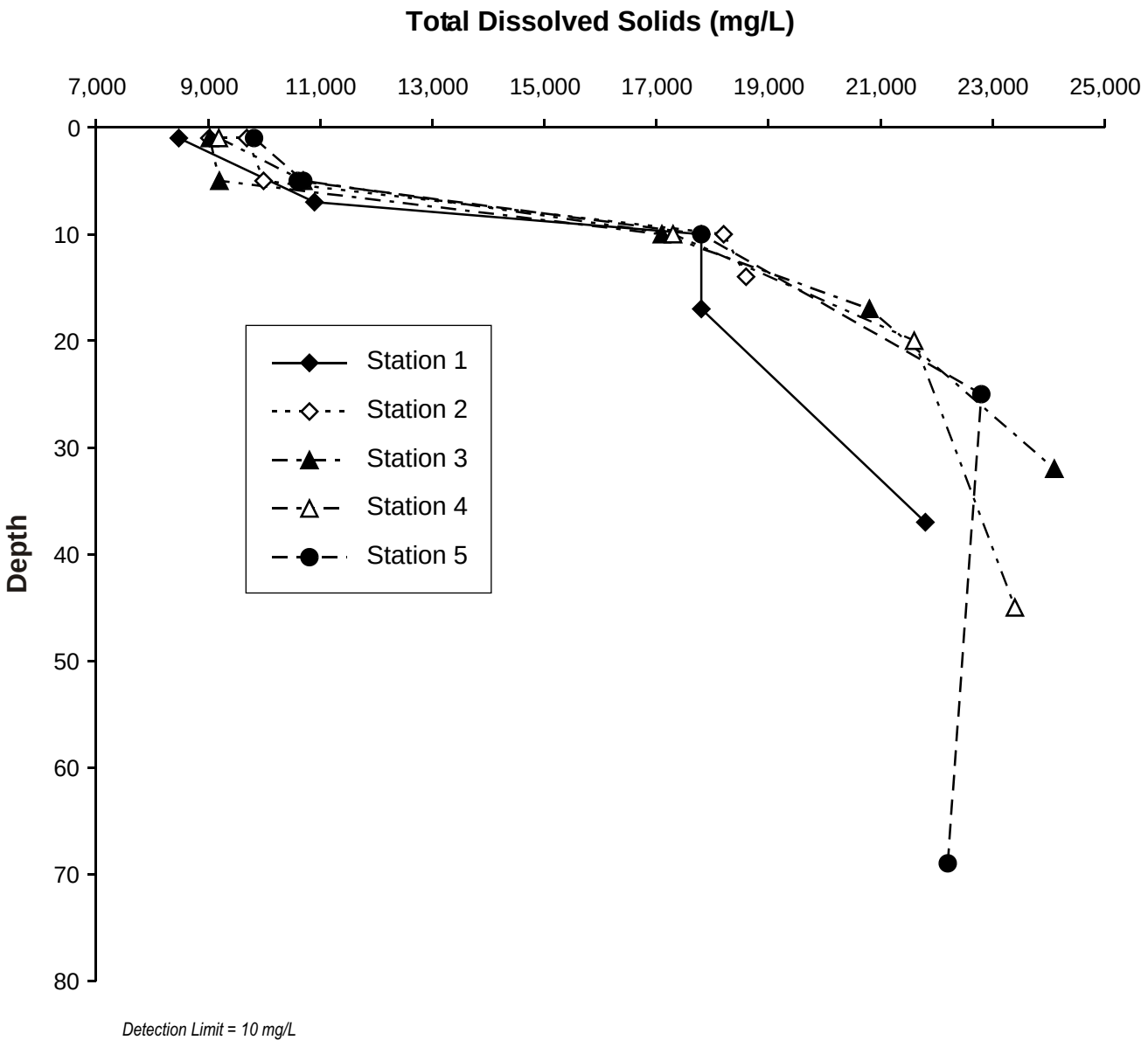

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Vertical Profiles of Total Dissolved Solids, Bathurst Inlet, August 2001

FIGURE 3.2-1

Rescan™

The concentrations of total suspended solids (TSS) were three orders of magnitude lower than the concentrations of TDS and they were more variable among stations and depths than the concentrations of TDS. TSS concentrations also decreased with depth at all five stations (Figure 3.2-2).

Turbidity was highly variable and showed a decreasing trend with increasing depth (Figure 3.2-3). That was opposite to the trend of TSS, thereby indicating that light transmission in the water column was influenced by other factors as well as the concentration of TSS.

The concentration of dissolved oxygen (DO) was constant with depth for the upper 15 m of the water column and then decreased with depth below 15 m (Figure 3.2-4).

3.2.2 Dissolved Anions

Acidity (adjusted to a pH of 8.3) decreased with depth with the greatest change occurring between 5 and 10 m (Figure 3.2-5). Alkalinity was relatively low and constant for the upper 5 m of the water column, and then decreased with depth (Figure 3.2-6).

The vertical profiles of the five major dissolved anions (fluoride, silicate, bromide, sulphate and chloride) all showed similar trends with depth – low concentrations in the upper 5 m, followed by rapid increases in concentration around the pycnocline (5-10 m), followed by gradual increases in concentration with depth, (Figures 3.2-7 to 3.2-11).

3.2.3 Nutrients

Nitrite concentrations were low throughout the water column at all five stations, and increased slightly with depth (Figure 3.2-12). Only one of the 26 nitrite measurements was below the detection limit.

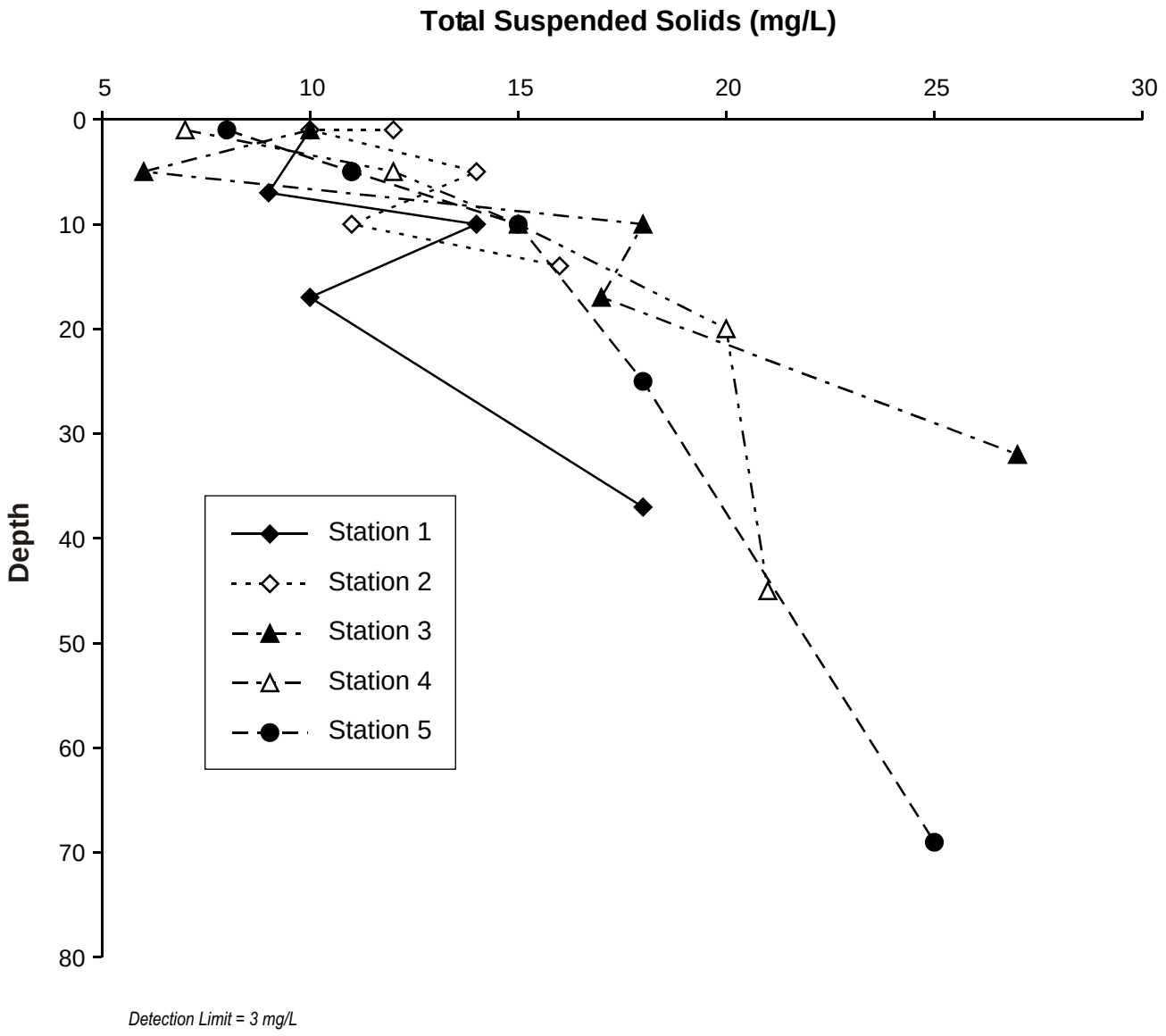
There were no consistent trends for ammonia at any of the five stations; the average concentration of ammonia for all stations and depths was 0.015 mg/L (SD = 0.004, n = 26). As with nitrite, there was only one value below the detection limit.

Nitrate concentrations were below detection limits in the upper 5 m of the water column (*i.e.*, 12 of the 26 values), but were greater than the detection limit for depths below 5 m (Figure 3.2-13).

The concentrations of dissolved orthophosphate were below the detection limit for 12 of the 15 measurements taken at stations 1, 2 and 3, but were above detection limits for all depths of stations 4 and 5 (Figure 3.2-14). Figure 3.2-14 shows the vertical profiles of dissolved orthophosphate for stations 4 and 5 and the concentrations at 17 and 32 m for station 3, but no profiles for stations 1 and 2.

Total phosphate concentrations were above the detection limit for all depths of stations 1, 4 and 5, but four of the five measurements taken at station 2 were below the detection limit and two of the five measurements taken at station 3 were below the detection limit (Figure 3.2-15). Figure 3.2-15 only shows the profiles for stations 1, 4 and 5 and part of station 3.

Concentrations of total organic carbon (TOC) decreased with depth at all five stations (Figure 3.2-16).



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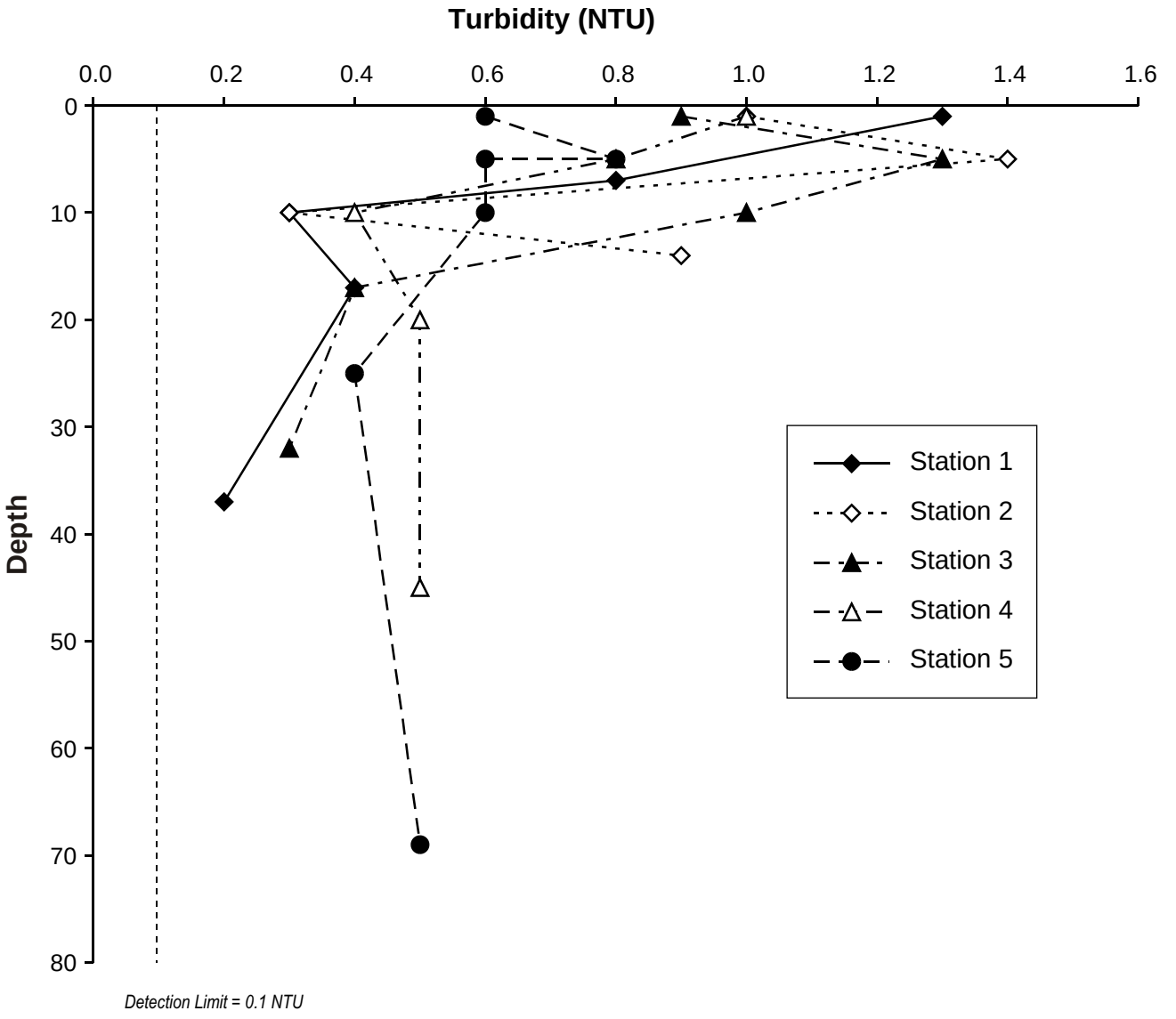
Vertical Profiles of Total Suspended Solids, Bathurst Inlet, August 2001

FIGURE 3.2-2

Rescan™



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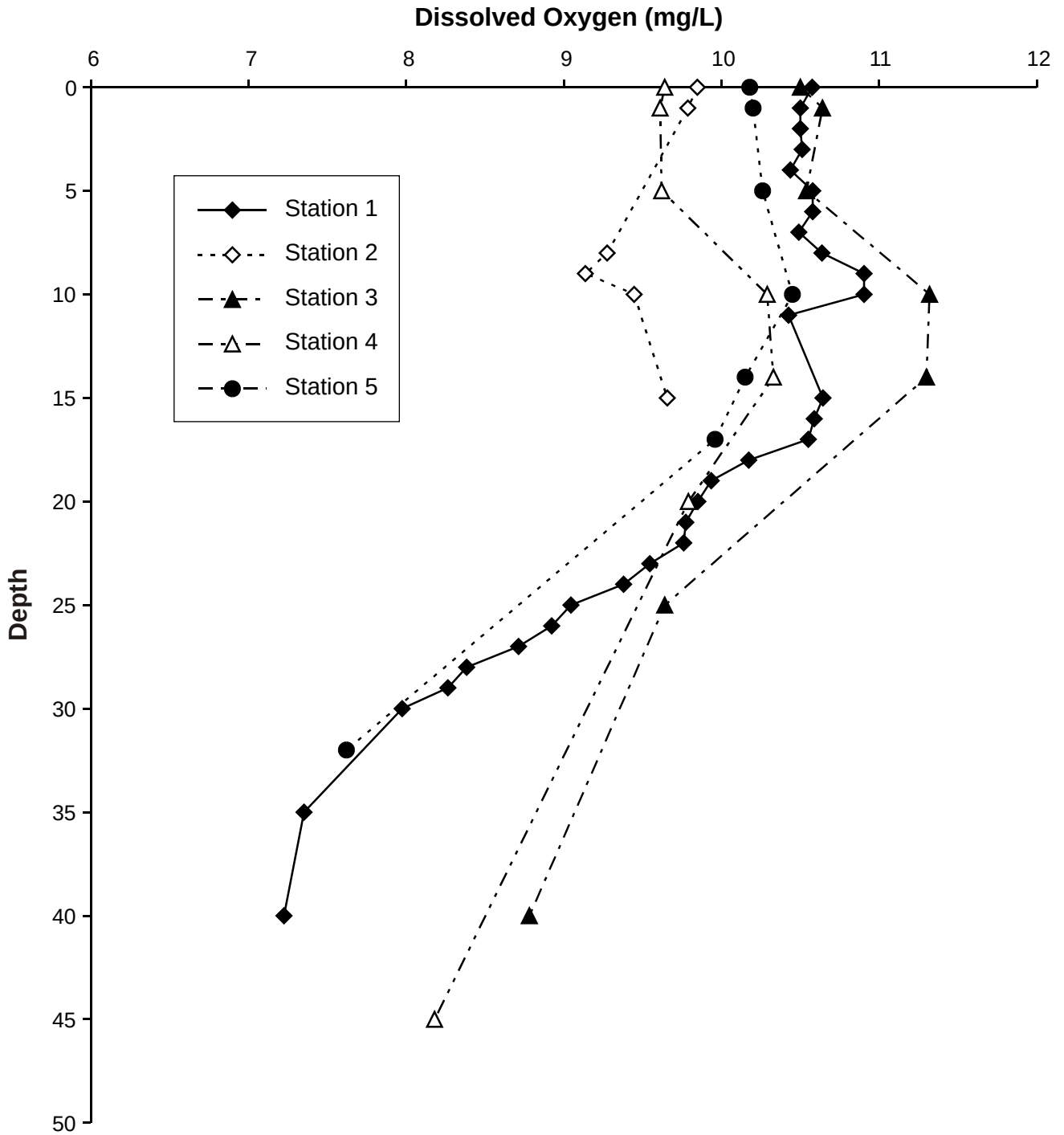
Vertical Profiles of Turbidity, Bathurst Inlet, August 2001

FIGURE 3.2-3

Rescan™



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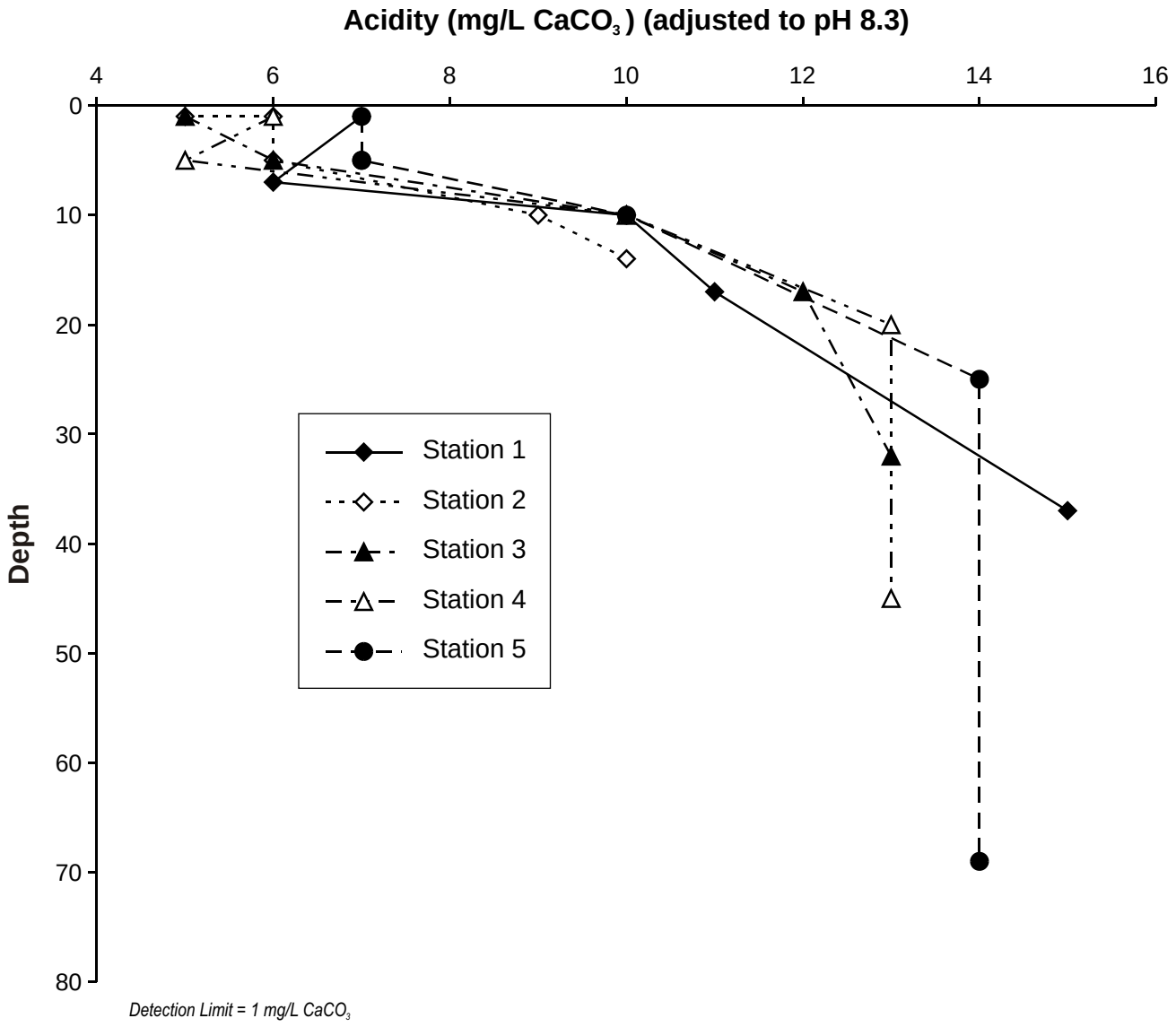
Vertical Profiles of Dissolved Oxygen Concentration, Bathurst Inlet, August 2001

FIGURE 3.2-4

Rescan™



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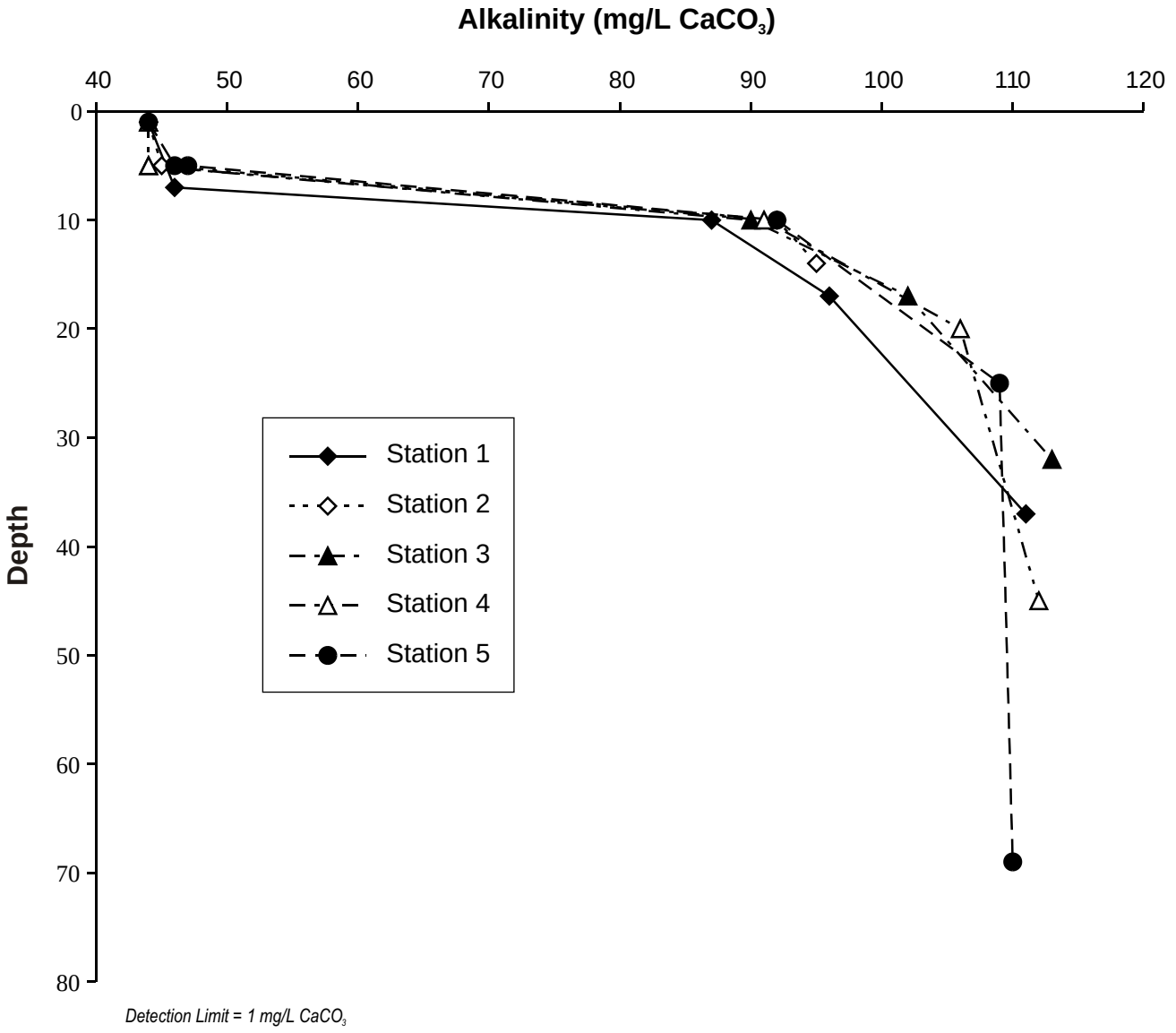
Vertical Profiles of Acidity, Bathurst Inlet, August 2001

FIGURE 3.2-5

Rescan™



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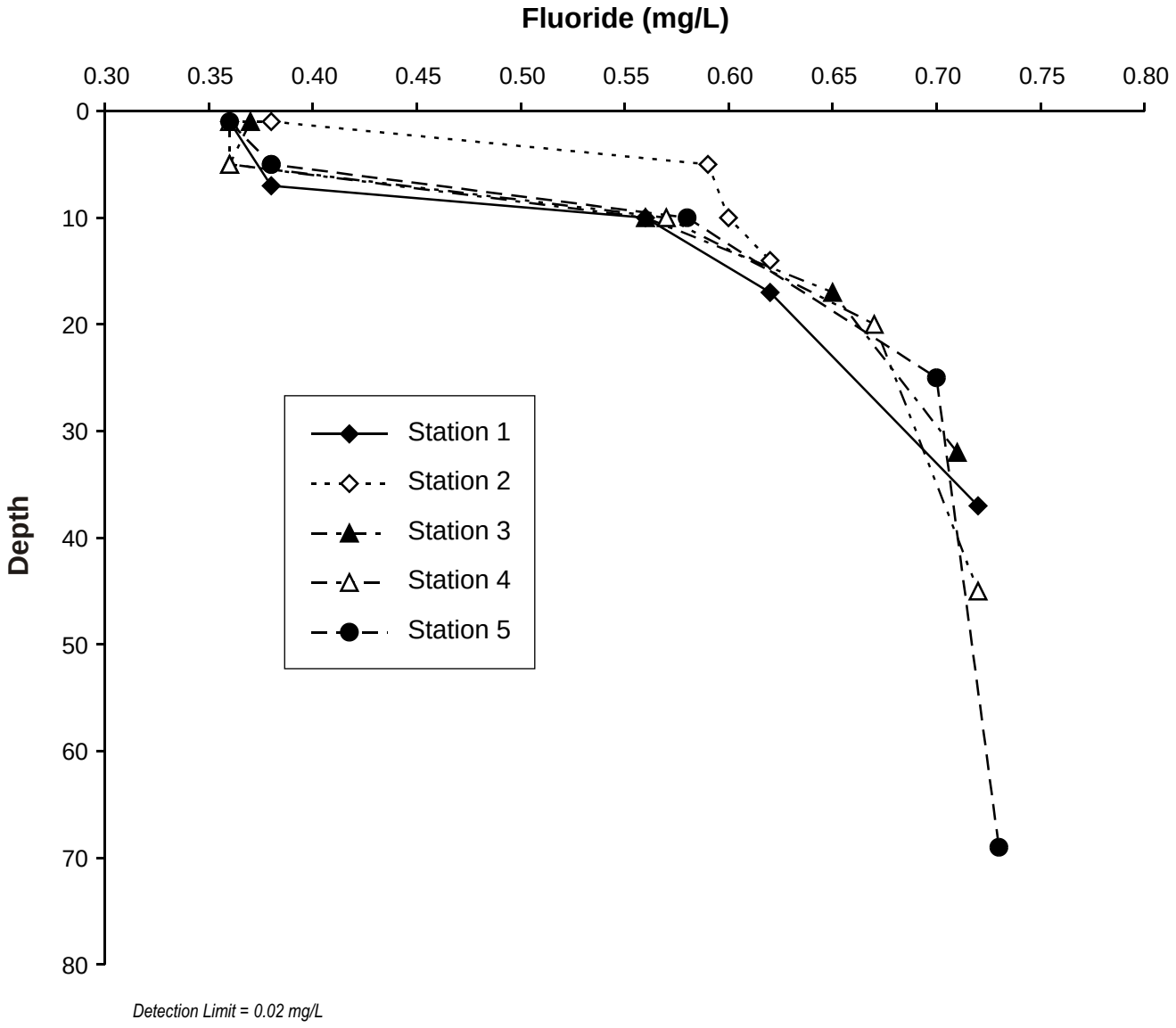
Vertical Profiles of Alkalinity, Bathurst Inlet, August 2001

FIGURE 3.2-6

Rescan™

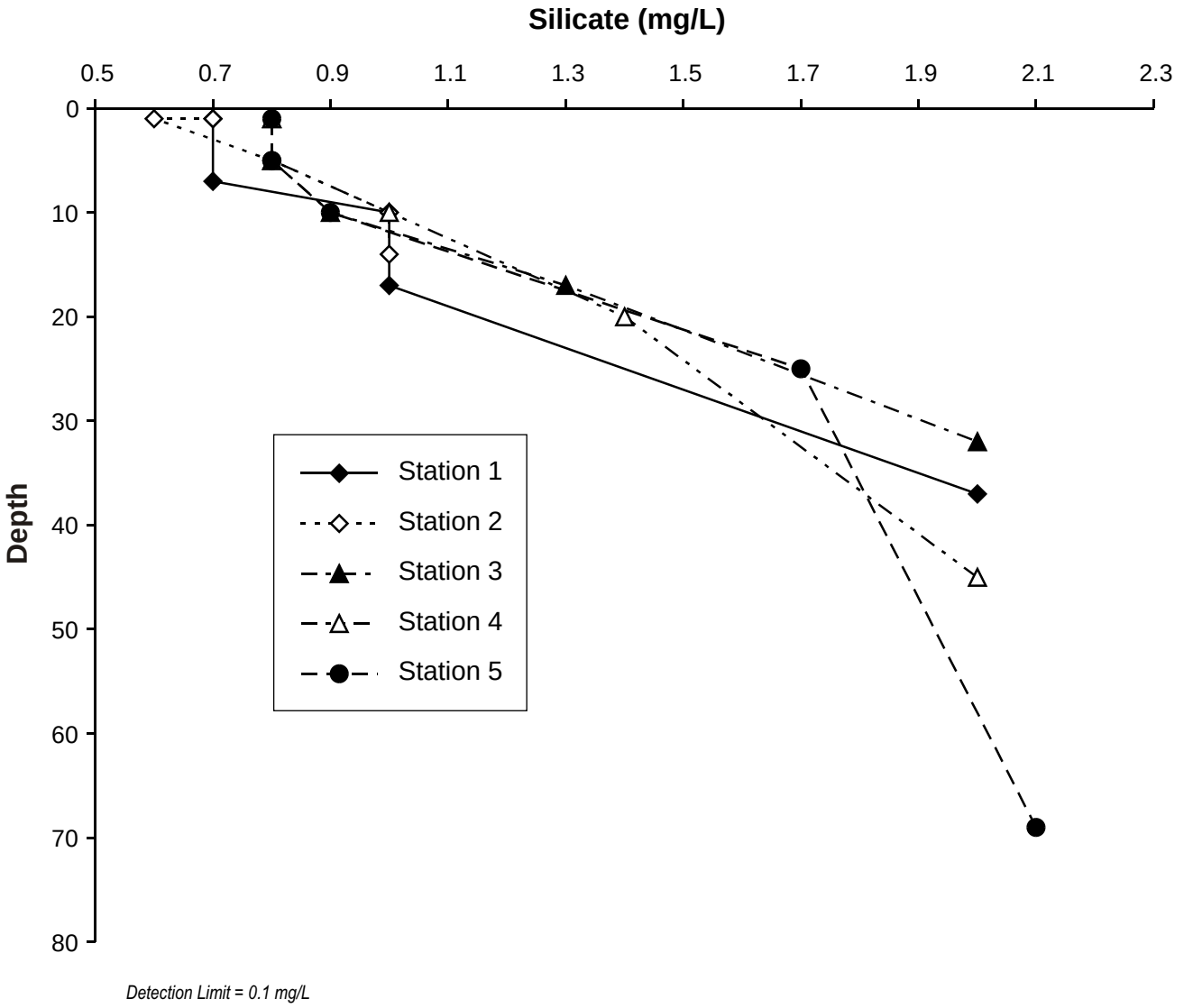


Vertical Profiles of Fluoride, Bathurst Inlet, August 2001

FIGURE 3.2-7

the BATHURST INLET PORT AND ROAD PROJECT

Rescan™



Detection Limit = 0.1 mg/L

Vertical Profiles of Silicate, Bathurst Inlet, August 2001

FIGURE 3.2-8

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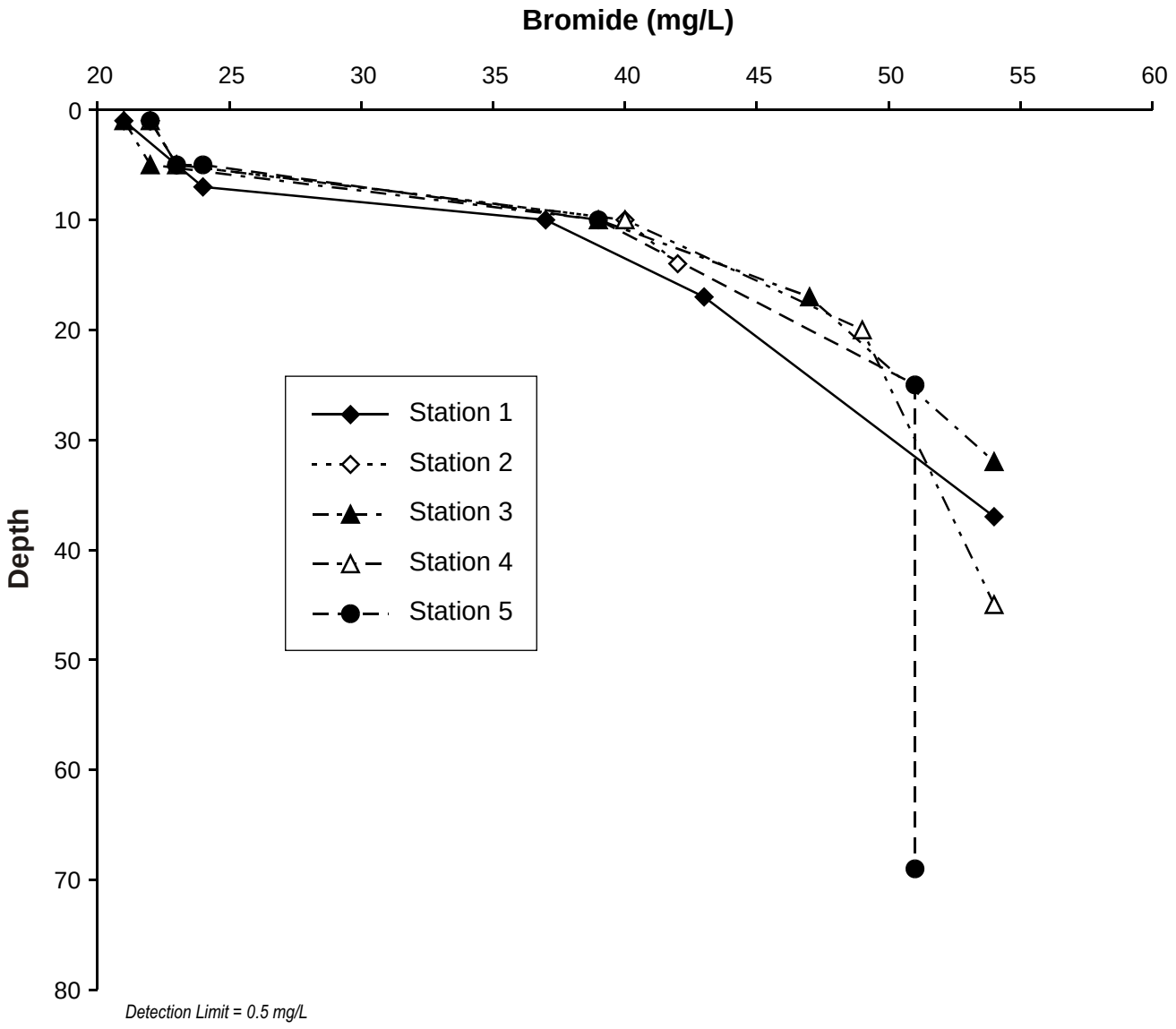
Rescan™



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Vertical Profiles of Bromide, Bathurst Inlet, August 2001

FIGURE 3.2-9

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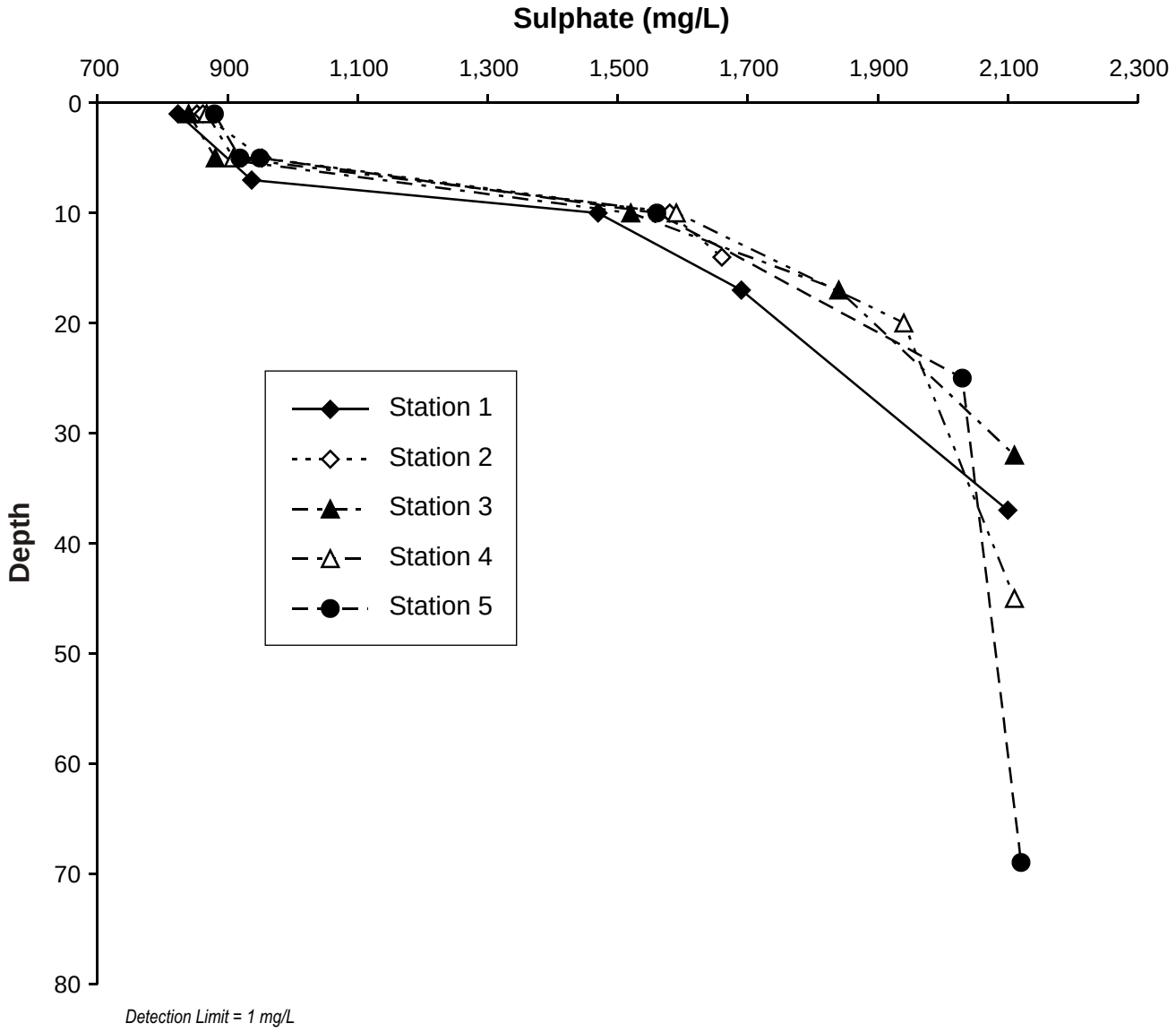

Vertical Profiles of Sulphate, Bathurst Inlet, August 2001

FIGURE 3.2-10

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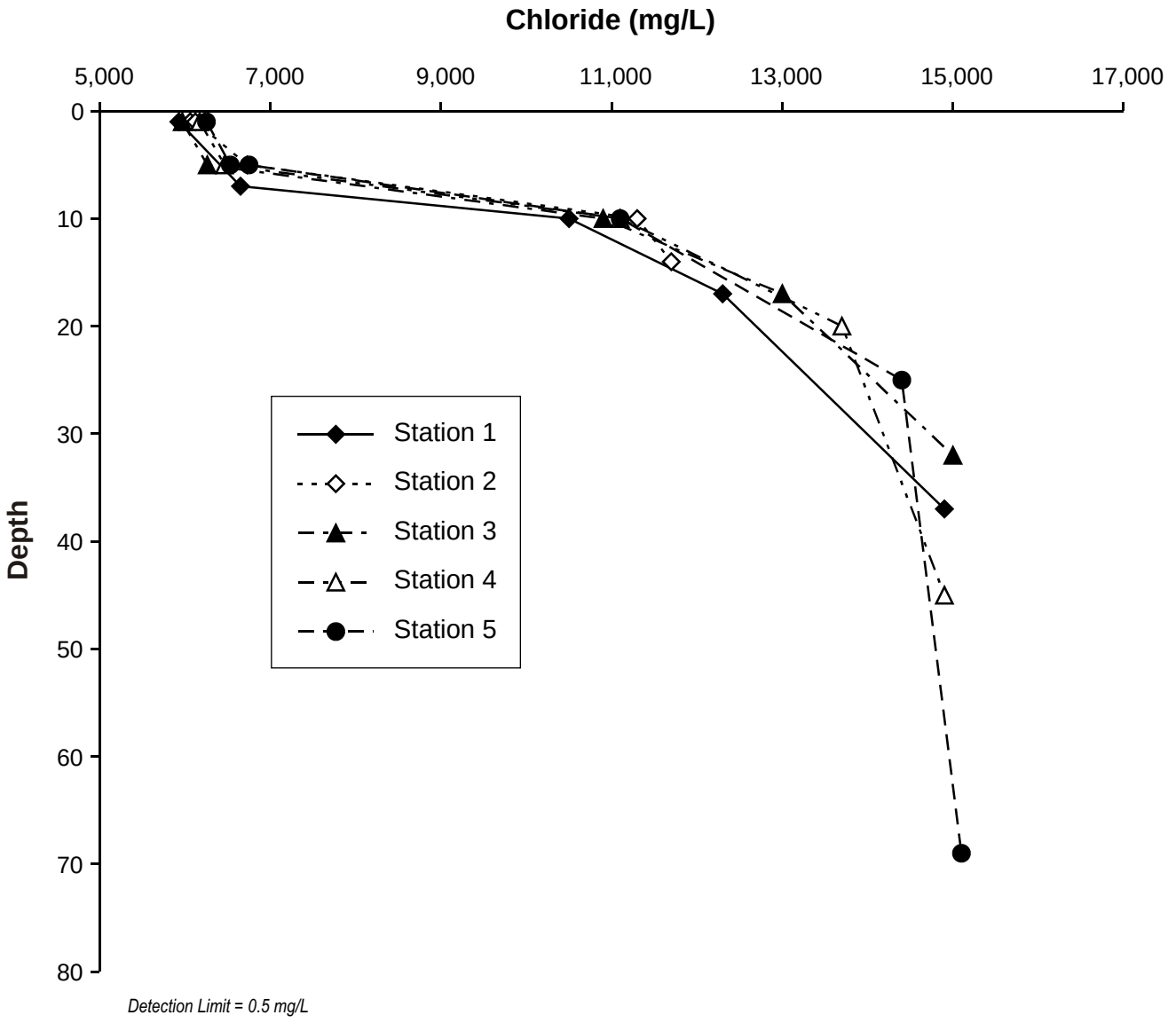

Vertical Profiles of Chloride, Bathurst Inlet, August 2001

FIGURE 3.2-11

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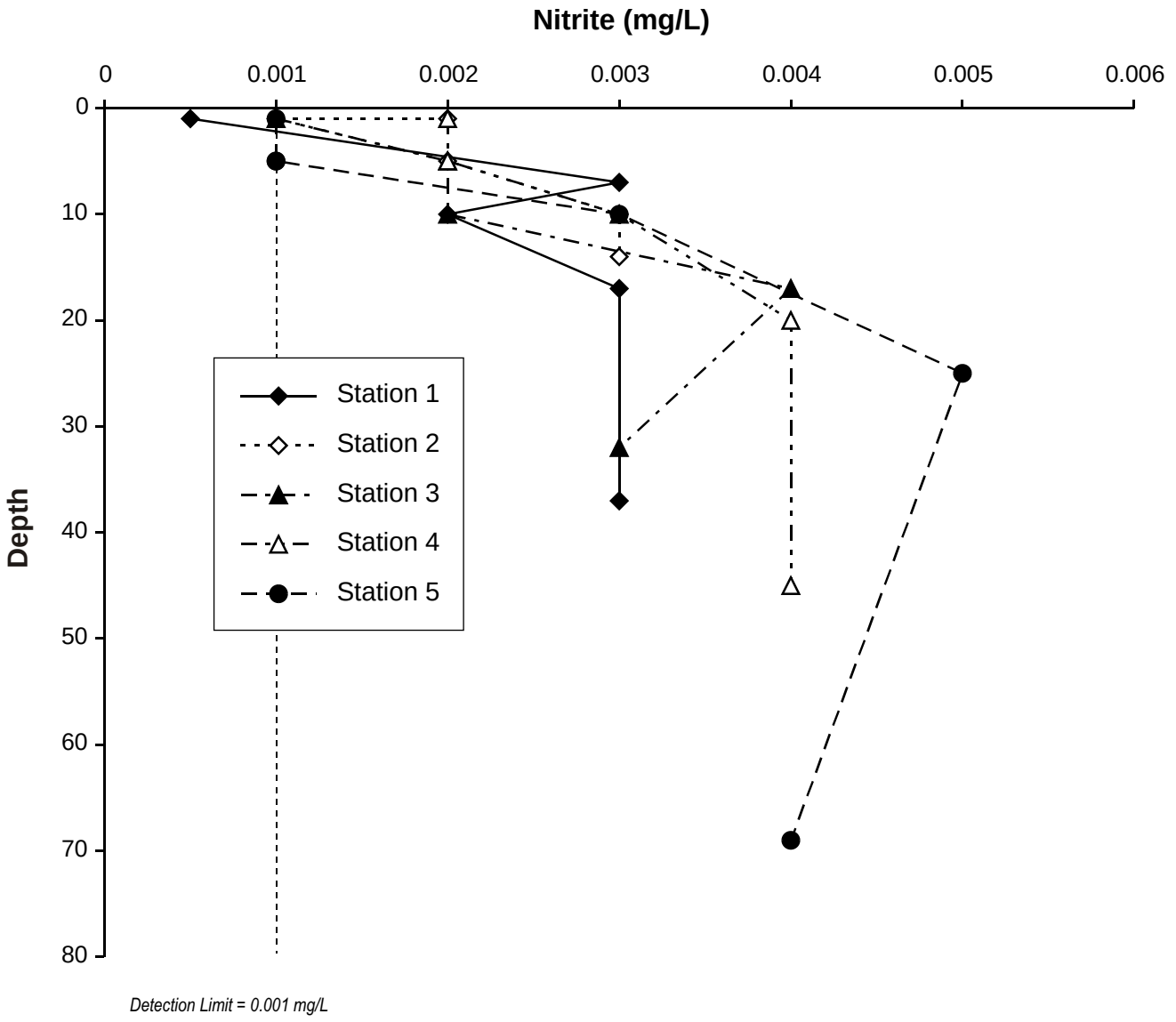
Rescan™



Vertical Profiles of Nitrite, Bathurst Inlet, August 2001

FIGURE 3.2-12

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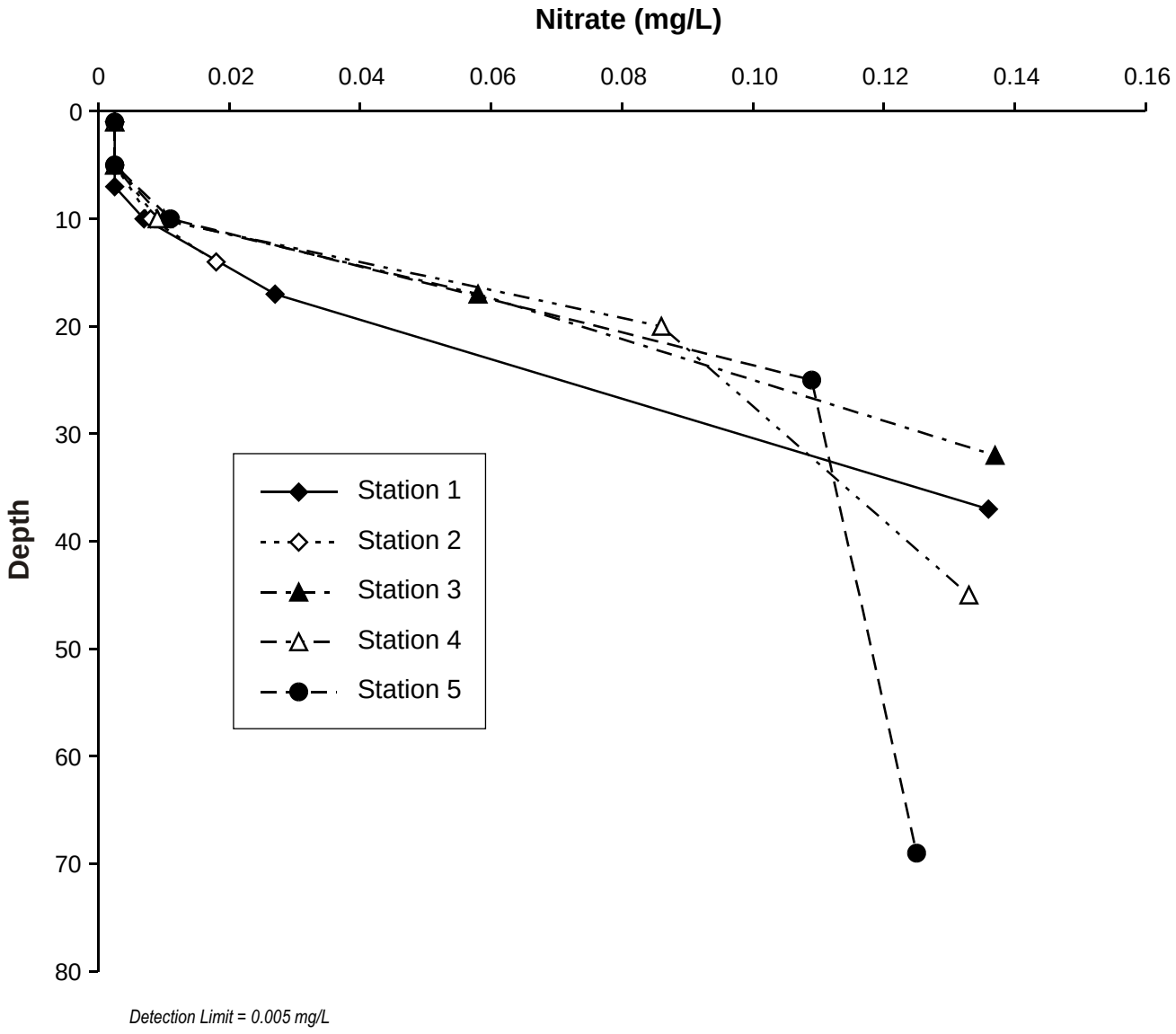

Vertical Profiles of Nitrate, Bathurst Inlet, August 2001

FIGURE 3.2-13

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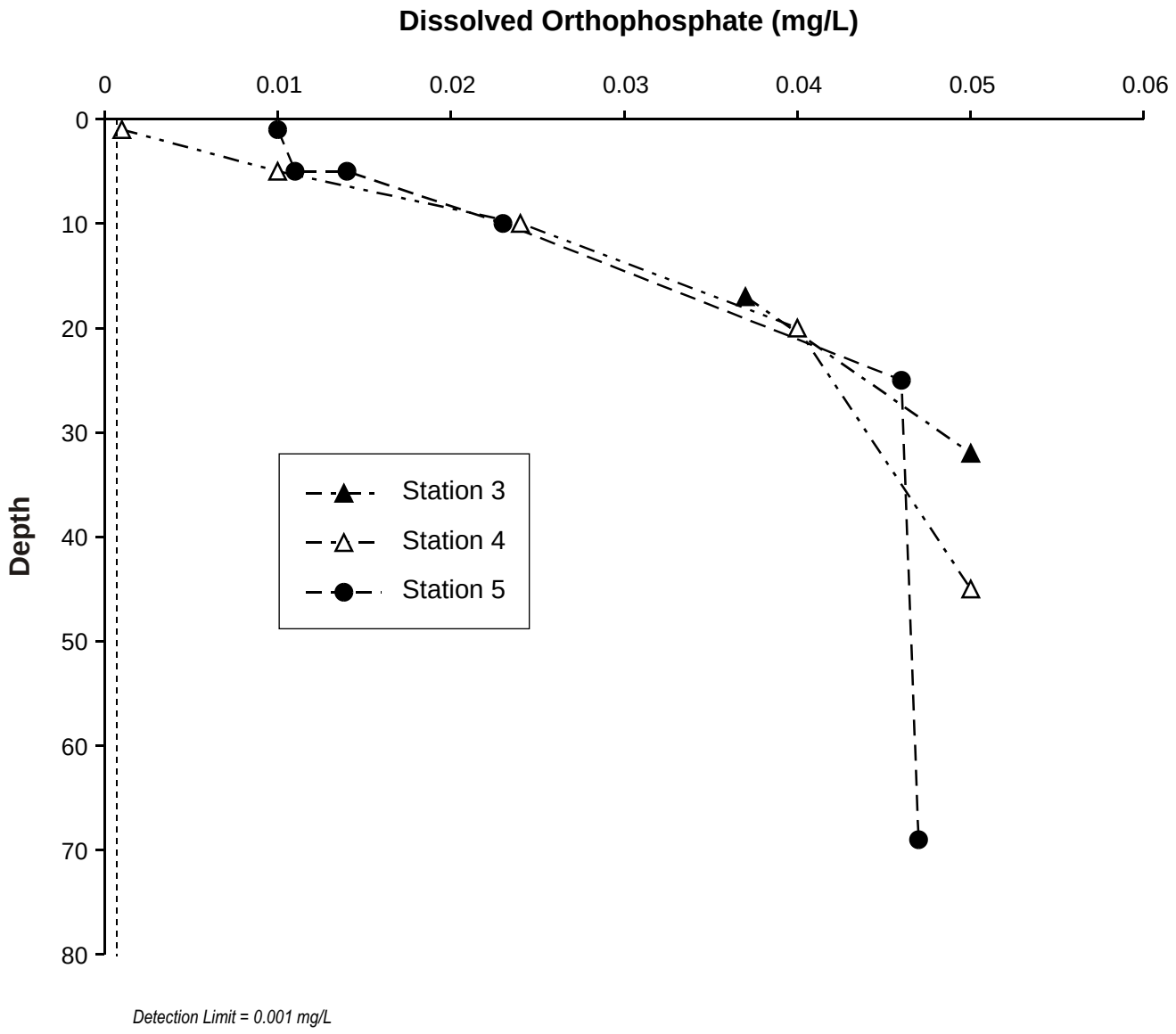

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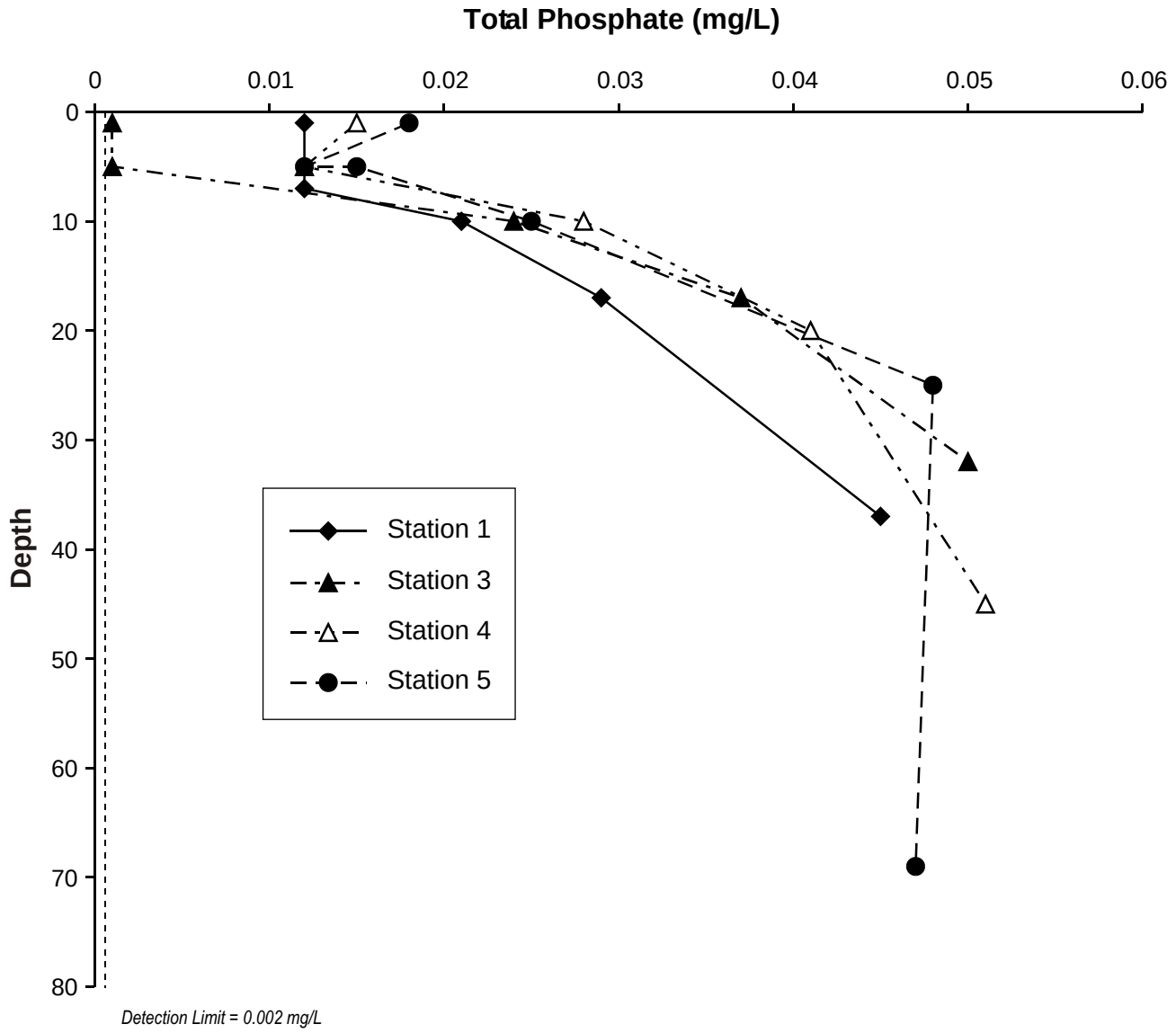
Vertical Profiles of Orthophosphate, Bathurst Inlet, August 2001

FIGURE 3.2-14

Rescan™



Vertical Profiles of Total Phosphate, Bathurst Inlet, August 2001

FIGURE 3.2-15

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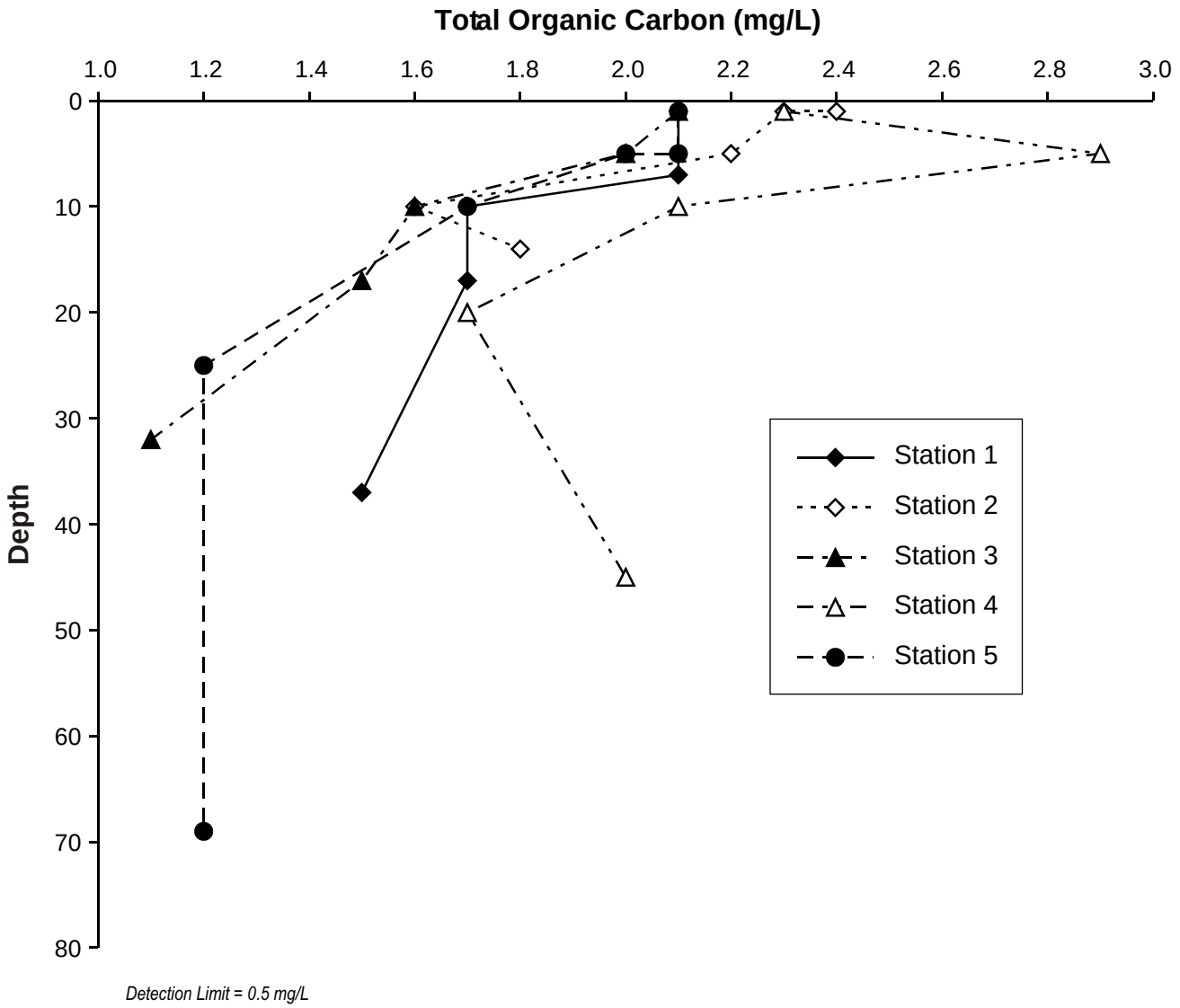
Rescan™



Detection Limit = 0.5 mg/L

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Vertical Profiles of Total Organic Carbon, Bathurst Inlet, August 2001

FIGURE 3.2-16

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3.2.4 Total and Dissolved Metals

Of the 33 metals analyzed for total and dissolved concentrations at each of the five stations, eight metals had one or more values above the detection limit. Five of those eight metals (calcium, magnesium, potassium, sodium and strontium) had all values above the detection limit for both the total and dissolved phases as they are major constituents of seawater. The other three metals having values above the detection limit were arsenic (1 value for the total phase and 3 values for the dissolved phase), manganese (6 values for the total phase and 4 for the dissolved phase), and silicon (7 values for each of the total and dissolved phases).

There were too few arsenic concentrations above the detection limit to identify meaningful trends among depths and stations. The average dissolved arsenic concentration for values above the detection limit was 0.07 mg/L (SD = 0.03, n = 3).

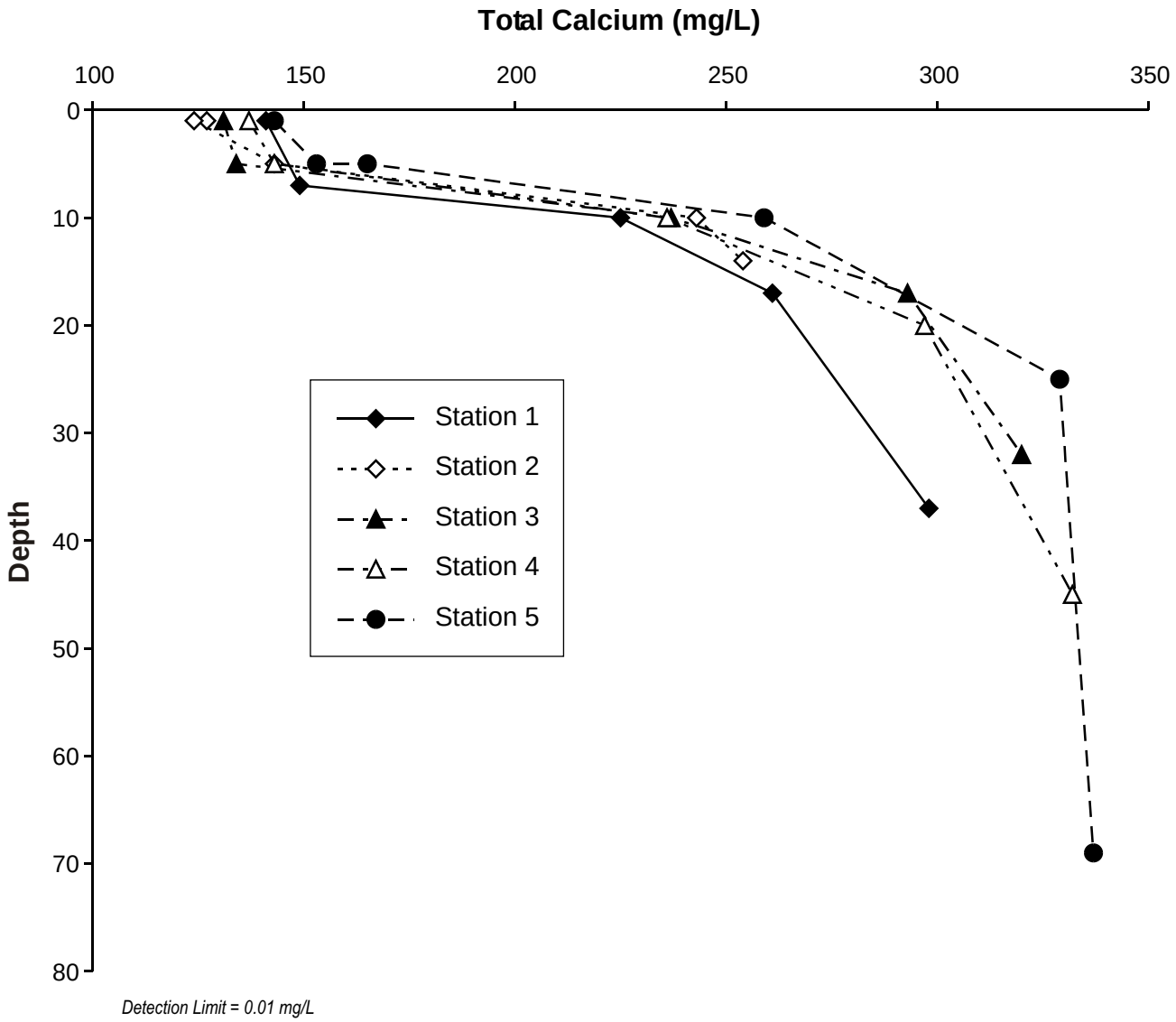
Concentrations of total manganese ranged from 0.03 to 0.04 mg/L for depths ranging from 10 to 69 m. All of the concentrations at depths above the pycnocline were below the detection limit. There appeared to be a trend of increasing total manganese with depth or at least between the upper and lower water layers. The average concentration of total manganese for the 10-69 m depth range was 0.03 mg/L (SD = 0.01, n = 6). The average concentration of dissolved manganese for the 25-69 m depth range was very similar: 0.03 mg/L (SD = 0.01, n = 4).

A similar pattern was found for silicon – concentrations of total silicon ranged from 0.6 to 1.0 mg/L for depths ranging from 17 to 69 m with an average total silicon concentration below the pycnocline of 0.8 mg/L (SD = 0.2, n = 7). Concentrations of dissolved silicon ranged from 0.5 to 0.9 mg/L for depths ranging from 17 to 69 m with an average dissolved silicon concentration of 0.7 mg/L (SD = 0.2, n = 7).

Average concentrations of the five metals with all of their values above detection limits were almost identical between the total and dissolved phases. For example, the average concentration of total calcium was 216 mg/L (SD = 77, n = 26) and the average concentration of dissolved calcium was 213 mg/L (SD = 75, n = 26). Therefore, only the vertical profiles of the total phase for those five metals were shown in this report (Figures 3.2-17 to 3.2-21). All five metals showed the same pattern of vertical distribution – low concentrations in the upper 5 m, rapid increases in concentration around the pycnocline (between 5 and 20 m), and a slow increase with depth at depths greater than 20 m.

3.3 Sediment Quality

Photographic records of all sediment grab samples are presented in Appendix 3.3-1. Laboratory analyses of the sediment samples are presented in Appendix 3.3-2. Although some differences in sediment quality exist between August 2001 and 2002 samples, these periods are considered together in the following sections. Important differences between the two years are noted where appropriate. See Appendix 3.3-3 for a statistical comparison of August 2001 and 2002 sediment quality data.



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Vertical Profiles of Total Calcium, Bathurst Inlet, August 2001

FIGURE 3.2-17

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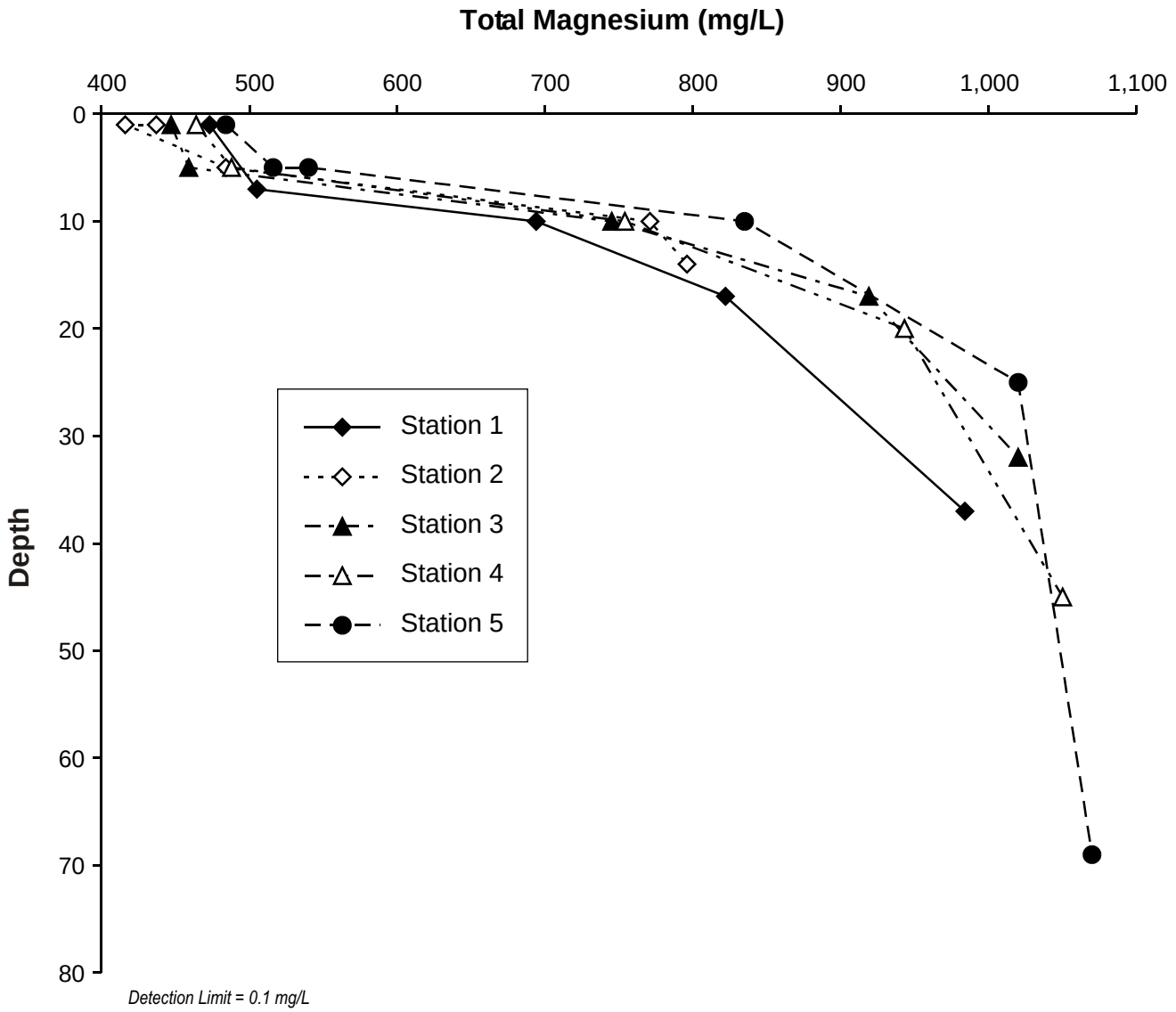

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Vertical Profiles of Total Magnesium, Bathurst Inlet, August 2001

FIGURE 3.2-18

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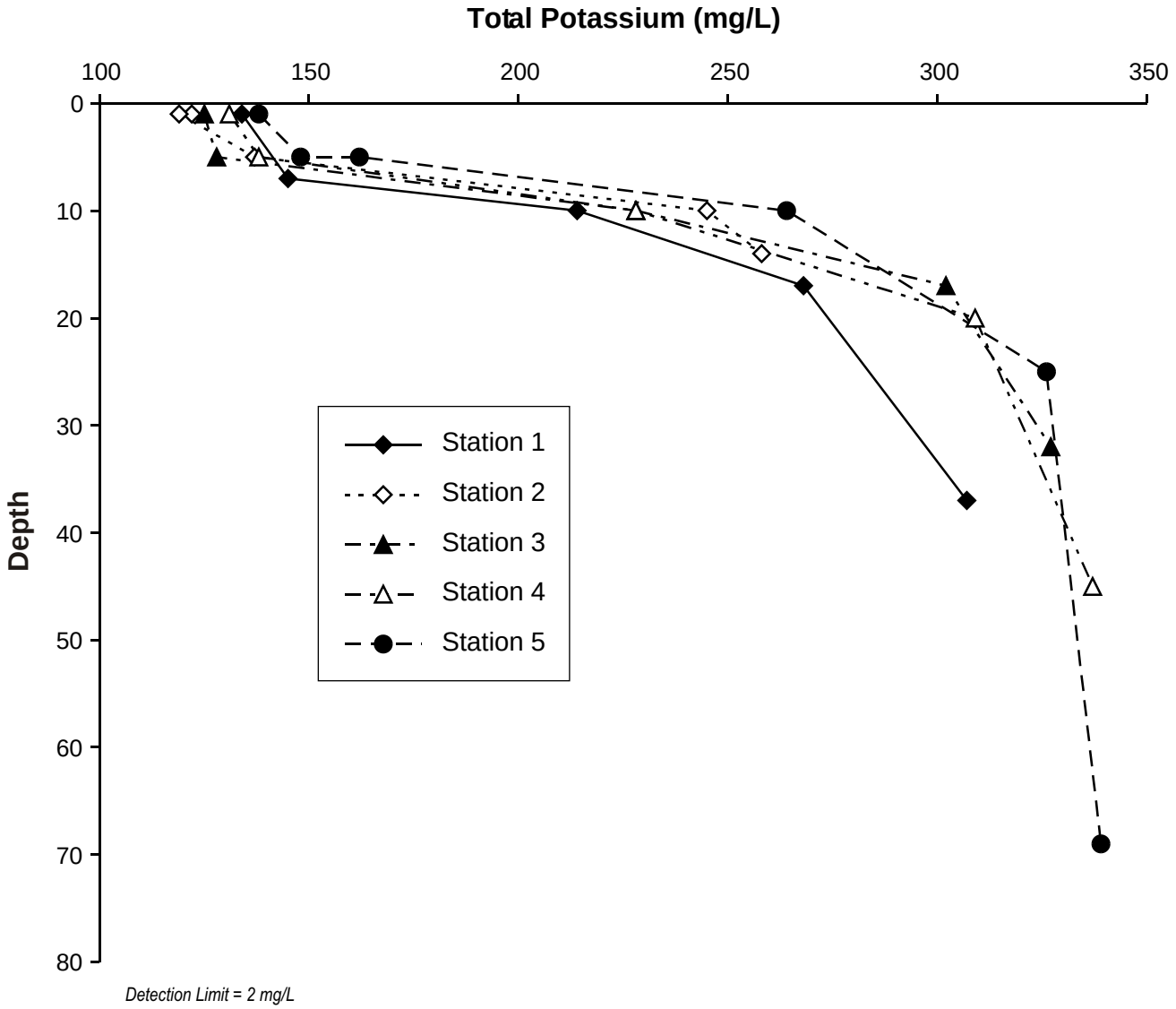

Vertical Profiles of Total Potassium, Bathurst Inlet, August 2001

FIGURE 3.2-19

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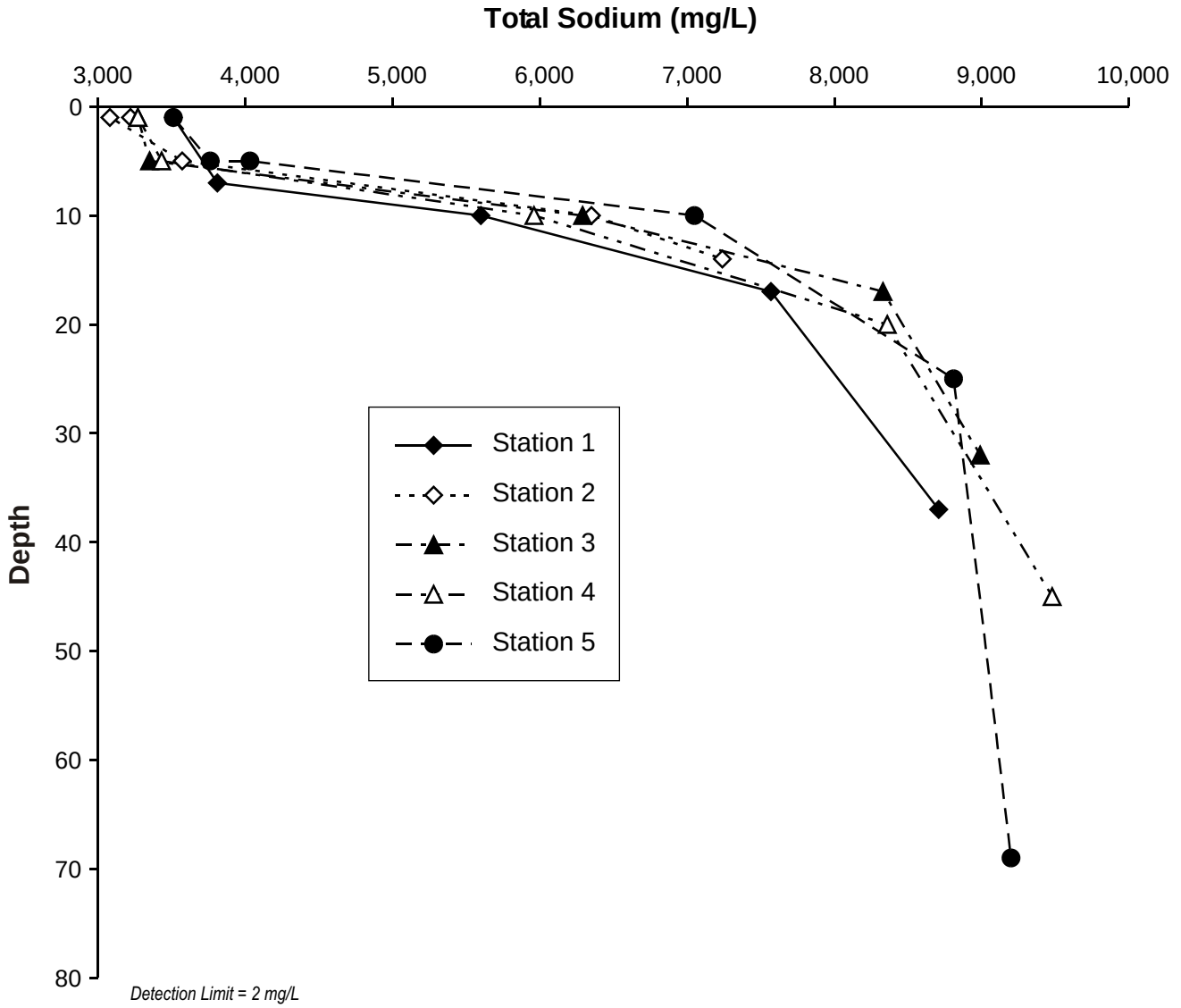

Vertical Profiles of Total Sodium, Bathurst Inlet, August 2001

FIGURE 3.2-20

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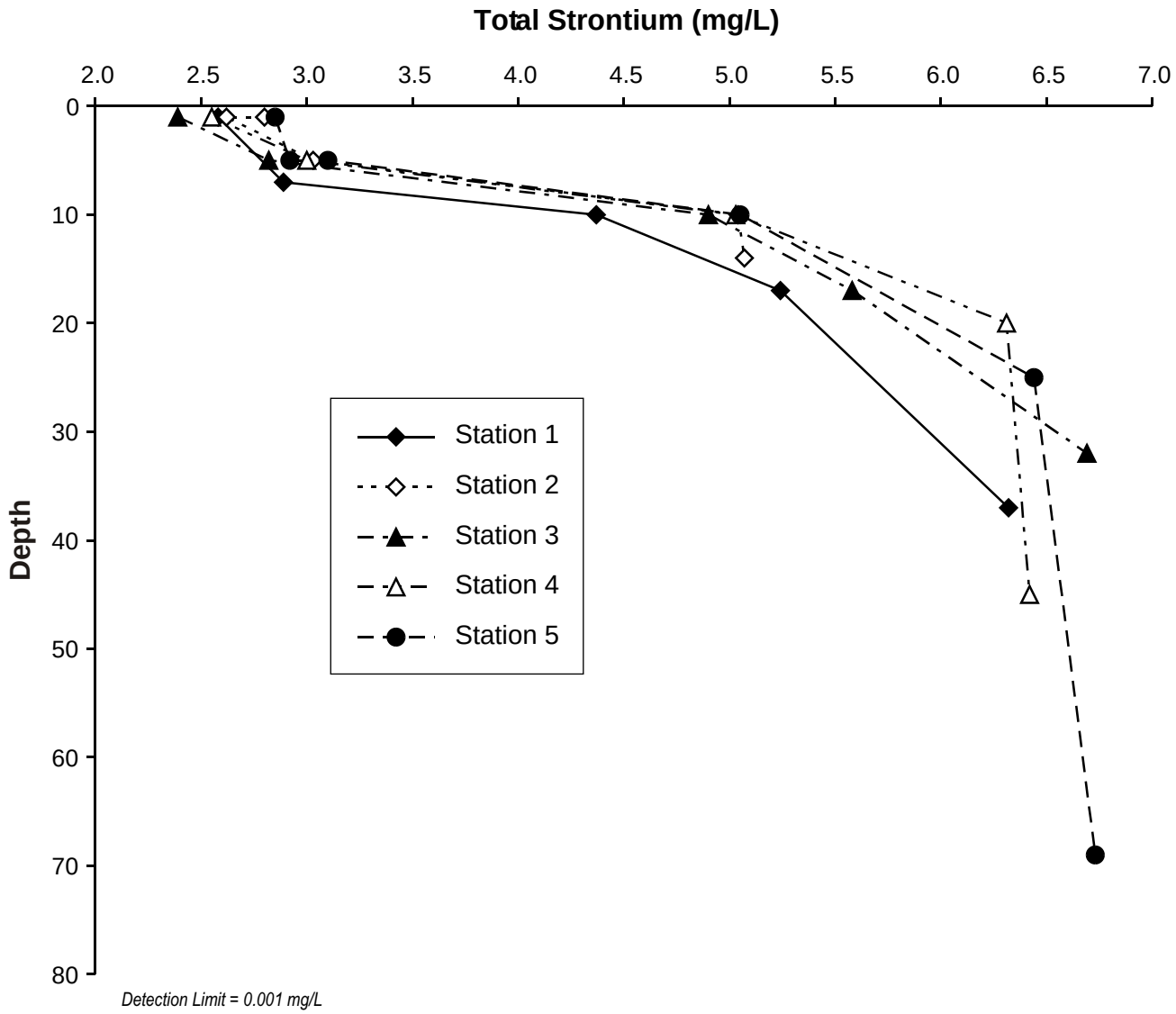

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Vertical Profiles of Total Strontium, Bathurst Inlet, August 2001

FIGURE 3.2-21

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3.3.1 Physical Characteristics

Six sediment samples were taken from five stations on August 16, 2001: one each at stations 1, 3, 4 and 5 and duplicates at station 2. An additional sample was taken at station 2 in August, 2002. Samples were similar in physical characteristics, consisting of soft, loosely bound clay with no distinct layers, no grit to touch but gritty to taste (Table 3.3-1). The samples from shallow stations 1, 2 and 3 (depth range: 17 to 42 m) were brown (7.5YR 5/2 or 5/3 on the Munsell colour chart), but the samples from the two deeper stations 4 and 5 (depth range: 64 to 70 m) were grey. Biological material was found in half of the samples and consisted of polychaete worms and a sculpin. No detritus of any kind was found. Photographs were taken of all samples and are presented in Appendix 3.3-1.

Moisture content ranged from 52.7 to 56.9% and averaged 54.3% (SE = 1.6, n = 7). Particle size distributions were very similar among stations and replicates. On average, 67.1% of the particles were clay, 29.6% were silt, 3.3% were sand and less than 0.1% was gravel (Figure 3.3-1).

3.3.2 Nutrients

The available phosphorus in the sediment samples ranged from 36 to 54 mg/kg dry weight (DW) and averaged 42.4 mg/kg DW (SE = 8.0, n = 7). Total nitrogen was low, ranging from 0.05 to 0.07% of the dry weight of the samples (mean = 0.06%, SE = 0.01, n = 7).

3.3.3 Metals

Concentrations of 8 of the 29 metals were generally below the detection limit and concentrations of the other 21 metals were above their respective detection limits (Table 3.3-2). To calculate average concentrations for each metal, concentrations below detection limits were replaced with one-half the detection limit.

The Canadian Council of Ministers of the Environment lists marine sediment quality guidelines for 7 of the 29 metals: chromium, zinc, copper, lead, arsenic, mercury and cadmium (CCME, 1999). There are two kinds of quality guidelines: Interim Sediment Quality Guidelines (or ISQG) and Probable Effects Level (or PEL). Both are in units of mg/kg dry weight. The ISQG is the lowest concentration for which adverse ecological effects have been identified and the PEL is the concentration above which adverse ecological effects are likely to occur. The percentage of adverse effects range from 3 to 9% for concentrations below the ISQG, from 13 to 27% for concentrations between the ISQG and the PEL, and from 37 to 71% for concentrations above the PEL. Comparison of average concentrations of those metals in Bathurst Inlet sediments with the guidelines shows that zinc, lead, arsenic, mercury and cadmium had average concentrations below the ISQG, and that chromium and copper had average concentrations between the ISQG and the PEL (Table 3.3-3). None of the metals had average concentrations above the PEL.

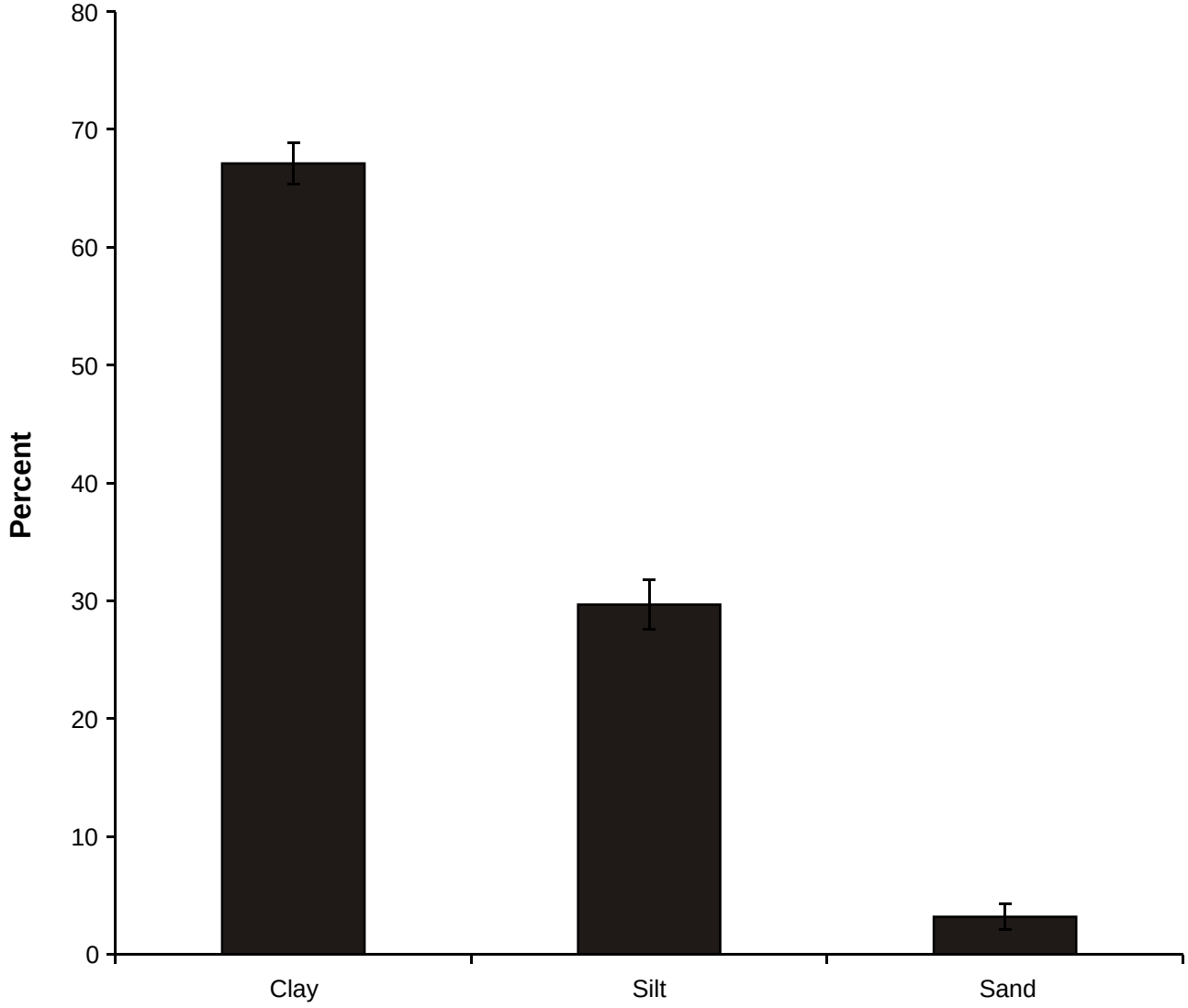
3.3.4 Total Sulphur and Extractable Hydrocarbons

Concentrations of total sulphur in Bathurst Inlet sediments were low, ranging from 0.04 to 0.13% of dry weight and averaging 0.1% (SE = 0.01, n = 7). The maximum total sulphur concentration in August, 2001 (0.05 mg/L) was much lower than the concentration determined from the single

Table 3.3-1
Characteristics of Marine Sediments of the Bathurst Port Area, August 2001 and 2002

Station	Date	Depth (m)	Replicate	Munsell Colour Classification	Biological Material	Physical Description
1	August 2001	40	NA	Brown 7.5YR 5/3	Polychaetes	One layer, homogenous, no grit to touch, grit to taste, sticky, loosely bound
2	August 2001	17	A	Brown 7.5YR 5/2	Sculpin, polychaete	Loosely bound soft clay, no grit to touch, grit to taste, sticky, homogenous, slight organic smell
2	August 2001	17	B	Brown 7.5YR 5/2	Worms	Loosely bound soft clay, no grit to touch, grit to taste, sticky, homogenous
2	August 2002	17	NA	Brown 7.5YR 5/2	Polychaetes	Loosely bound soft clay, no grit to touch, grit to taste, sticky, homogenous
3	August 2001	42	NA	Brown 7.5YR 5/2	None visible	Thin layer of green detritus on surface, loosely bound, no distinct layers, no grit to touch, grit to taste
4	August 2001	64	NA	Grey 7.5YR 5/1	None visible	Soft clay, fine, no grit to touch, grit to taste, surface sediment loosely bound but bottom sediment more firm in patches, no distinct layer
5	August 2001	70	NA	Grey 7.5YR 5/1	None visible	Homogenous soft clay, loosely bound, no grit to touch, grit to taste

NA = not applicable



Note: Error bars represent standard error of the mean.

Average Percent Distribution of Particle Sizes in Six Bathurst Inlet Sediment Samples

FIGURE 3.3-1

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grab sample taken in August, 2002 (0.13 mg/L). Concentrations of extractable petroleum hydrocarbons were also low. Detectable concentrations in August, 2002, were 59 mg/L for EPH10-19 and 44 mg/L for EPH19-32.

Table 3.3-2
Average Concentrations of Total Metals for Seven Sediment Samples from Bathurst Inlet

Total Metal	Percent Greater than Detection Limit	Concentration (mg/kg DW):	
		Mean	Std. Error
Aluminum	100	35,514	1,810
Arsenic	100	13.1	1
Barium	100	157	5
Beryllium	100	1.3	0.1
Calcium	100	5,934	712
Chromium	100	64	1
Cobalt	100	13	1
Copper	100	26	0.4
Iron	100	33,900	661
Lead	100	16	2
Lithium	100	53	1
Magnesium	100	15,000	157
Manganese	100	749	156
Mercury	100	0.022	0.002
Nickel	100	31	1
Phosphorus	100	1,294	85
Potassium	100	10,886	567
Strontium	100	128	4
Titanium	100	1,182	61
Vanadium	100	71	2
Zinc	100	62	2
Cadmium	86	0.1	0.02
Antimony	0	10	-
Bismuth	0	10	-
Molybdenum	0	2	-
Selenium	0	25	-
Silver	0	1	-
Thallium	0	25	-
Tin	0	5	-

Table 3.3-3
Comparison of Average Sediment Metal Concentrations with Canadian Guidelines

	Average Concentration (mg/kg DW)		Canadian Sediment Quality Guidelines for Protection of Aquatic Life (mg/kg DW)		Incidence of Adverse Effects (%)		
Total Metal	**Mean**	**Std. Error**	**ISQG**	**PEL**	**%<ISQG**	**ISQG<%<PEL**	**%>PEF**
Below ISQG							
Mercury	0.022	0.002	0.13	0.70	8	24	37
Cadmium	0.071	0.021	0.7	4.2	6	20	71
Lead	16	2	30.2	112	6	26	58
Zinc	62	2	124	271	4	27	65
Between ISQG and PEL							
Arsenic	13.1	1	7.24	41.6	3	13	47
Copper	26	0.4	18.7	108	9	22	56
Chromium	64	1	52.3	160	4	15	53

ISQG = Interim marine sediment quality guideline, PEL = probable effect level

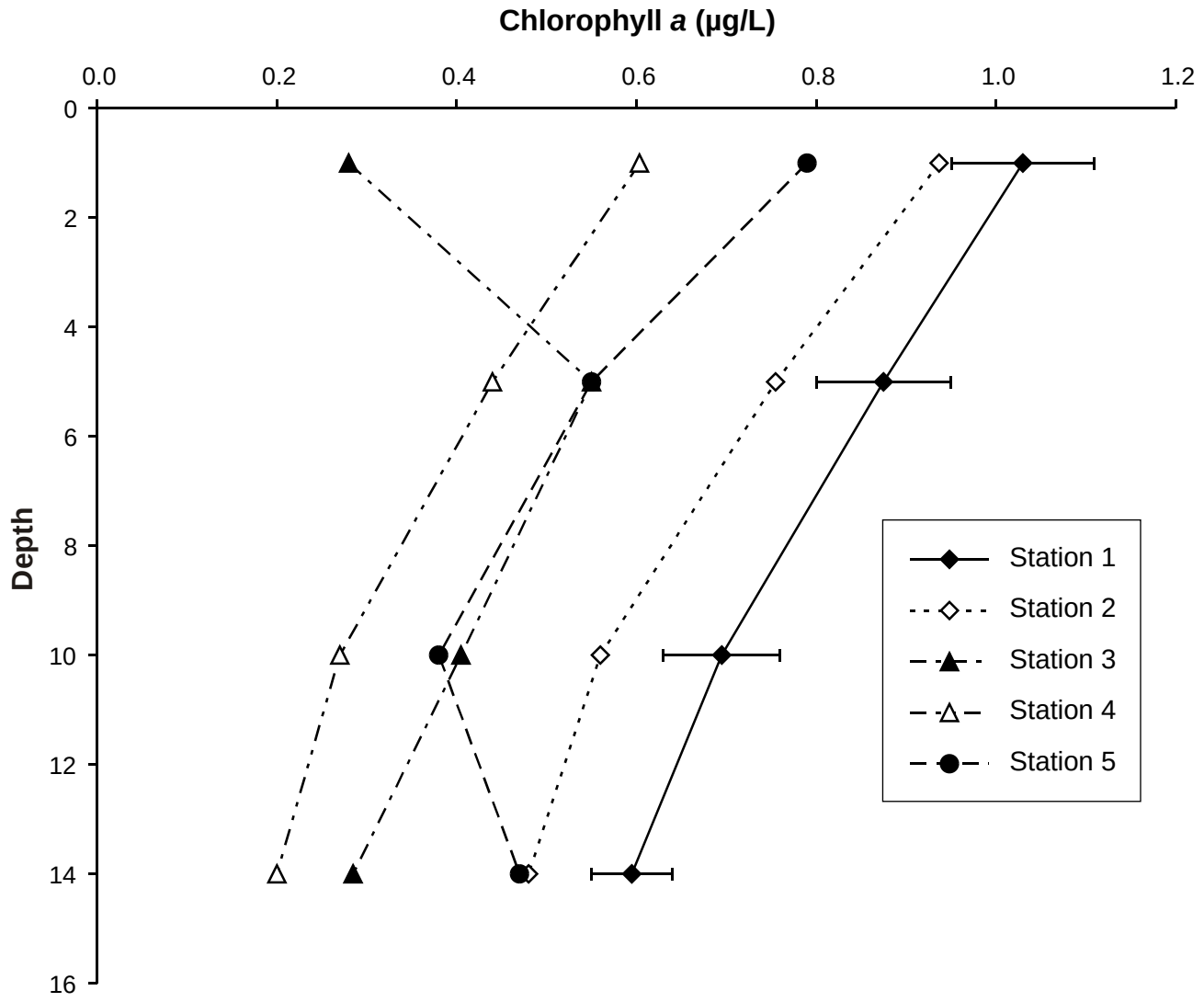
3.4 Phytoplankton

Appendix 3.4-1 shows the concentrations of chlorophyll *a*, the conventional index of phytoplankton biomass, that were measured at depths of 1, 5 10 and 14 m at each of stations 1 to 5. Three replicate samples were taken at 1 m depth and two replicates were taken at each of the other three depths.

Chlorophyll *a* concentrations ranged from 0.05 to 1.18 µg/L. Average concentrations of chlorophyll *a* decreased with depth over the upper 14 m for stations 1, 2, 4 and 5 (Figure 3.4-1). Average concentrations of chlorophyll *a* for station 3 showed no clear trend with depth.

Results from the taxonomic enumeration and identification of phytoplankton samples are provided in Appendix 3.4-2. Figure 3.4-2 presents the average abundance of phytoplankton cells at 1 m depth at the 5 stations sampled in August of 2001. Abundances ranged from 590 (station 2) to 989 cells/mL (station 5).

Figure 3.4-3 presents the taxonomic composition, by abundance, of the phytoplankton assemblages of all 5 stations sampled in August of 2001. Chlorophytes (23 to 31%) and cryptophytes (15 to 23%) dominated the identifiable assemblages at all 5 stations. Diatoms, (Bacillariophyceae) chrysophytes, cyanophytes, and pyrrhophytes (dinoflagellates) were also present during the sampling period.



Note: Error bars are ±1 SE and are shown for Station 1 only
Sample size was 3 at 1 m depth and 2 at all other depths

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Vertical Profiles of Average Chlorophyll *a* Concentration, Bathurst Inlet, August 2001

FIGURE 3.4-1

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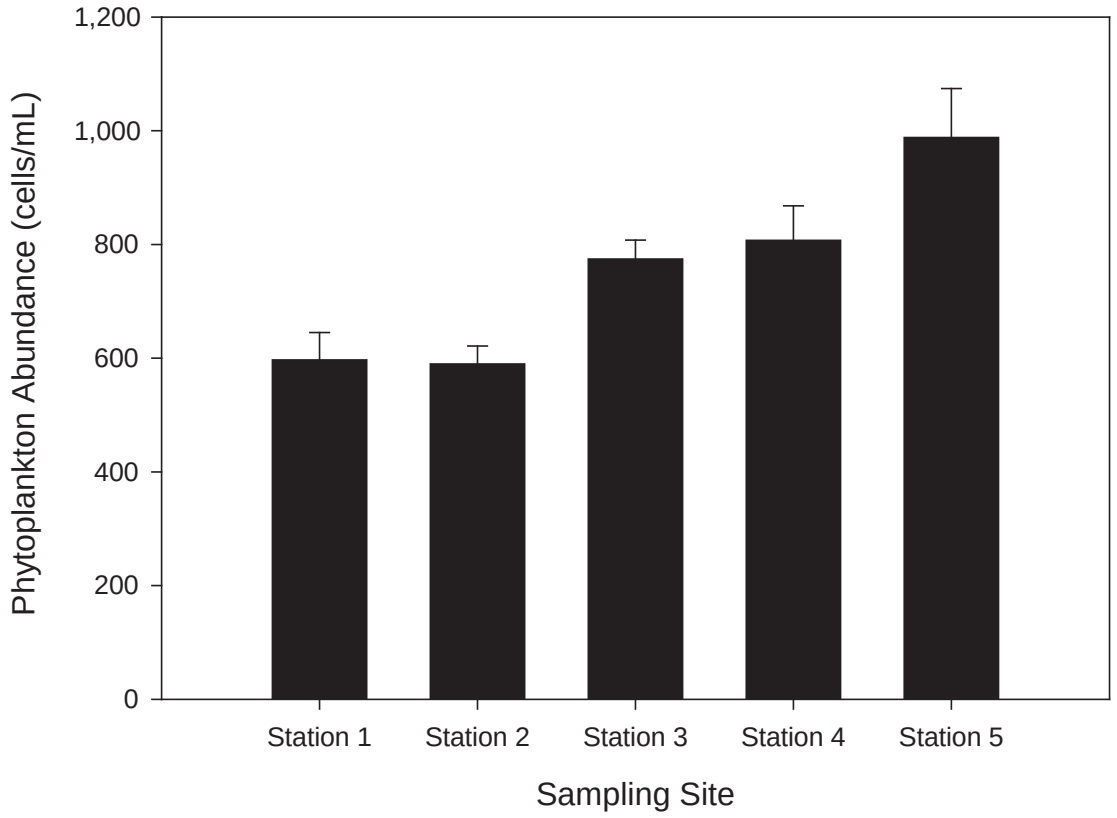
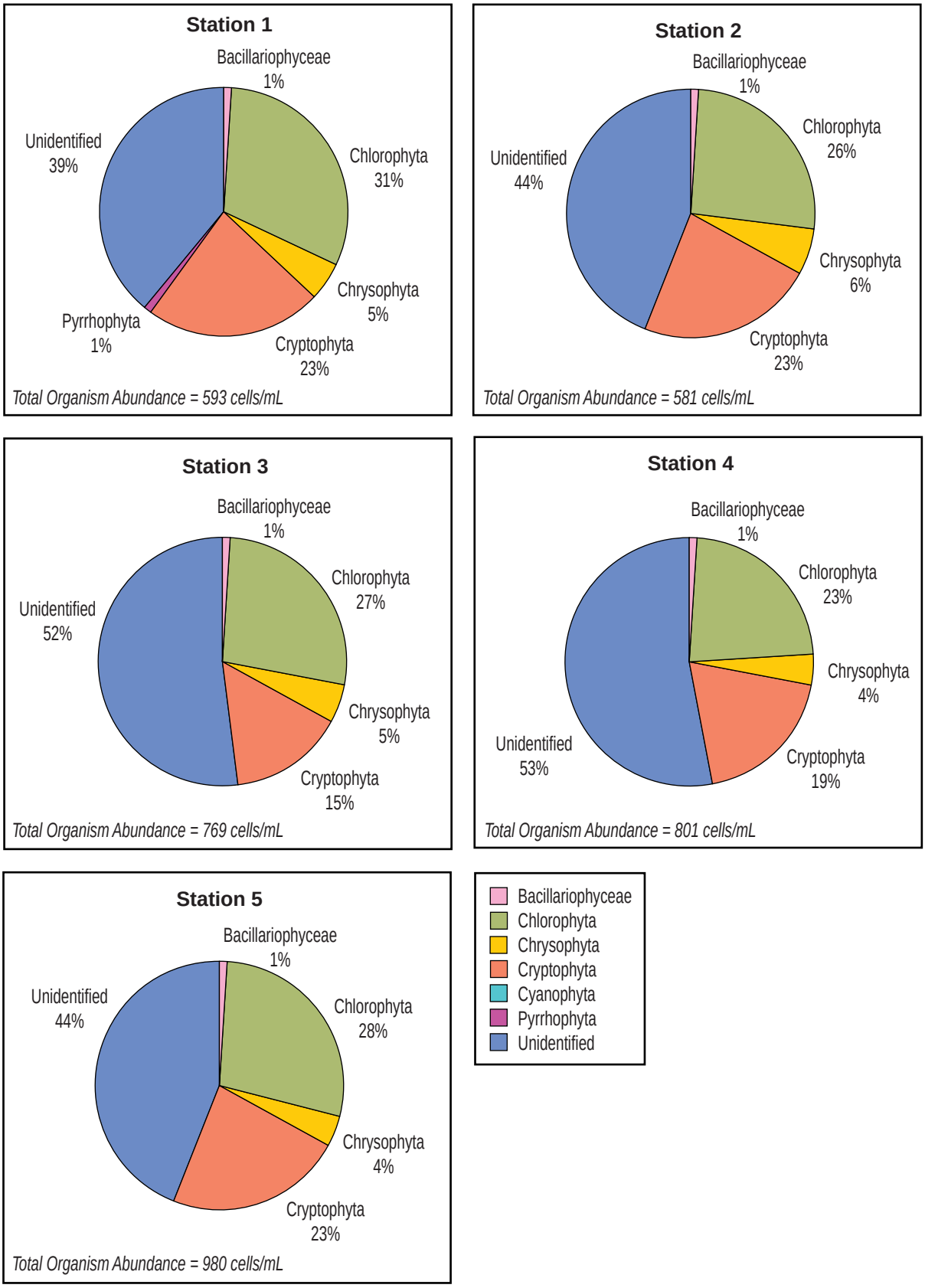


Note: Error bars represent standard error of the mean

Average Phytoplankton Abundances at 1 m Depth in Bathurst Inlet, August 2001

FIGURE 3.4-2



Taxonomic Composition of Marine Phytoplankton Communities, Bathurst Inlet, August 2001

FIGURE 3.4-3

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Table 3.4-1 presents average diversity indices for the assemblages at all 5 stations sampled near the proposed Port area in August 2001. Number of genera identified at each station, the number of genera contributing to 90% of the abundance and the maximum dominance accounted for by a single genus are also included in the table.

The number of positively identified genera ranged from 10 to 13 per station. It should be noted that these values likely underestimate the actual amount of genera present at the 5 stations sampled as many cells could not be positively identified or were not present in large enough numbers to quantify.

Three to four genera comprised 90% of the assemblages abundance. The dominant species numerically was a flagellate that was not identifiable. This flagellate (labelled as "Species A" by the algal taxonomist) represented approximately 40% of the samples. Of the positively identified genera, members of *Plagioselmis* (21.2%) and *Chlorella* (28.5%) dominated the 5 stations sampled.

Shannon diversity indices were very similar at the five stations sampled and ranged from 1.30 (stations 3 and 4) to 1.41 (station 2). Simpson diversity indices among stations were also similar and ranged from 0.66 (station 4) to 0.72 (station 2).

Table 3.4-1
Indices of Marine Phytoplankton Diversity, August 2001

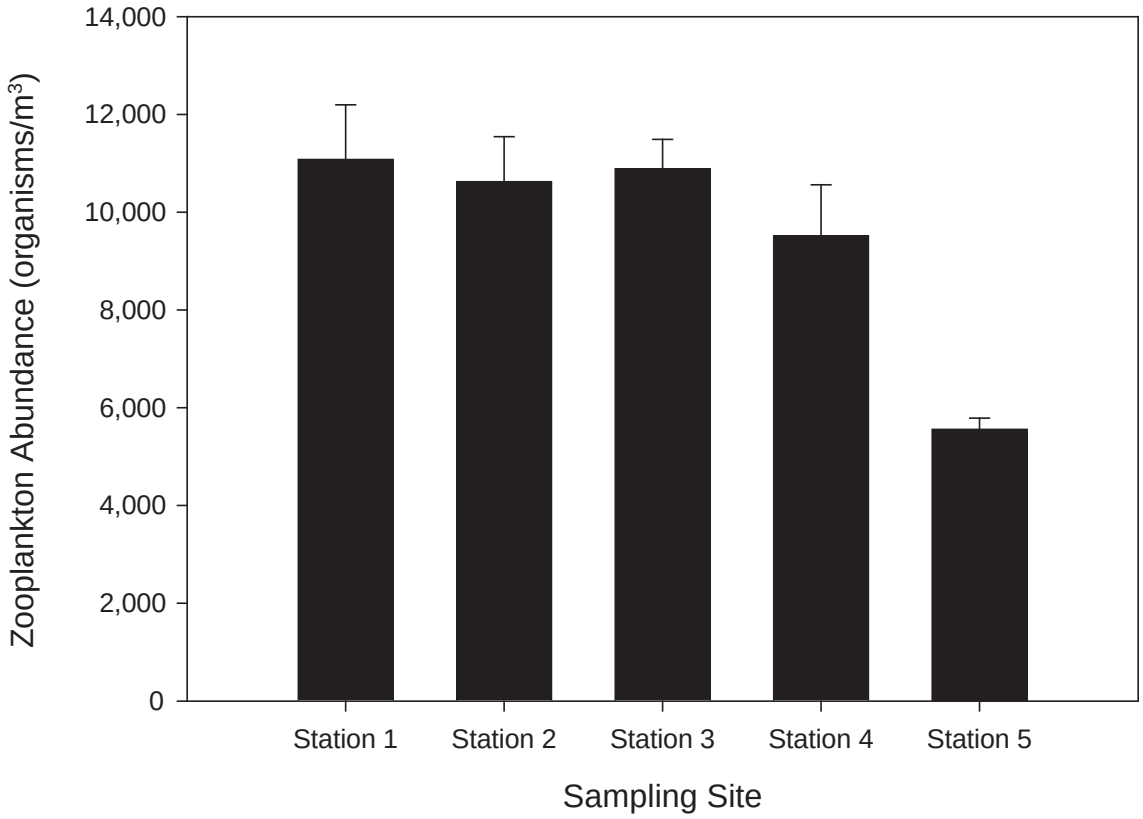
Station	G	G (90%)	Max. Dom. (%)	Shannon	Simpson
Stn 1	12	3	37.6	1.40	0.71
Stn 2	11	4	35.1	1.41	0.72
Stn 3	10	3	47.3	1.30	0.67
Stn 4	11	3	48.5	1.30	0.66
Stn 5	13	4	42.8	1.40	0.70

G = the number of genera per station
G (90%) = the number of genera per station representing 90% of the abundance
Max. Dom. (%) = the maximum dominance accounted for by a single genus

3.5 Zooplankton

Results from the taxonomic enumeration and identification of zooplankton samples are provided in Appendix 3.5-1. Figure 3.5-1 presents the average zooplankton at the 5 stations sampled in August of 2001. Abundances ranged from 5,562 (station 5) to 11,082 organisms/m^3 (station 1). Zooplankton abundance from stations 1 through 4 was fairly similar. Zooplankton abundance at station 5 was considerably lower than at the other four stations.

Figure 3.5-2 presents the taxonomic composition, by abundance, of the zooplankton assemblages of all 5 stations sampled in August of 2001. Calanoid copepods dominated the zooplankton assemblages at all 5 stations (81 to 90%). Cyclopoid copepods and cladocerans were also present and represented between 0 and 18% of the zooplankton abundance. Many other taxa were also present, but in minute amounts. These taxa are grouped together in Figure 3.5-2.



Note: Error bars represent standard error of the mean

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Average Zooplankton Abundance in Bathurst Inlet, August 2001

FIGURE 3.5-1

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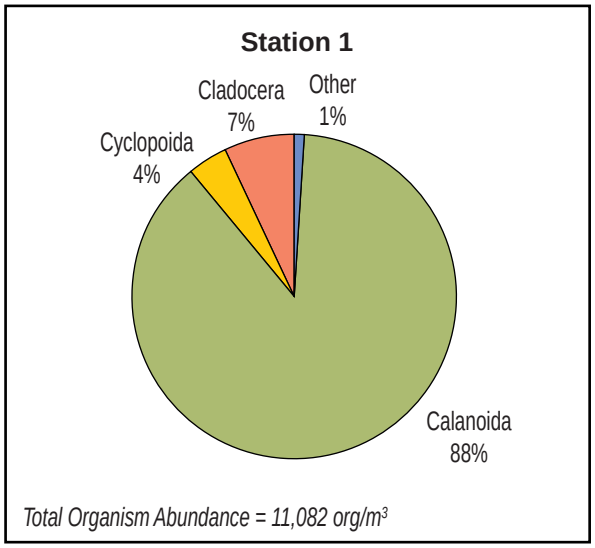

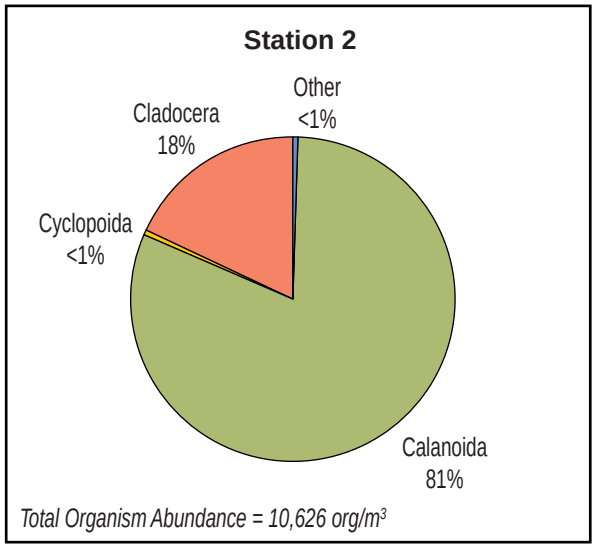

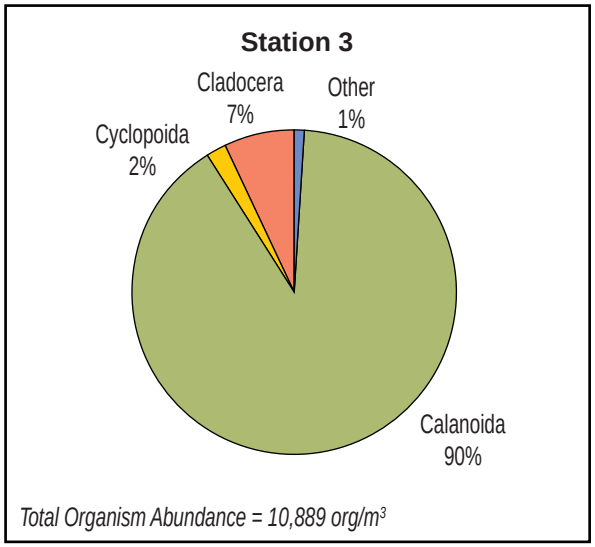

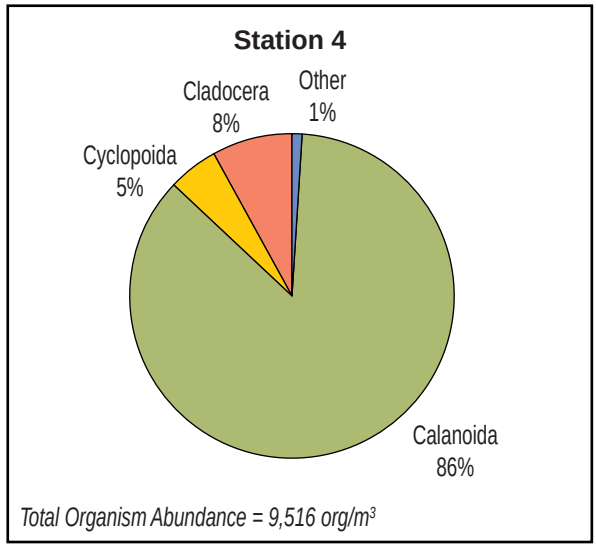

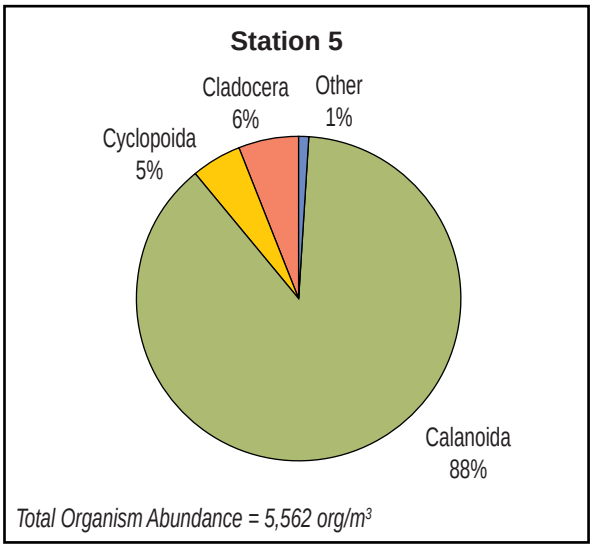

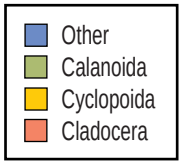

Note: Other *consists of:*
Coelenterata
Polychaeta
Monstrilloida
Harpacticoida
Cirripedia
Isopoda
Amphipoda
Euphausiacea
Decapoda
Mollusca
Chaetognatha
Larvacea
Fish

Taxonomic Composition of Marine Zooplankton Communities, Bathurst Inlet, August 2001

FIGURE 3.5-2

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Table 3.5-1 presents average diversity indices for the assemblages sampled at all 5 stations near the proposed port area in August 2001. Number of genera identified at each station, the number of genera contributing to 90% of the abundance and the maximum dominance accounted for by a single genus are also included in the table.

The number of positively identified genera ranged from 13 (station 2) to 19 (station 5). A number of organisms could not be identified to the taxonomic level of genus. Three or four genera accounted for 90% of the assemblage (by abundance). The predominant genus for the five stations sampled was *Pseudocalanus* (71.3%). The next predominant genus (*Acartia*) accounted for 10.9% of the zooplankton abundance. Both of the genera are calanoid copepods.

Shannon diversity indices ranged from 0.87 (station 5) to 1.34 (station 2) and Simpson diversity indices ranged from 0.34 (station 5) to 0.66 (station 2).

Table 3.5-1
Indices of Marine Zooplankton Diversity, August 2001

Station	G	G (90%)	Max. Dom. (%)	Shannon-Weiner	Simpson
Stn 1	15	3	74.3	0.96	0.43
Stn 2	13	4	50.8	1.34	0.66
Stn 3	16	3	78.2	0.89	0.38
Stn 4	14	4	78.3	0.93	0.38
Stn 5	19	3	80.6	0.87	0.34

G = the number of genera per station
G (90%) = the number of genera per station representing 90% of the abundance
Max. Dom. (%) = the maximum dominance accounted for by a single genus

3.6 Benthos

Marine benthos samples were collected in triplicate from station 3 on August 20, 2001, and again in triplicate from stations 1, 2, 3, 4 and 5, on August 6, 2002. Taxonomic enumeration and composition of the samples is presented in Appendix 3.6-1. Figure 3.6-1 presents the taxonomic composition, by abundance, of the benthic assemblage of all five stations. Diversity indices are presented in Table 3.6-1.

Table 3.6-1
Marine Benthos Diversity Values, August 2001 and 2002

Station	Date	G	G (90%)	Max. Dom. (%)	Shannon	Simpson
Stn 1	Aug 2001	30	20	15.1	2.98	0.93
Stn 2	Aug 2001	34	17	19.9	2.74	0.90
Stn 3	Aug 2002	39	19	38.0	2.56	0.83
Stn 3	Aug 2001	35	16	20.6	2.73	0.90
Stn 4	Aug 2001	29	15	23.0	2.70	0.90
Stn 5	Aug 2001	18	12	32.3	2.39	0.86

G = the number of genera per station
G (90%) = the number of genera per station representing 90% of the abundance
Max. Dom. (%) = the maximum dominance accounted for by a single genus

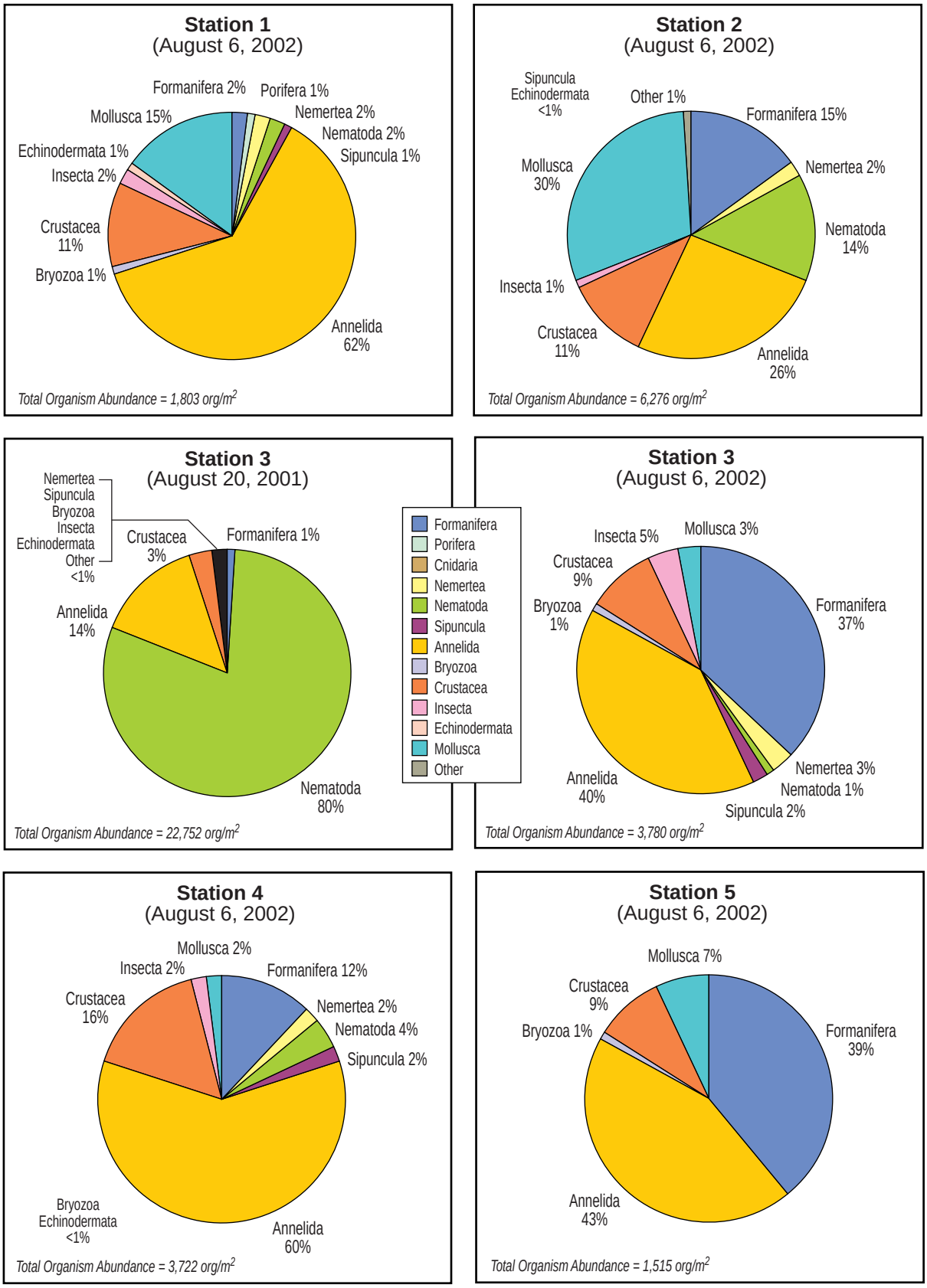

FIGURE 3.6-1

Taxonomic Composition of Marine Benthos Communities, Bathurst Inlet, August 2001 and 2002

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The average density of the three replicates in August, 2001, was 22,752 organisms/m^2. Nematodes were responsible for approximately 80% of the density (Figure 3.6-1). Average densities at all five stations in August, 2002, were much lower, ranging from 1,515 to 6,276 organisms/m^2, with an overall average of 3,419 organisms/m^2. In 2001, nematodes predominated, while in 2002, annelids and foraminiferans were the most abundant groups (Figure 3.6-1).

The average number of genera identified in samples from all five stations ranged from 18 to 39, with station 3 having the greatest number of genera. Between 12 and 20 genera were responsible for 90% of the density in all samples. Although nematodes were the most abundant group in August, 2001, the calculation of diversity indices for 2001 data did not include nematodes as they were not identified to genus (Appendix 3.6-1). Among the remaining taxa, the polychaete, *Laonice*, accounted for an average of 18% of the organisms identified at all stations. Another polychaete, *Aricidea*, accounted for 8%. Other abundant genera included the foraminiferans, *Nonion* (9%) and *Hippocrepinella* (7.6%). The Shannon diversity index ranged from 2.39 to 2.98 and the Simpson diversity index ranged from 0.83 to 0.93.

3.7 Fish Community

3.7.1 Fish Species

A total of 177 fish from 11 species were captured (Appendix 3.7-1 and Table 3.7-1). Fourhorn sculpin was the dominant species by number, making up 36% of all catches (Plate 3.7-1), followed in descending order by Arctic cisco (Plate 3.7-2), starry flounder (Plate 3.7-3), saffron cod (Plate 3.7-4), Arctic flounder (Plate 3.7-5), Pacific herring, broad whitefish, rainbow smelt, Arctic char, ogac and lake trout. The latter three species were each represented by a single specimen.

Plate 3.7-1. A fourhorn sculpin captured at site 1, Bathurst Inlet, on August 17, 2001.

Table 3.7-1
Total Catches of Fish by Number and Biomass, Bathurst Inlet, August 2001

	Number or Biomass				Percent of Total			
Species	**Site 1**	**Site 2**	**Site 3**	**Total**	**Site 1**	**Site 2**	**Site 3**	**Total**
Number								
Fourhorn sculpin	45	10	8	63	25	6	5	36
Arctic cisco	12	8	14	34	7	5	8	19
Starry flounder	8	9	3	20	5	5	2	11
Saffron cod	7	5	6	18	4	3	3	10
Arctic flounder	4	1	11	16	2	1	6	9
Pacific herring	1	6	4	11	1	3	2	6
Broad whitefish	9	0	1	10	5	0	1	6
Rainbow smelt	2	0	0	2	1	0	0	1
Arctic char	0	1	0	1	0	1	0	1
Ogac	0	1	0	1	0	1	0	1
Lake trout	0	0	1	1	0	0	1	1
Total	**88**	**41**	**48**	**177**	**50**	**23**	**27**	**100**
Biomass (kg)								
Broad whitefish	12.8	0.0	1.2	14.0	32	0	3	35
Arctic cisco	4.0	1.5	2.7	8.2	10	4	7	21
Saffron cod	1.7	2.0	2.3	6.1	4	5	6	15
Starry flounder	1.0	1.7	0.6	3.3	3	4	2	8
Fourhorn sculpin	1.4	0.8	0.4	2.7	4	2	1	7
Arctic flounder	0.7	0.3	0.9	1.9	2	1	2	5
Pacific herring	0.1	0.7	0.4	1.1	0	2	1	3
Ogac	0.0	0.9	0.0	0.9	0	2	0	2
Arctic char	0.0	0.8	0.0	0.8	0	2	0	2
Lake trout	0.0	0.0	0.5	0.5	0	0	1	1
Rainbow smelt	0.3	0.0	0.0	0.3	1	0	0	1
Total	**22.1**	**8.7**	**9.0**	**39.7**	**55**	**22**	**23**	**100**

Plate 3.7-2. An Arctic cisco captured at site 1, Bathurst Inlet, on August 18, 2001.

Plate 3.7-3. A starry flounder captured at site 1, Bathurst Inlet, on August 17, 2001.

Plate 3.7-4. A saffron cod captured at site 1, Bathurst Inlet, on August 17, 2001.

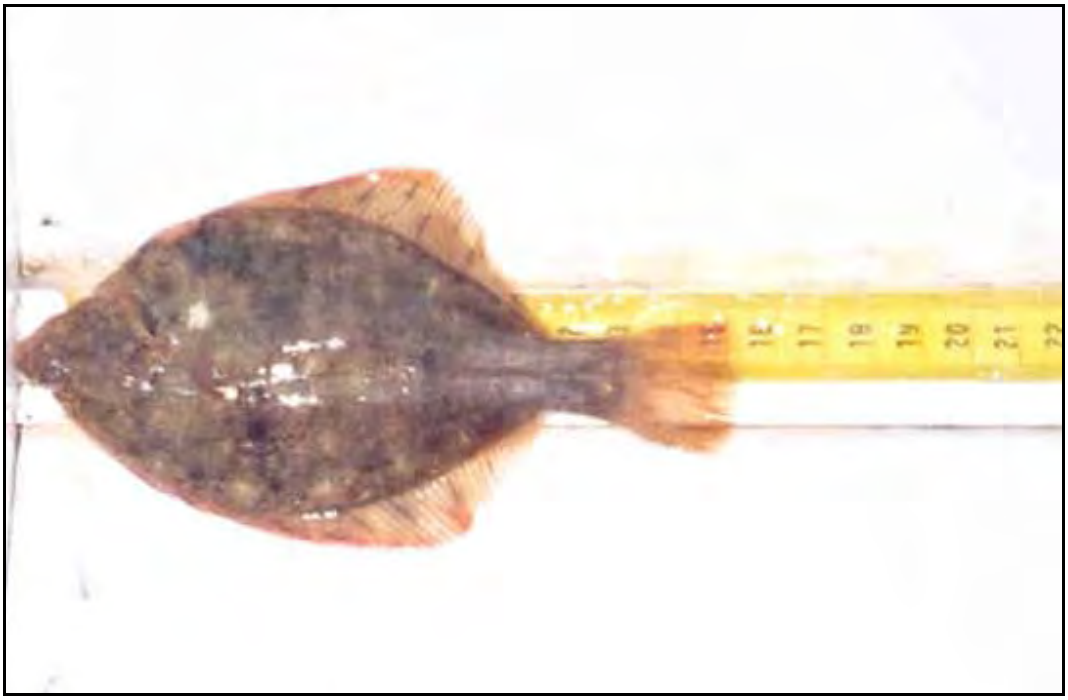


Plate 3.7-5. An Arctic flounder captured at site 1, Bathurst Inlet, on August 17, 2001.

A total of 39.7 kg of fish were caught. Broad whitefish was the dominant species by weight, making up 35% of the total biomass of all catches, followed in descending order by Arctic cisco,

saffron cod, starry flounder, fourhorn sculpin, Arctic flounder, Pacific herring, ogac, Arctic char, lake trout, and rainbow smelt.

Fifty percent of the total fish captured were from site 1, 23% from site 2 and 27% from site 3. Biomass of catch provided a similar ranking. A more accurate comparison of catches between sites required standardizing catches by fishing effort (discussed in Section 3.7.2).

Six (or 55%) of the species live only in marine habitat (fourhorn sculpin, starry flounder, saffron cod, Arctic flounder, Pacific herring and ogac – Table 3.7-2), three (27%) are anadromous (Arctic cisco, rainbow smelt and Arctic char), meaning they spawn and rear in freshwater but migrate to the sea to forage (although landlocked populations of all three species are common), and two (18%) are primarily freshwater but are occasionally captured in estuaries and brackish coastal waters of low salinity (broad whitefish and lake trout). Broad whitefish are well known as members of both freshwater and estuarine fish communities in Canada's Arctic, but the presence of lake trout in Bathurst Inlet was surprising because, it is the least tolerant of salt water of all the chars (Scott and Crossman, 1973). However, several authors cited by Scott and Crossman (1973) reported catching lake trout in coastal waters. Boulva and Simard (1968) reviewed the saltwater occurrences of lake trout in Canada's Arctic and concluded that the upper limit of their salinity tolerance was 11 to 13 parts per thousand (ppt). The lake trout was captured at site 3, where input of freshwater was in closer proximity.

Table 3.7-2
Species of Fish Captured in Bathurst Inlet in August 2001

Common Name	Scientific Name	Habitat	Depth Range	Depth (m)	
				Upper	Lower
Fourhorn sculpin[1]	*Triglopsis quadricornis*	Marine	demersal	0	100
Starry flounder	*Platichthys stellatus*	Marine	demersal	0	375
Saffron cod	*Eleginus gracilis*	Marine	demersal	0	730
Arctic flounder[2]	*Liopsetta glacialis*	Marine	demersal	-	-
Pacific herring	*Clupea pallasi*	Marine	pelagic	0	150
Ogac[3]	*Gadus ogac*	Marine	demersal	0	200
Broad whitefish	*Coregonus nasus*	Freshwater/Brackish	benthopelagic	-	-
Lake trout	*Salvelinus namaycush*	Freshwater/Brackish	benthopelagic	18	53
Arctic cisco	*Coregonus autumnalis*	Anadromous	pelagic	-	-
Rainbow smelt	*Osmerus mordax dentex*[4]	Anadromous	pelagic	0	150
Arctic char	*Salvelinus alpinus*	Anadromous	benthopelagic	0	70

[1] formerly *Myoxocephalus quadricornis* (Kottelat, 1997)
[2] formerly *Pleuronectes glacialis* (Cooper and Chapleau, 1998)
[3] also known as Greenland cod
[4] sub-species found in Arctic Canada. Not to be confused with *Osmerus mordax mordax*, the Atlantic rainbow smelt (M^{c} Allister, 1990)
Habitat types and depth ranges were taken from species descriptions shown on FishBase (www.fishbase.org)
Demersal = bottom feeders, pelagic = feed in open water, benthopelagic = feed in open water and on bottom

According to FishBase, five (or 46%) of the 11 species are demersal (fourhorn sculpin, starry flounder, saffron cod, Arctic flounder and ogac), meaning they forage primarily along the sea bottom, three (27%) are pelagic (Arctic cisco, Pacific herring and rainbow smelt), meaning they

forage in open water, usually in the upper and middle sections of the water column, and three (27%) are benthopelagic (broad whitefish, Arctic char and lake trout), meaning they forage in both the benthic and pelagic zones of either freshwater or marine habitats.

Table 3.7-2 also shows quantitative estimates of the depth range of each species, taken from FishBase. These estimates are for each species as a whole and are not reliable indicators of the depth distribution of each species in Bathurst Inlet. However, they are useful guides for comparing their depth distribution with other species that have been recorded from Bathurst Inlet. With four exceptions, all of the species captured in Bathurst Inlet in August, 2001, have been recorded from the surface to depths of between 53 and 730 m. FishBase does not provide a numerical depth range for Arctic cisco, Arctic flounder or broad whitefish, and lake trout is listed as having an upper depth of 18 m. The average upper depth for the species listed in the table was 2 m (SD = 6, range = 0-18 m) and the average lower depth was 228 m (SD = 226, range = 53-750 m).

None of the species captured in August, 2001, are endangered or threatened (COSEWIC, 2001).

3.7.2 Catch-per-Unit-Effort

3.7.2.1 Minnow Traps

The six minnow traps were each set four times; once overnight at each of sites 1, 2 and 3, plus an additional brief daytime set at site 2 (Appendix 3.7-1). Depths were about 1 m for all traps. Set times ranged from 5 to 22 hours with an average of 16 hours (SD = 6, n = 24). No fish were captured in any trap. The lack of catches was not due to an absence of small fish in the nearshore zone because beach seine sets caught juvenile fish, mainly sculpins, that were small enough to enter a minnow trap. The problem was not mesh size because all fish captured by the beach seine were large enough to be retained by a mesh width of 7 mm. The problem was also not the type of bait used because the raw fish used as bait in minnow traps attracted fish to the longlines. These traps did not catch fish.

3.7.2.2 Gillnets

Sinking and floating gillnets were each set three times at each site (Appendix 3.7-1). Depths of sinking gillnets ranged from 3 to 10 m and set times ranged from 1.6 to 2.8 hours with an average of 2.2 hours (SD = 0.4, n = 6). A total of 98 fish and 11 species were caught: 92 fish and 11 species in the sinking nets and 6 fish and 4 species in the floating nets (Table 3.7-3). The sinking gillnet caught the greatest number of fish and fish species of any of the six types of gear used in this study.

A similar result was found from catch biomass data: a total of 34.4 kg of fish (87% of the total catch) were caught with gillnets. Of those 34.4 kg, 87% were caught in the sinking gillnet and 13% in the floating gillnet.

Standardizing the number of fish by set time and net area showed that four times more fish were captured in the sinking nets (CPUE = 385/100 m^2/24 hours) than in the floating nets (CPUE = 96

Table 3.7-3
Gillnet Fish Catch and CPUE by Number and Biomass, Bathurst Inlet, August 2001

Date	Site	Gear Code	Fourhorn Sculpin	Arctic Cisco	Starry Flounder	Saffron Cod	Arctic Flounder	Pacific Herring	Broad Whitefish	Rainbow Smelt	Arctic Char	Ogac	Lake Trout	Total
Numbers of fish														
18-Aug	1	FN1	0	2	0	1	0	0	0	0	0	0	0	**3**
18-Aug	2	FN2	0	1	0	0	0	0	0	0	0	0	0	**1**
19-Aug	3	FN3	0	0	0	0	1	0	1	0	0	0	0	**2**
Subtotal			0	3	0	1	1	0	1	0	0	0	0	**6**
17-Aug	1	GN1	6	7	5	5	4	1	9	2	0	0	0	**39**
19-Aug	2	GN2	10	4	5	4	1	6	0	0	1	1	0	**32**
20-Aug	3	GN3	1	3	2	6	4	4	0	0	0	0	1	**21**
Subtotal			17	14	12	15	9	11	9	2	1	1	1	**92**
Total Number			**17**	**17**	**12**	**16**	**10**	**11**	**10**	**2**	**1**	**1**	**1**	**98**
Biomass (kg)														
18-Aug	1	FN1	0.0	1.8	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**2.3**
18-Aug	2	FN2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**
19-Aug	3	FN3	0.0	0.0	0.0	0.0	0.7	0.0	1.2	0.0	0.0	0.0	0.0	**1.9**
Subtotal			0.0	1.9	0.0	0.5	0.7	0.0	1.2	0.0	0.0	0.0	0.0	**4.3**
17-Aug	1	GN1	0.7	1.6	1.0	1.1	0.7	0.1	12.8	0.3	0.0	0.0	0.0	**18.3**
19-Aug	2	GN2	0.8	1.0	1.5	1.1	0.3	0.7	0.0	0.0	0.8	0.9	0.0	**7.1**
20-Aug	3	GN3	0.1	0.8	0.6	2.3	0.1	0.4	0.0	0.0	0.0	0.0	0.5	**4.7**
Subtotal			1.6	3.4	3.1	4.6	1.1	1.1	12.8	0.3	0.8	0.9	0.5	**30.1**
Total Biomass			**1.6**	**5.2**	**3.1**	**5.1**	**1.8**	**1.1**	**14.0**	**0.3**	**0.8**	**0.9**	**0.5**	**34.4**

Gear code: FN = floating gillnet, GN = sinking gillnet

(continued)

fish/100 m^2/24 hours), indicating that more fish in the nearshore zone moved along the sea bottom rather than near the water surface, at least during daylight hours when the nets were fishing. Comparison of CPUE among sites, after pooling floating and sinking gillnet CPUEs, showed that the highest CPUE was found at site 1, followed by sites 2 and 3. Standardizing the biomass of fish caught for set time and net area showed similar results.

3.7.2.3 Longlines

The sinking and floating longlines were each set three times at each site (Appendix 3.7-1). The sinking longlines were set in 10 m of water, and the floating longlines were installed at the water surface in areas with depths ranging from 1 to 5 m. Set times ranged from 3.0 to 4.5 hours for the sinking longlines and 3.5 to 20.2 hours for the floating longlines. A total of 8 fish and 2 species were caught: 7 fish and 2 species in the sinking longlines, and 1 fish in the floating longlines (Table 3.7-4).

Table 3.7-4
Longline Fish Catch and CPUE by Number and Biomass, Bathurst Inlet, August 2001

Date	Site	Gear Code	Fourhorn Sculpin	Saffron Cod	Total	Fourhorn Sculpin	Saffron Cod	Total
			Number			Biomass (kg)		
18-Aug	1	FLL2	0	0	0	0.0	0.0	**0.0**
18-Aug	2	FLL3	0	1	1	0.0	0.9	**0.9**
19-Aug	3	FLL5	0	0	0	0.0	0.0	**0.0**
Subtotal			*0*	*1*	*1*	*0.0*	*0.9*	***0.9***
18-Aug	1	SLL1	5	1	6	0.7	0.1	**0.8**
19-Aug	2	SLL4	0	0	0	0.0	0.0	**0.0**
20-Aug	3	SLL6	1	0	1	0.4	0.0	**0.4**
Subtotal			*6*	*1*	*7*	*1.1*	*0.1*	***1.2***
Total			**6**	**2**	**8**	**1.1**	**1.0**	**2.0**
			CPUE (# fish/line/24 hours)			CPUE (kg of fish/line/24 hours)		
18-Aug	1	FLL2	0	0	0	0.0	0.0	**0.0**
18-Aug	2	FLL3	0	2	2	0.0	2.1	**2.1**
19-Aug	3	FLL5	0	0	0	0.0	0.0	**0.0**
Subtotal			*0*	*2*	*2*	*0.0*	*2.1*	***2.1***
18-Aug	1	SLL1	40	8	48	5.8	0.9	**6.7**
19-Aug	2	SLL4	0	0	0	0.0	0.0	**0.0**
20-Aug	3	SLL6	7	0	7	2.5	0.0	**2.5**
Subtotal			*47*	*8*	*55*	*8.3*	*0.9*	***9.2***
Pooled	1	SLL1/FLL2	40	8	48	5.8	0.9	**6.7**
Pooled	2	FLL3/SLL4	0	2	2	0.0	2.1	**2.1**
Pooled	3	FLL5/SLL6	7	0	7	2.5	0.0	**2.5**

Notes: Gear Code: FLL = floating longline, SLL = sinking longline
Catches were standardized for a set of 24 hours duration and 15 hooks/line

Standardizing catches for set time and number of hooks showed that 28 times more fish were captured in the sinking longlines (CPUE = 55 fish/line/24 hours) than in the floating longlines (CPUE = 2 fish/line/24 hours), indicating that more fish moved along the sea bottom rather than near the water surface, supporting the results of the floating and sinking gillnets. Comparison of CPUE among sites, after pooling floating and sinking longline CPUE, showed that the highest longline CPUE was found at site 1, followed by sites 3 and 2, a result similar to that of the gillnets. Similar results were found when catches and CPUE were expressed as biomass rather than number.

3.7.2.4 Beach Seines

The beach seine was set three times at each site (Appendix 3.7-1). All sets were in about 2-3 m of water. A total of 71 fish and 4 species were caught (Table 3.7-5), many of which were juveniles. Fifty six percent of the catches by number were made at site 1, 10% at site 2 and 34% at site 3, a result similar to that of the gillnets and longlines (beach seine catches were not standardized for fishing effort because the same net was used in similar size areas for all sets). Because many of the fish captured at site 1 were juveniles, the biomass of the beach seine catch at site 1 was actually slightly lower than the biomass at site 2 and three times lower than the biomass at site 3.

3.7.3 Length, Weight, Condition, and Age

3.7.3.1 Length-Frequency Distributions

Length-frequency distributions of the fish sampled at each of the three sites were plotted on the same figure for comparison. The three sites were similar with the exception of the relatively large number of juvenile fish less than 50 mm long caught with beach seines at site 1 (Appendix 3.7-2 and Figure 3.7-1). Although the habitat at site 1 was similar to site 2 and different than site 3 (see Section 3.8.1), localized habitat differences within the site may explain the greater abundance of juvenile fish caught at site 1.

Length-frequency distributions were calculated for the seven species with sample sizes of 10 or greater by pooling all catches among sites (Figure 3.7-2). The distribution for fourhorn sculpins was bimodal with one mode for juveniles and a second mode for adults. The distributions for the other species were unimodal, and the modes were assumed to represent adults.

On the basis of average fork length, adult broad whitefish were the largest fish, followed in descending order by adult ogac, Arctic char, saffron cod, lake trout, rainbow smelt, Arctic cisco, starry flounder, Pacific herring, fourhorn sculpin and Arctic flounder (Table 3.7-6). The smallest fish were juvenile fourhorn sculpins.

3.7.3.2 Weight-Length Relationships

Sufficient numbers of fish were sampled to calculate significant weight-length regressions for seven species (Figure 3.7-3). All regressions were highly significant ($P<0.001$) and explained between 94 and 99% of the variation in ln(weight). Weight-length exponents ranged from 2.98 for broad whitefish to 3.45 for Pacific herring.

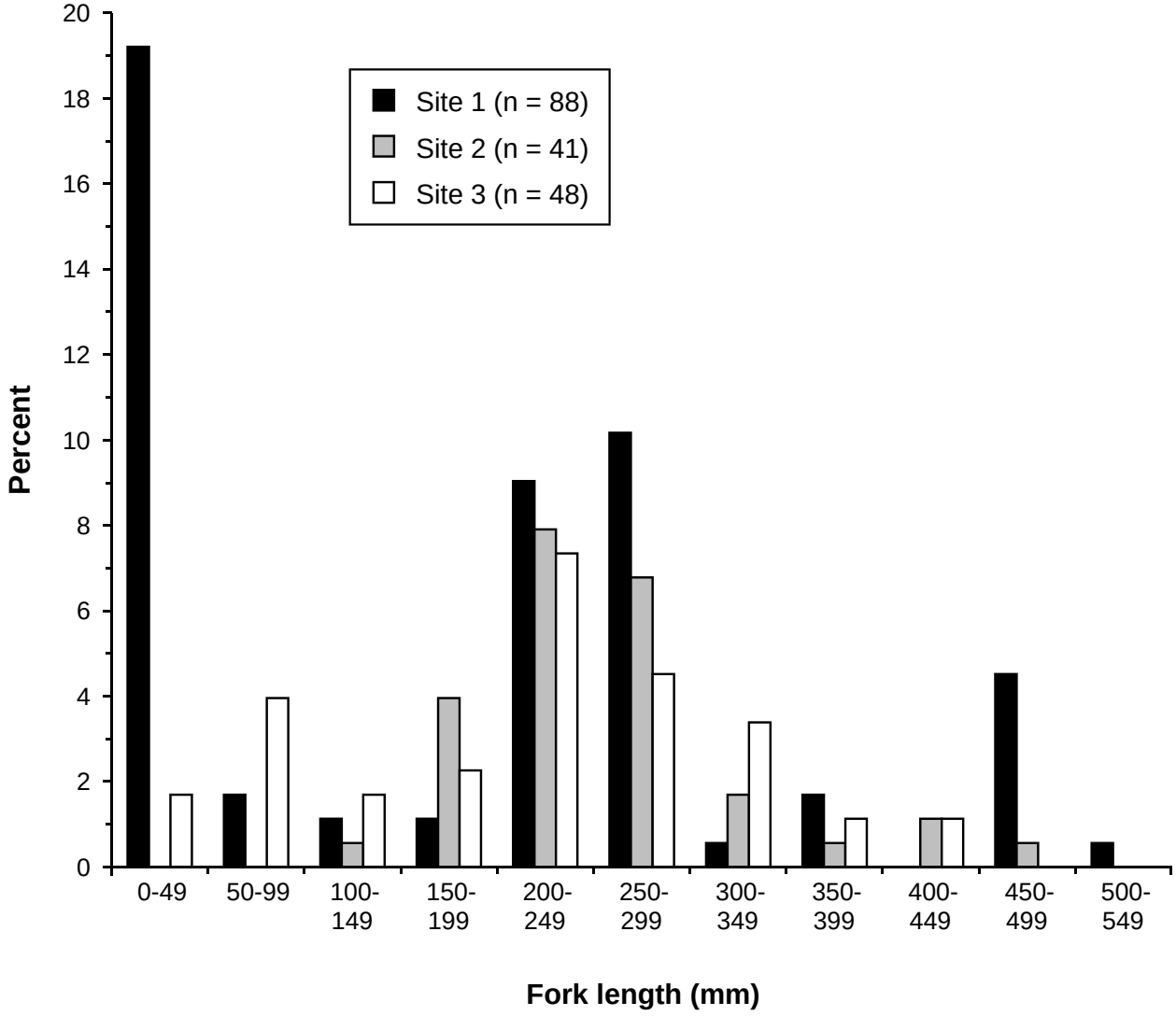
Table 3.7-5
Beach Seine Catches by Number and Biomass, Bathurst Inlet, August 2001

Date	Site	Gear Code	Fourhorn Sculpin	Arctic Cisco	Starry Flounder	Arctic Flounder	Total
Number of Fish							
18-Aug	1	BS1	15	0	0	0	**15**
18-Aug	1	BS2	10	1	2	0	**13**
18-Aug	1	BS3	9	2	1	0	**12**
Subtotal			*34*	*3*	*3*	*0*	***40***
18-Aug	2	BS4	0	1	3	0	**4**
18-Aug	2	BS5	0	2	1	0	**3**
18-Aug	2	BS6	0	0	0	0	**0**
Subtotal			*0*	*3*	*4*	*0*	***7***
19-Aug	3	BS7	4	0	0	0	**4**
19-Aug	3	BS8	2	2	1	6	**11**
19-Aug	3	BS9	0	9	0	0	**9**
Subtotal			*6*	*11*	*1*	*6*	***24***
Total Number			**40**	**17**	**8**	**6**	**71**
Biomass (g)							
18-Aug	1	BS1	6.2	0.0	0.0	0.0	**6.2**
18-Aug	1	BS2	8.7	250.0	5.8	0.0	**264.5**
18-Aug	1	BS3	3.4	350.0	0.2	0.0	**353.6**
Subtotal			*18.4*	*600.0*	*6.0*	*0.0*	***624.3***
18-Aug	2	BS4	0.0	254.0	157.8	0.0	**411.8**
18-Aug	2	BS5	0.0	201.0	50.4	0.0	**251.4**
18-Aug	2	BS6	0.0	0.0	0.0	0.0	**0.0**
Subtotal			*0.0*	*455.0*	*208.2*	*0.0*	***663.2***
19-Aug	3	BS7	29.7	0.0	0.0	0.0	**29.7**
19-Aug	3	BS8	0.6	339.0	53.9	79.1	**472.6**
19-Aug	3	BS9	0.0	1568.0	0.0	0.0	**1568.0**
Subtotal			*30.3*	*1907.0*	*53.9*	*79.1*	***2070.3***
Total Biomass			**48.7**	**2962.0**	**268.1**	**79.1**	**3357.8**

Gear Code: BS = Beach seine

3.7.3.3 Condition

Average condition of adult fish was greatest for lake trout, followed in descending order by Arctic flounder, broad whitefish, starry flounder, Arctic char, ogac, Arctic cisco, Pacific herring, fourhorn sculpin, rainbow smelt and saffron cod (Table 3.7-6). In general, condition was highest for short, broad fish such as Arctic flounder and starry flounder, and lowest for long, narrow fish such as rainbow smelt and saffron cod.



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Length Frequency Distributions of Fish Sampled at Sites 1 to 3, Bathurst Inlet, August 2001

FIGURE 3.7-1

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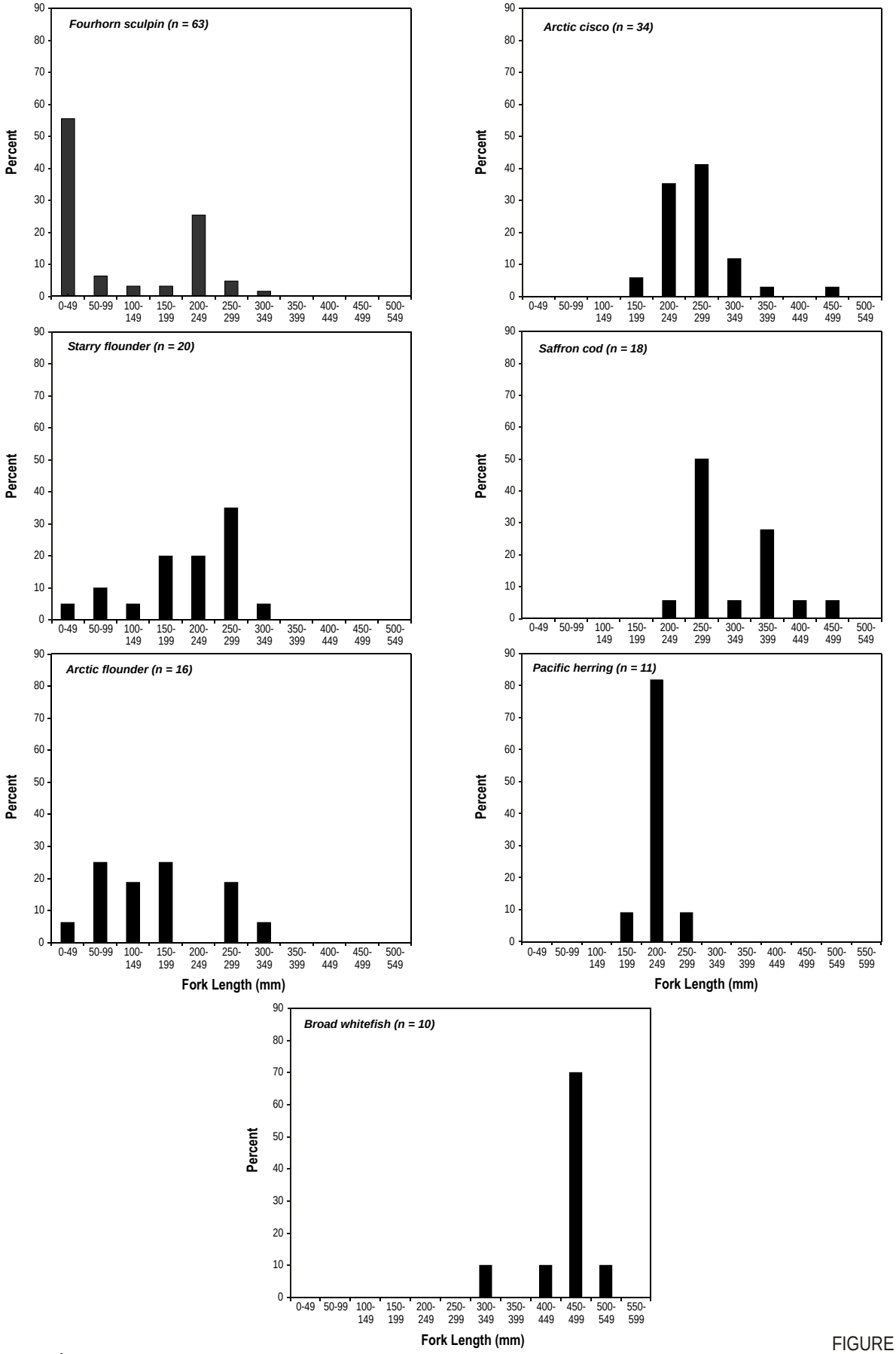

FIGURE 3.7-2

Length-Frequency Distributions of Seven Fish Species Captured at Bathurst Inlet, August 2001

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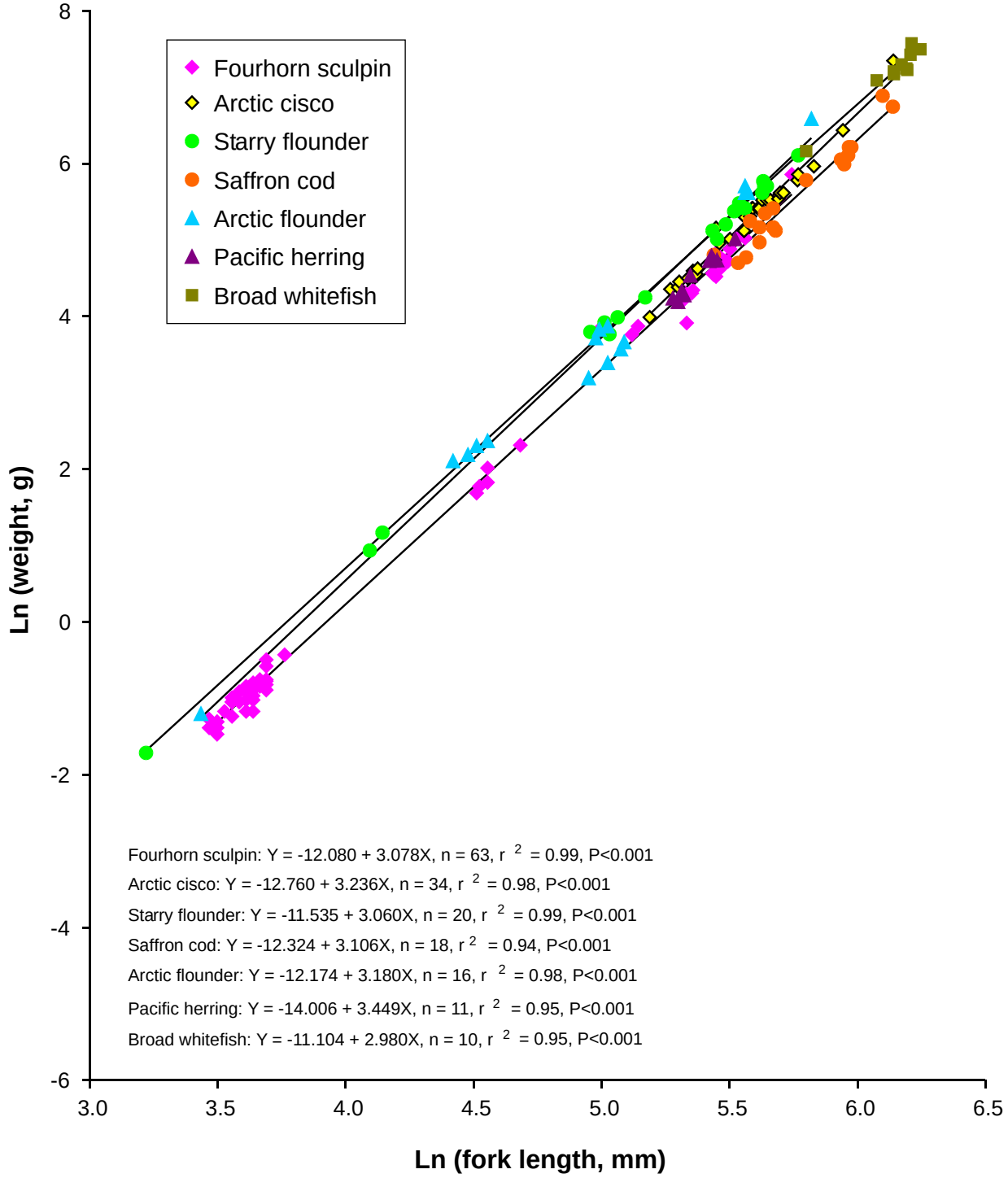

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Weight-Length Regressions of Seven Species Captured at Bathurst Inlet, August 2001

FIGURE 3.7-3

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3.7.3.4 Age

A total of 192 age estimates were made on structures from 137 fish. Age structures were not taken from 40 fish because they were clearly 0+ juveniles. They were assumed to have ages of zero years. In all species, otoliths provided the clearest annuli and the readings with the highest confidence. Fin rays were the next clearest structure. Scales were the least reliable structures due to resorption of annuli. Average ages of adult fish ranged from 2 years for Arctic flounder to 15 years for broad whitefish (Table 3.7-6).

Table 3.7-6
Average Lengths, Weights, Condition and Ages of Fish Captured at Bathurst Inlet, August 2001

			Fork length (m)		Weight (g)		Condition (g/mm^3)		Age (year)		
Species	**Life Stage**	**n**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Range**
Fourhorn sculpin	Juvenile†	35	37	3	0.39	0.10	0.76	0.08	0	0	-
	Adult‡	28	205	62	95	76	0.87	0.16	6	3	0-13
Arctic cisco	adult	34	264	58	241	258	1.07	0.12	6	3	2-18
Saffron cod	adult	18	327	71	337	251	0.83	0.13	5	3	2-16
Starry flounder	Juvenile/adult	20	204	84	166	128	1.34	0.11	6	4	0-13
Arctic flounder	Juvenile/adult	16	160	81	117	193	1.29	0.32	2	4	0-15
Pacific herring	adult	11	219	17	100	27	0.93	0.06	7	3	4-11
Broad whitefish	adult	10	466	53	1400	402	1.34	0.12	15	6	5-27
Rainbow smelt	adult	2	267	39	166	62	0.85	0.04	9	4	6-11
Ogac	adult	1	414	-	850	-	1.20	-	2	-	-
Arctic char	adult	1	405	-	825	-	1.24	-	4	-	-
Lake trout	adult	1	320	-	500	-	1.53	-	6	-	-

SD = standard deviation, n = sample size, and dashes indicate no data available
† <50 mm in fork length
‡ > 50 mm in fork length

3.7.3.5 Length-Age Relationships

Von Bertalanffy growth models were successfully fit to the seven species that had at least ten specimens (Figure 3.7-4). Between 42 and 96% of the variation in length was explained. In general, asymptotic lengths (L_∞) varied inversely with growth rates (K). For example, saffron cod had the highest L_∞ (616 mm) and the lowest K (0.054 year $^{-1}$) and Pacific herring had the lowest L_∞ (233 mm) and the highest K (1.032 year $^{-1}$).

3.7.3.6 Sex, Maturity and Reproductive Status

Of the 177 fish captured in Bathurst Inlet, 37 or 21% were examined for sex, maturity and reproductive status (Table 3.7-7). Of those 37 fish, 14 were male, 12 were female and 11 were of unknown sex. Sex ratios of the four species for which more than one specimen were examined ranged from 0.5 males/female to 2.0 males/female. That wide range in sex ratios was due to the low samples sizes for each species. The overall sex ratio for the 24 fish of eight species that were classified as either male or female was 1.2 males/female, close to the 1:1 ratio expected for all fish species.

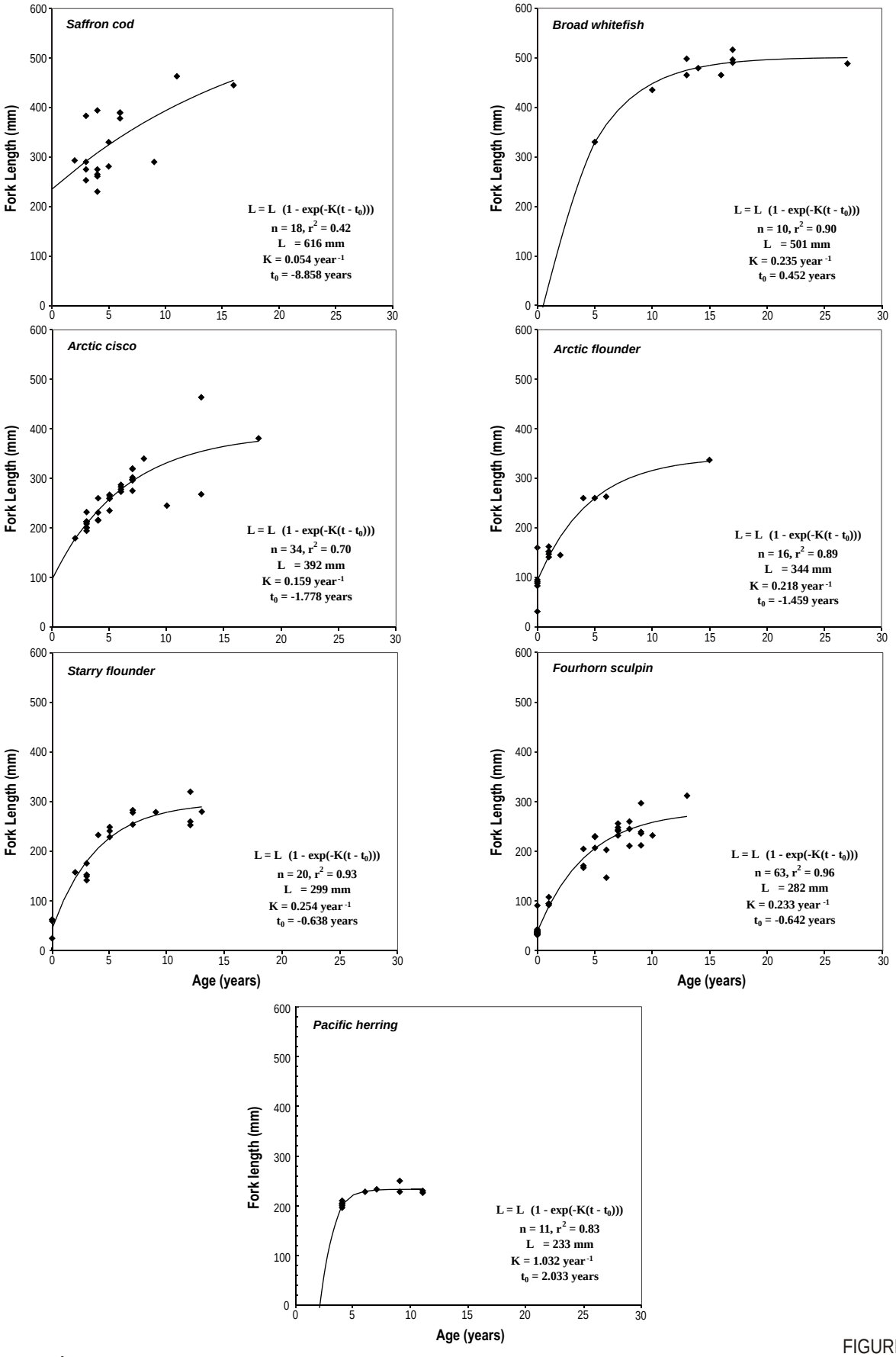

FIGURE 3.7-4

Length-Age Relationships of Fish Species Captured at Bathurst Inlet, August 2001

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Table 3.7-7
Sex, Maturity and Reproductive Status of Fish, Bathurst Inlet, August 2001

Species	n	Male	Female	Unknown	Sex Ratio (Male:Female)	Immature	Mature		Unknown
							Green	Ripe	
Starry flounder	17	5	3	9	1.7:1	0	8	0	9
Arctic cisco	6	2	4	0	0.5:1	3	2	1	0
Saffron cod	5	2	1	2	2.0:1	3	1	0	1
Broad whitefish	5	3	2	0	1.5:1	1	4	0	0
Lake trout	1	1	0	0	-	0	1	0	0
Rainbow smelt	1	1	0	0	-	0	0	1	0
Ogac	1	0	1	0	-	0	1	0	0
Pacific herring	1	0	1	0	-	0	1	0	0
Total	**37**	**14**	**12**	**11**	**1.2:1**	**7**	**18**	**2**	**10**
Percent	**100**	**38**	**32**	**30**	**-**	**19**	**49**	**5**	**27**

Note: n = sample size or total number, and dashes indicate no data available.
Green = maturing, Ripe = imminent spawner

Of the 37 fish examined, only 2 or 5% were sexually mature, 7 were immature, 18 were green and 10 were of unknown maturity. Of the 37 fish examined, 19% had undeveloped gonads (indicating they were immature), 49% had "green" gonads (indicating they were maturing , but still not fully mature), 5% were ripe (indicating they were near spawning), and 30% had gonads of an unknown status. Only two species had ripe gonads: Arctic cisco, which spawns in rivers during summer, and rainbow smelt, which also spawns in northern rivers during summer.

3.7.3.7 Stomach Contents and Trophic Relationships

A total of 36 stomachs from seven species were opened (Table 3.7-8). Twenty five percent of the stomachs were empty, and the remaining 75% contained a range of prey from benthic organisms such as clams, ophiurids (brittle stars) and amphipods to benthopelagic prey such as fish and crustaceans to prey that appeared of terrestrial origin such as insects (found in Arctic cisco). Some prey were too digested to be assigned to any taxa.

Comparison of the stomach contents with the general diet of each species (as reported by FishBase) showed that all the species examined in Bathurst Inlet showed the expected diet. The diets of most fish encompassed a wide range of prey. For example, all of the seven species whose stomachs were examined in this study (with the exception of broad whitefish) have been recorded as feeding on fish as well as on benthic invertebrates or zooplankton.

Based on the stomach content data and on the general diet of the species of fish captured in Bathurst Inlet, as reported by FishBase, a conceptual model was constructed of the trophic relationships of the nearshore fish community of Bathurst Inlet (Figure 3.7-5). The base of the food chain is phytoplankton. Herbivorous zooplankton graze the phytoplankton and are themselves prey for carnivorous zooplankton. Carcasses and phytoplankton cells fall to the sea bottom and are eaten by filter-feeding and detritus-eating benthic invertebrates. Pelagic fish such

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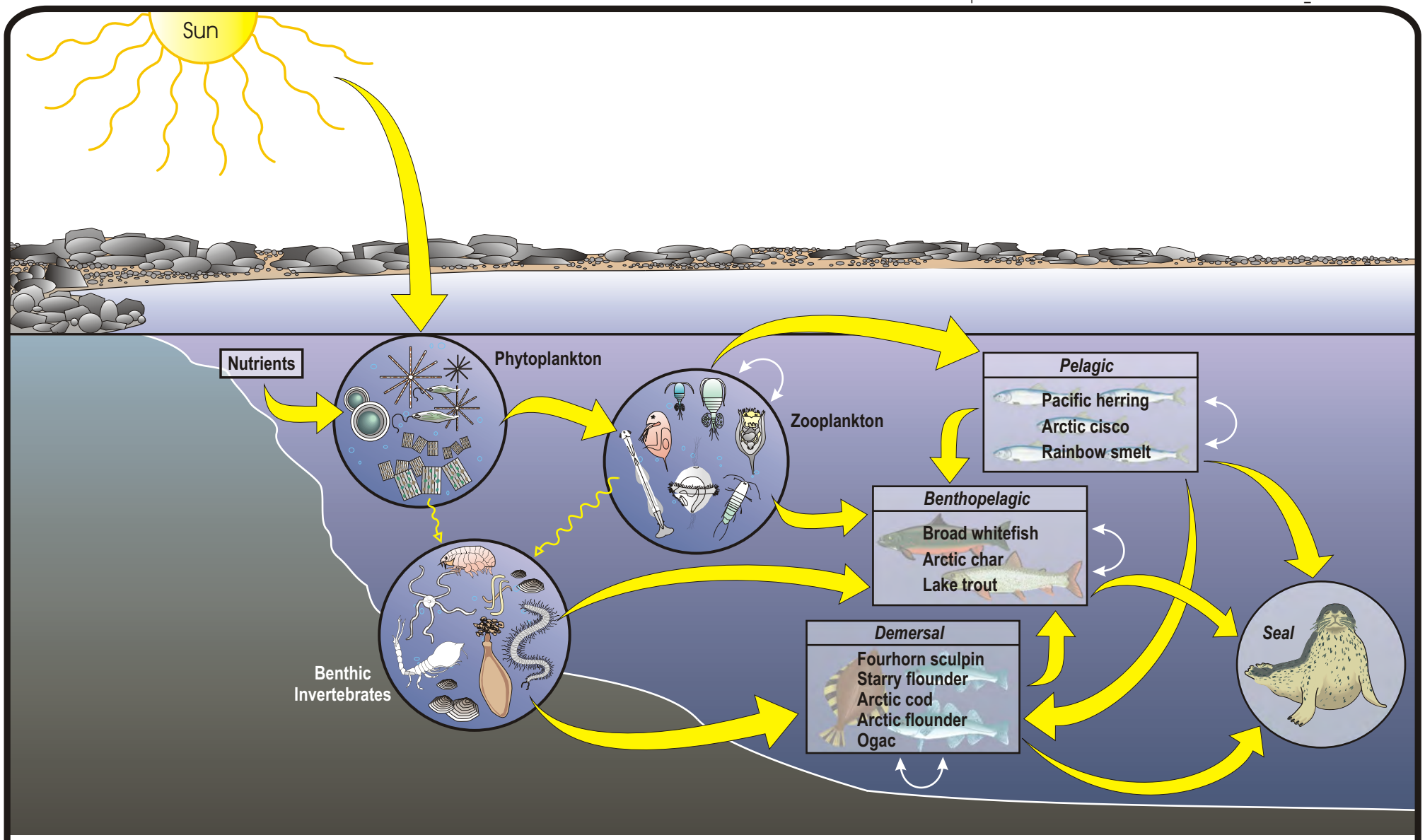

Trophic Relationships of the Nearshore Fish Community of Bathurst Inlet, August 2001

the Bathurst Inlet Port and Road Project

FIGURE 3.7-5

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as Pacific herring, Arctic cisco and rainbow smelt feed on zooplankton, and on the small larval and juvenile stages of other species of fish, including other pelagic species. In turn, pelagic fish, which are generally the smaller members of a fish community, are eaten by larger demersal and benthopelagic fish species and by marine mammals such as seals. Demersal fish such as sculpins, flounders and cods feed mainly on benthic invertebrates but also on smaller species of fish and on early life history stages of demersal and pelagic fish. Benthopelagic species such as broad whitefish, Arctic char and lake trout feed on a wide range of prey including zooplankton, benthic invertebrates and, in the case of Arctic char and lake trout, on smaller fish.

Table 3.7-8
Stomach Contents of Fish Captured at Bathurst Inlet, August 2001

	Number				
Species	**Empty**	**Full**	**Total**	**Contents**	**General Diet[1]**
Starry flounder	1	16	17	amphipods, clams, ophiurids, unknown	crustaceans, worms, small molluscs, brittle stars, and small fish
Arctic cisco	3	3	6	amphipods, insects	small crustaceans, insects and small fish
Saffron cod	3	2	5	amphipods, crustaceans	epibenthic mysids, amphipods, copepods and fish
Broad whitefish	1	4	5	clams	aquatic insect larvae, small molluscs and crustaceans
Lake trout	0	1	1	fish	freshwater sponges, crustaceans, insects, fish, plankton
Pacific herring	1	0	1	-	crustaceans, decapod and mollusc larvae and small fish
Rainbow smelt	0	1	1	fish	copepods, cladocerans, small crustaceans, fish, squid and worms
Total	**9**	**27**	**36**		
Percent	**25**	**75**	**100**		

[1] from FishBase, 2002

This conceptual model only captures the large elements of the food web and omits many of the smaller details. For example, benthic invertebrates release planktonic eggs and larvae which become part of the zooplankton prey of pelagic fish. Also, anadromous and freshwater/brackish fish species such as Arctic char and lake trout are only seasonal members of the nearshore fish community. Finally, there are undoubtedly other species that forage in the nearshore environment of Bathurst Inlet that were not captured in August 2001, and which are not shown in Figure 3.7-5, because of the shallow depth range that was fished. The Canadian Museum of Nature has records of 38 fish species from Bathurst Inlet (Appendix 3.7-3). Comparison of the fish captured in August 2001 and historical records are discussed in section 3.7-5. The only species that can be definitively excluded from the nearshore environment around the future port site are bathypelagic and bathydemersal deep water species.

3.7.4 Starry Flounder Tissue Metals Concentrations

Samples of muscle tissue from 15 starry flounder were analysed for concentrations of 29 total metals (Appendix 3.7-4). Average concentrations ranged over six orders of magnitude (Table 3.7-9). Metals that form the building blocks of fish muscle tissue such as potassium and

calcium had the highest average concentrations, and rare metals such as thallium and uranium had the lowest average concentrations. The lower the average concentration of a metal, the more likely it was at least one of the 15 measurements fell below the detection limit of the analytical method. Sixteen of the 29 metals had at least one measurement that was below the detection limit for the analytical method used, and eight of those 16 metals had all 15 measurements below the detection limit.

Table 3.7-9
Average Concentrations of Total Metals in Starry Flounder Muscle Tissue, Bathurst Inlet, August 2001

		Detection Limit	Concentration (mg/kg dry weight)			
Metal	**Symbol**	**(mg/kg)**	**Mean**	**SD**	**Minimum**	**Maximum**
Potassium	K	100	21013	1672	18400	25000
Magnesium	Mg	3	1775	240	1340	2070
Calcium	Ca	10	1291	912	515	3360
Aluminum	Al	10	45.9	48.8	10	195
Zinc	Zn	0.5	32.9	5.3	23.3	42.2
Iron	Fe	1	30	30	9	121
Boron	B	-	30	10	12	50
Arsenic	As	0.05	10.1	6.6	2.79	22.1
Strontium	Sr	0.05	6.30	4.90	2.31	19.90
Selenium	Se	1	2	1	1	3
Copper	Cu	0.05	1.84	0.37	1.28	2.53
Manganese	Mn	0.05	1.50	0.82	0.68	3.43
Mercury	Hg	0.005	0.266	0.189	0.064	0.750
Lithium	Li	0.5	0.3	0.0	0.3	0.3
Nickel	Ni	0.5	0.3	0.0	0.3	0.3
Vanadium	V	0.5	0.3	0.0	0.3	0.3
Chromium[1]	Cr	0.5	0.3	0.0	0.3	0.3
Beryllium[1]	Be	0.3	0.2	0.0	0.2	0.2
Bismuth[1]	Bi	0.3	0.2	0.0	0.2	0.2
Tin	Sn	0.2	0.2	0.2	0.1	0.8
Barium	Ba	0.05	0.19	0.15	0.03	0.62
Lead	Pb	0.1	0.1	0.1	0.1	0.4
Cobalt[1]	Co	0.1	0.1	0.0	0.1	0.1
Antimony[1]	Sb	0.05	0.03	0.00	0.03	0.03
Molybdenum[1]	Mo	0.05	0.03	0.00	0.03	0.03
Cadmium	Cd	0.03	0.02	0.01	0.02	0.05
Silver	Ag	0.03	0.02	0.00	0.03	0.03
Thallium[1]	Tl	0.03	0.02	0.00	0.02	0.02
Uranium[1]	U	0.01	0.01	0.00	0.01	0.01

Notes: SD = standard deviation of the average, and sample size was 15 for all metals.
Values below the detection limit were assigned a value of one-half the limit.
"-" indicates that detection limits were not available, because all measurements were above the limit
[1] all values for this metal were below the detection limit

Mercury, arsenic and selenium were highly correlated ($P<0.001$) with body weight (Figures 3.7-6 to 3.7-8), manganese and zinc were barely significantly correlated ($0.05<P<0.01$) with body weight, and the other 24 metals were not significantly ($P>0.05$) correlated with weight.

3.7.4.1 Mercury

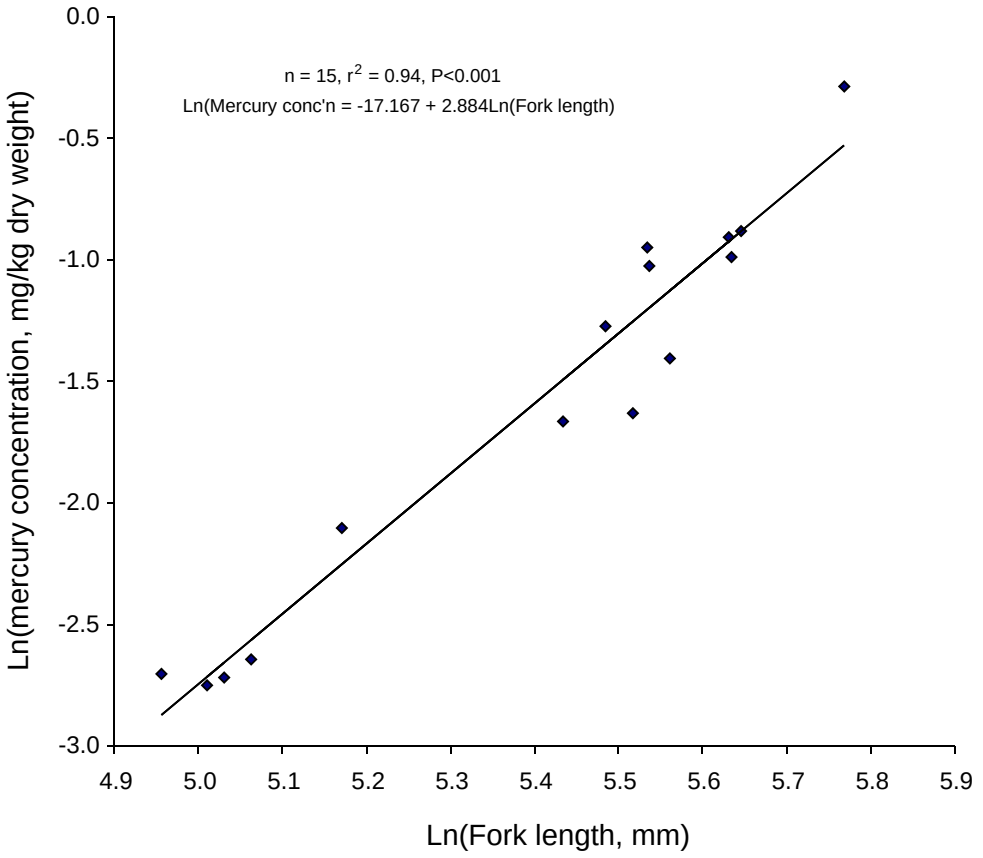
Mercury is a toxic metal with no known biological function (Eisler, 1987). In fish, it tends to bind tightly to proteins in muscle tissue and stay there permanently because fish lack the metabolic machinery to excrete mercury. Hence, mercury concentration increases directly with age and size of fish. For the same reason, mercury is biomagnified as it passes up the food chain. The significant positive relationship between mercury and starry flounder body weight found in this study has been reported for other species of fish in North America and the Northwest Territories.

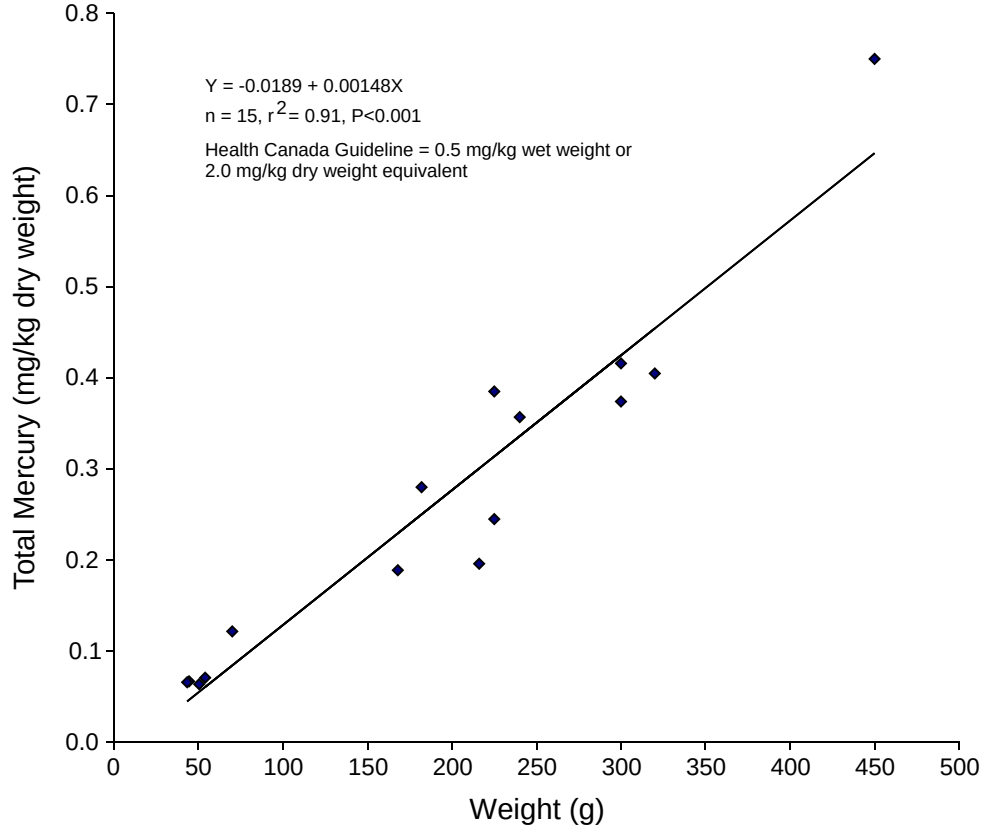
The Health Canada guideline for the maximum allowable concentration of total mercury in fish muscle tissue sold commercially is 0.5 mg/kg wet weight (Health Canada, 2002). British Columbia has set a similar guideline (RIC, 2001). That is equivalent to 2.5 mg/kg dry weight because the average moisture content of the 15 starry flounder tissue samples was 80.2% (SD = 1.4, range = 77.4 to 82.6%). All of the mercury concentrations measured in starry flounder of Bathurst Inlet were well below that limit. That was expected because Bathurst Inlet is currently a pristine location with no significant human sources of mercury and no known natural sources with high levels of mercury.

3.7.4.2 Arsenic

Arsenic is also a toxin, and also accumulates with age and size of fish (Eisler, 1988a). That is supported by the finding of a significant positive relationship between arsenic and starry flounder body weight in this study. Unlike mercury, arsenic does not biomagnify as it moves up the food chain because fish and other aquatic organisms possess the metabolic machinery to excrete it. Most living organisms normally contain measurable concentrations of arsenic, but except for marine biota, these are usually less than 1 mg/kg wet weight. Marine organisms, especially crustaceans, may contain more than 100 mg/kg dry weight, usually as arsenobetaine, a water-soluble organoarsenical that poses little risk to the organism or its consumer. Arsenic appears to be elevated in marine biota because of their ability to accumulate arsenic from seawater or food sources, and not due to localized pollution. The average concentration of arsenic in Bathurst Inlet starry flounder tissue was 10.1 mg/kg dry weight, which may reflect a diet largely composed of marine benthic invertebrates.

The maximum allowable Health Canada guideline for arsenic in fish tissue is 3.5 mg/kg wet weight or 17.5 mg/kg dry weight for fish from this study, but that guideline is for fish protein concentrate only, not wet tissue (Health Canada, 2002). There are no Canadian guidelines for arsenic in unprocessed fish tissue.





Regression of Muscle Tissue Mercury Concentration on Length and Weight for Starry Flounder, Bathurst Inlet, August 2001

FIGURE 3.7-6

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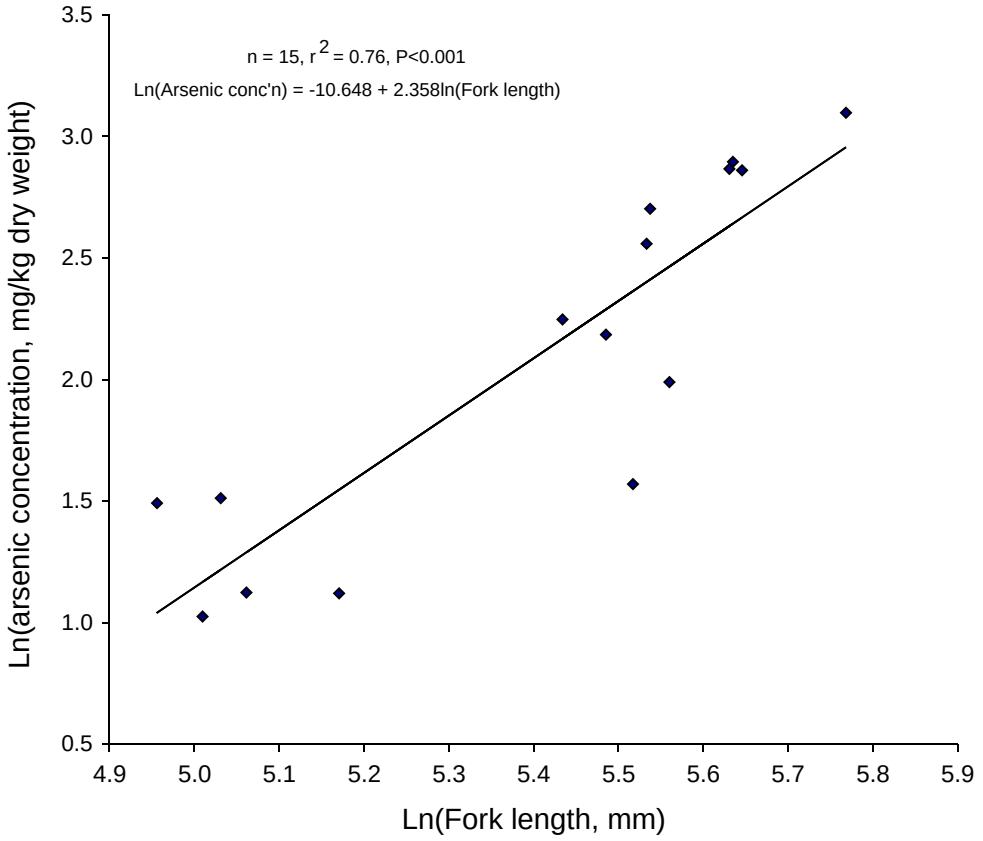

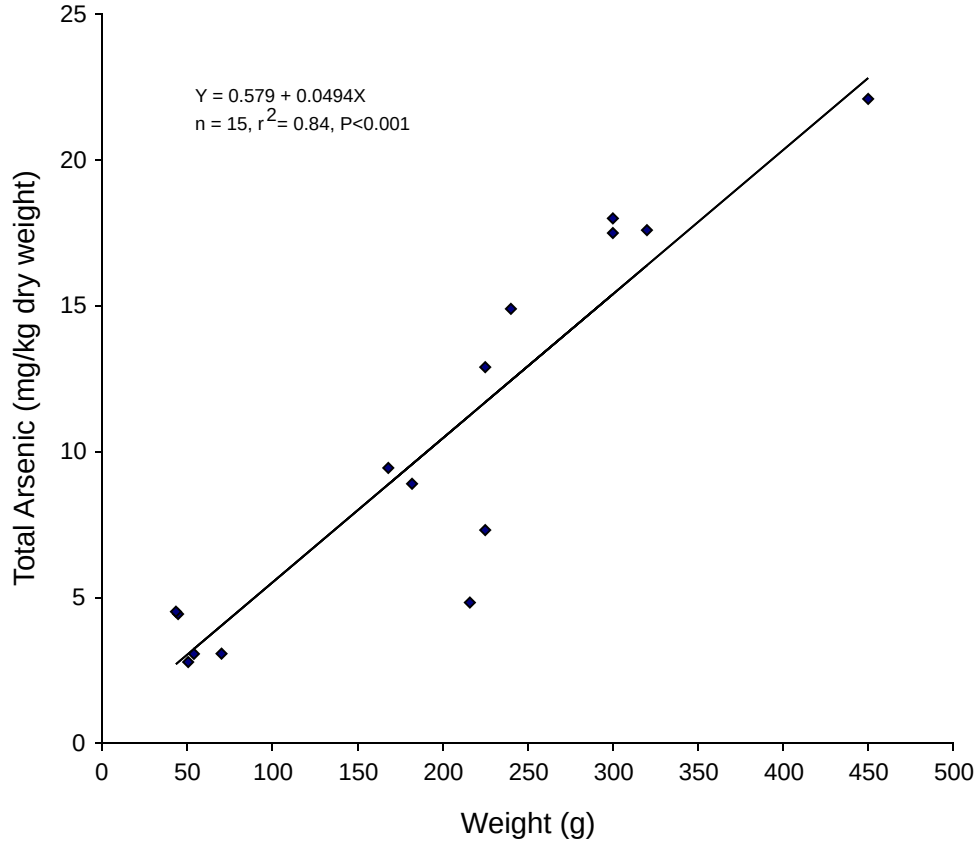

Regression of Muscle Tissue Arsenic Concentration on Length and Weight for Starry Flounder, Bathurst Inlet, August 2001

FIGURE 3.7-7

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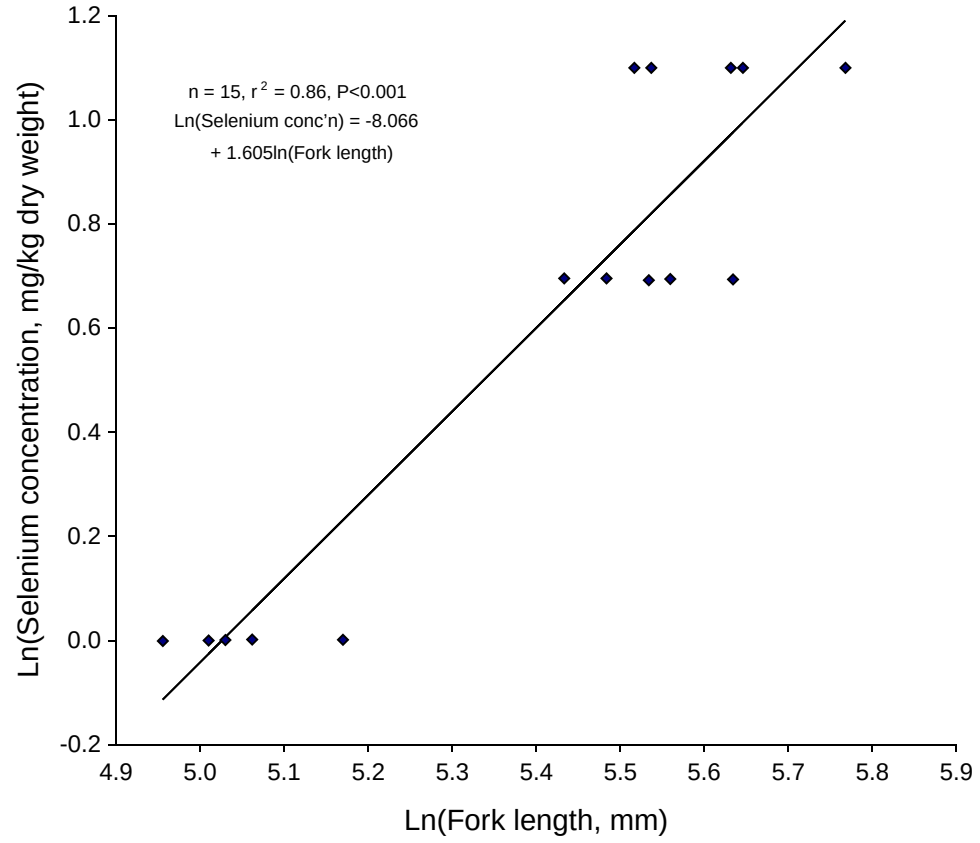

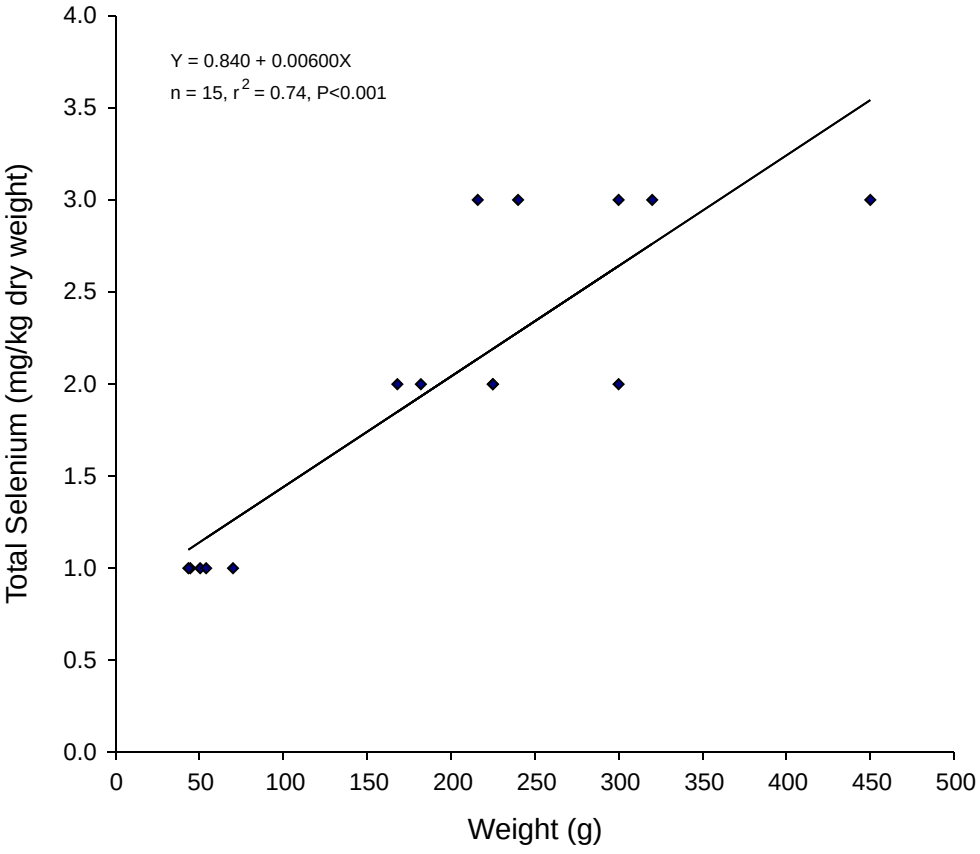

Regression of Muscle Tissue Selenium Concentration on Length and Weight for Starry Flounder, Bathurst Inlet, August 2001

FIGURE 3.7-8

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3.7.4.3 Selenium

Selenium is beneficial or essential in amounts from trace to part-per-billion concentrations for humans and some plants and animals, but toxic at some concentrations present in the environment (Eisler, 1985b). Bioconcentration of selenium would explain the significant positive relationship between selenium and body weight found in this study. There are no Canadian federal or provincial guidelines for selenium in fish tissue.

3.7.4.4 Lead

Lead is neither essential or beneficial to living organisms, and all measured effects of lead exposure are adverse (Eisler, 1988b). Lead is neither bioconcentrated or biomagnified. The maximum allowable Health Canada guideline for lead concentration in fish tissue is 0.5 mg/kg wet weight, but that guideline is for fish protein concentrate only, not wet tissue (Health Canada, 2002). British Columbia has set an upper limit for lead in fish tissue of 0.8 mg/kg wet weight (RIC, 2001), which is equivalent to 3.2 mg/kg dry weight assuming an average moisture content in starry flounder muscle of 80.2%. The average concentration of lead measured in this study was 0.1 mg/kg dry weight, an order of magnitude lower than the RIC guideline.

3.7.4.5 Cadmium

Cadmium, a relatively rare heavy metal, is not biologically essential (Eisler, 1985a). It is known to be a teratogen and carcinogen, and has been implicated as the cause of severe deleterious effects on fish and wildlife. According to Eisler (1985a), adverse effects on fish or wildlife are either pronounced or probable when cadmium concentrations exceed 0.1 mg/kg in the diet. Cadmium residues in vertebrate kidney or liver that exceed 2 mg/kg wet weight are evidence of probable cadmium contamination. Residues of 200 mg/kg wet weight kidney, or more than 5 mg/kg wet weight of the whole body, are probably life-threatening. The average cadmium concentration in the muscle of starry flounder from Bathurst Inlet was 0.02 mg/kg dry weight or 0.005 mg/kg wet weight (assuming an 80% moisture content), which is three orders of magnitude lower than concentrations expected to produce adverse effects. There are no federal or provincial guidelines for cadmium in fish tissue.

3.7.5 Fish Community Comparison with Historical Records

As of September, 2001, there were 208 captured fish records for Bathurst Inlet in the Canadian Museum of Nature's database. Those records included 38 species. None of those species are considered threatened or endangered (COSEWIC, 2001) (Appendix 3.7-3). However, one species the Bering wolffish, is listed as a species of "special concern" because "of characteristics that make it particularly sensitive to human activities or natural events". In this case, because the Bering wolffish has only ever been found in one place in Canada's Arctic – Bathurst Inlet. It's natural range is more westerly, extending from the shores of Hokkaido Island, Japan, through the Okhotsk Sea and into the Bering Sea. The Bering wolffish is a large member of the blenny family. Its preferred habitat is demersal: shallow water among algal-covered rocks or gravel and sand substrate (Houston and McAllister, 1990). It eats crabs and mussels. As ice forms along shorelines, it moves offshore. Little is known of its mating behaviour, spawning season or fecundity.

All 11 of the fish species captured in Bathurst Inlet in August, 2001, were also listed in the Museum's database (shown as bolded rows in Appendix 3.7-3). Hence, the August, 2001, survey did not catch any species not previously known to be present in Bathurst Inlet.

The number of species in the Museum's records was 3.5 times greater than the number of species found during the August 2001 survey. That was due to the much larger area covered by Museum's records as well as to the wider range of depths sampled. The latitude of the Museum's records ranged from 66°33' to 68°1', which was an order of magnitude greater than the latitude range (66°32.65' to 66°33.12') of the August 2001 survey. The number of species (or species "richness") is known to increase directly with the area surveyed for a wide range of animal taxa (Conner and McCoy, 2001).

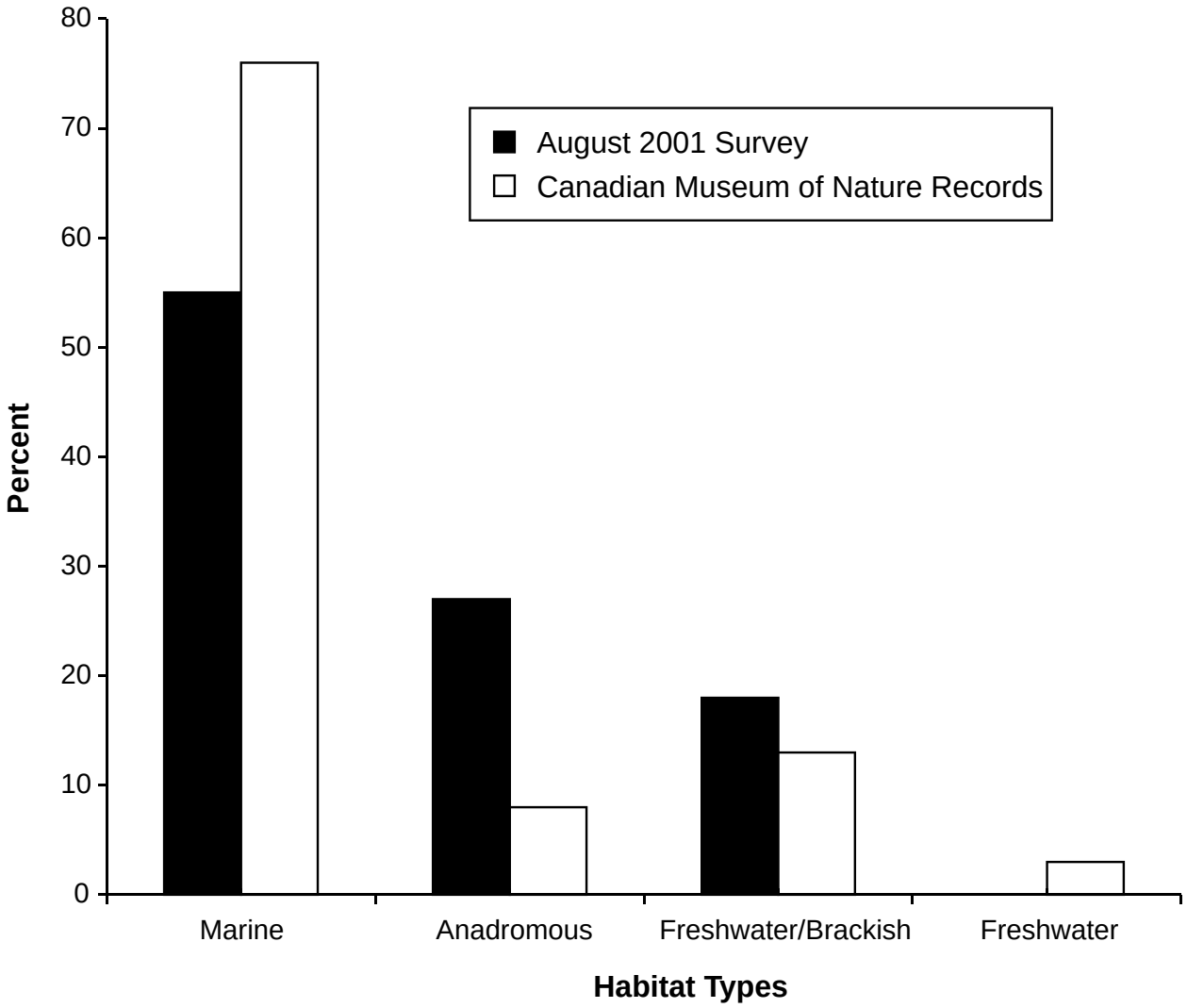
The most common species in the Museum's records was Arctic char, making up 27.4% of all records. That is probably due to the importance of Arctic char as a food fish to local residents. Also, Arctic char are found in freshwater, marine and brackish water, and in both benthic and pelagic habitats, which increases the likelihood that they would be captured often.

According to FishBase, 29 of the species listed in Appendix 3.7-3 (or 76%) live only in marine habitat, 3 (8%) are anadromous, 5 (13%) live in both fresh and brackish water, and 1 species (3%), Arctic grayling, is known only from freshwater. Two of the four records of Arctic grayling are listed as being from the mouths of the Hood and Footprint Rivers, and the other two are assumed to have also been captured in freshwater tributaries to Bathurst Inlet. Comparison of the percent distribution of fish species across habitats showed that the community from the August, 2001 survey had less marine fish, more anadromous fish and more freshwater/brackish fish than the records of the Canadian Museum of Nature (Figure 3.7-9). That was because the August, 2001 survey was based on nearshore sampling in relatively shallow water in an area with relatively low salinities, compared to deeper and more northern parts of the inlet.

Twenty five of the species (or 66%) in the Museum records are demersal, 4 (10%) are pelagic, 6 (16%) are benthopelagic, 2 (5%) are bathydemersal, (meaning they forage along the sea bottom at depths of 1,000 m or greater, and 1 (3%) are bathypelagic (meaning they forage in open water but at great depths). Comparison of the percent distribution of species across depth ranges showed that the August, 2001, sample had no bathydemersal and bathypelagic species, less demersal species, and more pelagic and benthopelagic species than the records of the Canadian Museum of Nature (Figure 3.7-10). That was also because the August, 2001 survey was based on nearshore sampling in relatively shallow water whereas the Museum's records included fish captured by deep-water sampling.

Depth ranges of the Museum records are highly variable ranging from 0 to 1,750 m. Depth ranges were not listed by FishBase for five of the 38 species. The average upper depth was 33 m (range = 0-274 m, SD = 62) and the average lower depth was 433 m (range = 30-1750 m, SD = 410).

In summary, the fish community surveyed in August, 2001, was composed mainly of nearshore, shallow-water fish with a relatively large component of anadromous species and species with low tolerance for salinity. All species are common fish in Canada's Arctic waters, and none are considered threatened or endangered.



Note: Habitat types taken from Fish Base (2002).

Comparison of the Percent Distribution of Habitats between Bathurst Inlet Fish Surveys: the August 2001 Survey versus Records of the Canadian Museum of Nature

FIGURE 3.7-9

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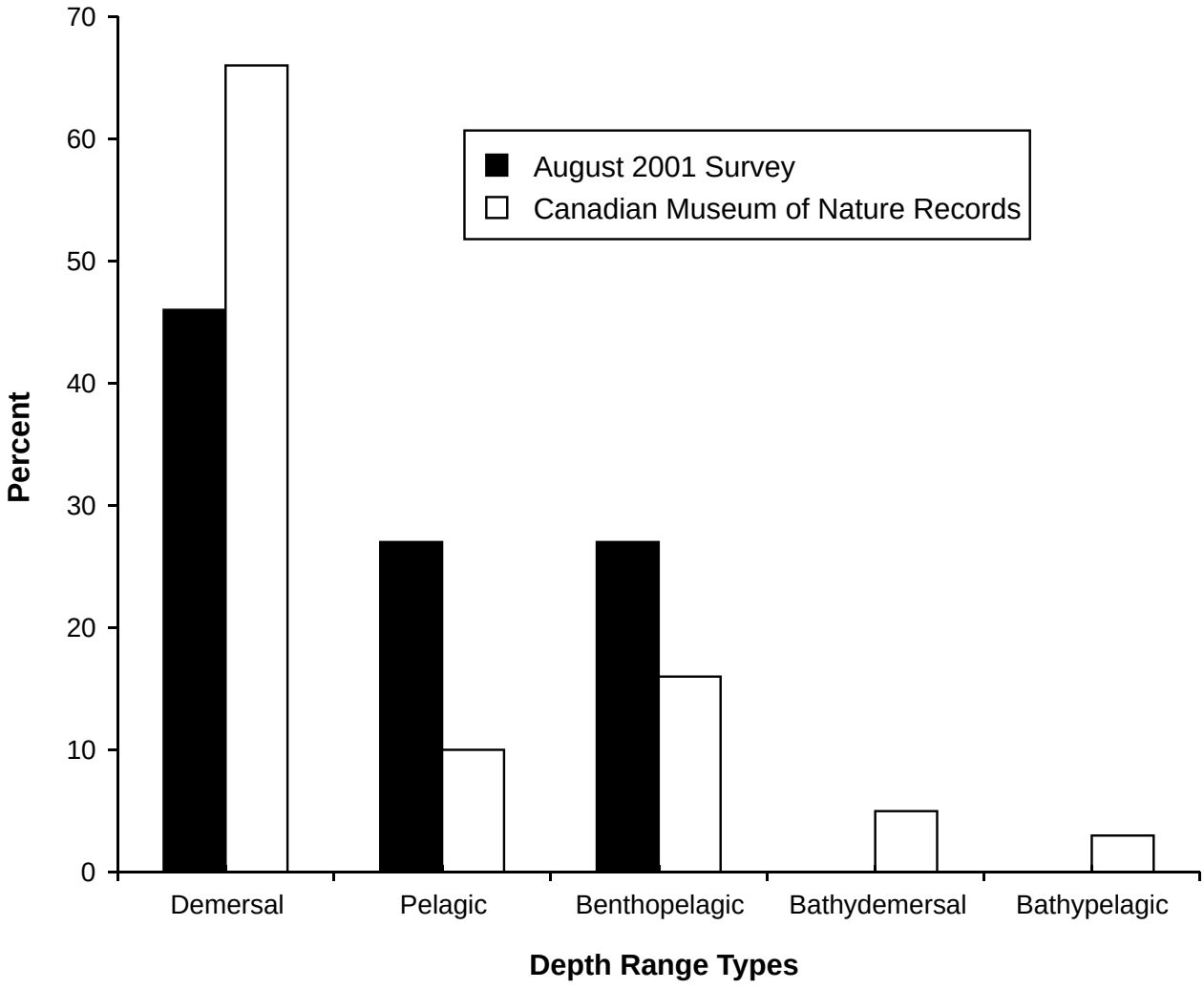

Note: Depth types taken from Fish Base (2002).

Comparison of the Percent Distribution of Depth Range Types between Bathurst Inlet Fish Surveys: the August 2001 Survey versus Records of the Canadian Museum of Nature

FIGURE 3.7-10

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3.8 Fish Habitat

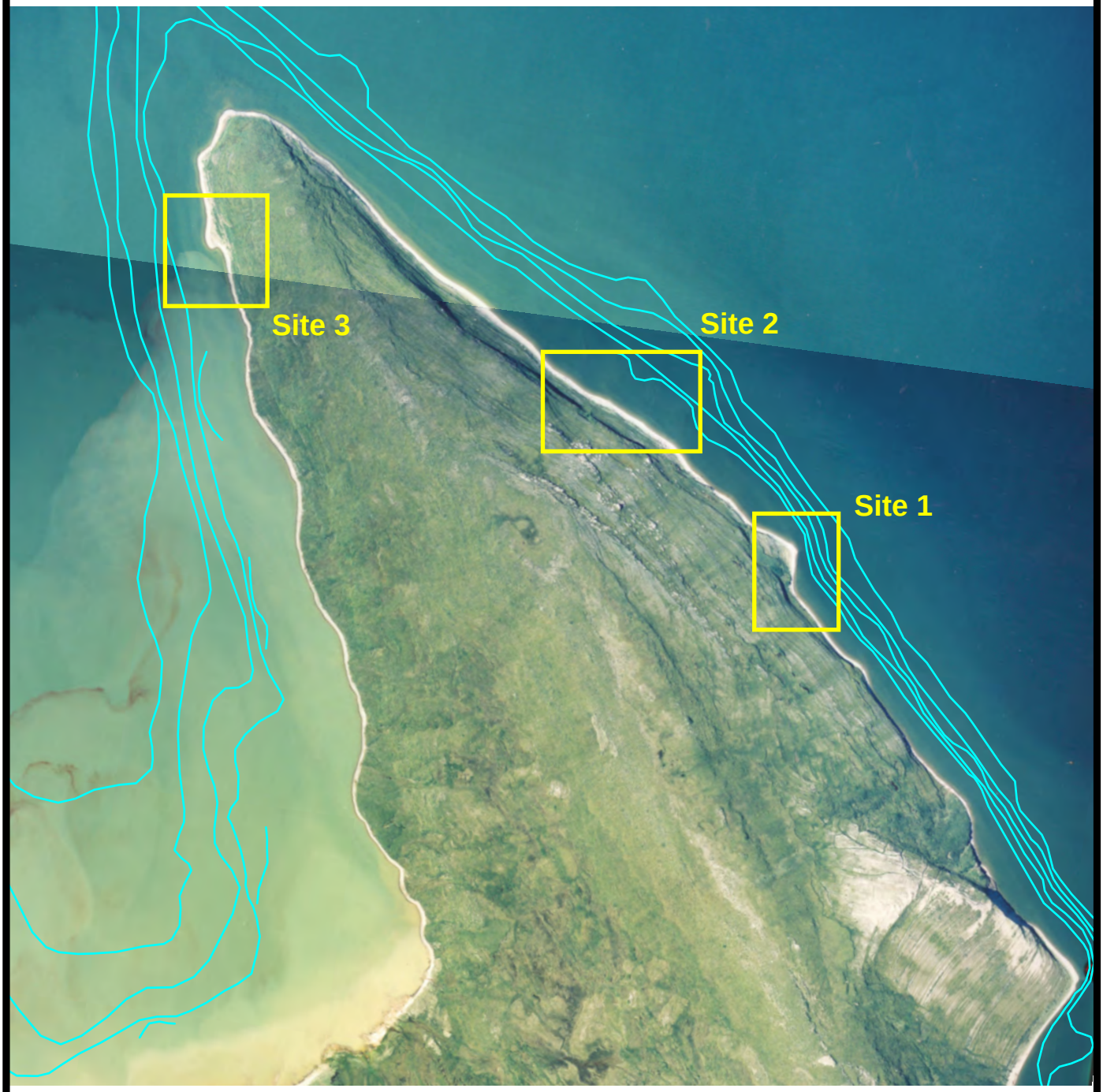
3.8.1 Fish Habitat Assessment

Habitat assessments were conducted at three sites near the proposed Port location on August 19, 2001. A total of 19 zones were delineated for the three sites together. Substrate composition of each zone is presented in Table 3.8-1. The locations where the habitat assessments were conducted are outlined and presented in Figure 3.8-1.

The delineation of each habitat zone is shown for site 2 in Figure 3.8-2. Habitat was mapped up to the high tide mark, which was defined by the presence of grasses. The zones were separated into bands parallel to the shoreline. At high tide, all the zones below the grass are submerged by water. The littoral zone of site 2 was mainly composed of gravel, followed by cobble and sand. A band (Zone D) of 3 to 4 m in the middle area of the exposed shore was composed entirely of very small gravel (2-6 mm). Zone F is mainly composed of cobble and can be identified in Figure 3.8-3.

Table 3.8-1
Substrate Composition of the Littoral Zone in the Vicinity of the Proposed Port, Bathurst Inlet, August 2001

Site	Section	Boulder	Cobble	Gravel	Sand	Grass
Site 1	A					100
	B		70	10	20	
	C				100	
	D			100		
	E		25	75		
	F		30	70		
	G					100
Site 2	A					100
	B	5	20	70	5	
	C	5	5	15	75	
	D			100		
	E		50	50		
	F		80	15	5	
	G				100	
Site 3	A	50	40	10		
	B	10			90	
	C	10		90		
	D	45	50	5		
	E	45	50	5		



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Fish Habitat Assessment Locations, Bathurst Inlet, August 2001

FIGURE 3.8-1

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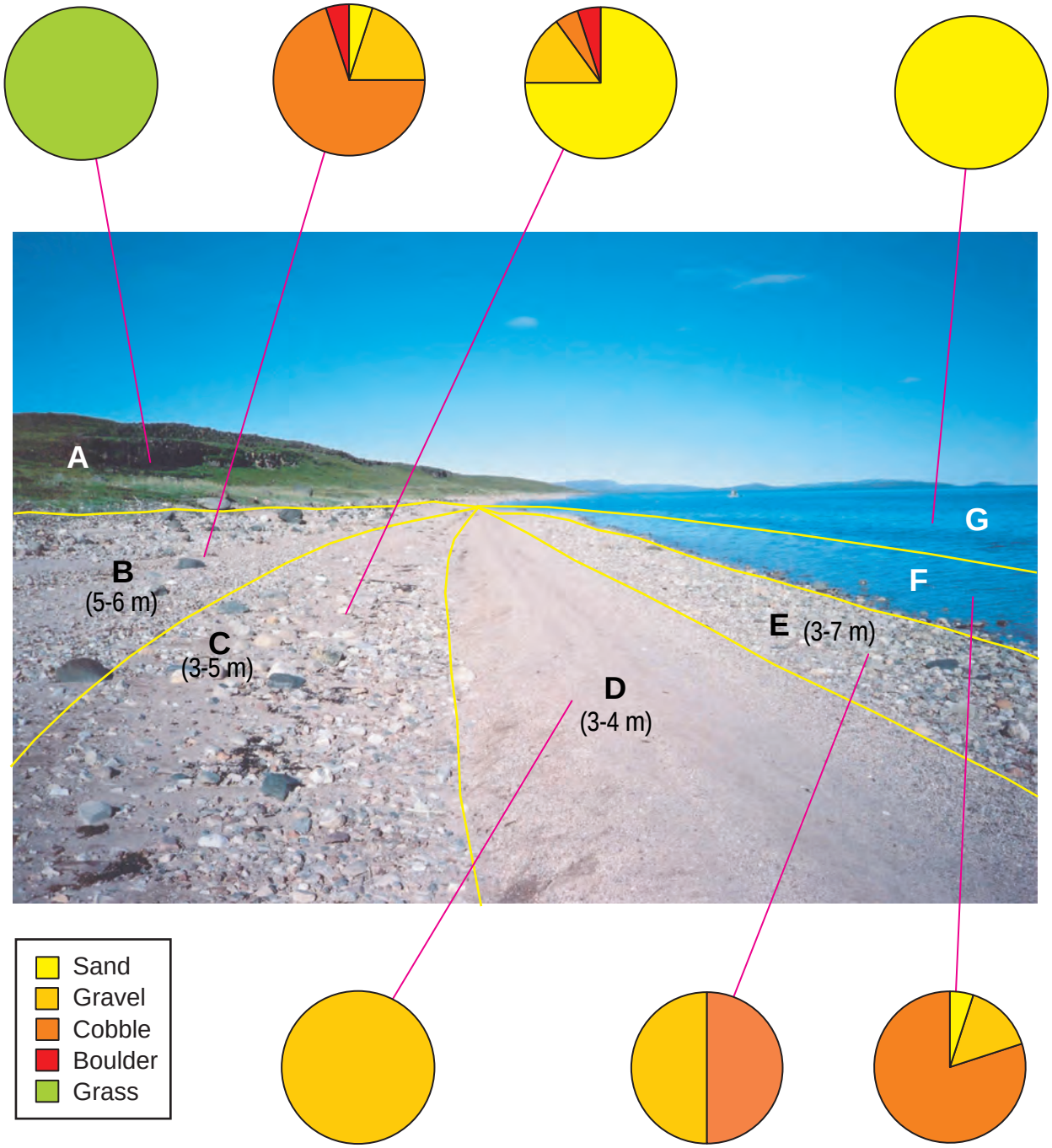

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Fish Habitat Assessment at Site 2 on the West Shore of the Penninsula near the Proposed Port, Bathurst Inlet, August 2001

FIGURE 3.8-2

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Aerial Photographs of Site 2, Bathurst Inlet, August 2001

FIGURE 3.8-3

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The littoral zone of site 1 was composed primarily of gravel, followed by cobble and sand as observed at site 2 (Figure 3.8-4). Habitat was mapped up to the high tide mark, which was defined by the presence of grasses. The zones were separated into bands parallel to the shoreline. At high tide, all the zones below the grass are submerged by water. As at site 2, there was a band in the middle area of the exposed shore that was composed entirely of small gravel. However, this band, at a width of 1 m, was much narrower than the band at site 2.

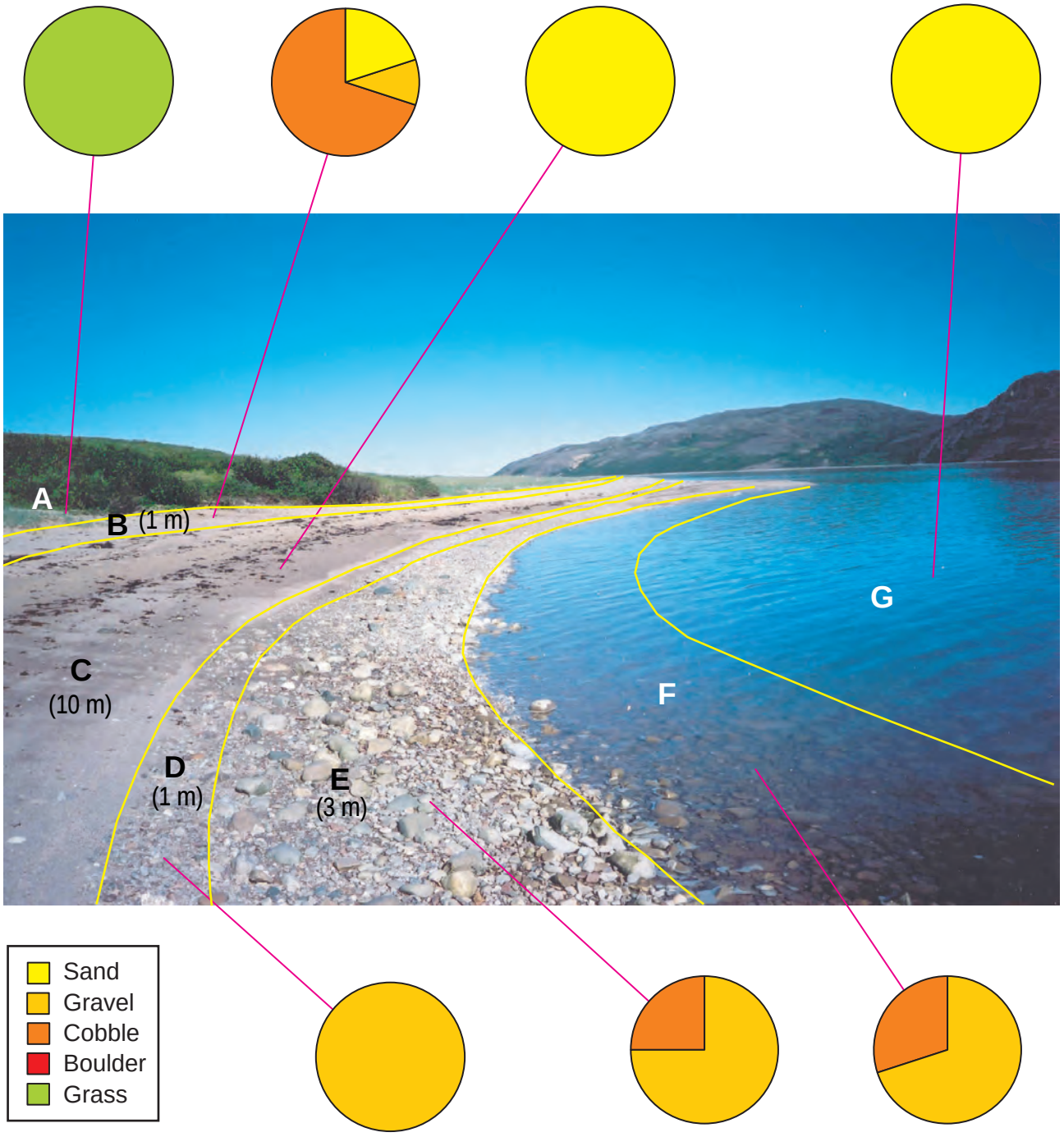
Delineation and zonation of site 3 was conducted in the same manner as it was for sites 1 and 2. In contrast to sites 1 and 2, boulder was the most abundant substrate (Table 3.8-1 and Figure 3.8-5) at site 3. Boulder was absent at site 2 and only sparsely distributed at site 1. Cobble was the next most abundant substrate at site 3. Gravel and sand were also present at site 3. Larger diameter substrate was more dominant at site 3 than at sites 1 and 2.

3.8.2 Habitat Preferences

This section describes the habitat preferences for 7 of the 11 fish species captured in Bathurst Inlet in August 2001. Habitat preferences of Pacific herring and rainbow smelt were not described because both use mainly pelagic habitat, which will not be significantly affected by construction and operation of the proposed marine Port. Pacific herring spawn on boulder and bedrock substrate in Arctic waters, but neither substrates were found near the proposed Port. Habitat preferences of ogac and lake trout were not described because neither species was abundant in the catches (only 1% each by number). The habitat preferences and depth ranges cited for the seven species are approximations only because some species (*e.g.*, starry flounder) are distributed over a wide range of latitudes with a wide range of preferred depths. Others (*e.g.*, Arctic char) have several different life history types, each of which have slightly different life history characteristics.

The habitat areas that were mapped were mainly shallow water habitat. These areas are preferred areas for flounders and fourhorn sculpins as was observed in the catch data and as explained in the following paragraphs. The littoral zone will be the area subjected to potential alteration or destruction from the proposed Port development. It will mainly affect the demersal (lives in association with the seafloor) species as presented below. The areas of abundant gravel are highly preferred spawning areas for fourhorn sculpins and Arctic ciscos. A summary of the habitat preferences for the seven species mentioned earlier is presented here.

Fourhorn sculpin was the most abundant species captured at the proposed Port site, making up 36% of the catch by number. It prefers cold, brackish and moderately saline waters near the Arctic coast. Small numbers are known to enter rivers, and that habit has produced relict populations (*i.e.*, populations left behind by retreating glaciers) in deep, cold lakes in Canada including the Great Lakes. Its habitat is demersal, living along the sea floor at depths between 0 and 100 m. It feeds mainly on benthic invertebrates such as crustaceans and worms, but will also eat small fish. Spawning takes place in gravel substrate in shallow water. The timing and depth of spawning depends on latitude and whether the population lives along the Arctic coast or in deep lakes. In the coastal Arctic, spawning occurs in late winter and early spring. Males dig a nest (a groove in the gravel) where pairing and egg laying occur, and males guard the eggs until



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Fish Habitat Assessment at Site 1 in Proximity to the Proposed Port, Bathurst Inlet, August 2001

FIGURE 3.8-4

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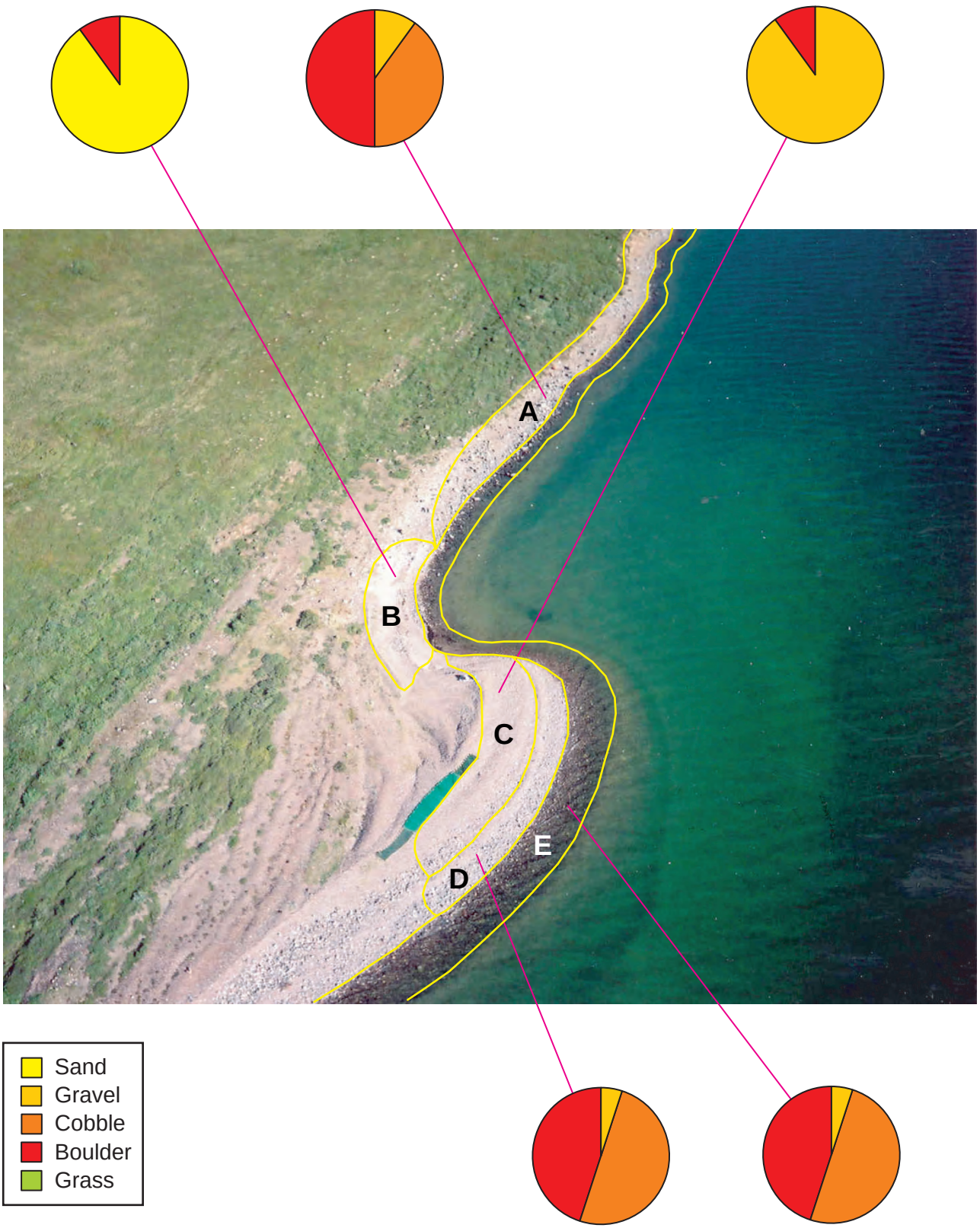

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Fish Habitat Assessment at Site 3 in Proximity to the Proposed Port, Bathurst Inlet, August 2001

FIGURE 3.8-5

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hatching. There is a brief larval phase and then the juveniles settle to the sea floor by mid-summer. Juveniles reside in shallow water during summer and autumn. Movements of all age classes are limited to short onshore-offshore seasonal migrations driven, in part, by movements of shoreline ice.

Arctic cisco was the second most common species (19% of catch by number). It is pelagic, meaning it lives in the open water column. For that reason, there are no depth ranges associated with its preferred habitat. It occurs most often in coastal areas, brackish lagoons and near river mouths. It feeds on pelagic zooplankton such as crustaceans, insects, and larval and juvenile fish. It is anadromous, meaning the adults enter rivers from late June to late August, sometimes reaching far upstream, spawn over gravel substrate under swift water from September to October, and then return to sea by November. The eggs incubate over winter, the fry emerge from the gravel in spring and descend to the sea in summer. Arctic cisco is a valued food fish by local residents.

Starry flounder was the third most common species (19% of catch by number). It is demersal, preferring sandy bottoms near shore and often in estuaries, but some (particularly the largest and oldest adults) reside in deeper water. Hence, its depth range is 0 to 375 m. Starry flounders feed on benthic invertebrates including crabs, shrimps, worms, molluscs, brittle stars and small fish. Spawning occurs in late winter and early spring, eggs are buoyant and rise to the sea surface, larvae are pelagic, and juveniles settle to the sea bottom in summer. They initially reside in shallow water with seasonal inshore-offshore (summer-winter) migrations and tend to move deeper with increasing age and size. Starry flounder are a food fish along its distributional range, but less so in the Arctic than along the Pacific coast.

Saffron cod was the fourth most common species (10% of catch by number). It resides mainly in coastal waters, but has been known to enter rivers. Saffron cod are demersal (range: 0 to 200 m) and feed on epibenthic food supplies, such as crustaceans, worms and young fish. Adults are known to have seasonal movements, residing in nearshore water during winter months and offshore water during summer months. Spawning takes place in December-February below the coastal sea ice, in sand and pebble substrate. Eggs are demersal and non-adhesive, larvae hatch in spring and have been known to associate with jellyfish. Saffron cod are fished commercially in Asia.

Arctic flounder was the fifth most common species (9% of catch by number). It resides in coastal waters and is not found far offshore. It is demersal and prefers shallow depths on mud bottoms, often in brackish water and may even enter rivers. The diet includes small fish and bottom invertebrates. Spawning occurs from January to May. Eggs are broadcast in open water or over the sea bottom. Eggs are buoyant, larvae are pelagic and juveniles settle to a benthic mode of life in the summer. Larvae feed on zooplankton, but metamorphosed juveniles that have settled to the sea floor feed on benthic prey. Like many coastal Arctic species, Arctic flounder appear to follow a seasonal migration pattern with offshore movement in the fall and onshore movement in the spring.

Broad whitefish made up only 6% of the catch by number, but it is a benthopelagic species, meaning it eats both benthic and pelagic prey. It is distributed in the fresh and brackish waters of

arctic drainages of north-west North America. It is most commonly found in streams, but lake-resident and estuarine-anadromous forms exist. It feeds on insect larvae, small molluscs and crustaceans. The mature adults make upstream spawning migrations beginning as early as June, spawn in July and August, and move back downstream after spawning to over winter in deep parts of rivers or in estuaries. Eggs incubate over the winter in gravel nests, and the young emerge in spring and move downstream to lakes or to coastal marine waters. Broad whitefish is a food fish for Arctic residents.

Arctic char made up only 1% of the catch by number but it is a benthopelagic species and the most popular food fish for local residents. It is found in inshore marine waters, lakes and rivers around the northern hemisphere. It may be anadromous or landlocked. The specimen caught in Bathurst Inlet was a member of an anadromous population. For those populations, large juveniles and adults leave their natal lakes and rivers in spring, migrate to sea where they feed in coastal waters in spring and early summer, and then return to their natal lakes and rivers in autumn (September and October). Eggs are deposited in gravel nests (called redds) in lake shoals or in large rivers. The eggs incubate over winter and fry emerge from the gravel in spring. After growing in lake habitat for several years, the young migrate to sea for the first time. Arctic char have a wide range of prey items including insects, zooplankton, amphipods, molluscs and fish. Their depth range in the sea is about 0 to 70 m. Arctic char are most easily caught by local residents during their late-summer in-river migration.

4. SUMMARY AND CONCLUSIONS

4. Summary and Conclusions

4.1 Water Column Structure

The water column was highly stratified in August. The upper mixed-layer had a thickness of 5 to 7 m and the euphotic zone extended to about 9 m depth. Below about 20 m depth the density gradient was flat. The physical profile at the eastern-most station 1 had a much more distinctive profile than the other stations. The surface layer was nearly fresh and density gradient was much more gradual than at other stations.

4.2 Water Quality

Water quality in southern Bathurst Inlet in August, 2001 reflected a pristine environment. The vertical distributions of the chemical characteristics of the water column were strongly influenced by the physical structure of the water column. The upper mixed-layer was characterized by low conductivity, low concentrations of dissolved suspended solids, low acidity and alkalinity, low concentrations of dissolved anions, low concentrations of nitrite, nitrate, orthophosphate and total phosphate, low concentrations of total and dissolved metals (except for the major constituents of seawater such as calcium, magnesium, potassium, sodium and strontium), and high concentrations of dissolved oxygen and total organic carbon. With the exception of total suspended solids, turbidity, dissolved oxygen and total organic carbon, the concentrations of all water quality variables increased dramatically at the pycnocline and continued to increase, albeit at a slower rate, with depth below the pycnocline. Three-quarters of metals were below detection limits at all depths and stations, and those metals that were above detection limits were non-toxic constituents of seawater.

4.3 Sediment Quality

The sediments sampled from Bathurst Inlet are soft, loosely bound clay-silt complexes with no organic debris, reflecting the absence of woody debris in the near-shore terrestrial environment. Concentrations of total nitrogen were also low, indicating the absence of significant quantities of organic matter in the sediments. Hydrocarbon concentrations were low, reflecting the absence of industrial activity near the Port site. Concentrations of total metals were generally below detection limits for 8 of the 29 metals. Comparison of the average concentrations of total metals with Canadian guidelines showed that zinc, lead, mercury and cadmium had concentrations below the ISQG, and that arsenic, chromium and copper had concentrations between the ISQG and the PEL. No significant adverse biological effects are expected from these low average metals concentrations. In general, the marine sediments of southern Bathurst Inlet near the Port are of high quality and reflect a pristine aquatic environment.

4.4 Phytoplankton

Chlorophyll *a* concentrations ranged from 0.05 to 1.18 µg/L, and average concentrations decreased with depth over the upper 14 m for four of the five stations. Average phytoplankton abundance ranged from 590 to 989 cells/mL at the five stations. Between 10 and 13 genera were found at each station, but only three or four genera dominated the phytoplankton community.

Chlorophytes (23 to 31%) and cryptophytes (15 to 23%) were the two most predominant taxa. The most predominant species was an unidentifiable flagellate. This flagellate, "Species A," made up about 40% of the sample. Of the positively identified genera, members of *Plagioselmis* (21.2%) and *Chlorella* (28.5%) predominated the five stations. Shannon and Simpson diversity indices were very similar among stations.

4.5 Zooplankton

Average zooplankton abundances ranged from 5,562 to 11,082 organisms/m^3. Calanoid copepods predominated the zooplankton assemblages, making up between 81 and 90% of average densities. Cyclopoid copepods and cladocerans made up between 0 and 18% of average densities. The number of positively identified genera ranged from 13 to 19. The predominant genus was *Pseudocalanus* (71.3%), and the next most predominant genus was *Acartia* (10.9%) (both genera are calanoid copepods). Diversity indices were similar among stations.

4.6 Benthos

Average benthos density in August, 2001, was 22,752 organisms/m^2, with nematodes being responsible for approximately 80% of numbers. Average densities in August, 2002, were much lower, ranging from 1,515 to 6,276 organisms/m^2, with an overall average of 3,419 organisms/m^2. In 2001, nematodes predominated, while in 2002, annelids and foraminiferans were the most abundant groups. The average number of genera identified in samples from all five stations ranged from 18 to 39, with station 3 having the greatest number of genera. Among non-nematodes, polychaete, *Laonice*, accounted for an average of 18% of the organisms identified at all stations. Another polychaete, *Aricidea*, accounted for 8%. Other abundant genera included the foraminiferans, *Nonion* (9%) and *Hippocrepinella* (7.6%).

4.7 Fish Community

A total of 177 fish from 11 species were captured from three sampling sites near the proposed Port. Fourhorn sculpin was the predominant species by number, followed by Arctic cisco, starry flounder, saffron cod, Arctic flounder, Pacific herring, broad whitefish, rainbow smelt, Arctic char, ogac and lake trout. The fish community was composed mainly of nearshore, shallow-water fish with a large component of anadromous species and species with low tolerance for salinity. All species are common fish in Canada's Arctic waters, and none are threatened or endangered.

Comparison of gill nets and long lines set at the surface and along the sea bottom showed that most fish in the nearshore zone were demersal and moved along the sea bottom, at least during daylight.

On the basis of average fork length, adult broad whitefish were the largest fish, followed by adult ogac, Arctic char, saffron cod, lake trout, rainbow smelt, Arctic cisco, starry flounder, Pacific herring, fourhorn sculpin and Arctic flounder. The smallest fish were juvenile fourhorn sculpin. Statistically significant weight-length regressions were calculated for seven species, and weight-length exponents ranged from 2.980 for broad whitefish to 3.449 for Pacific herring. Condition

(the ratio of weight to length cubed) was highest for short, broad fish such as Arctic flounder and starry flounder, and lowest for long, narrow fish such as rainbow smelt and saffron cod. Von Bertalanffy growth models were fit to the length-at-age data for the seven species with more than two specimens. In general, large-bodied species such as saffron cod had high asymptotic lengths (L_∞ = 616 mm) and low growth rates (K = 0.054 mm/year), and small-bodied species such as Pacific herring had low asymptotic lengths (L_∞ = 233 mm) and high growth rates (K = 1.032 mm/year).

Of the 37 fish examined for sex and sexual maturity, 14 were male, 12 were female and 11 were of unknown sex. Starry flounder was the only species for which sufficient numbers were examined to allow calculation of the rate at which sexual maturity increased with body size.

Nine of the 36 stomachs examined were empty, and the remaining 27 contained a range of prey from benthic organisms such as clams, brittle stars and amphipods to benthopelagic prey such as fish and crustaceans, to prey that appeared of terrestrial origin such as insects (found in Arctic cisco). Based on the stomach content data, and on the general diet of the species as reported in the scientific literature, a conceptual model was constructed of the trophic relationships of the nearshore fish community of southern Bathurst Inlet in August.

Concentrations of 29 metals were measured in the muscle tissue of 15 starry flounder, a species that resides year-round in the nearshore zone of the Project area. Sixteen metals had at least one measurement that was below the detection limit for the analytical method used, and eight of those 16 metals had all 15 measurements below the detection limit. Concentrations of mercury, arsenic and selenium were highly correlated with body weight. Average concentrations of mercury, arsenic and lead were below the guidelines established by Canadian and British Columbia food inspection agencies. Average concentrations of selenium and cadmium were below the levels known to cause adverse effects. In general, the metals concentrations in starry flounder of Bathurst Inlet reflect a pristine environment.

4.8 Fish Habitat

Habitat assessments were conducted at three sites near the proposed Port location using a combination of methods. The shoreline was walked and substrate composition was recorded. Photographs and video were taken from the air. Based on substrate composition, the three sites were delineated into 19 zones. Sites 1 and 2 were similar in their substrate and zonation. Both were primarily composed of gravel, cobble, and sand. A narrow band of small gravel intersected the middle of the exposed shore at both sites. The substrate composition of site 3 differed from sites 1 and 2. Boulder was the dominant substrate at site 3. Sites 1 and 2 are likely preferred habitat for starry flounder, Arctic flounder, and fourhorn sculpin.

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APPENDIX 3.2-1
WATER QUALITY AT STATIONS 1 TO 5, BATHURST INLET, AUGUST 2001

Appendix 3.2-1
Water Quality at Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

				Physical Variables:						Dissolved anions (mg/L):					
Date	Station	Depth (m)	Replicate	Conductivity (mS/cm)	Total dissolved Solids (mg/L)	Hardness (mg/L $CaCO_3$)	pH	Total suspended Solids (mg/L)	Turbidity (NTU)	Acidity (to pH 8.3) (mg/L $CaCO_3$)	Alkalinity (mg/L $CaCO_3$)	Bromide	Chloride	Fluoride	Silicate
14-Aug	1	1	N	18100	8480	2310	7.73	10	1.3	7	44	21	5930	0.36	0.7
14-Aug	1	7	N	19700	10900	2310	7.80	9	0.8	6	46	24	6650	0.38	0.7
14-Aug	1	10	N	29100	17800	3390	7.78	14	0.3	10	87	37	10500	0.56	1.0
14-Aug	1	17	N	33500	17800	3980	7.77	10	0.4	11	96	43	12300	0.62	1.0
14-Aug	1	37	N	39800	21800	4670	7.65	18	0.2	15	111	54	14900	0.72	2.0
14-Aug	2	1	N	18200	9020	2120	7.85	12	1.0	5	44	22	6060	0.36	0.7
15-Aug	2	1	Y	18400	9690	2090	7.82	10	1.0	6	44	22	6120	0.38	0.6
14-Aug	2	5	N	20000	9990	2350	7.80	14	1.4	6	45	23	6730	0.59	0.8
14-Aug	2	10	N	31500	18200	3840	7.81	11	0.3	9	92	40	11300	0.60	1.0
14-Aug	2	14	N	32600	18600	3970	7.79	16	0.9	10	95	42	11700	0.62	1.0
15-Aug	3	1	N	18100	9030	2150	7.85	10	0.9	5	44	21	5970	0.37	0.8
15-Aug	3	5	N	18400	9200	2190	7.82	6	1.3	6	44	22	6260	0.36	0.8
15-Aug	3	10	N	30000	17100	3550	7.80	18	1.0	10	90	39	10900	0.56	0.9
15-Aug	3	17	N	35200	20800	4400	7.75	17	0.4	12	102	47	13000	0.65	1.3
15-Aug	3	32	N	39500	24100	4820	7.83	27	0.3	13	113	54	15000	0.71	2.0
15-Aug	4	1	N	18400	9190	2290	7.86	7	1.0	6	44	22	6170	0.36	0.8
15-Aug	4	5	N	19100	10700	2420	7.82	12	0.8	5	44	23	6460	0.36	0.8
15-Aug	4	10	N	31000	17300	3720	7.81	15	0.4	10	91	40	11100	0.57	1.0
15-Aug	4	20	N	37100	21600	4510	7.74	20	0.5	13	106	49	13700	0.67	1.4
15-Aug	4	45	N	40100	23400	5210	7.82	21	0.5	13	112	54	14900	0.72	2.0
15-Aug	5	1	N	18700	9820	2280	7.72	8	0.6	7	44	22	6250	0.36	0.8
15-Aug	5	5	N	19700	10700	2530	7.77	11	0.8	7	46	23	6530	0.38	0.8
15-Aug	5	5	Y	20300	10600	2550	7.79	11	0.6	7	47	24	6750	0.38	0.8
15-Aug	5	10	N	31500	17800	4010	7.82	15	0.6	10	92	39	11100	0.58	0.9
15-Aug	5	25	N	39300	22800	5070	7.72	18	0.4	14	109	51	14400	0.70	1.7
15-Aug	5	69	N	40500	22200	5180	7.73	25	0.5	14	110	51	15100	0.73	2.1
	Travel Blank	NA	NA	<2	<10	29.5	5.73	<3	<0.1	<1	<1	<0.5	<0.5	<0.02	<0.1
	Travel Blank	NA	NA	<2	<10	3	5.81	<3	<0.1	<1	<1	<0.5	<0.5	<0.02	<0.1
	Travel Blank	NA	NA	<2	<10	1.6	5.84	<3	<0.1	<1	<1	<0.5	<0.5	<0.02	<0.1

Notes: NA = not available., N = no, Y = yes

(continued)

Appendix 3.2-1
Water Quality at Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

					Nutrients (mg/L):					Total Metals (mg/L):								
Date	Station	Depth (m)	Replicate	Sulphate	Ammonia	Nitrate	Nitrite	Dissolved ortho-phosphate	Total phosphate	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Calcium
14-Aug	1	1	N	824	0.018	<0.005	<0.001	<0.001	0.012	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	141
14-Aug	1	7	N	937	0.016	<0.005	0.003	<0.001	0.012	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	149
14-Aug	1	10	N	1470	0.017	0.007	0.002	<0.001	0.021	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	225
14-Aug	1	17	N	1690	0.020	0.027	0.003	0.027	0.029	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	261
14-Aug	1	37	N	2100	0.009	0.136	0.003	<0.001	0.045	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	298
14-Aug	2	1	N	853	0.017	<0.005	0.002	<0.001	0.011	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	127
15-Aug	2	1	Y	862	0.017	<0.005	0.001	<0.001	<0.002	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	124
14-Aug	2	5	N	953	0.017	<0.005	0.002	<0.001	<0.002	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	143
14-Aug	2	10	N	1580	0.016	0.008	0.003	<0.001	<0.002	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	243
14-Aug	2	14	N	1660	0.022	0.018	0.003	<0.001	<0.002	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	254
15-Aug	3	1	N	840	0.016	<0.005	0.001	<0.001	<0.002	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	131
15-Aug	3	5	N	881	0.017	<0.005	0.002	<0.001	<0.002	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	134
15-Aug	3	10	N	1520	0.017	0.010	0.002	<0.001	0.024	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	237
15-Aug	3	17	N	1840	0.011	0.058	0.004	0.037	0.037	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	293
15-Aug	3	32	N	2110	0.008	0.137	0.003	0.050	0.050	<1	<0.05	0.05	<0.03	<0.3	<0.3	<5	<0.03	320
15-Aug	4	1	N	868	<0.005	<0.005	0.002	0.001	0.015	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	137
15-Aug	4	5	N	909	0.018	<0.005	0.002	0.010	0.012	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	143
15-Aug	4	10	N	1590	0.015	0.009	0.003	0.024	0.028	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	236
15-Aug	4	20	N	1940	0.013	0.086	0.004	0.040	0.041	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	297
15-Aug	4	45	N	2110	0.010	0.133	0.004	0.050	0.051	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	332
15-Aug	5	1	N	880	0.017	<0.005	0.001	0.010	0.018	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	143
15-Aug	5	5	N	919	0.019	<0.005	0.001	0.011	0.012	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	153
15-Aug	5	5	Y	950	0.016	<0.005	0.001	0.014	0.015	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	165
15-Aug	5	10	N	1560	0.015	0.011	0.003	0.023	0.025	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	259
15-Aug	5	25	N	2030	0.011	0.109	0.005	0.046	0.048	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	329
15-Aug	5	69	N	2120	0.011	0.125	0.004	0.047	0.047	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	337
	Travel Blank	NA	NA	<1	0.007	<0.005	0.001	<0.001	<0.002	0.016	<0.0001	0.00	0.0006	<0.0005	<0.0005	0.02	<0.00005	2.33
	Travel Blank	NA	NA	<1	0.007	<0.005	<0.001	<0.001	<0.002	<0.002	<0.0001	<0.0001	0.0001	<0.0005	<0.0005	<0.01	<0.00005	0.24
	Travel Blank	NA	NA	<1	0.008	<0.005	0.001	<0.001	<0.002	0.009	<0.0001	<0.0001	<0.00005	<0.0005	<0.0005	<0.01	<0.00005	0.12

Notes: NA = not available., N = no, Y = yes

(continued)

Appendix 3.2-1
Water Quality at Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

Date	Station	Depth (m)	Replicate	Total Metals (mg/L): Chromium	Cobalt	Copper	Iron	Lead	Lithium	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silicon	Silver
14-Aug	1	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	473	<0.03	<0.00001	<0.03	<0.3	<3	134	<0.5	<0.5	<0.005
14-Aug	1	7	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	505	<0.03	<0.00001	<0.03	<0.3	<3	145	<0.5	<0.5	<0.005
14-Aug	1	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	694	0.04	<0.00001	<0.03	<0.3	<3	214	<0.5	<0.5	<0.005
14-Aug	1	17	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	822	<0.03	<0.00001	<0.03	<0.3	<3	268	<0.5	<0.5	<0.005
14-Aug	1	37	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	984	0.03	<0.00001	<0.03	<0.3	<3	307	<0.5	0.9	<0.005
14-Aug	2	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	437	<0.03	<0.00001	<0.03	<0.3	<3	122	<0.5	<0.5	<0.005
15-Aug	2	1	Y	<0.3	<0.05	<0.05	<0.3	<0.03	<3	416	<0.03	<0.00001	<0.03	<0.3	<3	119	<0.5	<0.5	<0.005
14-Aug	2	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	484	<0.03	<0.00001	<0.03	<0.3	<3	137	<0.5	<0.5	<0.005
14-Aug	2	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	771	<0.03	<0.00001	<0.03	<0.3	<3	245	<0.5	<0.5	<0.005
14-Aug	2	14	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	796	<0.03	<0.00001	<0.03	<0.3	<3	258	<0.5	<0.5	<0.005
15-Aug	3	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	447	<0.03	<0.00001	<0.03	<0.3	<3	125	<0.5	<0.5	<0.005
15-Aug	3	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	459	<0.03	<0.00001	<0.03	<0.3	<3	128	<0.5	<0.5	<0.005
15-Aug	3	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	745	<0.03	<0.00001	<0.03	<0.3	<3	228	<0.5	<0.5	<0.005
15-Aug	3	17	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	919	<0.03	<0.00001	<0.03	<0.3	<3	302	<0.5	0.6	<0.005
15-Aug	3	32	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	1020	0.03	<0.00001	<0.03	<0.3	<3	327	<0.5	0.9	<0.005
15-Aug	4	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	464	<0.03	<0.00001	<0.03	<0.3	<3	131	<0.5	<0.5	<0.005
15-Aug	4	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	488	<0.03	<0.00001	<0.03	<0.3	<3	138	<0.5	<0.5	<0.005
15-Aug	4	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	754	<0.03	<0.00001	<0.03	<0.3	<3	228	<0.5	<0.5	<0.005
15-Aug	4	20	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	943	<0.03	<0.00001	<0.03	<0.3	<3	309	<0.5	0.6	<0.005
15-Aug	4	45	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	1050	0.04	<0.00001	<0.03	<0.3	<3	337	<0.5	0.9	<0.005
15-Aug	5	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	484	<0.03	<0.00001	<0.03	<0.3	<3	138	<0.5	<0.5	<0.005
15-Aug	5	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	516	<0.03	<0.00001	<0.03	<0.3	<3	148	<0.5	<0.5	<0.005
15-Aug	5	5	Y	<0.3	<0.05	<0.05	<0.3	<0.03	<3	540	<0.03	<0.00001	<0.03	<0.3	<3	162	<0.5	<0.5	<0.005
15-Aug	5	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	835	<0.03	<0.00001	<0.03	<0.3	<3	264	<0.5	<0.5	<0.005
15-Aug	5	25	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	1020	0.03	<0.00001	<0.03	<0.3	<3	326	<0.5	0.8	<0.005
15-Aug	5	69	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	1070	0.04	<0.00001	<0.03	<0.3	<3	339	<0.5	1	<0.005
	Travel Blank	NA	NA	<0.0005	<0.0001	0.0003	<0.03	0.00011	<0.005	5.7	0.00061	<0.00001	0.00009	<0.0005	<0.3	<2	0.001	<0.05	<0.00001
	Travel Blank	NA	NA	<0.0005	<0.0001	<0.0001	<0.03	<0.00005	<0.005	0.6	0.0001	<0.00001	<0.00005	<0.0005	<0.3	<2	<0.001	<0.05	<0.00001
	Travel Blank	NA	NA	<0.0005	<0.0001	<0.0001	<0.03	<0.00005	<0.005	0.3	<0.00005	<0.00001	<0.00005	<0.0005	<0.3	<2	<0.001	<0.05	<0.00001

Notes: NA = not available., N = no, Y = yes

(continued)

Appendix 3.2-1
Water Quality at Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

Date	Station	Depth (m)	Replicate	Total Metals (mg/L): Sodium	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Dissolved Metals (mg/L): Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Calcium
14-Aug	1	1	N	3510	2.58	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	141
14-Aug	1	7	N	3810	2.89	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	140
14-Aug	1	10	N	5600	4.37	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	0.06	<0.03	<0.3	<0.3	<5	<0.03	222
14-Aug	1	17	N	7570	5.24	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	257
14-Aug	1	37	N	8710	6.32	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	291
14-Aug	2	1	N	3220	2.80	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	127
15-Aug	2	1	Y	3080	2.62	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	0.11	<0.03	<0.3	<0.3	<5	<0.03	126
14-Aug	2	5	N	3570	3.03	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	142
14-Aug	2	10	N	6350	5.04	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	248
14-Aug	2	14	N	7240	5.07	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	254
15-Aug	3	1	N	3270	2.39	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	129
15-Aug	3	5	N	3350	2.82	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	131
15-Aug	3	10	N	6290	4.90	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	227
15-Aug	3	17	N	8330	5.58	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	281
15-Aug	3	32	N	8990	6.69	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	317
15-Aug	4	1	N	3270	2.55	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	139
15-Aug	4	5	N	3430	3.00	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	146
15-Aug	4	10	N	5960	5.03	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	243
15-Aug	4	20	N	8360	6.31	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	290
15-Aug	4	45	N	9480	6.42	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	0.05	<0.03	<0.3	<0.3	<5	<0.03	330
15-Aug	5	1	N	3510	2.85	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	138
15-Aug	5	5	N	3760	2.92	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	155
15-Aug	5	5	Y	4030	3.10	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	155
15-Aug	5	10	N	7050	5.05	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	254
15-Aug	5	25	N	8810	6.44	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	319
15-Aug	5	69	N	9200	6.73	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	<1	<0.05	<0.05	<0.03	<0.3	<0.3	<5	<0.03	338
	Travel Blank	NA	NA	47	0.03	<0.0001	<0.0001	<0.01	0.00001	<0.001	0.002	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Travel Blank	NA	NA	5	0.003	<0.0001	<0.0001	<0.01	<0.00001	<0.001	<0.001	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Travel Blank	NA	NA	3	0.002	<0.0001	<0.0001	<0.01	<0.00001	<0.001	<0.001	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NA = not available., N = no, Y = yes

(continued)

Appendix 3.2-1
Water Quality at Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

Date	Station	Depth (m)	Replicate	Dissolved Metals (mg/L): Chromium	Cobalt	Copper	Iron	Lead	Lithium	Magnesium	Manganese	Mercury	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silicon
14-Aug	1	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	475	<0.03	<0.00001	<0.03	<0.3	<3	135	<0.5	<0.5
14-Aug	1	7	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	477	<0.03	<0.00001	<0.03	<0.3	<3	136	<0.5	<0.5
14-Aug	1	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	689	<0.03	<0.00001	<0.03	<0.3	<3	214	<0.5	<0.5
14-Aug	1	17	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	811	<0.03	<0.00001	<0.03	<0.3	<3	263	<0.5	<0.5
14-Aug	1	37	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	957	0.03	<0.00001	<0.03	<0.3	<3	302	<0.5	0.8
14-Aug	2	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	437	<0.03	<0.00001	<0.03	<0.3	<3	122	<0.5	<0.5
15-Aug	2	1	Y	<0.3	<0.05	<0.05	<0.3	<0.03	<3	432	<0.03	<0.00001	<0.03	<0.3	<3	120	<0.5	<0.5
14-Aug	2	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	483	<0.03	<0.00001	<0.03	<0.3	<3	137	<0.5	<0.5
14-Aug	2	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	783	<0.03	<0.00001	<0.03	<0.3	<3	252	<0.5	<0.5
14-Aug	2	14	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	810	<0.03	<0.00001	<0.03	<0.3	<3	260	<0.5	<0.5
15-Aug	3	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	445	<0.03	<0.00001	<0.03	<0.3	<3	124	<0.5	<0.5
15-Aug	3	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	452	<0.03	<0.00001	<0.03	<0.3	<3	126	<0.5	<0.5
15-Aug	3	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	725	<0.03	<0.00001	<0.03	<0.3	<3	219	<0.5	<0.5
15-Aug	3	17	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	898	<0.03	<0.00001	<0.03	<0.3	<3	287	<0.5	0.5
15-Aug	3	32	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	977	<0.03	<0.00001	<0.03	<0.3	<3	326	<0.5	0.8
15-Aug	4	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	472	<0.03	<0.00001	<0.03	<0.3	<3	134	<0.5	<0.5
15-Aug	4	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	500	<0.03	<0.00001	<0.03	<0.3	<3	142	<0.5	<0.5
15-Aug	4	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	756	<0.03	<0.00001	<0.03	<0.3	<3	243	<0.5	<0.5
15-Aug	4	20	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	920	<0.03	<0.00001	<0.03	<0.3	<3	301	<0.5	0.6
15-Aug	4	45	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	1060	0.04	<0.00001	<0.03	<0.3	<3	336	<0.5	0.9
15-Aug	5	1	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	469	<0.03	<0.00001	<0.03	<0.3	<3	133	<0.5	<0.5
15-Aug	5	5	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	519	<0.03	<0.00001	<0.03	<0.3	<3	150	<0.5	<0.5
15-Aug	5	5	Y	<0.3	<0.05	<0.05	<0.3	<0.03	<3	526	<0.03	<0.00001	<0.03	<0.3	<3	150	<0.5	<0.5
15-Aug	5	10	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	819	<0.03	<0.00001	<0.03	<0.3	<3	259	<0.5	<0.5
15-Aug	5	25	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	1040	0.03	<0.00001	<0.03	<0.3	<3	326	<0.5	0.7
15-Aug	5	69	N	<0.3	<0.05	<0.05	<0.3	<0.03	<3	1050	0.03	<0.00001	<0.03	<0.3	<3	339	<0.5	0.9
	Travel Blank	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Travel Blank	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Travel Blank	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes: NA = not available., N = no, Y = yes

(continued)

Appendix 3.2-1
Water Quality at Stations 1 to 5, Bathurst Inlet, August 2001 (completed)

Date	Station	Depth (m)	Replicate	Dissolved Metals (mg/L): Silver	Sodium	Strontium	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Total Organic Carbon (mg/L)
14-Aug	1	1	N	<0.005	3500	2.52	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.1
14-Aug	1	7	N	<0.005	3550	2.90	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.1
14-Aug	1	10	N	<0.005	6050	4.37	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.7
14-Aug	1	17	N	<0.005	7360	5.10	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.7
14-Aug	1	37	N	<0.005	8610	6.52	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.5
14-Aug	2	1	N	<0.005	3210	2.81	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.4
15-Aug	2	1	Y	<0.005	3150	2.69	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.3
14-Aug	2	5	N	<0.005	3570	2.83	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.2
14-Aug	2	10	N	<0.005	7020	4.96	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.6
14-Aug	2	14	N	<0.005	7350	5.45	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.8
15-Aug	3	1	N	<0.005	3240	2.73	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.1
15-Aug	3	5	N	<0.005	3310	2.77	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.0
15-Aug	3	10	N	<0.005	6130	4.71	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.6
15-Aug	3	17	N	<0.005	7940	5.92	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.5
15-Aug	3	32	N	<0.005	9060	6.75	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.1
15-Aug	4	1	N	<0.005	3310	2.67	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.3
15-Aug	4	5	N	<0.005	3550	2.86	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.9
15-Aug	4	10	N	<0.005	6170	4.90	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.1
15-Aug	4	20	N	<0.005	8450	6.04	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.7
15-Aug	4	45	N	<0.005	9570	6.63	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.0
15-Aug	5	1	N	<0.005	3380	2.75	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.1
15-Aug	5	5	N	<0.005	3760	2.96	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.1
15-Aug	5	5	Y	<0.005	3790	2.94	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	2.0
15-Aug	5	10	N	<0.005	6970	4.75	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.7
15-Aug	5	25	N	<0.005	8790	6.28	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.2
15-Aug	5	69	N	<0.005	9170	6.50	<0.05	<0.05	<0.1	<0.005	<0.5	<0.5	1.2
	Travel Blank	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.5
	Travel Blank	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.5
	Travel Blank	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.5

Notes: NA = not available., N = no, Y = yes

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APPENDIX 3.3-1
PHOTOGRAPHIC RECORD AND DESCRIPTION OF SEDIMENT SAMPLES AT STATIONS 1 TO 5, BATHURST INLET

APPENDIX 3.3-1
PHOTOGRAPHIC RECORD AND DESCRIPTION OF SEDIMENT SAMPLES AT STATIONS 1 TO 5, BATHURST INLET

Station 1, depth = 40 m, August 2001

Station 2, depth = 17 m, replicate A, August 2001

Station 2, depth = 17 m, replicate B, August 2001

Station 3, depth = 42 m, August 2001

Station 4, depth = 64 m, August 2001

Station 5, depth = 70 m, August 2001

APPENDIX 3.3-1
PHOTOGRAPHIC RECORD AND DESCRIPTION OF SEDIMENT SAMPLES AT STATIONS 1 TO 5, BATHURST INLET

Station 2, depth = 17 m, August 2002

APPENDIX 3.3-1
PHOTOGRAPHIC RECORD AND DESCRIPTION OF SEDIMENT SAMPLES AT STATIONS 1 TO 5, BATHURST INLET

Station	1
Date:	16 August, 2001
Time:	13:30
Grab Depth (m):	40
Physical Description:	One layer, homogeneous, no grit to touch, grit to taste, sticky, loosely bound
Munsell Color Classification:	Brown 7.5YR 5/3
Biological Material:	Polychaetes
Debris Material:	
Notes:	
Photograph (Y/N):	Yes

Station	2	2
Replicate	Rep A	Rep B
Date:	16 August, 2001	16 August, 2001
Time:	9:15	16:55
Grab Depth (m):	17	17
Physical Description:	Loosely bound soft clay, no grit to touch, grit to taste, sticky, homogeneous	Loosely bound soft clay, no grit to touch, grit to taste, sticky, homogeneous
Munsell Color Classification:	Brown 7.5YR 5/2	Brown 7.5YR 5/2
Biological Material:	Fish (sculpin), polychaete	Worms
Debris Material:		
Notes:	Slight organic smell	
Photograph (Y/N):	Yes	Yes

Station	3
Date:	16 August, 2001
Time:	10:00
Grab Depth (m):	42
Physical Description:	Thin layer of green detritus on surface, loosely bound, no distinct layers, no grit to touch, grit to taste
Munsell Color Classification:	Brown 7.5YR 5/2
Biological Material:	None visible
Debris Material:	
Notes:	
Photograph (Y/N):	Yes

APPENDIX 3.3-1
PHOTOGRAPHIC RECORD AND DESCRIPTION OF SEDIMENT SAMPLES AT STATIONS 1 TO 5, BATHURST INLET

Station	4
Date:	16 August, 2001
Time:	16:10
Grab Depth (m):	64
Physical Description:	Soft clay, fine, no grit to touch, grit to taste, surface sediment loosely bound but bottom sediment more firm in patches, no distinct layer
Munsell Color Classification:	Gray 7.5YR 5/1
Biological Material:	None visible
Debris Material:	
Notes:	Taken 15 m from GPS coordinate, drifting with tide/wind
Photograph (Y/N):	Yes

Station	5
Date:	16 August, 2001
Time:	15:50
Grab Depth (m):	70
Physical Description:	Homogeneous soft clay, loosely bound, no grit to touch, grit to taste
Munsell Color Classification:	Gray 7.5YR 5/1
Biological Material:	None visible
Debris Material:	
Notes:	
Photograph (Y/N):	Yes

Station	2
Replicate	Rep A
Date:	6 August, 2002
Time:	-
Grab Depth (m):	17
Physical Description:	Loosely bound soft clay, no grit to touch, grit to taste, sticky, homogeneous
Munsell Color Classification:	Brown 7.5YR 5/2
Biological Material:	Polychaete
Debris Material:	
Notes:	Slight organic smell
Photograph (Y/N):	Yes

APPENDIX 3.3-2
SEDIMENT QUALITY AT STATIONS 1 TO 5, BATHURST INLET, AUGUST 2001 AND 2002

Appendix 3.3-2
Sediment Quality at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002

Station	Date	Replicate	Depth (m)	Moisture (%)	Particle Size (%):				Available phosphorus (mg/kg DW)	Total nitrogen (%)	Total Metals (mg/kg DW):															
					Clay	Silt	Sand	Gravel			Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Magnesium
1	August 2001	NA	40	52.7	68.2	27.6	4.2	<0.1	36	0.06	33600	<20	14.0	154	1.3	<20	<0.1	5190	65	14	27	35600	27	51	15400
2	August 2001	A	17	56.9	67.9	28.1	4.0	<0.1	44	0.06	37600	<20	10.2	162	1.3	<20	<0.1	5160	63	12	24	31100	14	52	14500
2	August 2001	B	17	55.7	65.1	30.6	4.3	<0.1	36	0.07	40200	<20	12.0	165	1.4	<20	<0.1	5290	66	12	25	32800	14	55	14900
2	August 2002	NA	17	54.8	66.8	29.1	4.1	<0.1	56	0.06	27600	<20	14.0	132	1	<20	0.2	10200	59	11	25	35800	13	54	15100
3	August 2001	NA	42	52.9	66.5	30.9	2.6	<0.1	41	0.05	34900	<20	12.0	153	1.2	<20	<0.1	5350	65	14	26	33700	13	51	15000
4	August 2001	NA	64	53.1	69.6	28.0	2.4	<0.1	54	0.05	41700	<20	16.0	179	1.4	<20	<0.1	5300	69	14	26	35300	14	58	15600
5	August 2001	NA	70	54.1	65.4	32.9	1.7	<0.1	44	0.06	33000	<20	13.5	151	1.2	<20	<0.1	5050	63	15	26	33000	14	49	14500

Notes: NA = not applicable or not available, DW = dry weight

Particle size classes: clay (<4 mm), silt (4 mm to 0.063 mm), sand (0.063 to 2.000 mm), and gravel (>2 mm)

(continued)

Appendix 3.3-2
Sediment Quality at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002 (completed)

Station	Date	Replicate	Depth (m)	Total Metals (mg/kg DW):														Total Sulphur (%)	Extractable Petroluem Hydrocarbons	
				Manganese	Mercury	Molybdenum	Nickel	Phosphorus	Potassium	Selenium	Silver	Strontium	Thallium	Tin	Titanium	Vanadium	Zinc		EPH10-19	EPH19-32
1	August 2001	NA	40	760	0.025	<4	33	1520	10100	<50	<2	123	<50	<10	1220	71	66	0.05	NA	NA
2	August 2001	A	17	447	0.023	<4	30	1020	11600	<50	<2	120	<50	<10	1240	71	61	0.04	<100	<100
2	August 2001	B	17	395	0.021	<4	31	1140	12200	<50	<2	127	<50	<10	1320	74	62	0.04	<100	<100
2	August 2002	NA	17	342	0.013	<4	29	1170	8890	<50	<2	140	<50	<10	835	61	53	0.13	59	44
3	August 2001	NA	42	874	0.024	<4	32	1250	10300	<50	<2	119	<50	<10	1210	72	64	0.04	NA	NA
4	August 2001	NA	64	904	0.025	<4	33	1660	13200	<50	<2	145	<50	<10	1280	77	66	0.04	NA	NA
5	August 2001	NA	70	1520	0.025	<4	32	1300	9910	<50	<2	121	<50	<10	1170	71	63	0.04	NA	NA

Notes: NA = not applicable or not available, DW = dry weight

Particle size classes: clay (<4 mm), silt (4 mm to 0.063 mm), sand (0.063 to 2.000 mm), and gravel (>2 mm)

APPENDIX 3.3-3
COMPARISON OF SEDIMENT QUALITY BETWEEN AUGUST 2001 AND 2002

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Appendix 3.3-3
Comparison of Sediment Quality between August 2001 and 2002

Variable	August 2001								August 2002	One Sample t-Test		
	Station 1	Station 2a	Station 2b	Station 3	Station 4	Station 5	Mean	SE	Station 2	Ho	t-value	P
Moisture %	52.7	56.9	55.7	52.9	53.1	54.1	54.2	0.7	54.8	Mean = 54.8	0.8	NS
Nutrients												
Available Phosphorus P	36	44	36	41	54	44	42.5	2.7	56	Mean = 56	4.9	**
Total Nitrogen N (a)	0.06	0.06	0.07	0.05	0.05	0.06	0.06	0.0	0.06	Mean = 0.06	0.5	NS
Total Metals												
Aluminum T-Al	33600	37600	40200	34900	41700	33000	36833	1466.2	27600	Mean = 27600	6.3	**
Antimony T-Sb	<20	<20	<20	<20	<20	<20			<20			
Arsenic T-As	14	10.2	12	12	16	13.5	13.0	0.8	14	Mean = 14	1.3	NS
Barium T-Ba	154	162	165	153	179	151	161	4.3	132	Mean = 132	6.7	**
Beryllium T-Be	1.3	1.3	1.4	1.2	1.4	1.2	1.3	0.04	1	Mean = 1	8.2	***
Bismuth T-Bi	<20	<20	<20	<20	<20	<20			<20			
Cadmium T-Cd	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1			0.2			
Calcium T-Ca	5190	5160	5290	5350	5300	5050	5223	45.3	10200	Mean = 10200	109.9	***
Chromium T-Cr	65	63	66	65	69	63	65	0.9	59	Mean = 59	6.8	**
Cobalt T-Co	14	12	12	14	14	15	14	0.5	11	Mean = 11	5.0	**
Copper T-Cu	27	24	25	26	26	26	26	0.4	25	Mean = 25	1.6	NS
Iron T-Fe	35600	31100	32800	33700	35300	33000	33583	686.7	35800	Mean = 35800	3.2	*
Lead T-Pb	27	14	14	13	14	14	16	2.2	13	Mean = 13	1.4	NS
Lithium T-Li	51	52	55	51	58	49	53	1.3	54	Mean = 54	1.0	NS
Magnesium T-Mg	15400	14500	14900	15000	15600	14500	14983	185.1	15100	Mean = 15100	0.6	NS
Manganese T-Mn	760	447	395	874	904	1520	817	165.7	342	Mean = 342	2.9	*
Mercury T-Hg	0.025	0.023	0.021	0.024	0.025	0.025	0.024	0.001	0.013	Mean = 0.013	16.6	***
Molybdenum T-Mo	<4	<4	<4	<4	<4	<4			<4			
Nickel T-Ni	33	30	31	32	33	32	32	0.5	29	Mean = 29	5.9	**
Phosphorus T-P	1520	1020	1140	1250	1660	1300	1315	97.2	1170	Mean = 1170	1.5	NS
Potassium T-K	10100	11600	12200	10300	13200	9910	11218	542.9	8890	Mean = 8890	4.3	**
Selenium T-Se	<50	<50	<50	<50	<50	<50			<50			
Silver T-Ag	<2	<2	<2	<2	<2	<2			<2			
Strontium T-Sr	123	120	127	119	145	121	126	4.0	140	Mean = 140	3.5	*
Thallium T-Tl	<50	<50	<50	<50	<50	<50			<50			
Tin T-Sn	<10	<10	<10	<10	<10	<10			<10			
Titanium T-Ti	1220	1240	1320	1210	1280	1170	1240	21.8	835	Mean = 835	18.6	***
Vanadium T-V	71	71	74	72	77	71	73	1.0	61	Mean = 61	11.8	***
Zinc T-Zn	66	61	62	64	66	63	64	0.8	53	Mean = 53	12.6	***
Inorganic Parameters												
Total Sulphur (b)	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.002	0.13	Mean = 0.13	53.0	***
Extractable Hydrocarbons (c)												
EPH10-19	-	<300	<300	-	-	-			59			
EPH19-32	-	<300	<300	-	-	-			44			
Particle Size												
Gravel (>2.00mm) (%)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1			<0.1			
Sand (2.00mm - 0.063mm) (%)	4.2	4	4.3	2.6	2.4	1.7	3.2	0.5	4.1	Mean = 4.1	2.0	NS
Silt (0.063mm - 4um) (%)	27.6	28.1	30.6	30.9	28	32.9	29.7	0.9	29.1	Mean = 29.1	0.7	NS
Clay (<4um) (%)	68.2	67.9	65.1	66.5	69.6	65.4	67.1	0.7	66.8	Mean = 66.8	0.4	NS

Notes:
Results are expressed as milligrams per dry kilogram except where noted.
< = Less than the detection limit indicated.
EPH = Extractable Petroleum Hydrocarbons.
Particle Size and Total Sulphur results are expressed as percent.

NS = Not Significant
*** = Significant at a = 0.05**
**** = significant at a = 0.01**
***** = significant at a = 0.001**

APPENDIX 3.4-1
CHLOROPHYLL A CONCENTRATIONS AT SAT STATIONS 1 TO 5, BATHURST INLET, AUGUST 2001

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Appendix 3.4-1
Chlorophyll a Concentrations at Stations 1 to 5, Bathurst Inlet, August 2001

Station	Depth	Replicate	Date	Chl *a* (*u* g/L)	Mean	SE
Station 1	1 m	A	14-Aug-01	1.18		
Station 1	1 m	B	14-Aug-01	0.91		
Station 1	1 m	C	14-Aug-01	1.00	1.03	0.08
Station 1	5 m	A	14-Aug-01	0.80		
Station 1	5 m	B	14-Aug-01	0.95	0.88	0.06
Station 1	10 m	A	14-Aug-01	0.63		
Station 1	10 m	B	14-Aug-01	0.76	0.70	0.09
Station 1	14 m	A	14-Aug-01	0.64		
Station 1	14 m	B	14-Aug-01	0.55	0.60	0.06
Station 2	1 m	A	15-Aug-01	0.76		
Station 2	1 m	B	15-Aug-01	1.05		
Station 2	1 m	C	15-Aug-01	1.00	0.94	0.09
Station 2	5 m	A	15-Aug-01	0.78		
Station 2	5 m	B	15-Aug-01	0.73	0.76	0.08
Station 2	10 m	A	15-Aug-01	0.54		
Station 2	10 m	B	15-Aug-01	0.58	0.56	0.06
Station 2	14 m	A	15-Aug-01	0.44		
Station 2	14 m	B	15-Aug-01	0.52	0.48	0.04
Station 3	1 m	A	15-Aug-01	0.21		
Station 3	1 m	B	15-Aug-01	0.28		
Station 3	1 m	C	15-Aug-01	0.35	0.28	0.04
Station 3	5 m	A	15-Aug-01	0.54		
Station 3	5 m	B	15-Aug-01	0.56	0.55	0.07
Station 3	10 m	A	15-Aug-01	0.38		
Station 3	10 m	B	15-Aug-01	0.43	0.41	0.05
Station 3	14 m	A	15-Aug-01	0.22		
Station 3	14 m	B	15-Aug-01	0.35	0.29	0.06
Station 4	1 m	A	15-Aug-01	0.70		
Station 4	1 m	B	15-Aug-01	0.70		
Station 4	1 m	C	15-Aug-01	0.41	0.60	0.10
Station 4	5 m	A	15-Aug-01	0.40		
Station 4	5 m	B	15-Aug-01	0.48	0.44	0.03
Station 4	10 m	A	15-Aug-01	0.16		
Station 4	10 m	B	15-Aug-01	0.38	0.27	0.09
Station 4	14 m	A	15-Aug-01	0.31		
Station 4	14 m	B	15-Aug-01	0.09	0.20	0.09
Station 5	1 m	A	15-Aug-01	0.63		
Station 5	1 m	B	15-Aug-01	0.95		
Station 5	1 m	C	15-Aug-01	0.58	0.72	0.12
Station 5	5 m	A	15-Aug-01	0.52		
Station 5	5 m	B	15-Aug-01	0.32	0.42	0.08
Station 5	10 m	A	15-Aug-01	0.44		
Station 5	10 m	B	15-Aug-01	0.27	0.36	0.05
Station 5	14 m	A	15-Aug-01	0.67		
Station 5	14 m	B	15-Aug-01	0.05	0.36	0.18

APPENDIX 3.4-2
PHYTOPLANKTON TAXONOMY AND ABUNDANCE AT THE SURFACE OF STATIONS 1 TO 5, BATHURST INLET, AUGUST 2001

Appendix 3.4-2
Phytoplankton Taxonomy and Abundance at the Surface of Stations 1 to 5, Bathurst Inlet, August 2001

			Cell Density cells / mL					
FES Sample Number			**010374**	**010375**	**010376**	**Mean**	**SE**	**Percent**
Sampling Station			**Stn 1**	**Stn 1**	**Stn 1**			
Sample Replicate			**A**	**B**	**C**			
Sampling Date			**14-Aug-01**	**14-Aug-01**	**14-Aug-01**			
Volume analyzed (mL)			**100**	**100**	**100**			
Phylum	Order	Genera and Species						
Bacillariophyceae	Centrales	*Chaetoceros sp.*	<0.4					
		Chaetoceros resting spores		<0.4				
		Coscinodiscus spp.	<0.4	<0.4				
		Melosira arctica.						
		Melosira resting spores						
		Thalassiosira cf. *psuedonana*	0.8	0.8	6.0			
		Unidentified resting spore						
		Unidentified						
	Pennales	*Achnanthes* spp.	<0.4		0.4			
		Amphora sp.	<0.4	<0.4				
		Caloneis sp.						
		Cocconeis sp.	<0.4					
		Cymbella sp.	<0.4	0.4				
		Diatoma elongatum	0.4	0.4	0.8			
		Diploneis sp.						
		Entomoneis sp.						
		Fragilaria spp.						
		Gomphonema sp.						
		Hantzschia sp.						
		Licmophora sp.		<0.4	<0.4			
		Mastogloia sp.		<0.4				
		Navicula spp.	0.8	1.2	0.4			
		Nizschia closterium			<0.4			
		Nizschia spp.	0.4	0.4	<0.4			
		Pleurosigma/Gyrosigma spp.			<0.4			
		Rhoicosphenia curvata		<0.4	<0.4			
		Surirella sp.			<0.4			
		Synedra ulna	0.4	1.6	0.8			
		Synedra spp.	1.2	0.4	1.2			
		Pennate girdle view		<0.4	<0.4			
		SUM	**4**	**5.2**	**9.6**	**6.27**	**1.70**	**1.06**
Chlorophyta	Chlorococcales	*Ankistrodesmus* spp.		<0.4	0.4			
		Chlorella sp?	105.6	192.0	182.4			
		Scenedesmus sp.						
	Ulothricales	*Ulothrix sp.*		<0.4				
	Volvocales	*Pyramimonas* spp.	19.2	38.4	18.0			
Chlorophyta		Unidentified Flagellates	0.8	0.8	0.4			
		Unidentified Filamentous						
		SUM	**125.6**	**231.2**	**201.2**	**186.00**	**31.42**	**31.37**
Chrysophyta	Dictyochales	*Dictyocha speculum*						
	Ochromonadales	*Dinobryon sp.*						
		Calycomonas sp.	9.6	9.6				
Chrysophyta		Unidentified flagellates	28.8	28.8	9.6			
		SUM	**38.4**	**38.4**	**9.6**	**28.80**	**9.60**	**4.86**
Cryptophyta	Cryptomonadales	*Plagioselmis cf. prolonga*	96.0	115.2	67.2			
		Plagioselmis sp.	28.8	19.2	12.0			
		Teleaux sp. poss.	0.4	2.0	6.0			
		Unidentified flagellates	3.2	28.8	36.0			
		SUM	**128.4**	**165.2**	**121.2**	**138.27**	**13.63**	**23.32**
Cyanophyta		*Anabaena sp.*	<0.4	<0.4				
		Merismopedia sp.						
		Oscillatoria sp.						
		Pseudoanabaena sp?		<0.4				
		Unidentified filamentous			<0.4			
		SUM	**0**	**0**	**0**	**0.00**	**0.00**	**0.00**
Pyrrhophyta	Dinokontae	*Amphidinium* sp?						
		Alexandrium sp?	<0.4					
		Ceratium sp.						
		Cochlodinium sp?						
		Dinophysis acuminata	0.4	0.8	0.8			
		Dinophysis norvegica		<0.4	<0.4			
		Gymnodinium spp.		<0.4	<0.4			
		Heterocapsa sp?			<0.4			
		Nematodinium sp?			<0.4			
		Prorocentrum sp?	<0.4		<0.4			
		Scrippsiella sp.	<0.4		<0.4			
		Unidentified armoured	1.2	1.2	1.6			
		Unidentified unarmoured	0.8	1.2	1.2			
		SUM	**2.4**	**3.2**	**3.6**	**3.07**	**0.35**	**0.52**
Unidentified Flagellates			105.6	86.4	96.0			
Unidentified Cysts			0.4	9.6	9.6			
Sp. A			115.2	144.0	124.8			
		SUM	**221.2**	**240**	**230.4**	**230.53**	**5.43**	**38.88**
		TOTAL SUM	**520**	**683.2**	**575.6**	**592.93**	**47.90**	**100.00**
Protozoa		*Ebria sp.*		<0.4	0.4			
		Tintinnids	0.8	<0.4	<0.4			
		Ciliates	2.4	2.8	6.8			

Synonyms:
Cylindrotheca closterium = Nitzschia closterium
Diatoma tenuis = Diatoma elongatum
Entomoneis = Amphiprora

(continued)

Appendix 3.4-2
Phytoplankton Taxonomy and Abundance at the Surface of Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

			Cell Density cells / mL					
FES Sample Number			**010377**	**010378**	**010379**	**Mean**	**SE**	**Percent**
Sampling Station			**Stn 2**	**Stn 2**	**Stn 2**			
Sample Replicate			**A**	**B**	**C**			
Sampling Date			**15-Aug-01**	**15-Aug-01**	**15-Aug-01**			
Volume analyzed (mL)			**100**	**100**	**100**			
Phylum	Order	Genera and Species						
Bacillariophyceae	Centrales	*Chaetoceros sp.*		<0.4				
		Chaetoceros resting spores	<0.4		<0.4			
		Coscinodiscus spp.	<0.4	<0.4				
		Melosira arctica.						
		Melosira resting spores						
		Thalassiosira cf. *psuedonana*	6.0	1.6	6.0			
		Unidentified resting spore						
		Unidentified						
	Pennales	*Achnanthes* spp.		<0.4	<0.4			
		Amphora sp.		<0.4				
		Caloneis sp.						
		Cocconeis sp.						
		Cymbella sp.						
		Diatoma elongatum	<0.4	<0.4	0.4			
		Diploneis sp.						
		Entomoneis sp.						
		Fragilaria spp.						
		Gomphonema sp.						
		Hantzschia sp.						
		Licmophora sp.		<0.4	<0.4			
		Mastogloia sp.		<0.4				
		Navicula spp.	0.8	0.8	1.2			
		Nizschia closterium		<0.4	<0.4			
		Nizschia spp.	<0.4	0.4	<0.4			
		Pleurosigma/Gyrosigma spp.	<0.4	<0.4	<0.4			
		Rhoicosphenia curvata						
		Surirella sp.	<0.4	<0.4				
		Synedra ulna	0.4	1.2	0.4			
		Synedra spp.	<0.4	<0.4	0.8			
		Pennate girdle view		0.4	<0.4			
		SUM	**7.2**	**4.4**	**8.8**	**6.80**	**1.29**	**1.17**
Chlorophyta	Chlorococcales	*Ankistrodesmus* spp.	1.6		0.4			
		Chlorella sp?	124.8	134.4	105.6			
		Scenedesmus sp.						
	Ulothricales	*Ulothrix sp.*						
	Volvocales	*Pyramimonas* spp.	9.6	19.2	28.8			
Chlorophyta		Unidentified Flagellates	9.6	1.2	9.6			
		Unidentified Filamentous						
		SUM	**145.6**	**154.8**	**144.4**	**148.27**	**3.28**	**25.50**
Chrysophyta	Dictyochales	*Dictyocha speculum*	<0.4					
	Ochromonadales	*Dinobryon sp.*						
		Calycomonas sp.	0.4	19.2	9.6			
Chrysophyta		Unidentified flagellates	28.8	19.2	28.8			
		SUM	**29.2**	**38.4**	**38.4**	**35.33**	**3.07**	**6.08**
Cryptophyta	Cryptomonadales	*Plagioselmis cf. prolonga*	144.0	96.0	57.6			
		Plagioselmis sp.	1.2	9.6	9.6			
		Teleaux sp. poss.	0.4	<0.4	0.4			
		Unidentified flagellates	3.2	48.0	24.0			
		SUM	**148.8**	**153.6**	**91.6**	**131.33**	**19.91**	**22.59**
Cyanophyta		*Anabaena sp.*						
		Merismopedia sp.						
		Oscillatoria sp.	<0.4					
		Pseudoanabaena sp?		<0.4	<0.4			
		Unidentified filamentous						
		SUM	**0**	**0**	**0**	**0.00**	**0.00**	**0.00**
Pyrrhophyta	Dinokontae	*Amphidinium* sp?		<0.4				
		Alexandrium sp?						
		Ceratium sp.						
		Cochlodinium sp?			<0.4			
		Dinophysis acuminata	0.8	0.8	0.8			
		Dinophysis norvegica	<0.4	<0.4	<0.4			
		Gymnodinium spp.			<0.4			
		Heterocapsa sp?						
		Nematodinium sp?			<0.4			
		Prorocentrum sp?						
		Scrippsiella sp.						
		Unidentified armoured	0.8	0.8	1.6			
		Unidentified unarmoured	0.8	0.8	0.8			
		SUM	**2.4**	**2.4**	**3.2**	**2.67**	**0.27**	**0.46**
Unidentified Flagellates			124.8	134.4	96.0			
Unidentified Cysts			1.2	0.8	0.8			
Sp. A			153.6	124.8	134.4			
		SUM	**279.6**	**260**	**231.2**	**256.93**	**14.06**	**44.20**
		TOTAL SUM	**612.8**	**613.6**	**517.6**	**581.33**	**31.87**	**100.00**
Protozoa		*Ebria sp.*	0.4	<0.4	<0.4			
		Tintinnids		<0.4	<0.4			
		Ciliates	8.0	7.6	10.8			

Synonyms:
Cylindrotheca closterium = Nitzschia closterium
Diatoma tenuis = Diatoma elongatum
Entomoneis = Amphiprora

(continued)

Appendix 3.4-2
Phytoplankton Taxonomy and Abundance at the Surface of Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

			Cell Density cells / mL					
FES Sample Number			**010380**	**010381**	**010382**	**Mean**	**SE**	**Percent**
Sampling Station			**Stn 3**	**Stn 3**	**Stn 3**			
Sample Replicate			**A**	**B**	**C**			
Sampling Date			**15-Aug-01**	**15-Aug-01**	**15-Aug-01**			
Volume analyzed (mL)			**100**	**100**	**100**			
Phylum	Order	Genera and Species						
Bacillariophyceae	Centrales	*Chaetoceros sp.*						
		Chaetoceros resting spores		<0.4	<0.4			
		Coscinodiscus spp.	<0.4	<0.4	<0.4			
		Melosira arctica.						
		Melosira resting spores			<0.4			
		Thalassiosira cf. *psuedonana*	0.8	12.0	1.2			
		Unidentified resting spore		<0.4				
		Unidentified						
	Pennales	*Achnanthes* spp.	<0.4	<0.4				
		Amphora sp.		<0.4				
		Caloneis sp.	<0.4					
		Cocconeis sp.						
		Cymbella sp.	<0.4					
		Diatoma elongatum	<0.4		<0.4			
		Diploneis sp.						
		Entomoneis sp.						
		Fragilaria spp.	<0.4					
		Gomphonema sp.						
		Hantzschia sp.						
		Licmophora sp.	<0.4		<0.4			
		Mastogloia sp.			<0.4			
		Navicula spp.	0.4	0.8	0.4			
		Nizschia closterium	<0.4	<0.4	<0.4			
		Nizschia spp.	<0.4		<0.4			
		Pleurosigma/Gyrosigma spp.			<0.4			
		Rhoicosphenia curvata			<0.4			
		Surirella sp.						
		Synedra ulna	0.4	<0.4	<0.4			
		Synedra spp.	<0.4	<0.4	0.4			
		Pennate girdle view		<0.4	<0.4			
		SUM	**1.6**	**12.8**	**2**	**5.47**	**3.67**	**0.71**
Chlorophyta	Chlorococcales	*Ankistrodesmus* spp.	<0.4	<0.4	<0.4			
		Chlorella sp?	172.8	115.2	172.8			
		Scenedesmus sp.	<0.4					
	Ulothricales	*Ulothrix sp.*						
	Volvocales	*Pyramimonas* spp.	19.2	67.2	28.8			
Chlorophyta		Unidentified Flagellates	9.6	19.2	9.6			
		Unidentified Filamentous						
		SUM	**201.6**	**201.6**	**211.2**	**204.80**	**3.20**	**26.63**
Chrysophyta	Dictyochales	*Dictyocha speculum*			<0.4			
	Ochromonadales	*Dinobryon sp.*						
		Calycomonas sp.	9.6	19.2	<0.4			
Chrysophyta		Unidentified flagellates	38.4	38.4	19.2			
		SUM	**48**	**57.6**	**19.2**	**41.60**	**11.54**	**5.41**
Cryptophyta	Cryptomonadales	*Plagioselmis cf. prolonga*	76.8	115.2	57.6			
		Plagioselmis sp.	3.2	6.0	9.6			
		Teleaux sp. poss.	<0.4	3.0	<0.4			
		Unidentified flagellates	3.2	42.0	38.4			
		SUM	**83.2**	**166.2**	**105.6**	**118.33**	**24.79**	**15.39**
Cyanophyta		*Anabaena sp.*						
		Merismopedia sp.						
		Oscillatoria sp.						
		Pseudoanabaena sp?		<04	4.0			
		Unidentified filamentous						
		SUM	**0**	**0**	**4**	**1.33**	**1.33**	**0.17**
Pyrrhophyta	Dinokontae	*Amphidinium* sp?						
		Alexandrium sp?			<0.4			
		Ceratium sp.						
		Cochlodinium sp?						
		Dinophysis acuminata	2.4	1.2	0.4			
		Dinophysis norvegica	<0.4	0.4	<0.4			
		Gymnodinium spp.		<0.4				
		Heterocapsa sp?						
		Nematodinium sp?		0.4	0.4			
		Prorocentrum sp?						
		Scrippsiella sp.	<0.4		<0.4			
		Unidentified armoured	0.8	1.2	1.2			
		Unidentified unarmoured	0.8	1.2	0.8			
		SUM	**4**	**4.4**	**2.8**	**3.73**	**0.48**	**0.49**
Unidentified Flagellates			124.8	124.8	124.8			
Unidentified Cysts			<0.4	0.4	0.4			
Sp. A			278.4	268.8	259.2			
		SUM	**403.2**	**394**	**384.4**	**393.87**	**5.43**	**51.21**
		TOTAL SUM	**741.6**	**836.6**	**729.2**	**769.13**	**33.92**	**100.00**
Protozoa		*Ebria sp.*	<0.4	<0.4	<0.4			
		Tintinnids	<0.4	<0.4	1.2			
		Ciliates	4.8	4.0	6.8			

Synonyms:
Cylindrotheca closterium = Nitzschia closterium
Diatoma tenuis = Diatoma elongatum
Entomoneis = Amphiprora

(continued)

Appendix 3.4-2
Phytoplankton Taxonomy and Abundance at the Surface of Stations 1 to 5, Bathurst Inlet, August 2001 (continued)

			Cell Density cells / mL					
FES Sample Number			**010383**	**010384**	**010385**	**Mean**	**SE**	**Percent**
Sampling Station			**Stn 4**	**Stn 4**	**Stn 4**			
Sample Replicate			**A**	**B**	**C**			
Sampling Date			**15-Aug-01**	**15-Aug-01**	**15-Aug-01**			
Volume analyzed (mL)			**100**	**100**	**100**			
Phylum	Order	Genera and Species						
Bacillariophyceae	Centrales	*Chaetoceros sp.*		<0.4	<0.4			
		Chaetoceros resting spores						
		Coscinodiscus spp.			<0.4			
		Melosira arctica.	<0.4					
		Melosira resting spores	<0.4					
		Thalassiosira cf. *psuedonana*	1.2	1.2	12.0			
		Unidentified resting spore			0.4			
		Unidentified						
	Pennales	*Achnanthes* spp.			<0.4			
		Amphora sp.	<0.4	<0.4	0.4			
		Caloneis sp.						
		Cocconeis sp.		<0.4				
		Cymbella sp.						
		Diatoma elongatum	<0.4	<0.4	0.4			
		Diploneis sp.						
		Entomoneis sp.						
		Fragilaria spp.						
		Gomphonema sp.						
		Hantzschia sp.						
		Licmophora sp.		<0.4				
		Mastogloia sp.	<0.4					
		Navicula spp.	0.4	0.8	0.4			
		Nizschia closterium	<0.4	<0.4	<0.4			
		Nizschia spp.	<0.4	<0.4	0.4			
		Pleurosigma/Gyrosigma spp.						
		Rhoicosphenia curvata						
		Surirella sp.						
		Synedra ulna	0.4	<0.4	<0.4			
		Synedra spp.	0.4	0.8	0.4			
		Pennate girdle view	<0.4		<0.4			
		SUM	**2.4**	**2.8**	**14.4**	**6.53**	**3.94**	**0.82**
Chlorophyta	Chlorococcales	*Ankistrodesmus* spp.	<0.4	0.4	<0.4			
		Chlorella sp?	134.4	172.8	105.6			
		Scenedesmus sp.						
	Ulothricales	*Ulothrix sp.*						
	Volvocales	*Pyramimonas* spp.	19.2	28.8	57.6			
Chlorophyta		Unidentified Flagellates	9.6	9.6	19.2			
		Unidentified Filamentous	<0.4					
		SUM	**163.2**	**211.6**	**182.4**	**185.73**	**14.07**	**23.20**
Chrysophyta	Dictyochales	*Dictyocha speculum*						
	Ochromonadales	*Dinobryon sp.*			<0.4			
		Calycomonas sp.		9.6	9.0			
Chrysophyta		Unidentified flagellates	19.2	28.8	38.4			
		SUM	**19.2**	**38.4**	**47.4**	**35.00**	**8.32**	**4.37**
Cryptophyta	Cryptomonadales	*Plagioselmis cf. prolonga*	105.6	76.8	115.2			
		Plagioselmis sp.	19.2	4.0	9.6			
		Teleaux sp. poss.	<0.4	0.4	9.0			
		Unidentified flagellates	28.8	19.2	63.0			
		SUM	**153.6**	**100.4**	**196.8**	**150.27**	**27.88**	**18.77**
Cyanophyta		*Anabaena sp.*						
		Merismopedia sp.	<0.4		<0.4			
		Oscillatoria sp.		<0.4	<0.4			
		Pseudoanabaena sp?	3.2	<0.4	<0.4			
		Unidentified filamentous						
		SUM	**3.2**	**0**	**0**	**1.07**	**1.07**	**0.13**
Pyrrhophyta	Dinokontae	*Amphidinium* sp?	<0.4					
		Alexandrium sp?						
		Ceratium sp.		<0.4				
		Cochlodinium sp?			<0.4			
		Dinophysis acuminata	0.4	0.8	0.8			
		Dinophysis norvegica	<0.4	<0.4	0.4			
		Gymnodinium spp.	<0.4	<0.4	<0.4			
		Heterocapsa sp?			<0.4			
		Nematodinium sp?		<0.4	<0.4			
		Prorocentrum sp?						
		Scrippsiella sp.						
		Unidentified armoured	0.8	0.8	1.2			
		Unidentified unarmoured	0.4	0.8	1.2			
		SUM	**1.6**	**2.4**	**3.6**	**2.53**	**0.58**	**0.32**
Unidentified Flagellates			134.4	115.2	153.6			
Unidentified Cysts			0.4	0.4	0.4			
Sp. A			240.0	297.6	316.8			
		SUM	**374.8**	**413.2**	**470.8**	**419.60**	**27.90**	**52.40**
		TOTAL SUM	**718**	**768.8**	**915.4**	**800.73**	**59.18**	**100.00**
Protozoa		*Ebria sp.*	<0.4	0.4	<0.4			
		Tintinnids	0.4	<0.4	0.8			
		Ciliates	5.2	5.2	8.4			

Synonyms:
Cylindrotheca closterium = Nitzschia closterium
Diatoma tenuis = Diatoma elongatum
Entomoneis = Amphiprora

(continued)

Appendix 3.4-2
Phytoplankton Taxonomy and Abundance at the Surface of Stations 1 to 5, Bathurst Inlet, August 2001 (completed)

			Cell Density cells / mL					
FES Sample Number			**010386**	**010387**	**010388**	**Mean**	**SE**	**Percent**
Sampling Station			**Stn 5**	**Stn 5**	**Stn 5**			
Sample Replicate			**A**	**B**	**C**			
Sampling Date			**15-Aug-01**	**15-Aug-01**	**15-Aug-01**			
Volume analyzed (mL)			**100**	**100**	**100**			
Phylum	Order	Genera and Species						
Bacillariophyceae	Centrales	*Chaetoceros sp.*			<0.4			
		Chaetoceros resting spores						
		Coscinodiscus spp.	<0.4		<0.4			
		Melosira arctica.						
		Melosira resting spores	<0.4					
		Thalassiosira cf. *psuedonana*	0.8	9.0	2.4			
		Unidentified resting spore						
		Unidentified			<0.4			
	Pennales	*Achnanthes* spp.			<0.4			
		Amphora sp.	<0.4					
		Caloneis sp.						
		Cocconeis sp.						
		Cymbella sp.						
		Diatoma elongatum	0.4	0.4	<0.4			
		Diploneis sp.	<0.4					
		Entomoneis sp.			<0.4			
		Fragilaria spp.		<0.4				
		Gomphonema sp.	<0.4					
		Hantzschia sp.			<0.4			
		Licmophora sp.						
		Mastogloia sp.	<0.4		<0.4			
		Navicula spp.	1.2	0.4	1.6			
		Nizschia closterium	0.4	<0.4	0.4			
		Nizschia spp.		0.4	<0.4			
		Pleurosigma/Gyrosigma spp.		<0.4	<0.4			
		Rhoicosphenia curvata						
		Surirella sp.						
		Synedra ulna	0.4	<0.4	0.4			
		Synedra spp.	<0.4	0.8	0.4			
		Pennate girdle view	<0.4	<0.4	<0.4			
		SUM	**3.2**	**11**	**5.2**	**6.47**	**2.34**	**0.66**
Chlorophyta	Chlorococcales	*Ankistrodesmus* spp.			<0.4			
		Chlorella sp?	329.6	115.2	163.2			
		Scenedesmus sp.						
	Ulothricales	*Ulothrix sp.*						
	Volvocales	*Pyramimonas* spp.	57.6	38.4	57.6			
Chlorophyta		Unidentified Flagellates	19.2	19.2	19.2			
		Unidentified Filamentous						
		SUM	**406.4**	**172.8**	**240**	**273.07**	**69.43**	**27.85**
Chrysophyta	Dictyochales	*Dictyocha speculum*	<0.4		<0.4			
	Ochromonadales	*Dinobryon sp.*						
		Calycomonas sp.	19.2	9.6	19.2			
Chrysophyta		Unidentified flagellates	19.2	19.2	19.2			
		SUM	**38.4**	**28.8**	**38.4**	**35.20**	**3.20**	**3.59**
Cryptophyta	Cryptomonadales	*Plagioselmis cf. prolonga*	192.0	163.2	96.0			
		Plagioselmis sp.	9.6	6.0	9.6			
		Teleaux sp. poss.	9.6	6.0	0.8			
		Unidentified flagellates	67.2	76.8	48.0			
		SUM	**278.4**	**252.0**	**154.4**	**228.27**	**37.71**	**23.28**
Cyanophyta		*Anabaena sp.*			<0.4			
		Merismopedia sp.						
		Oscillatoria sp.						
		Pseudoanabaena sp?	<0.4		3.6			
		Unidentified filamentous						
		SUM	**0**	**0**	**3.6**	**1.20**	**1.20**	**0.12**
Pyrrhophyta	Dinokontae	*Amphidinium* sp?	0.4					
		Alexandrium sp?			<0.4			
		Ceratium sp.	<0.4					
		Cochlodinium sp?						
		Dinophysis acuminata	0.4	0.8	0.4			
		Dinophysis norvegica	<0.4	<0.4	<0.4			
		Gymnodinium spp.	0.4	<0.4				
		Heterocapsa sp?		<0.4				
		Nematodinium sp?		<0.4	<0.4			
		Prorocentrum sp?						
		Scrippsiella sp.		<0.4				
		Unidentified armoured	1.2	1.2	1.2			
		Unidentified unarmoured	1.6	0.8	2.0			
		SUM	**4**	**2.8**	**3.6**	**3.47**	**0.35**	**0.35**
Unidentified Flagellates			172.8	144.0	144.0			
Unidentified Cysts			0.8	1.2	0.4			
Sp. A			249.6	278.4	307.2			
		SUM	**423.2**	**423.6**	**451.6**	**432.80**	**9.40**	**44.14**
		TOTAL SUM	**1153.6**	**891**	**896.8**	**980.47**	**86.58**	**100.00**
Protozoa		*Ebria sp.*	<0.4	<0.4	<0.4			
		Tintinnids	<0.4	<0.4	<0.4			
		Ciliates	6.0	7.2	11.2			

Synonyms:
Cylindrotheca closterium = Nitzschia closterium
Diatoma tenuis = Diatoma elongatum
Entomoneis = Amphiprora

APPENDIX 3.5-1
ZOOPLANKTON TAXONOMY AND ABUNDANCE AT STATIONS 1 TO 5, BATHURST INLET, AUGUST 2001

Appendix 3.5-1
Zooplankton Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001

Location		Stn 1					Stn 2					Stn 3					Stn 4					Stn 5				
Depth		0-35 m					0-15 m					0-30 m					0-40 m					0-65 m				
Date		14-Aug-01					14-Aug-01					14-Aug-01					14-Aug-01					14-Aug-01				
Replicate		A	B	C	Mean	Percent	A	B	C	Mean	Percent	A	B	C	Mean	Percent	A	B	C	Mean	Percent	A	B	C	Mean	Percent
Sample No.		01951	01952	01953			01954	01955	01956			01957	01958	01959			01960	01961	01962			01963	01964	01965		
Volume Sampled (m^3)		5.673	6.068	5.445			3.064318	2.547689	3.636661			5.267587	5.424602	4.756024			6.706044	5.449927	6.685784			10.50478	9.111913	10.09959		
Species/Group	Stage	Abundance (organisms/m^3)					Abundance (organisms/m^3)					Abundance (organisms/m^3)					Abundance (organisms/m^3)					Abundance (organisms/m^3)				
COELENTERATA	**SUM**	**2.64**	**2.64**	**4.04**	**3.11**	**0.03**	**3.59**	**5.10**	**3.02**	**3.91**	**0.04**	**7.78**	**5.16**	**4.42**	**5.79**	**0.05**	**4.03**	**6.97**	**5.98**	**5.66**	**0.06**	**5.05**	**6.69**	**2.77**	**4.84**	**0.09**
Aeginopsis laurentii		1.41	1.98	2.20	1.86	0.02	0.98	4.71	1.92	2.54	0.02	2.09	2.03	1.26	1.79	0.02	1.19	2.39	1.94	1.84	0.02	1.05	1.21	1.49	1.25	0.02
Aglantha digitale		1.06	0.49	1.65	1.07	0.01	2.61	0.39	1.10	1.37	0.01	5.70	2.95	2.94	3.86	0.04	2.68	4.59	3.74	3.67	0.04	3.81	5.49	1.29	3.53	0.06
Euphysa flammea		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.03	0.00
Plotocnide borealis		0.00	0.00	0.18	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unidentified	juv	0.18	0.16	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.21	0.13	0.00	0.15	0.00	0.30	0.15	0.00	0.10	0.00	0.00	0.03	0.00
POLYCHAETA	**SUM**	**88.14**	**131.84**	**56.93**	**92.31**	**0.83**	**6.53**	**27.48**	**8.25**	**14.08**	**0.13**	**26.58**	**38.71**	**46.26**	**37.18**	**0.34**	**74.56**	**128.44**	**134.61**	**112.54**	**1.18**	**20.94**	**32.92**	**79.21**	**44.36**	**0.80**
POLYCHAETA	L	88.14	131.84	56.93	92.31	0.83	6.53	27.48	8.25	14.08	0.13	26.58	38.71	46.26	37.18	0.34	74.56	128.44	134.61	112.54	1.18	20.94	32.92	79.21	44.36	0.80
CALANOIDA	**SUM**	**50997.80**	**10268.09**	**11092.01**	**9789.24**	**88.34**	**47489.31**	**11893.61**	**9471.75**	**8621.14**	**81.13**	**47911.39**	**11558.78**	**12876.86**	**9780.20**	**89.82**	**45545.64**	**11159.97**	**10950.88**	**8212.55**	**86.31**	**43511.73**	**7021.01**	**7151.15**	**4881.72**	**87.76**
Acartia clausi	M	52.88	98.88	36.73	62.83	0.57	130.53	157.01	109.99	132.51	1.25	7.59	55.30	21.03	27.97	0.26	59.65	36.70	0.00	32.12	0.34	28.56	13.17	8.91	16.88	0.30
Acartia clausi	F	2115.36	807.53	569.34	1164.08	10.50	1925.39	2629.83	1622.37	2059.20	19.38	151.87	571.47	714.88	479.41	4.40	253.50	201.84	194.44	216.59	2.28	76.16	47.19	118.82	80.72	1.45
Acartia longiremis	M	0.00	0.00	0.00	0.00	0.00	0.00	3.93	5.50	3.14	0.03	3.80	1.84	21.03	8.89	0.08	0.00	0.00	29.91	9.97	0.10	0.00	3.29	0.99	1.43	0.03
Acartia longiremis	F	0.00	0.00	0.00	0.00	0.00	0.00	39.25	2.75	14.00	0.13	7.59	7.37	4.21	6.39	0.06	0.00	55.05	14.96	23.33	0.25	9.52	3.29	1.98	4.93	0.09
Acartia sp.	V	70.51	214.24	55.10	113.28	1.02	97.90	117.75	219.98	145.21	1.37	56.95	18.43	21.03	32.14	0.30	0.00	36.70	59.83	32.18	0.34	19.04	21.95	39.61	26.86	0.48
Acartia sp.	IV	0.00	0.00	0.00	0.00	0.00	65.27	78.50	55.00	66.26	0.62	18.98	73.74	105.13	65.95	0.61	0.00	18.35	14.96	11.10	0.12	0.00	0.00	0.00	0.00	0.00
Acartia sp.	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.00	18.33	0.17	0.00	36.87	21.03	19.30	0.18	0.00	18.35	44.87	21.07	0.22	0.00	0.00	0.00	0.00	0.00
Calanus glacialis	V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.04	0.00
Calanus glacialis	IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.10	0.07	0.00
Calanus glacialis	III	0.18	0.49	0.37	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.05	0.00	0.00	0.22	0.10	0.11	0.00
Calanus hyperboreus	V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.03	0.00
Calanus hyperboreus	IV	0.00	0.00	0.18	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.03	0.00
Calanus hyperboreus	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.37	0.00	0.17	0.00	0.10	0.00	0.20	0.10	0.00
Calanus sp.	II	5.29	4.94	0.73	3.66	0.03	0.65	1.57	2.75	1.66	0.02	0.19	0.92	0.00	0.37	0.00	1.49	1.10	5.98	2.86	0.03	1.43	2.19	1.68	1.77	0.03
Calanus sp.	I	0.00	16.48	55.10	23.86	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.06	0.00	0.00	36.70	7.48	14.73	0.15	2.86	2.19	0.00	1.68	0.03
Centropages abdominalis	M	49.36	32.96	49.59	43.97	0.40	9.46	2.75	7.70	6.64	0.06	96.82	97.70	84.10	92.88	0.85	70.09	53.21	62.82	62.04	0.65	40.93	37.31	33.66	37.30	0.67
Centropages abdominalis	F	47.60	19.78	45.91	37.76	0.34	3.26	7.46	4.95	5.22	0.05	79.73	47.93	84.10	70.59	0.65	37.28	58.72	55.34	50.45	0.53	19.99	17.56	17.82	18.46	0.33
Centropages abdominalis	V	52.88	64.27	62.44	59.87	0.54	29.37	51.03	30.25	36.88	0.35	64.55	53.46	147.18	88.40	0.81	89.47	128.44	79.27	99.06	1.04	32.37	53.78	41.59	42.58	0.77
Centropages abdominalis	IV	21.15	8.24	11.02	13.47	0.12	22.84	47.10	46.75	38.90	0.37	26.58	25.81	42.05	31.48	0.29	59.65	55.05	44.87	53.19	0.56	2.86	7.68	39.61	16.71	0.30
Centropages abdominalis	III	0.00	0.00	36.73	12.24	0.11	261.07	314.01	274.98	283.35	2.67	75.94	36.87	168.21	93.67	0.86	89.47	110.09	59.83	86.46	0.91	19.04	43.90	49.51	37.48	0.67
Centropages abdominalis	II	0.00	0.00	0.00	0.00	0.00	163.17	274.76	109.99	182.64	1.72	56.95	36.87	210.26	101.36	0.93	0.00	0.00	44.87	14.96	0.16	57.12	10.97	29.70	32.60	0.59
Tortanus discaudatus	M	1.76	0.00	0.55	0.77	0.01	0.00	0.00	0.00	0.00	0.00	0.57	0.55	1.05	0.72	0.01	0.75	0.18	0.30	0.41	0.00	0.48	0.44	0.40	0.44	0.01
Tortanus discaudatus	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tortanus discaudatus	V	5.29	0.00	1.84	2.38	0.02	1.96	1.18	2.75	1.96	0.02	1.71	3.69	0.63	2.01	0.02	0.60	0.92	5.98	2.50	0.03	2.86	1.87	1.88	2.20	0.04
Tortanus discaudatus	IV	0.00	0.00	0.00	0.00	0.00	0.00	3.93	2.75	2.22	0.02	0.00	3.69	0.00	1.23	0.01	0.00	3.67	1.50	1.72	0.02	0.19	10.97	1.98	4.38	0.08
Tortanus discaudatus	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	0.00	0.00	0.50	0.01	0.00	0.00	0.99	0.33	0.01
Tortanus discaudatus	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.91	0.00	0.00	4.97	0.05	0.00	0.00	0.00	0.00	0.00
Aetididae	V	0.00	0.00	0.37	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aetididae	IV	0.00	0.00	0.55	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.05	0.00	0.00	0.00	0.30	0.10	0.00
Aetididae	III	0.00	16.48	0.18	5.55	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.07	0.00	0.45	5.50	0.30	2.08	0.02	0.67	0.99	1.09	0.91	0.02
Aetididae	II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.70	0.01	0.00	3.67	0.00	1.22	0.01	0.00	10.97	0.10	3.69	0.07
Eurytemora herdmani	M	17.63	49.44	9.18	25.42	0.23	22.84	51.03	44.00	39.29	0.37	9.49	3.69	4.21	5.79	0.05	2.98	1.83	1.50	2.10	0.02	28.56	5.49	3.96	12.67	0.23
Eurytemora herdmani	F	0.35	3.30	22.04	8.56	0.08	2.61	31.40	24.75	19.59	0.18	5.70	73.74	8.41	29.28	0.27	8.95	9.17	10.47	9.53	0.10	3.81	10.97	4.95	6.58	0.12
Eurytemora herdmani	V	0.00	0.00	1.84	0.61	0.01	0.00	0.00	5.50	1.83	0.02	0.00	18.43	0.00	6.14	0.06	0.00	0.00	14.96	4.99	0.05	0.00	1.10	0.00	0.37	0.01
Metridia longa	V	0.00	0.16	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.20	0.13	0.00
Limnocalanus macrurus	M	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.27	0.22	0.00	0.00	0.00	0.21	0.07	0.00	0.00	0.00	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00
Limnocalanus macrurus	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.09	0.00	0.00	0.00	0.21	0.07	0.00	0.15	0.00	0.30	0.15	0.00	0.00	0.22	0.20	0.14	0.00
Limnocalanus macrurus	V	0.00	0.00	0.18	0.06	0.00	0.33	0.00	0.27	0.20	0.00	0.19	0.18	0.00	0.12	0.00	0.00	0.00	0.60	0.20	0.00	0.00	0.00	0.20	0.07	0.00
Limnocalanus macrurus	IV	0.00	1.65	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.03	0.00
Microcalanus pygmaeus	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.52	3.29	19.80	10.87	0.20
Microcalanus pygmaeus	V	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.96	4.99	0.05	9.52	0.00	0.00	3.17	0.06
Pseudocalanus minutus	M	564.10	576.81	1193.79	778.23	7.02	554.77	667.27	577.45	599.83	5.64	702.41	663.64	820.01	728.69	6.69	596.48	880.75	822.64	766.62	8.06	390.30	548.73	346.55	428.53	7.70
Pseudocalanus minutus	F	775.63	543.85	1010.13	776.54	7.01	358.97	235.51	148.49	247.66	2.33	892.25	903.29	1051.30	948.95	8.71	775.42	1027.54	1061.95	954.97	10.04	437.90	482.88	534.68	485.15	8.72
Pseudocalanus minutus	V	282.05	247.20	642.81	390.69	3.53	358.97	314.01	522.46	398.48	3.75	854.28	847.99	693.86	798.71	7.33	551.74	935.79	583.33	690.29	7.25	285.58	449.96	297.04	344.20	6.19
Pseudocalanus minutus	IV	2644.20	2142.44	1744.76	2177.13	19.65	1240.08	1256.04	824.93	1107.02	10.42	2259.10	2341.19	2670.30	2423.53	22.26	1789.43	2770.68	2557.67	2372.59	24.93	1085.22	1262.08	1514.91	1287.41	23.15
Pseudocalanus minutus	III	3173.04	2472.04	2479.40	2708.16	24.44	1860.12	2512.08	1787.35	2053.18	19.32	2259.10	2285.88	2691.32	2412.10	22.15	1550.84	1779.84	2198.70	1843.13	19.37	1208.97	1305.98	1316.89	1277.28	22.96
Pseudocalanus minutus	II	1586.52	988.82	550.98	1042.11	9.40	881.11	785.03	522.46	729.53	6.87	740.38	626.77	483.60	616.92	5.67	253.50	422.02	418.80	364.78	3.83	295.10	329.24	435.66	353.33	6.35
Pseudocalanus minutus	I	0.00	0.00	91.83	30.61	0.28	130.53	0.00	27.50	52.68	0.50	18.98	0.00	21.03	13.34	0.12	44.74	55.05	59.83	53.20	0.56	9.52	43.90	9.90	21.11	0.38
Spinocalanus sp.	F	0.00	0.00	0.37	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.04	2.19	1.98	7.74	0.14
Spinocalanus sp.	V	0.00	0.00	0.37	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.43	21.03	13.15	0.12	0.00	0.00	0.00	0.00	0.00	9.52	4.39	0.99	4.97	0.09

(continued)

Appendix 3.5-1
Zooplankton Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001 (completed)

Location		Stn 1					Stn 2					Stn 3					Stn 4					Stn 5				
Depth		0-35 m					0-15 m					0-30 m					0-40 m					0-65 m				
Date		14-Aug-01					14-Aug-01					14-Aug-01					14-Aug-01					14-Aug-01				
Replicate		A	B	C	Mean	Percent	A	B	C	Mean	Percent	A	B	C	Mean	Percent	A	B	C	Mean	Percent	A	B	C	Mean	Percent
Sample No.		01951	01952	01953			01954	01955	01956			01957	01958	01959			01960	01961	01962			01963	01964	01965		
Volume Sampled (m^3)		5.673	6.068	5.445			3.064318	2.547689	3.636661			5.267587	5.424602	4.756024			6.706044	5.449927	6.685784			10.50478	9.111913	10.09959		
Species/Group	Stage	Abundance (organisms/m^3)					Abundance (organisms/m^3)					Abundance (organisms/m^3)					Abundance (organisms/m^3)					Abundance (organisms/m^3)				
Calanoida	IV	35.26	0.00	91.83	42.36	0.38	0.33	0.00	2.75	1.03	0.01	94.92	18.43	21.03	44.79	0.41	0.00	9.17	59.83	23.00	0.24	28.56	76.82	69.31	58.23	1.05
Calanoida	III	35.26	0.00	36.73	24.00	0.22	97.90	39.25	27.50	54.88	0.52	18.98	184.35	231.29	144.87	1.33	14.91	73.40	194.44	94.25	0.99	114.23	54.87	69.31	79.47	1.43
Calanoida	II	17.63	0.00	183.66	67.10	0.61	97.90	196.26	329.97	208.04	1.96	265.78	405.56	357.44	342.93	3.15	134.21	311.93	194.44	213.53	2.24	114.23	131.70	99.01	114.98	2.07
Calanoida	I	352.56	0.00	91.83	148.13	1.34	97.90	78.50	109.99	95.46	0.90	56.95	129.04	126.16	104.05	0.96	59.65	55.05	29.91	48.20	0.51	47.60	32.92	29.70	36.74	0.66
Calanoida	naup	17.63	0.00	55.10	24.24	0.22	0.00	39.25	2.75	14.00	0.13	3.80	1.84	63.08	22.91	0.21	0.00	36.70	29.91	22.20	0.23	9.52	10.97	29.70	16.73	0.30
MONSTRILLOIDA	**SUM**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.18**	**0.00**	**0.06**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Monstrilla sp.	F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CYCLOPOIDA	**SUM**	**299.68**	**379.05**	**532.61**	**403.78**	**3.64**	**32.63**	**0.00**	**27.50**	**20.04**	**0.19**	**246.79**	**276.52**	**231.29**	**251.53**	**2.31**	**342.97**	**477.07**	**493.58**	**437.88**	**4.60**	**228.47**	**307.29**	**336.65**	**290.80**	**5.23**
Oithona similis	M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.98	0.00	0.00	6.33	0.06	0.00	0.00	0.00	0.00	0.00	0.00	21.95	9.90	10.62	0.19
Oithona similis	F	229.16	329.61	367.32	308.70	2.79	32.63	0.00	27.50	20.04	0.19	151.87	202.78	210.26	188.30	1.73	178.94	330.28	299.14	269.45	2.83	171.35	197.54	257.44	208.78	3.75
Oncaea borealis	M	0.00	0.00	36.73	12.24	0.11	0.00	0.00	0.00	0.00	0.00	18.98	0.00	0.00	6.33	0.06	0.00	0.00	14.96	4.99	0.05	9.52	10.97	0.00	6.83	0.12
Oncaea borealis	F	70.51	49.44	128.56	82.84	0.75	0.00	0.00	0.00	0.00	0.00	56.95	73.74	21.03	50.57	0.46	164.03	146.79	179.49	163.44	1.72	47.60	76.82	69.31	64.58	1.16
HARPACTICOIDA	**SUM**	**0.00**	**0.16**	**0.00**	**0.05**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Harpacticus uniremis	F	0.00	0.16	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CLADOCERA	**SUM**	**810.89**	**527.37**	**955.03**	**764.43**	**6.90**	**2088.56**	**2237.32**	**1512.38**	**1946.08**	**18.31**	**759.36**	**866.42**	**735.91**	**787.23**	**7.23**	**536.83**	**825.70**	**822.64**	**728.39**	**7.65**	**428.38**	**307.29**	**237.63**	**324.43**	**5.83**
Podon leuckarti		475.96	379.05	642.81	499.27	4.51	1207.45	1138.29	1044.91	1130.22	10.64	626.47	479.30	525.65	543.81	4.99	283.33	513.77	523.50	440.20	4.63	314.14	219.49	158.42	230.69	4.15
Evadne nordmanni		334.93	148.32	312.22	265.16	2.39	881.11	1099.04	467.46	815.87	7.68	132.89	387.13	210.26	243.42	2.24	253.50	311.93	299.14	288.19	3.03	114.23	87.80	79.21	93.75	1.69
CIRRIPEDIA	**SUM**	**17.80**	**1.81**	**0.18**	**6.54**	**0.06**	**1.96**	**7.85**	**1.37**	**3.29**	**0.03**	**7.78**	**7.37**	**6.31**	**4.62**	**0.04**	**1.49**	**11.01**	**4.64**	**5.22**	**0.05**	**2.38**	**7.68**	**4.95**	**4.85**	**0.09**
Cirripedia	nauplius	0.18	1.65	0.18	0.61	0.01	1.31	3.93	0.27	1.40	0.01	7.59	3.69	4.21	2.63	0.02	1.49	5.50	4.49	3.33	0.04	0.48	5.49	2.97	2.82	0.05
Cirripedia	cyprid	17.63	0.16	0.00	5.93	0.05	0.65	3.93	1.10	1.89	0.02	0.19	3.69	2.10	1.99	0.02	0.00	5.50	0.15	1.88	0.02	1.90	2.19	1.98	2.03	0.04
ISOPODA	**SUM**	**0.00**	**0.16**	**0.18**	**0.12**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.37**	**2.10**	**0.82**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.11**	**0.00**	**0.04**	**0.00**
ISOPODA	juvenile	0.00	0.16	0.18	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	2.10	0.82	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.04	0.00
AMPHIPODA	**SUM**	**0.18**	**0.00**	**0.37**	**0.18**	**0.00**	**0.00**	**0.39**	**0.00**	**0.13**	**0.00**	**0.19**	**0.55**	**0.42**	**0.39**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.29**	**0.22**	**0.20**	**0.23**	**0.00**
Hyperiidae	juvenile	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hyperia galba		0.00	0.00	0.37	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.55	0.21	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.11	0.10	0.10	0.00
Parathemisto abysssorum		0.18	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.11	0.10	0.13	0.00
Oedicerotidae		0.00	0.00	0.00			0.00	0.00	0.00			0.00	0.00	0.00			0.00	0.00	0.00			0.00	0.00	0.00		
Podoceros falcatus		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EUPHAUSIACEA	**SUM**	**0.00**	**0.00**	**0.18**	**0.06**	**0.00**	**0.00**	**0.00**	**5.50**	**1.83**	**0.02**	**0.00**	**0.18**	**0.00**	**0.06**	**0.00**	**0.30**	**0.18**	**0.15**	**0.21**	**0.00**	**0.10**	**0.11**	**0.20**	**0.13**	**0.00**
EUPHAUSIACEA	furcilia	0.00	0.00	0.18	0.06	0.00	0.00	0.00	5.50	1.83	0.02	0.00	0.18	0.00	0.06	0.00	0.30	0.18	0.15	0.21	0.00	0.10	0.11	0.20	0.13	0.00
DECAPODA	**SUM**	**0.00**	**0.16**	**0.00**	**0.05**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.19**	**0.37**	**0.63**	**0.40**	**0.00**	**0.15**	**0.37**	**0.15**	**0.22**	**0.00**	**0.10**	**0.00**	**0.20**	**0.10**	**0.00**
Brachyura	zoea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.18	0.42	0.26	0.00	0.15	0.18	0.15	0.16	0.00	0.10	0.00	0.00	0.03	0.00
Hippolytidae	juv	0.00	0.16	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.21	0.13	0.00	0.00	0.18	0.00	0.06	0.00	0.00	0.00	0.20	0.07	0.00
MOLLUSCA	**SUM**	**17.63**	**0.82**	**0.55**	**6.33**	**0.06**	**0.65**	**7.85**	**3.02**	**3.84**	**0.04**	**0.38**	**9.59**	**17.24**	**9.07**	**0.08**	**0.15**	**6.24**	**0.15**	**2.18**	**0.02**	**1.90**	**3.40**	**4.75**	**3.35**	**0.06**
Gastropoda	L	17.63	0.82	0.37	6.27	0.06	0.33	0.00	0.27	0.20	0.00	0.19	0.37	0.42	0.33	0.00	0.15	0.73	0.15	0.34	0.00	0.00	0.11	0.79	0.30	0.01
Bivalvia	V	0.00	0.00	0.18	0.06	0.00	0.33	7.85	2.75	3.64	0.03	0.19	9.22	16.82	8.74	0.08	0.00	5.50	0.00	1.83	0.02	1.90	3.29	3.96	3.05	0.05
CHAETOGNATHA	**SUM**	**10.58**	**11.54**	**23.88**	**15.33**	**0.14**	**1.63**	**27.48**	**4.95**	**11.35**	**0.11**	**18.98**	**7.19**	**9.04**	**11.74**	**0.11**	**10.44**	**16.51**	**5.23**	**10.73**	**0.11**	**7.62**	**8.78**	**5.94**	**7.45**	**0.13**
Eukrohnia hamata		0.00	0.00	0.00	0.00	0.00	0.33	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sagitta elegans		10.58	11.54	23.88	15.33	0.14	1.31	27.48	4.95	11.24	0.11	18.98	7.19	9.04	11.74	0.11	10.44	16.51	5.23	10.73	0.11	7.62	8.78	5.94	7.45	0.13
LARVACEA	**SUM**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.39**	**0.00**	**0.13**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Oikopleura vanhoeffeni		0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FISH	**SUM**	**0.18**	**0.00**	**0.00**	**0.06**	**0.00**	**0.00**	**0.39**	**0.00**	**0.13**	**0.00**	**0.00**	**0.18**	**0.00**	**0.06**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Clupeidae	L	0.18	0.00	0.00	0.06	0.00	0.00	0.39	0.00	0.13	0.00	0.00	0.18	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Abundance (organisms/m^3)		13171.83	9365.58	10707.53	11081.59	100.00	10550.80	12250.32	9078.11	10625.97	100.00	9900.17	10808.17	11966.72	10889.15	100.00	7432.85	10666.01	10449.34	9515.57	100.00	5116.43	5722.40	5848.56	5562.30	100.00

APPENDIX 3.6-1
BENTHOS TAXONOMY AND ABUNDANCE AT STATIONS 1 TO 5, BATHURST INLET, AUGUST 2001 AND 2002

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Appendix 3.6-1
Benthos Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002

Location		Station 1					Station 2				
Date		06-Aug-02					06-Aug-02				
Replicate		1236	1238	1240	Mean Abundance	Mean Composition	1242	1244	1246	Mean Abundance	Mean Composition
Sample No.		(counts as ind./sample)			(ind./m2)	(%)	(counts as ind./sample)			(ind./m2)	(%)
Species/Group	Stage										
Egg, unid					0	0		1	4	72.13758079	1.149425287
FORAMINIFERA					0	0				0	0
Milliamina sp					0	0				0	0
cf Nonion sp			1		14.42751616	0.8	2	8	42	750.2308403	11.95402299
Cornuspira sp		1	1		28.85503232	1.6	2	4	2	115.4201293	1.83908046
Globigerina					0	0				0	0
Hippocrepinella sp					0	0				0	0
Rheophax sp					0	0		5		72.13758079	1.149425287
PORIFERA					0	0				0	0
Porifera	dam			1	14.42751616	0.8				0	0
CNIDARIA					0	0				0	0
Zoantheria?					0	0			1	14.42751616	0.229885057
NEMERTEA	dam				0	0		1	8	129.8476454	2.068965517
Micrura sp		1	1		28.85503232	1.6		1		14.42751616	0.229885057
NEMATODA		1	2		43.28254848	2.4		14	48	894.5060018	14.25287356
SIPUNCULA					0	0				0	0
Golfingia sp		1			14.42751616	0.8	1			14.42751616	0.229885057
ANNELIDA					0	0				0	0
Polychaeta	juv/dam	2	2	1	72.13758079	4		2	1	43.28254848	0.689655172
Ampharetidae					0	0				0	0
Samytha (cf sexcirrata)		1	3		57.71006464	3.2		2	2	57.71006464	0.91954023
Cirratulidae	juv/dam	3		1	57.71006464	3.2	2			28.85503232	0.459770115
Aphelochaeta multifilis					0	0			1	14.42751616	0.229885057
Capitellidae					0	0				0	0
Mediomastus (cf capensis)					0	0				0	0
Flabelligeridae					0	0				0	0
Brada villosa			4		57.71006464	3.2	1			14.42751616	0.229885057
Pherusa sp					0	0		5		72.13758079	1.149425287
Lumbrinereidae					0	0				0	0
Lumbrinereis similabris					0	0				0	0
Lumbrinereis tenuis		3	1		57.71006464	3.2	2	1	3	86.56509695	1.379310345
Maldanidae	juv/dam	1	2		43.28254848	2.4	1	3	2	86.56509695	1.379310345
Maldane sarsi					0	0				0	0
Nephtyidae					0	0				0	0
Nephtys cornuta		1			14.42751616	0.8	2			28.85503232	0.459770115
Aglaophamus circinata		1			14.42751616	0.8	2	1		43.28254848	0.689655172
Opheliidae					0	0				0	0
Ophelia sp			2		28.85503232	1.6		1		14.42751616	0.229885057
Orbiniidae					0	0				0	0
Scoloplos acmeceps			1		14.42751616	0.8	1	1	1	43.28254848	0.689655172
Oweniidae					0	0				0	0
Owenia fusiformis		6	1	1	115.4201293	6.4	2	1		43.28254848	0.689655172
Paraonidae					0	0				0	0
Aricidea sp	juv	2	2		57.71006464	3.2	2	14	17	476.1080332	7.586206897
Aricidea quadrilobata		4	2	2	115.4201293	6.4	7		1	115.4201293	1.83908046
Paraonella spinifera		8	2		144.2751616	8	4	4	1	129.8476454	2.068965517
Phyllodocidae					0	0				0	0
Phyllodoce arenae					0	0				0	0
Polynoidae	dam				0	0				0	0
Sabellidae	dam				0	0			1	14.42751616	0.229885057
cf Euchone rubrocincta					0	0				0	0
Sigalionidae					0	0				0	0
Pholoe minuta			2		28.85503232	1.6		2	2	57.71006464	0.91954023
Spionidae					0	0				0	0
Laonice sp		14		2	230.8402585	12.8	11	2	1	201.9852262	3.218390805
Laonice cf cirrata					0	0				0	0
Lumbrinereidae					0	0				0	0
Lumbrinereis tenuis					0	0				0	0
Lumbrinereis latreilli					0	0				0	0
Paraonidae Unid	juv/dam				0	0				0	0
Paraonella spinifera					0	0				0	0
Maldanidae Unid	dam				0	0				0	0
Clymenella sp					0	0				0	0
Ampharetidae					0	0				0	0
Samytha (cf sexcirrata)					0	0				0	0
Nereidae					0	0				0	0
Nereis sp	dam				0	0				0	0
Micronereis nanaimoensis					0	0				0	0
Syllidae					0	0				0	0
Exogone sp	juv/dam				0	0			3	43.28254848	0.689655172
Brania welfleetensis					0	0				0	0
Orbiniidae					0	0				0	0
Ophelia bicornis					0	0				0	0
Scoloplos acmeceps					0	0				0	0
cf Euchone rubrocincta					0	0				0	0
Unid fragment					0	0				0	0
Sabellidae					0	0				0	0
Sigalionidae					0	0				0	0
Pholoe minuta					0	0				0	0
Trichobranchidae					0	0				0	0
Terebellides stroemi					0	0				0	0
BRYOZOA					0	0				0	0
Eucratea loricata			1		14.42751616	0.8				0	0

(continued)

Appendix 3.6-1

Benthos Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002 (continued)

Location		Station 1					Station 2				
Date		06-Aug-02					06-Aug-02				
Replicate		1236	1238	1240	Mean Abundance	Mean Composition	1242	1244	1246	Mean Abundance	Mean Composition
Sample No.		(counts as ind./sample)			(ind./m2)	(%)	(counts as ind./sample)			(ind./m2)	(%)
Species/Group	Stage										
CRUSTACEA					0	0				0	0
Isopoda	juv/dam				0	0				0	0
cf Stentrium sp			2		28.85503232	1.6				0	0
Cumaceae					0	0				0	0
Diastylis quadrispinosa		2	1		43.28254848	2.4	2	3	1	86.56509695	1.379310345
Eudorella sp					0	0				0	0
Amphipoda, Oedocerotidae					0	0				0	0
Amphipoda, Unid J					0	0		1		14.42751616	0.229885057
Apherusa glacialis					0	0				0	0
Arrhinopsis sp					0	0				0	0
Onisimus litoralis					0	0				0	0
Arrhinopsis sp		1			14.42751616	0.8	1			14.42751616	0.229885057
Bathymedon pumilus					0	0				0	0
Hippomedon sp			3		43.28254848	2.4		3	9	173.1301939	2.75862069
Tanaidaceae					0	0				0	0
Leptognatha caeca			2		28.85503232	1.6		7	7	201.9852262	3.218390805
Tanais cavolini					0	0				0	0
Copepoda					0	0				0	0
Calanoida					0	0				0	0
Limnocalanus macrurus	M				0	0				0	0
Limnocalanus macrurus	F				0	0				0	0
Acartia clausi	F				0	0		3		43.28254848	0.689655172
Tortanus discaudata	M				0	0				0	0
Centropages hamatus	M			1	14.42751616	0.8				0	0
Centropages hamatus	F				0	0				0	0
Cyclopoida					0	0				0	0
Dermatomyzon nigripes	F				0	0				0	0
Harpacticoida	juv				0	0				0	0
Harpacticus uniremis	F				0	0				0	0
Canuella canadensis	F				0	0				0	0
Tisbidae					0	0				0	0
Tisbe furcata	F				0	0				0	0
Canthocamptidae					0	0				0	0
Ostracoda Unid			2		28.85503232	1.6		7	5	173.1301939	2.75862069
Candona					0	0				0	0
Mysidacea					0	0				0	0
Mysis litoralis					0	0				0	0
INSECTA					0	0				0	0
Diptera, Unid A	A				0	0				0	0
Anopheles	A	1	1		28.85503232	1.6	1	1	1	43.28254848	0.689655172
Simulidae					0	0				0	0
Simulium	A			1	14.42751616	0.8			2	28.85503232	0.459770115
Chironomidae					0	0				0	0
Thienemannimyia	L				0	0				0	0
Eukiefferiella	L				0	0				0	0
ECHINODERMATA					0	0				0	0
Ophiuroidea	juv				0	0				0	0
Unid amphiuridae					0	0				0	0
Holothuroidea	juv				0	0			1	14.42751616	0.229885057
Holothuroidea	dam			1	14.42751616	0.8				0	0
Unid frag	dam				0	0				0	0
MOLLUSCA					0	0				0	0
Gastropoda					0	0				0	0
Cephalaspidea	dam				0	0			1	14.42751616	0.229885057
Cylichna alba					0	0		2		28.85503232	0.459770115
Oenopota sp					0	0			1	14.42751616	0.229885057
Retusa obtusa			2		28.85503232	1.6		7	14	302.9778393	4.827586207
Bivalvia	juv/dam				0	0	1	1	3	72.13758079	1.149425287
Astarte crenata			10		144.2751616	8		29	36	937.7885503	14.94252874
Axinopsis orbiculata					0	0				0	0
Bathyarca glacialis					0	0				0	0
Macoma calcarea			4		57.71006464	3.2		2		28.85503232	0.459770115
Portlandia arctica					0	0		6	7	187.5577101	2.988505747
Portlandia lenticula			1		14.42751616	0.8		5	9	201.9852262	3.218390805
Rochefortia tumida		1	1		28.85503232	1.6				0	0
cf Rochefortia tumida					0	0				0	0
Total		37303	1297	1251	1803.43952	100	37301	1394	1484	6275.969529	100

Petite Ponar Sample Area (m2) = 0.023104

(continued)

Appendix 3.6-1
Benthos Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002 (continued)

Location		Station 3 20-Aug-02					Station 3 06-Aug-02				
Replicate / Sample No.		01966	01967	01968	Mean Abundance (ind./m2)	Mean Composition (%)	1248	1250	1252	Mean Abundance (ind./m2)	Mean Composition (%)
		(counts as ind./sample)					(counts as ind./sample)				
Species/Group	**Stage**										
Egg, unid			1		14.42751616	0.063411541				0	0
FORAMINIFERA					0	0				0	0
Milliamina sp					0	0		1		14.42751616	0.381679389
cf Nonion sp					0	0	9	24	9	605.9556787	16.03053435
Cornuspira sp				1	14.42751616	0.063411541				0	0
Globigerina		4	6	12	317.4053555	1.3950539				0	0
Hippocrepinella sp					0	0	8	43		735.8033241	19.46564885
Rheophax sp					0	0			3	43.28254848	1.145038168
PORIFERA					0	0				0	0
Porifera	dam				0	0				0	0
CNIDARIA					0	0				0	0
Zoantheria?					0	0	1			14.42751616	0.381679389
NEMERTEA	dam	1		1	28.85503232	0.126823082	1	4		72.13758079	1.908396947
Micrura sp					0	0	2			28.85503232	0.763358779
NEMATODA		300	710	250	18178.67036	79.89854153	1	1	2	57.71006464	1.526717557
SIPUNCULA					0	0				0	0
Golfingia sp		1	3	1	72.13758079	0.317057705	1	2	2	72.13758079	1.908396947
ANNELIDA					0	0				0	0
Polychaeta	juv/dam	1	1	1	43.28254848	0.190234623				0	0
Ampharetidae					0	0				0	0
Samytha (cf sexcirrata)					0	0	5	7	3	216.4127424	5.72519084
Cirratulidae	juv/dam	2	1	1	57.71006464	0.253646164				0	0
Aphelochaeta multifilis		1	1	1	43.28254848	0.190234623		1		14.42751616	0.381679389
Capitellidae					0	0				0	0
Mediomastus (cf capensis)		2			28.85503232	0.126823082				0	0
Flabelligeridae					0	0				0	0
Brada villosa					0	0				0	0
Pherusa sp					0	0				0	0
Lumbrinereidae					0	0				0	0
Lumbrinereis similabris					0	0				0	0
Lumbrinereis tenuis					0	0	1	5	2	115.4201293	3.053435115
Maldanidae	juv/dam				0	0	1	1	1	43.28254848	1.145038168
Maldane sarsi					0	0				0	0
Nephtyidae					0	0				0	0
Nephtys cornuta		6	8	4	259.6952909	1.141407736	3	4	1	115.4201293	3.053435115
Aglaophamus circinata		1	3	4	115.4201293	0.507292327	2	2	2	86.56509695	2.290076336
Opheliidae					0	0				0	0
Ophelia sp					0	0		1		14.42751616	0.381679389
Orbiniidae					0	0				0	0
Scoloplos acmeceps					0	0	1	6	2	129.8476454	3.435114504
Oweniidae					0	0				0	0
Owenia fusiformis					0	0				0	0
Paraonidae					0	0				0	0
Aricidea sp	juv				0	0	5	7	1	187.5577101	4.961832061
Aricidea quadrilobata					0	0		3		43.28254848	1.145038168
Paraonella spinifera					0	0		1	1	28.85503232	0.763358779
Phyllodocidae					0	0				0	0
Phyllodoce arenae					0	0				0	0
Polynoidae	dam				0	0				0	0
Sabellidae	dam				0	0		1		14.42751616	0.381679389
cf Euchone rubrocincta					0	0				0	0
Sigalionidae					0	0				0	0
Pholoe minuta					0	0		1		14.42751616	0.381679389
Spionidae					0	0				0	0
Laonice sp		29	49	33	1601.454294	7.03868104	5	23	2	432.8254848	11.45038168
Laonice cf cirrata					0	0	1			14.42751616	0.381679389
Lumbrinereidae					0	0				0	0
Lumbrinereis tenuis		6	8	4	259.6952909	1.141407736				0	0
Lumbrinereis latreilli		1		6	100.9926131	0.443880786				0	0
Paraonidae Unid	juv/dam	1			14.42751616	0.063411541				0	0
Paraonella spinifera		1	1	1	43.28254848	0.190234623				0	0
Maldanidae Unid	dam	1	3	5	129.8476454	0.570703868				0	0
Clymenella sp				5	72.13758079	0.317057705				0	0
Ampharetidae					0	0				0	0
Samytha (cf sexcirrata)		3	5	3	158.7026777	0.69752695				0	0
Nereidae					0	0				0	0
Nereis sp	dam	1			14.42751616	0.063411541				0	0
Micronereis nanaimoensis		1			14.42751616	0.063411541				0	0
Syllidae					0	0				0	0
Exogone sp	juv/dam	2		1	43.28254848	0.190234623		1		14.42751616	0.381679389
Brania welfleetensis			1		14.42751616	0.063411541				0	0
Orbiniidae					0	0				0	0
Ophelia bicornis			1		14.42751616	0.063411541				0	0
Scoloplos acmeceps		1	2	2	72.13758079	0.317057705				0	0
cf Euchone rubrocincta				3	43.28254848	0.190234623				0	0
Unid fragment				1	14.42751616	0.063411541				0	0
Sabellidae					0	0				0	0
Sigalionidae					0	0				0	0
Pholoe minuta			1	2	43.28254848	0.190234623				0	0
Trichobranchidae					0	0				0	0
Terebellides stroemi					0	0		1		14.42751616	0.381679389
BRYOZOA					0	0				0	0
Eucratea loricata				1	14.42751616	0.063411541		1	1	28.85503232	0.763358779

(continued)

Appendix 3.6-1

Benthos Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002 (continued)

Location		Station 3 20-Aug-02					Station 3 06-Aug-02				
Replicate / Sample No.		01966 (counts as ind./sample)	01967	01968	Mean Abundance (ind./m2)	Mean Composition (%)	1248 (counts as ind./sample)	1250	1252	Mean Abundance (ind./m2)	Mean Composition (%)
Species/Group	Stage										
CRUSTACEA					0	0				0	0
Isopoda	juv/dam				0	0			1	14.42751616	0.381679389
cf Stentrium sp					0	0				0	0
Cumaceae					0	0				0	0
Diastylis quadrispinosa		6	6	5	245.2677747	1.077996195	1	7	4	173.1301939	4.580152672
Eudorella sp				2	28.85503232	0.126823082				0	0
Amphipoda, Oedocerotidae					0	0				0	0
Amphipoda, Unid J					0	0				0	0
Apherusa glacialis					0	0		1		14.42751616	0.381679389
Arrhinopsis sp		4	5	4	187.5577101	0.824350032				0	0
Onisimus litoralis					0	0		1		14.42751616	0.381679389
Arrhinopsis sp					0	0				0	0
Bathymedon pumilus					0	0	1	1	1	43.28254848	1.145038168
Hippomedon sp					0	0				0	0
Tanaidaceae					0	0				0	0
Leptognatha caeca					0	0				0	0
Tanais cavolini			2	1	43.28254848	0.190234623				0	0
Copepoda					0	0				0	0
Calanoida					0	0				0	0
Limnocalanus macrurus	M		1	1	28.85503232	0.126823082				0	0
Limnocalanus macrurus	F				0	0				0	0
Acartia clausi	F				0	0				0	0
Tortanus discaudata	M	1			14.42751616	0.063411541				0	0
Centropages hamatus	M				0	0			1	14.42751616	0.381679389
Centropages hamatus	F		1		14.42751616	0.063411541				0	0
Cyclopoida					0	0				0	0
Dermatomyzon nigripes	F				0	0			1	14.42751616	0.381679389
Harpacticoida	juv	1			14.42751616	0.063411541				0	0
Harpacticus uniremis	F				0	0				0	0
Canuella canadensis	F				0	0		1		14.42751616	0.381679389
Tisbidae					0	0				0	0
Tisbe furcata	F			1	14.42751616	0.063411541				0	0
Canthocamptidae		1			14.42751616	0.063411541				0	0
Ostracoda Unid					0	0				0	0
Candona		2			28.85503232	0.126823082				0	0
Mysidacea					0	0				0	0
Mysis litoralis			1		14.42751616	0.063411541	1		1	28.85503232	0.763358779
INSECTA					0	0				0	0
Diptera, Unid A	A				0	0				0	0
Anopheles	A		1	3	57.71006464	0.253646164	3	5		115.4201293	3.053435115
Simulidae					0	0				0	0
Simulium	A		1		14.42751616	0.063411541	3	1		57.71006464	1.526717557
Chironomidae					0	0				0	0
Thienemannimyia	L	2			28.85503232	0.126823082				0	0
Eukiefferiella	L		1		14.42751616	0.063411541				0	0
ECHINODERMATA					0	0				0	0
Ophiuroidea	juv				0	0				0	0
Unid amphiuridae			1		14.42751616	0.063411541				0	0
Holothuroidea	juv				0	0				0	0
Holothuroidea	dam				0	0				0	0
Unid frag	dam	1			14.42751616	0.063411541				0	0
MOLLUSCA					0	0				0	0
Gastropoda					0	0				0	0
Cephalaspidea	dam				0	0				0	0
Cylichna alba		2		1	43.28254848	0.190234623	1			14.42751616	0.381679389
Oenopota sp					0	0				0	0
Retusa obtusa					0	0		2	2	57.71006464	1.526717557
Bivalvia	juv/dam				0	0				0	0
Astarte crenata					0	0			1	14.42751616	0.381679389
Axinopsis orbiculata		1			14.42751616	0.063411541				0	0
Bathyarca glacialis			1		14.42751616	0.063411541				0	0
Macoma calcarea					0	0				0	0
Portlandia arctica					0	0				0	0
Portlandia lenticula					0	0				0	0
Rochefortia tumida		1		1	28.85503232	0.126823082		1		14.42751616	0.381679389
cf Rochefortia tumida		1			14.42751616	0.063411541				0	0
Total		36050	826	362	22752.19298	100	37317	1411	1296	3780.009234	100

Petite Ponar Sample Area (m2) = 0.023104

(continued)

Appendix 3.6-1

Benthos Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002 (continued)

Location		Station 4					Station 5			
Date		06-Aug-02					06-Aug-02			
Replicate		1254	1256	1258	Mean Abundance	Mean Composition	1260	1262	Mean Abundance	Mean Composition
Sample No.		(counts as ind./sample)			(ind./m2)	(%)	(counts as ind./sample)		(ind./m2)	(%)
Species/Group	Stage									
Egg, unid					0	0			0	0
FORAMINIFERA					0	0			0	0
Milliamina sp					0	0			0	0
cf Nonion sp		12	1	1	201.9852262	5.426356589	3	3	129.8476454	8.571428571
Cornuspira sp					0	0			0	0
Globigerina					0	0			0	0
Hippocrepinella sp		6	6	4	230.8402585	6.201550388	19	2	454.466759	30
Rheophax sp					0	0			0	0
PORIFERA					0	0			0	0
Porifera	dam				0	0			0	0
CNIDARIA					0	0			0	0
Zoantheria?					0	0		1	21.64127424	1.428571429
NEMERTEA	dam	1	2	1	57.71006464	1.550387597			0	0
Micrura sp					0	0			0	0
NEMATODA		6	2	2	144.2751616	3.875968992			0	0
SIPUNCULA					0	0			0	0
Golfingia sp			3	1	57.71006464	1.550387597			0	0
ANNELIDA					0	0			0	0
Polychaeta	juv/dam	1	2		43.28254848	1.162790698			0	0
Ampharetidae					0	0			0	0
Samytha (cf sexcirrata)		5	8	2	216.4127424	5.813953488	2	3	108.2063712	7.142857143
Cirratulidae	juv/dam		2	1	43.28254848	1.162790698			0	0
Aphelochaeta multifilis					0	0			0	0
Capitellidae					0	0			0	0
Mediomastus (cf capensis)					0	0			0	0
Flabelligeridae					0	0			0	0
Brada villosa		1	1		28.85503232	0.775193798			0	0
Pherusa sp					0	0			0	0
Lumbrinereidae					0	0			0	0
Lumbrinereis similabris					0	0		1	21.64127424	1.428571429
Lumbrinereis tenuis		2	2	1	72.13758079	1.937984496	2	1	64.92382271	4.285714286
Maldanidae	juv/dam	2	1		43.28254848	1.162790698	1	2	64.92382271	4.285714286
Maldane sarsi					0	0		1	21.64127424	1.428571429
Nephtyidae					0	0			0	0
Nephtys cornuta		2	3	1	86.56509695	2.325581395		1	21.64127424	1.428571429
Aglaophamus circinata		2	2	2	86.56509695	2.325581395		1	21.64127424	1.428571429
Opheliidae					0	0			0	0
Ophelia sp		1			14.42751616	0.387596899			0	0
Orbiniidae					0	0			0	0
Scoloplos acmeceps			3	1	57.71006464	1.550387597	1		21.64127424	1.428571429
Oweniidae					0	0			0	0
Owenia fusiformis					0	0			0	0
Paraonidae					0	0			0	0
Aricidea sp	juv	5	2	1	115.4201293	3.100775194			0	0
Aricidea quadrilobata		16	5	5	375.1154201	10.07751938	3	1	86.56509695	5.714285714
Paraonella spinifera		1			14.42751616	0.387596899			0	0
Phyllodocidae					0	0			0	0
Phyllodoce arenae			1		14.42751616	0.387596899			0	0
Polynoidae	dam	1	1		28.85503232	0.775193798			0	0
Sabellidae	dam	1			14.42751616	0.387596899			0	0
cf Euchone rubrocincta		2			28.85503232	0.775193798	1		21.64127424	1.428571429
Sigalionidae					0	0			0	0
Pholoe minuta					0	0			0	0
Spionidae					0	0			0	0
Laonice sp		20	16	16	750.2308403	20.15503876	6		129.8476454	8.571428571
Laonice cf cirrata					0	0			0	0
Lumbrinereidae					0	0			0	0
Lumbrinereis tenuis					0	0			0	0
Lumbrinereis latreilli					0	0			0	0
Paraonidae Unid	juv/dam				0	0			0	0
Paraonella spinifera					0	0			0	0
Maldanidae Unid	dam				0	0			0	0
Clymenella sp					0	0			0	0
Ampharetidae					0	0			0	0
Samytha (cf sexcirrata)					0	0			0	0
Nereidae					0	0			0	0
Nereis sp	dam				0	0			0	0
Micronereis nanaimoensis					0	0			0	0
Syllidae					0	0			0	0
Exogone sp	juv/dam	2	1		43.28254848	1.162790698		1	21.64127424	1.428571429
Brania welfleetensis					0	0			0	0
Orbiniidae					0	0			0	0
Ophelia bicornis					0	0			0	0
Scoloplos acmeceps					0	0			0	0
cf Euchone rubrocincta					0	0			0	0
Unid fragment					0	0			0	0
Sabellidae					0	0			0	0
Sigalionidae					0	0			0	0
Pholoe minuta					0	0			0	0
Trichobranchidae					0	0			0	0
Terebellides stroemi		5	3	3	158.7026777	4.263565891	1	1	43.28254848	2.857142857
BRYOZOA					0	0			0	0
Eucratea loricata			1		14.42751616	0.387596899	1		21.64127424	1.428571429

(continued)

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Appendix 3.6-1

Benthos Taxonomy and Abundance at Stations 1 to 5, Bathurst Inlet, August 2001 and 2002 (completed)

Location		Station 4					Station 5			
Date		06-Aug-02					06-Aug-02			
Replicate		1254	1256	1258	Mean Abundance	Mean Composition	1260	1262	Mean Abundance	Mean Composition
Sample No.		(counts as ind./sample)			(ind./m2)	(%)	(counts as ind./sample)		(ind./m2)	(%)
Species/Group	Stage									
CRUSTACEA					0	0			0	0
Isopoda	juv/dam				0	0			0	0
cf Stentrium sp					0	0			0	0
Cumaceae					0	0			0	0
Diastylis quadrispinosia		13	1	4	259.6952909	6.976744186		2	43.28254848	2.857142857
Eudorella sp					0	0			0	0
Amphipoda, Oedocerotidae					0	0			0	0
Amphipoda, Unid J					0	0			0	0
Apherusa glacialis					0	0			0	0
Arrhinopsis sp					0	0			0	0
Onisimus litoralis					0	0			0	0
Arrhinopsis sp					0	0			0	0
Bathymedon pumilus		5	1	2	115.4201293	3.100775194	3	1	86.56509695	5.714285714
Hippomedon sp		1	1		28.85503232	0.775193798			0	0
Tanaidaceae					0	0			0	0
Leptognatha caeca		1			14.42751616	0.387596899			0	0
Tanais cavolini					0	0			0	0
Copepoda					0	0			0	0
Calanoida					0	0			0	0
Limnocalanus macrurus	M				0	0			0	0
Limnocalanus macrurus	F	1			14.42751616	0.387596899			0	0
Acartia clausi	F				0	0			0	0
Tortanus discaudata	M				0	0			0	0
Centropages hamatus	M				0	0			0	0
Centropages hamatus	F				0	0			0	0
Cyclopoida					0	0			0	0
Dermatomyzon nigripes	F				0	0			0	0
Harpacticoida	juv				0	0			0	0
Harpacticus uniremis	F	1			14.42751616	0.387596899			0	0
Canuella canadensis	F				0	0			0	0
Tisbidae					0	0			0	0
Tisbe furcata	F				0	0			0	0
Canthocamptidae					0	0			0	0
Ostracoda Unid		3			43.28254848	1.162790698			0	0
Candona					0	0			0	0
Mysidacea					0	0			0	0
Mysis litoralis		6		1	100.9926131	2.713178295			0	0
INSECTA					0	0			0	0
Diptera, Unid A	A				0	0			0	0
Anopheles	A		1	3	57.71006464	1.550387597			0	0
Simulidae					0	0			0	0
Simulium	A			2	28.85503232	0.775193798			0	0
Chironomidae					0	0			0	0
Thienemannimyia	L				0	0			0	0
Eukiefferiella	L				0	0			0	0
ECHINODERMATA					0	0			0	0
Ophiuroidea	juv	1			14.42751616	0.387596899			0	0
Unid amphiuridae					0	0			0	0
Holothuroidea	juv				0	0			0	0
Holothuroidea	dam				0	0			0	0
Unid frag	dam				0	0			0	0
MOLLUSCA					0	0			0	0
Gastropoda					0	0	1	1	43.28254848	2.857142857
Cephalaspidea	dam				0	0			0	0
Cylichna alba					0	0			0	0
Oenopota sp					0	0			0	0
Retusa obtusa					0	0			0	0
Bivalvia	juv/dam	2			28.85503232	0.775193798			0	0
Astarte crenata		1			14.42751616	0.387596899			0	0
Axinopsis orbiculata					0	0			0	0
Bathyarca glacialis					0	0			0	0
Macoma calcarea		2	1		43.28254848	1.162790698			0	0
Portlandia arctica					0	0			0	0
Portlandia lenticula					0	0			0	0
Rochefortia tumida					0	0	1	2	64.92382271	4.285714286
cf Rochefortia tumida									0	0
Total		37397	1329	1312	3722.299169	100	37317	1287	1514.889197	100

Petite Ponar Sample Area (m2) = 0.023104

APPENDIX 3.7-1
LOCATION, SET TIME, AND TOTAL CATCHES PER SAMPLING GEAR, BATHURST INLET, AUGUST 2001

Appendix 3.7-1
Location, Set Time, and Total Catches per Sampling Gear, Bathurst Inlet, August 2001

									Number												
		Location		Gear	Depth	Time		Effort	Fourhorn	Arctic	Starry	Saffron	Arctic	Pacific	Broad	Rainbow	Arctic	Ogac	Lake	Total
Date	Site	inshore	offshore	code	(m)	in	out	(hours)	sculpin	cisco	flounder	cod	flounder	herring	whitefish	smelt	char		trout	
17-Aug	1	N66°32.759' W107°30.153'	N66°32.764' W107°30.024'	GN1	3	1023	1230	2.1	6	7	5	5	4	1	9	2	0	0	0	**39**
17-Aug	1	N66°32.647' W107°30.057'	N66°32.647' W107°30.057'	MT1	1	1045	0910[1]	22.4	0	0	0	0	0	0	0	0	0	0	0	**0**
17-Aug	1	-	-	MT2	1	1045	0910[1]	22.4	0	0	0	0	0	0	0	0	0	0	0	**0**
17-Aug	1	-	-	MT3	1	1045	0910[1]	22.4	0	0	0	0	0	0	0	0	0	0	0	**0**
17-Aug	1	-	-	MT4	1	1045	0910[1]	22.4	0	0	0	0	0	0	0	0	0	0	0	**0**
17-Aug	1	-	-	MT5	1	1045	0910[1]	22.4	0	0	0	0	0	0	0	0	0	0	0	**0**
17-Aug	1	N66°32.574' W107°29.906'	N66°32.574' W107°29.906'	MT6	1	1045	0910[1]	22.4	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	1	N66°32.702' W107°30.041'	N66°32.618' W107°29.949'	SLL1	10	0915	1215	3.0	5	0	0	1	0	0	0	0	0	0	0	**6**
18-Aug	1	N66°32.719' W107°30.051'	N66°32.676' W107°29.984'	FLL2	1	0945	1315	3.5	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	1	N66°32.683' W107°30.090'	N66°32.683' W107°30.090'	BS1	2	1000	1005	-	15	0	0	0	0	0	0	0	0	0	0	**15**
18-Aug	1	N66°32.671' W107°30.085'	N66°32.671' W107°30.085'	BS2	2	1015	1020	-	10	1	2	0	0	0	0	0	0	0	0	**13**
18-Aug	1	N66°32.663' W107°30.092'	N66°32.663' W107°30.092'	BS3	2	1025	1030	-	9	2	1	0	0	0	0	0	0	0	0	**12**
18-Aug	1	N66°32.574' W107°29.906'	N66°32.609' W107°29.866'	FN1	2	1150	1325	1.6	0	2	0	1	0	0	0	0	0	0	0	**3**
18-Aug	2	N66°32.964' W107°30.985'	N66°32.964' W107°30.985'	MT7	1	1410	0925[1]	19.3	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	2	-	-	MT8	1	1410	0925[1]	19.3	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	2	-	-	MT9	1	1410	0925[1]	19.3	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	2	-	-	MT10	1	1410	0925[1]	19.3	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	2	-	-	MT11	1	1410	0925[1]	19.3	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	2	N66°32.931' W107°30.874'	N66°32.931' W107°30.874'	MT12	1	1410	0925[1]	19.3	0	0	0	0	0	0	0	0	0	0	0	**0**
18-Aug	2	N66°32.975' W107°30.958'	N66°32.975' W107°30.938'	FLL3	5	1430	1040	20.2	0	0	0	1	0	0	0	0	0	0	0	**1**
18-Aug	2	N66°32.953' W107°30.821'	N66°32.968' W107°30.776'	FN2	2	1435	1645	2.2	0	1	0	0	0	0	0	0	0	0	0	**1**
18-Aug	2	N66°32.971' W107°31.011'	N66°32.971' W107°31.011'	BS4	2	1445	1450	-	0	1	3	0	0	0	0	0	0	0	0	**4**
18-Aug	2	N66°32.975' W107°31.420'	N66°32.975' W107°31.420'	BS5	2	1455	1500	-	0	2	1	0	0	0	0	0	0	0	0	**3**
18-Aug	2	N66°32.982' W107°31.059'	N66°32.982' W107°31.059'	BS6	2	1505	1510	-	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	N66°32.964' W107°30.985'	N66°32.964' W107°30.985'	MT13	1	0935	1445	5.2	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	-	-	MT14	1	0935	1445	5.2	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	-	-	MT15	1	0935	1445	5.2	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	-	-	MT16	1	0935	1445	5.2	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	-	-	MT17	1	0935	1445	5.2	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	N66°32.931' W107°30.874'	N66°32.931' W107°30.874'	MT18	1	0935	1445	5.2	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	N66°33.019' W107°30.995'	N66°33.040' W107°30.952'	SLL4	10	1010	1440	4.5	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	2	N66°33.021' W107°31.093'	N66°33.056' W107°31.036'	GN2	10	1030	1245	2.3	10	4	5	4	1	6	0	0	1	1	0	**32**
19-Aug	3	N66°33.115' W107°32.313'	N66°33.104' W107°32.354'	FN3	2	1510	1710	2.0	0	0	0	0	1	0	1	0	0	0	0	**2**
19-Aug	3	N66°33.126' W107°32.363'	N66°33.126' W107°32.363'	BS7	2	1525	1530	-	4	0	0	0	0	0	0	0	0	0	0	**4**
19-Aug	3	N66°33.126' W107°32.395'	N66°33.126' W107°32.395'	BS8	2	1535	1540	-	2	2	1	0	6	0	0	0	0	0	0	**11**
19-Aug	3	N66°33.131' W107°32.400'	N66°33.131' W107°32.400'	BS9	2	1545	1550	-	0	9	0	0	0	0	0	0	0	0	0	**9**
19-Aug	3	N66°33.104' W107°32.508'	N66°33.098' W107°32.527'	FLL5	1	1645	0930[1]	16.8	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	3	N66°33.122' W107°32.341'	N66°33.122' W107°32.341'	MT19	1	1700	1015[1]	17.3	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	3	-	-	MT20	1	1700	1015[1]	17.3	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	3	-	-	MT21	1	1700	1015[1]	17.3	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	3	-	-	MT22	1	1700	1015[1]	17.3	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	3	-	-	MT23	1	1700	1015[1]	17.3	0	0	0	0	0	0	0	0	0	0	0	**0**
19-Aug	3	N66°33.071' W107°32.304'	N66°33.071' W107°32.304'	MT24	1	1700	1015[1]	17.3	0	0	0	0	0	0	0	0	0	0	0	**0**
20-Aug	3	N66°33.131' W107°32.461'	N66°33.110' W107°32.633'	GN3	10	0915	1205	2.8	1	3	2	6	4	4	0	0	0	0	1	**21**
20-Aug	3	N66°33.071' W107°32.576'	N66°33.053' W107°32.678'	SLL6	10	1000	1325	3.4	1	0	0	0	0	0	0	0	0	0	0	**1**
Total Number									**63**	**34**	**20**	**18**	**16**	**11**	**10**	**2**	**1**	**1**	**1**	**177**
Percent of Total Number									**36**	**19**	**11**	**10**	**9**	**6**	**6**	**1**	**1**	**1**	**1**	**100**

[1]: Latitude and longitude were measured for the beginning and end of line of minow traps

APPENDIX 3.7-2
BIOLOGICAL CHARACTERISTICS OF FISH SAMPLED, BATHURST INLET, AUGUST 2001

Appendix 3.7-2
Biological Characteristics of Fish Sampled, Bathurst Inlet, August 2001

Date	Site	Gear code	Sample number	Species	Fork Length (mm)	Wet Weight (g)	Condition (g/mm^3)	Sex	Maturity	Reproductive Status	Age (years)				Tissue sample	Stomach contents	Comments
											otoliths	scales	fin rays	best estimate			
17-Aug	1	GN1	1	Broad whitefish	516	1800	1.31	-	-	-	-	17	17	17	-	-	released
17-Aug	1	GN1	2	Broad whitefish	496	1675	1.37	-	-	-	-	Y	17	17	-	-	released
17-Aug	1	GN1	3	Broad whitefish	465	1350	1.34	-	-	-	-	Y	16	16	-	-	released
17-Aug	1	GN1	4	Broad whitefish	465	1300	1.29	-	-	-	-	10	13	13	-	-	released
17-Aug	1	GN1	5	Broad whitefish	490	1375	1.17	F	mature	green	-	Y	17	17	-	clams	mortality
17-Aug	1	GN1	6	Saffron cod	275	175	0.84	-	-	-	-	3	4	4	-	-	released, Photo 6- 6
17-Aug	1	GN1	7	Saffron cod	389	450	0.76	-	-	-	-	5	6	6	-	-	released
17-Aug	1	GN1	8	Fourhorn sculpin	232	125	1.00	-	-	-	-	-	10	10	-	-	released, Photo 6- 7
17-Aug	1	GN1	9	Saffron cod	290	225	0.92	-	-	-	-	Y	9	9	-	-	released
17-Aug	1	GN1	10	Broad whitefish	488	1400	1.20	F	mature	green	27	11	21	27	-	clams	mortality
17-Aug	1	GN1	11	Saffron cod	261	118	0.66	-	-	-	-	Y	4	4	-	-	released
17-Aug	1	GN1	12	Saffron cod	293	168	0.67	-	-	-	-	Y	2	2	-	-	released
17-Aug	1	GN1	13	Broad whitefish	479	1475	1.34	M	mature	green	14	8	13	14	-	clams	mortality
17-Aug	1	GN1	14	Fourhorn sculpin	243	112	0.78	-	-	-	-	-	7	7	-	-	released
17-Aug	1	GN1	15	Fourhorn sculpin	229	96	0.80	-	-	-	-	-	5	5	-	-	released
17-Aug	1	GN1	16	Fourhorn sculpin	260	152	0.86	-	-	-	-	-	8	8	-	-	released
17-Aug	1	GN1	17	Fourhorn sculpin	256	158	0.94	-	-	-	-	-	7	7	-	-	released
17-Aug	1	GN1	18	Arctic flounder	260	275	1.56	-	-	-	-	-	4	4	-	-	released
17-Aug	1	GN1	19	Arctic flounder	260	300	1.71	-	-	-	-	-	5	5	-	-	released
17-Aug	1	GN1	20	Arctic flounder	152	48	1.37	-	-	-	-	-	1	1	-	-	released, Photo 6-8
17-Aug	1	GN1	21	Arctic flounder	147	46	1.45	-	-	-	-	-	1	1	-	-	released
17-Aug	1	GN1	22	Fourhorn sculpin	147	46	1.45	-	-	-	-	-	6	6	-	-	released
17-Aug	1	GN1	23	Starry flounder	283	300	1.32	U	U	U	-	-	7	7	MY	clams	Tissue sample #23
17-Aug	1	GN1	24	Broad whitefish	498	1950	1.58	M	mature	green	13	Y	13	13	-	clams	mortality
17-Aug	1	GN1	25	Starry flounder	241	182	1.30	U	U	U	-	-	5	5	MY	isopods	Tissue sample #25
17-Aug	1	GN1	26	Starry flounder	233	150	1.19	M	mature	green	Y	-	4	4	MY	empty	Tissue sample #26

Gear code: GN = sinking gillnet, FN = floating gillnet, BS = beach seine, SLL = sinking longline, FLL = floating longline

(continued)

Sex: F = female, M = male, U = unknown
Maturity: U = unknown
Reproductive Status: green = maturing, ripe = imminent spawner
Age: Y = sample taken, but age not read
Tissue Sample: MY = myomere (muscle)

Appendix 3.7-2
Biological Characteristics of Fish Sampled, Bathurst Inlet, August 2001

Date	Site	Gear code	Sample number	Species	Fork Length (mm)	Wet Weight (g)	Condition (g/mm^3)	Sex	Maturity	Reproductive Status	Age (years)				Tissue sample	Stomach contents	Comments
											otoliths	scales	fin rays	best estimate			
17-Aug	1	GN1	27	Starry flounder	229	168	1.40	M	mature	green	-	-	5	5	MY	clams	Tissue sample #27
17-Aug	1	GN1	28	Starry flounder	249	216	1.40	U	U	U	-	-	5	5	MY	clams	Tissue sample #28
17-Aug	1	GN1	29	Pacific herring	200	66	0.83	F	mature	green	4	Y	4	4	-	empty	released
17-Aug	1	GN1	30	Rainbow smelt	295	210	0.82	M	mature	ripe	-	11	11	11	-	fish	released
17-Aug	1	GN1	31	Rainbow smelt	240	122	0.88	-	-	-	-	6	6	6	-	-	released
17-Aug	1	GN1	32	Arctic cisco	235	142	1.09	-	-	-	-	5	5	5	-	-	released
17-Aug	1	GN1	33	Arctic cisco	194	78	1.07	M	immature	undeveloped	3	Y	3	3	-	amphipod	mortality
17-Aug	1	GN1	34	Arctic cisco	208	90	1.00	F	immature	undeveloped	3	3	3	3	-	empty	mortality
17-Aug	1	GN1	35	Arctic cisco	381	625	1.13	M	mature	green	18	Y	15	18	-	empty	mortality
17-Aug	1	GN1	36	Arctic cisco	268	225	1.17	F	mature	ripe	13	11	14	13	-	insects	mortality
17-Aug	1	GN1	37	Arctic cisco	265	202	1.09	F	immature	undeveloped	5	Y	5	5	-	amphipod	mortaliy
17-Aug	1	GN1	38	Arctic cisco	275	224	1.08	-	-	-	-	Y	7	7	-	-	released
17-Aug	1	GN1	39	Broad whitefish	330	475	1.32	M	immature	undeveloped	5	Y	5	5	-	empty	mortality
18-Aug	1	BS1	40	Fourhorn sculpin	39	0.44	0.74	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	41	Fourhorn sculpin	38	0.41	0.75	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	42	Fourhorn sculpin	36	0.35	0.75	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	43	Fourhorn sculpin	39	0.47	0.79	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	44	Fourhorn sculpin	43	0.65	0.82	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	45	Fourhorn sculpin	39	0.45	0.76	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	46	Fourhorn sculpin	38	0.31	0.56	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	47	Fourhorn sculpin	40	0.56	0.88	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	48	Fourhorn sculpin	40	0.46	0.72	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	49	Fourhorn sculpin	35	0.29	0.68	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	50	Fourhorn sculpin	40	0.41	0.64	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	51	Fourhorn sculpin	37	0.36	0.71	-	-	-	-	-	-	-	-	-	too small to age, released

Gear code: GN = sinking gillnet, FN = floating gillnet, BS = beach seine, SLL = sinking longline, FLL = floating longline

(continued)

Sex: F = female, M = male, U = unknown
Maturity: U = unknown
Reproductive Status: green = maturing, ripe = imminent spawner
Age: Y = sample taken, but age not read
Tissue Sample: MY = myomere (muscle)

Appendix 3.7-2
Biological Characteristics of Fish Sampled, Bathurst Inlet, August 2001

Date	Site	Gear code	Sample number	Species	Fork Length (mm)	Wet Weight (g)	Condition (g/mm^3)	Sex	Maturity	Reproductive Status	Age (years)				Tissue sample	Stomach contents	Comments
											otoliths	scales	fin rays	best estimate			
18-Aug	1	BS1	52	Fourhorn sculpin	35	0.35	0.82	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	53	Fourhorn sculpin	40	0.44	0.69	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS1	54	Fourhorn sculpin	32	0.28	0.85	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS2	55	Arctic cisco	278	250	1.16	-	-	-	-	6	6	6	-	-	released
18-Aug	1	BS3	56	Arctic cisco	260	200	1.14	-	-	-	-	Y	5	5	-	-	released
18-Aug	1	BS3	57	Arctic cisco	245	150	1.02	-	-	-	-	Y	10	10	-	-	released
18-Aug	1	BS2	58	Fourhorn sculpin	38	0.42	0.77	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS2	59	Fourhorn sculpin	37	0.40	0.79	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS2	60	Fourhorn sculpin	35	0.37	0.86	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS2	61	Fourhorn sculpin	38	0.45	0.82	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS2	62	Fourhorn sculpin	35	0.35	0.82	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS2	63	Fourhorn sculpin	33	0.27	0.75	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS2	64	Fourhorn sculpin	36	0.40	0.86	-	-	-	-	-	-	-	-	-	too small to age, preserved
18-Aug	1	BS2	65	Fourhorn sculpin	32	0.25	0.76	-	-	-	-	-	-	-	-	-	too small to age, preserved
18-Aug	1	BS2	66	Fourhorn sculpin	38	0.38	0.69	-	-	-	-	-	-	-	-	-	too small to age, preserved
18-Aug	1	BS2	67	Fourhorn sculpin	91	5.39	0.72	-	-	-	-	-	-	-	-	-	too small to age, preserved
18-Aug	1	BS2	68	Starry flounder	63	3.22	1.29	-	-	-	-	-	-	-	-	-	too small to age, preserved
18-Aug	1	BS2	69	Starry flounder	60	2.55	1.18	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	70	Starry flounder	25	0.18	1.15	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	71	Fourhorn sculpin	33	0.27	0.75	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	72	Fourhorn sculpin	40	0.47	0.73	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	73	Fourhorn sculpin	38	0.36	0.66	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	74	Fourhorn sculpin	34	0.31	0.79	-	-	-	-	-	-	-	-	-	too small to age, released

Gear code: GN = sinking gillnet, FN = floating gillnet, BS = beach seine, SLL = sinking longline, FLL = floating longline

(continued)

Sex: F = female, M = male, U = unknown
Maturity: U = unknown
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Appendix 3.7-2
Biological Characteristics of Fish Sampled, Bathurst Inlet, August 2001

Date	Site	Gear code	Sample number	Species	Fork Length (mm)	Wet Weight (g)	Condition (g/mm^3)	Sex	Maturity	Reproductive Status	Age (years)				Tissue sample	Stomach contents	Comments
											otoliths	scales	fin rays	best estimate			
18-Aug	1	BS3	75	Fourhorn sculpin	40	0.61	0.95	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	76	Fourhorn sculpin	39	0.43	0.72	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	77	Fourhorn sculpin	37	0.43	0.85	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	78	Fourhorn sculpin	37	0.31	0.61	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	BS3	79	Fourhorn sculpin	33	0.25	0.70	-	-	-	-	-	-	-	-	-	too small to age, released
18-Aug	1	SLL1	80	Fourhorn sculpin	236	102	0.78	-	-	-	-	-	9	9	-	-	released
18-Aug	1	SLL1	81	Fourhorn sculpin	245	132	0.90	-	-	-	-	-	8	8	-	-	released
18-Aug	1	SLL1	82	Fourhorn sculpin	232	92	0.74	-	-	-	-	-	7	7	-	-	released
18-Aug	1	SLL1	83	Fourhorn sculpin	248	146	0.96	-	-	-	-	-	7	7	-	-	released
18-Aug	1	SLL1	84	Fourhorn sculpin	297	256	0.98	-	-	-	-	-	9	9	-	-	released
18-Aug	1	SLL1	85	Saffron cod	253	110	0.68	U	U	U	3	3	3	3	-	amphipod	mortality, big otoliths
18-Aug	1	FN1	86	Arctic cisco	287	250	1.06	-	-	-	-	6	5	6	-	-	released
18-Aug	1	FN1	87	Arctic cisco	464	1550	1.55	-	-	-	-	11	13	13	-	-	released, Photo 16-13
18-Aug	1	FN1	88	Saffron cod	394	500	0.82	-	-	-	-	Y	4	4	-	-	released, Photo 16-12
18-Aug	2	BS4	89	Arctic cisco	296	254	0.98	-	-	-	-	Y	7	7	-	-	released
18-Aug	2	BS5	90	Arctic cisco	216	102	1.01	-	-	-	-	4	4	4	-	-	released
18-Aug	2	BS5	91	Arctic cisco	212	99	1.04	-	-	-	-	Y	3	3	-	-	released
18-Aug	2	BS4	92	Starry flounder	176	70	1.28	U	U	U	3	Y	2	3	MY	amphipod	Tissue sample #92
18-Aug	2	BS4	93	Starry flounder	142	44.5	1.55	U	U	U	3	-	2	3	MY	amphipod	Tissue sample #93
18-Aug	2	BS4	94	Starry flounder	153	43.3	1.21	U	U	U	3	-	2	3	MY	amphipod	Tissue sample #94
18-Aug	2	BS5	95	Starry flounder	150	50.4	1.49	U	U	U	3	-	2	3	MY	amphipod	Tissue sample #95
18-Aug	2	FN2	96	Arctic cisco	179	54	0.94	-	-	-	-	Y	2	2	-	-	released
19-Aug	2	FLL3	97	Saffron cod	463	850	0.86	-	-	-	-	Y	11	11	-	-	released
19-Aug	2	GN2	98	Arctic cisco	302	275	1.00	-	-	-	-	Y	7	7	-	-	released
19-Aug	2	GN2	99	Arctic cisco	267	225	1.18	-	-	-	-	5	5	5	-	-	released
19-Aug	2	GN2	100	Arctic cisco	298	275	1.04	-	-	-	-	Y	7	7	-	-	released

Gear code: GN = sinking gillnet, FN = floating gillnet, BS = beach seine, SLL = sinking longline, FLL = floating longline

(continued)

Sex: F = female, M = male, U = unknown
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Appendix 3.7-2
Biological Characteristics of Fish Sampled, Bathurst Inlet, August 2001

Date	Site	Gear code	Sample number	Species	Fork Length (mm)	Wet Weight (g)	Condition (g/mm^3)	Sex	Maturity	Reproductive Status	Age (years)				Tissue sample	Stomach contents	Comments
											otoliths	scales	fin rays	best estimate			
19-Aug	2	GN2	101	Pacific herring	250	150	0.96	-	-	-	-	7	9	9	-	-	released
19-Aug	2	GN2	102	Pacific herring	233	114	0.90	-	-	-	-	Y	7	7	-	-	released
19-Aug	2	GN2	103	Arctic cisco	283	250	1.10	-	-	-	-	6	7	6	-	-	released
19-Aug	2	GN2	104	Pacific herring	196	69	0.92	-	-	-	-	Y	4	4	-	-	released
19-Aug	2	GN2	105	Pacific herring	228	114	0.96	-	-	-	-	Y	9	9	-	-	released
19-Aug	2	GN2	106	Pacific herring	228	120	1.01	-	-	-	-	Y	6	6	-	-	released
19-Aug	2	GN2	107	Pacific herring	230	114	0.94	-	-	-	-	Y	11	11	-	-	released
19-Aug	2	GN2	108	Saffron cod	275	144	0.69	-	-	-	-	3	3	3	-	-	released
19-Aug	2	GN2	109	Saffron cod	290	175	0.72	-	-	-	-	3	3	3	-	-	released
19-Aug	2	GN2	110	Saffron cod	390	500	0.84	-	-	-	-	Y	6	6	-	-	released
19-Aug	2	GN2	111	Saffron cod	330	325	0.90	-	-	-	-	3	5	5	-	-	released
19-Aug	2	GN2	112	Arctic char	405	825	1.24	-	-	-	-	4	4	4	-	-	released
19-Aug	2	GN2	113	Fourhorn sculpin	230	117	0.96	-	-	-	-	-	5	5	-	-	released
19-Aug	2	GN2	114	Fourhorn sculpin	205	75	0.87	-	-	-	-	-	4	4	-	-	released
19-Aug	2	GN2	115	Fourhorn sculpin	171	48	0.96	-	-	-	-	-	4	4	-	-	released
19-Aug	2	GN2	116	Fourhorn sculpin	203	66	0.79	-	-	-	-	-	6	6	-	-	released
19-Aug	2	GN2	117	Fourhorn sculpin	241	113	0.81	-	-	-	-	-	7	7	-	-	released
19-Aug	2	GN2	118	Fourhorn sculpin	239	114	0.84	-	-	-	-	-	9	9	-	-	released
19-Aug	2	GN2	119	Fourhorn sculpin	211	74	0.79	-	-	-	-	-	8	8	-	-	released
19-Aug	2	GN2	120	Fourhorn sculpin	212	77	0.81	-	-	-	-	-	9	9	-	-	released
19-Aug	2	GN2	121	Fourhorn sculpin	167	43	0.92	-	-	-	-	-	4	4	-	-	released
19-Aug	2	GN2	122	Fourhorn sculpin	230	94	0.77	-	-	-	-	-	5	5	-	-	released
19-Aug	2	GN2	123	Arctic flounder	263	275	1.51	-	-	-	-	-	6	6	-	-	released
19-Aug	2	GN2	124	Ogac	414	850	1.20	F	mature	green	2	2	2	2	-	-	mortality
19-Aug	2	GN2	125	Starry flounder	320	450	1.37	F	mature	green	12	-	12	12	MY	ophiurids	Tissue sample #125
19-Aug	2	GN2	126	Starry flounder	260	225	1.28	M	mature	green	12	-	5	12	MY	clams	Tissue sample #126
19-Aug	2	GN2	127	Starry flounder	280	300	1.37	F	mature	green	13	-	10	13	MY	clams	Tissue sample #127

Gear code: GN = sinking gillnet, FN = floating gillnet, BS = beach seine, SLL = sinking longline, FLL = floating longline

(continued)

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Date	Site	Gear code	Sample number	Species	Fork Length (mm)	Wet Weight (g)	Condition (g/mm^3)	Sex	Maturity	Reproductive Status	Age (years)				Tissue sample	Stomach contents	Comments
											otoliths	scales	fin rays	best estimate			
19-Aug	2	GN2	128	Starry flounder	253	225	1.39	M	mature	green	12	-	10	12	MY	fish/opiurids/clams	Tissue sample #128
19-Aug	2	GN2	129	Starry flounder	278	275	1.28	F	mature	green	7	-	5	7	MY	clams	Tissue sample #129
19-Aug	3	BS9	130	Arctic cisco	319	325	1.00	-	-	-	-	Y	7	7	-	-	released
19-Aug	3	BS9	131	Arctic cisco	320	350	1.07	-	-	-	-	Y	7	7	-	-	released
19-Aug	3	BS9	132	Arctic cisco	259	167	0.96	-	-	-	-	Y	5	5	-	-	released
19-Aug	3	BS9	133	Arctic cisco	200	80	1.00	-	-	-	-	3	3	3	-	-	released
19-Aug	3	BS9	134	Arctic cisco	213	98	1.01	-	-	-	-	Y	3	3	-	-	released
19-Aug	3	BS9	135	Arctic cisco	298	275	1.04	-	-	-	-	Y	7	7	-	-	released
19-Aug	3	BS9	136	Arctic cisco	212	92	0.97	-	-	-	-	Y	3	3	-	-	released
19-Aug	3	BS9	137	Arctic cisco	215	95	0.96	-	-	-	-	Y	4	4	-	-	released
19-Aug	3	BS9	138	Arctic cisco	201	86	1.06	-	-	-	-	Y	3	3	-	-	released
19-Aug	3	BS8	139	Arctic cisco	273	225	1.11	-	-	-	-	Y	6	6	-	-	released
19-Aug	3	BS8	140	Arctic cisco	231	114	0.92	-	-	-	-	Y	4	4	-	-	released
19-Aug	3	BS8	141	Arctic flounder	145	41	1.34	-	-	-	-	-	2	2	-	-	released
19-Aug	3	BS8	142	Arctic flounder	91	10	1.33	-	-	-	-	-	0	0	-	-	released
19-Aug	3	BS8	143	Arctic flounder	83	8.2	1.43	-	-	-	-	-	0	0	-	-	released
19-Aug	3	BS8	144	Arctic flounder	88	8.9	1.31	-	-	-	-	-	0	0	-	-	released
19-Aug	3	BS8	145	Arctic flounder	95	10.7	1.25	-	-	-	-	-	0	0	-	-	released
19-Aug	3	BS8	146	Arctic flounder	31	0.3	1.01	-	-	-	-	-	-	-	-	-	too small to age (0+), released
19-Aug	3	BS8	147	Fourhorn sculpin	37	0.41	0.81	-	-	-	-	-	-	-	-	-	too small to age (0+), released
19-Aug	3	BS8	148	Fourhorn sculpin	33	0.23	0.64	-	-	-	-	-	-	-	-	-	too small to age (0+), released
19-Aug	3	BS8	149	Starry flounder	158	53.9	1.37	U	U	U	3	-	2	2	MY	U	Tissue sample #149
19-Aug	3	BS7	150	Fourhorn sculpin	108	10.1	0.80	-	-	-	-	-	1	1	-	-	released
19-Aug	3	BS7	151	Fourhorn sculpin	95	6.2	0.72	-	-	-	-	-	1	1	-	-	released
19-Aug	3	BS7	152	Fourhorn sculpin	95	7.5	0.87	-	-	-	-	-	1	1	-	-	released
19-Aug	3	BS7	153	Fourhorn sculpin	92	5.9	0.76	-	-	-	-	-	1	1	-	-	released

Gear code: GN = sinking gillnet, FN = floating gillnet, BS = beach seine, SLL = sinking longline, FLL = floating longline

(continued)

Sex: F = female, M = male, U = unknown
Maturity: U = unknown
Reproductive Status: green = maturing, ripe = imminent spawner
Age: Y = sample taken, but age not read
Tissue Sample: MY = myomere (muscle)

Appendix 3.7-2
Biological Characteristics of Fish Sampled, Bathurst Inlet, August 2001 (completed)

Date	Site	Gear code	Sample number	Species	Fork Length (mm)	Wet Weight (g)	Condition (g/mm^3)	Sex	Maturity	Reproductive Status	Age (years)				Tissue sample	Stomach contents	Comments
											otoliths	scales	fin rays	best estimate			
19-Aug	3	FN3	154	Broad whitefish	435	1200	1.46	-	-	-	-	Y	10	10	-	-	released
19-Aug	3	FN3	155	Arctic flounder	337	725	1.89	-	-	-	-	-	15	15	-	-	released
20-Aug	3	GN3	156	Arctic cisco	260	200	1.14	-	-	-	-	Y	4	4	-	-	released
20-Aug	3	GN3	157	Arctic cisco	340	390	0.99	F	mature	green	8	8	8	8	-	empty	mortality
20-Aug	3	GN3	158	Pacific herring	226	113	0.98	-	-	-	-	Y	11	11	-	-	released
20-Aug	3	GN3	159	Pacific herring	210	93	1.00	-	-	-	-	Y	4	4	-	-	released
20-Aug	3	GN3	160	Arctic cisco	232	174	1.39	-	-	-	-	3	3	3	-	-	released
20-Aug	3	GN3	161	Pacific herring	205	72	0.84	-	-	-	-	Y	4	4	-	-	released
20-Aug	3	GN3	162	Pacific herring	203	76	0.91	-	-	-	-	4	3	4	-	-	released
20-Aug	3	GN3	163	Fourhorn sculpin	207	50	0.56	-	-	-	-	-	5	5	-	-	released
20-Aug	3	GN3	164	Arctic flounder	162	39	0.92	-	-	-	-	-	1	1	-	-	released
20-Aug	3	GN3	165	Arctic flounder	160	35.5	0.87	-	-	-	-	-	0	0	-	-	released
20-Aug	3	GN3	166	Arctic flounder	152	29.7	0.85	-	-	-	-	-	1	1	-	-	released
20-Aug	3	GN3	167	Saffron cod	378	425	0.79	-	-	-	-	Y	6	6	-	-	released
20-Aug	3	GN3	168	Saffron cod	383	400	0.71	-	-	-	-	Y	3	3	-	-	released
20-Aug	3	GN3	169	Arctic flounder	141	24.3	0.87	-	-	-	-	-	1	1	-	-	released
20-Aug	3	GN3	170	Saffron cod	445	980	1.11	F	mature	green	16	Y	12	16	-	empty	mortality
20-Aug	3	GN3	171	Saffron cod	265	190	1.02	M	immature	undeveloped	4	Y	4	4	-	empty	mortality
20-Aug	3	GN3	172	Saffron cod	281	210	0.95	M	immature	undeveloped	5	Y	4	5	-	crustaceans (full)	mortality
20-Aug	3	GN3	173	Saffron cod	230	122	1.00	U	immature	undeveloped	-	Y	4	4	-	empty	mortality
20-Aug	3	GN3	174	Lake trout	320	500	1.53	M	mature	green	6	5	5	6	-	fish	mortality
20-Aug	3	GN3	175	Starry flounder	279	320	1.47	M	mature	green	-	-	9	9	MY	clams	Tissue sample #175
20-Aug	3	GN3	176	Starry flounder	254	240	1.46	U	U	U	-	-	7	7	MY	clams	Tissue sample #176
20-Aug	3	LL6	177	Fourhorn sculpin	312	350	1.15	-	-	-	-	-	13	13	-	-	released

Gear code: GN = sinking gillnet, FN = floating gillnet, BS = beach seine, SLL = sinking longline, FLL = floating longline **(completed)**
Sex: F = female, M = male, U = unknown
Maturity: U = unknown
Reproductive Status: green = maturing, ripe = imminent spawner
Age: Y = sample taken, but age not read
Tissue Sample: MY = myomere (muscle)

APPENDIX 3.7-3
SUMMARY OF RECORDS OF MARINE FISH SPECIES OF BATHURST INLET HELD BY THE CANADIAN MUSEUM OF NATURE

Appendix 3.7-3
Summary of Records of Marine Fish Species of Bathurst Inlet Held by the Canadian Museum of Nature

	Scientific Name			Habitat	Depth range	Depth (m)		Records	
Common name	**Family**	**Genus**	**Species**			**upper**	**lower**	**number**	**percent**
Arctic char	***Salmonidae***	***Salvelinus***	***alpinus***	**Anadromous**	**benthopelagic**	**0**	**70**	**57**	**27.4**
Ogac[1]	***Gadidae***	***Gadus***	***ogac***	**Marine**	**demersal**	**0**	**200**	**12**	**5.8**
Arctic alligatorfish	*Agonidae*	*Ulcina*	*olrikii*	Marine	demersal	15	520	10	4.8
Saffron cod	***Gadidae***	***Eleginus***	***gracilis***	**Marine**	**demersal**	**0**	**200**	**10**	**4.8**
Twohorn sculpin	*Cottidae*	*Icelus*	*bicornis*	Marine	demersal	1	560	9	4.3
Spatulate sculpin	*Cottidae*	*Icelus*	*spatula*	Marine	demersal	10	200	8	3.8
Arctic cisco	***Salmonidae***	***Coregonus***	***autumnalis***	**Anadromous**	**pelagic**	**-**	**-**	**8**	**3.8**
Atlantic poacher	*Agonidae*	*Leptagonus*	*decagonus*	Marine	demersal	120	930	7	3.4
Arctic cod	*Gadidae*	*Boreogadus*	*saida*	Marine	demersal	0	730	7	3.4
Starry flounder	***Pleuronectid***	***Platichthys***	***stellatus***	**Marine**	**demersal**	**0**	**375**	**7**	**3.4**
Pacific herring	***Clupeidae***	***Clupea***	***pallasii***	**Marine**	**pelagic**	**0**	**150**	**6**	**2.9**
Arctic staghorn sculpin	*Cottidae*	*Gymnocanthus*	*tricuspis*	Marine	demersal	0	240	6	2.9
Lake trout	***Salmonidae***	***Salvelinus***	***namaycush***	**Freshwater/Brackish**	**benthopelagic**	**18**	**53**	**6**	**2.9**
Ribbed sculpin	*Cottidae*	*Triglops*	*pingelii*	Marine	demersal	4	482	5	2.4
Polar cod	*Gadidae*	*Arctogadus*	*glacialis*	Marine	bathypelagic	0	1000	5	2.4
Arctic flounder[2]	***Pleuronectid***	***Liopsetta***	***glacialis***	**Marine**	**demersal**	**-**	**-**	**5**	**2.4**
Broad whitefish	***Salmonidae***	***Coregonus***	***nasus***	**Freshwater/Brackish**	**benthopelagic**	**-**	**-**	**4**	**1.9**
Arctic grayling	*Salmonidae*	*Thymallus*	*arcticus*	Freshwater	benthopelagic	0	30	4	1.9
Bering wolffish	*Anarhichadid*	*Anarhichas*	*orientalis*	Marine	demersal	-	-	3	1.4
Fourhorn sculpin[3]	***Cottidae***	***Triglopsis***	***quadricornis***	**Marine**	**demersal**	**1**	**100**	**3**	**1.4**
Round whitefish	*Salmonidae*	*Prosopium*	*cylindraceum*	Freshwater/Brackish	benthopelagic	0	72	3	1.4
Polar eelpout[4]	*Zoarcidae*	*Lycodes*	*polaris*	Marine	demersal	-	-	3	1.4
Shorthorn sculpin	*Cottidae*	*Myoxocephalus*	*scorpius*	Marine	demersal	0	110	2	1.0
Sea tadpole	*Liparidae*	*Careproctus*	*reinhardti*	Marine	bathydemersal	150	1200	2	1.0
Eelpout spp.[5]	*Zoarcidae*	*Lycodes*	*marisalbi*	Marine	demersal	60	980	2	1.0
Threespot eelpout	*Zoarcidae*	*Lycodes*	*rossi*	Marine	demersal	42	365	2	1.0
Slimy sculpin	*Cottidae*	*Cottus*	*cognatus*	Freshwater/Brackish	demersal	128	128	1	0.5
Bigeye sculpin	*Cottidae*	*Triglops*	*nybelini*	Marine	demersal	135	930	1	0.5
Gelatinous snailfish	*Liparidae*	*Liparis*	*fabricii*	Marine	bathydemersal	20	1750	1	0.5
Capelin	*Osmeridae*	*Mallotus*	*villosus*	Marine	pelagic	0	300	1	0.5
Rainbow smelt	***Osmeridae***	***Osmerus***	***mordax***	**Anadromous**	**pelagic**	**0**	**150**	**1**	**0.5**
Bering flounder	*Pleuronectid*	*Hippoglossoides*	*robustus*	Marine	demersal	18	425	1	0.5
Lake whitefish	*Salmonidae*	*Coregonus*	*clupeaformis*	Freshwater/Brackish	demersal	18	128	1	0.5
Stout eelblenny	*Stichaeidae*	*Anisarchus*	*medius*	Marine	demersal	10	150	1	0.5
Slender eelblenny	*Stichaeidae*	*Lumpenus*	*fabricii*	Marine	benthopelagic	0	175	1	0.5
Aurora unermak	*Zoarcidae*	*Gymnelus*	*retrodorsalis*	Marine	demersal	8	300	1	0.5
Fish doctor	*Zoarcidae*	*Gymnelus*	*viridis*	Marine	demersal	274	320	1	0.5
Pale eelpout	*Zoarcidae*	*Lycodes*	*pallidus*	Marine	demersal	60	980	1	0.5
Total								208	100.0

[1] also known as Greenland cod; [2] formerly *Pleuronectes glacialis* (Cooper and Chapleau, 1998); [3] formerly *Myoxocephalus quadricornis* (Kottelat, 1997); [4] also known as Canadian eelpout ; [5] formerly a sub-species of pale eelpout, but recently re-classified as a separate species (Moller, 2000).
Habitat types and depth ranges taken from species descriptions shown on FishBase.
Bolded rows indicates species captured in southern Bathurst Inlet in August 2001.

APPENDIX 3.7-4
STARRY FLOUNDER MUSCLE TISSUE ANALYSES, BATHURST INLET, AUGUST 2001

Appendix 3.7-4
Starry Flounder Muscle Tissue Analyses, Bathurst Inlet, August 2001

Sample number	23	25	27	28	92	93	94	95	125	126	127	128	149	175	176
Date Sampled	17-Aug	17-Aug	17-Aug	17-Aug	18-Aug	18-Aug	18-Aug	18-Aug	19-Aug	19-Aug	19-Aug	19-Aug	19-Aug	20-Aug	20-Aug
Moisture (% wet weight)	81.6	79.5	79.8	81.4	79.5	80.6	80.4	80.8	82.1	82.6	79.0	77.4	80.6	78.4	79.9
Total Metal concentration (mg/kg dry weight)															
Aluminum T-Al	105	78	16	46	32	41	40	195	15	37	22	16	20	10	15
Antimony T-Sb	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic T-As	17.50	8.90	9.44	4.83	3.08	4.43	4.52	2.79	22.10	7.31	18.00	12.90	3.07	17.60	14.90
Barium T-Ba	0.62	0.23	0.13	0.22	0.17	0.12	0.21	0.40	0.08	0.25	0.06	0.05	0.16	<0.05	0.14
Beryllium T-Be	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Bismuth T-Bi	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Boron T-B	16	26	20	25	44	33	31	32	41	34	12	22	50	31	28
Cadmium T-Cd	0.05	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Calcium T-Ca	610	943	618	753	1220	1200	2540	2840	515	1260	560	701	1630	616	3360
Chromium T-Cr	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cobalt T-Co	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Copper T-Cu	1.40	1.28	1.68	2.07	1.54	2.07	1.64	2.49	1.87	1.55	1.83	2.53	1.89	2.19	1.63
Iron T-Fe	121	25	15	26	20	50	18	71	12	28	21	12	10	9	14
Lead T-Pb	0.3	<0.1	<0.1	0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	0.1	<0.1	0.4
Lithium T-Li	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Magnesium T-Mg	1340	1460	1530	1890	1810	1980	1940	2010	1750	2070	1600	1600	2140	1620	1890
Manganese T-Mn	1.60	0.88	0.68	1.17	1.86	1.97	1.98	3.43	0.67	1.44	0.70	0.86	1.56	0.89	2.85
Mercury T-Hg	0.416	0.280	0.189	0.196	0.122	0.067	0.066	0.064	0.750	0.245	0.374	0.385	0.071	0.405	0.357
Molybdenum T-Mo	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Nickel T-Ni	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Potassium T-K	20000	18700	18400	21900	20400	21200	21200	21000	25000	22800	21300	19400	22500	20200	21200
Selenium T-Se	3	2	2	3	1	1	1	1	3	2	2	2	1	3	3
Silver T-Ag	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Strontium T-Sr	3.86	3.71	3.03	3.47	6.10	5.68	11.10	12.60	2.31	7.39	2.38	3.08	7.15	2.77	19.90
Thallium T-Tl	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tin T-Sn	0.8	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	0.5	<0.2
Uranium T-U	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Vanadium T-V	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc T-Zn	29.8	34.9	37.1	30.5	31.0	35.6	39.6	42.2	31.9	30.6	30.7	35.8	37.3	23.7	23.3

<=below detection limit

Appendix E-8
Baseline Marine Mammal Studies, September 2004

Author: **LGL Limited**
Date: **June 2005**

Photo credit: W.R. Koski, LGL Limited

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Bathurst Inlet Port and Road Project

Baseline Marine Mammal Studies, September 2004

prepared by

LGL LIMITED
environmental research associates

for

Bathurst Inlet Port and Road Joint Venture
340 Park Place, 666 Burrard Street
Vancouver, BC V6C 2X8

LGL Report TA4079-1

June 2005

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Bathurst Inlet Port and Road Project

Baseline Marine Mammal Studies, September 2004

prepared by

Ross Harris, Ted Elliott, and William E. Cross

LGL Limited, environmental research associates
22 Fisher St., POB 280
King City, ON L7B 1A6

for

Bathurst Inlet Port and Road Joint Venture
340 Park Place, 666 Burrard Street
Vancouver, BC V6C 2X8

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Executive Summary

The Bathurst Inlet Port and Road Project consists of a port on Bathurst Inlet connected to the mines and mineral deposits in Nunavut and Northwest Territories by a new 211 km all-weather road to Contwoyto Lake, and the existing "Tibbitt to Contwoyto" winter road. The port site will include a wharf to serve large ice-class vessels delivering fuel and bulk cargo to the port, a dock to handle barges serving Kitikmeot communities, and associated infrastructure and activities on shore. Noise, other disturbance, habitat alteration, and various types of discharges from project activities at the port and elsewhere along the shipping route during the construction and operations phases may disturb marine mammals. In winter and spring, ringed seals and possibly some bearded seals are expected to occur in Bathurst Inlet near the proposed port. In summer, belugas and some pinnipeds could occur in Bathurst Inlet. During the shipping period (August–September), ringed seals, bearded seals, belugas, narwhal, and other marine mammals (e.g., bowhead whales and polar bears) could occur along parts of the shipping route.

Marine mammal surveys were conducted from a fixed wing aircraft during 8–19 September 2004. They covered an area from Bathurst Inlet east and north to Peel Sound and Barrow Strait. Total survey effort was 44.9 hours and 10,031 km.

Several species of marine mammal were recorded during the surveys. There were 47 sightings of a total of 59 individuals identified as ringed seals throughout the survey area. An additional 20 sightings (25 individuals) were recorded as unidentified seals, many of which likely were ringed seals. There were eight sightings of individual bearded seals, and one sighting of two bearded seals. Some of the records of unidentified seals may have been of bearded seals. Bearded seals were widely scattered to the east and northeast of Cambridge Bay–in Queen Maud Gulf, Albert Edward Bay, Victoria Strait, Larsen Sound, and Franklin Strait. Given the difficulty in detecting seals in open water from a fast-moving aircraft, it is likely that only a very small proportion of the ringed and bearded seals there were seen.

Walruses were encountered only during the survey around Somerset Island and adjacent waters on 17 September. Two were seen in Radstock Bay, southwest Devon Island, hauled out on a pan of ice. Walruses may be present in small numbers along the most eastern portions of the proposed shipping route during August and September.

Belugas were observed in Peel Sound and Radstock Bay (southwestern Devon Island), but were not seen between Bathurst Inlet and southern Peel Sound. A total of 21 belugas were seen on a transect down the centre of Peel Sound and along the westward turn to the coast of Prince of Wales Island, and ~230 were seen along the southeastern coast of Prince of Wales Island. Approximately 240 belugas were sighted on transect in Radstock Bay. Adults and calves were present. No belugas were seen in Creswell Bay, Batty Bay, Elwin Bay, or elsewhere along the eastern coast of Somerset Island or in Barrow Strait. Based on the results of the 2004 and earlier surveys, it is unlikely that belugas would occur in Larsen Sound.

Belugas might be encountered in Bathurst Inlet. They have been recorded rarely at Kugluktuk, Taloyoak, Cambridge Bay, and Bathurst Inlet, and it is thought that those were extralimital occurrences. Given their occurrence in Amundsen Gulf, any belugas found in Coronation Gulf likely would be from that population.

One group of two bowhead whales was sighted in Radstock Bay on 17 September. Bowhead whales could be encountered along parts of the proposed shipping route during August and September. It is very unlikely that any would occur along the central portions, between Bathurst Inlet and Peel Sound. Most likely, they would be encountered in Admiralty Inlet, western Lancaster Sound, and Barrow Strait. A few might be in Peel Sound or as far south as Franklin Strait.

Narwhals also were recorded only on 17 September, when one group of ~12 was observed north of Prince Leopold Island in western Lancaster Sound and ~25 were seen in Radstock Bay. Narwhals occur commonly in many areas of the eastern and central Arctic islands, and could be encountered along parts of the shipping route. They would be rare south and west of Peel Sound and Franklin Strait. Depending on ice conditions, narwhals likely would be most abundant in Admiralty Inlet and western Lancaster Sound. Smaller numbers would occur in Barrow Strait and Peel Sound.

There were only two sightings of polar bears during the surveys; one was a single individual off the western coast of the Boothia Peninsula south of Weld Harbour, and the other was an adult and two cubs northwest of Gateshead Island in southern M'Clintock Channel. Both were in areas of heavy ice cover (95–99%). In addition to the two sightings, five kill sites (presumably by polar bears) and two observations of polar bear tracks were recorded. Polar bears are widely distributed and could occur along all northern portions of the shipping route during August and September, but likely would be encountered only where there is moderate to heavy ice cover.

1. Introduction

1.1 Background

The Bathurst Inlet Port and Road Project consists of a port on Bathurst Inlet connected to the mines and mineral deposits in Nunavut and Northwest Territories by a new 211 km all-weather road to Contwoyto Lake, and the existing "Tibbitt to Contwoyto" winter road. The port site will include a wharf to serve large ice-class vessels delivering fuel and bulk cargo to the port; a dock to handle barges serving the Kitikmeot communities of Kugluktuk, Bathurst Inlet, Cambridge Bay, Omingmaktok, Gjoa Haven, and Taloyoak; a 150-person construction camp and services; a 180 million-L diesel fuel tank farm; a truck and trailer maintenance shop; and a 1200-m airstrip. Noise, other disturbance, habitat alteration, and various types of discharges from project activities at the port and elsewhere along the shipping route during the construction and operations phases may disturb marine mammals. In winter and spring, ringed seals and possibly some bearded seals are expected to occur in Bathurst Inlet near the proposed port. In summer, belugas and some pinnipeds may occur in Bathurst Inlet. During the shipping period (August–September), ringed seals, bearded seals, belugas, narwhal, and other marine mammals (e.g., bowhead whales and polar bears) may occur along the shipping route.

1.2 Objectives

This baseline report presents and reviews background information on marine mammal abundance, distribution, movement patterns, and natural history in Bathurst Inlet and along the proposed shipping route to the east. The report includes a review of the literature and other background information, and the results of original field surveys conducted for this project during September 2004.

2. Methods

The September 2004 marine mammal surveys were conducted from a fixed wing aircraft during 8–19 September 2004. They covered an area from Bathurst Inlet east to Peel Sound and Barrow Strait.

2.1 Survey Design

The baseline surveys of the marine mammal populations that may be affected by the Bathurst Inlet Port and Road Project were designed to

- coincide with the time of year at which whales (i.e., belugas, bowhead whales, and narwhal) are expected to have travelled farthest into the central Arctic from the western and eastern Arctic;
- document marine mammal occurrence during the September portion of the proposed shipping period;
- cover the area of the proposed shipping route for which there is the least information on marine mammal occurrence;

- survey coastal and offshore areas to increase the chances of detecting belugas; and
- sample the marine mammal population quantitatively in a manner that would be repeatable.

Survey coverage extended from Bathurst Inlet east to Peel Sound in the central High Arctic. Areas surveyed included Bathurst Inlet, Elu Inlet, Melville Sound, Dease Strait, Queen Maud Gulf, Albert Edward Bay, Victoria Strait, southern M'Clintock Channel, Rasmussen Basin, St. Roch Basin, Larsen Sound, Franklin Strait, Peel Sound, and Barrow Strait (Fig. 1).

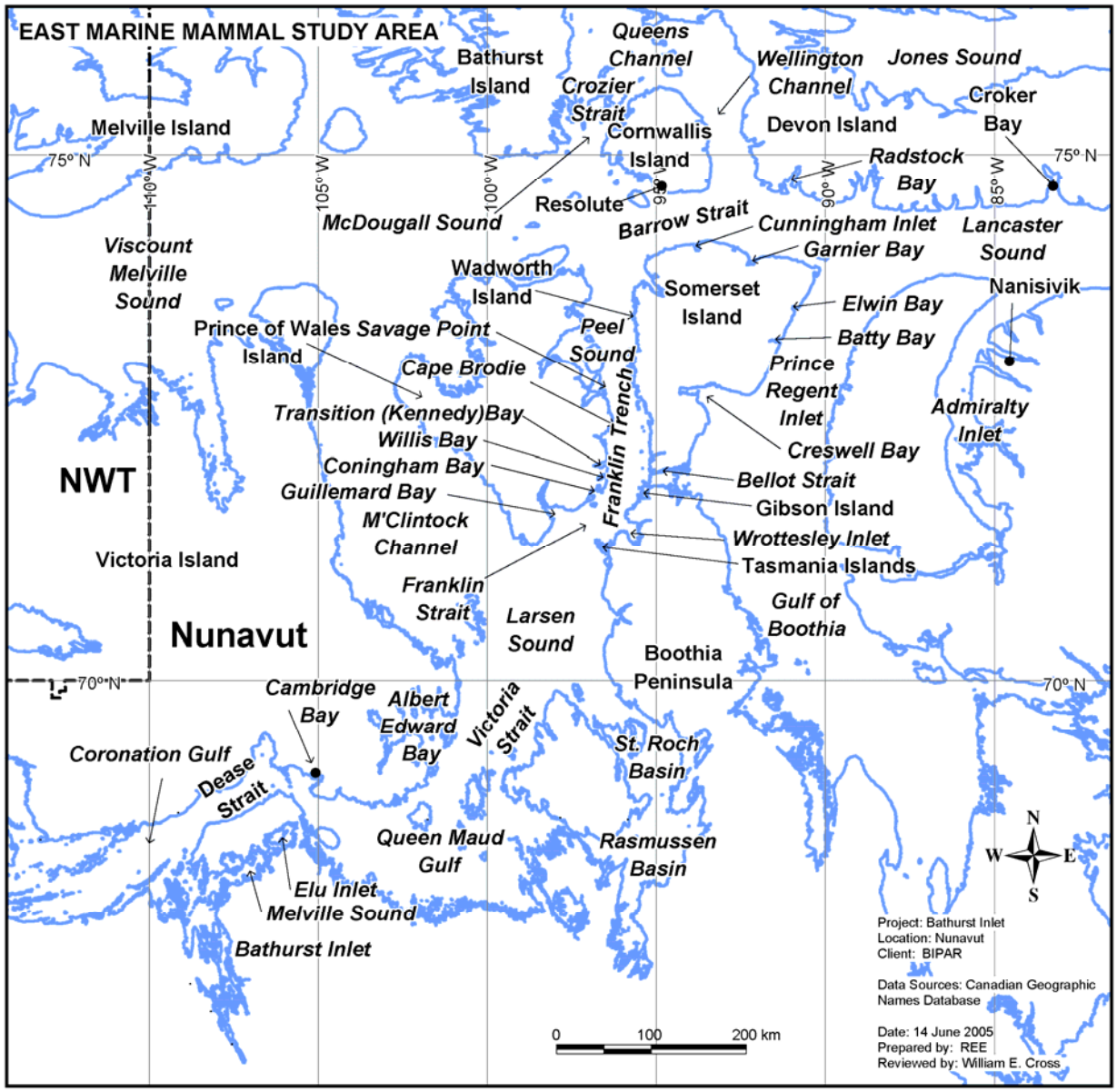

Figure1. Eastern Arctic, showing locations named in text.

An aerial survey employing strip transect methodology was selected as the most efficient technique for surveying the vast study area effectively within the relatively brief ice-free window available. Transects were situated to provide survey coverage of offshore and coastal areas. For most of the study area, offshore transects were parallel, straight transects, oriented north-south. Coastal transects connected offshore lines and paralleled the shoreline at a distance of 500 m offshore. Offshore lines were spaced one-half degree of longitude apart. In other parts of the study area (e.g. straits and bays), transects were situated in a different manner than described above to provide adequate survey coverage given the configuration of the coast (Fig. 2).

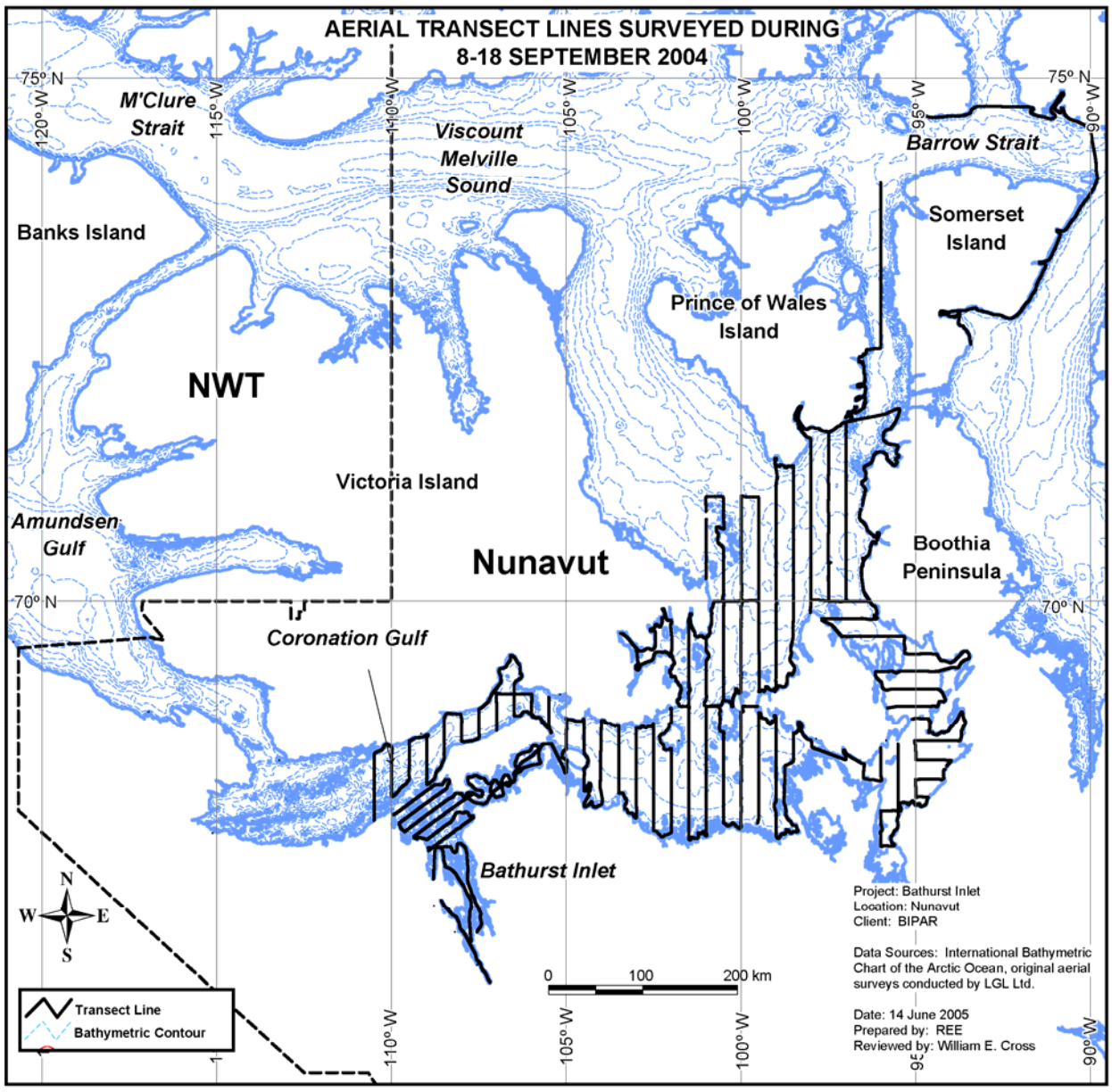

Figure 2. Marine mammal survey transect lines flown during 8–19 September 2004.

A special reconnaissance survey was flown during 17 September 2004 to locate the eastern-most belugas. That survey visited areas that eastern Arctic belugas are known to use, including Creswell Bay (Somerset Island), Radstock Bay (Devon Island), and several bays along southwestern Peel Sound (e.g., Coningham Bay; Fig. 1).

2.2 Survey Procedures

Surveys were flown in a twin-engine, high-wing aircraft (DHC-6 Twin Otter) at an altitude of 152 m (500 ft) above sea level and at a ground speed of 220 km/h (~120 knots). The survey aircraft, pilots, and an engineer were provided by Kenn Borek Air Limited of Calgary, Alberta, and staged out of their base in Resolute, Nunavut. There were two bubble windows on the aircraft, at the rear seat on each side.

Three observers were on the aircraft—two LGL biologists, and an Inuit observer who was trained by the LGL biologists. The two LGL biologists (primary observers) sat on opposite sides of the aircraft two seats behind the pilot (left side) and co-pilot (right side), respectively. They looked through flat windows. The Inuit biologist sat at the back on the right side of the aircraft, and looked through a bubble window. Two pilots were with the aircraft during all surveys.

We surveyed transect strips ~695 m wide on each side of the aircraft. These strips extended ~220 m–915 m from the centreline. Strip boundaries were marked on the aircraft's windows with tape at the appropriate clinometer angles, which were 9.5º and 34º below the horizontal for surveys at 152 m altitude. Sightings of marine mammals inside ~220 m or beyond ~915 m were recorded as off-transect sightings. For consistency with previous marine mammal surveys, we have *not* attempted to adjust the strip boundaries or calculated densities to take account of the "earth curvature" corrections described by Lerczak and Hobbs (1998). The surveys were usually flown during mid-day.

On occasion, it was difficult while flying on transect either to identify a sighting to species, or to obtain a precise count of the number of individuals in a large group. In those cases, we circled off transect to obtain a better look at the animals and then returned back on transect and continued the survey.

2.3 Data Recording Procedures

Data on wildlife sightings (including birds and mammals other than marine mammals) and environmental parameters were recorded by each observer. The position of the aircraft during a survey was recorded by a data-logging system.

For each marine mammal sighting, the observer dictated onto audio tape the time of the sighting to the nearest second, and the species (or general species group if species identification could not be made), number of individuals, habitat (hole or crack in ice, or open water), and behaviour (look, move, dive, or none) of the marine mammal(s), and noted whether the sighting was on or off transect. Similar data were recorded for other wildlife sightings. The specific times of sightings were used to extract their locations subsequently from the GPS data log files (see below).

The two primary observers also recorded the visibility (n.mi.), sea state (Beaufort scale), ice cover (%), ice deformation (%), melt water (%), sun glare (none, moderate, or severe), and overall sightability conditions (ranging from "excellent" to "impossible", and incorporating glare, fog, precipitation, and sea state). Those observations, along with the time, were recorded onto audio tape at the end of each 1-min (~3.7 km) time period, and were the estimated average values of each parameter during the preceding 1-min interval. An electronic timer signalled the observers at 1-min intervals. Estimated percentage values were categorized by intervals of 10%. Ice cover, ice deformation, and meltwater parameters were applied only to the conditions on-transect. Ice deformation was the estimated percent of the on-transect ice surface surveyed during the preceding minute that was deformed rather than smooth ice. Cracks and leads in the ice were also noted by the observers at the specific times when seen, allowing their locations to be extracted subsequently from the data log files. Cloud cover (in tenths), wind speed (knots), wind direction (ºT), and air temperature (ºC) were recorded (with the assistance of the pilots) at least once during each survey flight. Wind data were acquired from the aircraft's GPS, and air temperature from a thermometer mounted externally on the aircraft.

The data logging system consisted of a notebook computer, a DC to AC power inverter, and two GPS units (Garmin Model eTrex Vista). The GPS receivers were positioned on the dashboard of the aircraft. One GPS receiver was set to log aircraft position every 15 sec, storing it in the unit's onboard memory. The other GPS receiver was connected by a serial cable to the notebook computer. The notebook computer logged the GPS-derived aircraft position every 2 sec and also displayed the aircraft's position on a moving map display on the computer. The map display aided the observers in navigating to transect start and end points, and in monitoring how closely the pilots were following the predetermined flight lines.

2.4 Data Analysis Procedures

The location of each marine mammal (and other wildlife) sighting was determined by matching the time of the sighting with the position recorded for that time in the GPS logs. Time periods with severely impaired sightability conditions were excluded from all analyses. Each sighting was also linked to the environmental variables recorded for the corresponding 1-min (3.7-km) time period.

2.5 Survey Effort

A summary of the locations, dates, and times of each survey flight is presented in Table 1. Each transect was flown once. Total survey effort was 44.9 hours and 10,031 km.

2.6 Ice cover

For most of the year, virtually all of the study area is icebound. The proposed shipping period is during the most ice-free period of the year along the Northwest Passage—August and September. However, even during that period the entire Northwest Passage is rarely ice-free. Heavy ice cover typically remains in the central Arctic Archipelago (e.g., Larsen Sound). The distribution and abundance of marine mammals in the study area are highly dependent on the extent and nature of the ice cover.

Table 1. Summary of dates, locations, times, and survey effort for marine mammal surveys conducted in the Canadian High Arctic during 8-19 September 2004

Date (September 2004)	General Survey Area	Survey Period		Survey Effort	
		Start Time	Finish Time	Duration (h)	Distance (km)
8	Southern Bathurst Inlet	09:35	11:56	2.3	479.6
8	Northern Bathurst Inlet	14:30	16:46	2.3	505.1
9	Eastern Coronation Gulf, Dease Strait	10:25	13:37	3.2	712.3
10	Elu Inlet, Melville Sound	09:38	11:59	2.3	519.5
10	Dease Strait	12:11	12:47	0.6	134.6
10	Albert Edward Bay	14:12	15:15	1.0	237.6
11	Western Queen Maud Gulf	12:25	16:03	3.6	802.4
12	Western Victoria Strait	10:29	12:37	2.1	474.1
12	Eastern Victoria Strait	14:45	16:29	1.7	380.3
13	Central Queen Maud Gulf	12:13	15:03	2.8	628.2
14	Rasmussen Basin	09:39	12:15	2.6	573.1
15	Eastern Queen Maud Gulf	11:26	14:18	2.9	639.8
15	Eastern King William Island	15:57	18:51	2.9	647.8
16	Central Larsen Sound	10:57	13:06	2.1	472.7
16	Western Larsen Sound	16:37	17:41	1.1	238.6
17	Eastern Somerset Island, southwestern Devon Island, Barrow Strait	11:32	14:22	2.8	634.1
17	Peel Sound, eastern Larsen Sound	15:44	18:28	2.7	610.5
18	Central Larsen Sound	11:22	14:10	2.8	626.9
18	Eastern Larsen Sound	15:55	17:48	1.9	449.2
19	Southern M'Clintock Channel	11:04	12:15	1.2	264.4
	TOTALS			58.8	13,119.5

During the September 2004 surveys, substantial ice cover was encountered only in Larsen Sound and southern M'Clintock Channel (Fig. 3).

3. Results and Discussion

The results of the review of the literature and the September 2004 surveys are presented below, organized as species accounts. Table 2 summarizes the conservation status of those species. No marine mammal species that occur along the proposed shipping route are listed under Schedule 1 of the Species at Risk Act (SARA).

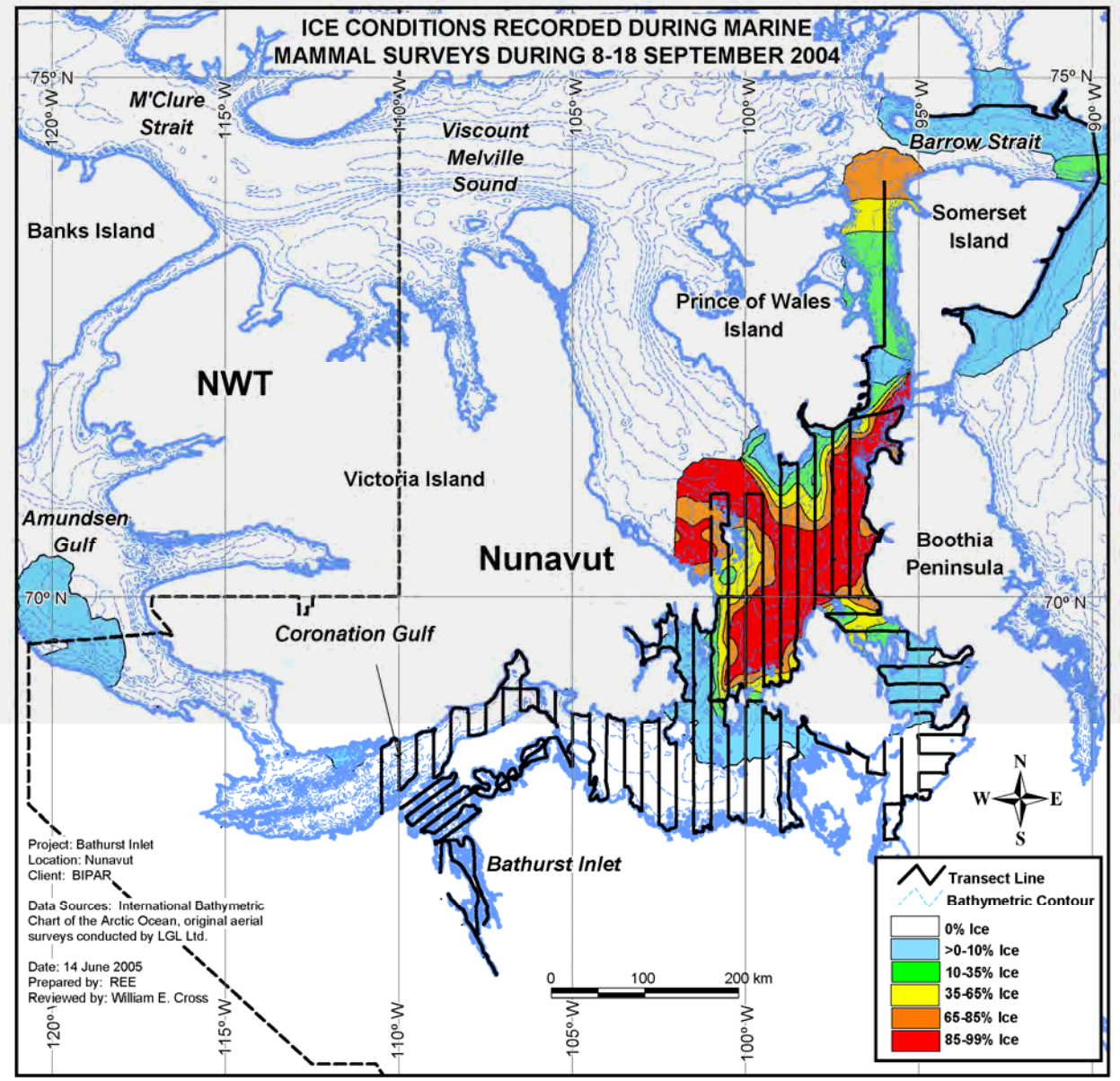

Figure 3. Ice cover recorded during marine mammal surveys flown during 8–19 September 2004.

3.1 Ringed Seal (Pusa hispida)

3.1.1 Range and Population Status

Ringed seals have a continuous northern circumpolar distribution. In Canada, their distribution is centred in the Arctic Archipelago, but they range from Newfoundland to the Beaufort Sea. Canadian populations are not considered to be at risk (COSEWIC 2004).

Table 2. Conservation status of marine mammals that occur along the proposed shipping route.

Species	Population/location	Status[1]		
		SARA[2]	COSEWIC[3]	CESCC[4]
Bowhead Whale	Eastern Arctic	Schedule 2: EN	NA	Sensitive
	Davis Strait-Baffin Bay	NA	T	NA
	Bering-Chukchi-Beaufort	Schedule 2: EN	SC	NA
Beluga Whale	Eastern Beaufort Sea	NL	NAR	Secure
	Eastern High Arctic – Baffin Bay	Schedule 3: SC[5]	SC	Sensitive
Narwhal	Canada	NL	SC	Sensitive
Walrus	Eastern Arctic	NL	NAR	Sensitive
Ringed Seal	Canada	NL	NAR	Secure
Bearded Seal	Canada	NL	DD	Secure
Harp Seal	Canada	NL	NL	Secure
Polar Bear	Nunavut	Schedule 3: SC	SC	Sensitive

Notes:
NA = Not applicable
[1] Nunavut does not have a list of species at risk.
[2] Species at Risk Act; NL=Not listed, SC=Special Concern, EN=Endangered,.
[3] Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007): NAR=Not at Risk; DD=Data Deficient; SC=Special Concern; T=Threatened; NL=Not Listed.
[4] Canadian Endangered Species Conservation Committee (2005).
[5] Under consideration for addition to Schedule 1.

Ringed seals are the most abundant marine mammal in the Canadian Arctic, but accurate population estimates are difficult to obtain. Canadian researchers have estimated the numbers of visible seals hauled out on the ice in spring; but those estimates may substantially underestimate the actual size of the populations. Some of the estimates are: (1) at least 40,000 ringed seals in the Canadian Beaufort Sea (Stirling et al. 1981b); (2) 50,000 in northern Amundsen Gulf (Kingsley 1990); (3) 49,000 in Prince Albert Sound (Kingsley 1990); and (4) 90,000 in the Canadian High Arctic (Kingsley 1985, 1990). No population estimates are available for Coronation Gulf or Bathurst Inlet.

There can be large natural variations in the numbers of ringed seals in an area over a period of a very few years (Stirling et al. 1977). In 1974–1975, there was a marked decrease in the abundance and productivity of seals in the Canadian Beaufort Sea and Amundsen Gulf (Stirling et al. 1977; Smith and Stirling 1978). There was another such decrease between 1982 and 1985 (Harwood and Stirling 1992).

3.1.2 Natural History

Ringed seals are year-round residents in the Arctic and are highly adapted for living in arctic conditions. Ice conditions influence ringed seal distribution and abundance (Smith and Stirling 1975, 1978; Moulton et al. 2002b), and densities have been shown to vary with

ecological circumstances such as biological productivity (Kingsley et al. 1985; Stirling and Øritsland 1995).

Ringed seals do not haul out on land, but haul out on sea ice to moult and rest. They also give birth to young on the ice, in subnivean lairs. As the ice forms in autumn, ringed seals open and then maintain breathing holes in the sea ice through the ice-covered period. As snow drifts over their breathing holes, seals excavate lairs in the drifts. There are two types of lairs; the haul-out lair and the breeding lair. Haul-out lairs are made as early as January, and breeding lairs are constructed in mid-March at the earliest (Smith et al. 1991). Ringed seals prefer to breed on landfast ice in all areas within the study area (McLaren 1958; Kelly 1988). However, ringed seals may also breed in the pack ice (Finley et al. 1983; Kelly 1988).

Ringed seal pups are born in the birth lairs in April. They nurse for 38–44 d (Smith et al. 1991). Newborn pups do not have a layer of blubber to protect them from the cold. They rely on their white fur, high metabolic rates, and the birth lair for protection from the cold. Newborn pups can and do enter the water to escape predation, however, they must return to the birth lair to prevent hypothermia (Smith et al. 1991). Pups are subject to intense predation by foxes and polar bears (Smith 1976; Kingsley 1990). In some areas, mortality from fox predation may be as high as 40% (Smith 1976).

During summer, ringed seals are dispersed throughout open-water areas. Some disperse to offshore areas after the landfast ice breaks up in summer (Heide-Jørgensen et al. 1992); in some regions, they move into coastal waters. Seasonal concentrations related to food sources are known in offshore waters of the Canadian Beaufort Sea off the Tuktoyaktuk Peninsula and off Cape Dalhousie (McLaren and Davis 1985; Harwood and Stirling 1992). Ringed seals encountered in the Alaskan Beaufort Sea during open-water seismic exploration were broadly dispersed as individuals or small groups (Harris et al. 1997, 1998; Lawson and Moulton 1999, 2001; Moulton and Lawson 2000, 2001; Moulton et al. 2002a).

Ringed seals are capable of moving distances of 1000 km or more during the summer (Heide-Jørgensen et al. 1992; Kapel et al. 1998; Teilmann et al. 1999), although they tend to show site fidelity (Teilmann et al. 1999). Ringed seals feed primarily on fish (especially arctic cod) and large crustacean zooplankters such as amphipods, euphausiids, epibenthic mysids, and decapods (Bradstreet et al. 1986; Smith 1987).

3.1.3 Results of September 2004 Surveys

There were 47 sightings identified as ringed seals during the September 2004 aerial surveys. Those accounted for a total of 59 individual seals. Most of the records were of single seals (37 sightings), with many fewer sightings of two seals (6), three seals (2), and four seals (1). An additional 20 sightings (total of 25 individuals) were recorded as unidentified seals, many of which likely were ringed seals. Most of those records also were of individual seals (16 sightings), with three records of groups of two seals, and one sighting of a group of three seals. Ringed seals and unidentified seals were observed throughout the survey area.

Ringed seal sightings were not mapped because the results of the September 2004 surveys should not be interpreted as indicative of the true distribution and abundance of ringed

seals. Seals in the open water are very difficult to detect from a fast-moving aircraft flying at 500-foot altitude, and most probably are not detected. However, most of Larsen Sound was ice-covered and seals at or on the surface would have been more readily detected. Therefore it probably is noteworthy that very few seals, or seal holes, were observed in that region.

3.1.4 Conclusions

Ringed seals likely would occur in Bathurst Inlet on fast ice in spring and in open water in summer. Ringed seals also occur commonly along the shipping route. Their local distribution would be determined in part by ice conditions.

3.2 Bearded Seal (Erignathus barbatus)

3.2.1 Range and Population Status

Bearded seals have a northern circumpolar distribution. They are distributed throughout the Canadian Arctic in relatively low densities. Canadian populations are designated "Not at Risk" (COSEWIC 2004).

Uncorrected estimates of the number of the number of bearded seals in eastern Lancaster Sound and western Baffin Bay ranged from 7400 to 9500 (Koski and Davis 1980). Maximum densities of bearded seals in that region ranged from 0.05 to 0.24 seals/km^2 (Finley 1976; Koski and Davis 1979; Koski 1980a,b; Koski and Davis 1980; Kingsley et al. 1985).

3.2.2 Natural History

During winter, bearded seals are primarily restricted to areas of moving, broken pack ice. Because they have only a limited capability to maintain breathing holes in ice, most bearded seals are excluded from areas of fast ice during winter (e.g., many of the channels in the Arctic Archipelago), although some use ice holes made by ringed seals. Most bearded seals undertake seasonal migrations in response to the advance and retreat of fast ice (Martell et al. 1984). Limited numbers of bearded seals overwinter in polynyas (Cleator et al. 1989).

The bearded seal is a benthic feeder that is most abundant in areas where it can reach the bottom to feed, usually in waters less than 200 m deep (Burns and Frost 1983; Finley and Evans 1983). The bearded seal's preferred habitat is areas with thin, broken or rotten ice, or the floe edge (Kingsley 1985). This species also prefers less stable ice during break-up, and tends to avoid areas heavily used by walruses.

In the eastern Arctic Islands, fish, especially arctic cod, comprise much of the diet (Finley and Evans 1983). There, bearded seals are most abundant where water depths are less than 100 m (Kingsley 1985). This species is sparsely distributed throughout the central High Arctic, primarily in coastal areas, west to at least eastern Melville Island.

Throughout the year, bearded seals typically occur alone or in small groups.

3.2.3 Results of September 2004 Surveys

Very few bearded seals were identified during the September 2004 aerial surveys. There were eight sightings of individual bearded seals, and one sighting of two individuals. Some of the records of unidentified seals may have been of bearded seals. All nine sightings identified as bearded seals were widely scattered to the east and northeast of Cambridge Bay–in Queen Maud Gulf, Albert Edward Bay, Victoria Strait, Larsen Sound, and Franklin Strait.

Bearded seal sightings were not mapped because the results of the September 2004 aerial survey should not be interpreted as indicative of the true distribution and abundance of bearded seals in the survey area. Given the difficulty in detecting seals in open water from a fast-moving aircraft, it is likely that only a very small proportion of the bearded seals there were seen.

3.2.4 Conclusions

Ringed seals could occur in Bathurst Inlet on fast ice in spring and in open water in summer. Low numbers of bearded seals also could be encountered along the shipping route, especially where water depths are <100 m and there are scattered ice pans.

3.3 Harp Seal (Phoca groenlandica)

3.3.1 Range and Population Status

Harp seals summer in the eastern and central Canadian Arctic and in European Arctic waters. They do not occur in the western Canadian Arctic. The Newfoundland stock of harp seals whelps and moults in the Gulf of St Lawrence and on the ice front in the Strait of Belle Isle during February through May. They migrate north from those areas in April and May to summer in arctic waters. They are found in summer from northern Hudson Bay, Hudson Strait, and Davis Strait north to northern Baffin Bay and Jones Sound, west to offshore southwestern Greenland, and east through Lancaster Sound to Prince Regent Inlet, Barrow Strait, and Peel Sound. Numbers of harp seals occurring in various parts of the Canadian Arctic in summer are poorly known (Davis et al. 1980).

Canadian populations of the harp seal are not listed by COSEWIC (COSEWIC 2004).

3.3.2 Natural History

Harp seals are present in the High Arctic from June through October. Most summer in the eastern portions of the Arctic Archipelago, with a relatively low proportion moving as far west as Barrow Strait or Peel Sound (Finley 1976). They are relatively more numerous in Croker Bay, Admiralty Inlet, and northern Navy Board Inlet (Johnson et al. 1976; Koski and Davis 1979; Fallis et al. 1983).

The most important route for harp seals migrating into the central Arctic is via Lancaster Sound. Harp seals may concentrate at the southern end of the Lancaster Sound ice edge until leads open up, when they migrate westward through the leads. A steady movement of seals

occurs along the northeastern coast of Baffin Island from mid June to late August with stragglers noted as late as mid September (Koski and Davis 1979). Most of the animals that enter Lancaster Sound are adults (Davis et al. 1980).

Most of the estimated 150,000 harp seals that may enter Lancaster Sound do not move as far west as Barrow Strait (Finley 1976). However, in some years several thousand travel as far west as Barrow Strait and Peel Sound (Finley 1976; Finley and Johnston 1977). Ice permitting, they can appear in the Barrow Strait area in early July. Harp seals may concentrate at the Peel Sound ice edge and then migrate south into the sound as ice breaks up. They also occur in Wellington Channel (Johnson et al. 1976; Koski and Davis 1979; Fallis et al. 1983). Harp seals migrate out of Barrow Strait during August and most have departed by late August (Finley 1976). However, some were found in Peel Sound as late as mid and late September. They were swimming north, presumably migrating out of the sound (Finley and Johnston 1977). Harp seals may leave the Bellot Strait area in Prince Regent Inlet in early September.

Harp seals are gregarious and often travel in groups of up to 100 (Koski and Davis 1979), or even up to 500 when on the summer range (Fallis et al. 1983). Large congregations can be found almost anywhere within their summer range. Harp seals will concentrate to feed on their principal prey, the arctic cod, which itself congregates in large numbers (Finley et al. 1990a). Harp seals will haul out on ice pans while on their summer range.

Harp seals depart the Lancaster Sound region in late September. They remain along the coasts until the outbound migration, which coincides with the formation of pan ice in offshore waters in mid to late September (Koski and Davis 1980). There can be large numbers in offshore waters, but they are widely dispersed (Koski and Davis 1980). The outbound movement along the north shore of Lancaster Sound is protracted, lasting from spring through summer to fall. The outbound migration along the south shore of Lancaster Sound can be ~2 weeks in duration in late September (Koski and Davis 1980). Most have departed the region by October.

3.3.3 Results of September 2004 Surveys

One harp seal was tentatively identified during the September 2004 surveys. That was along the coast of the Boothia Peninsula south of Wrottesley Inlet, near the Tasmania Islands during 18 September.

3.3.4 Conclusions

Harp seals could be encountered only along the shipping route. Encounters most likely would occur in Admiralty Inlet and western Lancaster Sound. The probability of encountering harp seals would decrease to the west through Barrow Strait and Peel Sound. Harp seals likely would not be encountered beyond Peel Sound.

3.4 Walrus (Odobenus rosmarus)

3.4.1 Range and Population Status

Walruses are widespread in the eastern Canadian Arctic, but largely absent in Canadian waters west of there. The Atlantic subspecies, the only population that occurs regularly in the Canadian Arctic, is widely distributed from approximately Barrow Strait, Bathurst Island, and Devon Island east to Baffin Bay and south into Foxe Basin and Hudson Bay. The western Arctic subspecies of walrus winters in the Bering Sea and undertakes an annual summer migration into the western Beaufort Sea (Fay 1982). A very few of those western walruses are found east of Barrow, Alaska, in summer, and extremely few are found as far east as the Canadian Beaufort Sea.

The walrus population in the Canadian central High Arctic is small, estimated to be 1000–2000 (Davis et al. 1978a). Walruses are more numerous farther south, in northern Foxe Basin and northern Hudson Bay (Richard 2001). Canadian walrus populations have been designated "Not at Risk" by COSEWIC (2004), and are not listed under SARA.

There are records of extralimital occurrences of walrus in the central Arctic Archipelago. Stewart and Burt (1994) listed records for Kugluktuk, Taloyoak, and Bathurst Inlet.

3.4.2 Natural History

Walruses cannot overwinter in areas of solid ice, and must make seasonal movements to areas of broken pack ice. Consequently, the Canadian high arctic population evacuates most of the central Arctic Archipelago and winters in Baffin Bay and in polynyas at the west end of Jones Sound, in Penny Strait, and in Queens Channel (Davis et al. 1978a; Kiliaan and Stirling 1978).

Most walruses that winter in Baffin Bay migrate from there to summering areas in the central High Arctic via Lancaster Sound. The summer range is centred on Cornwallis Island, Bathurst Island, and western Devon Island. The timing of migration westward into the central Arctic through Lancaster Sound depends on ice break up but usually peaks in July. The movement occurs primarily along the south coast of Devon and Cornwallis islands. About 300–500 animals are involved (Davis et al. 1978a; Koski 1980b). Numbers of walruses in Lancaster Sound decrease after mid August (Johnson et al. 1976), as most apparently migrate farther west to summering areas. About 200–300 may follow another route to the central High Arctic from Baffin Bay via Jones Sound (Davis et al. 1978a; Koski 1980b). Most walruses reach their summering areas by late July or early August. About 100–150 summer in eastern Lancaster Sound (Johnson et al. 1976; Koski and Davis 1979). A few are found in the vicinity of the Wollaston Islands, but densities are much lower on the south side of Lancaster Sound than on the north side (Johnson et al. 1976; RRCS 1977). Very few walruses use the offshore waters and south shores of Barrow Strait, the west shores of Prince Regent Inlet and the Gulf of Boothia, or Peel Sound (Davis et al. 1978a).

Most walruses retrace the spring route back to Baffin Bay at the time of freeze up. Fall migration out of the central High Arctic begins at the end of September and may peak in mid October (Koski and Davis 1980). Major eastward movements occur in eastern Lancaster Sound in mid October (Koski and Davis 1980). As freeze up continues, some walruses that summered

in Queen's Channel and McDougal Sound migrate to overwintering areas in polynyas at Hell Gate/Cardigan Strait and Penny Strait.

Although widely distributed in the eastern Arctic, walruses tend to be abundant only in a few areas that provide suitable habitat. They prefer shallow waters (usually <100 m), where they can most easily reach their preferred benthic food sources, and where they have access to ice pans on which to haul out (Lowry 1985). If sea ice is unavailable during summer, walruses use traditional terrestrial haul-out sites (Salter 1979). They are gregarious, foraging and migrating in herds and hauling out in densely packed groups on the ice or shore. In the vicinity of the proposed shipping route, summer terrestrial haul-out sites have been reported along southwest Devon Island, and in the Crozier Strait area (between Bathurst and Cornwallis islands) (Davis et al. 1978a).

Walruses are primarily benthic feeders. They prey on many species of benthic animals, but mainly consume clams (Fay 1982).

Walruses have a low birth rate, at best giving birth to one calf approximately every two years. The calves are born on the ice flows in May or June, and are dependent on the female for ~18 months to two years (Mansfield 1958; Fay 1982).

3.4.3 Results of September 2004 Surveys

Walruses were encountered only during the reconnaissance survey around Somerset Island and adjacent waters on 17 September 2004. Two walruses were seen in Radstock Bay, southwest Devon Island, hauled out on a pan of ice.

3.4.4 Conclusions

Walruses may be present in small numbers along the most eastern portions of the proposed shipping route during August and September. At that time, most walruses are either along the north side of Barrow Strait and Lancaster Sound, or north of Barrow Strait. Few walruses occur offshore in Barrow Strait or south of Barrow Strait to Peel Sound. West of Peel Sound, walruses are rare. It is possible that walruses could be found further south along the shipping route or in Bathurst Inlet, as there have been extralimital sightings there.

3.5 Beluga (Delphinapterus leucas)

3.5.1 Range and Population Status

The beluga has a northern circumpolar distribution, ranging south into the subarctic. Two populations of beluga in the Canadian Arctic are of potential concern to the project: the Eastern Beaufort Sea and Eastern High Arctic–Baffin Bay stocks (Davis and Finley 1979; Finley et al. 1987; COSEWIC 2004). The Eastern Beaufort Sea population, possibly the source of the belugas that have been recorded in Coronation Gulf and Bathurst Inlet, summer in the eastern Beaufort Sea and Amundsen Gulf (Finley et al. 1987); they are not discussed further here. The Eastern High Arctic–Baffin Bay stock summers in the Canadian central High Arctic and winters in Baffin Bay.

The summer range of the Eastern High Arctic–Baffin Bay population overlaps in part with the proposed shipping route. That population is listed under Schedule 3 of SARA as "Special Concern". COSEWIC (2004) also has designated that population as of Special Concern; i.e., the population may become threatened or endangered because of a combination of biological characteristics and identified threats. Innes et al. (2002) provided an estimate of abundance for this population, corrected for submerged animals, of 21,213 (95% CI = 10,985–32,619). That estimate is based on aerial and photographic surveys of Prince Regent Inlet, Barrow Strait, and Peel Sound during 31 July to 3 August 1996. Although that area does not include all belugas summering in the Canadian High Arctic, it does encompass the core summering range and includes the estuaries and bays used by large congregations of belugas (e.g., Creswell Bay on Somerset Island).

Belugas typically do not occur in the central Arctic Archipelago. It is hypothesized that they do not because belugas (and some other marine mammals) cannot penetrate the extensive areas of permanent pack ice that occur year-round in many of the central Arctic channels. Nevertheless, there are extralimital records of beluga whales in the central Arctic Archipelago. Belugas have been recorded rarely at Kugluktuk, Taloyoak, Cambridge Bay, and Bathurst Inlet (Stewart and Burt 1994; Priest and Usher 2004).

3.5.2 Migration and Seasonal Movements

The Eastern High Arctic–Baffin Bay population winters in loose pack ice along the west coast of Greenland south of Disko Island (Davis and Finley 1979; McLaren and Davis 1983), and also in the North Water polynya in northern Baffin Bay (Finley and Renaud 1980; Richard et al. 1998a, 2001a; Heide-Jørgensen et al. 2003b). Belugas from the smaller population wintering in the North Water begin entering Lancaster Sound in late April or early May (Finley and Renaud 1980), and the peak movement of Greenland-wintering animals occurs later, in late June and July (Davis and Finley 1979; Koski et al. 2002). During the migration into the central High Arctic, the westward passage of whales is often blocked by fast ice edges across channels such as Lancaster Sound. In such circumstances, large congregations of belugas can occur along the ice edges (Finley et al. 1984a,b). For example, 1800 belugas were found along a 60-km portion of the fast ice edge across eastern Lancaster Sound on 11 July 1978 (Koski and Davis 1979).

The core summering range of the eastern high arctic beluga whale population is in offshore and coastal waters around Somerset Island: in Prince Regent Inlet, Barrow Strait, and Peel Sound (Koski et al. 2002). Some range north and west of Barrow Strait, around Cornwallis Island and eastern Bathurst Island. Very few belugas summer in eastern Lancaster Sound. During the early open-water period (mid July to mid August), belugas concentrate in large herds of up to several thousand in a few shallow estuaries along the northern and eastern coasts of Somerset Island (Finley 1976; Smith et al. 1985; Koski et al. 2002). The estuaries regularly used during that period are Creswell Bay, Batty Bay, Elwin Bay, Garnier Bay, and Cunningham Inlet. Belugas appear to be persistent in their use of estuaries, and use of the estuaries may be site-traditional and critical to the life scheme of the species (Finley et al. 1987). The warm, brackish waters in estuaries are thought to enhance the skin moult; apparently little feeding occurs in estuaries (Koski et al. 2002).

Most belugas abandon the estuaries along northern and eastern Somerset Island by mid August, and a large proportion shift to Peel Sound and northern Franklin Strait until fall migration begins in early to mid September (Richard et al. 2001a; Koski et al. 2002). During surveys in August and September 1976, most belugas were observed offshore in southern Peel Sound and along the southeastern coast of Prince of Wales Island, in Coningham Bay and north to Savage Point (Koski et al. 2002). An estimated 2340 individuals were present in Peel Sound on 4 September 1976 (Koski et al. 2002).

Belugas satellite-tagged during July 1996 in estuaries around Somerset Island used several bays on Prince of Wales Island (Transition/Kennedy Bay, Willis Bay, and Coningham Bay) and made daily trips to a deep-water area offshore in Peel Sound called the Franklin Trench (Richard et al. 2001a; Heide-Jørgensen et al. 2003b; P. Richard 2005, pers. comm.). There they frequently dove to the seabed. Some of those animals also occasionally used the eastern side of Peel Sound/Franklin Strait, including Wrottesley Inlet on the Boothia Peninsula, where Smith and Martin (1994) have also reported belugas. Belugas are also known from an estuary on the west coast of Somerset Island north of Wadworth Island (Smith and Martin 1994).

During late summer, belugas feed on coastal concentrations of polar cod (*Boreogadus saida*) under pan ice and in deep offshore waters (Finley and Johnston 1977; Bradstreet et al. 1986; Koski et al. 2002).

Satellite-tagged belugas departed southern Peel Sound in late August and early September and quickly swam to the southern coast of Devon Island (Richard et al. 2001a; Heide-Jørgensen et al. 2003b). Smith and Martin (1994) reported similar findings. The rapid fall migration of belugas out of the central High Arctic occurs in mid to late September and is concentrated close along the south coast of Devon Island (Davis and Finley 1979; Koski and Davis 1979, 1980; Heide-Jørgensen et al. 2003b). The fall migration is almost exclusively along the northern margin of Lancaster Sound and within 400 m of shore (Koski et al. 2002). Most of the population passes through Lancaster Sound in less than a week (Koski et al. 2002). The whales then turn north along the eastern coast of Devon Island. Some enter Jones Sound, and others swim directly on to southeastern Ellesmere Island and northern Baffin Bay (Koski et al. 2002). Tagged beluga whales moved along the southern and eastern coasts of Devon Island, arriving in Jones Sound and northern Baffin Bay from late September to early October (Richard et al. 2001a; Heide-Jørgensen et al. 2003b). Seventeen of 20 tagged individuals travelled to the North Water and were recorded there until the last of the tags ceased transmitting, from mid October to late November. Three animals continued on to coastal waters of southwestern Greenland (Richard et al. 2001a; Heide-Jørgensen et al. 2003b).

During both spring and fall migrations, belugas are found regularly in large groups of up to several hundred (Koski and Davis 1979, 1980). The timing and extent of spring, summer, and autumn movements in the central High Arctic varies from year to year, sometimes dramatically, in response to ice conditions (Koski et al. 2002).

3.5.3 Results of the September 2004 Aerial Surveys

Belugas were observed in Peel Sound and Radstock Bay on southwestern Devon Island (Fig. 4), but were not seen between Bathurst Inlet and southern Peel Sound.

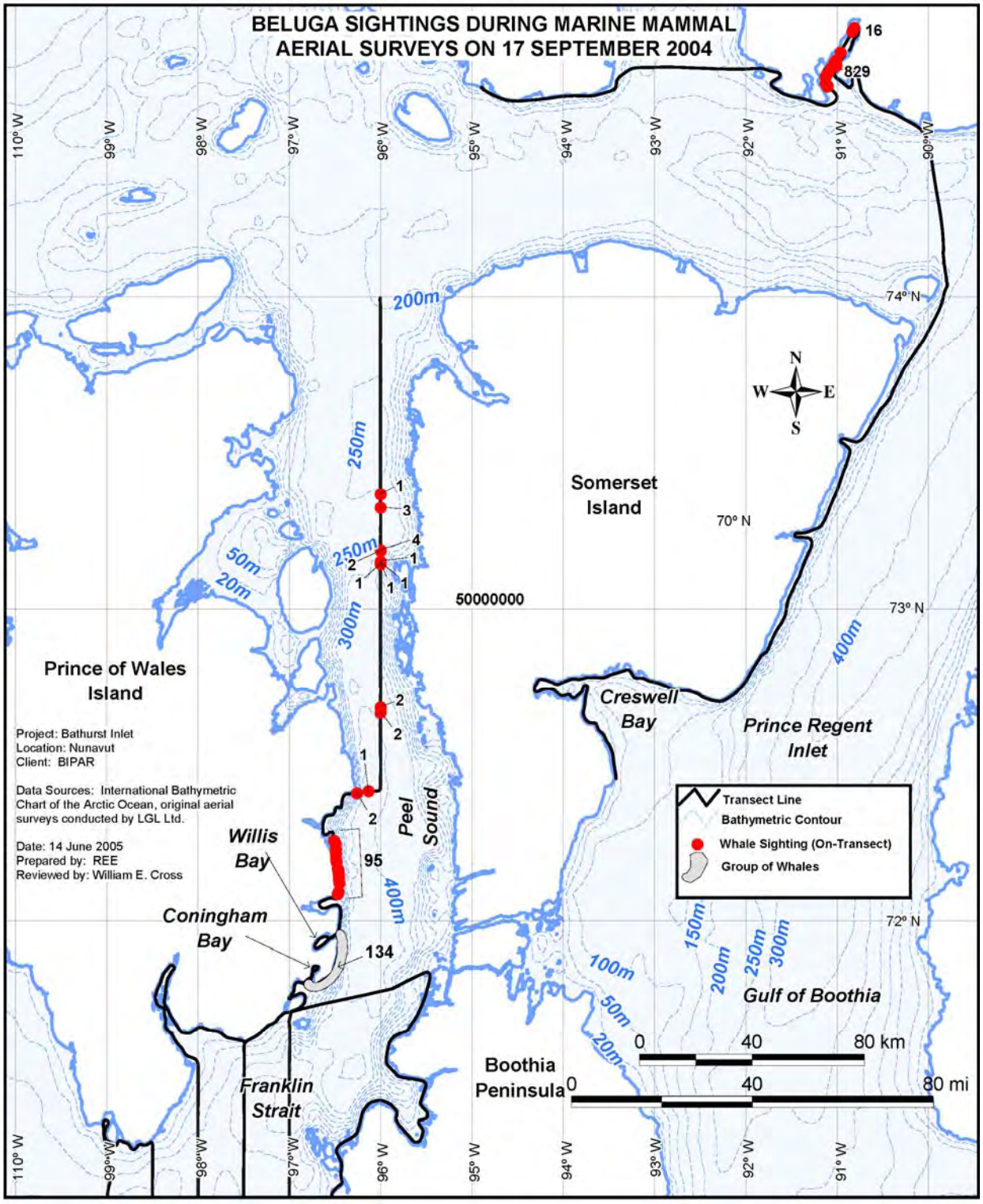

Figure 4. Belugas recorded during marine mammal surveys flown during 8–19 September 2004.

On 17 September 2004, a reconnaissance survey was conducted to determine where the eastern population of belugas was located. Belugas had not been sighted east of Bathurst Inlet to

that point. It was expected that the eastward migration out of the central High Arctic would have begun by mid September, but it was unclear whether all beluga whales had departed Peel Sound. The initial survey flight on 17 September was flown along the eastern coast of Somerset Island, across Barrow Strait to southwestern Devon Island (including into Radstock Bay), and west to Resolute, and the second flight that day was flown south through Peel Sound and along the southeastern coast of Prince of Wales Island. Belugas were observed in Radstock Bay, Peel Sound, and along the southeastern coast of Prince of Wales Island (Fig. 4).

Approximately 240 belugas were sighted on transect in Radstock Bay by the prime observers during the 17 September survey. At least another 30 were seen off transect. Adults and calves were present. No belugas were seen in Creswell Bay, Batty Bay, Elwin Bay, or elsewhere along the eastern coast of Somerset Island or in Barrow Strait.

The survey of Peel Sound initially followed the centre of the sound (longitude 96˚W) south from latitude 74˚N (south side of Barrow Strait) to 72˚25'N (opposite Cape Brodie on Prince of Wales Island). The transect then turned westward to the coast of Prince of Wales Island and followed the coast south to the mouth of Guillemard Bay (Figs. 1 and 4). A total of 21 belugas were seen on transect down the centre of Peel Sound and along the westward turn to the coast of Prince of Wales Island.

Along the southeastern coast of Prince of Wales Island, ~230 belugas were recorded. Ninety-five were encountered between Cape Brodie and Willis Bay (Fig. 4). Willis Bay itself was ice-covered. Along the coast between Willis Bay and Coningham Bay was a large group, all swimming to the south. To estimate the number of whales in that group, we broke off the transect and circled over the whales at a higher altitude (approximately 700–800 ft ASL). Two passes over the group provided an estimate of 134 individuals. No belugas were seen within Coningham Bay (there was <1% ice cover in the mouth of Coningham Bay and 30-50% ice cover within the bay), and no belugas were seen south of Coningham Bay. That included earlier and subsequent surveys of Franklin Strait, Larsen Sound, Wrottesley Inlet, and the western coast of the Boothia Peninsula south from Gibson Island (south of Bellot Strait).

3.5.4 Conclusions

Belugas are expected to occupy waters along the proposed shipping route during the August–September shipping season. Belugas likely would be distributed in Lancaster Sound, Prince Regent Inlet, Barrow Strait, Peel Sound (and possibly Franklin Strait), and along the coasts of Somerset Island and the eastern coast of Prince of Wales Island. Based on the results of the 2004 and earlier surveys, it is unlikely that belugas would occur south of Franklin Strait. The shipping season includes the times when the Eastern High Arctic belugas are farthest into the central High Arctic (late August-mid September), and when those same whales are migrating out of the High Arctic through Lancaster Sound (early September into early October). Most individuals would be in Prince Regent Inlet, around eastern and northern Somerset Island, eastern Prince of Wales Island, and in Peel Sound during August. By late August and early September, belugas begin moving from Peel Sound through Barrow Strait to southern Devon Island. However, some belugas were present in southern Peel Sound as late as 17 September during the 2004 surveys. During mid to late September, virtually all eastern arctic belugas

depart the Central High Arctic via the southern and eastern coasts of Devon Island. The eastern High Arctic population of belugas is designated "Special Concern" by COSEWIC (2004).

Belugas might be encountered in Bathurst Inlet. Belugas have been recorded rarely at Kugluktuk, Taloyoak, Cambridge Bay, and Bathurst Inlet (Stewart and Burt 1994; Priest and Usher 2004), and it is thought that those were extralimital occurrences. Given their occurrence in Amundsen Gulf, any belugas found in Coronation Gulf likely would be from that population.

3.6 Bowhead Whale (Balaena mysticetus)

3.6.1 Range and Population Status

The bowhead whale is a large, slow-moving Arctic baleen whale that is well-adapted for living in ice-covered waters. It is rare; all stocks were severely reduced in numbers by intensive commercial whaling during the 1800s and early 1900s. The Davis Strait-Baffin Bay stock that ranges throughout the eastern and central Canadian High Arctic (Davis and Koski 1980; Finley 2001) is on the proposed shipping route.

COSEWIC recognizes two stocks of bowhead whales in the Canadian eastern Arctic. The Davis Strait-Baffin Bay stock, along with the Hudson Bay-Foxe Basin stock, comprises the Eastern Arctic population. Both of those stocks are designated "Threatened" by COSEWIC, with a present population estimated to be less than 3000 animals (COSEWIC 2005). Prior to commencement of commercial exploitation in the early 19th century, the Davis Strait stock may have numbered about 11,000 individuals (I.W.C. 1992).

Recent satellite-tracking studies of bowhead whales in West Greenland and the eastern Canadian Arctic suggest that there is only one stock of eastern bowhead whales, rather than two, and that Hudson Strait is an important wintering area for that population (Heide-Jørgensen et al. 2005). Based on surveys of Hudson Strait and the West Greenland coast conducted during March 1981 and 1982, and an assumed population growth rate of 3.4% per year (George et al. 2004), Koski et al. (2005) derived a projected population estimate of 3971 (95% CI 1654–9532) for the overall eastern bowhead whale population in 2004.

3.6.2 Migration and Seasonal Movements

The wintering areas, summering areas, and migration routes of eastern arctic bowheads are not understood completely. Bowheads apparently winter primarily in Hudson Strait, and in smaller numbers in Baffin Bay, e.g., along the coast of western Greenland (Koski et al. 2005; W.R. Koski pers. comm.). Bowheads are known to summer in northern Hudson Bay-Foxe Basin, and in the central High Arctic. Recent satellite tracking studies have indicated that some bowheads use both summering areas (Heide-Jørgensen et al. 2005). The central High Arctic summering area and the associated migration routes are relevant to the proposed shipping route. Bowhead whale migration into the eastern and central High Arctic is via Lancaster Sound. That migration movement can extend from early to mid May through early August, with a peak in late June (Davis and Koski 1980). During May to early July, bowheads are found at the floe edge and in the pack ice off Lancaster Sound and Pond Inlet (Reeves et al. 1983; Moore and Reeves

1993). When the pack ice melts, they quickly migrate through Lancaster Sound to the channels of the Arctic Archipelago.

About half of the existing Davis Strait-Baffin Bay stock summer in the bays and passages of the central and eastern High Arctic islands during August and September (Davis and Koski 1980; Koski and Davis 1980). Principal summering areas include Isabella Bay (eastern Baffin Island), Eclipse Sound (northern Baffin Island), Milne Inlet, Admiralty Inlet, and Prince Regent Inlet, with the latter area considered to be a major nursery area (Lubbock 1937). A few bowheads occur in the Peel Sound/Franklin Strait area and in Barrow Strait (Davis and Koski 1980; Davis et al. 1980). They are present in the region from late June through September. Some of the Davis Strait stock summer off northeast Baffin Island (Davis and Koski 1980).

The fall migration out of the eastern Arctic Archipelago occurs during late August through October. In late August and September, whales that summer in Prince Regent Inlet and areas to the west migrate to the north coast of Baffin Island, at which point the migration occurs close to shore. Whales that summer in Eclipse Sound and Milne Inlet proceed north through Navy Board Inlet and then east along Bylot Island (Koski and Davis 1980), then migrate along the east coast of Baffin Island to Isabella Bay where they join whales that have summered in that area (Finley 1990, 2001). The migration along Bylot Island and NE Baffin Island is coastal; all sightings were made within 1.5 km of the coast (Koski and Davis 1980). The migration is quite rapid, with the whales averaging 5 km/h (Koski and Davis 1980).

Ground-based observations at Cape Adair, northeast Baffin Island, documented the timing of the outbound fall migration (Koski and Davis 1980). The migration begins at the end of September and peaks between early and, at least, mid October (Koski and Davis 1980; Finley 1990).

3.6.3 Results of the September 2004 Surveys

One group of two bowhead whales–a large individual and a smaller animal (adult and young?)–was sighted in Radstock Bay during the 17 September reconnaissance survey (Fig. 5).

3.6.4 Conclusions

Bowhead whales could be encountered along parts of the proposed shipping route during August and September. It is very unlikely that any would occur along the central portions of the shipping route, between Bathurst Inlet and Peel Sound. Bowhead whales most likely would be encountered in Admiralty Inlet, western Lancaster Sound, and Barrow Strait. A few might be in Peel Sound or as far south as Franklin Strait during August and early September.

3.7 Narwhal (Monodon monoceros)

3.7.1 Range and Population Status

The narwhal inhabits deep marine waters of the eastern Canadian Arctic from northern Hudson Bay and Davis Strait west to the central Arctic Archipelago (Reeves et al. 2002). It does

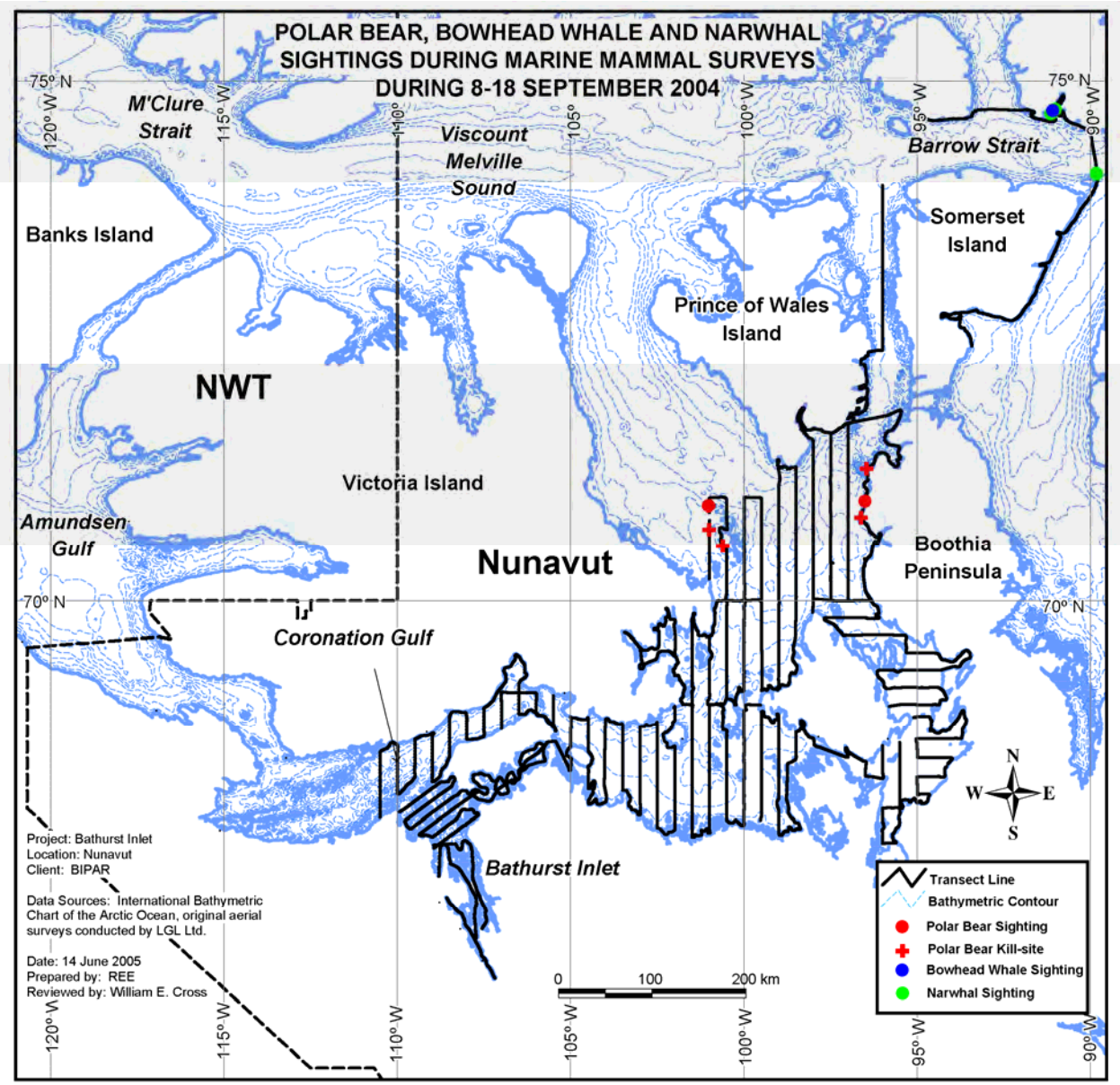

Figure 5. Bowhead whales, narwhals, and polar bears recorded during marine mammal surveys flown during 8–19 September 2004.

not usually occur in the Beaufort Sea or elsewhere in the western Canadian Arctic. Those that summer in the Canadian High Arctic winter in Baffin Bay. Narwhals are also found in the Greenland Sea and parts of the Barents Sea (Reeves et al. 2002).

Davis et al. (1978b) estimated that the entire narwhal population in the Canadian High Arctic numbered 20,000–30,000. Smith et al. (1985) estimated that ~13,200–18,000 summered in Lancaster Sound and adjoining waterways. Up to 10,000 may summer in Admiralty Inlet, 3000 in Eclipse Sound, and 10,000 in Prince Regent Inlet. About 2000 summer in Peel Sound and 1000 in Barrow Strait. Numbers in each area vary from year to year (Fallis et al. 1983;

Smith et al. 1985; Koski and Davis 1994; Richard et al. 1994). Innes et al. (2002) provided a more recent estimate of 45,358 individuals (95% confidence interval 23,397–87,932) for the narwhal population summering around Somerset Island. That estimate was based on 1996 surveys of western Lancaster Sound, Barrow Strait, Prince Regent Inlet, and Peel Sound, and thus did not include all areas in the Canadian High Arctic where narwhals are known to concentrate (e.g., Gulf of Boothia, Admiralty Inlet, and Eclipse Sound).

Narwhal are not listed under SARA, but are designated "Special Concern" by COSEWIC (2004).

3.7.2 Migration and Seasonal Movements

Narwhals winter in very heavy pack ice throughout northern Davis Strait and southern Baffin Bay (McLaren and Davis 1982). In spring, they move north through the loosening pack ice and appear near and in Lancaster Sound in April. They enter Pond Inlet and Lancaster Sound in late June and July after break up of the ice edge, en route to summering areas farther west (Koski and Davis 1979; Koski 1980a). Large congregations can develop in Lancaster Sound during those years when the entrance to the Sound is blocked by fast ice (e.g., Finley et al. 1990b). The peak movement of narwhals westward into the central High Arctic, from Baffin Bay via Lancaster Sound, occurs in late June and July.

In summer, narwhals do not frequent shallow waters or estuaries (as do many belugas), but prefer deep-water fiords, inlets, and channels. They also occur in inshore areas (Born et al. 1994; Dietz et al. 1994; Kingsley et al. 1994; Richard et al. 1994; Heide-Jørgensen et al. 2003a). In larger bays, narwhal are strongly associated with ice during summer, but use narrow fiords only when ice-free (Kingsley et al. 1994).

Most narwhals summer in the fiords of northern Baffin Island (e.g., Admiralty Inlet, Navy Board Inlet, and Eclipse Sound) (Fallis et al. 1983; Smith et al. 1985; Koski and Davis 1994; Richard et al. 1994). Other important summering areas are Prince Regent Inlet and the Gulf of Boothia. Smaller numbers summer in Barrow Strait and Peel Sound (Fallis et al. 1983; Smith et al. 1985; Koski and Davis 1994; Richard et al. 1994; Heide-Jørgensen et al. 2003a). Two thousand narwhal may summer in Peel Sound (Finley and Johnston 1977; Smith et al. 1985). Narwhals are present in the central High Arctic through September.

During the ice-free season narwhals do not move great distances. Narwhals tagged with satellite transmitters in Tremblay Sound on the northeastern coast of Baffin Island were sedentary (Dietz et al. 2001). Individuals tagged in August in Creswell Bay on Somerset Island remained within 200 km of that locality. Transmitters on two of the animals continued transmitting until the following summer, allowing them to be tracked back to Somerset Island. This suggests that at least some individuals are faithful to summering grounds (Heide-Jørgensen et al. 2003a).

Narwhals exit the central High Arctic during their autumn migration back to Baffin Bay via Lancaster Sound. The outbound migration occurs at a much slower pace than that of belugas (Finley and Johnston 1977). During fall migration, narwhals are dispersed in open water and remain there as long as open water permits. Thus, they are present after the belugas have

departed. At that time, most are found in offshore waters of the passages among the central Arctic islands (Koski and Davis 1980). By mid to late September most satellite-tagged narwhals have moved out of most of those passages and into Lancaster Sound (Heide-Jørgensen et al. 2003a). Outbound migration becomes concentrated near the north and south coasts of Lancaster Sound during at least the first part of the migration (Koski and Davis 1980). On their way out of Lancaster Sound and into northern Baffin Bay, the pace of outbound migration speeds up and becomes very rapid. Some animals remain in Lancaster Sound and Pond Inlet into mid October, but most have left by the middle of the month (Heide-Jørgensen et al. 2003a).

Little is known of the reproductive biology of this species (Davis et al. 1980; Kingsley 1989). Narwhal are social and are usually seen in small groups (Strong 1988). They can be encountered in groups of up to hundreds during migration, and concentrations do occur along some fast ice edges (Strong 1988). Narwhal feed primarily on fish, especially arctic cod and halibut (Finley and Gibb 1982).

3.7.3 Results of the September 2004 Surveys

Narwhals were recorded only during the reconnaissance survey on 17 September. During that survey, ~37 narwhals were seen. One group of ~12 was observed north of Prince Leopold Island off the northeast coast of Somerset Island. Another 25 were seen in Radstock Bay (Fig. 5).

3.7.4 Conclusions

Narwhals occur commonly in many areas of the eastern and central Arctic islands, and could be encountered along parts of the shipping route. They would be rare south and west of Peel Sound and Franklin Strait. Depending on ice conditions, narwhal likely would be most abundant in Admiralty Inlet and western Lancaster Sound. Smaller numbers would occur in Barrow Strait and Peel Sound.

3.8 Polar Bear (Ursus maritimus)

3.8.1 Range and Population Status

Polar bears are distributed throughout the circumpolar Arctic in a number of relatively discrete populations (Stirling et al. 1984). Fourteen polar bear populations are identified in Canada (Stirling and Taylor 1999; Lunn et al. 2002). Of those, two occur along the proposed shipping route: the Lancaster Sound (estimated population size 1700) and M'Clintock Channel (240) populations. Current information on the status of the populations suggests that they are stable (Stirling and Taylor 1999; Lunn et al. 2002).

The overall Canadian population of polar bears is listed under Schedule 3 of SARA as "Special Concern". COSEWIC (2004) also designates Canadian populations as "Special Concern", and the Government of the Northwest Territories identifies the population there as "Sensitive" (GNWT 2000). The Nunavut government has not designated their wildlife populations. Polar bears are of great cultural and economic significance to northern peoples.

3.8.2 Natural History

The local distribution and abundance of polar bears vary through the year, and are strongly influenced by those of their principal prey, the ringed seal, and by the presence or absence, distribution, and quality of sea ice. During winter and spring, most polar bears are found on the sea ice (Amstrup 2000). They tend to concentrate along pressure ice that parallels the coasts, and in the vicinity of floe edges. In those areas of thinner ice, they are able to hunt seals most effectively (Stirling et al. 1984). In summer, when the pack ice retreats offshore, polar bears are found along the edge of the pack ice (DeMaster and Stirling 1981; Amstrup 1995). During years with little or no pack ice near the coast, polar bears are often found along the coastline and on barrier islands (Stirling 1974). Polar bears usually exhibit fidelity to spring feeding and denning areas (Ramsay and Stirling 1990; Wiig 1995; Born et al. 1997).

Polar bears are typically restricted to areas that contain sea ice throughout most of the year. Males and non-breeding animals feed offshore along ice edges and in the transition zone where bearded seals and non-breeding ringed seals concentrate. In summer, they tend to remain with the multi-year pack ice, which usually, but not always, retreats to the north at that time (Stirling et al. 1975, 1981a).

High arctic polar bears feed primarily on ringed seals, especially on pups and subadults (Stirling and Archibald 1977). Bearded seals are taken less often than ringed seals, and are more important in the diet of western arctic polar bears than in the eastern Arctic (Stirling and Archibald 1977). If circumstances are favourable, polar bears will also hunt and feed on narwhal, beluga, and walrus (Lowry et al. 1987; Calvert and Stirling 1990; Smith and Sjare 1990). Polar bears do most of their hunting from the ice. They are strong swimmers, but cannot match a seal in the water. However, they may occasionally hunt and capture seals in open water (Furnell and Oolooyuk 1984).

Polar bears have low reproductive rates. Females reach sexual maturity at 4 to 6 years of age; most males take longer, generally 8–10 years. At most, a female has cubs once every 3 years. Polar bears generally do not live longer than 25 years (Stirling and Taylor 1999).

In December, pregnant females give birth in snow dens in coastal areas or on the ice. Polar bear dens are concentrated in some areas, but throughout the Arctic Archipelago denning habitat appears to be unlimited and denning occurs at low densities along most coastlines that have been investigated (Stirling et al. 1979, 1981a; Schweinsburg et al. 1981).

In late March and early April, females with cubs return to the sea ice to hunt seals, usually concentrating in places where ringed seals are pupping (Davis et al. 1980). In the western Arctic, females and cubs hunt along coastal fast ice after emerging from coastal denning sites. Cubs generally remain with the female for 2–2.5 years (Stirling and Latour 1978).

In summer, bears are relatively concentrated in areas with irregular coastlines such as bays (Stirling et al. 1979). They do occur along coastlines with no irregularities, and their distribution is not clumped (Stirling et al. 1979). Bays within which ice remains longer than in other areas are important hunting areas for bears, especially females with cubs and pregnant females (Stirling et al. 1979).

Most of the recent information on movements of polar bears in the Beaufort Sea is from studies of female bears equipped with satellite tags. In the Beaufort Sea, annual movements of female polar bears were 1406–6203 km over annual ranges of 7264–596,800 km² (Amstrup et al. 2000). In the southern Beaufort Sea, polar bears had the highest movement rates in June and July, when the ice was breaking up. In both the southern and northern Beaufort Sea, polar bears also had high rates of movement in early winter when ice was consolidating (Amstrup et al. 2000).

3.8.3 Results of the September 2004 Surveys

All polar bear sightings, kill sites, and tracks recorded during the September 2004 aerial surveys are mapped on Figure 5.

There were only two sightings of polar bears during the September 2004 aerial surveys. One was a single individual pulling itself out of the water onto an ice pan off the western coast of the Boothia Peninsula south of Weld Harbour at approximately 71º N (Fig. 5). That sighting was made on 18 September in an area of 95–99% ice cover. The second sighting occurred on 19 September northwest of Gateshead Island in southern M'Clintock Channel (Fig. 5), also in an area of heavy ice cover (95–99%), where an adult and two cubs were feeding on a seal.

In addition to the two sightings above, five kill sites (presumably by polar bears) and two observations of polar bear tracks were recorded. Presumed polar bear kill sites were recorded in eastern Larsen Sound and southern Franklin Strait (two kills), and in the vicinity of Gateshead Island (three kills) during surveys on 17, 18, and 19 September. Polar bear tracks were seen in two locations: north of Prince Leopold Island in western Lancaster Sound (17 September), and off the western coast of the Boothia Peninsula very near the above sighting of the bear pulling itself out of the water (18 September). All the kill sites and one track record were in areas of heavy ice cover (>90%). The tracks in Lancaster Sound were in <20% ice cover.

3.8.4 Conclusions

Polar bears are widely distributed and could occur along all northern portions of the shipping route during August and September. However, they are likely to be encountered only where there is moderate to heavy ice cover. In most years, the heaviest ice cover along the shipping route during August and September occurs in Larsen Sound and vicinity (see Fig. 3). Typically, encounters would be with individuals and small family groups of bears. Because the distribution and quality of sea ice varies from year to year, the occurrence of polar bears changes as well.

3.9 Other Species

Project interactions with the following two species are possible but unlikely.

3.9.1 Killer Whale (*Orcinus orca*)

Small numbers of killer whales have been seen in the Lancaster Sound-western Baffin Bay area during the open water period (RRCS 1977; Koski and Davis 1979, 1980). Killer whales avoid areas of heavy ice and so do not penetrate far into the Arctic Archipelago (Davis et al. 1980).

3.9.2 Hooded Seal (*Crystophora cristata*)

Hooded seals are sometimes seen in Lancaster Sound during the summer. Western Atlantic hooded seals whelp and breed in March on ice floes off northern Newfoundland and southern Labrador and in Davis Strait (Sergeant 1976). Most migrate north to western Greenland and then to the Denmark Strait to moult, but small numbers reach the eastern Lancaster Sound-western Baffin Bay area in summer. Their routes into (and out of) the area are unknown.

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Appendix E-9
Baseline Marine Mammal Studies, June-July 2007

Author: **LGL Limited**
Date: **September 2007**

Photo credit: W.R. Koski, LGL Limited

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Bathurst Inlet Port and Road Project

Baseline Marine Mammal Studies, June–July 2007

prepared by

for

Bathurst Inlet Port and Road Joint Venture
340 Park Place, 666 Burrard Street
Vancouver, BC V6C 2X8

LGL Report TA4474-1

5 September 2007

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Bathurst Inlet Port and Road Project

Baseline Marine Mammal Studies, June–July 2007

prepared by

William E. Cross and Ted Elliott

LGL Limited, environmental research associates
22 Fisher St., POB 280
King City, ON L7B 1A6

for

Bathurst Inlet Port and Road Joint Venture
340 Park Place, 666 Burrard Street
Vancouver, BC V6C 2X8

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1. Introduction

1.1 Background

The proposed Bathurst Inlet Port and Road (BIPR) Project consists of a port on Bathurst Inlet connected to mines and mineral deposits in Nunavut and Northwest Territories by a new, 211-km, all-weather road to Contwoyto Lake, and the existing "Tibbitt to Contwoyto" winter road. The port site will include a wharf to serve large ice-class vessels delivering fuel and bulk cargo to the port; a dock to handle barges serving the Kitikmeot communities of Kugluktuk, Bathurst Inlet, Cambridge Bay, Umingmaktok, Gjoa Haven, and Taloyoak; a 150-person camp and services; a 180 million-L diesel fuel tank farm; a truck and trailer maintenance shop; and a 1200-m airstrip. Noise, other disturbance, habitat alteration, and various types of discharges from project activities at the port and elsewhere along the shipping route during the construction and operations phases may disturb marine mammals. In winter and spring, ringed seals and probably some bearded seals are expected to occur in Bathurst Inlet near the proposed port. In summer, belugas and some pinnipeds may occur near the port.

1.2 Objectives

This baseline report presents and reviews background information on abundance, distribution, movement patterns, and natural history of marine mammals occurring in Bathurst Inlet during spring. The report also includes the results of original field surveys conducted for this project during June–July 2007.

2. Methods

The spring seal surveys were conducted from a fixed wing aircraft during 27 June–1 July 2007. Strip transect methodology was used, generally following the methods of Frost and Lowry (1988) and Moulton et al. (2002a). That methodology has been standard for previous aerial surveys of ringed seals in Alaska.

2.1 Survey Design

The baseline surveys of the seal population that may be affected by the BIPR Project were designed to:

- coincide with the peak period of seal haul-out during the spring,
- cover not only the immediate area of the proposed dock location but also an area beyond, where seals may be influenced by noise and other disturbance effects, and
- sample the seal population quantitatively in a manner that would be repeatable.

Surveys covered an area that extended from the extreme south of Bathurst Inlet north to a line from the southwest tip of the Kent Peninsula to Cape Barrow, at ~68.1ºN (Fig. 1). Coverage of the southern portion of Bathurst Inlet, from the extreme south, ~25 km south of the proposed dock site, to ~67.4ºN, ~100 km north of the proposed dock site, was repeated on the first and last days. Transects generally were oriented north-south but also east-west in some channels between the islands in Bathurst

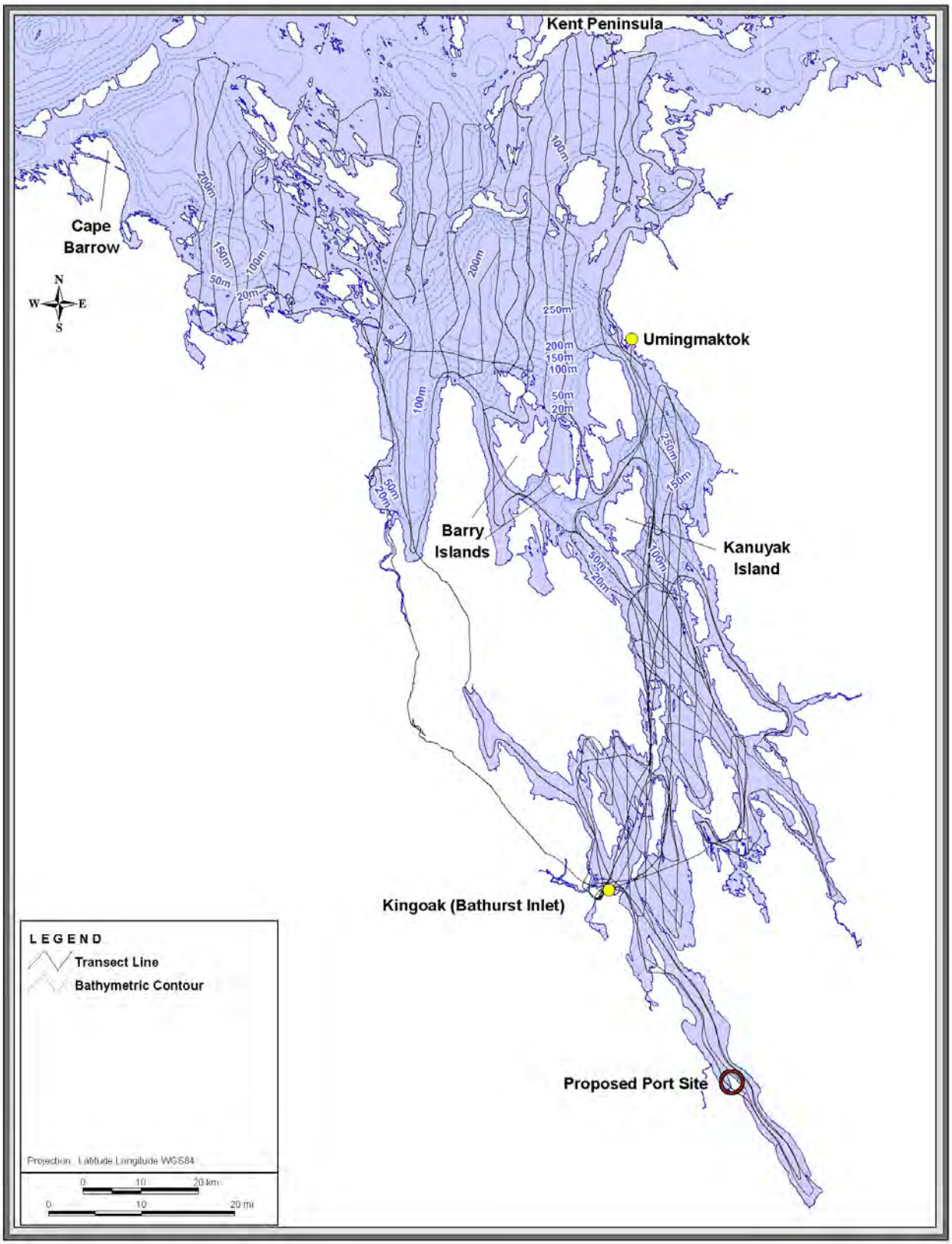

Figure1. Bathurst Inlet, showing locations named in text and transect lines flown during 27 June–1 July 2007.

Inlet. The total length of all transects was 3585 km, and the total area surveyed was ~2823 km^2. Adjacent lines were ~2.8 km apart.

2.2 Survey Procedures

The surveys were flown in a single-engine, high-wing aircraft (DeHavilland Beaver) at an altitude of 91 m (300 ft) above sea level and at a ground speed of 130–157 km/h (70–85 knots). The survey aircraft and two pilots were provided by Bakers Narrows Air Service of Flin Flon, Manitoba. There were bubble windows on the passenger doors of the aircraft.

Three observers were on the aircraft—two LGL biologists and an Inuit observer who was trained by the LGL biologists. The two LGL biologists (primary observers) sat on opposite sides of the aircraft, two seats behind the pilot (left side) and co-pilot (right side), respectively. The Inuit observer sat on the right side of the aircraft, one seat behind the LGL observer on that side.

We surveyed transect strips ~410 m wide on each side of the aircraft. These strips extended ~135 m–545 m from the centerline. Strip boundaries were marked on the aircraft's windows with tape at the appropriate inclinometer angles, which were 9.5º and 34º below the horizontal for surveys at 91-m altitude. Sightings of seals inside 135 m or beyond 545 m were recorded as off-transect sightings. For consistency with previous ringed seal surveys, we have *not* attempted to adjust the strip boundaries or calculated densities to take account of the "earth curvature" corrections described by Lerczak and Hobbs (1998). The transect width used in the BIPR surveys likely is underestimated, but the error associated with inclinometer angles >5º is negligible.

The surveys were usually flown during mid-day, when numbers of seals hauled out on the ice were expected to be highest.

2.3 Data Recording Procedures

Data on wildlife sightings and environmental variables were recorded by each observer. The position of the aircraft was recorded by a data-logging system.

For each seal sighting, the observer dictated onto audio tape the time of the sighting to the nearest second, and the species, number of individuals, habitat (hole or crack), and behaviour (look, move, dive, or none) of the seal(s), and noted whether the sighting was on or off transect. Similar data were recorded for other wildlife sightings. Beginning on 28 June, unoccupied seal holes were recorded also. The specific times of sightings were used to extract their locations subsequently from the GPS data log files (see below).

The two primary observers also recorded the visibility (nautical miles), ice cover (%), ice deformation (%), melt water (%), sun glare (none, moderate, or severe), and overall sightability conditions (ranging from "excellent" to "impossible", and incorporating glare, fog, and precipitation). Those observations, along with the time, were recorded onto audio tape at the end of each 1-min (2.1–2.6-km) time period, and were the estimated average values of each variable during the preceding 1-min interval. An electronic timer signaled the observers at 1-min intervals. Estimated percentage values were categorized by intervals of 10%. Ice cover, ice deformation, and melt water variables applied to the conditions on transect only. Ice deformation was the estimated percent of the on-transect ice surface surveyed during the preceding minute that was deformed rather than smooth ice. Cracks and leads in the

ice were also noted by the observers at the specific times when seen, allowing their locations to be extracted subsequently from the data log files. Cloud cover (in tenths), wind speed (knots), wind direction (ºT), and air temperature (ºC) were recorded (with the assistance of the pilots) at least once during each survey flight. Wind data were acquired from the aircraft's GPS, and air temperature from a thermometer mounted externally on the aircraft.

The data logging system consisted of two GPS units (Garmin Model eTrex Vista and Garmin GPSMap CS). The GPS receivers were positioned on the dashboard of the aircraft. Both GPS receivers were set to log aircraft position every 5 seconds, storing it in the unit's onboard memory. The pilots did not have a GPS moving map display, so they were given maps and longitude coordinates for the north-south transect lines and they followed those as best they could while maintaining the target survey speed and altitude.

2.4 Data Analysis Procedures

The location of each seal (and other wildlife) sighting was determined by matching the time of the sighting with the position recorded for that time in the GPS logs. Time periods with severely impaired sightability conditions were excluded from all analyses. Each sighting was also linked to the environmental variables recorded for the corresponding 1-min (2.1–2.6-km) time period.

2.5 Survey Effort

A summary of survey effort is presented in Table 1. Surveys were flown on each of the five days between 27 June and 1 July. Total survey effort comprised 25.1 hours and 3585 km.

Table 1. Summary of survey effort for the June 2007 seal survey in Bathurst Inlet.

	Survey Period		Survey Effort		Average Speed
Date	Start	Finish	Time (h)	Distance (km)	(km/hr)
27 June	11:25	15:43	4.3	676.3	157.2
28 June	10:31	15:22	4.8	678.5	140.1
29 June	10:26	16.00	5.6	797.0	143.3
30 June	10:07	16:16	5.8	752.7	130.9
1 July	10:23	14:59	4.6	680.5	148.0
				3585.0	

3. Results and Discussion

3.1 Bathymetry and Ice Cover

At the mouth of Bathurst Inlet, water depth is up to 200 m, with a few small basins >250 m deep. Depths are <20 m throughout the southern half of the inlet (south of the Barry Islands), among the Barry Islands, and generally within ~1 km of the shoreline in the northern half. The entire survey area was covered by landfast ice, and there was no pack ice offshore. There were varying degrees of ice deformation (rough *vs*. smooth) and amounts of melt water on top of the ice surface. Several small cracks in the ice were interspersed throughout the survey area.

Ice break up was not far advanced even at the end of the survey (1 July 2007). Rivers were completely ice free, open water was present around the mouths of the larger rivers and in several narrow channels between islands, and turbid river floodwater had covered large areas of near-shore ice near the mouths of the rivers.

The results of the review of the literature and the June–July 2007 surveys are presented below for the two species that were encountered.

3.2 Ringed Seal (Pusa hispida)

3.2.1 Range and Population Status

Ringed seals have a continuous northern circumpolar distribution. In Canada, their distribution is centred in the Arctic Archipelago, but they range from Newfoundland to the Beaufort Sea. Canadian populations are considered "Not at Risk" by COSEWIC (2006).

Ringed seals are the most abundant marine mammal in the Canadian Arctic, but accurate population estimates are difficult to obtain. Canadian researchers have estimated the numbers of visible seals hauled out on the ice in spring; but those estimates may substantially underestimate the actual size of the populations. Some of the estimates are: (1) at least 40,000 ringed seals in the Canadian Beaufort Sea (Stirling et al. 1981); (2) 50,000 in northern Amundsen Gulf (Kingsley 1990); (3) 49,000 in Prince Albert Sound (Kingsley 1990); and (4) 90,000 in the Canadian High Arctic (Kingsley 1985, 1990). No population estimates are available for Coronation Gulf or Bathurst Inlet.

There can be large natural variations in the numbers of ringed seals in an area over a period of a very few years (Stirling et al. 1977). In 1974–1975, there was a marked decrease in the abundance and productivity of seals in the Canadian Beaufort Sea and Amundsen Gulf (Stirling et al. 1977; Smith and Stirling 1978). There was another such decrease between 1982 and 1985 (Harwood and Stirling 1992).

Ringed seal harvests were reported for all four communities on Coronation Gulf (Kugluktuk, Cambridge Bay, Bathurst Inlet, and Umingmaktok) from 1996 to 2001 (Priest and Usher 2004). The numbers of seals harvested were small in the small communities of Bathurst Inlet and Umingmaktok. Kugluktuk recorded the highest harvest, an average of ~280 seals per year for the five years. Most (76%) were harvested in August and September, but smaller numbers were harvested in every other month. The harvest in Cambridge Bay increased from 38 in 1996/1997 to 277 in 2000/2001, with a five-year average of ~96 seals per year. Most were harvested in July to September (68%) and May and June (26%) with small numbers taken in November, December, March, and April. (The numbers above include some unidentified seals, most of which are thought to be ringed seals.)

3.2.2 Natural History

Ringed seals are year-round residents in the Arctic and are highly adapted for living in arctic conditions. Ice conditions influence ringed seal distribution and abundance (Smith and Stirling 1975, 1978; Moulton et al. 2002a), and densities have been shown to vary with ecological circumstances such as biological productivity (Kingsley et al. 1985; Stirling and Øritsland 1995).

Ringed seals do not haul out on land, but haul out on sea ice to moult and rest. They also give birth to young on the ice, in subnivean lairs. As the ice forms in autumn, ringed seals open and then maintain breathing holes in the sea ice throughout the ice-covered period using the claws of their front flippers (Vibe 1950). Each seal maintains numerous breathing holes because it must breathe every 15 min. or so (Riedman 1990:105). As snow drifts over their breathing holes, seals excavate lairs in the drifts. There are two types of lairs; the haul-out lair and the breeding lair. Haul-out lairs are made as early as January, and ringed seals frequently begin to haul out in the open air on top of the ice to undergo moult from mid-May through early June. Breeding lairs are constructed in mid-March at the earliest (Smith et al. 1991). Ringed seals prefer to breed on landfast ice in all areas within the study area (McLaren 1958; Kelly 1988). However, ringed seals may also breed in the pack ice (Finley et al. 1983; Kelly 1988).

Ringed seal pups are born in the birth lairs in April. They nurse for 38–44 d (Smith et al. 1991). Newborn pups do not have a layer of blubber to protect them from the cold. They rely on their white fur, high metabolic rates, and the birth lair for protection from the cold. Newborn pups can and do enter the water to escape predation, but they must return to the birth lair to prevent hypothermia (Smith et al. 1991). Pups are subject to intense predation by foxes and polar bears (Smith 1976; Kingsley 1990). In some areas, mortality from fox predation may be as high as 40% (Smith 1976).

During summer, ringed seals are dispersed throughout open-water areas. Some disperse to offshore areas after the landfast ice breaks up in summer (Heide-Jørgensen et al. 1992); in some regions, they move into coastal waters. Seasonal concentrations related to food sources are known in offshore waters of the Canadian Beaufort Sea off the Tuktoyaktuk Peninsula and off Cape Dalhousie (McLaren and Davis 1985; Harwood and Stirling 1992). Ringed seals encountered in the Alaskan Beaufort Sea during open-water seismic exploration were broadly dispersed as individuals or small groups (Harris et al. 1997, 1998; Lawson and Moulton 1999, 2001; Moulton and Lawson 2000, 2001; Moulton et al. 2002b).

Ringed seals are capable of moving distances of 1000 km or more during the summer (Heide-Jørgensen et al. 1992; Kapel et al. 1998; Teilmann et al. 1999), although they tend to show site fidelity (Teilmann et al. 1999). Ringed seals feed primarily on fish (especially arctic cod) and large crustacean zooplankters such as amphipods, euphausiids, epibenthic mysids, and decapods (Bradstreet et al. 1986; Smith 1987).

3.2.3 Results of June–July 2007 Surveys

Ringed seals were widely distributed throughout Bathurst Inlet during the study period (Figs. 2 to 6). A total of 841 ringed seals were seen on transect. Some seals undoubtedly were the same individuals seen on other days, particularly in the bottom of the inlet, which was surveyed twice. The surveys covered a total of 2823 km^2 of fast ice habitat. The observed overall uncorrected density of seals was 0.3/km^2 (Table 2). Uncorrected density means that no adjustments were made for the estimated proportions of seals not hauled out (availability bias) or on the ice but missed (detection bias). This density is well within the normal range of densities for ringed seals seen on landfast ice during studies in other areas in the Canadian and U.S. Arctic (Table 3). Ringed seals were observed in most parts of the inlet, but density was considerably lower in the southern part of the inlet (Table 2), especially near the proposed dock site. Only one seal was seen south of the proposed dock site (~15 km south; Fig. 6), and the closest seal was ~7.5 km north of the proposed dock site (Fig. 2). A few unoccupied seal holes were seen within 5 km of the proposed dock site (Fig. 7).

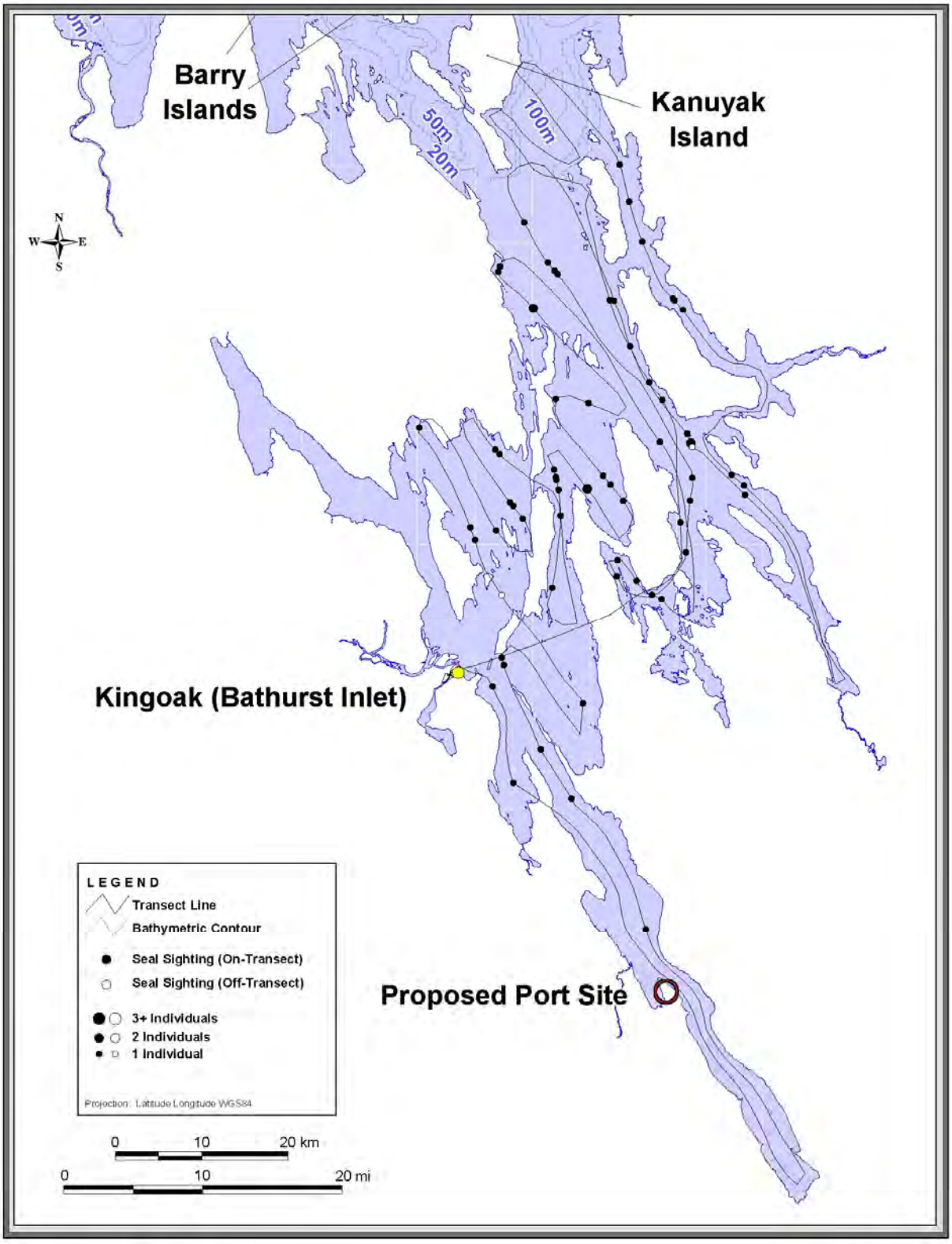

Figure 2. Ringed seal distribution during an aerial survey in Bathurst Inlet, Coronation Gulf, on 27 June 2001.

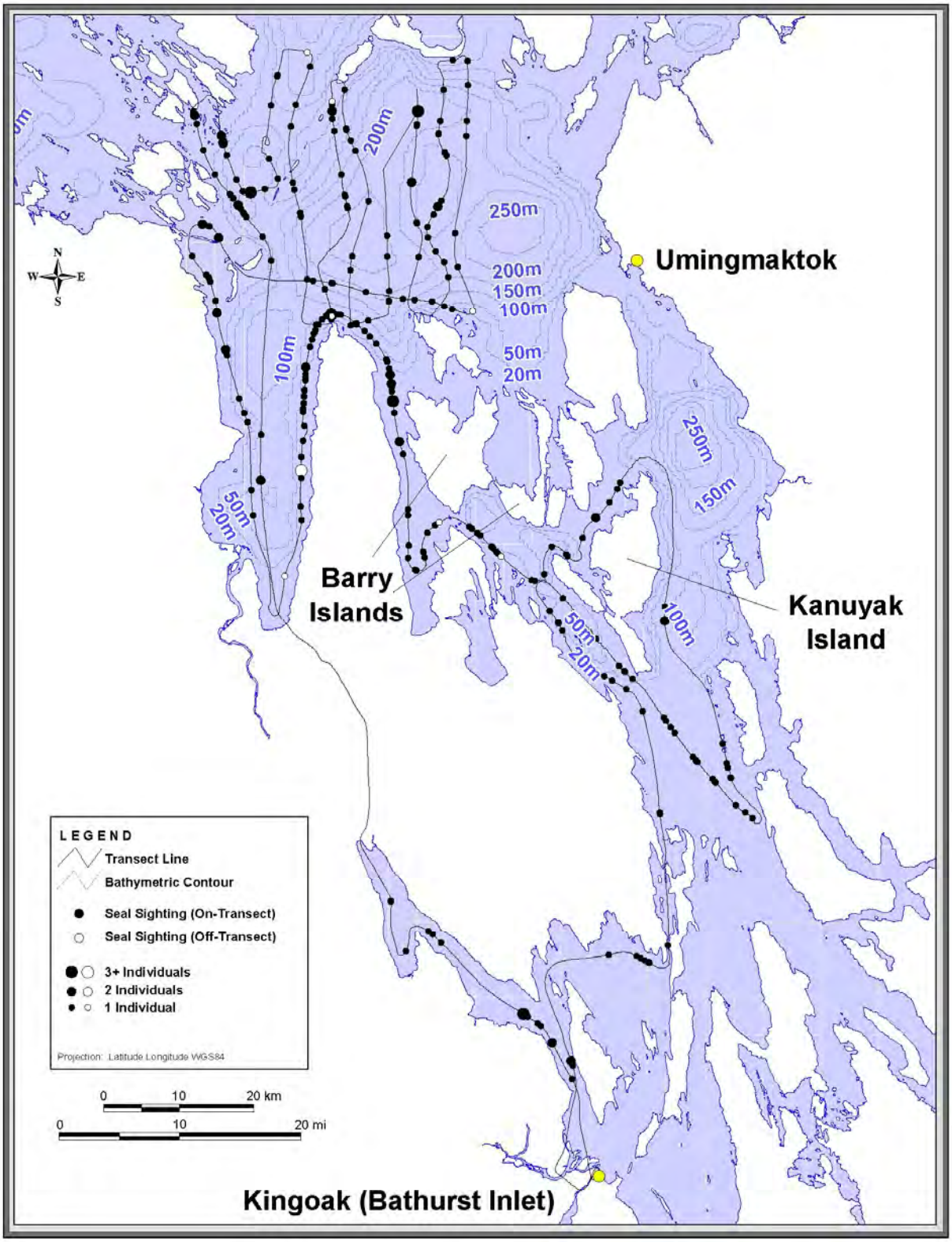

Figure 3. Ringed seal distribution during an aerial survey in Bathurst Inlet, Coronation Gulf, on 28 June 2001.

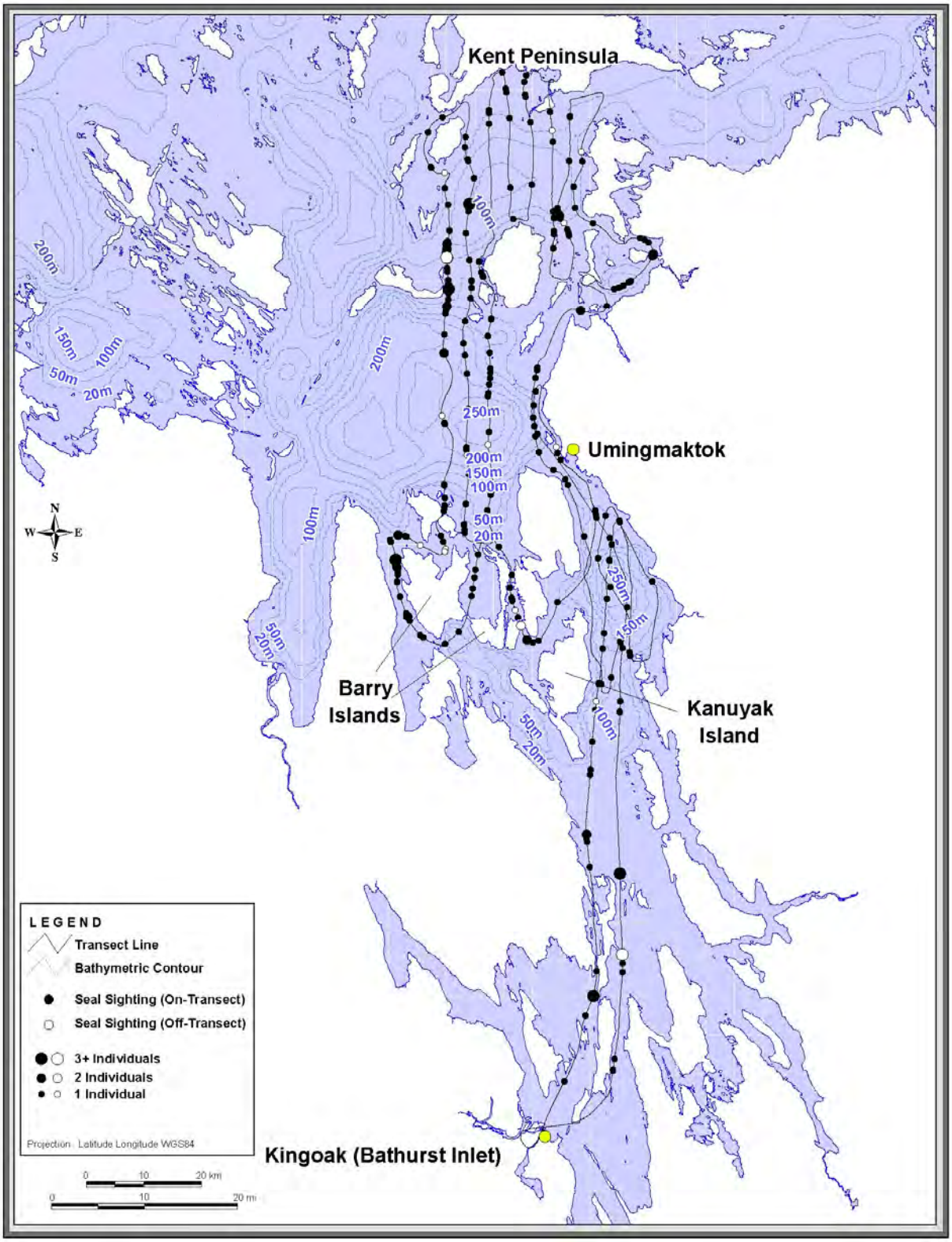

Figure 4. Ringed seal distribution during an aerial survey in Bathurst Inlet, Coronation Gulf, on 29 June 2001.

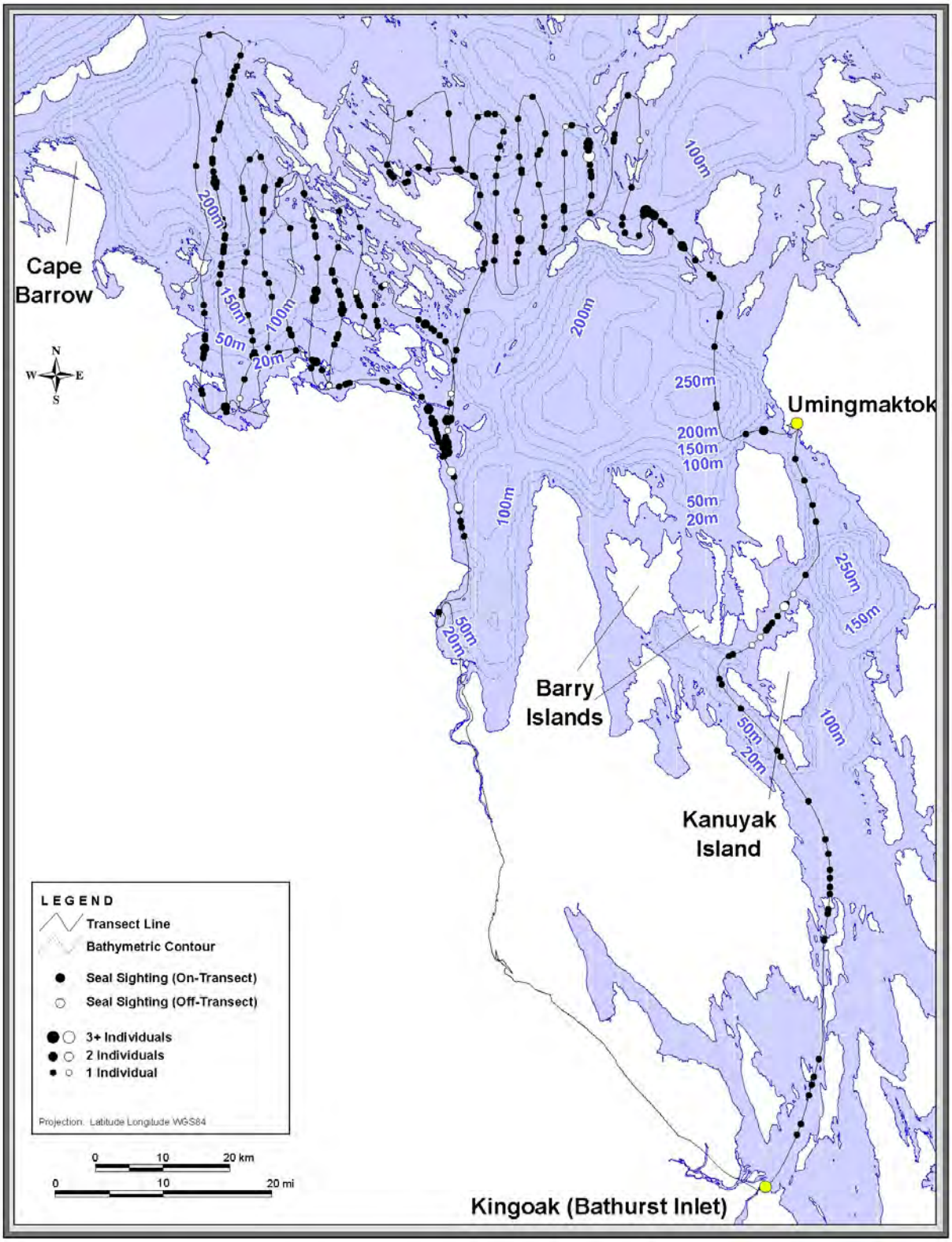

Figure 5. Ringed seal distribution during an aerial survey in Bathurst Inlet, Coronation Gulf, on 30 June 2001.

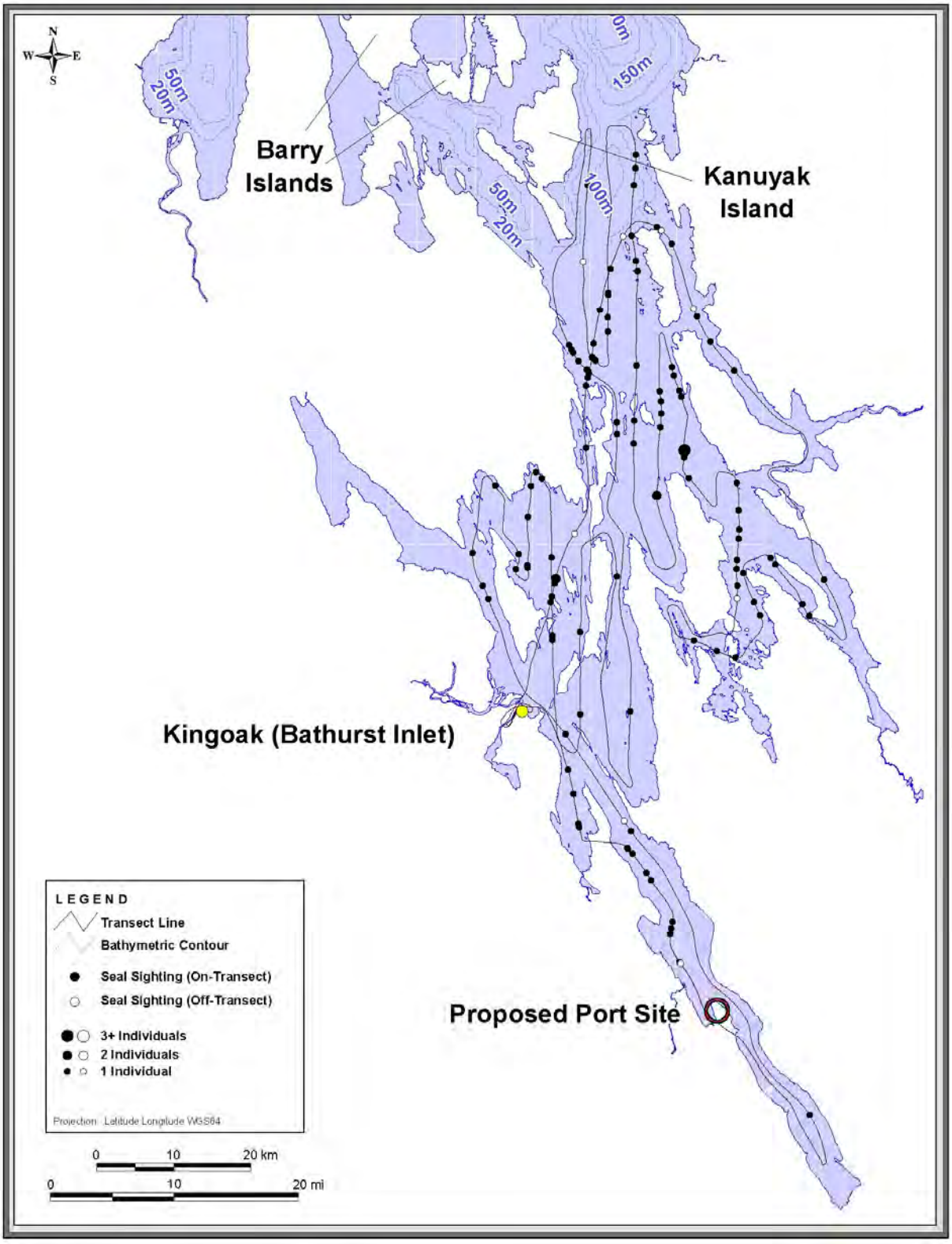

Figure 6. Ringed seal distribution during an aerial survey in Bathurst Inlet, Coronation Gulf, on 1 July 2001.

Table 2. Survey date (= area) *vs*. observed and expected numbers of ringed seal sightings on landfast ice in Bathurst Inlet during 27 June–1 July 2007. See Figures 2-6 for survey locations within the inlet.

Survey date	Area surveyed (km^2)	Proportion of total area surveyed	Observed # seal sightings	Expected # seal sightings[1]	Proportion of total observed in each interval	95% Bonferroni Confidence Limits on proportion of occurrence		Observed proportion relative to CI	Observed density (#/km^2)
						Lower	Upper		
27-Jun	526.36	0.19	68	157	0.08	0.06	0.11	<Expected	0.13
28-Jun	541.17	0.19	219	161	0.26	0.22	0.30	>Expected	0.40
29-Jun	630.11	0.22	215	188	0.26	0.21	0.30	Within	0.34
30-Jun	596.3	0.21	266	178	0.32	0.27	0.36	>Expected	0.45
01-Jul	529.45	0.19	73	158	0.09	0.06	0.11	<Expected	0.14
Total	2823.39	1.00	841	841	1				0.30

[1]Expected numbers are proportional to area surveyed, assuming the same number of sightings/km² in each stratum. Observed vs. expected number of seal sightings per date bin for all strata: $\chi^2 = 164.45$, df = 4, $P < 0.001$.

Table 3. Observed ringed seal densities (#/km^2) on landfast ice from other studies in the Alaskan and Canadian Arctic.

Year	Country	Location	#/km^2	Citation
1975	Canada	Central Arctic (early June)	1.32	Finley 1976
1975	Canada	Central Arctic (late June)	0.67	Finley 1976
1978	Canada	Baffin Island Fiords	1.72	Finley et al. 1983
1979	Canada	Northwest Baffin Island	1.31	Finley et al. 1983
1980, 1981	Canada	Central Arctic	0.27, 0.41	Kingsley et al. 1985
1981 to 1984	Canada	Beaufort, Amundsen, Prince Albert Sound	0.06–0.41	Kingsley 1986
1985 to 1999	US	North Slope, Alaska	0.58–1.67	Frost et al. 2002
1997	Canada	Barrow Strait Fiords	8.70	Finley 1979
1997 to 2002	US	Prudhoe Bay Area	0.39–0.83	Moulton et al. 2005
2004	Canada	Coronation Gulf	0.69	LGL Ltd., unpubl. data

Most ringed seals did not exhibit any obvious "negative" response to the aircraft as it flew overhead. Almost half (43.8%) showed no obvious response, 37.2% looked up at the aircraft, 9.5% moved on the ice, and 8.7% dove into their holes or cracks in apparent response to the aircraft. Five seals were in their holes, and two were swimming in the water.

Figure 7 shows all seal holes sighted during the surveys[1], including unoccupied holes and holes occupied by ringed seals, most of which were basking on the snow beside a hole. All ringed seal sightings are shown in Figure 8. A comparison of the two figures shows that there are many more holes than seals. The overall density of seal holes was ~1.1/km^2 (Table 4), ~3.5 x the density of seals. Although some seals likely were underwater during the surveys, the difference is mostly because each seal maintains numerous breathing holes.

[1] Unoccupied seal holes were not counted on 27 June.

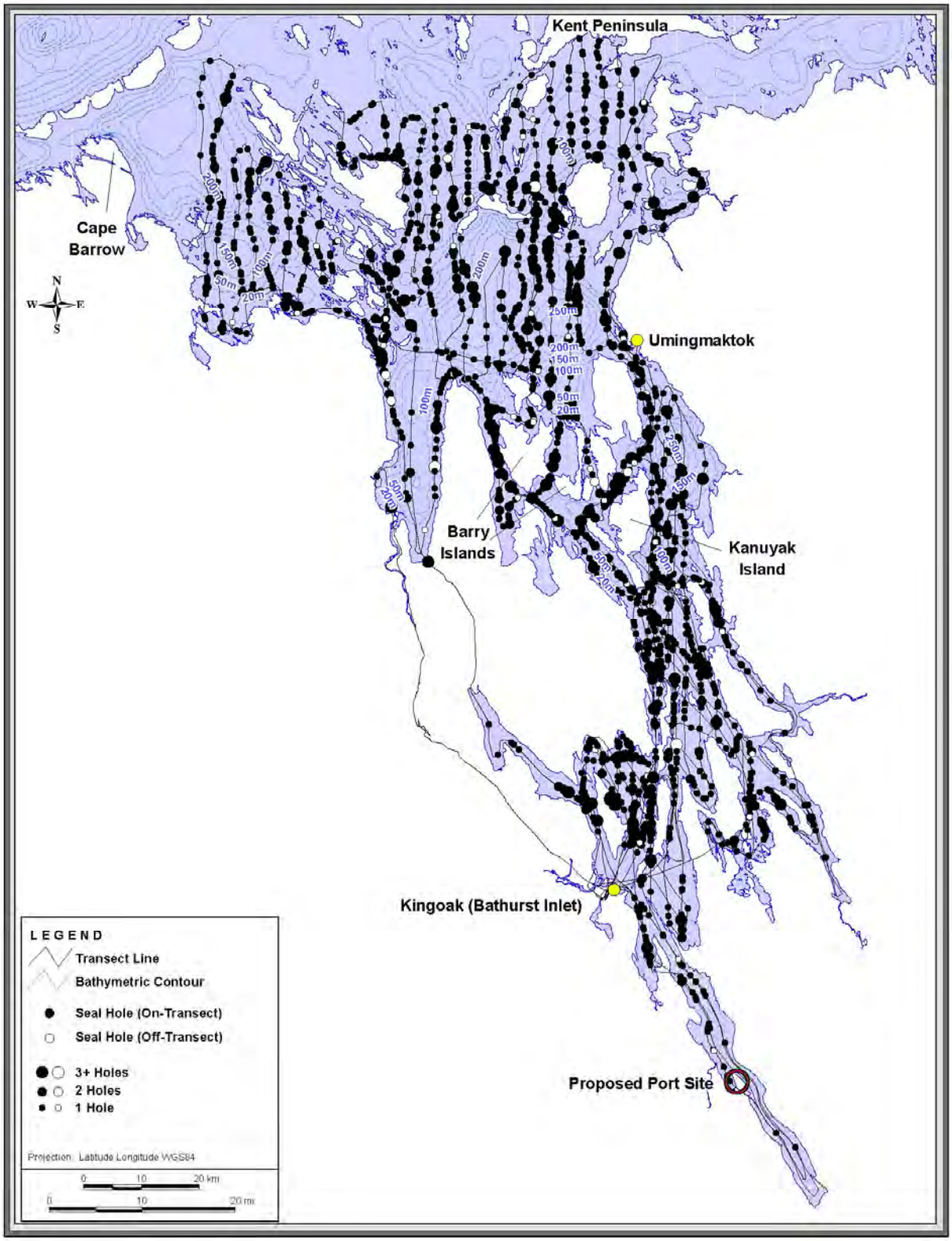

Figure 7. Distribution of all unoccupied seal holes during aerial surveys in Bathurst Inlet, Coronation Gulf, on each day during 28 June–1 July 2001, and all occupied holes during 27 June–1 July 2001.

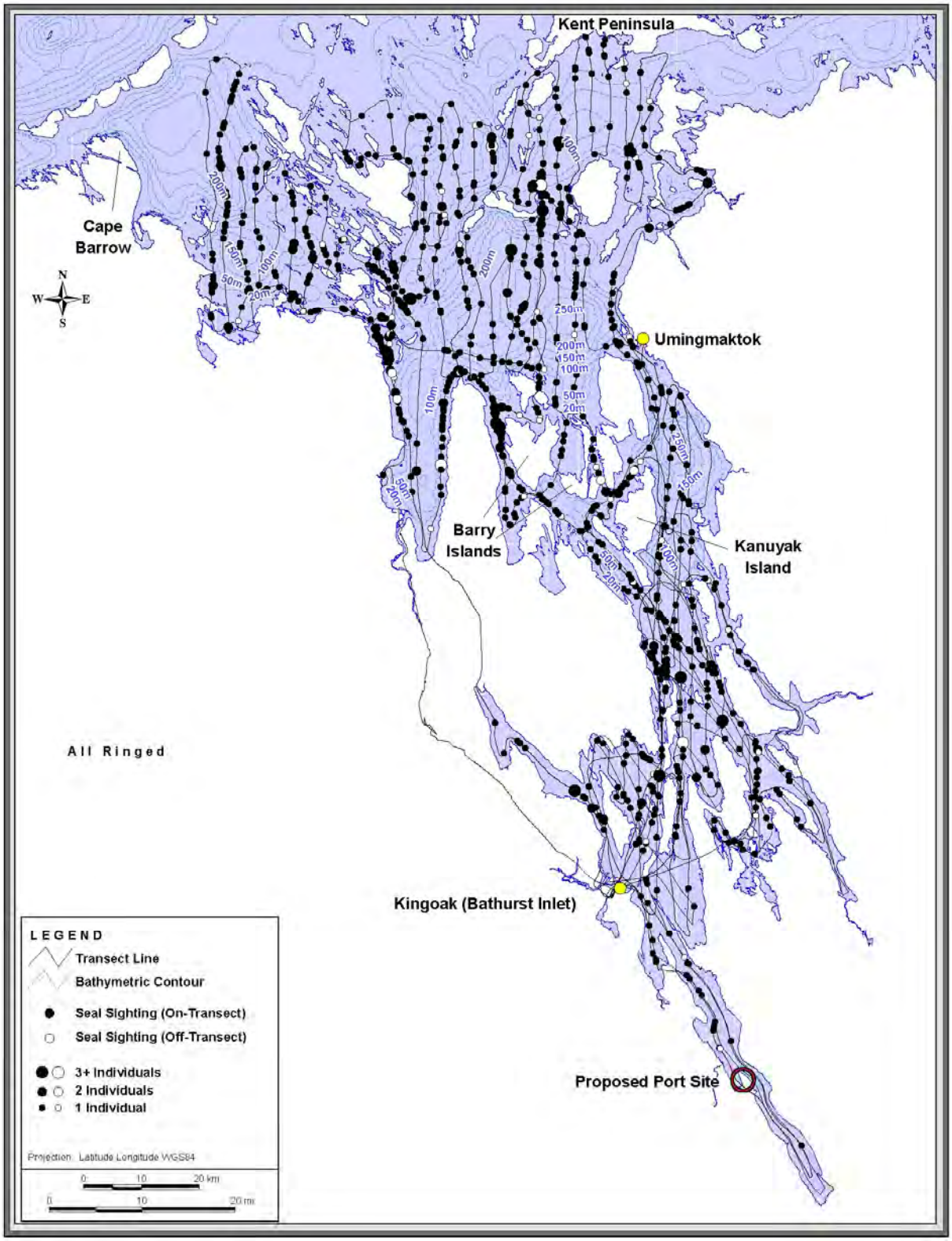

Figure 8. Distribution of ringed seals during aerial surveys in Bathurst Inlet, Coronation Gulf, on each day during 27 June–1 July 2001.

Table 4. Survey date (= area) *vs*. observed and expected numbers of ringed seal holes on landfast ice in Bathurst Inlet during 28 June–1 July 2007[1]. See Figures 3-6 for survey locations within the inlet.

Survey date	Area surveyed (km^2)	Proportion of total area surveyed	Observed # seal holes	Expected # seal holes[2]	Proportion of total observed in each interval	95% Bonferroni Confidence Limits on proportion of occurrence		Observed proportion relative to CI	Observed density (#/km^2)
						Lower	Upper		
28-Jun	541.17	0.24	560	573	0.23	0.21	0.25	Within	1.03
29-Jun	630.11	0.27	667	667	0.27	0.25	0.30	Within	1.06
30-Jun	596.3	0.26	739	631	0.30	0.28	0.33	>Expected	1.24
01-Jul	529.45	0.23	466	561	0.19	0.17	0.21	<Expected	0.88
Total	2297.03	1.00	2432	2432	1				1.06

[1] Unoccupied seal holes were not counted on 27 June, so all data from that date are excluded from the analysis.

[2] Expected numbers are proportional to area surveyed, assuming the same number of sightings/km² in each stratum. Observed *vs*. expected number of holes sighted per date bin for all strata: $\chi^2 = 164.45$, df = 4, P <0.001.

The observed number of seal holes was lower than expected in the southernmost part of the inlet (surveyed on 1 July; Table 4), as was the case with the numbers of seals (Table 2). The observed numbers of seals and seal holes were higher than expected in the area surveyed on 30 June (Fig. 5), most of which was the farthest north of any of the areas surveyed. Differences could be attributable to water depth or availability of prey. It is also possible that the seals had moved out of the far south of the inlet because of freshwater input with the spring melt; the ratio of seal holes to seals was high there (6.8) when compared with ratios on days when the northern part of the inlet was surveyed (2.59–3.11).

3.2 Bearded Seal (Erignathus barbatus)

3.2.1 Range and Population Status

Bearded seals have a northern circumpolar distribution. They are distributed throughout the Canadian Arctic in relatively low densities. Canadian populations are designated "Not at Risk" (COSEWIC 2006).

The most recent estimates for the size of the eastern Beaufort Sea population of the bearded seal range from 1200 to 3100 animals (Stirling et al. 1977, 1981, 1982). The Bering/Chukchi population, some of which summer in the Beaufort Sea, is estimated at 300,000–450,000 (Burns 1981).

Uncorrected estimates of the number of bearded seals in eastern Lancaster Sound and western Baffin Bay ranged from 7400 to 9500 animals (Koski and Davis 1980). Maximum densities of bearded seals in that region ranged from 0.05 to 0.24 seals/km^2 (Finley 1976; Koski and Davis 1979; Koski 1980a,b; Koski and Davis 1980; Kingsley et al. 1985).

Bearded seal harvests were reported for all communities on Coronation Gulf except Cambridge Bay during 1996–2001 (Priest and Usher 2004). The numbers of seals harvested were small in all communities. Kugluktuk recorded the highest harvest, an average of two bearded seals per year for the five years. Bearded seals were taken from May to September, with the majority (50%) harvested in July.

3.2.2 Natural History

During winter, bearded seals are primarily restricted to areas of moving, broken pack ice. Because they have only a limited capability to maintain breathing holes in ice, most bearded seals are excluded from areas of fast ice during winter (e.g., many of the channels in the Arctic Archipelago), although some use ice holes made by ringed seals. Most bearded seals undertake seasonal migrations in response to the advance and retreat of fast ice (Martell et al. 1984). Limited numbers of bearded seals overwinter in polynyas (Cleator et al. 1989).

The bearded seal is a benthic feeder that is most abundant in areas where it can reach the bottom to feed, usually in waters <200 m deep (Burns and Frost 1983; Finley and Evans 1983). In the Canadian Beaufort Sea, the bearded seal is most abundant over depths of 25–50 m (Stirling et al. 1981). Thus, bearded seals prefer shallow-water areas with some amount of pack ice cover on which to haul out. The bearded seal's preferred habitat is areas with thin, broken or rotten ice, or the floe edge (Kingsley 1985). This species also prefers less stable ice during break-up, and tends to avoid areas heavily used by walruses (Cleator and Stirling 1990).

In the Beaufort Sea and other parts of Alaska, this species feeds mainly on shrimp, crabs, clams (mainly the cockle, *Serripes*), octopus, gammarid amphipods, isopods, and fish (Burns and Frost 1983). During the summer open-water period, much of the Canadian Beaufort is unsuitable for feeding because the pack-ice habitat preferred by bearded seals typically retreats north to waters deeper than those preferred by bearded seals. During marine mammal monitoring during seismic exploration off the Mackenzie Delta and Tuktoyaktuk Peninsula in late July–early October 2001 and July–August 2002, low numbers of bearded seals were observed (Moulton et al. 2002b; Miller and Moulton 2003). However, bearded seals are relatively common in certain nearshore areas along southern Banks Island, Cape Parry, and Herschel Island during summer.

In the eastern Arctic Islands, fish, especially arctic cod, comprise much of the diet (Finley and Evans 1983). There, bearded seals are most abundant where water depths are <100 m (Kingsley 1985). Throughout the year, bearded seals typically occur alone or in small groups.

3.2.3 Results of June–July 2007 Surveys

There were 40 sightings and a total of 42 bearded seals recorded during all surveys (Fig. 8). Two sightings included two individuals, and the remainder were singletons. Sightings were dispersed within the inlet except in the south (only one bearded seal was seen south of Kanuyak Island) and in the deeper areas of the northern part of the inlet. Bearded seals tended to be close to shore (Fig. 8); 26 of the 42 seals (62%) were in water depths <20 m, and only 3 (7%) were in water >100 m deep.

Of the 25 bearded seals whose behaviour was recorded, most (72%) showed little or no apparent reaction to the aircraft (12 showed no response, 6 looked up, 1 was swimming). Four dove and two moved. Density calculations and further analyses were not conducted because of the small number of bearded seals seen.

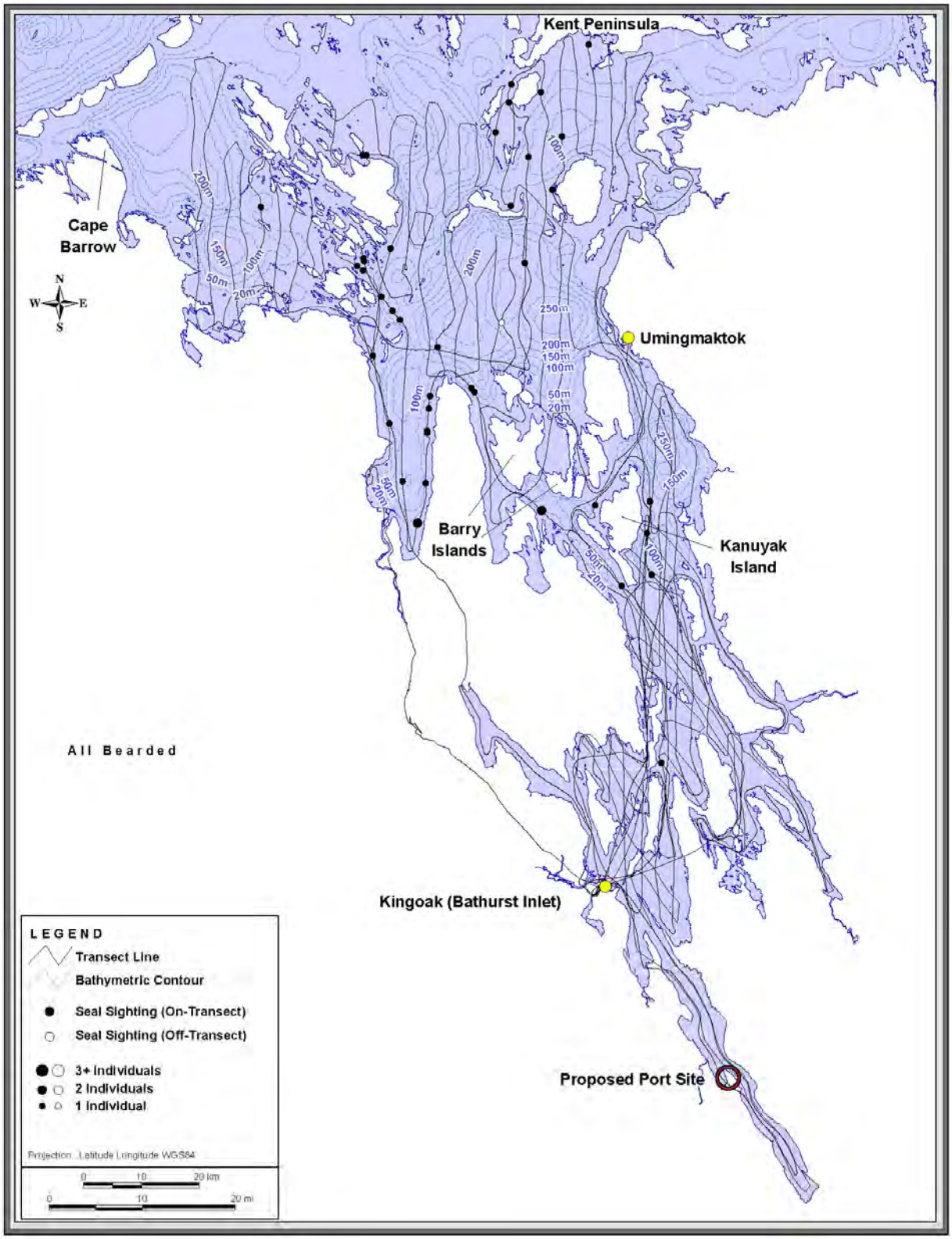

Figure 8. Bearded seal distribution recorded during aerial surveys in Bathurst Inlet, Coronation Gulf, on each day during 27 June–1 July 2001.

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Appendix E-10
Marine Physical Processes

Author: **Rescan Environmental Services Ltd.**
Date: **November 2007**

the BATHURST INLET PORT AND ROAD PROJECT

Bathurst Inlet Port and Road Project

Nunavut, Canada

Bathurst Inlet Port and Road Marine Physical Processes

Prepared by:

Rescan™ Environmental Services Ltd.
Vancouver, British Columbia, Canada

November 2007

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Bathurst Inlet Port and Road Project
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ACRONYMS AND ABBREVIATIONS

Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
BIPR	Bathurst Inlet Port and Road
Canarctic	Canarctic Shipping Company Limited
CHS	Canadian Hydrographic Service
CTD	conductivity, temperature, and depth
DEIS	Draft Environmental Impact Statement
EMP	environmental management plan
NPC	Nunavut Planning Commission
PSU	practical salinity units
the Project	the Bathurst Inlet Port and Road Project
Rescan	Rescan Environmental Services Ltd.
USACE	United States Army Corps of Engineers Coastal Engineering

1. INTRODUCTION

1. Introduction

The proposed Bathurst Inlet Port and Road (BIPR) Project (the Project) includes the construction of a port and wharf that will accommodate a variety of barges and ships up to the 50,000 tonne ice-class. The proposed port will be located in the Kitikmeot region of Nunavut, on the west side of Bathurst Inlet (66°33'N and 107°31'W), about 40 km south of the community of Bathurst Inlet. A 211 km road will be constructed between the Bathurst Inlet port site and Contwoyto Lake to provide a new transportation alternative for several existing and potential mine developments in the region. The proponent is the Bathurst Inlet Port & Road Joint Venture.

Two components of the Project will be in a marine setting: the port site and the shipping route. The marine shipping routes for the Project would use existing shipping lanes from the eastern arctic. The shipping route extends from Barrow Strait, south through Peel Sound and Franklin Strait, through Victoria Strait, crosses Queen Maud Gulf, passing through Dease Strait, and into Bathurst Inlet (Figure 1-1). The proposed port site will have two structures that extend into Bathurst Inlet: the wharf to accommodate up to 50,000 tonne vessels that extend 140 m from shore to a depth of 14 m and a jetty to accommodate ocean barges extending 100 m from shore to a depth of 6 m (Figure 1-2).

Ocean currents, tides, waves and storm surges affect the chemical, geological, and biological aspects of the marine environment. The physical processes that occur within Bathurst Inlet and along the shipping route will influence, and potentially be influenced by, the two components of the Project.

The objective of this report is to describe the Project's environmental setting with respect to physical marine processes.

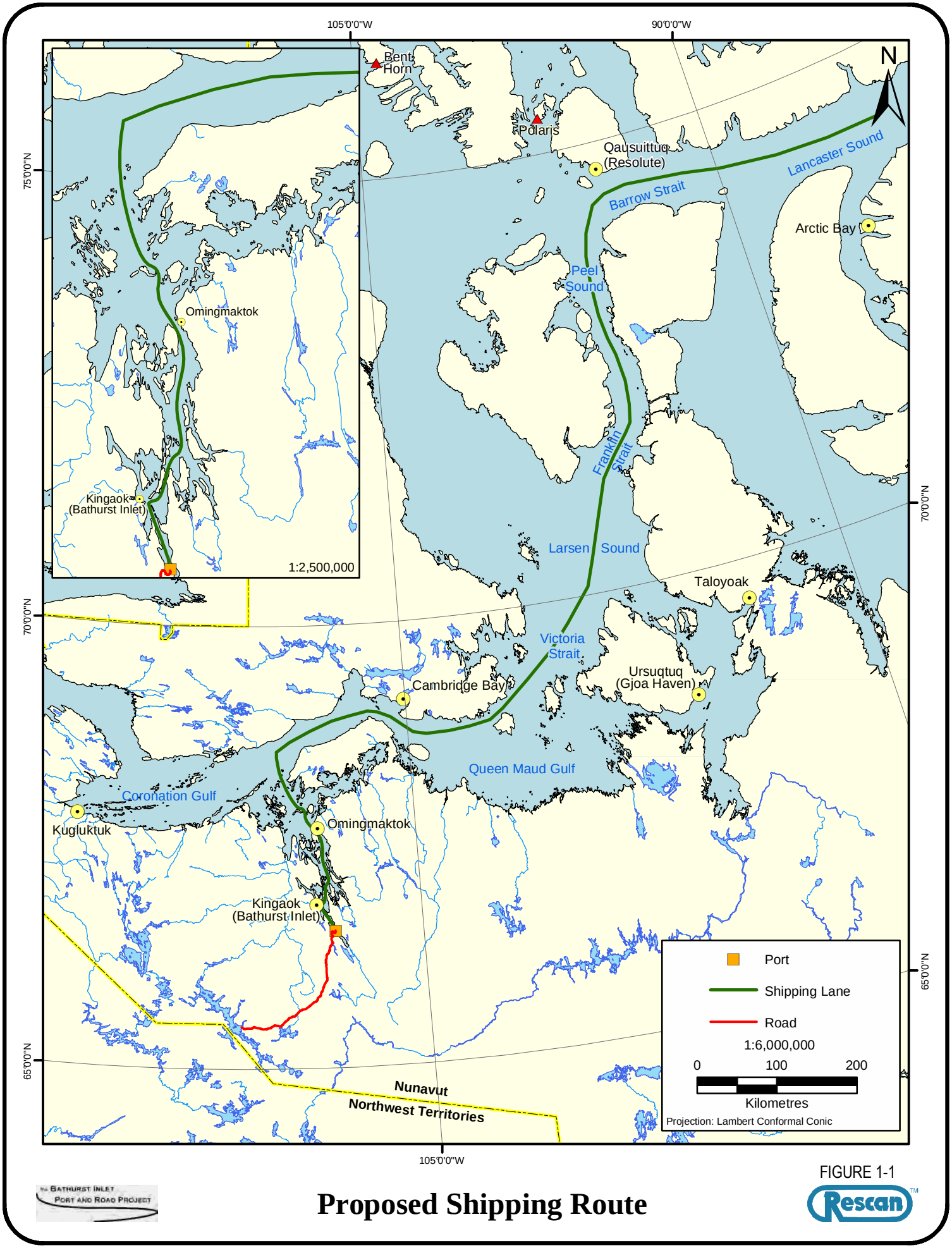

FIGURE 1-1

Proposed Shipping Route

Bathurst Inlet Port and Road Project

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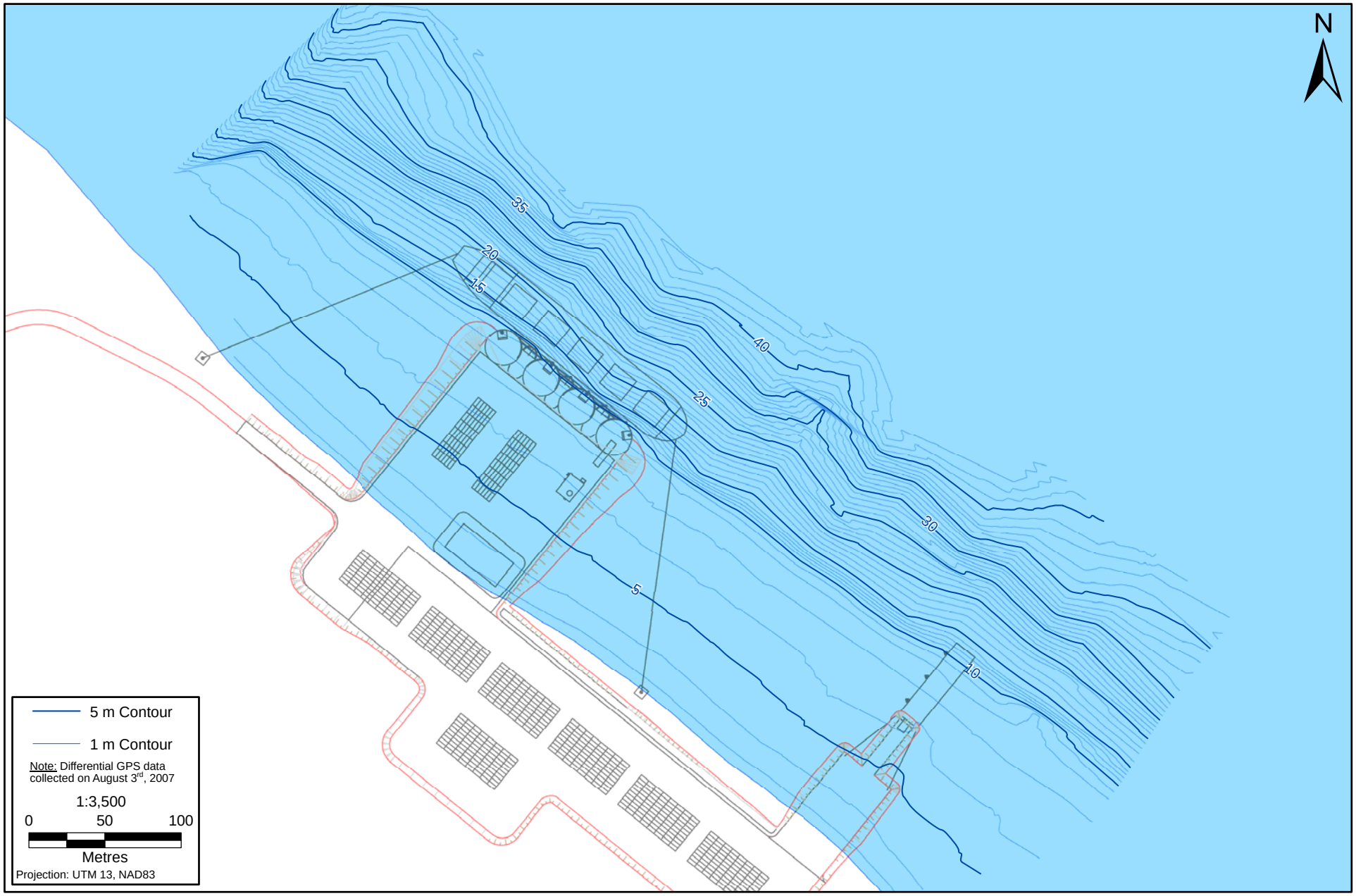

the Bathurst Inlet Port and Road Project

FIGURE 1-2

Bathurst Port Site Bathymetry

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2. DATA SOURCES

2. Data Sources

Information on the physical marine processes that occur in the Project area was obtained. This section outlines the data sources used in this report.

Numerous environmental field studies have been conducted by Rescan Environmental Services Ltd. (Rescan). These studies include:

- Fish Habitat Characterization (Appendix E-3 of the Draft Environmental Impact Statement (DEIS));
- Marine Environmental Baselines Studies, 2001-2002 (Appendix E-7 of the DEIS); and
- Meteorology Baseline Study (Appendix B-5 of the DEIS); and
- Marine Water and Sediment Effects Assessment (Appendix E-1 of the DEIS).

Data from these studies have been used in this report for marine physical processes characterization.

Canadian government resources were used including online data from the Canadian Ice Services, Environment Canada, and bathymetric charts from the Canadian Hydrographic Service (CHS). Data on marine currents was obtained in the Sailing Directions produced by the CHS were used (CHS, 1994).

The libraries of the Department of Fisheries and Oceans and the Institute of Ocean Sciences were searched for references applicable to the nearshore physical oceanography of Bathurst Inlet. Generally, information was available for the Arctic coast, along the Beaufort Sea; this was collected in response to oil and gas development in the late 1970s. There is limited information available for the Canadian archipelago (Pettipas *et al.*, 2006) and none specifically for Bathurst Inlet.

A study was produced by Canarctic (1993) to provide generally for context and proof of concept for shipping operations in Coronation Gulf. The Bathymetry for the shipping route was sourced from the Canarctic study as well as identified potential navigational hazards.

The Coastal Engineering Manual (Resio *et al.*, 2002) is a technical document addressing coastal processes, planning, and design. This document was used, along with meteorological data collected by Rescan, to estimate wave heights in the port area.

Although available data are sparse, all data used in this report are of high quality. However, the lack of ocean current data near the port is a gap. The proposed plan is to deploy an ADCP with pressure sensor at the port site during open water season of 2008. This instrument will provide data on the vertical structure of currents along with valuable information on water level variations including tidal range, surface waves, and storm surges. From these data, sediment transport processes could be better quantified.

3. ENVIRONMENTAL SETTING

3. Environmental Setting

All components of the marine physical processes environmental setting are broken into subsections for each of the two relevant components.

3.1 Bathymetry

3.1.1 Shipping Route

Bathymetric charts are available with contours and soundings from the CHS as shown below in Table 3.1-1.

Table 3.1-1
Summary of Available Bathymetric Charts for Proposed Shipping Route

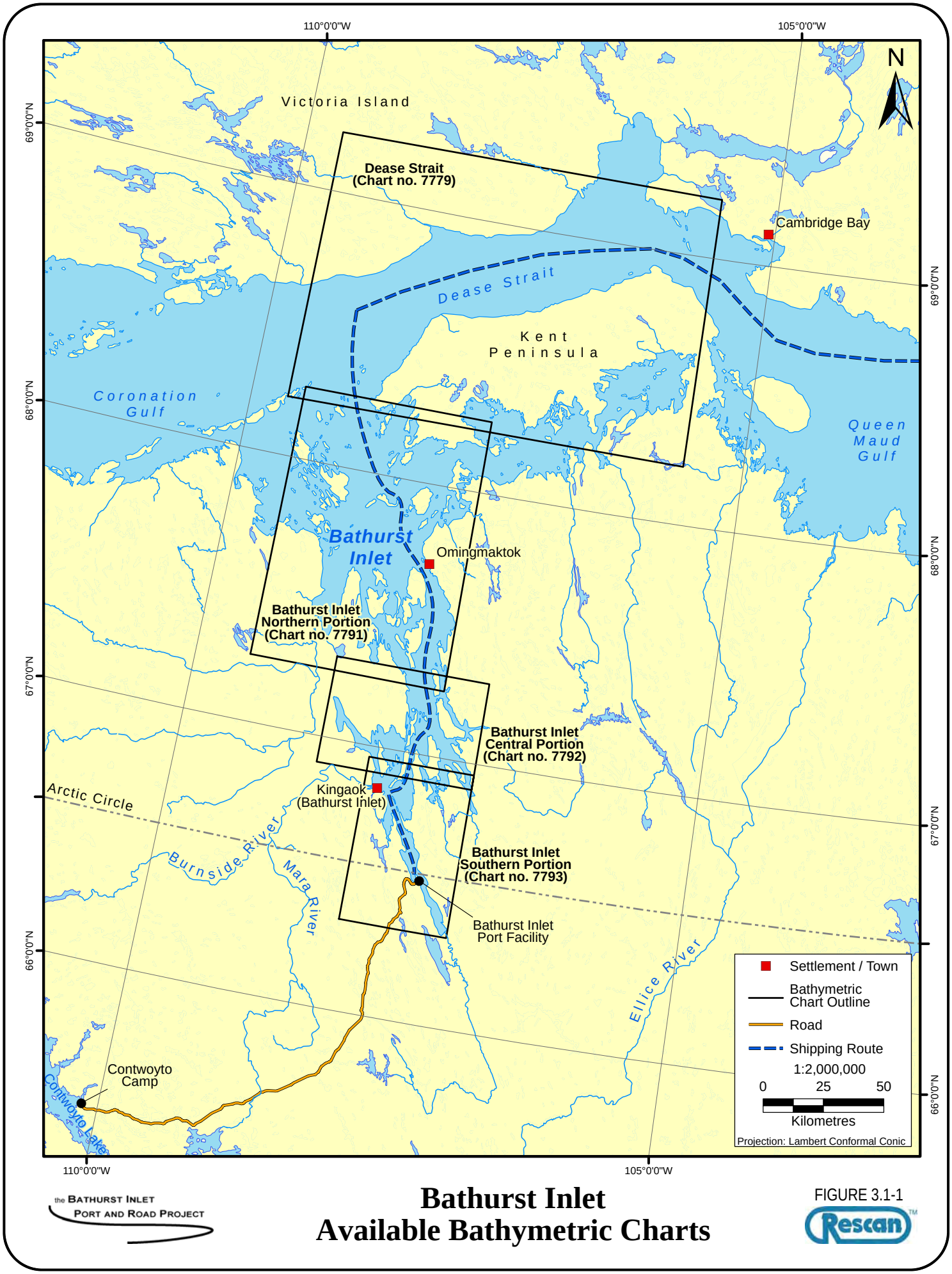
Chart Area Name	Chart Number	Publication Date
Cambridge Bay	7779	2006
Northern Bathurst Inlet	7791	2004
Central Bathurst Inlet	7792	2004
Bathurst Inlet	7793	2004

The charts focus primarily on the navigable areas within Bathurst Inlet (Figure 3.1-1). The bathymetry in the area of the proposed shipping route is mapped quite thoroughly. The shipping corridor is generally deep, at times exceeding 300 m, but passes between small islands. Canarctic (1993) evaluated the shipping lane from Lancaster Sound to the Coronation Gulf, part of which will be used to access Bathurst Inlet. The primary risk identified by this report is the shallow water around Jenny Lind Island. The bathymetric soundings in this area are sparse but suggest a depth of 16 m. Vessels travelling through this area have had drafts of up to 12 m. The maximum draft of vessels used for the project, based on maximum dimensions for the permanent dock at the port, is a loaded draught of 12.5 m.

3.1.2 Port Site

Detailed nearshore bathymetric data were collected at the port site on August 3, 2007 (Figure 1-2). A shallow water shelf extends at a slope of approximately 8% to a depth of 10 m and a distance of 120 m from the shoreline. Beyond this distance, the seabed slopes steeply at about 30% to depths greater than 40 m.

The coast near the proposed port site is responding to isostatic rebound and thus is emergent relative to sea level. Therefore, relict shorelines can be observed, but the rate of isostatic rebound is gradual: approximately 1 cm/year. It is unlikely that this gradual rise would contribute to observed sorting of beach material shown in Plate 3.1-1. Other processes contribute to banding



Bathurst Inlet
Available Bathymetric Charts

FIGURE 3.1-1

the Bathurst Inlet Port and Road Project

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Plate 3.1-1. Banding and sediment sorting at the port site is probably due to wave action during storm surges.

along the upper beach such as ice push. The bands of fine and coarse material indicate recent temporarily higher sea levels, likely during storm surges when wave action is usually strongest. Coarser material will remain in the zone of wave breaking, while finer material would have been deposited seaward of the breaker zone. If the banding is assumed to have occurred relatively recently, then the highest band may be taken as indicative of the height of a large storm surge.

3.2 Sea Ice Conditions

Sea ice covers about 7% of the world's oceans. Recent observational evidence indicates that the sea ice in the Arctic is retreating and thinning. Currently, the retreat of sea ice has increased the practicality of navigation in Canada's Arctic.

Studies, including the *Naonaiyaotit Traditional Knowledge Project* (KIA, 2006) indicate that traditionally, Inuit travelled by sea ice and lived on the sea ice in large igloo camps where they hunted seals through the animals' breathing holes (*agloos*). Inuit also hunted seals in the fall, using boats along the edge of the ocean's thin crust of ice.

The *Draft West Kitikmeot Regional Land Use Plan* prepared by the Nunavut Planning Commission (NPC, 2005) states that seasonal freezing usually starts around mid-September on Victoria Island, and about a week later in the coastal and mainland areas. Seasonal melting generally begins around mid-June on Victoria Island and approximately a week earlier on the mainland. By mid-December, ice covers most of the Coronation and Queen Maud Gulfs.

Through the Canadian Ice Services, Environment Canada maintains a comprehensive database on Arctic ice conditions (Environment Canada, 2007).

3.2.1 Shipping Route

Contour plots of the mean dates of break-up and freeze-up within the study area, based on data from 1971 through 2000, are presented in Figure 3.2-1. Recent ice coverage data, collected between 2000 and 2007, are presented for Barrow Strait, Franklin Strait and the area between Queen Maud and Coronation Gulfs (Figure 3.2-2). The bar graphs show the percent of ice coverage expressed as a percent of the total sea area on a weekly basis compared to the 1971 to 2000 data.

There is significant spatial variation in the timing of break-up (when an area is 100% free of ice) and freeze-up within the study area (Figure 3.2-1). Ice break-up at either end of the shipping route (*i.e.*, Bathurst Inlet and Barrow Strait) occurs early in the season: usually by June 18. In the intermediate area (*i.e.*, Franklin Strait), break-up does not occur until late August, if at all (Environment Canada, 2007).

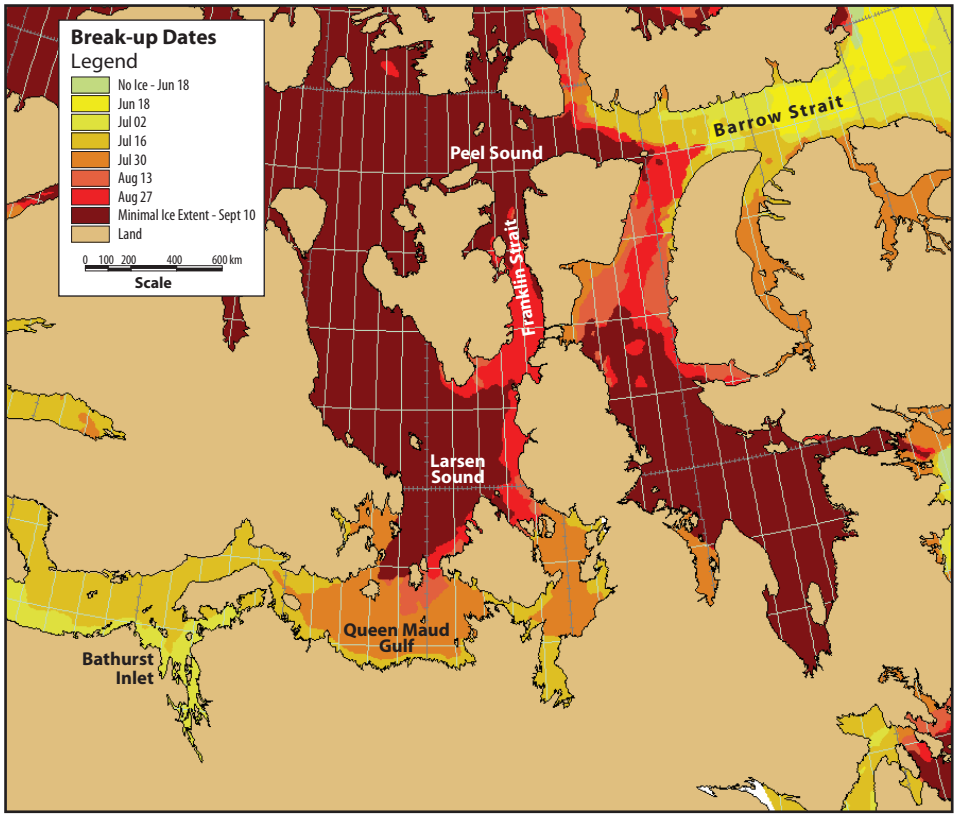
Recent data on the concentration of ice cover collected between 2000 and 2007 for each area show varying trends (Figure 3.2-2):

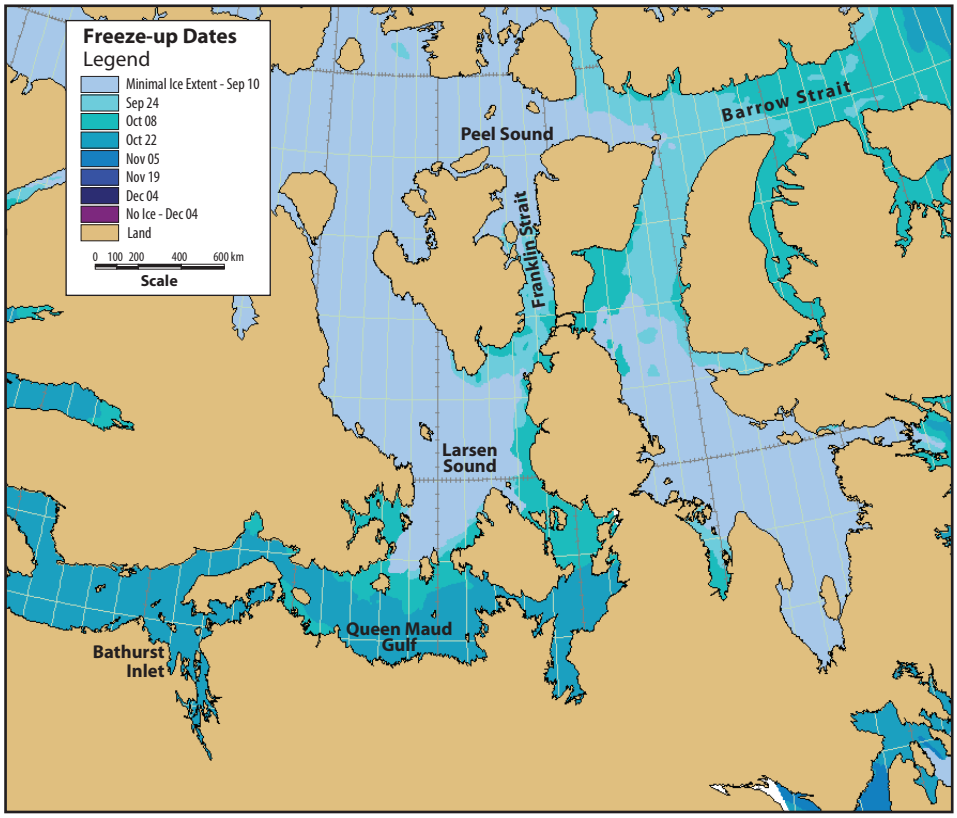
- by mid-June in Barrow Strait, less than 50% of the area is ice-covered; break-up is occurring earlier each year;
- Franklin Strait has recently remained over 50% ice-covered through the summer; however, in 2007, the area became completely ice-free; and
- variation in ice cover in the Coronation to Queen Maud Gulfs area is very consistent year to year, with less than 50% of the area covered by ice at the end of July.

Ice coverage reaches a minimum in mid-September, after which freeze-up begins. The date of freeze-up also varies significantly over the area of the proposed shipping route (Figure 3.2-1). Based on data collected between 1971 and 2000, freeze-up starts in the southern portion of Larsen Sound and in Peel Sound, and then fills the area between them, continuing to grow east into Barrow Strait and south into Queen Maud Gulf and Bathurst Inlet. By mid-October, the proposed shipping route is completely ice-covered, with the exception of Barrow Strait.

3.2.1.1 Ice Data Report

In September 2004, a report reviewing the range of expected ice conditions and shipping seasons for ice-strengthened cargo vessels was prepared for a shipping route serving Grays Bay in the Coronation Gulf region of Nunavut (Dickins, 2004). This report presents findings from a feasibility study into the proposed use of deep-sea vessels to serve Grays Bay and other Western Arctic communities along with updated information on the present status of Arctic shipping regulations, ship classifications (Type and Canadian Arctic Class) and possible long term trends in ice severity relating to climate change. A portion of the shipping route reviewed follows the proposed shipping route for BIPR (*i.e.*, Peel Sound to Dease Strait) and relevant findings are reported here.





Source: Environment Canada (2007)

the BATHURST INLET PORT AND ROAD PROJECT

Average Ice Break-up and Freeze-up Dates, 1971 to 2000

FIGURE 3.2-1

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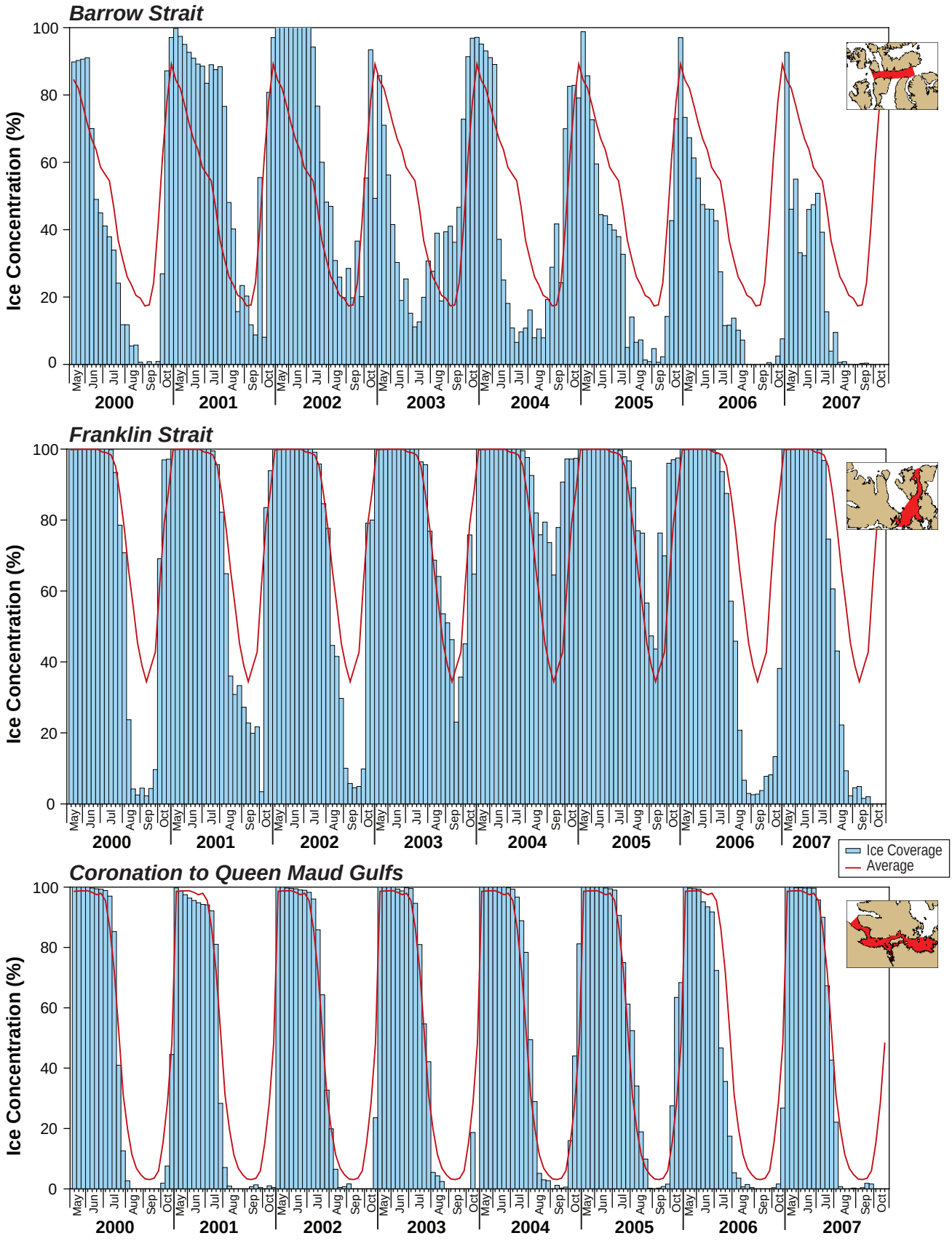

Note: Red line indicates 1971 to 2000 average
Source: Environment Canada (2007)

the BATHURST INLET PORT AND ROAD PROJECT

Historical Weekly Ice Coverage, 2000 to 2007

FIGURE 3.2-2

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Primary conclusions relating to the feasibility of access through Peel Sound and Franklin Strait to the Coronation Gulf were based on an examination of expected shipping seasons for different Type class vessels, strengthened to safely encounter different thickness of ice (Type A – 70 to 120 cm through E – 10-15 cm) over a ten year period (1988 to 1997). The study was concerned with only the Type class ships designed to operate in mostly first-year ice. Their results showed that for vessel Types A/B:

- during favourable ice condition years, the maximum berth season (*i.e.*, entering Peel Sound, docking in Grays Bay and departing Peel Sound) totaled 42 days;
- during average ice condition years, the maximum berth season totaled 17 days;
- only three out of ten years had a possible shipping season of more than three weeks; and
- four out of ten years had a likelihood of no shipping season except for pockets of less than one week scattered throughout the summer.

Ice breaking (CAC) cargo ships equal or better than the FedNav MV Arctic, in terms of capability, would be required to access Bathurst Inlet in most years. It is reported that ice going cargo ships managed by Seascot ASP have reliable serviced High Arctic mines for numerous years.

3.2.1.2 Traditional Knowledge on Sea Ice Conditions

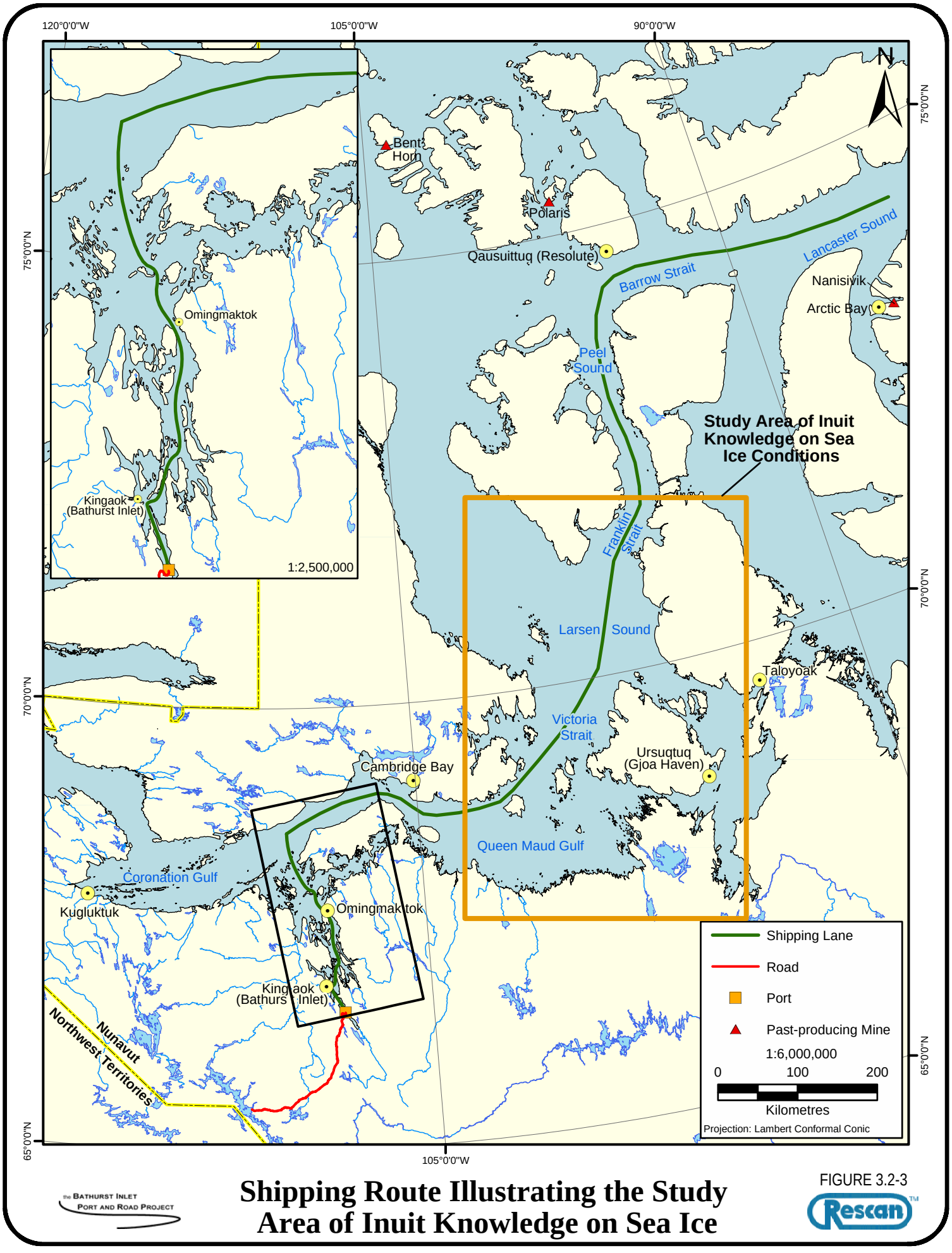
Traditional Knowledge on sea-ice conditions along the shipping route was obtained from a project conducted by the Gjoa Haven Hunters' and Trappers' Organization on Inuit Knowledge of Polar Bears. There was a consensus among interviewees that sea-ice within the study area (Figure 3.2-3) is freezing later and breaking up sooner when compared to the era before the 1970s (Keith *et al.*, 2005). Interviewees made observations on the sea-ice changes in the area:

> *"I remember they used to tell us that the trapping season started on November 1, and we used to go out and start putting out our traps and there [were] no dangerous spots on the ocean everything would be frozen over. Now…the first of November there are a lot of open spots in the ocean."*

> *"In the springtime the ice goes away a lot faster now, and it takes a lot longer to freeze up…in the fall. When I was young the ice used to go away in August. Today the ice goes away in mid-July and even in the first week of July."*

Other sea-ice changes remarked on are the time it takes for the sea-ice to become safe and the thickness of the sea-ice that is making travel more dangerous than in the past.

> *"…I notice the difference between now and then, when it comes to the ice and snow conditions. In the old days, there used to be a lot of snow and lots of thick ice around the edge, but these days there is a lot less snow and the ice is not as thick…We have to be able to interpret the ice conditions in order to make it out there, but it's becoming more difficult to do so as the climate changes (Bob Konana)."*



Shipping Route Illustrating the Study Area of Inuit Knowledge on Sea Ice

FIGURE 3.2-3

the Bathurst Inlet Port and Road Project

Rescan

Another change noted by interviewees was the disappearance of icebergs. This change, as with the change in sea-ice, is associated with the era of changing from dog teams to snowmobiles, around the 1970s. Keith *et al.* outline that the exact timing of the disappearance of icebergs is not easy to determine, as the definition of an iceberg is subjective. For instance, what younger hunters may consider a true iceberg (piqalujaq) older hunters may define as a piece of multi-year ice (hikutuqaq).

3.2.2 Port Site

No data on ice specific to the port site are available. However, Bathurst Inlet is included in the descriptions of the area between Queen Maud and Coronation Gulfs.

3.3 Marine Currents

Ocean currents in and near the port site are not well documented. Limited data from outside sources are available for several locations along the shipping route and are summarized in Sections 3.3.1 and 3.3.2. Information on ocean currents have been compiled, and a modelling tool was used to develop a vector flow diagram mean residual (*i.e.*, average, non-tidal) surface currents in the study area (Figure 3.3-1). Appendix E-6 presents a complete description of data sources, and explanations of assumptions and limitations.

Current meters will be deployed in Bathurst Inlet in 2008. Data recorded with these instruments will address concerns of mariners and will help quantify the circulation in the inlet.

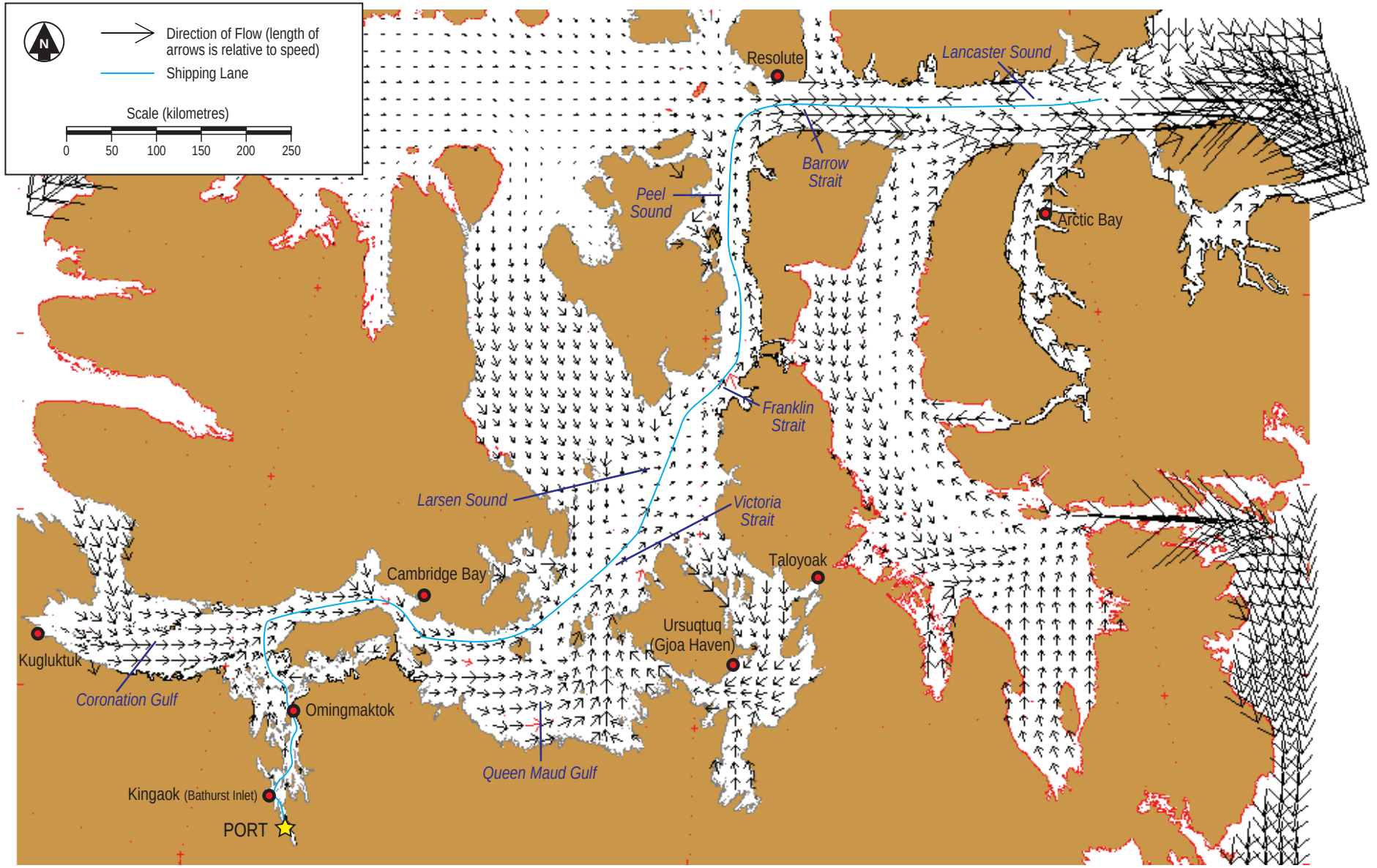
3.3.1 Shipping Route

A time series for marine currents in Barrow Strait is available through Fisheries and Oceans Canada (Pettipas *et al.*, 2006). Four current meters deployed along a transect between Devon (74°34’, 90°16’) and Sommerset (74°01’, 94°10’) islands show seasonal changes in the vertical profiles of current speeds and direction. Several earlier current measurement programs were conducted in the late 1970s and the early 1980s in support of evaluation of the Northwest Passage as an export shipping route for hydrocarbons (petroleum and liquid natural gas) from the Arctic Islands.

Currents in Barrow Strait vary significantly along the transect, with mean annual along-strait velocities of 20 cm/s to the east at the surface at the southern side of the strait, to 2 cm/s to the west on the northern side. The currents differ in magnitude depending on time of year, with strongest currents (up to 45 cm/s along the strait at the surface) observed during the ice free season between late August and September, and the weakest currents (6 cm/s along the strait at the surface) during the ice covered season of December to March.

3.3.2 Port Site

Port site-specific marine currents have not been documented in detail. CHS (1994) notes that tides within Bathurst Inlet are generally 0.3 m or less and contribute little to the currents in the inlet, and that several rivers flow into Bathurst Inlet (*e.g.*, Burnside River, Hood River, the Western River at the southern end of Bathurst and Amagok and No Name Creeks entering the bay to the west of the proposed port site).



Source: S.L. Ross

the BATHURST INLET PORT AND ROAD PROJECT

Estimated Current Speed and Direction for the Shipping Lane of the Bathurst Inlet Port and Road Project

FIGURE 3.3-1

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The nearest Canadian Hydrographic Station is at Omingmaktok (Baychimo, Station # 6250), which is located on the northeast edge of Bathurst Inlet near the mouth of the fjord, more than 120 km north of the proposed port location. For the period of July 1, 2007 to October 1, 2007, tides at Omingmaktok could be described as diurnal, or very weak semidiurnal. There was typically one maximum and one minimum tide per day. The maximum tidal height during this period was ~0.6 m, and the minimum tidal height during this period was ~0.07 m. The typical change in water height due to the tides ranged from about 0.2 to 0.4 m per cycle (DFO, 2007).

River flow into the long fjord of Bathurst Inlet will create an estuarine circulation and produce a predominantly northward setting current near the surface in the port area and a weak south flowing return current at depth. A northward setting current has also been reported in CHS (1994). The estuarine influence is clear in the low salinity, warmer surface layer and the higher salinity, cold deep layer described in Section 3.6. Longitudinal gradients of salinity are typical of fjord estuaries.

The proposed port site will have two structures that extend into Bathurst Inlet that could have an impact on the marine currents. These structures include the wharf and a jetty that extends 140 m and 100 m, respectively offshore. The width of Bathurst Inlet at the port site is nearly 2 km. As the proposed port structures are small compared to the width of Bathurst Inlet, it is probable that they will have minimal impact on the inlet's current regime.

3.4 Waves and Storm Surges

Storm surges occur when strong winds transport surface water downwind. The sea surface slope increases until it balances the force applied by the wind stress. The abnormal increase in sea level may be extremely destructive to low-lying coastal areas. There are no storm surge data available for Bathurst Inlet. However, the banding visible on the beach suggests that storm surges of approximately 1 to 2 m occur (Plate 3.1-1).

The current meters to be deployed in 2008 will be equipped with pressure sensors to record sea level variations, including tidal, wind waves, and storm surges.

Wave data are not available for either the shipping route or the port site. However, data on meteorology at the port site and several stations along the shipping route are available. Based on predominant wind speed and direction, and effective fetch (the distance across the water on which the wind can act), the wave heights can be estimated.

3.4.1 Shipping Route

Wave climate varies along the shipping route as a function of exposure or effective fetch and ice cover. Thus, maximum wave heights will be largest in Lancaster Sound and smallest in well-sheltered Bathurst Inlet.

The maximum wind speed at Cambridge Bay increases from July (71 km/h) through the summer to October (101 km/h).

3.4.2 Port Site

An order-of-magnitude calculation can be performed, with the limited information available, to determine the anticipated wave conditions at the port site. The most frequent wind directions are from the north and northeast (Table 3.4-1), giving a maximum effective fetch of approximately 20 km. Using an average wind speed of 20 km/h and a maximum wind speed of 48 km/h, empirical formulas give significant wave height predictions of 0.4 m and 1.0 m, respectively.

Table 3.4-1
Bathurst Port Site Meteorological Data

Month	Average Wind Speed (km/h)	Maximum Hourly Wind Speed (km/h)	Most Frequent Direction
July	19.4	41.0	N
August	20.1	47.9	N
September	21.8	57.8	NE
October	21.2	45.0	NE

Source: Resio *et al*. (2002).

3.5 Long Shore Processes

Sediment is introduced to the marine environment from a variety of sources, including suspended sediments in river runoff and shoreline erosion. In summer, wind wave erosion is most pronounced on exposed coasts; other transport processes, such as estuarine circulation, may dominate in sheltered areas such as Bathurst Inlet. Ice interaction with the shoreline is an important erosional process, particularly in the presence of a large tide range or an exposure to the open sea (*e.g.*, the Beaufort Sea coast). Large tides cause the repeated scour of the intertidal while "ice push" can drive sea ice considerable distances up the beach.

Bathurst Inlet is sheltered and tides are small, so erosional processes are likely moderate or small compared with other locations along the shipping route.

3.5.1 Shipping Route

Limited information is available for long shore processes along the shipping route. Shipping along the majority of the proposed shipping route has been frequent for many years and coastal environmental sensitivity studies have been performed for the route.

3.5.2 Port Site

Three major sources of riverine sediments exist in close proximity to the port site: Western River and No Name and Amagok Creeks. Sediment is deposited into Bathurst Inlet from No Name Creek (Plate 3.5-1). Sediment deposition occurs primarily during freshet. A delta has formed at the mouth of the Western River, indicating a significant sediment load carried by the river's runoff.

It is probable that fine river-derived sediments are transported seaward in the surface layer of the estuarine system in Bathurst Inlet. Fine sediments will flocculate as they enter the marine

environment so that deposition should be more pronounced as surface seawater salinity increases.

Plate 3.5-1. Aerial photo taken in 2001 of riverine sediment input from No Name Creek, to the west of the proposed port site.

Shoreline erosion is also a potential source for sediment transport from shore to the sea. In Bathurst Inlet, it is unclear if this process is significant compared to riverine inputs. Due to ice scour, there can be little fine sediment in the intertidal and lower to a depth equal to the ice thickness. However, no major erosional features (*e.g.*, cliffs) are present in Bathurst Inlet The nearshore sediments have been characterized as part of the marine baseline studies (Rescan, 2002). As shown in Plate 3.5-2, shoreline sediment is mostly gravel (*i.e.*, particle size between 2 and 64 mm) and cobble (*i.e.*, particle size between 64 and 256 mm). Further from shore, sediment grab samples indicate a substrate of fines (*i.e.*, particle size smaller than 2 mm, typically sand, silt, and clay) and gravel (Plate 3.5-3). The distribution of substrate material tends to confirm the process of shoreline scouring by ice. It should be noted that the Arctic intertidal characteristically has very sparse benthic life due to impingement of ice.

Wave erosion may be a significant process at the port site during storm surges when the largest waves can propagate and break higher on the beach.

Based on satellite images of the proposed port site, only one qualitative indicator of long-shore transport exists in the coastal morphology. A spit, approximately 15 km southeast of the port site, indicates that the direction of sediment transport is northward. In the presence of deep fjord topography, one would expect sedimentation to occur in a deltaic fashion, prograding seaward from river mouths.

Plate 3.5-2. Cobble and gravel on shoreline characteristic of port site, 2007.

Plate 3.5-3. Fines and gravel taken from the seabed in 2007 at 5 m depth, 150 m from shore.

3.6 Water Column Structure

Physical characteristics that are discussed include vertical profiles of water temperature, salinity and dissolved oxygen, and euphotic zone depth. Secchi depth is a measure of water clarity from which the depth of the euphotic zone is calculated. The euphotic zone is the zone with sufficient light for photosynthesis to take place, making it an environment suitable for primary producers (*i.e.,* phytoplankton). Changes in these parameters can signal changing water conditions that may affect biological organisms.

3.6.1 Port Site

Port site water column structure data were collected as part of baseline studies conducted in 2001 (Rescan, 2002; Appendix E-7 of the DEIS). Additional data were collected in 2007 (unpublished report). The sampled stations (Stations 1 to 3 and 5 in 2001, and Stations 1 to 3 plus one reference station in 2007) are illustrated in Figure 3.6-1.

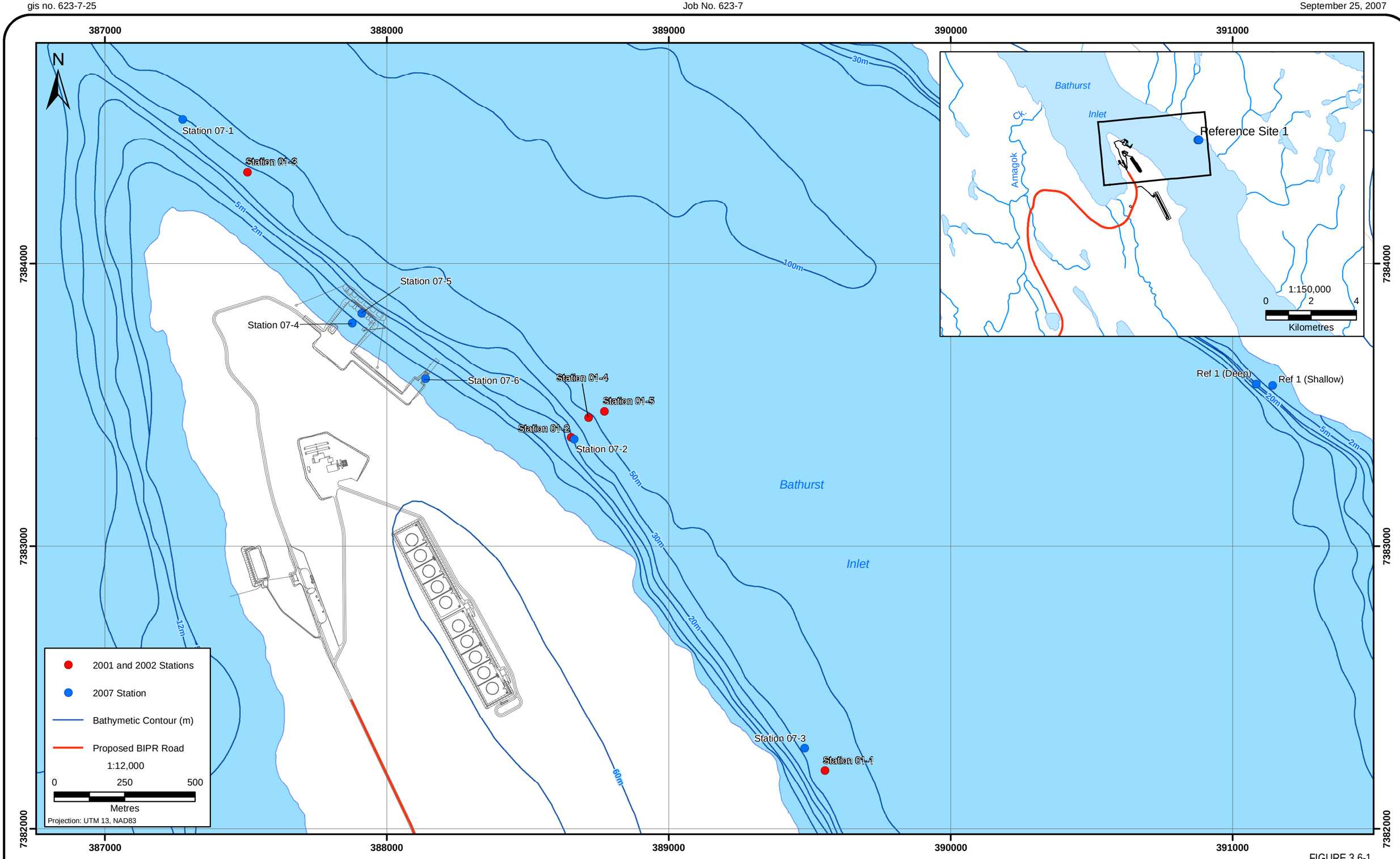
The average Secchi depth collected near the port site during the 2001 and 2007 surveys was 3.5 m (standard deviation = 0.3 m, n=8). The resulting calculated average depth of the euphotic zone was 9.8 m deep (standard deviation = 0.7 m, n = 8).

The water column was highly stratified in August of both 2001 and 2007, with layering observed at several stations in 2001. Data show a warmer, fresher mixed layer approximately 7 m deep overlying a water column continuously stratified in both temperature and salinity. The surface temperature in both years was approximately 11°C, and salinity was approximately 10 PSU in 2001 and 16 PSU in 2007. The exception was Station 011, which exhibited a surface layer of freshwater (*i.e.,* 0 PSU) that was not present in August 2007.

Salinity approached 26 psu and temperature approached 0ºC at depths greater than 30 m.

The water column structure present near the port site is typical of partially mixed estuaries, characteristic of the seaward reaches of fjords where there is relatively greater wind mixing, stronger tidal currents and action, and lower run-off than at the head of the fjord (which is sheltered and usually the location of the freshwater source).

Vertical profiles of dissolved oxygen collected in 2007 show an oxygen maximum at approximately 15 m depth, suggestive of highly oxygenated, cooler, and saltier offshore water sinking beneath the fresher surface layer.



the Bathurst Inlet Port and Road Project

FIGURE 3.6-1

Marine Sampling Locations for Bathurst Inlet Port and Road Project

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An explanation of the acronyms used throughout this reference list can be found in the *Acronyms and Abbreviations* section.

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