REPORT ON

TECHNICAL INFORMATION DOCUMENT
KIGGAVIK PROJECT
NUNAVUT

Submitted to:
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June 2008
08-1362-0479

LIST OF ACRONYMS

agl	above ground level
AREVA	AREVA Resources Canada Inc.
BIC	Benthic Invertebrate Community
BHPB	BHP Billiton
BQCMB	Beverly and Qamanirjuaq Caribou Management Board
BP	Before present
CCREM	Canadian Council of Resource and Environment
CEC	Cation exchange capacities
CLEY	Department of Culture, Language, Elders and Youth
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CNMN	Canadian National Museum of Nature
CPUE	catch per unit effort
CWS	Canadian Wildlife Services
DDMI	Diavik Diamond Mines Inc.
De Beers	De Beers Canada Mining Inc.
EA	environmental assessment
EC	Environment Canada
EEM	Environmental effects monitoring
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ELC	Ecological Land Classification
ELS	Ecological Land Survey
FEARO	Federal Environmental Assessment and Review
GN	Government of Nunavut
Golder	Golder Associates Ltd.
GIS	Geographic Information System
GPS	global positioning system
GSI	gonadosomatic index
HRIA	Heritage Resources Impact Assessment
ISQG	Interim Sediment Quality Guidelines
LSA	local study area
LSI	liversomatic index
Miramar	Miramar Hope Bay Ltd.
MVEIRB	Mackenzie Valley Environmental Impact Review Board
OMNR	Ontario Ministry of Natural Resources
NAPL	National Air Photo Library
NIRB	Nunavut Impact Review Board
NLUIS	Northern Land Use Information Series
NU	Nunavut
NT	Northwest Territories
Pb	Lead

LIST OF ACRONYMS (Continued)

PEL	Probable Effect Level
Po	Polonium
QA/QC	quality assurance/quality control
RSA	regional study area
SARA	Species at Risk Act
SOCC	State of the Canadian Cryosphere
SPANS	Spatial Analysis System
SRC	Saskatchewan Research Council
Tahera	Tahera Corporation
Th	Thorium
TID	Technical Information Document
TM	Thematic Mapper
TRTE	University of Toronto, Erindale Campus
UTM	universal transverse mercator
VC	valued components
VEC	valued ecosystem components
VSEC	valued socioeconomic components
WSC	Water Survey of Canada
YOY	Young-of-the-year

LIST OF UNITS

^oC	Degrees celsius
Bq	Becquerels
cm	centimetres
g	grams
ha	hectares
km	kilometres
km^2	square kilometres
L	litre
m	metres
m^2	square metres
m^3	cubic metres
mg	Milligrams
mm	millimetres
µg/g	micrograms
µm	micrometres
µS	micro seconds

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1.0 INTRODUCTION

1.1 Background

AREVA Resources Canada Inc. (AREVA) will be preparing an Environmental Assessment (EA) Report to be submitted to the regulatory agencies, in support of the Kiggavik Project (the Project), located approximately 80 km west of Baker Lake, Nunavut. In order to support the forthcoming EA, all of the existing technical information available for the Project was compiled and synthesized into a Technical Information Document (TID). The technical document has been prepared for the future use by project planners, operations personnel, and federal and provincial regulators. In addition, it is anticipated that this document will be widely used by mine personnel, aboriginal leadership, communities adjacent to the Project, and the general public.

AREVA contracted Golder Associates Ltd. (Golder) to compile the TID. The areas of study assigned to Golder included a description of the existing environment, with specific emphasis on the biophysical environment. The areas of assessment included the following:

- Surface Water Hydrology and Climate;
- Heritage Resources;
- Aquatic Resources; and
- Terrestrial Resources (including Soil, Wildlife, and Vegetation).

1.2 Objectives of the Technical Information Document

This TID presents information from past and current environmental studies in a clear and concise manner. The overall goal of the report is to provide a comprehensive, current understanding of the biophysical environment at and surrounding the project site. To meet this goal, several specific objectives have been identified:

- to compile and summarize relevant existing information on environmental components to establish pre-development baseline conditions;
- to provide temporal and spatial comparison of the information (where applicable); and
- to identify data gaps in the existing body of baseline information.

The TID is intended to provide sufficient detail in terms of study objectives, methods, and results so that the future users can make a well informed assessment of the potential effects of the Project on the existing local environment. Moreover, the TID will function as a repository of environmental information (which will be updated from time-to-time and) that will facilitate future licence applications, EAs, project planning initiatives and the design of environmental monitoring programs. The TID will facilitate future licence applications, EAs, design basis for planning, and environmental effects monitoring (EEM).

1.3 Information Sources

There is a wide range of pre-development baseline data for the Project contained in numerous sources. Much of this information comprises part of the initial site characterization and included inventories of local and regional fauna and flora as well as data regarding various components of the physical environment (e.g., climate, meteorology, soils, lake sediments, water). This type of information is provided as Appendices in the TID. Results from field investigations conducted by Golder in 2007 have been incorporated into the TID. Also, there is a large amount of baseline data that has been used in the early 1990's to assess environmental effects from the Project. While the proposed mining plan and ancillary facilities may be substantially revised as the AREVA development plan proceeds, the information was a key component of the study design, and will provide background values to compare against future measurements of environmental endpoints obtained during operations. In addition, relevant information collected for research purposed or on behalf of other projects in the region has been included in the TID document.

1.4 Report Content

This report contains the following information:

- Section 1 – Introduction;
- Section 2 – Site Description;
- Section 3 – Hydrology;
- Section 4 – Surface Water and Sediment ;
- Section 5 – Freshwater Aquatic Organisms and Habitat;
- Section 6 – Surficial Geology and Soils;
- Section 7 – Vegetation;
- Section 8 – Wildlife and Wildlife Habitat; and
- Section 9 – Archaeology.

Sections 1 and 2 provide the objectives of the TID and the Kiggavik Project site description. A summary of the Valued Ecosystem Components of other similar projects in the region are also provided in section 2. Sections 3 to 9 provide information on the different disciplines (archaeology, aquatics, hydrology, and terrestrial resources).

Information was collected in the study area from 1975 to 2007. Detailed tables of data are provided in Appendices I to XI.

2.0 SITE DESCRIPTION

2.1 Kiggavik-Sissons Lease Site

AREVA Resources Canada Inc. (AREVA) owns the Kiggavik Project (the Project) in Nunavut. The Project is located approximately 80 km west of Baker Lake, and currently consists of camp infrastructure.

The Project comprises two large groups of mining leases and mineral claims subdivided into Kiggavik leases to the north and Sissons leases to the south (Figure 2.1-1). Mine development plans for the Kiggavik lease area include two or three open-pit mines, a mill, and the camp infrastructure. The open pits will be located near the headwater of Pointer Lake. One of the inlet streams to Pointer Lake (east tributary) will be diverted around the open pit. Currently, two options are being considered for the discharge of the main effluent: Pointer Lake and Sik Sik Lake. Both lakes flow into Judge Sissons Lake via Rock Lake. .

The Sissons lease mining activities would include two open pits or underground mines. End Grid Lake and Andrew Lake (Lower Shack Lake system) will probably be directly affected by mining activities (e.g., dust transport, erosion, and habitat loss). In addition, the effluent from the open pit operation (e.g., groundwater) would probably be released in End Grid Lake or Andrew Lake. The camp, mill, and waste rock storage, and related infrastructure will be located near Cirque and Ridge Lakes. Skinny Lake, Squiggly Lake and Siamese Lake are potential water sources for the development. Ultimately all the discharges from the Project would be discharged into Judge Sissons Lake, a large lake with a total surface area of 95.5 km^2 (Ecometrix 2006).

2.2 Issues and Valued Components

Several recent environmental impact statements (EIS) for mining-related projects that have been completed or are currently in the Nunavut Impact Review Board (NIRB) environmental review process, were examined to develop an understanding of current regulatory issues that may need to be addressed during a future environmental assessment for the project. These include the Doris North project, Meadowbank project, and the Jericho project. It should be noted that none of these proposed developments is a uranium mine; however, they have many aspects in common with the Project (e.g., water management, infrastructure development, waste rock storage, tailings disposal, etc.).

Figure 2.1-1 Kiggavik Study Area

The EISs were also examined to assess potential valued components (VCs) that may be of interest. VCs can be defined as “those environmental attributes or components identified as a result of an ecological and social scoping exercise, which were determined on the basis of perceived public concerns related to social, cultural, economic and aesthetic values. They also reflect scientific concerns of the professional community as expressed through social scoping procedures (i.e., hearings, questionnaires, interviews, workshops, media reports, etc.), and through technical studies (Cumberland Resources Ltd. 2003).

2.2.1 Doris North Project

For the Doris North project, located approximately 573 km northwest of the Kiggavik Project, the selection of VCs was based on both western scientific data and *Inuit Qaujimajatuqangit*. The inclusion of both science-based and traditional knowledge was considered important in the completion of the environmental assessment, it reflected a process that was balanced and included a synthesis of a wide range of information regarding the project, the environmental setting where the project is located and an understanding of concerns and issues associated with the responsible development of the project. Miramar Hope Bay Ltd. (Miramar) used a wide variety of information in the determination of a functional range of VCs to reflect both the scope and scale of the project. The VCs were also defined to include socioeconomic components.

The Doris North VC selection process included the following activities:

- examining NIRB direction and EIS guidelines;
- review of literature (previous EIAs and ES review) and soliciting input from technical experts;
- carrying out baseline studies;
- project description and alternative analysis;
- studying project environmental interactions;
- consultations with regulators, resource managers, and other stakeholders;
- consultation with KIS Inuit communities and the public;
- use of noise/emissions, habitat, water quality, hydrology predictive models; and
- Inuit Qaujimajatuqangit.

The selected Doris North VCs were grouped into three categories: pathways, biophysical, and socioeconomic.

Doris North pathway VCs included:

- atmospheric environment; and

- water quality.

Doris North biophysical VCs included:

- Arctic char;
- Lake trout;
- Lake whitefish;
- Ninespine stickleback;
- Caribou;
- Grizzly bear;
- Wolverine;
- Upland breeding birds;
- Waterfowl;
- Raptors;
- Nearshore marine process;
- Heritage resources; and
- Environmental health.

Doris North Socioeconomic VCs included:

- community services and infrastructure; and
- employment and economy.

2.2.2 Meadowbank Project

The Meadowbank project, located approximately 100 km northeast of the Kiggavik Project, VCs were primarily identified in consultation with regulatory and governmental authorities, as well as through discussions with members of the local community. Each VC is of ecological importance, and many are intimately connected with one another. The Meadowbank VCs are:

- Ungulates;
- Raptors;
- Fish habitat;
- Waterfowl and other bird species;
- Fish populations;
- Air quality;
- Marine mammals;
- Water quality;
- Permafrost;
- Surface water quantity and distribution;

- Small mammals;
- Predatory mammals; and
- Vegetation cover.

2.2.3 Jericho Project

The VCs considered for the Jericho project, located approximately 668 km west of the Kiggavik Project, included all physical and biological components of the environment assessed for potential project impacts. The valued socioeconomic components were considered in the socioeconomic impact assessment and are outside the scope of this document. In developing the VCs for the Jericho Project, reference was made to community consultations where people identified particular issues of concern. Issues raised by communities were limited, but a number of concerns were brought forward consistently: water quality, wildlife habitat, and wildlife (specifically caribou, grizzly, wolf, and wolverine).

The VC list considered for cumulative effects assessment for the Jericho Project includes:

- air quality;
- water quantity and quality;
- permafrost;
- terrestrial and aquatic habitats;
- terrestrial and aquatic plants and animals; and
- heritage resources.

2.2.4 Comparison of Aquatic Valued Components

The VCs in the three environmental impact statements illustrate some common themes, although their respective levels of detail differs in each case. Pathway VCs and species specific VCs have been used to evaluate potential impacts of the proposed projects.

Based on the review of the recent EIS documents it is recommend that the VCs for future EA studies for the project include both pathway VCs and fish species that represent different trophic levels, as well as those that are considered to be of socioeconomic importance. These may include:

- water quality;
- benthic invertebrate community (BIC);
- plankton community;
- slimy sculpin;

- ninespine stickleback;
- Arctic grayling;
- lake trout;
- Arctic char; and
- round whitefish.

It is recommended that the Technical Information Document (TID) and subsequent baseline studies focus on these species, so that adequate information can be gathered to use these species as VCs in a future environmental impact assessment. It is important to note that the list of VCs noted above is considered preliminary and this list will be revised and updated following discussions with NIRB and after community consultations have been initiated.

2.3 Archaeology Issues and Valued Ecosystem Components

Archaeological resources have been identified as valued ecosystem components in previous studies for mining ventures carried out in Nunavut over the past decade (e.g. Tahera Corporation 2003; Miramar Hope Bay Ltd. 2005). Archaeological resources are recognized as important sources of historical knowledge and cultural identity that are non-renewable. Local communities, organizations and the Government of Nunavut consider archaeological resources to be valuable, and as a result, they have been granted protection under Article 33 of the Nunavut Land Claims Agreement (1993).

2.4 Selection of Wildlife Valued Components for Baseline Studies

Valued ecosystem components (VCs) represent physical, biological, cultural, and economic properties of the social-ecological system that are considered to be important by society. In general, the selection of wildlife VCs for EAs and effects monitoring programs in Nunavut and the Northwest Territories (NWT) has been quite consistent. For example, caribou, grizzly bears, wolverine, wolves, foxes, upland breeding birds, waterfowl, raptors, and wildlife habitat were chosen as VCs for EAs for the Ekati, Diavik, Snap Lake, and Gahcho Kué projects in the NWT (BHP 1995; DDMI 1998; De Beers 2002; MVEIRB 2007), and for the Jericho and Doris North projects in Nunavut (Tahera 2000; Miramar 2005). Muskoxen were also selected as a study species for the Jericho and Doris North projects, and muskoxen and moose were included for the Gahcho Kué project. Species selected for monitoring the effects from these projects during construction and operation included caribou, muskoxen, grizzly bears, wolverines, wolves, upland breeding birds, waterfowl, and raptors (Tahera 2005; Miramar 2006; BHPB 2007; DDMI 2007; De Beers 2007).

Based on this review, the following wildlife VCs were selected to focus baseline studies for the Project:

- caribou;
- muskoxen;
- grizzly bear;
- wolverine;
- wolf and foxes;
- upland breeding birds (songbirds, shorebirds, ptarmigan);
- water birds (ducks, geese, swans, loons); and,
- raptors (falcons, hawks, eagles, ravens, owls).

Information on the presence and location of other wildlife species should also collected during the baseline program.

2.5 Hydrology Issues and Valued Components

Water quality and quantity and the atmospheric environment have been identified as VC's in previous EIS documents as presented in Section 2.2. Both components may be viewed as pathways that have the potential to affect the biophysical environment. Issues associated with the atmospheric environment may include decreased air quality and contaminant transport. Issues associated with hydrologic resources may include decreased water quality, increased or decreased water volumes, temporal variations of stream flow and water levels, and contaminant and sediment transport.

3.0 HYDROLOGY

Water management is a key consideration with most mining developments. The construction of surface facilities can disrupt natural drainage paths. Water withdrawal or releases into existing streams may modify the existing flow regime. Surface water assessments are an important component in evaluating the environmental impact of a potential development and are required to characterize baseline flow conditions; against which the magnitude of project related modifications can be measured. Surface water data are also an important basis for various engineered designs and are also an important component in evaluations conducted by other disciplines such as hydrogeology, water quality, and aquatic ecology. The reliable prediction of project impacts will allow the development of effective mitigation plans and focus monitoring on key aspects. Water management is typically an important operating license component and will be a major area for review by regulatory agencies. This report describes regional and local hydrology including measured and estimated stream flow data, seasonal distribution of runoff and extreme flow events. Climatic parameters that are relevant for water balance purposes are also described.

Hydrologic data are required for a wide range of engineering design purposes including cross-drainage structures such as culverts and bridges, ditches, water management ponds, tailings containment areas, fresh water diversions, and erosion control planning. Targeted effluent dilution potential and site water balance calculations will also be partly dependent on hydrologic data.

Hydrological data may be used for water management purposes and impact assessments including but not limited to the following:

- calculating flood magnitude and frequency for design purposes (culverts, bridges, water treatment ponds, tailings facilities, freshwater diversions);
- establishing rainfall and snow melt runoff relationships for water management purposes;
- predicting changes in flow volumes for local streams, bogs and ponds;
- predicting water quality assessments including dilution potential, contaminant loading and plume delineation;
- water availability;
- evaluating potential impact to aquatic organisms from changes in water quality and quantity;
- operational site water management;
- sediment control; and
- reestablishment of pre-development watersheds, flow regimes, and vegetation.

The following sections include descriptions of potential issues, as well as a compilation of historical and current data that has been collected with respect to the hydrological regime near the Kiggavik Project (the Project).

3.1 Climate

The Project is located in the Southern Arctic terrestrial ecozone, which is characterized by continuous permafrost that may be present just a few centimetres below the surface (EC 2005). Summers in the Southern Arctic Ecozone are cool and approximately four months in length. This ecozone is bounded to the south by the treeline, a broad ecological division between the taiga forest and the treeless arctic tundra, and to the north by the Northern Arctic Ecozone, which includes most of the islands off the northern shores of Nunavut and the Northwest Territories, as well as the top of the Ungava Peninsula. The terrain is undulated with numerous lakes and ponds that were formed by the melting glaciers of the last glaciation. Low precipitation and extremely low winter temperatures stunt tree growth in this ecozone (NRCAN 2004).

3.1.1 Regional Climate

Climate stations nearest to the Project are listed in Table 3.1-1. The nearest climate station is located at Baker Lake, approximately 80 km east of the Project area.

Table 3.1-1
Regional Climate Stations

Station ID	Station Name	Latitude	Longitude	Approximate Distance from Kiggavik Project (km)	Period of Record*
2300500	Baker Lake A	64° 18.000' N	96° 4.800' W	80	1946-2008
n/a	Meadowbank Project[(a)]	65° 01.184"N	96° 04.000"W	100	1997-2003
2300MQM	Back River	66° 5.400' N	96° 30.600' W	193	1995-2004
2301331	Brown River	66° 1.800' N	91° 49.800' W	320	1994-2004
230J048	Dubawnt Lake	63° 13.800' N	101° 45.600' W	240	1993-2005
2301102	Ennadai Lake	61° 7.800' N	100° 52.800' W	402	1994-2008
2303610	Robertson Lake	65° 6.000' N	102° 25.800' W	233	1994-2008
2303401	Rankin Inlet	62° 49.200' N	92° 7.200' W	329	1981-2008
2304058	Yathkyed Lake	62° 42.600' N	98° 17.400' W	201	1993-2004

* Period of record was determined from daily climate data availability
a = Source: Cumberland Resources 2003

Data have been collected at the Baker Lake climate station since 1946 and are considered the most representative of conditions at the Project site based, on its close proximity and the long period of record. These data were used for the previous environmental assessment for the Project (BEAK 1990), and also for environmental assessments for other mining operations in Nunavut, such as the Meadowbank project (Cumberland Resources Ltd. 2003).

In addition to the meteorological stations operated by Environment Canada (EC) in the region (Table 3.1-1), other short-term meteorological stations operated by resource developers exist in the region. A meteorological station was installed for the Meadowbank project in 1997 (Cumberland Resources Ltd. 2003). This station was located 70 km north of Baker Lake, and is approximately 100 km northeast of the Project. The parameters measured at this station included air temperature, soil temperature, relative humidity, net radiation, and wind speed. In addition, snow surveys were carried out in 1999 and 2003. Pan evaporation was measured in 2002 between June and September, and from this lake evaporation was estimated.

Temperature and precipitation normals for these regional climate stations were examined to determine the extent to which regional trends existed. However, the majority of these stations did not have sufficient data or sufficiently quality data to produce long-term normals for the most recent 30-year period. In addition, Doris North, High Lake, and Jericho are between 600 km and 700 km northwest of the Project.

Mean Annual Precipitation

Table 3.1-2 and Figure 3.1-1 presents climate normals (temperature and precipitation) for Baker Lake (1971-2000). Monthly precipitation data measured over the period of record for Baker Lake climate station are provided in Table I-1 (Appendix I). EC also maintains a record of Adjusted Historical Climate Data, where precipitation and temperature records have been adjusted for a number of northern climate stations (EC 2007a). The main adjustment is for snow gauge undercatch which provides for a more accurate representation of snowfall than is provided in the standard climate normals data. In the case of Baker Lake, the adjusted precipitation is 40% greater than reported in climate normals.

The mean annual precipitation for Baker Lake over the period 1971 to 2000 was 270 mm, 157 mm of which falls as rain (Table 3.1-2). Table 3.1-2 and Figure 3.1-1 present mean monthly and mean annual rainfall, snowfall, and precipitation for Baker Lake, in addition to the 25th and 75 percentile data (EC 2008). It is noted that snowfall may occur during any month during the year at Baker Lake (EC 2008). The months of

October, November, and April have generally had the highest amounts of snowfall during the period of record (Beak Consultants Limited 1990).

Table 3.1-2
Rainfall, Snowfall, and Precipitation for Baker Lake, 1971-2000

Month	Rainfall (mm)			Snowfall (mm)[(a)]			Total Precipitation (mm)		
	Mean	25th Percentile	75th Percentile	Mean	25th Percentile	75th Percentile	Mean	25th Percentile	75th Percentile
Jan	0	0.0	0.0	7.4	2.5	10.3	7.5	2.2	10.3
Feb	0	0.0	0.0	7.2	3.6	10.2	7.2	3.6	10.2
Mar	0	0.0	0.0	10.4	5.8	12.9	10.5	5.8	12.9
Apr	0.5	0.0	0.0	13.1	7.3	17.4	13.6	7.3	18.7
May	6.7	0.2	8.2	8.8	9.3	12.8	15.6	9.5	19.7
Jun	20.8	10.5	25.6	3.3	0.5	6.5	24.1	10.3	30.3
Jul	41.8	23.0	57.8	0.0	0.0	0.0	41.8	23.0	57.8
Aug	45.7	28.2	63.4	1.3	9.2	0.0	47.0	37.4	65.1
Sep	35.8	19.5	48.7	8.1	8.6	9.2	44.1	28.1	57.9
Oct	5.3	0.2	7.2	26.5	17.8	36.9	32.1	17.1	44.1
Nov	0.1	0.0	0.0	16.7	10.9	19.1	17.0	10.9	19.1
Dec	0	0.0	0.0	10.5	6.3	14.4	10.2	6.3	14.4
Annual	156.7	124.5	179.8	112.0	113.4	122.1	270.4	237.9	302.0

a = Snowfall depths are recorded in centimetres and are converted to millimetres of snow water equivalent to contribute to total precipitation estimates

Figure 3.1-1 Recorded and Adjusted Temperature and Precipitation for Baker Lake

Adjusted precipitation data were calculated for Baker Lake climate station over the period 1950 to 2006 (Table 3.1-3) (EC 2007a). From the adjusted dataset, mean annual precipitation was estimated to be 378 mm, 176 mm (49%) of which falls as rain.

Table 3.1-3
Adjusted Historical Precipitation for Baker Lake, 1971-2000

Month	Rainfall (mm)			Snowfall (mm)			Total Precipitation (mm)		
	Mean	25th Percentile	75th Percentile	Mean	25th Percentile	75th Percentile	Mean	25th Percentile	75th Percentile
Jan	0.1	0.0	0.0	14.6	7.3	18.8	14.7	7.5	18.8
Feb	0.1	0.0	0.0	14.3	7.7	19.1	14.4	7.9	19.1
Mar	0.0	0.0	0.0	19.7	10.4	24.0	19.8	10.4	24.0
Apr	0.9	0.0	0.9	22.8	14.6	30.5	23.7	14.6	30.6
May	8.3	1.4	10.1	15.9	7.2	19.9	24.2	14.5	33.0
Jun	23.8	13.7	29.4	5.1	0.5	4.6	28.8	14.7	39.4
Jul	45.4	26.4	61.3	0.0	0.0	0.0	45.4	26.5	61.3
Aug	50.1	33.2	68.5	1.9	0.0	0.5	52.0	41.0	68.5
Sep	38.4	22.3	52.8	12.2	3.0	18.2	50.6	34.6	64.6
Oct	7.0	1.5	8.8	43.5	28.1	54.3	50.5	31.5	62.7
Nov	0.4	0.0	0.6	31.7	21.3	36.8	32.1	21.8	36.8
Dec	0.1	0.0	0.0	20.5	12.8	25.6	20.6	12.8	25.7
Annual	175.6	144.2	199.1	201.9	166.3	229.4	377.5	331.4	403.0

Snowfall and Snow Course Data

The climate station at Baker Lake, Nunavut has recorded daily snow depths with a ruler over its period of record, 1946 to 2008 (MSC 2008). In combination with snow depth, snow density estimates have been made for Baker Lake from bi-monthly or monthly snow course station observations over the period 1965 to 2006; although no data were available for the years 1994 to 2002 (SOCC 2008). As a result of these datasets, bi-monthly or monthly snow water equivalent data are available for Baker Lake for the period 1965 to 2006. Documentation for the Canadian Snow Water Equivalent Database, including the Baker Lake data, is provided by Environment Canada (AES 1998). Real-time Meteorological Service of Canada snow course observations for Baker Lake are available on the State of the Canadian Cryosphere website (SOCC 2008).

Mean monthly and extreme monthly values of SWE were estimated for Baker Lake over the period 1965 to 2006 (Table 3.1-4). Mean monthly SWE was generally highest in May over the period of record. The highest recorded SWE of 188 mm was measured January 1, 1975.

Table 3.1-4
Mean and Extreme Monthly Snow Water Equivalent Calculated for Baker Lake Based on the Snow Course Dataset, 1965-2006*

Month	Mean SWE (mm)	Extreme Maximum SWE (mm)	Extreme Minimum SWE (mm)
October	29.0	91	0
November	29.6	94	0
December	37.1	130	1
January	47.7	188	9
February	48.6	150	7
March	53.8	163	12
April	59.6	160	11
May	71.9	163	0
June	25.4	127	0

* No data were provided for the years 1994 to 2002

Snowfall is redistributed within and between watersheds each year due to wind; and certain terrain types tend to collect greater amounts of snow than others. For example, SWE measured for the Jericho Project in Nunavut ranged from 68 mm on the tundra, to 76 mm on the lakes, and to 117 mm in the valley areas (Tahera 2006). Thus the historical snow course survey results for Baker Lake may not necessarily be representative of the snow water equivalent in the Project area due to local snowfall accumulation, redistribution patterns, and losses to sublimation.

Streamflow measured at Qinguq Creek was compared with the maximum SWE observed for the Baker Lake climate station for each year between 1969 and 1994. The Qinguq Creek streamflow station is located approximately 14 km southwest of the community of Baker Lake, and its watershed drains into the west side of the lake. Twelve years of coincident SWE and annual runoff data were available for the period 1969 to 1994. This preliminary assessment indicated that there was some correlation (R-squared equal to 0.5) of years with higher measured snow water equivalents and higher annual runoff volumes. However, SWE alone does not accurately predict spring runoff. Additional factors that may contribute to or influence annual runoff volumes include antecedent moisture conditions in the fall, spring climate, and rainfall amounts.

Extreme Rainfall Statistics

Extreme rainfall statistics were estimated for Baker Lake, Nunavut (Hogg and Carr 1985; Beak Consultants Limited 1990). The intensity-duration-frequency rainfall data determined for Baker Lake are provided in Table 3.1-5.

Table 3.1-5
Extreme Rainfall (mm) Statistics for Baker Lake Climate Station

Duration	Return Period (years)					
	2	5	10	20	50	100
24 hours	24.4	33.2	39.1	44.7	51.9	57.4
12 hours	16.1	20.6	23.5	26.3	30.0	32.7
6 hours	11.9	15.0	17.1	19.0	21.6	23.5
1 hour	5.2	6.8	7.8	8.9	10.2	11.1
15 minutes	2.2	3.3	4.0	4.6	5.5	6.2

Mean Air Temperatures

The mean daily temperature for Baker Lake is estimated to be -12°C. Mean, maximum, and minimum daily temperatures are presented in Table 3.1-6 (EC 2008) and Figure 3.1-1. July was generally the warmest month at the Baker Lake climate station and January was the coolest month (-32.3°C daily average) over the period 1971 to 2000.

Table 3.1-6
Temperature Climate Normals for Baker Lake Climate Station, 1971-2000

Month	Daily Average (°C)	Daily Maximum (°C)	Daily Minimum (°C)
Jan	-32.3	-28.7	-35.8
Feb	-31.5	-27.9	-35.1
Mar	-27.2	-22.9	-31.5
Apr	-17.4	-12.6	-22.1
May	-5.8	-2.2	-9.4
Jun	4.9	9.2	0.5
Jul	11.4	16.7	6
Aug	9.5	14	5
Sep	2.6	5.9	-0.6
Oct	-7.5	-4.2	-10.7
Nov	-20.1	-16.3	-23.9
Dec	-28.4	-24.8	-31.9
Annual	-11.8	-7.8	-15.8

Environment Canada also provides adjusted temperature records for Baker Lake as illustrated in Table 3.1-7 and Figure 3.1-1. On average, the adjusted and non-adjusted temperature records are similar.

Table 3.1-7
Adjusted Historical Temperature for Baker Lake, 1971-2000

Month	Daily Average (°C)	Daily Maximum (°C)	Daily Minimum (°C)
Jan	-32.4	-24.2	-38.0
Feb	-31.7	-25.8	-40.6
Mar	-27.5	-21.7	-31.8
Apr	-17.6	-12.4	-22.7
May	-6.0	-2.6	-11.5
Jun	4.6	7.8	-0.3
Jul	11.1	14.8	7.0
Aug	9.2	12.0	6.1
Sep	2.5	6.4	-1.5
Oct	-7.6	-3.0	-15.0
Nov	-20.1	-11.8	-25.8
Dec	-28.4	-21.7	-34.6
Annual	-12.0	-6.9	-17.4

3.1.2 Evaporation and Evapotranspiration

Factors that influence evaporation and evapotranspiration rates include temperature, precipitation, relative humidity, wind speed, and net radiation. Water loss by evapotranspiration has previously been estimated for the Project area using Thornthwaite and Blaney-Criddle methods (BEAK 1989). Evaporation and evapotranspiration estimates were also made by Roulet and Woo in 1983 utilizing evaporation pans and the Bowen-ratio energy balance (Roulet and Woo 1986). The estimates for evapotranspiration made by BEAK (1989) were similar to those calculated by Roulet and Woo (1986) over the periods of record for which data overlap (i.e., June and July 1983). Evaporation estimates that have been made for other locations within the Northwest Territories and Nunavut in addition to the calculated and literature values for evaporation and evapotranspiration at Baker Lake are provided in Table 3.1-8. Estimates of evapotranspiration at Baker Lake have ranged from less than 100 mm to 360 mm. Mean annual estimates for evaporation rates for Baker Lake and other regional locations are in the range of 150 mm to 232 mm.

Table 3.1-8
Calculated and Literature Estimates for Actual and Potential Evapotranspiration and Evaporation for the Kiggavik Project Area

Method	Location	Source	Evapotranspiration (mm)		Evaporation (mm)
			1983	1988	Mean Annual
Blaney-Criddle[(a)]	Baker Lake, NU	BEAK 1989	137	290	--
Thornthwaite[(a)]	Baker Lake, NU	BEAK 1989	205	360	--
Penman and Priestley-Taylor	Nanisivik, NU[(b)]	Reid 2001			189
Pan Evaporation	Baker Lake, NU	Prowse and Ommanney 1990	<100	--	150
Pan Evaporation	Doris North, NU[(c)]	Golder Associates 2006			220
Pan Evaporation	Meadowbank, NU	Cumberland Resources 2003			232

a = Potential Evapotranspiration
b = Located on Baffin Island, approximately 400 km southeast of Resolute Bay
c = Located 685 km Northeast of Yellowknife and 160 km southwest of Cambridge Bay, based on 1997 data

Relative Humidity

The relative humidity data presented in Table 3.1-9 represent the long-term climate data for Baker Lake over the period 1971 to 2000 (EC 2008). Data are archived every hour, and the long term normal is computed from relative humidity measurements at 0600 LST and 1500 LST. On average relative humidity at Baker Lake is about 69.2% and ranges from about 58% in July to 81.4% in October. It is noted that the long-term average at 1500 hours is lower than at 0600 hours for the warmer months of the year.

Wind

The most frequent wind direction at the Baker Lake climate station over the period 1971 to 2000 is northwest (Table 3.1-9). The mean monthly wind strength varies between 16.5 km/h in June and 23.7 km/h in January (EC 2008).

Extreme wind data for a number of communities are provided in the National Building Code of Canada (NRC 1995). The 1:10, 1:30, and 1:100 year 1-hour wind pressure values are available for Baker Lake. The wind pressure data may subsequently be converted to wind velocities, and NRC (1995) also provides an equation to convert the 1:10 and 1:30 year wind velocities into an nth-year wind velocity, as follows:

$$V_{1/n} = V_{1/30} + \frac{V_{1/10} - V_{1/30}}{-1.1339} * \ln\frac{-0.0339}{\ln(1-1/n)}$$

Table 3.1-9
Wind Speed, Wind Direction, and Relative Humidity for Baker Lake Climate Station over the period 1971-2000

Month	Speed (km/h)	Most Frequent Direction	Average Relative Humidity 0600LST (%)	Average Relative Humidity 1500LST (%)
Jan	23.7	NW	65.7	64.8
Feb	22.9	NW	65.1	63.9
Mar	21.6	NW	65.5	65
Apr	20.5	NW	72.7	73
May	19.4	NW	84	80
Jun	16.5	E	82.7	66.9
Jul	16.6	N	81	58
Aug	17.7	NW	86.4	64.6
Sep	19.4	NW	88.2	73.6
Oct	21.8	NW	84.5	81.4
Nov	22.3	NW	73	72.5
Dec	22.7	NW	66.7	66.7
Year	20.4	NW	-	69.2

Extreme wind statistics for Baker Lake are presented in Table 3.1-10. One-hour wind speeds of 78 km/h can be expected at a biennial frequency. Wind speeds exceeding 100 km/h are expected to occur only once in 30 years or more.

Table 3.1-10
Extreme Wind (km/h) Statistics for Baker Lake

Duration	Return Period (years)					
	2	5	10	30	50	100
1 hour	78.0	86.3	91.8	100.1	103.9	108.7

Note: Extreme wind statistics for the 10-year, 30-year, and 100-year return periods were provided by NRC (1995) while the remaining wind statistics were calculated

Radiation

Several EC climate stations in the region around the Project collect radiation data of various types. The nearest climate station at Baker Lake has collected net all-wave radiation since 1963, and on a continuous basis since 1969. Net all-wave radiation measures the difference of incoming and outgoing short-wave and long-wave radiation. Net radiation data are a key component of many empirical evapotranspiration and evaporation calculation methods. In addition to net radiation, global solar radiation data were collected at Baker Lake from 1970 to 1981 (EC 2007b). Global solar radiation measures all the incoming radiation at the earth's surface, including diffuse (i.e., reflected) radiation and short-wave radiation.

Net radiation data are archived by EC on an hourly basis (K. Dickson pers. comm.). Mean monthly net radiation data over the period 1969 to 2003 are presented in Table 3.1-11 (EC 2006). Mean net radiation over this period ranged between -83.9 W/m^2 in February to 455.9 W/m^2 in June (Table 3.1-11). In addition, the maximum and minimum monthly net radiation values (based on the hourly archive data) are included in Table 3.1-11. Net radiation data were measured with a CSIRO Middleton CN-1 net pyrradiometer (K. Dickson pers. comm.). It is noted that extreme net radiation values are the extreme maximum total net radiation values recorded over a 24 hour period, determined for each month. Daily extreme net radiation ranged between 0.6 MJ/m^2 in November to 16.8 MJ/m^2 in June between 1969 and 2003.

Table 3.1-11
Net All-Wave Radiation Monthly Statistics for Baker Lake Climate Station over the period 1969-2003

Month	Maximum Net Radiation (W/m^2)	Mean Net Radiation (W/m^2)	Minimum Net Radiation (W/m^2)	Extreme Net Radiation Daily (RF4) (MJ/m^2)
Jan	44.6	-79.0	-223.9	1.1
Feb	52.7	-83.9	-215.8	1.2
Mar	88.3	-66.1	-197.3	2.1
April	219.2	-15.3	-169.5	5.2
May	810.0	158.0	-115.5	15.9
June	887.1	455.9	22.8	16.8
July	785.7	443.1	48.2	15.8
Aug	553.7	270.5	-15.8	11.1
Sept	327.1	109.1	-100.2	6.9
Oct	125.4	-36.3	-257.0	3.0
Nov	46.3	-79.7	-261.8	0.6
Dec	35.8	-74.5	-227.5	0.8

Permafrost and Active Layer

The Project is located within the zone of continuous permafrost (NRCAN 2003); however, the active layer in this region varies each year and varies with different local landscapes. Previously reported active layer thickness estimates in the region range from 2 m to 4 m (Cumberland Resources Ltd. 2003). At the time of their evaporation studies, Roulet and Woo (1986) noted that the active layer thickness had an average depth of 0.55 m. Active layer thickness varies with factors such as proximity to lakes, overburden thickness, vegetation, snow cover, climate conditions, and slope direction (Cumberland Resources Ltd. 2003). Approximately 90% to 100% of the land area surrounding the Meadowbank project was expected to be underlain by continuous permafrost, but was not present under bodies of water that were too deep to freeze entirely. The depth of permafrost at the Meadowbank project was estimated to be 400 m to 500 m based on thermistor data (Cumberland Resources Ltd. 2003).

3.1.3 Local Climate

Local meteorological data have not been collected near the Project site with the exception of a short-term research study in 1982 and 1983 (Roulet and Woo 1986) and another study over a one year period from September 1990 – August 1991 (Senes Consultants Limited 1992). Air temperature, wind speed and direction, and humidity were collected at Kiggavik. Tables 3.1-12, 3.1-13, and 3.1-14 present the monthly temperature, wind speed and wind frequency data, respectively, at Kiggavik in 1990-1991 (Senes Consultants Limited 1992).

Table 3.1-12
Temperature Record for Kiggavik, September 1990-August 1991 (^{o}C)

Month	Extreme Max	Extreme Min	Mean Daily
Jan	-24.2	-42.2	-35.8
Feb	-4.8	-41.6	-31.2
Mar	-10.5	-43.2	-29.9
Apr	-3.5	-27.1	-16.3
May	6.2	-23.5	-6.1
Jun	21.7	-4.3	6.4
Jul	31.7	-1.1	12.5
Aug	27	1.5	4.9
Sep	17	-5.2	1.2
Oct	1.3	-25.1	-9.5
Nov	-7.7	-34	-23.3
Dec	-11.8	-41.4	-33.7
Year	31.7	-43.2	-13.4

Table 3.1-13
Wind Speed Record for Kiggavik, September 1990-August 1991 (m/s)

Direction	Annual	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
N	8	8.5	6.7	6.2	10.9
NNE	5.9	4.9	4.3	5.6	8.8
NE	4.9	2.1	5.1	4.8	7.7
ENE	4.1	3.3	4.6	3.7	4.6
E	4.7	4.7	5.2	4.6	4.4
ESE	4.7	4.9	4.5	4.9	4.4
SE	5.4	5.6	4.6	5.5	5.9
SSE	5.7	9.2	4.6	4.1	4.8
S	5.5	10	3.2	4.9	4.1
SSW	3.4	3.3	2.2	4	4.3
SW	3.5	3	2.3	4.1	4.7
WSW	3.6	3.8	2.6	4.3	3.6
W	4.1	5	2.6	4.8	4
WNW	5.6	6.7	5.1	4.9	5.5
NW	6.8	8.4	6.3	5.7	6.7
NNW	8	10.2	7.7	6.2	7.9
Mean	5.5	5.9	4.5	4.9	5.8

Table 3.1-14
Wind Frequency Record for Kiggavik, September 1990-August 1991 (%)

Direction	Annual	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov
N	10.2	6.1	10.4	10.3	13.9
NNE	5.6	0.9	5.6	5.8	10.2
NE	4.1	2.4	3.8	3.8	6.3
ENE	3.8	3.1	4.6	4.5	3.1
E	6.3	3.8	7.3	7.7	6.5
ESE	4.7	2.4	6.7	4.8	5
SE	4.4	2.9	4.4	4.4	5.7
SSE	3.7	0.8	3.9	4.8	5.1
S	4.3	0.7	3.5	9.3	3.9
SSW	2.8	0.5	3.5	3.9	3.4
SW	3.6	0.7	5.2	4	4.5
WSW	3.8	2.3	4.8	4.5	3.6
W	5.5	5.1	5.1	7.7	4.2
WNW	9.7	18.5	8.3	7.1	5.1
NW	14.9	29.9	10.2	8.2	11.4
NNW	12.2	19.7	12	9.3	8
C	0.3	0.2	0.8	0	0.1

Comparison of the Kiggavik climate data to the data from Baker Lake over the same period of record indicates the following:

- average annual wind speeds at Kiggavik were 10% higher than at Baker Lake;
- mean daily temperatures were approximately 1°C lower at Kiggavik than recorded at Baker Lake, although daily maximum (minimum) were not as high (low) as those at Baker Lake;
- average seasonal wind speeds were 14% higher at Baker Lake than Kiggavik for Dec-Feb, but 58% higher at Kiggavik than Baker Lake during Jun-Aug; and
- average annual percent frequency of the most frequent wind directions (N, NNW, NW) was similar at the two sites; however, Kiggavik experiences more winds in the easterly direction, compared with the ESE direction at Baker Lake.

A more detailed synthesis of climate data for Kiggavik will be provided in a separate report for the purposes of assessing potential air quality impacts.

Representativeness of Baker Lake Data for Kiggavik Project

Baker Lake climate station provides the most reasonable climate data for use at the Kiggavik site, as other long-term climate stations exist within 100 km of the site. The representativeness of meteorological data from Baker Lake climate station for the Projectarea was discussed previously in three reports by Beak Consultants Limited (1989, 1990a, 1992). Differences in the climate between Baker Lake and the Kiggavik site were attributed to the positioning of the climate station at the west end of Baker Lake, and the difference in elevation between the two sites; 180 masl at Kiggavik versus 12 masl at Baker Lake. It was suggested that the presence of Baker Lake would have a modifying influence on the local climate as measured at the climate station during the ice-free period.

Installation of a meteorological station at Kiggavik would allow for improved comparisons with the Baker Lake climate station. Considering the relative close proximity and length of record available for Baker Lake site, the Baker Lake climate normals provide a good approximation of climate conditions at the project site (BEAK 1990a).

3.2 Hydrology

3.2.1 Regional Drainage Patterns

The Kiggavik and Sissons deposits are located within the Anigaq River watershed, which is located within the Hudson Bay drainage basin. The streams within the Anigaq River watershed eventually flow into the Anigaq River, which drains into the western edge of

Baker Lake. Baker Lake drains into Chesterfield Inlet, which further drains into Hudson Bay. Watersheds that are adjacent to that of the Anigaq River system include the Thelon River and Qinguq Creek, both of which also drain into Baker Lake (Figure 3.2-1). Estimates for contributing drainage areas for Hudson's Bay, Baker Lake (at its outlet), the Thelon River, the Anigaq River, and Qinguq Creek (all at their respective inlets to Baker Lake) are presented in Table 3.2-1.

Table 3.2-1
Estimated Regional Drainage Areas

Basin, Sub-basin, or Waterbody Name	Drainage Area (km^2)
Hudson Bay	3,861,400
Baker Lake	1,800,000
Thelon River*	154,000
Anigaq River*	5,096
Quinguq Creek*	432

*At the inflow to Baker Lake

The Water Survey of Canada (WSC) has operated a number of hydrometric monitoring stations within the region, including seven streamflow stations within 100 km of the AREVA Kiggavik Project (Figure 3.2-2). Station names, drainage areas, distances to the Kiggavik site, periods of record and mean annual discharge values are presented in Table 3.2-2. Of these stations, there are only two which are currently operational: the Dubawnt River at the Outlet of Marjorie Lake; and, the Thelon River Below the Outlet of Schultz Lake.

Table 3.2-2
Regional Water Survey of Canada Streamflow Stations

Station ID	Station Name	Drainage Area (km^2)	Period of Record	Mean Annual Flow (m^3/s)	Mean Annual Runoff ($m^3/s/km^2$)	Approximate Distance from Kiggavik (km)
06KC003	Dubawnt River at Outlet of Marjorie Lake	67,300	1968-2006	367	0.0055	95
06LC002	Kunwak River below Princess Mary Lake	12,100	1977-1994	74.7	0.0062	71
06MA002	Qinguq Creek near Baker Lake	432	1969-1994	2.73	0.0063	69
06MA003	Thelon River above Baker Lake	154,000	1973-1982	757	0.0049	61
06MA005	Prince River near Baker Lake	2,100	1979-1990	11.9	0.0057	94
06MA006	Thelon River below outlet of Schultz Lake	152,000	1983-2006	932	0.0061	49
06MA007	Anigaq River below Audra Lake	2,740	1984-1994	17.0	0.0062	54

Figure 3.2-1 Nunavut Watershed Boundaries

Figure 3.2-2 Regional Hydrometric Stations

Mean annual discharge was estimated for numerous streams in the Project area based on data from the Qinguq Creek Water Survey of Canada station (Golder 2007). This station was chosen in part because Qinguq Creek has the smallest drainage area of any of the regional WSC stations within 100 km and it is most similar in size to the Judge Sissons Lake watershed. While the majority of the streams and lakes near the Project drain into Anigaq River, this station has a relatively shorter period of record compared with Qinguq Creek. It is noted that both of these watersheds are located in the Southern Arctic terrestrial ecozone (NRCAN 2004). These two drainages are similar in ecology, topography, and proportion of lakes that occur in the drainage (Golder 2007). The mean, maximum, and minimum hydrographs for each river/stream presented in Table 3.2-2 are illustrated in Figures 3.2-3a and b).

The hydrographs illustrated in Figures 3.2-3a and 3.2-3b exhibit peaks during the spring that may be attributed to snow melt. Within some of the hydrographs, secondary peaks are evident towards the fall. These secondary peaks may be attributed to late summer/fall precipitation events. Rivers that have smaller contributing drainage areas (and consequently lower flows) may cease to flow during the winter months, as the water freezes to the base of the channel. Periods of zero flow have been recorded for the Prince River, Anigaq Rive, and Qinguq Creek.

3.2.2 Regional Unit-Area Runoff

Unit area runoff was estimated for several Water Survey of Canada (WSC) stations near the Project over the period of record, as presented in Table 3.2-2. Despite a wide range of drainage areas, mean annual unit-area runoff ranged from 0.0061 $m^3/s/km^2$ to 0.0063 $m^3/s/km^2$ for the Thelon River, Anigaq River, and Qinguq Creek, which are closest to the Project. Mean unit-area runoff was estimated to be 0.0058 for 6 WSC stations within 100 km of the Project (Table 3.2-2).

Figure 3.2-3a Regional Hydrographs

Figure 3.2-3b Regional Hydrographs

Runoff ratios may be defined as the total annual runoff divided by total annual precipitation. While these ratios vary each year, they give an indication of the percentage of precipitation falling on a watershed that reports as runoff. The range of the average runoff ratios estimated for the Kivalliq[1] region were between 0.60 and 0.75 (BEAK 1992). It is noted that the mean runoff ratio was 0.52 for Qinguq Creek near Baker Lake, calculated with annual runoff values provided by the WSC (EC 2006) and total annual precipitation (adjusted) values provided by EC (2007a) for the Baker Lake climate station, calculated for a hydrological year starting in October. The runoff ratios for Qinguq Creek varied from 0.27 in 1977 to 0.81 in 1992. It is noted that the high runoff ratio determined for 1992 may be related to the above average annual precipitation measured in the preceeding few years. The mean runoff ratio for Anigaq WSC station between 1984 and 1993 was 0.50.

3.2.3 Flood Magnitude and Frequency

The nearest locations to the Project for which EC has operated hydrometric stations are located on the Anigaq River, Qinguq Creek, and the Thelon River. Based on factors such as drainage size, period of record, and classification of ecozone, the Qinguq Creek data set has been chosen to be most representative of the Project. Flood magnitude and frequency estimates were calculated for Qinguq Creek based on the WSC daily discharge dataset (EC 2006). These results are provided in Table 3.2-3. The Log-Pearson III distribution was fit to the maximum annual discharge values over a total of 23 years (i.e., 1970 to 1978, 1981 to 1994). It is noted that all of the annual peak discharge events occurred between the dates of May 28 and June 30 over the period of record.

Table 3.2-3
Flood Magnitude and Frequency Analysis for Qinguq Creek (1970 to 1994)

Exceedance Probability	Approximate Return Interval (yr)	Discharge (m^3/s)
0.99	1.01	9.4
0.95	1.05	16.8
0.9	1.11	22.1
0.8	1.25	29.8
0.5	2	48.3
0.2	5	70.3
0.1	10	82.3
0.05	20	92.1
0.02	50	102.6
0.01	100	109.2

[1] Previously the Keewatin Region

3.2.4 Flow Duration Analysis

A flow duration analysis was conducted for Qinguq Creek. Flow duration is useful for the purposes of knowing what percentage of time a stream may flow, either for dilution or water supply purposes. Qinguq Creek ceases to flow during the winter season as the water freezes to the bottom of the stream bed. The flow duration analysis presented in Table 3.2-4 includes the results of 8,572 recorded and infilled[2] daily data over the period 1969-1994, and also includes the zero flow conditions over the winter periods. Table 3.2-4 describes the percentage of time that a flow may be exceeded on a daily basis. For example, a discharge of 0.7 m^3/s may be expected to be exceeded 30% of the time. A zero flow condition may be expected to be exceeded 40% of the time (and conversely, zero flow conditions may be expected for 60% of the year).

Table 3.2-4
Flow Duration Analysis for Qinguq Creek

Duration[(a)]	Daily Discharge (m^3/s)
1%	39.2
2%	26.3
5%	12.0
10%	6.2
20%	2.6
30%	0.7
40%	0

a = Percentage of time (annual) that corresponding flow is expected to be exceeded

3.2.5 Local Drainage Patterns

The local drainage direction surrounding the Project deposits is towards Judge Sissons Lake. In general, the lakes in the vicinity of the southern Sissons deposit flow easterly into Judge Sissons Lake, whereas the lakes in the vicinity of the northern Project deposit flow southward into Judge Sissons Lake. Judge Sissons Lake is drained by the Anigaq River, which flows eastwardly into Baker Lake. In general, there are four drainage systems that discharge into Judge Sissons Lake: the Boulder Lake system; the Lower Lake system; the Caribou Lake System; and the Willow Lake system. Skinny and Kavisilik Lakes drain to the Anigaq River via Audra Lake. Although the majority of the streams in the vicinity of the Kiggavik project drain into the Anigaq River system, one stream that was monitored in the 2007 field season (Outflow of Squiggly Lake) drains

[2] Missing data over the assumed period of ice coverage (October through May) were assigned zero discharge values.

into the Thelon River, whose watershed lies adjacent to that within which the project is found (Figure 3.2-4). Squiggly Lake outflow was measured as Squiggly Lake was initially included among lakes that could potentially supply water for the Project. Squiggly Lake is now considered an unlikely option.

In a report by Golder (2007), mean annual discharge and lake drainage area estimates had been provided for lakes within the Project area. These estimates were based upon flow proportions from the Qinguq Creek hydrometric station annual mean stream discharge measurements as calculated for the outflow of each lake (Table 3.2-5).

Early Investigations

A series of hydrology field programs have been completed for the Kiggavik Project over the past decades. Previous studies were completed from 1988 to 1991 and the results are provided in BEAK (1989) and BEAK(1992). It was noted that snowfall was minimal in 1990 and 1991 compared to 1988 to 1989, and this was reflected in the hydrographs. Watersheds in the Project area are highly responsive during the snowmelt period; high volumes of water are lost in a relatively short period of time (BEAK 1992).

Figure 3.2-4 Local Drainage Boundaries, Flow Directions and Monitoring Locations

Table 3.2-5
Estimates for Mean Annual Discharge and Drainage Areas for Lakes Within the Kiggavik Project Area

Lake	Drainage Area (km^2)	Mean Annual Discharge (m^3/s)
Andrew Lake	33.6	0.204
Bear Island Lake	9.2	0.056
Boulder Lake	68.6	0.418
Caribou Lake	80.9	0.493
Cigar Lake	11.8	0.072
Cirque Lake	0.7	0.005
Crash Lake	10.6	0.064
Drum Lake	5.6	0.034
Escarpment Lake	2.7	0.016
Felsenmeer Lake	1.3	0.008
Fox Lake	28.9	0.176
Gerhard Lake	27.1	0.165
Jaegar Lake	50.4	0.307
Judge Sissons Lake	704.6	4.289
Kavisilik Lake	148.4	0.903
Knee Lake	11.6	0.070
Lin Lake	7.2	0.044
Lower Lake	69.0	0.420
Lunch Lake	29.6	0.180
Meadow Lake	1.2	0.007
Mushroom Lake	4.4	0.027
Pointer Lake	79.0	0.481
Ridge Lake	2.1	0.013
Rock Lake	99.2	0.604
Scotch Lake	11.7	0.071
Shack Lake	47.2	0.287
Siamese Lake	85.2	0.519
Sik Sik Lake	1.8	0.011
Skinny Lake	111.7	0.680
Sleek Lake	31.8	0.194
Smoke Lake	5.6	0.034
Squiggly Lake	41.8	0.254
Willow Lake	101.9	0.620

In 1988 and 1989 streamflow data was collected at the outlets of the following lakes: Ridge Lake, Pointer Lake, Jaeger Lake, Skinny Lake, Cirque Lake, and Escarpment Lake. Estimated mean monthly discharge and peak discharge (as determined from discharge hydrographs), and contributing drainage area are presented in Table 3.2-6.

Annual hydrographs for 1988 and 1989 are available in Figures 3.2-5, and 3.2-6, respectively.

Table 3.2-6
Mean Monthly Discharge for 1988 and 1989 as Estimated from Annual Hydrographs[3]

Lake Outlet Name	Average Discharge (m^3/s)							Instantaneous Peak (m^3/s)	
	June		July		August		September		
	1988	1989	1988	1989	1988	1989	1988	1988	1989
Escarpment Lake	0.175	0.093	0.022	0.047	0.015	0.022	0.033	0.71	0.498
Cirque Lake	0.039	0.040	0.009	0.020	0.007	0.004	n/a	0.126	0.149
Jaeger Lake	3.80	5.22	0.57	0.396	0.047	0.140	0.08	12.43	11.8
Pointer Lake	8.93	10.18	1.35	1.20	0.40	0.37	0.36	30.22	28.6
Ridge Lake	0.151	0.123	0.010	0.016	0.005	0.006	0.008	0.594	0.557
Skinny Lake	6.65	9.22	0.52	1.11	0.10	0.40	0.47	18.14	20.5

In 1991 data was collected for streams closer to the Sissons deposit (Andrew Lake, Andrew Lake Study Area, Cigar Lake, Judge Sissons Lake, Mushroom Lake, and Pointer Lake). Estimated mean monthly discharge and peak discharge (as determined from discharge hydrographs), and contributing drainage area are presented in Table 3.2-7. Annual hydrographs for 1991 are available in Figure 3.2-7.

Table 3.2-7
Mean Monthly Discharge for 1991 as Estimated from Annual Hydrographs[4]

Lake Outlet Name	Average Discharge (m^3/s)			Instantaneous Peak (m^3/s)
	June	July	August	
Andrew Lake	2.922	0.052	0.000	26.09
Andrew Lake Study Area	9.174	0.069	0.000	53.96
Cigar Lake	1.084	0.366	0.928	10.30
Judge Sissons Lake	32.90	7.29	1.74	81.31
Mushroom Lake	0.158	0.017	0.005	0.700
Pointer Lake	6.45	0.181	0.000	29.16

[3] BEAK 1989

[4] BEAK 1992

Figure 3.2-5 Local Hydrographs, 1988

Figure 3.2-6 Local Hydrographs, 1989

Figure 3.2-7 Local Hydrographs, 1991

Recent Investigations

Field hydrology investigations were completed during the open-water season of 2007 (see Golder [2008]). A total of twelve stream discharge monitoring stations and seven lake elevation monitoring stations were installed near the Project. The locations of each monitoring station are presented in Table 3.2-8 (in Universal Transverse Mercator [UTM] coordinates) and Figure 3.2-4. Field visits were completed over the following dates in 2007: June 11 to 18, July 30 to August 3, and September 17 to 20. Continuous stage recorders were installed at several of the streamflow monitoring locations as noted in Table 3.2-8. An additional desktop hydrological investigation was completed to assist with identifying suitable water intake and release locations for the Project (Golder 2007).

Table 3.2-8
Stream Discharge Monitoring Locations and Contributing Drainage Areas at the Kiggavik Project

Station	Description	Crossing Location (UTM - NAD 83)	Contributing Drainage Area (km^2)
SF1	Outflow of Skinny Lake	14 W 571655 7155266	111.7
SF2	Fox Lake Inflow*	14 W 563554 7146242	14.0
SF3	Northeast Inflow of Pointer Lake	14 W 565717 7147088	3.6
SF4	Outflow of Sik Sik Lake*	14 W 565790 7140386	1.8
SF5	Outflow of Pointer Lake*	14 W 566477 7140840	79.0
SF6	Outflow of Unknown Lake downstream of Shack Lake*	14 W 558223 7131912	54.5
SF7	Anigaq River*	14 W 574605 7134734	676.2
SF8	Outflow of Siamese Lake*	14 W 580364 7146775	86.0
SF9	Outflow of Squiggly Lake*	14 W 552993 7163630	69.7
SF10	Tributary to the Northeast Inflow of Pointer Lake	14 W 565328 7146771	1.46
SF11	Northwest Inflow of Pointer Lake	14 W 565015 7144882	2.02
SF 12	Outflow of Jaeger Lake	14 W 567690 7143581	55.1

* Water levels were measured continuously at these locations during the open water period in 2007

Stream discharge measurement results for the 12 stations established in 2007 are provided in Table 3.2-9. Streamflow measured during the summer filed program decreased from the initial measurements taken in June at all stations. Streamflow was very low and/or not measurable at a few of the smaller streams by the summer and fall field visits; including at the Fox Lake inflow, Sik Sik Lake outflow, the northwest inflow to Pointer Lake, and a tributary of the northeast inflow to Pointer Lake. Stream flow had increased from the summer measurements to those taken in the fall program (although these remained lower than those measured in the spring). Increased discharge during the fall often corresponds to precipitation events. In addition to instantaneous stream discharge measurements, stream stage elevations were surveyed relative to local benchmarks located near the channel cross-sections. The resultant stream-discharge rating curves for streams at which three discharge readings were taken are presented in Figure 3.2-8.

Table 3.2-9
Stream Discharge and Water Level Measurements in 2007

Station	Description	Level (m)	Discharge (m^3/s)	Date
SF1	Outlfow of Skinny Lake	98.201	0.024	3-Aug-07
		98.355	0.524	19-Sep-07
SF2	Fox Lake Inflow	99.021	0.704	14-Jun-07
		98.680	0.004	2-Aug-07
		98.732	0.046	18-Sep-07
SF3	Northeast Inflow of Pointer Lake	98.908	0.054	15-Jun-07
SF4	Outflow of Sik Sik Lake	98.604	0.362	16-Jun-07
		99.203	n/a	31-Jul-07
		99.261	n/a	18-Sep-07
SF5	Outflow of Pointer Lake	98.441	0.058	31-Jul-07
		99.498	0.240	18-Sep-07
SF6	Outflow of Unknown Lake downstream of Shack Lake	99.763	2.946	16-Jun-07
		99.090	0.023	3-Aug-07
		99.351	0.234	18-Sep-07
SF7	Anigaq River	98.633	6.857	14-Jun-07
		98.514	5.639	31-Jul-07
		98.458	2.766	17-Sep-07
SF8	Outflow of Siamese Lake	99.237	0.889	2-Aug-07
		99.160	0.413	19-Sep-07
SF9	Outflow of Squiggly Lake	99.362	3.003	18-Jun-07
		98.965	0.240	1-Aug-07
		99.050	0.436	19-Sep-07
SF10	Tributary to the Northeast Inflow	98.908	0.054	15-Jun-07
	of Pointer Lake	98.813	0.000	1-Aug-07
		98.835	0.003	18-Sep-07
SF11	Northwest Inflow of Pointer Lake	99.758	1.442	15-Jun-07
		99.446	0.012	18-Sep-07
SF12	Outflow of Jaeger Lake	99.189	0.065	20-Sep-07

m^3/s = cubic metres per second

Figure 3.2-8 Stage-Discharge Curves, 2007

Monthly mean discharge was estimated for four streamflow stations at the Project site in 2007 (Table 3.2-10). Mean monthly discharge was determined from continuous stage records during the monitoring period, and preliminary stage-discharge rating curves established for these stations. A minimum of three coincident measurements of stage and discharge are required to create preliminary rating curves. Due to inclement weather and ice conditions, only eight of 12 stations were established in the spring of 2007. In addition, mean discharge was not calculated for the outflow of Sik Sik Lake as it ceased to flow by July 2007. Annual hydrographs for the 2007 season are presented in Figure 3.2-9. Estimated mean daily discharge or mean daily water elevation for streams in which water level sensors were installed are presented in Tables I-3 to I-6 (Appendix I).

Table 3.2-10
Monthly Mean Discharge Estimates in 2007

Station ID	Stream	June[(a)]	July	August	September[(a)]
SF2	Fox Lake Inflow	0.992	0.065	0.089	0.073
SF6	Outflow of Unknown Lake downstream of Shack Lake	3.5	0.355	0.138	0.32
SF7	Anigaq River	12.279	6.702	2.892	2.001
SF9	Outflow of Squiggly Lake	3.211	0.486	0.489	0.386

a = Calculation of the mean was based upon an incomplete month of data; however, spring freshet levels were recorded

The monitoring stations for which mean monthly estimates were calculated are provided as unit-area runoff estimates and presented in Table 3.2-11. Historical runoff data for regional streamflow monitoring stations are also provided in Table 3.2-11. The differences in the historical and local estimates for unit-area runoff may be attributed to any of a number of factors, including differences in precipitation, size of contributing drainage areas, topography, number and size of waterbodies within the drainage relative to the entire drainage, and location of the gauging station relative to a waterbody. The unit-area runoff values for streams in the Project area are within the maximum and minimum range that have occurred on the Anigaq River and Qinguq Creek. Unfortunately the periods of record for the streams near the Project and the Anigaq River and Qinguq Creek are not coincident; therefore, the 2007 data cannot be related to a longer-term record of discharge on either of these rivers.

Figure 3.2-9 Local Hydrographs, 2007

Table 3.2-11
Average Monthly Unit Area Runoff ($m^3/s/km^2$) for Selected Streams Near the Kiggavik Project

	1984-1994	1969-1994	2007			
Stream	**Anigaq River Max (Min)**	**Qinguq Creek Max (Min)**	**Outflow of Cirque Lake**	**Outflow of Shack Lake**	**Anigaq River**	**Outflow of Squiggly Lake**
Station ID	**06MA002**	**06MA007**	**SF2**	**SF6**	**SF7**	**SF9**
Jun	0.0533 (0.0248)	0.0863 (0.0149)	0.0708	0.0642	0.0182	0.0461
Jul	0.0401 (0.0072)	0.0282 (0.0027)	0.0046	0.0065	0.0099	0.0070
Aug	0.0171 (0.0021)	0.0223 (0.0008)	0.0063	0.0025	0.0043	0.0070
Sep	0.0196 (0.0016)	0.0396 (0.0003)	0.0052	0.0059	0.0030	0.0055

3.2.6 Regional Lake Level Monitoring Stations

Regional Lake level stations had been maintained by WSC include Baker Lake and Marjorie Lake (Table 3.2-12). Both stations were decommissioned in the 1990's and currently there are no regional stations that collect lake elevation data within 100 km of the Project site. The closest WSC lake level monitoring station that is currently operational is located at Ennadai Lake, which is approximately 400 km southwest of the Project site.

Table 3.2-12
Regional Water Survey of Canada Lake Elevation Stations

Station ID	Station Name	Period of Record	Location (UTM Coordinates, NAD 83)	Approximate Distance from Kiggavik (km)
06KC002	Marjorie Lake at Outlet	1966-1990	14W 476865E 7122853N	90
06MA001	Baker Lake at Baker Lake	1965-1994	14W 643541E 7135964N	80

The average daily water elevations (as per an assigned datum) over their respective periods of record for Marjorie Lake and Baker Lake are presented in Figure 3.2-10. In both lakes, the maximum mean daily water elevation occurs at the start of July (Table 3.2-13). Minimum mean daily water elevations are observed at the end of May in the case of Marjorie Lake and at mid-April in the case of Baker Lake.

Table 3.2-13
Estimated Maximum and Minimum Mean Daily Water Elevations for Marjorie Lake and Baker Lake[5]

WSC Station Name	Maximum Level (m)	Date of Maximum Level	Minimum Level (m)	Date of Minimum Level	Maximum Fluctuation (m)
Marjorie Lake at Outlet	14.13	Start of July	13.55	End of May	0.58
Baker Lake at Baker Lake	8.42	Start of July	7.42	Mid April	1.00

3.2.7 Local Lake Level Data

It is important to monitor lake elevations in order to document natural fluctuations and variations, and also to have baseline data for comparison with the operational period.

Fluctuations in water levels are also of significance during ice-covered periods. Aquatic organisms may be sensitive to changes in lake chemistry such as dissolved oxygen levels (Cott et al. 2008). Therefore, documentation of lake parameters such as area, volume, and depth are significant for water withdrawal criteria. The current protocol for water withdrawal under ice-covered waters in Nunavut is 5% of the under-ice volume for lakes whose depths are greater than or equal to 1.5 m below the maximum ice thickness (Fisheries and Oceans Canada [DFO] 2005). However, recent research suggests that a withdrawal threshold of 10% may pose minimal risk to overwintering fish, and that the current protocol may be revised (Cott et al. 2008). It must also be noted that the protocol published by DFO is a guideline, and water withdrawal criteria may be established on a project and site-specific basis.

Lake elevations have been collected at selected locations during field seasons in open water periods in 1983 and 2007.

[5] As per respective assigned datums at each site

Figure 3.2-10 Regional Lake Elevations

Early Investigations

Lake elevation data were not collected during the 1988, 1989, or 1991 field programs. However, in a study by Roulet and Woo (1988), lake elevation data near the Project site were collected on one small lake during part of the open water period in 1983. This study was conducted at a basin approximately 1.36 km^2 in size located at 14W 558564E 7147722N (UTM coordinates, NAD 83). In relation to the Project, the basin is located between Squiggly and Sleek Lakes (Figure 3.2-4). A peak lake elevation was recorded during the second week in June (in response to snow melt), and the lake elevation returned to its pre-melt condition five weeks later. The maximum fluctuation over the monitoring period (first week of June to second week in August) was approximately 0.75 m.

Recent Investigations

Seven lakes were monitored at the same frequency that stream discharge was measured for the Project (Table 3.2-14). Lake elevations are measured relative to local benchmarks in the uplands adjacent to the lakes. Results of the lake elevation surveys in 2007 are provided in Table 3.2-15. In the future, lake elevations may be referenced to each other with the use of Light Detection and Ranging (LiDAR) data.

Table 3.2-14
Lake Elevation Monitoring Locations at the Kiggavik Project

Station	Description	Benchmark Location (UTM - NAD 83)
LE1	Pointer Lake	14 W 565652 7142467
LE2	Unknown Lake Upstream of Fox Lake	14 W 563603 7146244
LE3	Judge Sissons Lake	14 W 574537 7134751
LE4	Squiggly Lake	14 W 556354 7156066
LE5	Skinny Lake	14 W 571626 7154893
LE6	Kavisilik Lake	14 W 571712 7155299
LE7	Siamese Lake	14 W 576086 7151648

Table 3.2-15
Lake Elevation Measurements in 2007

Monitoring Station	Lake	Date	Elevation (m)
LE1	Pointer Lake	18-Jun	98.906
		31-Jul	98.197
		18-Sep	98.223
LE2	Unknown Lake upstream of Fox Lake	14-Jun	99.068
		2-Aug	98.738
		18-Sep	98.754
LE3	Judge Sissons Lake	17-Jun	99.797
		31-Jul	99.670
		17-Sep	99.548
LE4	Squiggly Lake	18-Jun	96.653
		1-Aug	96.428
		19-Sep	96.435
LE5	Skinny Lake	3-Aug	99.211
		19-Sep	99.308
LE6	Kavisilik Lake	3-Aug	98.170
		20-Sep	98.255
LE7	Siamese Lake	3-Aug	97.050
		19-Sep	96.980

Note: m = metres

3.2.8 Local Lake Volumes and Residence Times

In a report detailing potential sources of water supply and release locations near the Project (Golder 2007), lake volumes were estimated based upon bathymetric data that were collected in the 1980's and 1990's (BEAK 1992 and BEAK 1989) (see Section 5.5). In 2007, bathymetric data were again collected for Pointer Lake (Section 5.4.9). The summarized estimates for lake areas, volumes, mean depths, maximum depths, and retention times are presented in Table 3.2-16.

For smaller lakes within the study area, lake volumes were calculated from the product of the mean depth and the surface area. For larger lakes, volumes were calculated utilizing digital interpolation of bathymetric data.

Lake residence times were estimated utilizing the calculated total volume of and mean annual discharge rates from Table 3.2-5. The residence (retention) time was determined to be the length of time required to flush the volume of the lake using the annual outflow volume.

Stage-storage information for lakes that contain the largest estimated volumes are presented in Table 3.2-17 (as estimated by previous bathymetric surveys by BEAK 1992). Stage-storage information as determined from the 2007 field data for

Pointer Lake is presented in Table 3.2-18. Stage-Storage-Volume curves are presented in Figure 3.2-11.

Table 3.2-16
Estimates for Surface Areas, Volumes and Retention Times for Selected Lakes within the Kiggavik Project Area[6]

Lake	Drainage Area (km^2)	Surface Area (ha)	Mean Depth (m)	Total Volume (m^3)	Mean Annual Discharge (m^3/s)	Retention Time (yr)
Andrew Lake	33.6	54	0.2	1.08E+05	0.204	0.02
Bear Island Lake	9.2	36.5	0.5	1.83E+05	0.056	0.10
Boulder Lake	68.6	478	no bathymetry	--	0.418	--
Caribou Lake	80.9	341	1.4	4.77E+06	0.493	0.31
Cigar Lake	11.8	113	1.5	1.70E+06	0.072	0.75
Cirque Lake	0.7	5.6	2.6	1.46E+05	0.005	1.02
Crash Lake	10.6	8.1	1.1	8.91E+04	0.064	0.04
Drum Lake	5.6	25	1.3	3.25E+05	0.034	0.30
Escarpment Lake	2.7	13	2.2	2.86E+05	0.016	0.55
Felsenmeer Lake	1.3	20.8	2.0	4.16E+05	0.008	1.65
Fox Lake	28.9	128	1.7	2.18E+06	0.176	0.39
Gerhard Lake	27.1	962	no bathymetry	--	0.165	--
Jaegar Lake	50.4	281	1.6	4.50E+06	0.307	0.46
Judge Sissons Lake	704.6	9,550	4.6	4.39E+08	4.289	3.25
Kavisilik Lake	148.4	564	4.2	2.37E+07	0.903	0.83
Knee Lake	11.6	34.9	0.2	6.98E+04	0.070	0.03
Lin Lake	7.2	48	1.3	6.24E+05	0.044	0.45
Lower Lake	69.0	49	0.4	1.96E+05	0.420	0.01
Lunch Lake	29.6	78	0.6	4.67E+05	0.180	0.08
Meadow Lake	1.2	14	0.8	1.12E+05	0.007	0.50
Mushroom Lake	4.4	40	2.6	1.04E+06	0.027	1.23
Pointer Lake	79.0	393	1.5	5.45E+06	0.481	0.36
Ridge Lake	2.1	16.7	2.3	3.84E+05	0.013	0.95
Rock Lake	99.2	29	no bathymetry	--	0.604	--
Scotch Lake	11.7	201	3.5	7.04E+06	0.071	3.13
Shack Lake	47.2	60	0.6	3.60E+05	0.287	0.04
Siamese Lake	85.2	2,750	no bathymetry	--	0.519	--
Sik Sik Lake	1.8	16	0.8	1.28E+05	0.011	0.37
Skinny Lake	111.7	197	3.1	6.11E+06	0.680	0.28
Sleek Lake	31.8	376	no bathymetry	--	0.194	--
Smoke Lake	5.6	63.5	1.3	8.26E+05	0.034	0.77
Squiggly Lake	41.8	638	6.0	3.83E+07	0.254	4.78
Willow Lake	101.9	55	1.4	7.70E+05	0.620	0.04

[6] In all cases, estimates were made based upon bathymetric data as presented by BEAK (1991) with the exception of Pointer Lake, where data were collected in 2007.

Figure 3.2-11 Local Stage-Storage-Area Lake Information

Table 3.2-17
Stage-Storage-Area Estimates for Selected Lakes within the Kiggavik Project Area[7]

	Depth Contour Elevation (m)	Volume Below Contour (x 10^6 m^3)	Surface Area at Contour (ha)
Judge Sissons Lake	136	423.34	9,981
	135	336.69	8,038
	133	200.59	6,238
	131	106.48	3,859
	129	49.12	2,273
	127	22.86	989
	125	8.64	520
	123	2.42	164
	121	0.73	51
	119	0.23	14
Kavisilik Lake	169	24.37	559
	167	14.59	437
	165	7.05	316
	163	2.35	172
	161	0.43	49
	159	0.02	6
Scotch Lake	158	7.3	211
	156	3.71	153
	154	1.1	111
Skinny Lake	169	5.82	192
	167	2.78	117
	165	1.29	58
	163	0.67	24
	161	0.3	14
	159	0.08	8
Squiggly Lake	218	37.45	657
	216	25.65	533
	214	15.98	438
	212	8.47	319
	210	3.69	187
	208	1.11	87
	206	0.05	26

[7] Surface areas may be slightly different than those presented in Table 3.2-16. The differences may be attributed to the elevation at which the areas are calculated.

Table 3.2-18
Stage-Storage-Area Estimates for Pointer Lake, 2007

Depth (m)	Volume Below Contour (x10^6 m^3)	Surface Area at Contour (ha)
0.0	5.452	392.92
0.5	3.611	345.15
1.0	2.025	284.05
1.5	0.784	201.54
2.0	0.116	60.22
2.5	0.008	5.58

3.3 Hydrology Data Gaps

Data gaps associated with climate and hydrology include the abbreviated periods of record over which data were collected. More years of site-specific data would allow for better comparisons to longer-term records, which may consequently allow for generation of longer-term site specific records. Unfortunately, the long-term hydrometric stations that are closest to the Project were discontinued in the 1990's. The re-establishment of these stations may allow for a regression analysis to be performed on the streams that are currently measured in the baseline program.

In terms of hydrologic resources, a data gap also exists along the proposed access and hauls roads to the Project. Verification of stream locations and quantification of stream flows would be important in the design of crossing structures and mitigation of harmful effects to the aquatic environment.

4.0 SURFACE WATER AND SEDIMENT

4.1 Surface Water Quality

Field studies were carried out in 1979, 1980, 1986, 1988, and 1989 to document existing baseline concentrations of trace metals, radionuclides, nutrients and major ions in watersheds in the local study area. Existing environmental conditions were documented to provide baseline data for use in future environmental assessment as well as to assist in the design of project layout and infrastructure. Figure 4.1-1 displays the different sub basins within the Project area.

The 1979 and 1980 field studies were broad and general in scope, as the Project had not advanced to the conceptual design stage. The 1986 studies were carried out as part of a pre-feasibility study, and were focused on assessing the existing environmental conditions relevant to the initial conceptual project design (BEAK 1990). Field surveys were carried out in 1988 and 1989 to fill in data gaps that became apparent as a more detailed project design unfolded. These studies also addressed concerns expressed by the Regional Environmental Committee on the Project Design Description document (BEAK 1990).

Aquatic environmental studies were commenced in the Andrew Lake area in August 1990 to collect baseline data (BEAK 1990). Baseline studies were continued at the Kiggavik Project (the Project) area in 1991 to gather additional data from the Andrew Lake area and to gather data necessary to address Federal Environmental Assessment Review Office (FEARO) requests for additional information (BEAK 1990). The 1991 program included a winter survey, which was conducted in late February and early March, to document under-ice conditions in the late winter.

Figure 4.1-1 Sub Basin Map of the Kiggavik Project Area

4.1.1 Data Collection Methods

4.1.1.1 Sampling period 1979 to 1980

Field sampling was conducted in August of 1979 on eight waterbodies in the Project area, including:

- Baker Lake;
- Crash Lake;
- Judge Sissons Lake;
- Jaeger Lake;
- Scotch Lake;
- Lin Lake; and
- Sik Sik Lake.

Field surveys were carried out in August of 1980 on eight waterbodies in the Project area, including:

- Baker Lake;
- Crash Lake;
- Judge Sissons Lake;
- Jaeger Lake;
- Pointer Lake
- Scotch Lake;
- Kavisilik; and
- Squiggly Lake.

Sampling methods used in the 1979 and 1980 field surveys could not be confirmed with the information available at the time this document was prepared.

4.1.1.2 Sampling period 1986 to 1989

Water sampling of 13 waterbodies as well, as the drainage from the drill site, was undertaken in the Project area in July 1986. Lakes sampled during this period included:

- Crash Lake;
- Skinny Lake;
- Pointer Lake;
- Judge Sissons Lake;
- Escarpment Lake;

- Cirque Lake;
- Ridge Lake;
- Scotch Lake;
- Sik Sik Lake;
- Caribou Lake;
- Drum Lake;
- Felsenmeer Lake; and
- Meadow Lake.

Field surveys were carried out in June and July of 1988 on eight waterbodies in the Project area, including:

- Skinny Lake;
- Pointer Lake;
- Pointer Lake tributary;
- Judge Sissons Lake;
- Jaeger Lake;
- Escarpment Lake;
- Ridge Lake; and
- Scotch Lake.

Field sampling was conducted in June and August of 1989 on eight waterbodies in the Project area, including:

- Skinny Lake;
- Pointer Lake;
- Baker Lake;
- Judge Sissons Lake;
- Jaeger Lake;
- Escarpment Lake;
- Ridge Lake; and
- Cirque Lake.

All water samples collected in these surveys (1986 to 1989) were surface grab samples taken from the outlets of each waterbody (or in the case of the Pointer Lake tributary, were directly from the stream).

4.1.1.3 Sampling Period 1990 to 1991

Water samples were collected in the Project area during the 1990 and 1991 field seasons to augment existing baseline information. Parameters analyzed included nutrients, trace metals and radionuclides. Sulphate was included in the parameter list for the 1991 field survey, as were dissolved oxygen readings under-ice (BEAK 1992).

Water samples were collected from below the surface of each water body. Prior to collecting the samples the bottles were rinsed three times. Samples for mercury, metals, nutrients and radionuclides were appropriately preserved in the field. Samples were kept cool as necessary prior to delivery to the BEAK laboratory. Dissolved oxygen and temperature were determined using a calibrated YSI Model 54 dissolved oxygen meter (BEAK 1992).

Water samples were collected from the surface of five waterbodies in August 1990 including:

- Shack Lake inlet from Mushroom Lake;
- Lunch Lake inlet from Cigar Lake;
- Knee Lake outlet;
- Shack Lake inlet from Andrew Lake; and
- 2 km upstream from mouth of the Lower Lake inlet.

Collected samples were intended to be representative of the outflow from each of the headwaters and subwatersheds.

Water quality was monitored from the March 1 to 6, 1991 in five waterbodies, including:

- Judge Sissons Lake;
- Pointer Lake;
- Cigar Lake;
- Mushroom Lake; and
- Ridge Lake.

At each location, a hole was made in the ice with an auger. Judge Sissons, Pointer and Ridge lakes were sampled in the vicinity of their deepest basins. Surface water samples were collected using a Teflon bailer, originally designed for the collection of water from piezometers.

A lake ice sample was also collected from Judge Sissons Lake for analysis. Snow drift samples were also collected near the Lone Gull camp, in the area upwind of the camp where staff were housed.

Water samples were collected in the spring and summer of 1991 from four waterbodies including:

- Cigar Lake;
- Mushroom Lake;
- Judge Sissons Lake (at lake outlet); and
- Outlet of the Andrew Lake study area drainage into Judge Sissons Lake.

Oxygen-temperature profiles were not measured due to previous surveys clearly demonstrating an absence of thermal stratification in summer.

4.1.2 Results

4.1.2.1 Sampling period 1979 to 1980

Physio-Chemical Parameters

Surface waters in the Project area remain ice-covered for most of the year, with ice thawing in June (smaller lakes) and July (larger lakes). Ice begins forming again by September. Judge Sissons Lake is much larger than the other lakes surveyed in the area, and is typically slower to warm and lose its ice cover.

The water temperature data indicate that the lakes can be generally characterized as cold, monomictic lakes during the ice-free season. Monomic lakes have a single period of complete circulation annually. For the Project area lakes, mixing occurs during the ice-free period, which is illustrated by the relatively uniform temperature, dissolved oxygen, pH and conductivity measurements (e.g., Judge Sissons Lake and Scotch Lake, Table 4.1-1). Temperatures within the lakes show little variation with depth during the summer ice-free period.

Tables 4.1-1 and 4.1-2 provide detailed results for physio-chemical parameters measured in Project area lakes during the 1979 and 1980 survey. Samples were collected from a depth of 1 m in all of the lakes surveyed in 1979 with the exception of Judge Sissons Lake, which was also sampled at 18 m and 19 m. Temperatures in the study area ranged from 1.3°C to 10.0°C, with the range illustrating surface temperatures from just after ice-out (July 3, 1979) to late summer. Detailed results of the physio-chemical parameters sampled in 1979 and 1980 are presented in Appendix II.

Values of the remaining physio-chemical parameters sampled in 1979 remained consistent amongst waterbodies. Small ranges were observed in dissolved oxygen, pH and conductivity across the study area. Dissolved oxygen ranged from 10.2 mg/L to

11.7 mg/L, pH ranged from 6.1 to 8.0, and conductivity ranged from 8 µS/cm to 35 µS/cm.

Secchi depths were measured on several occasions in 1979, and were always found to be greater than maximum lake depths when measured in Pointer, Jaeger, and Scotch lakes (BEAK 1990). The transparency in Judge Sissons Lake ranged between 7 m and 8.5 m during the same year, reflecting low levels of suspended particulates and color.

Table 4.1-1
Physio-Chemical Parameters of Kiggavik Area Lakes Sampled in 1979

Location	Sampling Date	Depth (m)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity µS/cm
Ace Lake	27-Aug-79	1	5.4	11.4	6.6	19
Jaeger Lake (deep basin)	27-Aug-79	1	5.4	11.4	-	-
Pointer Lake (deep basin)	21-Jun-79	-	-	-	7.0	19
	3-Jul-79	1	1.3	11.3	8.0	8
	6-Jul-79	1	4.9	11.2	8.0	11
	16-Jul-79	-	-	-	6.4	9.4
	19-Jul-79	1	10.0	10.2	7.2	10
	24-Jul-79	1	8.5	11	7.25	10
	31-Jul-79	1	7.5	10.9	7.15	10
	3-Aug-79	1	8.5	11	7.2	10
	7-Aug-79	1	8.5	11.3	7.1	10
Scotch Lake (deep basin)	27-Aug-79	1	6.0	11.4	6.6	11
	27-Aug-79	4	6.0	11.0	6.6	9
Judge Sissons Lake (deep basin)	21-Jun-79	-	-	-	7.2	19.6
	16-Jul-79	-	-	-	6.1	14.3
	10-Aug-79	-	8.5	11.7	7.15	15
	10-Aug-79	1	7.0	10.9	7.2	20
	10-Aug-79	19	7.0	10.8	7.15	20
	11-Aug-79	-	-	11.7	7.10	15
	11-Aug-79	-	-	11.3	7.25	15
	11-Aug-79	-	-	10.2	7.20	25
	16-Aug-79	1	8.3	10.8	7.1	20
	16-Aug-79	18	7.9	11.2	7.15	20
	19-Aug-79	-	-	11.3	7.05	18
	19-Aug-79	-	-	11.2	7.15	22
	19-Aug-79	-	-	11.3	7.20	35
	24-Aug-79	1	8.3	10.6	7.1	18
	24-Aug-79	18	8.3	10.6	7.15	18
Judge Sissons Lake Outlet	21-Jun-79	-	-	-	6.9	28
	16-Jul-79	-	-	-	6.5	20

Notes: m = metre; °C = degrees Celcius; mg/L = milligrams per litre; pH = pH units; Jun = June; Jul = July; Aug = August.

Source BEAK 1990

Table 4.1-2
Physio-Chemical Parameters of Kiggavik Area Lakes Sampled in 1980

Location	Sampling Date	Depth (m)	Water Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity
Kavisilik Lake (deep area)	18-Jun-80	1	1.7	11.2	4.9	21
	18-Jun-80	6	2.3	13.7	5.0	27
	13-Jul-80	1	7.3	12.4	5.6	22
	13-Jul-80	6	7.1	12.4	5.6	17
	16-Aug-80	1	14.0	10.0	5.3	7
	16-Aug-80	9	13.9	10.2	5.3	7
Kavisilik Lake Outlet	29-Jul-80	-	11.9	11.0	5.7	6
	7-Aug-80	-	16.3	9.4	5.9	7
Pointer Lake (deep area)	14-Jun-80	2	0.5	12.2	6.2	26
	10-Jul-80	1	11.4	11.3	5.9	8
	10-Jul-80	2	11.4	11.2	5.9	8
	5-Aug-80	1	15.4	10.1	6.1	9
	5-Aug-80	2	15.4	10.1	6.1	8
Pointer Lake Outlet	28-Jun-80	-	5.2	12.5	5.6	10
	5-Aug-80	-	16.3	9.8	6.5	9
Scotch Lake (deep area)	17-Jun-80	1	0.8	12.2	4.8	11
	17-Jun-80	6	3.6	6.8	4.7	31
	23-Jul-80	1	11.5	10.5	5.9	10
	23-Jul-80	6	11.6	10.4	6.0	18
	15-Aug-80	1	14.6	10.1	5.6	8
	15-Aug-80	6	14.4	10.0	5.6	7
Scotch Lake Outlet	6-Aug-80	-	16.3	10.0	6.5	9
Judge Sissons Lake (deep area)	17-Jun-80	1	0.2	12.6	4.1	0
	17-Jun-80	18	2.8	3.7	5.0	28
	14-Jul-80	1	6.9	12.8	6.0	30
	14-Jul-80	19	5.0	12.9	5.9	19
	21-Jul-80	-	7.5	12.4	6.2	15
	12-Aug-80	1	12.5	10.6	6.2	17
	12-Aug-80	19	11.1	8.8	5.4	24
Squiggly Lake (deep area)	19-Jun-80	1	0.9	12.8	4.5	0
	19-Jun-80	7	2.8	10.2	5.0	23
	20-Jul-80	1	9.7	11.5	6.1	25
	20-Jul-80	7	9.2	11.5	6.0	21
	19-Aug-80	1	12.8	9.9	5.4	9
	19-Aug-80	14	12.8	9.9	5.6	9
Squiggly Lake Outlet	31-Jul-80	-	10.5	11.4	5.8	22
	8-Aug-80	-	13.4	10.6	5.6	8

Notes: m = metre; °C = degrees Celcius; mg/L = milligrams per litre; pH = pH units; Jun = June; Jul = July; Aug = August.

Source BEAK 1990

Physical measurements taken in 1980 were consistent amongst all waterbodies and similar to measurements taken the previous year, though pH was generally lower at all locations in 1980 as compared to 1979. Small ranges in values were observed for pH (4.1 to 6.5) and specific conductivity (0 µS/cm to 30 µS/cm). Dissolved oxygen ranged from 3.7 mg/L to 12.9 mg/L, with most values above 10 mg/L. There were two relatively low values observed in June 1980 (3.7 mg/L at 18 m depth in Judge Sissons Lake; 6.8 mg/L at the 6 m station in Scotch Lake). These values reflected late winter dissolved oxygen concentrations, indicating that the deep lakes had not yet begun to mix.

Chemical Characteristics

Detailed results of the chemical characteristics measured in 1979 and 1980 in the Project area lakes are presented in Table II-1 to II-19 of Appendix II. All parameters measured in the water collected from the Project area lakes were below maximum acceptable concentrations as established by Health and Welfare Canada for drinking water supplies (BEAK 1990).

Three metals (copper, cadmium and chromium) occurred in some samples at concentrations that were above the Canadian Council of Resource and Environment Ministers (CCREM) 1987 water quality guidelines for the protection of aquatic life. All concentrations of these metals fell within ranges identified as background for unpolluted Canadian surface waters by CCREM (1987), with the exception of copper and zinc sampled in 1979, in which case sample contamination was strongly suspected (BEAK 1990).

Radionuclides

Radionuclides in waters samples collected during the 1979 and 1980 surveys were at or below analytical detection limits for unconcentrated samples. The radionuclide levels in the Project area and Saqvaqjuac lakes were generally similar, with concentration ranges for each radionuclide overlapping. In the Project area, Th-230, U, and Ra-226 tended to occur, this was believed to be due to the mineralogy in the area (BEAK 1990). The results of surface water radionuclides analysis are provided in Appendix II.

4.1.2.2 Sampling period 1986 to 1989

Physio-Chemical Parameters

With the exception of dissolved oxygen in 1988, physio-chemical parameters in the Project area lakes were not measured during the 1986, 1988 and 1989 surveys. Under-ice measurements of dissolved oxygen taken in early June 1988 showed concentrations of approximately 3 mg/L in Pointer Lake (mean depth of 1.6 m), 4 mg/L in Jaeger Lake (mean depth 1.6 m), and 10 mg/L to 12 mg/L in Skinny Lake (mean depth 3.1 m) and

Escarpment Lake (mean depth 2.2 m) (BEAK 1990). These numbers indicated that the amount of under-ice oxygen depletion is greater in shallower lakes as opposed to the deeper lakes in the study areas. Similar observations were made in the Saqvaqjuac lakes located east of Baker Lake, which reported that lakes with a mean depth of greater than 3 m had adequate dissolved oxygen to support fish over winter (BEAK 1990).

Chemical Characteristics

Detailed results of the chemical characteristics measured in 1986, 1988 and 1989 in the Project area lakes is presented in Appendix II. Also included is a summary of Baker Lake chemistry from 1974 to 1982 that was collected by the Water Survey of Canada.

Overall, concentrations of nutrients, (e.g., phosphorus and nitrogen) were low in the Kiggavik area lakes, falling within the range of concentrations that are expected for oligotrophic lakes (BEAK 1990).

Some differences between winter and summer conditions were apparent in the Project area lakes water quality in 1988. Ions such as Na^+, Mg^{2+}, K^+, and Cl^- had lower concentrations during the open water season, which was attributed to the effects of dilution by snow melt and cryoconcentration (freeze-out) (BEAK 1990). Freeze-out tends to concentrate these elements in the unfrozen volume of the lake, and may also account for some increase in nutrient concentrations under ice.

Chemical analysis of snow core samples in 1988 and 1989 showed that the snow was acidic and had low levels of conductivity, alkalinity, organic carbon, color, calcium, magnesium, potassium, and barium relative to lake water (BEAK 1990). Concentrations of some heavy metals in snow were much greater than in the lake waters. BEAK (1990) indicated that the lake chemistry is less acidic than the snow, suggesting that the lakes sampled in the 1988 and 1989 surveys had considerable buffering capacities, which is particularly relevant with respect to controlling optimal conditions for aquatic life (BEAK 1990).

A small stream draining through a mineral exploration area towards Pointer Lake was sampled in 1986, 1988 and 1989. Results showed elevated concentrations of total dissolved solids, chloride, sulphate, calcium, sodium, potassium and several trace metals (iron, manganese, aluminum, barium) relative to other local surface waters (BEAK 1990). Elevated concentrations of ions in the tributary were observed when active drilling was being performed in 1986, as opposed to 1988 when no drilling was carried out. Salt used to keep drills and drill holes from freezing was identified as a major source of ions in the tributary (BEAK 1990). None of the parameters that had elevated concentrations in the drainage from the mineral exploration area were found in Pointer Lake at concentrations above typical background levels of other local lakes.

Generally, it was found that project area waters were relatively low in both conductivity and concentrations of most dissolved substances. Low nutrient (phosphorous) concentrations suggest that local lakes were relatively unproductive (i.e., olgiotrophic or ultra olgiotrophic) (BEAK 1990).

All parameters measured in water samples collected from lakes in the Project area were below maximum acceptable concentrations as established by Health and Welfare Canada for drinking water supplies (BEAK 1990). In general, the Project area lakes were found to be dilute in comparison with the global average for river water, and many parameters tended to be more dilute than Saqvaqjuac lakes (BEAK 1990).

Radionuclides

Results of radionuclide analysis of surface waters from the Project area for the periods of 1986 to 1989 are shown in Appendix II. Prior to 1988, levels of most radionuclides analyzed from Project area lakes were at or below analytical detections limits for unconcentrated water samples. Detectable levels were reported for 1988 and 1989, owing to the analysis of samples pre-concentrated from large volume samples (BEAK 1990). Ra-226, analyzed only by Rn-emanation due to the Ba-133 tracer and stable Ba carrier used in sample pre-concentration, was undetected in 1988. This lack of detection can in part be attributed to the relatively high detection limits of the Rn-emantion method (BEAK 1990).

With the exception of an unusually high uranium value for Jaeger Lake in 1988 (8.6 µg/L), uranium concentrations found in 1988 and 1989 were close to those reported in earlier years from the Project area lakes (BEAK 1990). Total uranium concentrations were higher and Th-232 levels were lower in the Project area surface waters than those recorded in Saqvaqjuac surface waters.

The Pointer Lake tributary, draining an area of surface mineralization, showed higher concentrations of most radionuclides than in any lake samples. Samples were collected downstream of the mineralized area in 1988, when no drilling was being carried out in the watershed. Samples from 1986 were collected both upstream and downstream of the ore bodies. The conclusion drawn from the data collected in these surveys was that radionuclides are mobilized from the mineralized area to the watershed (BEAK 1990).

4.1.2.3 Sampling Period 1990 to 1991

Levels of most parameters collected during the 1990 and 1991 sampling events were within the reported background range previously noted for the Project area lakes during earlier surveys. In 1991, snow samples were collected for analysis from the snow drifts in the Lone Gull camp (refer to Appendix II). These samples had similar pH and Hg values as the previously mentioned 1989 snow samples. Values were lower for most parameters in the snow and ice samples as compared to lake water samples. Values for Ra-226 were slightly elevated above the detection limit in Cigar Lake, Pointer Lake, and the snow sample (0.003 Bq/L, 0.004 Bq/L, and 0.003 Bq/L respectively) (BEAK 1992).

During water quality sampling on Ridge and Judge Sissons lakes, water was observed to be effervescing, which was suggestive of gas supersaturation (BEAK 1992). Oxygen readings confirmed this with oxygen saturation levels in excess of 150%. Some depletion of oxygen was evident in 1991, and was most apparent in shallower lakes such as Pointer and Cigar lakes. Pointer Lake oxygen levels were similar to those measured under the ice in June 1988 (BEAK 1992).

Water quality sampling from the spring and summer of 1991 focused on providing baseline data on the Andrew Lake area watersheds and was completed in early June and under low flow conditions (August). It was shown that in general, levels of most parameters were within the background range reported for the Project area surface waters (BEAK 1992). Parameters that were outside of the background range in some waterbodies during the 1991 survey included hardness, total dissolved solids, and zinc (BEAK 1992).

The most recent historical data (prior to Golder’s 2007 study) is summarized in Table 4.1-3. Additional references and information can be found in Appendix II.

Table 4.1-3
Historical Water Quality Data of Kiggavik Area Lakes Prior to 2007

Analyte Name	Units	Cigar Lake 1991	Mushroom Lake 1991	Knee Lake Outlet 1990	Lunch Lake Inlet 1990	Shack Lake Inlet 1990	Upstream of Lower Lake Inlet 1990	Andrew Lake Sub Basin 1991	Judge Sissons Lake 1991	Pointer Lake 1991
Physio-Chemical		Value	Value	Value	Value	Value	Value	Value	Value	Value
pH, lab	pH units	6.35	6.90	7.10	6.80	7.00	7.10	7.20	6.70	6.45
Conductivity	µS/cm	53	20.3	33/32	12.9	27	31	38.6	28.3	141
Alkalinity as $CaCO_3$	mg/L	12	4	12	6	9/8	11	7	6	53
Dissolved Inorganic Carbon	mg/L	3.3	1.9					3.9	0.7	13.4
Dissolved Organic Carbon	mg/L	6.6	3.6					6.3	2.4	26
Hardness as $CaCO_3$	mg/L	12.4	9.5					18.0	9.5/8.5	57
Total dissolved solids	mg/L		23					28	22	
Total suspended solids	mg/L		<2					<2	<2	
Nutrients										
Ammonia as nitrogen	mg/L	0.094	0.008					0.027	0.011	0.025
Nitrate	mg/L	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
Nitrite	mg/L	0.01	<0.01					<0.01	<0.01	<0.01
Silica (as $Si0_2$)	mg/L		0.28					0.18		
Sol. Reactive Phosphorous	mg/L	0.003	<0.001					<0.001	0.002	<0.001
Total Kjeldahl Nitrogen	mg/L	0.69	0.24					0.47	0.18	1.34
Total Phosphorous	mg/L	0.011	0.006	0.003	0.002	0.002	0.002	0.009	0.003	0.015
Major Ions										
Calcium	mg/L	0.1	2.3	4.3	1.55	3.3	4.0	4.6	2.7/2.3	16.7/16.8
Chloride	mg/L	1.07	0.36	0.27	0.27	1.34	0.38	0.95	0.44	3.2
Fluoride	mg/L	0.19	0.09	0.430	0.130	0.250	0.180	0.23	0.04	0.16
Hydroxide	mg/L									
Magnesium	mg/L	0.05	0.80	1.30	0.50	1.10	1.30	1.60	0.75/0.70	5.2/5.2
Potassium	mg/L	0.1	0.3	0.15	0.10	0.15	0.10	0.5	0.35/0.35	2.0/2.1
Sodium	mg/L	0.5	<0.5	2.0	1.5	1.0	2.0	0.5	<0.5/<0.5	2.5/2.5
Sulphate	mg/L	0.54	0.5	0.70	0.30	0.30	0.40	0.3	0.6	3.2

Table 4.1-3
Historical Water Quality Data of Kiggavik Area Lakes Prior to 2007 (continued)

Analyte Name	Units	Cigar Lake 1991	Mushroom Lake 1991	Knee Lake Outlet 1990	Lunch Lake Inlet 1990	Shack Lake Inlet 1990	Upstream of Lower Lake Inlet 1990	Andrew Lake Sub Basin 1991	Judge Sissons Lake 1991	Pointer Lake 1991
Total Metals										
Aluminum	mg/L	0.02	0.02	0.05	0.05	0.04	0.02	0.02	<0.02	0.08/0.10
Arsenic	µg/L	2	<2	<2	<2	<2	<2	<2	<2	<5
Barium	mg/L	0.01	0.02	0.08	0.02	0.05	0.04	0.04	0.03	0.34/0.37
Bromide	mg/L			<0.05	<0.05	<0.05	<0.05			
Cadmium	µg/L	0.2	<2	<2	<2	<2	<2	<2	<2	0.2/0.4
Chromium	µg/L	2	<10	<1	<1	<1	<1	<10	<10	<1/<2
Cobalt	µg/L	1	<10	<5	<5	<5	<5	<10	<10	1/1
Copper	µg/L	2.5	<5	<5	<5	<5	<5	<5	<5	4/4
Iron	mg/L	<0.02	0.14	0.23	0.13	0.16	0.17	0.24	<0.02	0.5
Lead	µg/L	1	<20	<1	<1	<1	<1	<20	<20	<0.5/<1
Manganese	µg/L	2	<10	<10	<10	<10	<10	<10	<10	76
Mercury	µg/L		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	
Nickel	µg/L	2	<10	<5	<5	<5	<5	<10	<10	4/4
Selenium	µg/L	<2	<2	<1	<1	<1	<1	<2	<2	<2/<5
Silicon	mg/L							0.18		
Silver	µg/L	<0.1	0.28	<5	<5	<5	<5	<5	0.05	<0.1
Strontium	mg/L	<0.01	0.02					0.04	0.01	0.13/0.13
Uranium	µg/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	
Uranium - preconcentrated	µg/L		0.5						0.5	
Zinc	µg/L	<5		<5	<5	<5	<5	<10		5
Radionuclides										
Radium-226	Bq/L	0.002	<0.002	<0.005	<0.005	<0.005	<0.005	<0.002	<0.002	
Lead-210	Bq/L			<0.04	<0.04	<0.04	0.08			
Polonium-210	Bq/L			0.04	<0.01	<0.01	0.01			
Thorium-230	Bq/L			<0.02	<0.02	<0.02	<0.02			

Source: BEAK 1990, 1992.

4.2 Sediment Quality

Lake sediments consist of organic and inorganic matter introduced through erosion of soils and other geologic materials in the watershed, and through the deposition of particulate mineral matter and organic material produced in the lake (BEAK 1990). The field studies carried out between 1979 and 1991 broadly covered the Kiggavik study area. The objectives were to collect baseline information on sediment particle size characteristics, sediment chemistry, and sedimentation rates.

4.2.1 Sediment Collection Methods

Available historical sediment quality information includes particle size characterization, chemistry analysis (radionuclides, nutrients, major ions, metals, and organic carbon), and sedimentation rates. Sediment sampled for particle size characterization were collected from Skinny, Willow, Caribou, Boulder, Sissons, and Lower sub basins in 1988. Sediment chemistry samples were collected in 1979, 1986, 1988, 1990, and 1991 from Skinny, Willow, Caribou, Boulder, Sissons, and Lower sub basins. Sedimentation rate samples were collected from Pointer Lake and Judge Sissons Lake before 1990, the exact year of collection was not provided in BEAK (1990). The sampling methods, intensity, and areas tended to differ between surveys, which should be kept in mind when comparing results from the various data sets. Additional sediment quality information was collected in a number of lakes in the Project area in 2007 to provide current information. Based on similarities in sampling methods and intensity, the field studies and results have been grouped into sampling periods for the purposes of this report. The sampling periods that have been identified are:

- 1979: Willow and Sissons sub basins;
- 1986: Kavisilik, Willow, Caribou, Boulder, and Sissons sub basins;
- 1988: Willow, Caribou, and Sissons sub basins;
- 1990 to 1991: Willow, Sissons, and Lower sub basins; and
- 2007: Kavisilik, Willow, Caribou, and Lower sub basins.

Results from the identified sampling periods are found in Appendix III (Tables III-1 and III-2).

4.2.1.1 Sampling Period 1979: Willow and Sissons Sub Basins

In 1979, sediments were collected in Scotch Lake, Jaeger Lake, Pointer Lake, and Judge Sissons Lake using a Kajak Brinkhurst (KB) corer (BEAK 1990). The number of samples collected at individual locations varied from one to 14 and were divided into surface (top 3 cm) and subsurface samples (10 cm to 13 cm depth). Each surface and subsurface sample were analyzed for metals (i.e., arsenic, cadmium, chromium, copper, lead, mercury, selenium, and tellurium) for all the lakes. In addition, uranium, Pb-210, Ra-226, Th-228, Th-230, and Th-232 were analyzed in all the lakes samples, except Jaeger Lake (BEAK 1990).

4.2.1.2 Sampling Period 1986: Kavisilik, Willow, Caribou, Boulder, and Sissons Sub Basins

In 1986, sediment samples were collected from ten lakes in the Kiggavik study area (BEAK 1990). Limited information was available on the objectives of the 1986 program and the methods used. The Judge Sissons Lake sample was collected from a depth of about 5 m offshore from the inlet of the Willow Lake sub basin. Samples were collected from areas near the deepest parts of the remaining smaller lakes. BEAK (1990) reported that it was difficult to locate zones of soft sediment accumulation in the shallow and relatively large lakes, such as Pointer, Caribou and Boulder; however, with repeated attempts sufficient material was recovered. Whole sediment samples were analyzed for the following:

- major ions (i.e., calcium, magnesium, potassium, sodium);
- metals (i.e., aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, uranium, and zinc);
- percent chemical oxygen demand;
- percent loss-on ignition;
- radionuclides (i.e., Pb-210, Ra-226, Th-230, and Th-232);
- total kjeldahl nitrogen; and
- total phosphorus.

4.2.1.3 Sampling Period 1988: Willow, Caribou, and Sissons Sub Basins

In 1988, sediment samples were collected from five lakes in the Kiggavik study area (BEAK 1990). Limited information was available on the objectives of the 1988 program and the methods used. Sediment samples were collected from the deep parts of each lake surveyed, with the exception of Pointer Lake. In Pointer Lake the bottom material of the main basin of the lake consisted of sticky clay, sand, and rock, which could not be cored.

Samples were split in two to analyze for fine and whole fractions (BEAK 1990). Fine samples were sieved using a 63 μm sieve. Sediment samples were analyzed for the following:

- cation exchange capacity;
- chemical oxygen demand;
- loss-on ignition;
- major ions (i.e., calcium and magnesium);
- metals (i.e., aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, strontium, and zinc);
- total kjeldahl nitrogen;
- total phosphorus; and
- particle size.

In addition, uranium, Pb-210, Po-210, Po-220, Ra-226, Ra-228, Th-228, Th-230, and Th-232 were analyzed in Pointer, Jaeger, Scotch, Crash, and Judge Sissons lakes (BEAK 1990).

4.2.1.4 Sedimentation Rates: Willow and Sissons Sub Basins

Sedimentation rates were measured in Pointer Lake and Judge Sissons Lake using the Pb-210 method (BEAK 1990). Sediment chronologies can be determined from the Pb-210 method when the supply of Pb-210 occurs at a constant rate to the sedimentation rate or if the Pb-210 supply is proportional to a varying sedimentation rate (McKee et al. 1987). This method has been used in measuring sedimentation in other Arctic lakes, as well as many other lakes (BEAK 1990). However, Pb-210 dating will probably not be useful in other Kiggavik area lakes receiving mill effluents in the future, due to the dispersion of the natural radionuclide loadings. This problem was documented in Quirke Lake, a waterbody affected by uranium mining and milling near Elliot Lake, Ontario, although a combination of Lead-210 and Ra-226 could be used if the effluent rates (i.e., loading rates) are known and relatively consistent (BEAK 1990).

Sediment cores were collected in duplicate using a KB corer equipped with 4.7 cm (inside diameter) polycarbonate core tubes. Cores were collected from two depths (11 m and 13 m) in Judge Sissons Lake, and one depth (approximately 1.8 m) in Pointer Lake. Attempts to collect cores from the main body of Pointer Lake (depths of 2 m to 2.3 m), and from depths below about 10 m in the eastern basin of Judge Sissons Lake were unsuccessful, apparently due to the presence of rock, coarse sand or dense clay on the sediment surface. Core samples were sliced off 0.5 m to 2 cm sections in a plastic collar. Detailed analytical methods and calculation methods for sedimentation rates can be found in BEAK (1990).

4.2.1.5 Sampling Period 1990-1991: Willow, Sissons, and Lower Sub Basins

Field studies were carried out in August 1990 and July 1991 to collect additional baseline data from the Andrew Lake and the Kiggavik site development areas and to address the FEARO requests for additional information (BEAK 1992).

In 1990, sediment samples were collected from five locations within Shack Lake, Lunch Lake and a waterbody 2 km upstream of Lower Lake (BEAK 1992). Each of the five samples comprised five pooled subsamples collected in each embayment. Samples were collected from the surficial layer (0 cm to 5 cm) with an Ekman or Ponar grab and transferred to a labelled plastic bag with a plastic spoon. Samples were kept cool with ice, prior to delivery to the analytical laboratory were they were analyzed using the <500 µm size fraction. Samples were analyzed for the following:

- major ions (i.e., calcium, magnesium, potassium, and sodium);
- metals (i.e., aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, strontium, titanium, uranium, vanadium, and zinc);
- radionuclides (i.e., Ra-226, Pb-210, Po-210, and Th-230); and
- total organic carbon.

Samples were collected from three waterbodies in July 1991, including Shack Lake, Pointer Lake, and Judge Sissons Lake. Sediment cores were collected in triplicate by KB-corer from the deep basins of Pointer Lake and Shack Lake. Only one sample was collected in Judge Sissons Lake despite several attempts using both a KB-corer and a Ponar grab. The collected cores were sectioned in the field into three depth strata corresponding to 0 cm to 5 cm, 5 cm to 10 cm, and 10 cm to 15 cm. The 0 cm to 5 cm (surficial) samples were analyzed using the <63 µm size fraction for the following parameters:

- loss-on ignition;
- major ions (i.e., calcium, magnesium, potassium, and sodium);
- metals (i.e., aluminum, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, strontium, titanium, uranium, vanadium, and zinc);
- radionuclides (i.e., Ra-226 and Po-210);
- total kjeldahl nitrogen; and
- total phosphorus.

The remaining core samples were archived for future analysis if required (BEAK 1992).

4.2.1.6 Sampling Period 2007: Kavisilik, Willow, Caribou, and Lower Sub Basins

Twelve lakes from four different sub basins were included in the 2007 sediment sampling program:

- Skinny Lake from the Kavisilik Lake sub basin;
- Sik Sik, Pointer, and Willow lakes from the Willow Lake sub basin;
- Ridge, Cirque, Crash, and Fox lakes from the Caribou Lake sub basin; and
- Lower, Shack, Andrew, and End Grid lakes from the Lower Lake sub basin.

Sediment sampling was conducted at two locations in each lake (deepest station and 1 m deep station), with two exceptions. Only one sample was taken from Willow Lake due to an absence of soft sediment at the deepest station. A single sample was collected in Skinny Lake due to time constraints during the 2007 field program. Sediment samples were collected using an (15.2 cm) Ekman grab. One grab sample was collected at each replicate station.

Samples were analyzed for the following:

- nutrients (ammonia nitrogen, nitrite + nitrate nitrogen, and total phosphorus);
- radionuclides (Pb-210, Po-210, Ra-226, and Th-230);
- total metals (aluminium, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, strontium, titanium, uranium, vanadium, and zinc);
- particle size (i.e., gravel, coarse sand, fine sand; silt; clay);
- loss-on-ignition; and
- moisture.

4.2.2 Sediment Baseline Results: 1979 - 1991

4.2.2.1 Particle Size

Kiggavik area lake bottom substrates vary from rock, boulder and sand in shallower areas to organic-rich (soft light to dark brown) sediments in deeper depositional areas. The surficial light to dark brown sediments are typically 2 cm to 10 cm thick, and usually have an underlying layer of tan or grey deposits (BEAK 1987). BEAK (1987) provides a comparison to regional sediment quality data in Keewatin District lakes.

The only historical survey that quantitatively assessed sediment particle size was conducted in 1998 (Table 4.2-1). During the 1988 sampling program, silt was the dominant particle size category in all lakes sampled except in Pointer Lake and Judge

Sissons Lake (Table 4.2-1). Surface sediment in the main body of Pointer Lake was dominated by rock, coarse sand, and dense clay (BEAK 1990). Judge Sissons Lake sediment samples collected in 1988 had nearly equal amounts of fine sand, very fine sand, silt and clay. Underlying glacial clay was found in the core.

The core sample collected in Judge Sissons Lake in 1991 consisted of sticky glacial clay and no soft organic sediments (BEAK 1990; BEAK 1992). The 1991 result suggests that sediment deposition occurs sporadically in Judge Sissons Lake (BEAK 1992). Differences in sediment texture between smaller lakes and Judge Sissons Lake can be attributed to the much greater depth of Judge Sissons Lake and the varying depositional environment provided in deep lakes (BEAK 1990).

Table 4.2-1
Particle Size Data for Surficial Lake Sediments in Kiggavik Area, July 1988

Category	Range (mm)	Pointer Lake 1 %	Pointer Lake 2 A %	Pointer Lake 2 B %	Pointer Lake 2 C %	Jaeger Lake %
Coarse sand	0.5 - 1.0	0	0	0	0	1.01
Medium sand	0.25 - 0.5	0.62	1.28	1.08	7.66	2.54
Fine sand	0.088 - 0.025	3.71	3.2	3.54	12.31	16.71
Very fine sand	0.0625 - 0.088	49.41	13.15	13.67	26.29	39.49
Silt	0.0039 - 0.0625	37.69	71.53	70.18	42.96	27.69
Clay	<0.0039	8.59	10.82	11.54	10.77	12.47

Notes: % = percent; mm = millimetres
Source BEAK 1990

4.2.2.2 Chemistry Results

Based on the 1979 results, differences in metal concentrations between surface and subsurface layers were not apparent, with the exception of chromium (Table 4.2-2). The surface sediments show a slight enrichment in chromium relative to the subsurface layer (BEAK 1990). Because there are no local contamination sources that would explain this enrichment, it is probably a natural phenomenon resulting from the variations in the reduction-oxidation potential with depth in the sediment (BEAK 1990).

Comparisons of chemistry results among sampling years are difficult as little information on the sampling method is available for most of the sampling years. This is compounded by the fact that sampling methods can affect sediment chemistry results.

Table 4.2-2
Average Quality of Surficial and Subsurficial Sediments Collected in Kiggavik Area Lakes, 1979

Analyte	Unit	Pointer Lake		Scotch Lake		Jaeger Lake		Judge Sissons Lake	
		Surface	Subsurface	Surface	Subsurface	Surface	Subsurface	Surface	Subsurface
		n = 10	*n* = 7	*n* = 2	*n* = 2	*n* = 1	*n* = 0	*n* = 14	*n* = 14
Arsenic	µg/g	1.50	1.98	0.86	1.39	2.32	-	4.48	2.32
Cadmium	µg/g	<0.5	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5
Chromium	µg/g	85.5	60.7	85.0	60.0	100.0	-	82.5	73.2
Copper	µg/g	18.0	15.0	22.5	15.0	15.0	-	14.4	15.0
Lead	µg/g	<5.0	<5.0	<5.0	<5.0	<5.0	-	<5.0	<5.0
Mercury	µg/g	0.0141	0.0073	0.0265	0.0125	0.0060	-	0.0174	0.0170
Selenium	µg/g	0.052	0.059	0.090	0.130	0.020	-	0.034	0.043
Tellerium	µg/g	<0.1	<0.1	<0.1	<0.1	<0.1	-	<0.1	<0.1

Notes: n = sample size; µg/g = micrograms per gram; concentrations are in µg/g dry weight, except for arsenic, selenium, and tellerium which are µg/g wet weight; surface = top 3 centimetres, subsurface = 10 to13 centimetres.
Source: BEAK 1990

Soft sediments in Kiggavik area lakes typically have organic contents (loss-on-ignition) of 9% to 28% by weight. Nutrient (total Kjeldhl nitrogen and phosphorus) and major ions concentrations were generally similar among sites (Table 4.2-3), outside of a few exceptions. Sodium concentrations in samples collected in Lower Lake and Shack Lake in 1990, had lower concentrations (<10 µg/g) than the other lakes (ranging from 125 µg/g to 480 µg/g). Potassium concentrations measured in 1990 and 1991 (all lakes) were higher (230 µg/g to 2400 µg/g) than concentrations measured in 1986 (1.15 µg/g to 6.2 µg/g). The difference could possibly be attributed to an unit error (µg/g versus mg/g) in one of the reports (BEAK 1990; BEAK 1992).

In general, sediment metal and radionuclide concentrations in the Kiggavik study area were similar among lakes (Appendix III). Arsenic concentrations in samples from Escarpment Lake (30 µg/g to 34 µg/g), Willow Lake (6 µg/g), and Ridge Lake (60 µg/g) from the 1986 program, and Sissons Lake 1991 (12 µg/g) were above the Interim Sediment Quality Guidelines (ISQG) of 5.9 µg/g; although only Escarpment Lake and Ridge Lake were above the Probable Effect Level (PEL) of 17.0 µg/g. Chromium concentrations in sediment samples collected from 12 lakes of the Kiggavik area between 1979 and 1991 were above the ISQG of 37.3 µg/g. Only one sediment sample collected from Jaeger Lake in 1979 (100 µg/g) had a chromium concentration above the PEL (90.0 µg/g). Concentrations of copper in sediment collected in 1986 from Escarpment Lake (34 µg/g to 36 µg/g), Lin Lake (63 µg/g), Ridge Lake (39 µg/g), and Cirque Lake (59 µg/g) were above the ISQG (35.7 µg/g) but below the PEL (197 µg/g). Mercury concentrations in Shack Lake 1990 (1 µg/g to 3 µg/g) were above the ISQG (0.17 µg/g) and the PEL (0.486 µg/g). Other sediment concentrations were below ISQG and PEL when values were available.

Table 4.2-3
Physical Properties, Nutrients and Major Ions in Sediment Collected in Kiggavik Area Lakes

Analyte	Units	Ridge Lake	Cirque Lake	Crash Lake	Caribou Lake	Judge Sissons Lake				Lower Lake	Shack Lake		Lunch Lake
		1986	1986	1988	1986	1979	1986	1988	1991	1990	1990	1991	1990
		n = 1	n = 1	n = 1	n = 1	n = 14	n = 1	n = 1	n = 1	n = 1	n = 2	n = 3	n = 2
Physical Properties													
Loss-on-ignition	%	13.0	18.2	-	7.5	-	2.4	-	1.8-1.8	-	-	21.2-21.5	-
Chemical Oxygen Demand	%	2.7	6.7	-	1.9	-	0.75-0.82	-	-	-	-	-	-
Nutrient													
Total Kjeldahl-N	µg/g	6000	7700	-	2600	-	790	-	1560-1500	-	-	610-7400	-
Total Phosphorous	µg/g	4700	1160	-	1170	-	700	-	1060	-	-	760-830	-
Major Ion		-	-										
Calcium	mg/g	2.7	2.5	-	3.6	-	1.9	-	2.8	-	-	4.5-5.3	-
Magnesium	mg/g	6	7.3	-	7.4	-	2.4	-	4.4	2.1	1.42-4.1	4.2-5.0	0.88-6.2
Potassium	µg/g	4.1	6.2	-	2.7	-	1.15	-	2100	460	350-1530	1770-2400	230-2200
Sodium	µg/g	480	350	-	400	-	125	-	300	<10	<10	300-400	240-360

Notes: n = sample size.

Source: BEAK 1990.

4.2.2.3 Sedimentation Rates

Sedimentation rates were measured to permit the estimation of future chemical fluxes from the water column. The lakes were found to have low, but variable sedimentation rates, reflecting the oligotrophic conditions of the aquatic ecosystem and possibly the frequent wind-driven sediment re-suspension (BEAK 1990). Given the small volume of many of the lakes, it is also possible that there is a short water retention time in the lakes, which would also influence sedimentation rates.

Sedimentation rates in the Kiggavik area cores were 1.6 mm/year in Pointer Lake and between 0.11 mm/year and 0.26 mm/year in Judge Sissons Lake (Table 4.2-4). The average annual depth of accumulation (mm/yr) is based on mass accumulation rates and on the dry bulk densities for the four surface core slices collected from the top 2 cm to 2.5 cm (BEAK 1990).

Table 4.2-4
Sedimentation Rates in Kiggavik Area Before 1990

Unit	Pointer Lake	Judge Sissons Lake	
		11 m depth	13 m depth
$g/m^2/yr$	300	11	20
mm/yr	1.6	0.11	0.26

Notes: m = meters; g = grams; m^2 = square meters; yr = year; mm = millimetres.
Source: BEAK 1990

Within the 11 m Sissons cores, a sticky grey clay was encountered below a depth of 18.4 cm. This is probably a layer deposited during the deglaciation, which occurred in the area approximately 6,000 to 8,000 years B.P (BEAK 1990). The total mass accumulated above this layer was 5.3 g/cm^2, which is equivalent to an overall average annual rate of 7.6 $g/m^2/yr$ over 7,000 years. This is approximately 70% of the 11 $g/m^2/yr$ measured in recent sediments by Pb-210, probably reflecting an increase in sedimentation rate in recent history relative to earlier post-glacial time. These changes can be attributed to various factors, including glacial rebound and changes in erosion rates, climatic vegetation changes, and changes in the lake basin itself. Post-depositional oxidation of organic matter may also be a factor contributing to the lower rates occurring over the long-term (BEAK 1990).

4.2.3 Sediment Baseline Results: 2007

4.2.3.1 Particle Size

Table 4.2-5 provides the grain size and loss-on-ignition results for sediment samples collected in 2007. Soft sediments were dominated by silt and clay or silt and fine sand throughout the Caribou and Willow Lake sub basin (Table 4.2-5). Lower Lake sub basin lake sediment samples were mainly comprised silt and fine sand or silt and coarse sand. Figure 4.2-1 shows the sediment sampling locations for the 2007 Golder field season work.

Table 4.2-5
Grain Size and LOI at Lakes in the Caribou Lake, Willow Lake and Lower Lake Sub Basins, Fall 2007

Sub Basin	Waterbody	Gravel (%)	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Moisture (%)	LOI (%)
Caribou Lake Sub basin	Cirque Lake	1.24	6.59	23.41	48.24	20.52	4.06	11.81
		2.34	2.39	25.66	51.23	18.38	3.03	12.53
	Crash Lake	8.65	9.52	55.73	21.68	4.43	2.64	5.98
		6.52	40.06	31.46	16.47	5.49	2.13	5.86
	Fox Lake	<0.01	0.49	6.35	74.07	19.1	4.61	13.52
		<0.01	0.82	13.15	69.06	16.97	4.34	13.55
	Ridge Lake	19.31	0.83	10.85	47.19	21.82	1.63	9.51
		0.44	0.13	6.2	68.06	25.17	2.47	13.31
Willow Lake Sub basin	Pointer Lake	26.76	2.86	14.07	45.53	10.78	2.99	8.87
		<0.01	0.04	2.79	86.08	11.09	6.06	23.46
	Sik Sik Lake	<0.01	0.06	1.05	69.81	29.09	5.71	15.44
		11.43	0.08	1.88	69.18	17.42	4.27	11.92
	Willow Lake	0.04	0.13	31.79	55.48	12.56	1.15	4.59
Lower Lake Sub basin	Andrew Lake	0.16	49.03	42.22	6.57	2.02	<0.01	0.53
		0.57	36.2	44.81	14.84	3.58	0.49	2.42
	End Grid Lake	3.38	30.61	48.96	14.54	2.51	0.95	2.82
		4.94	20.18	49.57	21.18	4.13	2.89	7.23
	Lower Lake	<0.01	0.02	5.17	77.1	17.7	4.88	12.96
		<0.01	<0.01	1.52	79.72	18.76	4.28	14.91
	Shack Lake	1.63	26.41	57.07	12.32	2.57	0.86	3.14
		6.58	31.56	50.79	8.67	2.41	0.67	2.38

Note: % = percent; LOI = Loss of ignition; < = less than
Source Golder 2008

Figure 4.2-1 Sediment Sampling Locations

4.2.3.2 Chemistry Results

Metal levels were generally below ISQG and PEL, where guidelines are available (Table 4.2-6). PEL sediment guidelines for the protection of aquatic life were exceeded three times: arsenic concentration in Ridge Lake (Station 1) 31 µg/g; Shack Lake (Station 1) had a zinc concentration of 410 µg/g; and Andrew Lake (Station 2), which had a zinc concentration of 440 µg/g.

ISQG values were exceeded for arsenic, chromium, copper, and zinc. Seven lakes, Sik Sik, Pointer, Lower, Fox, Crash, Cirque, and Skinny lakes, all exceeded the ISQG for mean arsenic concentrations. Additionally, Sik Sik, Lower, Fox, and Cirque lakes mean values exceeded ISQG values for chromium. One station in Ridge Lake exceed ISQG values for chromium, however the mean value for the lake was below ISQG values. Mean copper concentrations in Shack, Andrew, Fox, Cirque, Ridge, and Skinny lakes exceeded the ISQG value. One station in Sik Sik Lake exceed copper values, however once again the mean for the entire lake was below guidelines. Cirque and Skinny lakes, also exceeded the ISQG value for mean zinc concentrations.

Sediment samples from Sik Sik, Ridge, Cirque, Lower, Skinny, and Shack lakes show some of the highest mean metal concentrations of the lakes sampled in 2007. Sik Sik Lake had the highest mean concentrations of aluminium, nickel, strontium, and vanadium. Ridge Lake had the highest mean concentrations of arsenic, barium, iron, and manganese. Cirque Lake had the highest mean concentrations of boron and molybdenum and Lower Lake shows the highest mean concentrations of cobalt and titanium. The highest concentration of beryllium and uranium occurred in Skinny Lake, while the highest mean concentrations of selenium occurred in Shack Lake.

Skinny Lake also shows consistently higher radionuclide levels than all other lakes for Pb-210, Ra-226, and Po-210. Skinny and Cirque lakes had the highest concentrations for Th-230 (Table 4.2-7).

Table 4.2-6
2007 Sediment Chemistry Data from Lakes in the Kiggavik Project Area

Parameter	Units	Sediment Quality Guidelines		Willow Lake Sub basin					Lower Lake Sub basin								Caribou Lake Sub basin								Kavisilik Lake Sub basin
				Willow Lake	Sik Sik Lake		Pointer Lake		Lower Lake		Shack Lake		Andrew Lake		End Grid Lake		Fox Lake		Crash Lake		Cirque Lake		Ridge Lake		Skinny Lake
		ISQG	PEL	WIL-SD2	SSL-SD1	SSL-SD2	PRL-SD1	PRL-SD2	LWL-SD1	LWL-SD2	SHL-SD1	SHL-SD2	ANL-SD1	ANL-SD2	EGL-SD1	ENL-SD2	FXL-SD1	FXL-SD2	CRL-SD1	CRL-SD2	CQL-SD1	CQL-SD2	RDL-SD1	RDL-SD2	SKL-SD1
Nutrients																									
Nitrite+Nitrate nitrogen	µg/g	-	-	9	10	10	10	9	7	10	5	4	5	4	4	8	10	10	9	8	10	10	20	20	5
Ammonia as nitrogen	µg/g	-	-	30	140	90	60	70	100	100	6	10	7	20	10	30	80	60	40	80	120	70	120	100	120
Phosphorus, total	µg/g	-	-	710	990	1,000	940	1040	920	950	350	350	270	240	290	330	840	800	460	530	820	730	2520	1130	1420
Metals																									
Aluminium	µg/g	-	-	10,300	29,400	22,400	14,100	18,900	19,500	18,000	5,000	4,300	4,100	4,100	6,000	7,200	20,100	20,500	13,900	21,500	32,000	17,100	20,800	24,200	21,200
Arsenic	µg/g	5.9	17.0	5.3	11	9.7	6.5	7.4	7.8	7.3	2.7	1.5	1.3	2.4	2	2.8	6.6	5.9	8.4	8.6	10	5	**31**	8.2	8.7
Barium	µg/g	-	-	180	360	290	140	310	240	200	76	68	54	58	62	83	280	290	230	320	470	280	480	440	330
Beryllium	µg/g	-	-	0.9	1.6	1.3	0.8	1.1	1.2	1	0.3	0.3	0.3	0.3	0.3	0.4	1	1.1	0.8	1.2	2.3	1.3	1.5	1.6	2.3
Boron	µg/g	-	-	<1	30	15	9	28	<1	2	8	<1	<1	<1	<1	1	1	24	<1	28	35	18	<1	10	<1
Cadmium	µg/g	0.6	3.5	<0.1	0.2	0.2	<0.1	0.2	0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	0.2	0.2	0.6	<0.1	<0.1	<0.1	0.3
Chromium	µg/g	37.3	90.0	23	39	37	34	37	40	44	8.7	8.6	6.2	6.6	10	12	40	47	31	27	44	31	27	43	29
Cobalt	µg/g	-	-	4.3	8.8	7.5	5.2	5.4	8.9	7.8	3.1	1.9	1.8	1.5	2.8	2.8	5.6	5.8	7.6	7.1	11	4.6	7.1	6.6	5.4
Copper	µg/g	35.7	197	9.6	44	24	19	33	19	25	120	8.9	21	130	4.7	20	30	44	12	32	58	47	29	45	62
Iron	µg/g	-	-	15000	34,700	23,200	15,900	15,400	27,600	26,400	5,500	5,800	5,700	5,200	6,200	8,800	12,300	12,600	15,900	16,700	24,500	14,400	52,800	26,800	32,900
Lead	µg/g	35.0	91.3	8.3	14	11	10	14	11	11	11	4	4	13	2.7	4.7	16	16	6.3	9.5	17	13	12	14	16
Manganese	µg/g	-	-	150	390	260	140	160	280	230	52	54	43	51	60	83	140	150	140	170	330	160	480	280	200
Mercury	µg/g	0.17	0.486	<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	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Molybdenum	µg/g	-	-	0.4	0.5	0.5	0.6	0.7	0.5	0.6	0.2	<0.1	<0.1	0.2	<0.1	0.4	0.7	0.4	1	1.4	8.2	2.5	5.9	2.9	1.7
Nickel	µg/g	-	-	16	40	32	19	29	34	32	14	7.2	7.1	11	9.3	12	31	32	24	30	48	23	29	33	23
Selenium	µg/g	-	-	<0.1	0.4	0.3	0.5	0.4	0.2	0.2	1.3	0.4	0.3	1.2	<0.1	0.2	0.3	0.3	<0.1	0.2	0.9	0.3	0.4	0.5	0.8
Silver	µg/g	-	-	<0.1	0.6	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8	<0.1	<0.1	<0.1	0.2	<0.1	0.3	<0.1	0.2	0.2	0.2
Strontium	µg/g	-	-	110	240	230	170	190	200	170	44	50	38	37	39	49	140	120	70	99	160	110	150	140	99
Titanium	µg/g	-	-	320	610	550	450	570	670	660	200	180	150	170	190	240	380	390	180	360	410	310	270	340	230
Uranium	µg/g	-	-	1.9	3.3	2.7	1.9	2.7	2.9	2.5	1.1	0.9	0.8	0.7	0.9	1.9	2.1	2.2	1.6	2.2	5.6	2	2.2	2.5	5.5
Vanadium	µg/g	-	-	22	45	41	29	34	40	41	9.6	9.2	8.2	8.4	11	15	30	32	25	30	44	27	34	38	27
Zinc	µg/g	123	315	45	120	69	62	76	83	100	**410**	29	74	**440**	13	70	83	130	51	110	150	130	76	100	170
Radionuclides																									
Radium-226	Bq/g	-	-	0.03	0.05	0.04	0.06	0.04	0.04	0.04	0.03	<0.01	0.02	0.02	<0.01	0.02	0.04	0.04	0.04	0.05	0.07	0.03	0.06	0.04	0.1
Lead-210	Bq/g	-	-	0.02	0.12	0.06	0.07	0.08	0.17	0.12	<0.02	<0.02	<0.02	0.02	<0.02	0.03	0.12	0.06	0.05	0.12	0.13	0.12	0.1	0.12	0.24
Polonium-210	Bq/g	-	-	0.06	0.09	0.09	0.08	0.08	0.11	0.11	0.02	0.01	0.02	0.02	0.02	0.05	0.15	0.06	0.03	0.09	0.14	0.09	0.08	0.14	0.28
Thorium-230	Bq/g	-	-	0.04	0.06	0.05	0.05	0.06	0.07	0.07	0.04	<0.02	0.03	0.02	<0.02	0.02	0.03	0.05	0.04	0.04	0.09	0.05	0.06	0.06	0.09

Notes: µg/g = Micrograms per gram; Bq/g = Becquerel per gram; < = less than; - = not available.
ISQG = Interim Sediment Quality Guidelines (CCME 2002); PEL = Probable Effect Levels (CCME, 2002).
Shaded values exceed the ISQG guidelines; bolded values exceed the PEL levels.
Source: Golder (2008)

Table 4.2-7
Maximum Concentrations of Radionuclides

Analyte	Unit	Concentration	Waterbody
Ra-226	Bq/g	0.10	Skinny Lake
Pb-210	Bq/g	0.24	Skinny Lake
Po-210	Bq/g	0.28	Skinny Lake
Th-230	Bq/g	0.09	Skinny/Cirque lakes

Bq/g = Becquerels per gram. Source Golder 2008

Concentrations of nitrogen compounds (e.g., nitrates/nitrites) and phosphorus appears higher in sediments from Ridge Lake than compared to other lakes.

4.3 Data Gaps

4.3.1 Water Quality Data Gaps

Water quality information is readily available for several years and seasons from Kiggavik-Sissons area watersheds, as documented in Supporting Document No. 4 (BEAK 1990) and supplemental Aquatic Baseline Report for 1990-1991 (BEAK 1992).

The Kiggavik FEARO panel did not identify any major deficiencies associated with the water quality database that was provided with the 1991 Environmental Impact Statement (EIS) submission, with the exception of recommended additional sampling during the under-ice period (Ecometrix 2006). Late winter sampling was conducted in March 1991 to address this gap.

The data that currently exists is approximately 17 years old, and will need to be updated in a number of locations to determine whether the existing data is representative of the current baseline conditions and analytical detection limits. It was recommended by Ecometrix (2006) that a cross-section of the lakes be analyzed and monitored for most aquatic components. Three lakes were identified from each of the three subwatersheds where the mine/mill facility will be located including both lower elevation, relatively shallow tundra lakes and the higher, deeper escarpment lakes.

Water chemistry and limnological data was collected from a range of lakes during the fall of 2007 from waterbodies within the Caribou Lake, Lower Lake and the Willow Lake sub basins (Golder 2008). Water quality sampling locations from the sampled sub basins is shown on Figure 4.3-1. Many of the lakes will be resampled in 2008 to provide supporting water chemistry data for benthic invertebrate community analysis. Therefore, following the successful completion of the 2008 field program, current water quality conditions should be established.

Several additional waterbodies outlined in Ecometrix (2006) may need to be sampled during future surveys depending upon the evolution of the conceptual design of project infrastructure. These include:

- Escarpment Lake;
- Jaeger Lake;
- Caribou Lake;
- Mushroom Lake; and
- Judge Sissons Lake.

In addition to the open water sampling conducted in the fall of 2007, additional sampling may need to occur in some lakes to document spring and under-ice conditions (Ecometrix 2006). The need for this should be determined following an assessment of the 2007 and 2008 fish capture information.

4.3.2 Sediment Quality Data Gaps

Although information has been collected between 1979 and 1991, there are several data gaps identified pertaining to sediment quality. With the exception of the 2007 sampling, most of the sediment chemistry results are outdated, having been collected more than 15 years ago. In this time, there have been improvements in analytical detection limits for many metals. In addition, the Arctic has been subject to long-range transport of atmospheric pollutants and climate change. As a result of changes to the development plans, some lakes that may be affected by the project have not been previously assessed (e.g., Mushroom Lake and Squiggly Lake). Therefore, it is important to establish a current benchmark of sediment quality.

Figure 4.3-1 Water Quality Sampling Locations

As recommended in the Ecometrix report (2006), a number of lakes from each watershed should be monitored for most aquatic components. The Kiggavik FEARO Panel identified a need for additional data on sediment quality based on the use of cores to measure variation with sediment depth (BEAK 1990). The panel also suggested that the analysis should examine metal concentrations in the fine sediment fractions. This additional core and fine-fraction sampling was not completed as part of the baseline program between 1979 and 1991 (Ecometrix 2006).

The objective of the sediment sampling program in 2007 was to fill some of the gaps. Still, only one or two stations were sampled in most waterbodies during 2007, whereas three to five stations would provide more representative results of the sediment chemistry of each lake. In addition, some lakes have still not been assessed. Sediment information remains to be collected from the following waterbodies:

Willow Lake Sub Basin:

- Rock Lake

Caribou Sub Basin:

- Caribou Lake; and
- Calf Lake.

Lower Lake Sub Basin:

- Cigar Lake;
- Knee Lake;
- Andrew Lake;
- Mushroom; and
- Shack Lake.

Judge Sissons Lake is the ultimately recipient of the three sub basins noted above. Attempts to study the entire lake would be time consuming and unnecessary to conduct, given the size of the lake. Stations scattered around the lake, instead of sampling the lake in complete entirety, is recommended.

Skinny Lake, Siamese Lake, and Squiggly Lake are located north of the Kiggavik area and are outside the Judge Sissons Lake sub basin. These lakes have been identified as potential sources of process water. Sediment quality information should be collected from these lakes as part of the baseline characterization of these lakes, and can be used as a reference for the operational period of the proposed mine.

5.0 FRESHWATER AQUATIC ORGANISMS AND HABITAT

5.1 Information Sources

Several aquatic baseline programs were completed in the Kiggavik area between 1979 and 1991 (BEAK 1990, 1992; Ecometrix 2006), and during 2007 (Golder 2008) to characterize the fish, benthic and planktonic communities in the waterbodies in and near the Project area. Table 5.1-1 presents a summary of the aquatic baseline information collected during that period. Baseline information gathered during these studies has included:

- phytoplankton and zooplankton community structure;
- benthic invertebrate structure and density;
- fish community structure;
- fish habitat; and
- fish chemistry (limited to three salmonid species).

5.2 Fish

5.2.1 Species and Life History

There are eight species of fish that have been captured in previous studies in the waters of the Kiggavik project area, including: Arctic char (*Salvelinus alpinus*), lake trout (*S. namaycush*), lake cisco (*Coregonus artedi*), round whitefish (*Prosopium cylindraceum*), ninespine stickleback (*Pungitius pungitius*), burbot (*Lota lota*), slimy sculpin (*Cottus cognatus*), and Arctic grayling (*Thymallus arcticus*; BEAK 1990; BEAK 1992). Three additional species of fish have been captured in Baker Lake. These include longnose sucker (*Catostomus catostomus*), lake whitefish (*Coregonus clupeaformis*), and fourhorn sculpin (*Myoxocephalus quadricornis*; McLeod et al. 1976). Although Baker Lake is outside the Kiggavik project area, the waters from the lakes in the project area eventually drain into Baker Lake via the Aniguq River.

The eleven fish species are from the following six taxonomic families;

- Catostomidae (longnose sucker);
- Salmonidae (lake cisco, lake whitefish, round whitefish, Arctic grayling, lake trout, Arctic char);
- Gasterosteidae (ninespine stickleback);
- Gadidae (burbot); and
- Cottidae (slimy sculpin, fourhorn sculpin).

Table 5.1-1
Summary of Aquatic Baseline Information Collected from the Kiggavik Project Area Between 1975 and 2007

Sub basin	**Siamese**	**Kavisilik**		**Willow**										
Water body	**Siamese Lake**	**Kavisilik Lake**	**Skinny Lake**	**Escarpment Lake**	**Felsenmeer Lake**	**Meadow Lake**	**Drum Lake**	**Lin Lake**	**Scotch Lake**	**Jaegar Lake**	**Sik Sik Lake**	**Pointer Lake**	**Rock Lake**	**Willow Lake**
Water Quality		1980	1986, 1988, 1989, 2007	1986, 1988, 1989	1986	1986	1986	1979	1979, 1980, 1986, 1988	1979, 1980, 1988, 1989	1979, 1986, 2007	1979, 1980, 1986, 1988[e], 1989, 1991, 2007		2007
Sediment Chemistry			1986, 2007	1986	1986			1986	1979, 1988	1979, 1988	2007	1979, 1988, 1991, 2007		1986, 2007
Phytoplankton									1979	1979, 1989		1979, 1989, 1991		
Zooplankton									1979	1979, 1989, 1991		1979, 1989, 1991		
Benthic Invertebrate Community		1980	1989 [b]						1979, 1980	1989[b]	2007	1979, 1980, 1989[b], 1990, 2007		2007
Bathymetry[a]		1979-1986	1979-1986	1979-1986	1979-1986	1979-1986	1979-1986	1979-1986	1979-1986	1979-1986, 2007	1979-1986	1979-1986, 2007	1979, 1980, 1986	1979-1986, 2007
Fish Community		1986	1986	1986	1986		1980	1986	1986	1980, 2007	2007	1979, 1986, 1988, 2007		1980, 2007
Fish Chemistry					1986			1986				1988		1986

Table 5.1-1
Summary of Aquatic Baseline Information Collected from the Kiggavik Project Area Between 1975 and 2007 (Continued)

Sub basin	Caribou					Boulder	Sissons	Lower										Squiggly	Baker
Water body	**Ridge Lake**	**Cirque Lake**	**Crash Lake**	**Fox Lake**	**Caribou Lake**	**Boulder Lake**	**Judge Sissons Lake**	**Lower Lake**	**Bear Island Lake**	**Shack Lake**	**Andrew Lake**	**Cigar Lake**	**End Grid Lake**	**Smoke Lake**	**Knee Lake**	**Lunch Lake**	**Mushroom Lake**	**Squiggly Lake**	**Baker Lake**
Water Quality	1986, 1988, 1989, 1991, 2007	1986, 1989, 2007	1979, 1980, 1986, 2007	2007	1986		1979, 1980, 1986, 1988, 1989, 1991	2007		1990, 2007	2007	1991	2007	1990	1990	1990	1991	1980	1975, 1979, 1980, 1989
Sediment Chemistry	1986, 2007	1986, 2007	1988, 2007	2007	1986	1986	1979, 1986, 1988, 1991	1990[c], 2007		1990, 1991, 2007	2007		2007	1990		1990			
Phytoplankton	1989, 1991	1989					1979, 1989, 1990, 1991	1990, 1991	1990	1990		1990, 1991		1990			1990, 1991		1975
Zooplankton	1989	1989					1979, 1989, 1991	1990	1990	1990		1990, 1991		1990	1990	1990	1990, 1991		1975
Benthic Invertebrate Community	1989, 2007[b]	2007	2007	2007			1979, 1980	1990[d] 2007		1990[d], 2007	2007	1990	2007	1990	1990[d]	1990[d]	1990	1980	1975
Bathymetry[a]	1979-1986, 2007	1979-1986, 2007	1979-1986, 2007	1979-1986, 2007	1979-1986		1979-1986	2007		2007	2007		2007	1990				1979-1986	
Fish Community	1986, 2007	1986, 2007	1980, 2007	1980, 2007	1986		1979, 1986	1990, 2007	1990	1990, 2007	1990, 2007	1990	2007	1990	1990	1990	1990	1980	1975
Fish Chemistry	1986				1986		1980	1990			1990	1990					1990		1989

Notes: a = Bathymetry surveys were conducted in 1979, 1980 and 1986.
b = Samples were collected in the outlet in 1989.
c= Sediment samples collected 1km upstream of Lower Lake in unnamed pond.
d= Benthic invertebrate samples collected in lakes in inlet streams in 1990.
e= Water quality samples also collected in Pointer Lake tributary.
Source: BEAK 1990 and 1992; Golder 2008

A brief summary of the life-history of each fish species is presented in the following subsections. This information is intended to provide a summary of the habitat requirements for the various species and help to identify data gaps in the fish and fish habitat existing data.

5.2.1.1 Longnose Sucker

The longnose sucker is commonly found throughout the NT and NU (Richardson et al. 2001). Longnose suckers occur in a variety of freshwater habitats including lakes, rivers and streams throughout their geographic range. They are known to exhibit lacustrine, adfluvial, and riverine life history types (Richardson et al. 2001).

Sexual maturity occurs at approximately five years for males and six years for females (Richardson et al. 2001). Longnose suckers spawn in the spring, from April to June, shortly after melting of ice cover on lakes (Richardson et al. 2001). Longnose suckers are broadcast spawners that primarily spawn in streams and rivers. Lake spawning may also occur in the shallows of lakes, along rocky and wave swept shorelines. Lake spawning usually occurs in water depths of 15 cm to 30 cm, over gravel or sand substrates (Richardson et al. 2001). The adhesive eggs incubate from 11 to 15 days before hatching (Richardson et al. 2001). The young remain in the gravel substrate for seven to fourteen days before emerging (depending upon water temperature). They will then occupy shallow areas of lakes, in association with vegetation and sandy substrates. Juveniles are also known to inhabit shallow weedy areas (Richardson et al. 2001).

Adult longnose suckers often inhabit deeper waters than other species of suckers, and have been known to occur at water depths of up to 183 m (Richardson et al. 2001). Longnose sucker grow considerably larger and live much longer in northern lakes, such as Great Slave Lake in the NT, than in southern water bodies.

The diet of longnose sucker consists mostly of amphipods, chronomids, midge larvae, caddis fly larvae and sphaeriid clams (Richardson et al. 2001). Their ventral mouth and large papillose lips aid in suction as they primarily feed on invertebrates from stream and lake beds (Mecklenburg et al. 2002).

5.2.1.2 Lake Cisco

Lake cisco are also known as lake herring, and commonly referred to simply as cisco in many reports. It has the most extensive North American distribution of any cisco species and is found throughout much of Canada (Scott and Crossman 1998). It is found in lakes from eastern Quebec, through the Great Lakes system and in Ontario, Manitoba, Saskatchewan, Alberta, Nunavut and the Northwest Territories. Lake cisco are present from the western Hudson Bay coast of NU to the Mackenzie River system in the NT, as far north as Great Bear Lake and south to the border of Alberta (Scott and Crossman 1998).

Lake cisco is primarily a lacustrine species but may be found in larger rivers in the NT and NU. They exhibit a lacustrine life history but anadromous[1] life-histories occur in areas outside of the NT and NU (James Bay - Quebec). For a complete description of lacustrine habitat requirements and life history for the lake cisco please refer to Richardson et al. (2001).

In Hudson Bay, the lake cisco can enter salt water and occurs in ponds on many of the islands (Richardson et al. 2001). A dwarf form of the lake cisco exists but literature does not report it selecting a different habitat than the normal form and will therefore not be separated when discussing habitat requirements. The dwarf-form can occur sympatrically with normal forms of cisco. Spawning is reported to primarily occur in lakes during the fall but McLeod et al. (1976) reported large concentrations of lake ciscoes at the mouth of the Thelon River during mid-November, where there is a considerable amount of coarser sand, gravel, and cobble that could provide suitable spawning habitat. Also lake cisco were caught in a pool area of the Thelon River 11 km upstream from the mouth. This area is separated from Baker Lake by sections of rapids. River spawning runs have also been reported in the Hudson Bay Region; however, rivers are not normally considered as lake cisco habitat (Scott and Crossman 1998).

A wide variety of food items comprise the diet of the lake cisco. The young are reported to feed on algae, copepods and Cladocera (Pritchard 1930). As adults they feed on copepods, small minnows, crustaceans, aquatic insects (mayflies and caddisflies), water mites, zooplankton, their own eggs and those of other fish species (Scott and Crossman 1998). Lake cisco are a significant part of the diet of many other fishes, including being a preferred food source for lake trout (Scott and Crossman 1998).

Most of the reports of lake cisco in rivers in the NT and NU have resulted from surveys of polar gas pipeline routes, arctic land use programs, or reviews of fish stocks. The function that rivers serve as habitat is unknown at this time.

[1] Note that the term anadromous is often applied to many Arctic fish species that move into marine environments as part of their life-history; however, most of these species in the Arctic are not truly anadromous (Myers 1949). Anadromous species undergo smoltification and adapt their physiology to the marine environment (e.g., Pacific salmon *Oncorhynchus* species).

5.2.1.3 Lake Whitefish

The lake whitefish complex includes three species of whitefish: lake whitefish (*C. clupeaformis*), Alaskan whitefish (*C. nelsoni*) and humpback whitefish (*C. pidschian*) (Richardson et al. 2001). This three species complex is simply referred to as lake whitefish as they are not recognized as distinct species by many authors and are only distinguishable from each other by modal gill raker counts (Mecklenburg et al. 2002).

Lake whitefish are found throughout the NT to their northern limit on Banks Island, as well as in NU from Victoria Island to the Keewatin District (McPhail and Lindsey 1970; Scott and Crossman 1998). They are most commonly found in lakes, although they may be found in larger rivers and brackish waters. As such, they are known to exhibit lacustrine, adfluvial and anadromous life history types (Richardson et al. 2001). In the Ungava, Hudson Bay Region, lake whitefish will enter brackish waters (Scott and Crossman 1998). Lacustrine populations have been shown to occur in two differing forms, normal and dwarf, as noted by Richardson et al. (2001); however, the literature does not show differential habitat use between the two forms, and so it assumed they exhibit similar habitat preferences (Richardson et al. 2001).

Anadromous Forms

Anadromous lake whitefish populations in the Mackenzie River begin upstream spawning migrations from September to October (Richardson et al. 2001). Spawning then occurs in upper reaches of tributary rivers starting from late September to October, followed by post-spawning out-migration to near shore areas and deep delta channels to overwinter (Richardson et al. 2001). Spawning is presumed to take place over gravel substrates for both anadromous and lacustrine populations. Lake whitefish eggs incubate over the winter and the fry will emerge the following spring and then are entrained in downstream flows to the delta or estuary (Richardson et al. 2001). In the Mackenzie River Delta, juvenile whitefish appear to use lakes in the Tuktoyaktuk Peninsula and other coastal reaches in the Mackenzie Delta (Richardson et al. 2001).

Anadromous lake whitefish tend to prefer waters with relatively low salinity, but in the NT will feed during the summer in the outer delta, channels and near shore areas (Reist et al. 2001). The diet of the anadromous lake whitefish includes a variety of organisms: gastropods, pelecypods, amphipods, chironomids, notostracans, cladocerns, ostracods and various insects (Reist et al. 2001).

Freshwater Resident Forms

Freshwater resident forms of lake whitefish may spawn anywhere from the late summer to December; however, spawning usually occurs from mid-September to mid-October in northern regions (Richardson et al. 2001). They are known to spawn in both lake and river systems over a variety of substrates from large boulders to gravel and occasionally sand (Richardson et al. 2001). Although lake whitefish appear to avoid using soft bottomed substrates for spawning locations, several authors have noted spawning in areas with silt substrates or emergent vegetation (Richardson et al. 2001).

Spawning usually takes place in shallow water areas at depths less than 8 m, but deeper spawning has been reported (Scott and Crossman 1998). Eggs are released randomly over the hard or stony substrate (Scott and Crossman 1998). The eggs settle into crevices where they incubate for several months before hatching in approximately March to May (Richardson et al. 2001). In northern waters, individual fish may only spawn every two or three years (Scott and Crossman 1998). In Great Slave and Great Bear lakes, approximately half of all males and females mature within their eighth year (McPhail and Lindsey 1970).

Juveniles are commonly found near the surface in shallow water areas close to spawning areas. Within these shallow water zones, young lake whitefish area frequently associated with boulder, cobble or sand substrates in association with emergent vegetation and woody debris (Ford et al. 1995).

Adult lake whitefish tend to leave the spawning grounds shortly after spawning, immediately returning to deepwater habitat to over winter (Ford et al. 1995). They are frequently found at depths greater than 10 m for most of the year to in excess of 100 m (McPhail and Lindsey 1970). Despite being primarily bottom dwelling, they may be found in the pelagic zone of lakes as well (Ford et al. 1995).

Lake whitefish are known to have nocturnal onshore movements into shallow water habitats at night to feed (McPhail and Lindsey 1970). The diet of lake whitefish includes: snails, clams, terrestrial insects, aquatic insects, plankton, and small fishes (Scott and Crossman 1998). The types of food consumed by lake whitefish are associated to their number and length of gill rakers. Food type has been correlated with gill raker length to such a strong degree that fish with shorter and more plentiful rakers have been shown to eat a higher proportion of benthic food sources (Scott and Crossman 1998).

Lake whitefish are preyed upon by lake trout, burbot and whitefish themselves in both the egg and adult life-stages (Scott and Crossman 1998). They are also deemed to be one of the most valuable commercial freshwater fish species in Canada (Scott and Crossman 1973).

5.2.1.4 Round Whitefish

Round whitefish occur in the NT and NU. They are found from Great Slave Lake and the Mackenzie River Valley in the NT, east to the Keewatin district of NU (Scott and Crossman 1998).

Spawning occurs from autumn to early winter, although in the more northern regions it usually occurs in October, primarily in lakes and occasionally in streams and rivers. Gravel and rubble (cobble sized material) substrates are preferred by round whitefish for spawning purposes (Normandeau 1969; Richardson et al. 2001). Males will usually arrive on the spawning grounds first, once the females arrive the fish will pair up instead of large spawning schools occurring (Scott and Crossman 1998). Round whitefish broadcast spawn their eggs over the chosen substrate, in 15 cm to 200 cm of water (Normandeau 1969). Hatching time will vary depending upon water temperatures, but generally occurs between March and May (Goodyear et al. 1982). After emerging from the eggs the young are generally found near the bottom and are associated with rock, sand and gravel substrates (Goodyear et al. 1982).

Adult round whitefish tend to be found over rocky substrates often in association with boulders (McPhail and Lindsey 1970). They are commonly found in shallows of lakes or slow flowing rivers and streams, and even in brackish waters (McPhail and Lindsey 1970; Scott and Crossman 1998).

The diet of round whitefish consists of a variety of benthic invertebrates, primarily mayfly, caddisfly and chronomids larvae, as well as small crustaceans, fishes and molluscs (Scott and Crossman 1998). Round whitefish are also suspected to feed on the eggs of other species of fish (Scott and Crossman 1998). In the north, they are known to be a component of the diet of lake trout; however, they do not make up a large portion of the diet (Scott and Crossman 1998).

5.2.1.5 Arctic Grayling

Arctic grayling are found throughout most of the NT and NU and have a holarctic distribution (Northcote 1995, Scott and Crossman 1998). In the Project study areas, the Arctic grayling is the most commonly occurring fish species and has been captured in each of the associated sub basins (BEAK 1992; BEAK 1990). Arctic grayling are primarily distributed in clear and cold waters of rivers, streams and lakes and are they known to exhibit lacustrine, adfluvial as well as riverine life-history types

(Richardson et al. 2001). Their preferred habitat consists of clear and cold waters, avoiding turbid areas such as the Mackenzie River, but are known to enter milky glacier streams (Scott and Crossman 1998). They are assumed to overwinter in deep pools of rivers and in deeper portions of lakes (Ford et al. 1985).

Spawning occurs as the ice is first starting to break up in the smaller streams. This timing can vary from April to June depending on the particular subarctic to arctic habitat (Scott and Crossman 1998). As the ice actually begins to break up the adults will begin their migration from the lakes and larger rivers to smaller streams and tributaries with areas of small gravel or rock bottomed substrates (Scott and Crossman 1998). Arctic grayling do not prepare a redd or nest; however males are territorial on the spawning grounds and will chase away other intruding males, displaying their large raised fins (Scott and Crossman 1998). The spawning pair create vibrations that help the discharged eggs and milt settle into the substrate with a covering of material stirred up during mating vibrations. This may occur once or several times during the spawning period. Post-spawning adults return to the lakes or rivers from which they migrated from (Scott and Crossman 1998).

The eggs hatch after approximately thirteen to eighteen days, with the alevin still absorbing their egg sac for a further eight or more days. Additionally, the young display rapid growth (Scott and Crossman 1998). Sub basins with lakes provide important rearing habitat for young-of-the-year (YOY) Arctic grayling. Lakes tend to contribute to higher summer water temperatures, which is attributed to increased growth rates compared to sub basins with few or no lakes (Luecke and MacKinnon 2008).

Both males and females have been noted to reach maturity at four years of age, but most spawners are between six to nine years of age as demonstrated in spawning populations in Great Slave Lake (Bishop 1971; Scott and Crossman 1998). Arctic grayling spawn numerous times throughout their lives; however, spawning does not always occur each and every year. Most spawners over the age of nine years tend to be females within the population and maximum ages for both sexes are between 11 to 12 years of age (Scott and Crossman 1998).

Young Arctic grayling feed primarily on zooplankton, shifting to immature insects as they grown in size. Adult grayling are primarily planktivores (Schmidt and O'Brien 1982), although they will feed on a large assortment of invertebrates, including both aquatic and terrestrial insects (Scott and Crossman 1998). The insects consumed include: caddisflies, midges, bees, wasps, grasshoppers, ants and a variety of beetles. They will also feed on small fishes, eggs, and crustaceans (Scott and Crossman 1998).

5.2.1.6 Lake Trout

Lake trout are found throughout the NT and NU, including on many of the Arctic islands, primarily in deep-water lakes (McPhail and Lindsey 1970; Lee et al. 1980). Lake trout may also be found in large, clear rivers (McPhail and Lindsey 1970; Scott and Crossman 1998; Lawrence and Davies 1978; Morrow 1980).

Both lacustrine and adfluvial life-history types are exhibited by lake trout (Scott and Crossman 1973; Goodyear et al. 1982). Lake trout are also known to exhibit several ecological forms or morphs within larger lakes (Alfonso 2004; Richardson et al. 2001).

Lake trout are late summer and early autumn lacustrine spawners. They are known to spawn through September and October in northern regions (Scott and Wheaton 1998; McPhail and Lindsey 1970; Scott and Crossman 1998; Martin and Olver 1980; Ford et al. 1995). The shallow, inshore areas of the lake are where most spawning tends to occur (McPhail and Lindsey 1970; Ford et al. 1995). Spawning substrate includes: cobble, rubble and large gravel substrates, interspersed with boulders. Areas free of sand, silt, clay and mud are preferable (McPhail and Lindsey 1970; Scott and Crossman 1973; Ford et al. 1995), although spawning has been known to occur, to a lesser extent, over these areas as well (Goodyear et al. 1982; Beauchamp et al. 1992). Additionally, lake spawning grounds are often associated with areas affected by water currents and wave actions. This is believed to keep the spawning grounds free of silt, sand and detritus (McPhail and Lindsey 1970; Martin and Oliver 1980; Sly and Evans 1996). Lake trout spawn at an variety of depths, from 0.12 m to 55 m deep (Morrow 1980; Goodyear et al. 1982; Marcus et al. 1984); although, depths in excess of 100 m have also been noted (Thibedeau and Kelso 1990). In large northern lakes, such as Great Slave and Great Bear lakes, individual lake trout appear to spawn every second or third year respectively (McPhail and Lindsey 1970).

Once laid, lake trout eggs settle into the cracks and crevices amongst the rocks, incubating for four to five months (Goodyear et al. 1982; Thibedeau and Kelso 1990; Marsden et al. 1995). The eggs usually hatch from March to April and even June in northern lakes such as Great Bear Lake (Scott and Crossman 1998). The YOY remain in spawning areas for several weeks, and even several months, before moving to deeper cooler waters (Scott and Crossman 1998; Martin and Oliver 1980; Morrow 1980; Goodyear et al. 1983; Peck 1982). Juvenile lake trout are often closely associated with cobble, boulder and rubble substrates usually within 0.3 m of the bottom. They seek shelter amongst boulders and woody debris (Ford et al. 1985; Davis et al. 1997). Juvenile lake trout are primarily solitary and display diel depth distribution. They are usually found in deeper waters during the day and move into shallow water habitat at night (Davis et al. 1997).

Adult lake trout may disperse to deeper water habitats after spawning has occurred (Scott and Crossman 1998; Goodyear et al. 1982). Often found in the pelagic zone within a lake, adults are most commonly found at depths in excess of ten meters (Scott and Crossman 1998; Martin and Olver 1980; Ford et al. 1985). Warmer summer water temperatures will drive the lake trout deeper to cooler (˜10°C) waters below the thermocline (Scott and Crossman 1998; Martin and Olver 1980; Sellers et al. 1998). Although lake trout exhibit a low salinity tolerance, they have been reported to occur in coastal regions of the NT (Communications Directorate 1991).

Stream and river spawning does occur in the Arctic, although it is rarer than lake spawning (Evans et al. 2002). In the NT, lake trout are known to spawn in some river mouths from September to early October (Scott and Wheaton 1954; MacDonald and Stewart 1980). In NU, spawning is also thought to occur in rivers, although perhaps not every year (MacDonald and Stewart 1980). Riverine spawning habitat and substrate consists of large boulders mixed with rubble and gravel in eddies in wide slow sections of the rivers (MacDonald and Stewart 1980).

Although lake trout are dispersed throughout Arctic and northern river systems, knowledge of exact riverine habitat use is limited compared to known lacustrine use.

Lake trout are able to take advantage of a variety of food sources. They are predacious and will feed on everything from freshwater sponges, plankton, aquatic insects, terrestrial insects, crustaceans, small mammals and numerous species of fishes (Scott and Crossman 1998). Fish species that they feed on include, but are not limited to: cisco, whitefish, smelt, perch, sculpin, shiners, sticklebacks, troutperch, suckers and even other lake trout.

5.2.1.7 Arctic Char

Arctic char occur in the coastal regions of both the NT and NU. They are the most northerly distributed freshwater fish, occurring on northern Ellesmere Island, as well as on many of the Arctic islands (e.g., Banks, Victoria, Devon, Somerset and Baffin) (Walters 1955; McPhail and Lindsey 1970; Scott and Crossman 1998; Babaluk et al. 1997). In coastal regions of the Arctic, they are found east of the Mackenzie River, around the Boothia and Melville peninsulas then south along the west Hudson Bay coast (McPhail and Lindsey 1970; Scott and Crossman 1998; Lee et al. 1980; Babaluk et al. 1997). In some northern fresh waters, Arctic char are the only fish present (Johnson 1980). There are several different Inuktitut names for Arctic char, each distinguishes a different life-history phase of the fish. The marine form is known as *iqalukpik*. The small land-locked form is called *nutilliq*, while the bright red spawning phase is known as *ivitaaruq* (COSEWIC 2003).

Arctic char display both anadromous and freshwater resident lacustrine life histories and they are found in rivers, lakes, estuaries and marine environments at different stages of their lifecycle (Scott and Crossman 1998; Lee et al. 1980; Johnson 1989). Anadromous char generally remain in freshwater systems for four to five years before undertaking their first seaward migration; however, there is variability in freshwater residence time as some char will only stay two years while others reside as long as nine years (McPhail and Lindsey 1970; Johnson 1989; Stewart et al. 1993).

When residing in lakes, adult Arctic char usually occupy the pelagic zone during the summer months feeding on zooplankton, making seasonal shifts to benthic and littoral areas in the latter months when food is less plentiful (Bjoru and Sandlund 1995; Jamet 1995). Within the lake, Arctic char may occur at assorted depths, but they are most common in less than 5 m of water over boulder, rubble and cobble substrates (Jamet 1995). Arctic char feed on a wide variety of organisms including algae, insects, fish and plankton while residing in freshwater habitats (Hunter 1970; McPhail and Lindsey 1970).

Anadromous adult char overwinter in lakes and migrate downstream during the spring ice break-up (Scott and Crossman 1998; Morrow 1980). They will then reside and feed in estuarine and marine environments before making the return migration to overwinter in lakes (Scott and Crossman 1998; Moore 1975; Johnson 1980; 1989). While in the marine environment they feed on several marine fish species during summer migrations including capelin (*Mallotus villosus*), sand lance (*Ammodytes americanus*), Arctic cod (*Boreogadus saida*) and young Greenland cod (*Gadus ogac*; Johnson 1989). Migrating char do not always return to the same river and may immigrate to other river systems (Johnson 1980; Gyselman 1984). Younger anadromous Arctic char display a high fidelity rate to their natal systems to spawn; however, fidelity decreases as they get older. In addition, there is an exchange of resting fish (non-spawning adults or juvenile fish) between different freshwater systems (Johnson 1980; Gyselman 1994).

The anadromous and resident forms of Arctic char spawn in both rivers and/or lakes; however, in the more northern regions, they principally spawn in deep lakes that withstand freezing over the winter months (Johnson 1980). Arctic char will mainly use rivers as migration routes, but some populations are believed to spawn in larger rivers (Kristofferson 1988; MacDonell 1996, 1997).

Timing for lacustrine spawning populations of Arctic char have been noted from September through October (Scott and Crossman 1973; Johnson 1980). This is at approximately the same time as the anadromous populations of char spawn (Gyselman 1984). Spawning occurs mainly over cobble and gravel substrates (McPhail and Lindsey 1970; Scott and Crossman 1998; Johnson 1980) in water ranging from

0.5 m to 6 m deep (Gyselman 1984; Johnson 1989). Additionally, they have also been reported as spawning in shallow water (0.5 m to 2 m) over silt, mud and clay substrates at times in association with vegetation (Hunter 1970; Gyselman 1984).

Individual Arctic char spawn on an intermittent basis every two to five years and three years is believed to be the likely average (Johnson 1980; 1989). A female char will build a redd in which her eggs are deposited and then later covered with gravel (Scott and Crossman 1998; Johnson 1989). After spawning, the adults over winter in the lake then migrate downstream to the ocean to feed the following spring (Johnson 1989).

The fry will hatch from the eggs in late March to April, but will remain in the gravel for a few more weeks before emerging close to the time of ice breakup (Scott and Crossman 1998; Johnson 1980). The YOY remain on the spawning grounds and move to the littoral zone later in the summer (Johnson 1980). When residing in the littoral zone, YOY are found amongst cobble, rubble, rocks seeking shelter and protection from predators (McPhail and Lindsey 1970; Richardson et al. 2001). Juvenile char may reside in small tributary streams and lacustrine habitats, moving in the fall to over winter in deeper lacustrine habitats that do not freeze to the bottom (Hunter 1976; Johnson 1980). YOY have also been observed occasionally in rivers (Moore 1975).

Within the Arctic char complex, both normal and dwarf forms have been well documented as occurring in the same lake (Johnson 1982; Reist et al. 1995). Dwarf forms of adult char generally inhabit shallow littoral habitats and then move to pelagic zones during late summer and fall. Normal forms of Arctic char occupy shallower littoral and benthic habitats than the dwarf forms (Richardson et al. 2001). Spawning differences also occur between forms, the dwarf char spawn at greater depths than normal char. Additionally, dwarf char are believed to mature much earlier (Parker and Johnson 1991). Sympatric populations of freshwater resident morphs of Arctic char are also known to occur in lakes (Richardson et al. 2001).

5.2.1.8 Ninespine Stickleback

The ninespine stickleback occurs throughout the NT and NU, from the Mackenzie Delta and River, in most rivers and lakes of north-central Canada, as well as in portions of the Arctic Archipelago (McPhail and Lindsey 1970; Scott and Crossman 1998; Lee et al. 1980). Ninespine stickleback are known to frequent slow streams, tundra ponds and the shallow bays of lakes (McPhail and Lindsey 1970; Scott and Crossman 1998; Lee et al. 1980). They display lacustrine, riverine and anadromous life history types (McPhail and Lindsey 1970; Scott and Crossman 1998).

Ninespine sticklebacks primarily mature in their first year, with a life expectancy of approximately only three and a half years (Scott and Crossman 1998; Wootton 1984). They tend to spawn in shallow waters during the spring and summer, ranging from May to July (McPhail and Lindsey 1970; Scott and Crossman 1998; Wootton 1976). Nests are built by the males, amongst weeds in densely vegetated areas. The nests are usually 10 cm to 15 cm off the bottom or sometimes directly on the bottom (Scott and Crossman 1998; McPhail and Lindsey 1970; Wootton 1976; Morrow 1980; Scott and Scott 1988). The male produces a kidney like secretion to bind the aquatic vegetation and debris together into a nest like structure. Males may also create nests using burrows made in muddy organic bottoms or may use areas between rocks along wave swept lake shores (McPhail and Lindsey 1970; Scott and Crossman 1998; Wootton 1976; Morrow 1980). Females will enter the nest, laying 20 to 30 eggs, which the male then fertilizes (Scott and Crossman 1998). The male chases the female away and guards the nests from predators (Scott and Crossman, 1998). Eggs hatch after four to seven days and the YOY are then moved into a nursery area constructed by the male from nest building material immediately above the nest (McPhail and Lindsey 1970; Wootton 1976; Morrow 1980). Until they are free swimming, they young remain in the nest. They then disperse into vegetation filled shallow waters and into deepwater waters in the fall to overwinter (McPhail and Lindsey 1970; Morrow 1980; Goodyear et al. 1982).

Adult sticklebacks typically inhabit densely vegetated areas: however, they can also utilize open water areas over sand and gravel beaches with sparse vegetation (McPhail and Lindsey 1970; Scott and Crossman 1998). The stickleback is a species that is able to tolerate low oxygen levels.

The diet of the Ninespine stickleback consists of aquatic insects, chronomid larvae, small crustaceans, mollusks, cladocerans and other zooplankton (McPhail and Lindsey 1970; Scott and Crossman 1973). When their numbers are in abundance the ninespine stickleback is of considerable importance to the diets of other piscivorous fish species (Scott and Crossman 1998).

5.2.1.9 Burbot

Burbot are found throughout most of the continental portions of the NT and NU (McPhail and Lindsey 1970; Scott and Crossman 1973). The burbot generally live in deep-water lakes; however, they are also found in rivers, streams and ponds (McPhail and Lindsey 1970; Scott and Crossman 1973). Burbot are known to exhibit lacustrine and riverine life history types within the Canadian Arctic, including both NT and NU (Scott and Crossman 1998). There are resident populations that complete their life-cycle within a single lake. There are also migratory populations that feed and rear mainly in lakes but then spawn in rivers or streams (Ford et al. 1995; McPhail 1997). Burbot have been documented as spawning in lakes, rivers and streams (McPhail and Lindsey 1970; Scott and Crossman 1998).

Burbot reach sexual maturity between three and four years of age, or later in the NT, with males maturing faster than females (Scott and Crossman 1998). They are a highly fecund species of fish, and a single female may lay up to a million eggs in its lifetime.

Burbot spawn under the ice between January and April, with spawning associated with water temperatures that are usually between 0.6°C and 1.7°C (Scott and Crossman 1998). Burbot are broadcast spawners, dispersing their eggs over sand, gravel or rubble substrates at a depth of 0.5 m to 3.0 m (Scott and Crossman 1998; Morrow 1980; Ford et al. 1995). Typically burbot spawn in shallow water, although activity has been documented at much greater depths (Morrow 1980; Goodyear et al. 1982). After fertilization, the eggs settle into interstices of the substrate (Scott and Crossman 1998; Ford et al. 1995). The eggs incubate from three weeks to three months depending on water temperature (Scott and Crossman 1998; Goodyear et al. 1982).

Upon hatching sac-fry are found primarily in the pelagic zone congregating over sand and rubble substrates (McPhail 1997). At the fingerling stage, YOY burbot become benthic littoral feeders (Ryder and Pisendorfer 1992). This change in habitat is matched by a change in activity patterns, from crepuscular (active at twilight) to nocturnal.

Nocturnal juvenile burbot seek daytime shelter in shallow water under physical structure such as boulders, cobble, logs, or within submergent vegetation, remaining inactive unless disturbed (Ryder and Pisendorfer 1992; Ford et al. 1995). Juvenile habitat includes rock and gravel bottoms along rocky shorelines (Ford et al. 1995). In early summer, both juvenile and adults will move to deeper offshore waters in the hypolimnion (Scott and Crossman1998; Ford et al. 1995).

Adult burbot prefer cooler deeper waters in the summer, and like juveniles, may make diel movements at night into shallower waters to feed. Both juveniles and adults are found over boulder, rubble, cobble and sand substrates (Scott and Crossman 1998).

In the north, burbot using river habitats are associated with the turbid waters in the main channels, and then enter tributaries in autumn (Breeser et al. 1988). Studies show that they prefer areas of moderate to high turbidities, low velocities (under 46 cm/s) and shallow depths (under 76 cm) (Suchanek et al. 1984). The turbidity of the water is used as cover (Ford et al. 1995).

Burbot are known to be sensitive to sub-surface illumination; they will seek shelter under stones, roots and in aquatic vegetation during the day (McPhail and Lindsey 1970).

Despite being considered to be a sedentary fish, they are known to make extensive migrations of over four hundred km in the NT. Northern populations also are thought to live longer, reaching greater size than southern populations (Scott and Crossman 1998).

Burbot are known to be voracious night feeding predators. Young burbot will feed on aquatic insects, crayfish, molluscs and invertebrates. Adults feed on eggs, invertebrates and numerous species of fish (Scott and Crossman 1998).

5.2.1.10 Slimy Sculpin

The slimy sculpin is distributed throughout the NT and NU, with the exception of the mainstem Mackenzie River and Arctic islands (McPhail and Lindsey 1970; Scott and Crossman 1998). They have both lacustrine and riverine life-history types and can be found in cool, clear or muddy waters of rivers; in streams with rocky or gravelly bottoms; as well as in lacustrine habitats (Craig and Wells 1976; Lee et al. 1980; McPhail and Lindsey 1970; Scott and Crossman 1998).

Slimy sculpin spawn in May, usually over sand, gravel and rock substrates in shallow waters (Lee et al. 1980; McPhail and Lindsey 1970; Morrow 1980; Scott and Crossman 1998). Males will select the spawning site, preferably under a rock, a log or a submerged tree root. A female is courted by the male, entering the nest to deposit her adhesive eggs on the ceiling, which the male then fertilizes. The female is driven out by the male, and he will guard the nest until they hatch approximately four weeks later (Lee et al. 1980; Mousseau and Collins 1987; Scott and Crossman 1998). A male sculpin may entice several females to lay eggs in his nest (Goodyear et al. 1982). Most male and female slimy sculpin reach maturity at age-2 (Mohr 1984).

After emerging, young are commonly found over shallow gravel and sand substrates (Mohr 1984). As they mature the young slimy sculpin will gradually shift from shallow water habitat to utilizing deepwater habitat (Mohr 1985). Adult slimy sculpin can be found at a wide range of depths (0.5 m to 210 m) and commonly occupy gravel and rocky substrates in lakes (Mohr 1984, 1985; Scott and Crossman 1998). Some slimy sculpin are known to inhabit soft sediment substrates and show increased growth, suggesting that these environments may be more productive. When living in small and shallow lakes their distribution has been known to show seasonal and diurnal changes due to changes in water temperature and or oxygen concentrations (Mohr 1984, 1985). In the NT, slimy sculpin were found in areas with both current and wind action in waters <10 m deep (McPhail and Lindsey 1970).

Slimy sculpin prey on a variety of aquatic insects, crustaceans, small fishes and aquatic vegetation (McPhail and Lindsey 1970; Mohr 1984).

5.2.1.11 Fourhorn Sculpin

The fourhorn sculpin (freshwater form) is a land locked relic, found in cold, deep freshwater lakes of northern Canada, Finland, Norway, Sweden, and Russia (COSEWIC 2003). Canadian museum records indicate that the fourhorn sculpin inhabit lakes in both the NT and NU (COSEWIC 2003). The fourhorn sculpin is called *kanayok* in Inuktitut (COSEWIC 2003). In comparison to the other species of fish previously discussed much less is known about the life-history and biology of the fourhorn sculpin; never the less, COSEWIC (2003) states that they may be of value as an indicator of environmental quality and may be considered a key species to monitor in areas of development in the Arctic.

The freshwater fourhorn sculpin is small, usually under 100 mm in length (Bengtsson and Bengtsson 1983; Muus and Dahlstrøm 1999). The marine form of the fourhorn sculpin is easily distinguished from other cottids by the presence of four long, club-like protuberances, which are actually frontal and parietal spines, on the top of the head (COSEWIC 2003). These spines are usually either reduced or entirely absent in the freshwater form (COSEWIC 2003). Although fourhorn sculpin that are found in lakes are considered to be of the freshwater form, some of these forms are known to be capable of inhabiting saline to hypersaline conditions (COSEWIC 2003).

Very little is known about the freshwater life-history of the fourhorn sculpin. The distribution of the species is believed to be restricted to about 23 lakes in the Canadian Arctic, only one of which has been studied in any detail (COSEWIC 2003). Despite little being known about the populations found in Arctic lakes, they are believed to be genetically unique and sensitive to natural and anthropogenic disturbances (COSEWIC 2003).

A large part of the biological information regarding this species has been contributed from research conducted in Garrow Lake, a meromictic lake[2] on Little Cornwallis Island, NU (Dickman 1991; Fallis et al. 1987). Sculpin from this lake have been found at a depth range of 3.8 m to 15 m (Fallis et al. 1987; Dickman 1991, 1995) within the salinity range of 3-35 ppt (Dickman 1995). The majority of specimens were caught at 7 m to 12 m (Dickman 1995). The Garrow Lake sculpin were shown to have a restricted depth range due to temperature, oxygen, and dissolved oxygen preference ranges. It is currently unknown if other lacustrine Canadian Arctic fourhorn populations exhibit similar depth distributions or if migrations occur (COSEWIC 2003). In the European range, freshwater fourhorn sculpin have a much deeper depth distribution, with specimens having been collected from depths up to 90 m (COSEWIC 2003).

[2] Meromictic lakes are stratified lakes in which the layers of the lake do not mix.

Temperature preferences are also believed to be a factor contributing to their depth distribution. Fourhorn sculpin populations studies appear to show the fish are restricted to depths greater than 40 m in late summer (August to September) to avoid warm water temperatures (Hammar et al. 1996). Seasonal migrations have been demonstrated within the Lake Vättern population as they migrate to depths greater than 40 m from August through September to avoid warmer summer waters (Hammar et al. 1996). Juveniles that were collected in studies were from within or below the thermocline in temperatures below 10°C. Fourhorn sculpin are usually found near the lake bottom at temperatures of 5°C or less; although, the freshwater form may have a higher tolerance for warmer temperatures, with some specimens being caught near the surface at 17°C (Hammar et al. 1996).

The reproduction of the freshwater fourhorn sculpin is not well understood (COSEWIC 2003). The age at first maturity for the species is unknown. A study of Lake Vättern fourhorn sculpin, ranging in length from 82 mm to 110 mm, suggested that sexual maturity may be reached at age four to six, or older (Hammar et al. 1996). In comparison, the reproductive cycle of the marine form has been described by Morrow (1980) and it is believed that some general features could also apply to the freshwater form (COSEWIC 2003). Fertilization is internal for the species. They are known to be territorial nest-builders with the males defending the eggs until they hatch into pelagic larvae (COSEWIC 2003).

As with reproduction, little is known concerning the growth of this sculpin. Garrow Lake sculpin are noted as having a very slow growth rate when compared to marine specimens from the Beaufort Sea based on length-weight regressions (COSEWIC 2003). In the Yukon, marine fourhorn sculpin grew slowly to a maximum otolith age of 14 years (Bond and Erickson 1989). YOY sculpin were 10 mm to14 mm in total length in late June and by September total lengths of 15 mm to 39 mm were observed by Bond and Erickson (1989). Other age-classes of sculpin ranged in size from 40 mm to 99 mm (Bond and Erickson 1989). Both the maximum age and timing of generations in the freshwater form are unknown (COSEWIC 2003).

The fourhorn sculpin is preyed on by piscivorous fishes and birds, including burbot, lake trout and Arctic char (Dickman 1995; Hammar et al. 1996). The feeding patterns of the fourhorn sculpin are largely nocturnal, but such activities become diurnal from November to April (COSEWIC 2003). Priapulids, mysids, isopods, amphipods, copepods, annelids, chironomids, and mollusks, small fishes and fish eggs comprise most of the food items consumed by the fourhorn sculpin (COSEWIC 2003). Stomach contents also have been found to contain insects, plant material, sand, gravel, and unidentified animal material (Morrow 1980; Muus et al. 1999).

5.2.2 Fish Baseline Collections in the Project Area

All the sub basins within the project study area have been surveyed for fish. The majority of the lakes in the Kiggavik project area were sampled during the past 30 years, with a variety of surveys carried out in 1975, 1979, 1980, 1986, 1990, 1991, and 2007. The sampling methods, intensity and areas have differed between surveys. Based on similarities in sampling methods and intensity, the field studies and results have been grouped into several sampling periods:

- 1975: Baker Lake sub basins;
- 1979 to 1986: Judge Sissons Lake, Caribou Lake, Willow Lake, Squiggly Lake, and Kavisilik sub basins; and
- 1990 to 1991: Lower Lake sub basins.

Additionally, 2007 sampling was carried out by Golder (2008). The methods and available results of the sampling program are discussed later in the Technical Information Document (TID) within a separate section.

5.2.2.1 Sampling Period 1975: Baker Lake

A fisheries study was carried out in the west end of Baker Lake from June 20th to September 16th, 1975 (McLeod et al. 1976). Baker Lake was studied in conjunction with the Lower Thelon River to provide environmental information for the proposed Arctic Island gas pipeline project. The methods used to capture fish were gill nets, dip nets, angling, beach seines, and electrofishing. Electrofishing was unsuccessful, presumably due to low water conductivity (McLeod et al. 1975). The mesh size of the gill nets used were 3.8, 6.4, 8.9, 11.4, and 14.0 cm.

Fork length and weight were measured for each species. Arctic char, lake trout, burbot and fourhorn sculpin were aged via otoliths. All other species were aged using scales. Stomach contents of fish were examined to determine dietary information. As well, gender, reproductive status, maturity, and fecundity, were collected.

The data collected was used to provide information on fish presence, distribution and relative abundance. The results also provided insight into patterns of sex ratios, age, growth, diet, spawning, and the local importance of the different fish species captured.

5.2.2.2 Sampling Period 1979-1989: Judge Sissons, Caribou, Squiggly, and Kavisilik Lake Sub Basins

The field studies, carried out in 1979 and 1980, were designed to collect baseline information over a broad area within the Project study area (BEAK 1990). In July 1986, additional sampling was implemented as part of pre-feasibility studies, with greater focus placed on documenting environmental conditions in a more rigorous manner. During the 1979, 1980 and 1986 studies, fish were sampled using index monofilament gill nets with six stretch mesh sizes ranging from 3.8 cm to 12.7 cm (BEAK 1987; BEAK 1990). Because the methods used in 1979, 1980 and 1986 were similar direct comparison of results between lakes and amongst those years is possible.

Information was collected and compiled on fish presence, distribution and relative abundance.

5.2.2.3 Sampling Period 1990-1991: Lower Lake Sub Basin

Field studies were carried out to collect information from lakes, within the Lower Lake sub basin, which had not been previously sampled in the 1979 to 1986 surveys (BEAK 1992). Sampling occurred in seven lakes and the connecting watercourses of the Lower Lake sub basin.

Field surveys were initiated in August of 1990. Due to high winds, it was not possible to sling the inflatable Zodiac boat between lakes, therefore fish sampling methods were limited to angling and seining. The following year (July 1991), fish were sampled using gill nets, with mesh sizes ranging from 3.8 cm to 12.7 cm. Each of the nine lakes previously sampled in 1990, were re-sampled, including: Cigar, Smoke, Knee, Lunch, Shack, Mushroom, Andrew, Bear Island and Lower lakes. Two identical nets were set overnight at Cigar Lake, whereas the rest of the lakes only had a single overnight set.

Information was collected and compiled on fish presence, distribution and relative abundance. Fork length and weight were measured and the stomach contents of fish were examined. Gender and reproductive status information were also collected.

5.2.3 Fish Baseline Results: 1975 - 1992

5.2.3.1 General Fish Distribution and Abundance

Eight species of fish were caught in the Kiggavik project area, an additional three species of fish were caught in Baker Lake (Table 5.2-1). None of these species is considered regionally or locally rare. The most common species was the Arctic grayling, which were caught in all the sub basins sampled. The second-most common species was lake trout, which were also caught in all sub basins, although in fewer lakes. The other two most common species were cisco and round whitefish; however, these species were not caught in the Caribou Lake sub basin.

Fish communities in Project area lakes are dominated by lake trout and Arctic grayling, with round whitefish, cisco, burbot, ninespine stickleback and sculpin also present in some waterbodies (Table 5.2-1). Shallow lakes that freeze to the bottom appear not to support overwintering fish populations. Deeper lakes, such as Ridge Lake and Cirque Lake, which have tributaries that offer no potential for fish passage, tend to have limited fish communities due to their isolation. Shallow lakes with larger inlet and outlet streams, such as Pointer Lake, have periodic winterkills but are readily repopulated from elsewhere in the sub basin. Judge Sissons Lake, the largest lake studied, has a full complement of all the species found within the Project area. Arctic char were not found to inhabit the upper Aniguq sub basin, presumably the result of a barrier to upstream movements closer to Baker Lake. Baker Lake had the largest number of fish species.

Species with limited distribution in the Project area included burbot, ninespine stickleback, Arctic char, slimy sculpin, and fourhorn sculpin. Ninespine stickleback was found in a small number of lakes in Judge Sissons, Baker, Pointer, Willow, and Caribou sub basins. Fourhorn sculpin, lake whitefish and longnose sucker were only caught in Baker Lake. Arctic char were not captured in the Kiggavik local study area, but were caught in Squiggly and Baker lakes, in the regional study area. It appears that Arctic char may not have been able to access the sub basins of the local study area. Slimy sculpin were caught in only three lakes in the Judge Sissons, Willow and Baker Lake sub basins. Burbot were captured in Andrew, Judge Sissons, Squiggly and Baker lakes (Table 5.2-1).

Table 5.2-1
Fish Species Distribution in the Kiggavik and Baker Lake Areas From 1975 to 2007

Fish Species	Longnose Sucker	Lake Cisco	Lake Whitefish	Round Whitefish	Arctic Grayling	Lake Trout	Arctic Char	Ninespine Stickleback	Burbot	Slimy Sculpin	Fourhorn Sculpin
	Catostomus catostomus	*Coregonus artedi*	*Coregonus clupeaformis*	*Prosopium cylindraceum*	*Thymallus arcticus*	*Salvelinus namaycush*	*Salvelinus alpinus*	*Pungitius pungitius*	*Lota lota*	*Cottus cognatus*	*Myoxocephalus quadricornis*
Lower Lake Sub Basin											
Andrew Lake					X	X			X		
Lower Lake		X			X	X					
Bear Island Lake					X	X					
Shack Lake					X	X					
Cigar Lake		X		X	X	X					
End Grid Lake					X						
Smoke Lake		X			X						
Knee Lake					X	X					
Lunch Lake		X		X	X	X					
Mushroom Lake		X		X	X	X					
Judge Sissons Lake Sub Basin											
Judge Sissons Lake		X		X	X	X		X	X	X	
Boulder Lake Sub Basin											
Boulder Lake*											
Willow Lake Sub Basin											
Pointer Lake		X		X	X	X		X			
Escarpment Lake				X	X	X					
Felsenmeer Lake				X	X	X					
Meadow Lake											
Drum Lake					X						
Lin Lake					X						
Scotch Lake				X		X		X		X	
Jaegar Lake											
Sik Sik Lake								X			
Rock Lake*											
Willow Lake					X	X		X			
Caribou Lake Sub Basin											
Caribou Lake					X	X					
Ridge Lake						X					
Cirque Lake					X			X			
Crash Lake					X						
Fox Lake					X	X					
Lower Lake Sub Basin											
Siamese Lake*											
Kavisilik Lake Sub Basin											
Skinny Lake		X		X	X	X					
Kavisilik Lake		X		X	X	X					
Squiggly Lake Sub Basin											
Squiggly Lake				**X**	X	X	**X**		X		
Baker Lake Sub Basin											
Baker Lake	X	X	**X**	**X**	X	X	**X**	X	X	X	X

Note: * = no field survey information;
Source = BEAK 1990 and 1992; Golder 2008

5.2.3.2 Fish Distribution and Abundance by Sampling Period

Summary of the Results from the Baker Lake 1975 Survey

Eleven species of fish were captured in Baker Lake. The most common species, in decreasing order of abundance, were lake cisco, lake trout, lake whitefish, round whitefish, Arctic char and Arctic grayling. These six species made up approximately 97% of the total catch (McLeod et al. 1976). The remaining 3% of the catch in decreasing order of abundance were slimy sculpin, ninespine stickleback, longnose sucker, fourhorn sculpin, and burbot (see Table 5.2-2).

Table 5.2-2
Number and Species of Fish Captured During the 1975 Baker Lake Survey

Species	# Caught
Lake Cisco	841
Lake Trout	202
Lake Whitefish	155
Round Whitefish	96
Arctic Char	82
Arctic Grayling	11
Ninespine stickleback	11
Longnose sucker	7
Fourhorn sculpin	5
Slimy Sculpin	2
Burbot	1
Total	1,413

Notes: Source: McLeod 1976: Table 16

A total of 1413 fish were caught, of which 841 were cisco, making them the most abundant species captured. Lake cisco were caught at all netting sites, and when nets were set at 35 m depths, they made up over 76% of the fish caught. Lake trout were the second most abundant species with 202 fish caught during the survey (McLeod 1976). Lake trout is also probably the most abundant predator species in the lake. Round whitefish comprised about ten percent of the total number of fish collected. The largest catches of lake whitefish were from the relatively warm shallow waters, near islands and along the south shore at the mouth of Kingak and Kamaniguak lakes (McLeod 1976). Lake cisco, lake trout, and round whitefish made up 84.8% of the total catch.

Despite an extensive netting program and the use of various methods, very few Arctic grayling (11), ninespine stickleback (11), longnose suckers (7), fourhorn sculpin (5), slimy sculpin (2) and burbot (1) were caught. The presence of longnose suckers in Baker Lake is believed to represent the limit of their northeastern distribution in Keewatin district (McLeod 1976). The presence of fourhorn sculpin in Baker Lake is important because they were of the marine form (McLeod 1976). All the fourhorn sculpin caught were mature females captured in water 3 m to 24 m deep.

Summary of the Results from the 1979 – 1986 Survey of Sissons, Caribou, Willow, Squiggly, and Kavisilik Lake Sub Basins

Seven species of fish were caught during the 1979-1986 surveys, including lake trout, lake cisco, round whitefish, arctic grayling, burbot, ninespine stickleback and slimy sculpin. Data were compiled to show the distribution and relative abundance of the five most common species (Table 5.2.3). Catch data were also converted into standardized catch per unit effort to provide an additional measure of relative abundance (Table 5.2-4).

Lake trout and Arctic grayling were the most widely distributed species. Arctic grayling were captured in 21 of the 25 sampled lakes. In some of the lakes (e.g., Cirque, Drum, Lin) it was the only species present (Table 5.2-3).

Lake trout was captured in 14 of the 25 lakes sampled (Table 5.2-3). Lake trout were the dominant species in Escarpment, Felsenmeer, Ridge, Judge Sissons, Scotch, Skinny, Kavisilik and Squiggly lakes; however, lake trout were scarce in Caribou and Pointer lakes. Biomass of lake trout in each of the lakes is found in Table 5.2-4.

Round whitefish were captured in the larger and deeper lakes, where their populations were abundant. Lake cisco were captured in many of the same lakes as round whitefish.

Arctic char were only caught in Squiggly Lake and Baker Lake. No fish were caught in Sik Sik or Meadow lakes. In Ridge Lake, lake trout was the solitary species captured.

Table 5.2-3
Distribution and Relative Abundance of Fish Species in Study Area Lakes From 1979 to 1986

Lake	Lake Trout	Arctic Grayling	Round Whitefish	Cisco	Arctic Char
Escarpment	A	C	A	-	-
Felsenmeer	A	A	A	-	-
Meadow	-	-	-	-	-
Ridge	A	-	-	-	-
Cirque	-	A	-	-	-
Drum	-	A	-	-	-
Lin	-	A	-	-	-
Sik Sik	-	-	-	-	-
Caribou	S	C	-	-	-
Willow	C	C	-	-	-
Judge Sissons	A	S	C	C	-
Pointer	S	S	-	C	-
Scotch	A	-	A	-	-
Skinny	A	S	A	C	-
Kavisilik (Lake 575)	A	S	C	A	-
Squiggly	A	S	A	-	C
Smoke	-	A	-	C	-
Cigar	C	C	A	C	-
Mushroom	C	A	A	C	-
Lunch	S	A	-	-	-
Andrew	-	S	-	-	-
Shack	-	A	-	-	-
Bear Island	-	S	-	-	-
Lower	-	C	C	S	-
Knee	-	S	-	-	-

Notes: A = Abundant; C = Common; S = Scarce. Qualitative abundance based on limited catch data.
Source: BEAK 1990: Table 3.3.8, BEAK 1990 Table 7.13

Table 5.2-4
Standardized Catch per Unit Effort for Fish Stocks in Lower Lakes

Lake	Figure ID	Species	Number	Biomass (kg)		Total Biomass of all Species (kg)
				Total	Mean	
Ridge	K4	Lake Trout	17	26.5	1.6	26.5
Escarpment	K26	Lake Trout	8	13.4	1.7	
		Grayling	4	1.4	0.4	
		Round Whitefish	26	13.2	0.5	28
Felsemeer	K24	Lake Trout	8	13.2	1.7	
		Grayling	8	4.2	0.5	
		Round Whitefish	7	2.3	0.3	19.7
Skinny	K39	Lake Trout	9	27.6	3.1	
		Round Whitefish	8	3.4	0.4	
		Cisco	1	0.5	0.5	31.5
Kavisilik	K37	Lake Trout	11.3	26.6	3.2	
		Cisco	10	2.4	0.2	
		Round Whitefish	1	0.3	0.3	39.3
Lin	K30	Grayling	62	13.3	0.2	13.3
Cirque	K11	Grayling	11	2.6	0.2	2.6
Caribou	K22	Lake Trout	1	1.2	1.2	
		Grayling	4	1	0.3	2.2
Pointer	K5	Lake Trout	2	7.2	3.6	
		Cisco	6	1.1	0.2	
		Grayling	1	0.3	0.3	4.1
Judge Sissons	S2-S9	Lake Trout	9.8	26.5	2.7	
		Cisco	1.7	0.5	0.3	
		Round Whitefish	1.4	0.5	0.4	
		Grayling	0.3	0.2	0.6	
		Burbot	0.2	0.1	0.5	27.8
Scotch	K34	Lake Trout	11	24.3	2.2	
		Round Whitefish	7.3	4.6	0.6	28.9

Notes: a = One standard unit of effort represents an 18-hour set of index monofilament gill nets of 45.7 m (150 feet) total length, consisting of 7.6 m (25 feet) panels of the following stretch mesh sizes: 3.8 cm (1.5 inch), 5.1 cm (2 inch), 6.4 cm (2.5 inch) 7.6 cm (3 inch), 10.2 cm (4 inch) and 12.7 cm (5 inch). Source: BEAK 1992 Table 4

Summary of Results from the 1990 – 1991 Survey of Lower Lake Sub Basin

Four species of fish were captured in the survey of the Lower Lake sub basin. Arctic grayling were the major species and were present in all the sampled lakes (Table 5.2-5). Lake trout were also present in each sampled lake, with the exception of Smoke Lake. Lake cisco and round whitefish were both found in Cigar, Mushroom and Lower Lakes. Round whitefish and lake cisco were always found together, with the exception of capturing only lake cisco in Smoke Lake.

Additional fish data collected include catch-per-unit effort, fork length, weight, sex, stomach contents, age, fecundity, gonad condition. Tables showing fork length, weight, sex and stomach contents of fish are provided in Appendix III.

Table 5.2-5
Lower Lake Sub Basin Major Fish Species Presence and Abundance, 1991 Survey

Lake	Arctic Grayling	Lake Trout
Cigar	P	P
Knee	A	P
Lunch	A	P
Andrew	A	P
Shack	A	P
Mushroom	P	P
Bear Island	A	P
Lower	A	P
Smoke	A	-

Note: P = presence, A = abundant, - = not captured.
Source :BEAK 1992 Table 4.9

5.2.3.3 Fish Species Distribution, Abundance, and Health 1975 - 1992

The fish population and health information is presented by fish species starting with the most widely distributed fish species.

Arctic Char

Distribution and Relative abundance

Arctic char were only captured in Squiggly and Baker lakes. In Squiggly Lake, Arctic char were classified as common. Arctic char made up 5.8% of the total catch and was the fifth in abundance of fish netted in Baker Lake.

Age and Growth

The maximum age of captured fish was nineteen years and it had a fork length of 574 mm (McLeod et al. 1976).

Maturity

Based on the Baker Lake collections, it was estimated that females matured at age-8 and males at age-11, but it was often difficult to assign maturity, especially for male fish (McLeod et al. 1976).

Food Habits

Stomach contents of Arctic char were consisted mainly of plecopterans, detritus, and an unidentifiable material. Molluscs, insects, and fish remains (slimy sculpin) were found in stomach contents as well (McLeod et al. 1976).

Spawning

About a quarter of the female char caught during the sampling program were mature females containing re-absorbing eggs from a previous spawning attempt and were deemed capable of spawning again in the coming season (McLeod et al. 1976). No spawning or rearing areas were identified within the lake and very few juvenile fish were captured.

Arctic Grayling

Distribution and Relative Abundance

Arctic grayling was the most widely distributed species and abundant species (Table 5.2-3). It occurred in all of the sampled sub basins and was captured in twenty-five of the thirty surveyed lakes (BEAK 1992). In Drum, Lin and Crash lakes it was the only fish species present and it was characterized as relatively abundant (Table 5.2-3).

During the 1986 surveys, Arctic grayling was found in most of the lakes that lake trout were found in. It was abundant or common in all lakes except Judge Sissons, Pointer, Skinny, Kavisilik and Squiggly lakes. During the 1990 and 1991 surveys of the Lower Lake sub basin, Arctic grayling was found in all of the nine surveyed lakes, and it made up approximately one-half the fish captured (52%). In the 1975 survey of Baker Lake, Arctic grayling was the sixth most abundant fish species collected.

It was not possible to compare the Arctic grayling populations over time with the available data. The fish sampling was not done in a manner that would provide estimates of stock size.

Age and Growth

In Lin and Cirque Lakes, the Arctic grayling population was highly abundant, but comprised of small stunted fish (BEAK 1992). This is believed to be probably due to the absence of trout or other predatory species. In other lakes where lake trout, lake cisco or round whitefish were present, the grayling population was less abundant, but consisted of individuals of larger average size (BEAK 1987).

Maturity

Approximately 49% of Arctic grayling collected during the 1975 Baker Lake survey were immature juveniles (McLeod 1976). More than 65% of the Arctic grayling collected from Lunch lake during the 1990/1991 surveys were immature fish (BEAK 1992).

Food Habits

An examination of the stomach contents of Arctic grayling from Baker Lake showed that their diet consisted of benthic invertebrates, aquatic insects, and plants (McLeod et al. 1976). The stomach contents of Arctic grayling captured lakes in the Lower sub basin at the project site showed a predominance of snails, midge larvae, and other insects, zooplankton and bottom material (BEAK 1992). The occurrence of food items in the stomach contents of captured fish didn't greatly differ from site to site: Smoke Lake (snails and bottom material), Cigar Lake (snails, midge larvae, and beetles), Mushroom Lake (snails, clams, midge larvae, and other insects), Lunch Lake (bottom material), Shack Lake (zooplankton, midge larvae, and other insects), Lower Lake (zooplankton, snails, midge larvae, and other insects).

Spawning

Of the collected Arctic grayling, two had already spawned. The spawning season was probably completed before June (McLeod et al. 1976). No spawning information was collected during the Lower sub basin surveys.

Burbot

Distribution and Relative Abundance

Burbot were captured in only four lakes in the Project area; however, each of the four lakes, (Andrew, Judge Sissons, Squiggly and Baker), are in four different sub basins. Burbot appear to be widely distributed amongst the sub basins, but they are not very abundant. The Baker Lake survey involved extensive netting operations, seining, electrofishing, angling and dip netting, for nearly three months and only one burbot was captured (Table 5.2-2) (McLeod et al. 1976). It should be noted that the burbot are difficult to capture in gill nets (the primary collection method used in many of the studies) and therefore, their abundance in the catch may under represent their actual relative abundance.

Additional information

No additional information has been collected regarding age, growth, maturity, diet or spawning.

Lake Cisco

Distribution and Relative Abundance

Lake cisco are one of the five major fish species in the project area. It was captured in nine of the thirty-three lakes in the study area, including Cigar, Smoke, Lunch, Mushroom, Judge Sissons, Pointer, Skinny, Kavisilik, and Baker lakes. Lake cisco, like the round whitefish, seem to prefer larger and deeper lakes (e.g., Baker, Kavisilik, Skinny, and Judge Sissons lakes), but was also be found in shallower lakes that are linked to other lakes by well defined stream channels (e.g., Mushroom, Lunch, Smoke, and Cigar lakes) (BEAK 1987a, b).

Lake cisco were the most abundant fish captured during the Baker Lake survey, comprising about 60% of the total number of fish captured (Table 5.2-2). The most abundant catches of lake cisco were made in shallow waters (McLeod et al. 1976). During the 1979 to 1986 surveys, it was classified as abundant in Kavisilik Lake and common in Judge Sissons, Pointer, and Skinny lakes.

There is no information on the relative abundance of lake cisco in the lakes of Lower Lake sub basin.

Age and Growth

Age and growth information is available only from Baker Lake (McLeod et al. 1976). The oldest lake cisco captured from Baker Lake was fourteen years, which also equals the oldest specimen previously recorded (McLeod et al. 1976). The largest fish was a twelve year old with a fork length of 421 mm and a weight of 1150 g (McLeod et al. 1976).

Maturity

Mature females and males collected in Baker Lake were sexually mature at age-8 and age-9, respectively (McLeod et al. 1976).

Food Habits

The stomach contents of lake cisco from the Lower Lake sub basin showed that their diet mainly consisted of snails, zooplankton, clams, and bottom material (BEAK 1992). An examination of the stomach contents of lake cisco from Baker Lake showed that zooplankton was a common food item, while insects, mysids, and water mites were also major components of their diet (McLeod et al. 1976).

Spawning

During the Baker Lake survey, several gravid lake cisco were captured; however, no completely ripe fish were obtained by mid September, indicating that spawning probably occurs during freeze up and under ice (McLeod et al. 1976).

Importance

Lake cisco are an important food source for lake trout (McLeod et al. 1976).

Lake Trout

Distribution and Relative Abundance

Lake trout was the second most widely distributed fish species, found in twenty-one of the thirty sampled lakes during baseline surveys. Although it was also the second most abundant species, lake trout was the most abundant piscivorous fish species in the project area.

Lake trout was the dominant species in Escarpment, Felsenmeer, Ridge, Judge Sissons, Scotch, Skinny, Kavisilik and Squiggly Lakes. In Felsenmeer, Ridge and Escarpment lakes, lake trout has survived in small isolated stable populations with no probability of recruitment from other lakes as reflected in the present genetics (BEAK 1987). Lake trout were absent or scarce in the tundra plain lakes (e.g., Caribou, Drum, Lin, Willow, and Pointer lakes) likely due to limited winter habitat when most or all of the lake water freezes completely (BEAK 1987). Although often found in the same lakes as Arctic grayling, lake trout was the only species captured in Ridge Lake.

Age and Growth

Lake trout from Baker Lake were aged using otolith examination. The oldest fish recorded was thirty years old. The largest was twenty-eight years old, weighing 6,885 g with a fork length of 820 mm. The youngest fish collected was two years old (McLeod et al. 1976).

The lake trout populations in Judge Sissons, Skinny, Kavisilik, and Squiggly lakes contained a broad range of age classes (BEAK 1987). Table 5.2-6 presents information on lake trout sampled from the Pointer and Judge Sissons lakes. The oldest lake trout was approximately forty-one years old, with a fork length of 756 mm (Table 5.2-6).

Maturity

The sampling programs found it difficult to identify the maturity stage of lake trout caught in Baker Lake, so the fish were often designated as sexually developing. Developing males and females, were recorded as late as the 18 year age group for males and 23 year age group for females.

Food Habits

An examination of the stomach contents of lake trout from Baker lake showed that they were primarily piscivorous; however they did consume a wide variety of food items including fish and benthic invertebrates. Lake cisco, round whitefish, slimy sculpin and ninespine stickleback were found in more than 70% of the stomachs containing food (McLeod 1976). An examination of the food contents in lake trout from Lower Lake sub basin showed that the most common food items were snails and fish (BEAK 1992).

Table 5.2-6
Mean Fork Lengths (mm) and Weights (g) of Lake Trout in All Age Classes Sampled from Pointer and Judge Sissons Lakes

Age Class	No. of Fish	Mean Length (mm)	Standard Deviation	Mean Weight (g)	Standard Deviation
5	2	227.5	38.9	142.5	45.9
7	1	265.0	-	175.0	-
8	4	345.0	23.5	381.3	122.4
9	12	346.3	48.8	481.9	235.6
10	9	365.9	57.6	573.9	297.2
11	6	364.8	57.1	530.0	340.2
12	3	454.0	45.2	1,010.0	371.6
13	6	512.0	36.9	1,421.7	333.8
14	9	565.9	108.2	1,983.3	938.5
15	12	541.9	65.8	1,816.7	656.1
16	4	603.3	69.0	2,670.0	825.0
17	5	596.0	36.0	2,500.0	387.3
18	18	562.6	64.2	1,906.1	686.8
19	11	606.4	39.7	2,430.0	451.9
20	11	623.6	60.4	2,850.0	793.7
21	4	648.8	37.3	2,950.0	526.0
22	5	656.6	41.7	3,270.0	717.3
23	10	698.7	85.8	4,030.0	1,944.8
24	9	664.3	81.8	3,634.4	1,438.1
25	4	673.0	112.1	3,612.5	1,946.1
26	4	640.5	68.5	3,000.0	912.9
27	3	704.3	33.0	3,866.7	665.8
28	5	708.0	48.8	4,300.0	940.7
29	3	643.3	12.6	3,000.0	-
30	3	691.0	76.9	3,950.0	1,344.4
31	3	674.0	80.5	3,350.0	1,310.5
32	1	705.0	-	5,700.0	-
33	4	763.8	56.2	5,350.0	1,171.2
34	3	826.7	69.0	6,833.3	2,478.6
35	3	829.0	18.5	6,400.0	600.0
36	2	650.0	77.8	3,225.0	671.8
37	1	735.0	-	6,000.0	-
38	1	775.0	-	5,000.0	-
39	3	808.0	90.1	6,100.0	2,946.2
40	2	737.5	38.9	4,850.0	636.4
41	1	756.0	-	4,500.0	-

Source: Table 3, BEAK 1992

Spawning

All fish captured during the June to September Baker Lake survey were not ripe. McLeod et al. (1976) noted that lake trout probably spawned in late fall; therefore, the previous sampling in the Project area likely terminated before onset of spawning maturation. Suitable boulder and cobble spawning habitat is prevalent in the western portion of Baker Lake; however, spawning areas were not actually located. In fact, no spawning information has been collected from the surveys of the lakes in the Project area.

Lake Whitefish

Distribution and Relative Abundance

Lake whitefish were only captured during the 1975 survey in Baker Lake. They were the third most abundant fish species in the lake, in terms of the number collected during netting, after lake cisco and lake trout and comprised 10% of the total catch (McLeod et al. 1976).

Age and Growth

The Baker Lake collection included fish from age-2 to age-17, with most of the fish captured being from the age-9 to age-10 groups (McLeod et al. 1976). Mean fork length ranged from 169 mm for age-2 fish and 511 mm for age-17 fish (McLeod et al. 1976).

Maturity

The youngest mature male and female collected were age age-11 and age-8, respectively.

Food Habits

Stomach contents of 143 lake whitefish from Baker Lake were analyzed. The major food items are listed in Table 5.2-7. Fish with empty stomachs constituted 36.4% of the sample.

Spawning

No fry or juveniles were captured during the 1975 survey. Confirmed spawning locations were not found during the survey; however, boulder, rubble, sand substrate, and deep waters over silty substrate were all identified in Baker Lake. This known preferred spawning habitat for lake whitefish was common through Baker Lake (McLeod et al. 1976).

Table 5.2-7
Frequency of Food Items in Stomachs of Lake Whitefish from Baker Lake

Food Item	No.	Percentage
Gastropoda	62	68.1
Chironomidae (larvae/pupae)	29	31.9
Pelecypoda	26	28.6
Fish	8	8.8
Notostraca	8	8.8
Unidentified Invertebrates	7	7.7
Hydracarina	2	2.2
Trichoptera	1	1.1
Unidentified Plant/Animal Material	1	1.1
Empty stomachs	52	36.4
Total Fish Sampled	143	

Note: No = number of times the food item occurred. Percentage values are based only on those stomachs that contained food and often these contained more than one food item. Source McLeod et al 1976: Table 27.

Longnose Sucker

Distribution and Relative Abundance

Longnose sucker have only been captured in Baker Lake, and its presence is thought to represent the approximate limit of its northeastern distribution in the Keewatin district (McLeod et al. 1976). Only seven fish were captured despite an extensive netting program using different net sizes (McLeod et al. 1976).

Other Information

Apart from water temperature and habitat description, no additional biological data has been collected.

Round Whitefish

Distribution and Relative Abundance

Round whitefish are the third-most widely distributed species in the Project area. They were found mostly in the larger and deeper lakes and was generally absent from the shallower lakes in the project area. Round whitefish were captured in Cigar, Lunch, Mushroom, Pointer, Judge Sissons, Escarpment, Felsenmeer, Scotch, Skinny, Kavisilik, Squiggly and Baker lakes. The first four lakes are shallow, whereas the rest are deeper (6 to >20 m deep).

Round whitefish were abundant or common in each of the lakes it was captured in (Tables 5.2-3). In Baker Lake, it was fourth most commonly collected species netted after lake cisco, lake trout and lake whitefish (Table 5.2-2).

Age and Growth

The maximum age recorded for round whitefish in Baker Lake was sixteen years. That individual was also the largest round whitefish, with a fork length of 457 mm and a weight of 1,410 g (McLeod et al. 1976).

Maturity

Maturity was reported at age-8 and age-9 for males and females, respectively (McLeod et al. 1976).

Food Habits

An analysis of the stomach contents of round whitefish captured in Baker Lake shows that they fed on a variety of organisms including, insects, plants, mollusks, and fish eggs (McLeod et al 1976). The stomach contents of round whitefish captured from Cigar, Mushroom, and Lower lakes indicated that their diet was similarly varied. The most common food item was zooplankton; although, snails, midge larvae, and bottom material were also common (BEAK 1992).

Spawning

During the 1975 Baker Lake survey, several schools of YOY round whitefish were observed and specimens were collected in Baker Lake at the mouth of the Thelon River, indicating that the area may be used as a spawning or nursery habitat (McLeod 1976).

Ninespine Stickleback

Distribution and Relative Abundance

Ninespine stickleback were captured in seven lakes, including Judge Sissons, Pointer, Sik Sik, Scotch, Willow, Cirque and Baker. Ninespine stickleback were absent from the Lower Lake, Kavisilik Lake, and Squiggly Lake sub basins. Although they were more widely distributed than burbot, slimy sculpin, fourhorn sculpin, Arctic char, lake whitefish and longnose sucker, they were not considered a major fish species in the study area by previous studies (BEAK 1987a, b; McLeod et al. 1976). They do constitute an import forage species for lake trout.

Although numerous sightings were made in Baker Lake in shallow inshore waters over sandy, rocky or vegetated substrate, only eleven individuals were actually captured. This is likely an artifact of sampling methods (i.e., gill nets), rather than an indication of relative abundance. There is no information on their relative abundance of this species from the other lakes.

Additional information

No additional information has been collected regarding their age, growth, maturity, diet or spawning.

Slimy Sculpin

Distribution and Relative abundance

Slimy sculpin were captured in four lakes; Judge Sissons, Scotch, Sik Sik, and Baker. They are not considered to be an abundant or a widely distributed species in the study area. Only two slimy sculpin were captured during the Baker Lake field survey (Table 5.2-2).

Additional information

Slimy sculpin were used as a food source by lake trout (McLeod et al. 1976). No additional information has been collected on age, growth, maturity, diet or spawning.

Fourhorn Sculpin

Distribution and Relative Abundance

The fourhorn sculpin has only been found in Baker Lake (Table 5.2-2). After nearly three months of sampling effort, only five individuals were caught during the 1975 survey. Although fourhorn sculpin is primarily a deepwater marine species, local residents around Baker Lake reported catching them frequently (McLeod et al. 1976).

Other information

All captured fourhorn sculpin were mature female adults.

5.3 Fish Tissue Chemistry

There was very little fish tissue chemistry analysis included in the studies from 1975 to 1991. Chemical analysis of fish tissues was carried out for fish species from some of the lakes (Felsenmeer, Lin, Pointer, Willow, Ridge, Caribou, Judge Sissons, Lower, Andrew, Cigar, Mushroom, and Baker lakes). Tissue chemistry analysis was been limited to the most abundant species: Arctic grayling and lake trout. Arctic char from Baker Lake were also analyzed (BEAK 1990).

Due to the differences in labs used and chemical analysis requested, the information will be presented as follows:

- 1979 and 1986 (Judge Sissons, Felsenmeer, Lin, Willow, Ridge, and Caribou lakes);
- 1988 and 1989 (Pointer and Baker lakes); and
- 1990 (Lower, Andrew, Cigar and Mushroom lakes).

5.3.1 Methods

5.3.1.1 Judge Sissons, Felsenmeer, Lin, Willow, Ridge and Caribou Lakes: 1979 and 1986

Fish tissue (boneless, skinless fillet) was collected from Arctic grayling and lake trout from Judge Sissons, Felsenmeer, Lin, Willow, Ridge and Caribou lakes and sent to the lab for analysis of radionuclides, and metals (zinc, cadmium, manganese, cobalt, copper, iron, lead, chromium, nickel, beryllium, and molybdenum) (BEAK 1987).

5.3.1.2 Pointer and Baker Lakes: 1988 - 1989

Composite samples of fish tissue (boneless, skinless fillet) from Arctic grayling and lake trout captured from Pointer Lake in July 1988 as well as Arctic char captured in August 1989, were sent for analysis of trace metals and radionuclides. The metals being analysed were cadmium, lead, nickel, mercury, arsenic and selenium.

Fish tissue (boneless, skinless fillet) from lake trout and Arctic grayling from Ridge, Caribou, Willow, Lin, and Felsenmeer lakes were also analysed for radionuclides (Th-230, Ra-226, Pb-210, Th-232, Ra-228 and Th-228).

5.3.1.3 Lower Lake Sub Basin - 1990

Fish tissue samples were collected from lake trout and Arctic grayling caught in Cigar, Mushroom, Shack, and Judge Sissons lakes. Tissues from three to five fish were collected from each species caught in one lake, composited and analysed for metals and radionuclides (BEAK 1992).

5.3.2 Fish Chemistry Analysis Results

5.3.2.1 Judge Sissons, Felsenmeer, Lin, Willow, Ridge and Caribou Lakes: 1979 and 1986

The results of chemical fish tissue analysis showed that radionuclides were low and close to the detection limit. There were no observed differences between levels in either Arctic grayling or lake trout (BEAK 1987). The details of chemical analysis for 1986 are presented in Table 5.2-9.

5.3.2.2 1988 – 1989 Pointer and Baker Lakes

Concentrations of trace metals in fish from Pointer Lake were low, with the exceptions of nickel and mercury (Table 5.2-8). The level of mercury was above the Health Canada limit in both Arctic char and lake trout. The results of radionuclides tests showed concentrations tended to be below detection limits (Tables 5.2-9 and 5.2-10).

5.3.2.3 Lower Lake Sub basin - 1990

The results of metals and radionuclides analysis of fish captured in the Lower Lake sub basin are presented in Tables 5.2-10 and 5.2-11. The majority of the metals and radionuclides were below detection limits. The concentrations of mercury in fish tissue from Cigar, Mushroom, and Andrew lakes ranged from 0.52 µg/g to 0.58 µg/g, which exceeds the Federal consumption guidelines for mercury (0.50 µg/g) (BEAK 1992).

Table 5.2-8
Concentrations of Trace Metals in Pointer Lake Arctic Grayling and Lake Trout, July 1988, and Baker Lake Arctic Char (August 1989)

	Fish Characteristics			Metal					
	Fish Length (mm)	Weight (g)	Sex	Cd	Pb	Ni	Hg	As	Se
Arctic grayling									
	318	375	M	L 0.01	L 0.1	0.2	0.04	L 0.2	0.2
	305	325	M	L 0.01	L 0.1	0.1	0.06	L 0.2	0.2
	298	325	M	0.01	0.1	0.2	0.08	L 0.2	0.2
	311	350	M	L 0.01	L 0.1	0.3	0.08	L 0.2	0.2
	311	350	M	L 0.01	L 0.1	L 0.1	0.06	L 0.2	L 0.2
	318	400	M	L 0.01	L 0.1/L 0.1	L 0.1/L 0.1	0.08/0.10	L 0.2/L 0.2	0.2/0.2
	321	380	M	L 0.01	L 0.1	L 0.1	0.14	L 0.2	0.2
	298	330	M	0.06	1.0	0.3	0.14	L 0.2	0.2
	356	475	F	L 0.01	L 0.1	0.4	0.18	L 0.2	0.2
	286	310	F	L 0.1	L 0.1	0.2	0.08	L 0.2	0.2
Lake trout									
	724	4,800	M	L 0.01	L 0.1	L 0.1	1.02	L 0.2	0.2
	527	1,600	F	L 0.01	L 0.1/L 0.2	0.1/L 0.2	0.60/0.54	L 0.2/L 0.2	0.2/0.2
	597	2,300	F	L 0.01	0.1	0.1	0.44	L 0.2	0.2
Arctic char									
A	-	-	-	L 0.01	0.05	L 0.2	0.5	1.4	1.8
B	-	-	-	L 0.01	0.10	L 0.2	0.5	8.0	1.8

All concentrations are µg/g fresh weight of boneless, skinless fillets

Source BEAK 1990, Table 7.19

L = less than

Table 5.2-9
Concentrations and Activities of U-238 and TH-232 Decay Chain Radionuclides in Fish from Kiggavik Area Lakes [(a)]

Lake	Species/Tissue	U (µg/g)	TH-230 (Bq/g)	Ra-226 (Bq/g)	Pb-210 (Bq/g)	Po-210 (Bq/g)	Th-232 (Bq/g)	Ra0228 (Bq/g)	Th-228 (Bq/g)
July 1988									
Point Lake	Arctic grayling composite 1-5	L 0.2	L 0.005	L 0.005	L 0.02	L 0.005	L 0.005	L 0.1	L 0.005
	Arctic grayling composite 6-10	L 0.2	L 0.005	L 0.005	L 0.02	L 0.005	L 0.005	L 0.1	L 0.005
	Lake trout composite 11-13	L 0.2	L 0.005	L 0.005	L 0.02	L 0.005	L 0.005	L 0.1	L 0.005
	Arctic grayling bone composite 1-5	L 0.2	L 0.005	0.017±0.005	L 0.02	L0.005	L 0.005	L 0.1	L 0.005
	Arctic grayling bone composite 6-10	L 0.2	L 0.005	0.017±0.005	L 0.02	0.007±0.005	L 0.005	L 0.1	L 0.005
July 1986									
Ridge Lake	Lake trout composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
Caribou Lake	Lake trout composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
	Arctic grayling composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
Willow Lake	Lake trout composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
	Arctic grayling composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
Lin Lake	Arctic grayling composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
Felsenmeer Lake	Lake trout composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
	Arctic grayling composite	L 0.5	L 0.001	L 0.001	L 0.001	L 0.001	L 0.002	-	-
Summer 1980									
Judge Sissons Lake	Lake trout	L 0.2	L 0.008	0.013	L 0.01	-	L 0.0012	-	-
		L 0.2	L 0.008	0.005	L 0.01	-	L 0.0012	-	-
		L 0.2	L 0.008	0.003	0.02	-	L 0.0012	-	-
		L 0.2	L 0.008	0.003	L 0.01	-	L 0.0012	-	-
		L 0.2	L 0.008	0.005	L 0.01	-	L 0.0012	-	-
		L 0.2	L 0.008	0.003	L 0.01	-	L 0.0012	-	-
		L 0.2	L 0.008	0.003	L 0.01	-	L 0.0012	-	-

a = All samples from skinless, boneless filets unless indicated otherwise. Source: BEAK 1990, Table 7.20)
L = less than

Table 5.2-10

Concentrations[a] of Trace Metals in Grayling and Lake Trout from Various Andrew Lake Study Area Lakes, August 1990[b]

Lake	Figure ID	Species	Total Length (mm)	Parameter											
				Cd	Pb	Ni	Hg	As	Se	Z	Mn	Co	Cu	Fe	Cr
Cigar	A6	Lake trout	500-730	<0.05	<0.2	0.5	0.58	<0.2	0.2	6.2	<0.2	<0.1	0.6	6.4	0.4
Mushroom	A1	Lake trout	401-610	<0.05	<0.2	0.1	0.58	<0.2	0.2	3.6	<0.2	<0.1	0.5	3.4	0.3
Andrew	A17	Arctic grayling	212-305	<0.05	<0.4	0.5	0.52	<0.2	0.2	5.4	<0.4	<0.1	0.3	5	0.3
Lower	A27	Arctic grayling	225-333	<0.05	<0.2	0.1	0.22	<0.2	0.2	4.2	<0.2	<0.1	0.3	4.4	0.2

Notes: mm = millimetre.
a = All concentrations in µg/g fresh weight of boneless, skinless tissue.
b = All samples were composites of three to five fish each. Source Table 4.10 BEAK 1992

Table 5.2-11

Concentrations and Activities of U-238 and Th-232 Decay Chain Radionuclides in Fish from Andrew Lake Study Area Lakes, August 1990[a,b]

Lake	Figure ID	Species	Total U (mm)	Parameter						
				Pb-210 µg/g	Po-210 Bq/g	Ra-226 Bq/g	Th-228 Bq/g	Th-230 Bq/g	Th-232 Bq/g	Bq/g
Cigar	A6	Lake trout[c]	500-730	<0.004	<0.002	0.001	0.0004	<0.0004	0.0004	<0.0004
Mushroom	A1	Lake trout[c]	401-610	<0.004	<0.002	0.002	<0.0002	<0.0004	<0.0004	<0.0004
Andrew	A17	Arctic grayling[c]	212-305	<0.005	<0.002	0.002	<0.0002	<0.0005	<0.0005	<0.0005
Lower	A27	Arctic grayling[c]	225-333	<0.005	<0.002	0.004	<0.0002	<0.0005	<0.0005	<0.0005

Notes: mm = millimetre; µg/g = microgram per gram; Bq/g = becquerel per gram.
a = All samples from boneless, skinless fillets.
b = Values expressed on dry weight basis.
c = All samples were composites of three to five fish each. Source Table 4.11 BEAK 1992.

5.4 Fish Field Data Collection 2007

The objective of the 2007 fish inventory was to assess the fish communities (presence/absence; juvenile/adult) in the Project area (Golder 2008). The fish sampling was undertaken between August 25, 2007 and September 3, 2007 in lakes of three sub basins: the Willow Lake sub basin, the Caribou Lake sub basin, and the Lower Lake sub basin. A summary of the 2007 aquatic program is shown on Figure 5.4-1.

5.4.1 Data Collection Methods

Methods of capture included short-duration gill nets, minnow traps, and angling. Captured fish were held in a holding pen until they could be processed (i.e., length, weight, and an external health assessment). Sampling time (start and end times); universal transverse mercator (UTM) coordinates (start and end locations for gill nets and minnow traps) a general habitat description for the site sampled,, and number of fish species captured/observed was recorded for each fishing effort.

Each captured fish was assigned a unique biomarker identification code. Fork length and total body weight were recorded for all captured fish. Fork length was measured using a special cradle marked by metric graduations with a precision of 1 mm. Total body weight was measured using an Acculab® V-600 electronic scale with a precision of 0.1 g.

An external examination for health assessment (see Table IV-12 was conducted on all captured fish. Detailed observations were made on any features of the fish that did not appear “normal” (i.e., wounds, tumours, parasites, fin fraying, parasites or lesions). When possible, information on reproductive status, gender, and overall health was recorded.

Pectoral fin rays and scales were collected from specific salmonid species to determine age. Ageing structures were sent to an independent consultant for processing. In accordance with Golder’s standard quality assurance/quality control (QA/QC) protocol, 10% of the age data was randomly selected and re-analyzed. A greater than 10% difference would have resulted in the ageing structures being reanalyzed.

Catch-per-unit-effort (CPUE) was calculated for each fish species and was summarized by area and sampling method to document the effort expended in collecting the fish. The CPUE data also provided a measure of relative abundance among lakes by standardizing the catch data (see table IV-13 in Appendix IV).

Figure 5.4-1 2007 Golder Aquatic Summary Program

Summary statistics for each biological variable (i.e., sample size, arithmetic mean, median, minimum, maximum, standard deviation and standard error) were calculated for mature fish and summarized by area, species and gender. Biological indices, including condition factor (k), gonadosomatic index (GSI), and liversomatic index (LSI), were calculated.

The biological variables that were summarized for all fish included the following:

- physical abnormalities (e.g., tumours, surficial lesions, obvious parasites);
- age;
- total body weight;
- length; and
- condition factor.

5.4.2 Sampling Results

A complete summary of the fish health survey, including fish that had a complete health assessment and those that were only measured for length and weight will be available in a separate technical report (Golder 2008; in preparation) as the 2007 sampling results were not available at the time the Technical Information Document was prepared. Similar amounts of fishing effort were expended in all of the study lakes, gill net and minnow traps were used in the study design. Also, 30 minutes of angling was performed on Ridge Lake, which resulted in no fish being caught (Golder 2008). Figure 5.4-2 shows the locations of the 2007 fish health and sampling study.

5.4.3 Sub Basin Sampling Results

Willow Lake Sub Basin

Gill netting effort in Pointer Lake yielded two Arctic grayling, one cisco, and one lake trout, with respective CPUE values of $2.7\text{x}10^{-1}$, $1.4\text{x}10^{-1}$, and $1.4\text{x}10^{-1}$ fish per hour per 100 m of net. Pointer Lake minnow trapping produced five ninespine stickleback with a CPUE of $9.6\text{x}10^{-3}$ fish per trap per hour. Three ninespine stickleback (CPUE was $1.7\text{x}10^{-2}$ number of fish per trap per hour) were captured in minnow traps placed in Sik Sik Lake. Gill netting in Willow Lake yielded one Arctic grayling, with a CPUE of $2.3\text{x}10^{-1}$ fish per hour per 100 m of net.

Figure 5.4-2 Fish Health and Community Sampling Locations

Caribou Lake Sub Basin

There were no fish caught in Ridge Lake. Minnow trapping in Cirque Lake yielded seven ninespine sticklebacks with a CPUE of 1.7×10^{-1} fish per trap per hour. Crash Lake minnow trapping produced two Arctic grayling for a CPUE of 4.6×10^{-2} fish per trap per hour. No fish were captured in Fox Lake (Golder 2008)..

Lower Lake Sub Basin

Minnow traps in Andrew Lake yielded one burbot and a CPUE of 2.4×10^{-2} fish per trap per hour. Three Arctic grayling were captured in minnow traps set in End Grid Lake, with a CPUE of 1.0×10^{-1} fish per trap per hour. There were no fish caught in Shack Lake. Gill netting effort in Lower Lake yielded two Arctic grayling, a CPUE of 2.1×10^{-1} fish per trap per hour.

5.4.3 Fish Condition

Condition factor (*k*) is used to describe the plumpness and, by inference, the well being of individual fish. Formulas are used to calculate condition factors using the fish's length and weight and are based on the principle that the weight of a fish will vary with the cube of its length. The formula that Golder (2008) used (for metric length and weight data) is as follows:

$$k = [\text{weight (g)} \times 10^5] / \text{fork length}^3 \text{ (mm)}$$

Condition factor is believed to reflect the nutritional state or well-being of an individual fish. The *k* value will be 1.0 when the weight is equal to the cube of fork length. Fish that have a *k* value >1.0 are more plump and are thought to have a higher degree of well-being or to be in a better nutritional state-of-health, whereas fish with a value <1.0 are considered to be less robust (Golder 2008). Results for 2007 condition factors are found in Table IV-12 of Appendix IV.

The condition factor of the Pointer Lake Arctic grayling ranged from 1.00 to 1.42; the cisco and the lake trout had condition factors of 1.51 and 1.11 respectively. The condition factor for the Pointer Lake ninespine sticklebacks ranged from 0.80 to 1.70. The Sik Sik Lake ninespine sticklebacks had a condition factor that ranged from 0.63 to 1.31. The Willow Lake Arctic grayling had a condition factor of 1.45.

The ninespine sticklebacks from Cirque Lake had a condition factor that ranged from 0.93 to 2.40. The Arctic grayling from Crash Lake had a condition factor that ranged from 1.07 to 1.17.

The lone burbot captured in Andrew Lake had a condition factor of 1.17. Arctic grayling from End Grid had condition factors ranging from 1.02 to 1.35. Arctic grayling from Lower Lake had condition factors ranging from 0.85 to 1.03.

External Health Assessment

The vast majority of the fish observed appeared to be in good physical health. Only one fish, the single lake trout from Pointer Lake, was reported to have any external abnormalities. This fish had mild scarring on the tail and was blind in both eyes possibly due to cataracts Appendix IV, Figure IV-1.

5.4.4 Fish Habitat

5.4.5 Objective

The principal objective of the Golder 2007 fish habitat assessment was to start to document and map the types and distribution of fish habitat within the study area, building on information collected as part of the earlier baseline studies. Habitat mapping can be used to provide an ecologically relevant inventory of the type and diversity of habitats found within a given area. The value of specific habitats to the fish species and various life stages can then be determined. Important features in evaluating aquatic habitat within a study area relate to the diversity of habitat available. This includes the availability and quality of: refuge and cover habitat; over wintering habitat, deep water habitat, spawning habitat, rearing habitat, and foraging habitat. Lake bathymetry and habitat sampling locations for the 2007 field survey are shown on Figure 5.4-3.

5.4.6 Study Area

The lakes within the study area are divided into three sub basins: Willow Lake sub basin; Caribou Lake sub basin; and Lower Lake sub basin. In the fall 2007 field surveys, fish habitat assessments were completed in the following waterbodies:

Willow Lake Sub Basin:

- Pointer Lake;
- Sik Sik Lake; and
- Willow Lake.

Figure 5.4-3 Bathymetry and Habitat Sampling Locations

Caribou Lake Sub Basin:

- Ridge Lake;
- Cirque Lake;
- Crash Lake; and
- Fox Lake.

Lower Lake Sub Basin:

- Andrew Lake;
- End Grid Lake;
- Shack Lake; and
- Lower Lake.

5.4.7 Methods

The assessment of fish habitat within the study area was completed in accordance with the habitat mapping protocols outlined in the Golder Technical Procedure 8.5-1 Watercourse Habitat Mapping and Golder Technical Procedure 8.19-0 Lake Habitat Mapping (unpublished file information). Ground surveys were completed for all waterbodies assessed in September 2007.

Characteristics, such as shoreline substrate type, presence/absence of aquatic vegetation, shoreline slope, bank stability, channel units, and water depth at sampling locations were recorded on waterproof paper with the outline of a waterbody provided. Representative photos were taken within assessed areas. Information was transferred to a geographical information system (GIS) to create the final habitat maps.

Bathymetry measurements were completed using a Garmin Global Positioning System (GPS) map 178C Sounder. The GPS component provided the position of the boat using satellite triangulation, while the sounding transducer provided the water depth at each location. The sounder was configured to record geo-referenced depths at five second intervals. The field crew traveled in a zigzag pattern throughout the entire lake at speeds ranging between 7 km/hr to 10 km/hr. The recorded information was then transferred to GIS to generate a bathymetry map.

5.4.8 Willow Lake Sub Basin Results

5.4.8.1 Pointer Lake

Bathymetry data were collected in Pointer Lake during the fall 2007 field program (Figure VI-1). At the time of the assessment, the surface area of the lake was 395.3 ha, the shoreline perimeter was 11,543 m, and the maximum water depth was 3.0 m (Table 5.4-1).

Pointer Lake shoreline substrate consisted primarily of cobble and boulder, with patches of sand (Table 5.4-1). The shoreline slope was predominantly shallow. The shoreline vegetation was primarily grasses and low bush shrubs. Upland habitat surrounding Pointer Lake was tundra. Several exposed boulder gardens and some emergent vegetation were present.

5.4.8.2 Sik Sik Lake

At the time of the assessment, the surface area of the lake was 17.6 ha, the shoreline perimeter was 2,121 m, and the maximum water depth recorded at the sampling stations was 1.7 m (Table 5.4-1). Substrate consisted primarily of boulder and cobble. The shoreline slope was predominantly shallow, and the shoreline vegetation consisted primarily of grasses and low bush shrubs. Upland habitat surrounding the lake was tundra. Exposed boulder gardens and some inundated vegetation were present.

5.4.8.3 Willow Lake

At the time of the assessment, the surface area of the lake was 62.2 ha, the shoreline perimeter was 4,321 m, and the maximum water depth recorded at the sampling stations was 2.0 m (Table 5.4-1). Substrate consisted primarily of boulder and cobble. The shoreline slope was predominantly shallow, and the shoreline vegetation consisted primarily of grasses and low bush shrubs. Upland habitat surrounding the lake was tundra. Several exposed boulder gardens and some inundated vegetation was present.

Table 5.4-1
Fish Habitat Assessment Summary for the Willow Sub basin, Fall 2007

Waterbody	Surface Area (ha)	Main Shoreline Perimeter (m)	Max Depth (m)	Substrate (dominant/subdominant)	Habitat Assessment	Fish Observed/Captured
Willow Lake Sub Basin						
Pointer Lake	395.3	11,543	3.0	cobble/boulder	• shoreline vegetation predominantly grasses and low bush shrubs, backed by Tundra • predominantly had a shallow slope • exposed boulders present; • emergent vegetation present	Arctic grayling, cisco, lake trout, ninespine stickleback
Sik Sik Lake	17.6	2,121	1.7	boulder/cobble	• shoreline vegetation predominantly grasses and low bush shrubs, backed by Tundra • predominantly had a shallow slope • exposed boulders present; • inundated vegetation present	ninespine stickleback
Willow Lake	62.2	4,321	2.0	boulder/cobble	• shoreline vegetation predominantly grasses and low bush shrubs, backed by Tundra • predominantly had a shallow slope • exposed boulders present	Arctic grayling

Notes: ha= hectares; m=meters; Maximum depth is the maximum depth collected at sampling stations.

5.4.9 Caribou Lake Sub Basin Results

5.4.9.1 Cirque Lake

At the time of the assessment, the surface area of the lake was 5.5 ha, the shoreline perimeter was 946 m, and the maximum water depth recorded at the sampling stations was 5.0 m (Table 5.4-2). Substrate consisted primarily of cobble and boulder, with gravel also present. The shoreline slope was predominantly shallow. The shoreline vegetation was primarily grasses. Upland habitat surrounding the lake was tundra.

5.4.9.2 Crash Lake

At the time of the assessment, the surface area of the lake was 6.1 ha, the shoreline perimeter was 1,078 m, and the maximum water depth recorded at the sampling stations was 1.0 m (Table 5.4-2). Substrate consisted primarily of silt and sand, with boulder also present. The shoreline slope was predominantly shallow. The shoreline vegetation was primarily grasses and low bush shrubs. Upland habitat surrounding the lake was tundra. Exposed boulder gardens were present.

5.4.9.3 Fox Lake

At the time of the assessment, the surface area of the lake was 137.3 ha, the shoreline perimeter was 5,194 m, and the maximum water depth recorded at the sampling stations was 2.6 m (Table 5.4-2). Substrate consisted primarily of cobble and boulder, with sand and gravel also present. The shoreline slope was predominantly shallow. The shoreline vegetation was primarily grasses. Upland habitat surrounding the lake was tundra. Exposed boulder gardens and sand beaches were present.

5.4.9.4 Ridge Lake

At the time of the assessment, the surface area of the lake was 20.8 ha, the shoreline perimeter was 2,643 m, and the maximum water depth recorded at the sampling stations was 7.1 m (Table 5.4-2). Substrate consisted primarily of cobble and boulder. The shoreline slope was predominantly shallow and the shoreline consisted primarily of cobble and boulder. The shoreline vegetation was minimal. Upland habitat surrounding the lake was tundra. Exposed boulder gardens were present.

Table 5.4-2
Fish Habitat Assessment Summary for the Caribou Lake Sub Basin, Fall 2007

Waterbody	Surface Area (ha)	Main Shoreline Perimeter (m)	Max Depth (m)	Substrate (dominant/subdominant)	Habitat Assessment	Fish Observed/Captured
Caribou Lake Sub Basin						
Cirque Lake	5.5	946	5.0	cobble/boulder	• shoreline vegetation predominantly grasses backed by Tundra • predominantly had a shallow slope	ninespine stickleback
Crash Lake	6.1	1,078	1.0	silt/sand/boulder	• shoreline vegetation predominantly grasses and low bush shrubs, backed by Tundra • predominantly had a shallow slope • exposed boulders present	arctic grayling
Fox Lake	137.3	5,194	2.6	cobble/boulder	• shoreline vegetation predominantly grasses, backed by Tundra; • predominantly had a shallow slope • exposed boulders present	none
Ridge Lake	20.8	2,643	7.1	cobble/boulder	• shoreline vegetation was minimal, predominantly cobble/boulder, backed by Tundra • predominantly had a shallow slope	none

Notes: ha; hectares; m=meters; Maximum depth is the maximum depth collected at sampling stations.

5.4.10 Lower Lake Sub Basin Results

5.4.10.1 Andrew Lake

At the time of the assessment, the surface area of the lake was 54.4 ha, the shoreline perimeter was 4,479 m, and the maximum water depth recorded at the sampling stations was 1.0 m (Table 5.4-3). Substrate consisted primarily of sand and cobble, with boulder also present. The shoreline slope was predominantly shallow and the shoreline vegetation was primarily grasses and low bush shrubs. Upland habitat surrounding the lake was tundra. Exposed boulder gardens and inundated vegetation was present.

5.4.10.2 End Grid Lake

At the time of the assessment, the surface area of the lake was 13.4 ha, the shoreline perimeter was 1,597 m, and the maximum water depth recorded at the sampling stations was 1.0 m (Table 5.4-3). Substrate consisted primarily of sand and organics, with cobble and boulder also present. The shoreline slope was predominantly shallow. The shoreline vegetation was primarily grasses. Upland habitat surrounding the lake was tundra. Exposed boulder gardens and inundated vegetation were present.

5.4.10.3 Lower Lake

The lake is divided into north and south basins by a channel approximately 500 m long and approximately 75 m wide. The channel consisted of run and riffle stream habitat. Substrate within the channel was cobble and boulder and some inundated vegetation was present.

At the time of the assessment, the surface area was 46.2 ha, shoreline perimeter was 4,828 m, and the water depth recorded at the sampling stations was 1.4 m (Table 5.4-3). Substrate consisted primarily of sand and organics, with cobble and boulder also present. The shoreline slope was predominantly shallow and the shoreline vegetation was primarily grasses. Upland habitat surrounding the lake was tundra. Exposed boulder gardens and inundated vegetation were present.

Table 5.4-3
Fish Habitat Assessment Summary for the Lower Lake Sub Basin, fall 2007

Waterbody	Surface Area (ha)	Main Shoreline Perimeter (m)	Max Depth (m)	Substrate (dominant/ subdominant)	Habitat Assessment	Fish Observed/Captured
Lower Lake Sub Basin						
Andrew lake	54.4	4479	1.0	sand/cobble	• shoreline vegetation predominantly grasses and low bush shrubs, backed by Tundra • predominantly had a shallow slope • exposed boulders present • inundated vegetation present	burbot
End Grid Lake	13.4	1597	1.0	sand/organic/cobble	• shoreline vegetation predominantly grasses, backed by Tundra • predominantly had a shallow slope • exposed boulders present • inundated vegetation present	Arctic grayling
Lower Lake	46.2	4828	1.4	cobble/boulder	• shoreline vegetation predominantly grasses, backed by Tundra • predominantly had a shallow slope • exposed boulders present • inundated vegetation present • channel connecting north and south ends of lake had run and riffle habitat	Arctic grayling
Shack Lake	58	4983	1.3	sand/boulder/cobble	• shoreline vegetation predominantly grasses and low bush shrubs, backed by Tundra • predominantly had a shallow slope • exposed boulders present • inundated vegetation present	none

Notes: ha; hectares; m = metres; Maximum depth is the maximum depth collected

5.4.10.4 Shack Lake

At the time of the assessment, the surface area of the lake was 58 ha, the shoreline perimeter was 4,983 m, and the water depth recorded at the sampling stations was 1.3 m (Table 5.4-3). Substrate consisted primarily of sand and boulder, with cobble also present. The shoreline slope was predominantly shallow and the shoreline vegetation was primarily grasses and low bush shrubs. Upland habitat surrounding the lake was tundra. Exposed boulder gardens, sand beaches and inundated vegetation were present.

5.5 Fish Habitat

Fish habitat requirements for different life-stages of fish species known to be in the local and regional study have been summarized in Tables 5.5-1 and 5.5-2.

5.5.1 Results of Fish Habitat Surveys

5.5.1.1 Fish Habitat Surveys: 1979, 1980 and 1986

Bathymetry surveys of Felsenmeer, Meadow, Escarpment, Jaeger, Scotch, Sik Sik, Drum, Lin, Pointer, Rock, Willow, Ridge, Cirque, Crash, Fox, Caribou, Judge Sissons, Skinny, and Kavisilik lakes were completed during the 1979, 1980 and 1986 field programs. Information was collected on mean depth (m), lake surface area (ha) and lake volume (m^3). Measurements of pH, conductivity, total dissolved solids and alkalinity were also collected.

The results of the bathymetry surveys showed that lakes in the upland headwaters of Judge Sissons Lake drainage are typically small and relatively deep (BEAK 1987). Bathymetry maps are presented in Appendix V. A summary of the physical characteristics of the lake and the number of fish caught in each lake are provided in Table 5.5-3.

5.5.1.2 Fish Habitat Surveys: 1990 - 1991

During the 1990 and 1991 field survey, fish habitats were mapped in Cigar, Smoke, Mushroom, Lunch, Knee, Andrew, Bear Island, and Lower lakes. In Cigar, Smoke, and Mushroom lakes, the water depth allowed the use of a boat to take sonar readings. A minimum of four transects were followed to allow accurate depth contour construction (BEAK 1992). Lunch, Knee, Andrew, Bear Island, and Lower lakes were very shallow (less than 1.5 m) and water depth was measured both by boat and on foot.

Table 5.5-1
Fish Habitat Requirements for Longnose Sucker, Lake Cisco, Lake Whitefish, Round Whitefish, Arctic Grayling, Lake Trout and Arctic Char

Habitat Features	Longnose Sucker Ratings[(a)]				Lake Cisco Ratings[(a)]				Lake Whitefish Ratings[(a)]				Round Whitefish Ratings[(a)]				Arctic Grayling Ratings[(a)]				Lake Trout Ratings[(a)]			
Categories[(b)]	S	YOY	J	A	S	YOY	J	A	S	YOY	J	A	S	YOY	J	A	S	YOY	J	A	S	YOY	J	A
Depth																								
0 to 1 m	H	H	H	H	H				M	M	H	M	H	H	H	H	H	H		H	H	L	L	
1 to 2 m			H	H	H				H	M	H	M	M	H	H	H				H	H	M	M	M
2 to 5 m			H	H	H			L	H	M	H	H	M							H	H	H	H	M
5 to10 m				H	M			M	M	H	H	H	L			H				L	H	H	H	M
10+ m				H	L			H	M	M	M	H	L			H					H	H	H	H
Substrate																								
Bedrock													L	L	L	L					L			
Boulder		H		H	M	M			H	H	H	H	M	H							H	H	H	H
Rubble		H			M	M			H	H	H		M	H			H			H	H	H	H	H
Cobble	M								H	H	H	H	H	H			H			H	H	H	H	H
Gravel	H			H	H				H	H	H	H	L				H			H	H			
Sand	H	H		H	H			L	M	H		H	L				H			M	L	M		
Silt				H	L				L								H			M	L			
Muck (detritus)					M				L								H				L			
Clay					M			L	L			M									L			
Pelagic										H	H	M												L
Cover																								
None																					H			H
Submergents		H	H		L	M											H			L	L			
Emergents		H	H		L	M			L	H	H		L				H			L				
Overhead																								
In Situ				H						L	L							L				H	H	
Trees and Brush																								

a = Ratings are nil (default), low, medium or high;
b = Categories are S = spawning; Y = young-of-the-year (YOY); J = juveniles; A = adults.
Source: Richardson et al. 2001

Table 5.5-2
Fish Habitat Requirements for Arctic Char, Ninespine Stickleback, Burbot, and Slimy Sculpin

	Arctic Char (freshwater resident normal)				Arctic Char (freshwater resident dwarf)				Ninespine Stickleback				Burbot				Slimy Sculpin			
Habitat Features	**Ratings[(a)]**				**Ratings[(a)]**				**Ratings[(a)]**				**Ratings[(a)]**				**Ratings[(a)]**			
Categories[(b)]	S	YOY	J	A	S	YOY	J	A	S	YOY	J	A	S	YOY	J	A	S	YOY	J	A
Depth																				
0 to 1 m	L	L	L	H	M			H	H	H		H	H	H	H					
1 to 2 m	M	L	L	H	M			H	L	H		H	H	H	H		H	H	H	H
2 to 5 m	H	L	L	H				H	L	H		H	L	H	H	L	H	H	H	H
5 to10 m	H	L	H	H		H	H	M	L	M		M	L	L	L	L	M	H	H	H
10+ m	M	H	H	H	H	H	H	M	L	M		M	L	L	L	H	M	H	H	H
Substrate																				
Bedrock			L													H				
Boulder		H	H	H										H	H	H	H	H		
Rubble	L	H	H	H					H			H	L	H	H	H	H	H	H	H
Cobble	H	H	H	H	H	H	H	H	H			H	H	H	H	H	H	H	H	H
Gravel	H				H	H	H	H	L			L	H	H	H	H	H	H	H	H
Sand					H	H	H	H	M	L		L	H	L	L	L	H	H		
Silt	L								H	H			L			L	M			
Muck (detritus)	L								H	H			L				M			
Clay	L				H				H	H		H	L				M	M		
Pelagic	L	L	H	H			M	H						M						
Cover																				
None																				
Submergents	L		H			H	H	L						M	M	M				
Emergents			H											M	M	M				
Overhead														M	M	M				
In Situ		H	H											M	M	M	H			
Trees and Brush																				

a = Ratings are nil (default), low, medium or high
b = Categories are S = spawning; Y = young-of-the-year; J = juveniles; A = adults.
Source: Richardson et al. 2001

Bathymetry maps are presented in Appendix V. A summary of the physical characteristics of the lakes are provided in Table 5.5-3.

5.5.2 Fish Habitat Description

There are three major sub basins in the regional project area: Thelon, Sissons and Baker Lake sub basins. These three areas are further divided into ten sub-basins based on their waterflow direction and outlets (Figure 5.4-1).

Table 5.5-3
Physical Characteristics of Lakes in the Study Area

Lake Name	Maximum Water Depth (m)	Mean Water Depth (m)	Surface Area (ha)	Lake Volume (m^3)	Drainage Area (km^2)	No. of Fish Species
Lower Lake Sub Basin						
Andrew Lake	NA	0.2	54	12.6×10^4		3
Lower Lake	1.0	0.4	49	21.2×10^4		3
Bear Island Lake	1.0	0.5	36.5	18.3×10^4		2
Shack Lake	1.0	0.6	60	38.2×10^4		2
Cigar Lake	NA	1.5	113	169×10^4		4
End Grid Lake						1
Smoke Lake	1.3	1.3	63.5	81.8×10^4		2
Knee Lake	1.0	0.2	34.9	5.8×10^4		2
Lunch Lake	NA	0.6	77.8	46.7×10^4		4
Mushroom Lake	8.0	2.6	40.0	104×10^4		4
Judge Sissons Lake Sub Basin						
Judge Sissons Lake	20	4.6	9,550	4.4×10^8	680	7
Boulder Lake	*					*
Willow Lake Sub Basin						
Pointer Lake	2.9	1.5	374	5.6×10^6	82	5
Escarpment Lake	8	2.2	13	2.8×10^5	2.4	3
Felsenmeer Lake	6	2	20.8	4.2×10^5	1.4	3
Meadow Lake	2	0.8	14	1.2×10^5	4.1	-
Drum Lake	2	1.3	25	3.3×10^5	5.4	1
Lin Lake	NA	1.3	48	6.3×10^5	7.6	1
Scotch Lake	6	3.5	201	7.1×10^6	19	4
Jaeger Lake	4.0	1.6	281	4.6×10^6	56	1
Sik Sik Lake	2	0.8	16	1.3×10^5	2.4	1
Rock Lake	NA	1.4	26.9	37.7×10^2		
Willow Lake	2	1.4	55	7.7×10^5	104	3
Caribou Lake Sub Basin						
Caribou Lake	2	1.4	341	4.9×10^6	80	2
Ridge Lake	6	2.3	16.7	3.8×10^5	2.3	1
Cirque Lake	4	2.6	5.6	1.5×10^5	1.1	2
Crash Lake	2	1.1	8.1	8.7×10^4	14	1
Fox Lake	2	1.7	128	2.2×10^6	29	2

Table 5.5-3
Physical Characteristics of Lakes in the Study Area (Continued)

Lake Name	Maximum Water Depth (m)	Mean Water Depth (m)	Surface Area (ha)	Lake Volume (m^3)	Drainage Area (km^2)	No. of Fish Species
Siamese Lake Sub Basin						
Siamese Lake	*		2,750		85	*
Kavisilik Lake Sub Basin						
Skinny Lake	12	3.1	197	6.1×10^6	122	4
Kavisilik Lake	12	4.2	564	2.4×10^7	156	4
Squiggly Lake Sub Basin						
Squiggly Lake	14	6	638	3.8×10^7	56	5
Baker Lake Sub Basin						
Baker Lake		15	189,000	2.8×10^{10}	230,000	11

Note: * = no field survey information; NA = not applicable; – = no fish; Compiled from BEAK 1987, BEAK 1992, BEAK 1992, Watters 1989

There are seven lake sub basins in the Project area. Listed in order from North to South

- Siamese;
- Kavisilik;
- Willow;
- Caribou;
- Boulder;
- Sissons; and
- Lower.

There are two other sub basins in the regional study area that could be affected by the project activities:

- Squiggly; and
- Baker.

The lakes in the area can be grouped in three categories based on the geomorphology of the study area:

- Escarpment headwater lakes: these have a mean depth greater than 2 m and are small;
- Tundra plain lakes: these have a mean depth between 1 m and 2 m and are larger than the escarpment lakes; and
- Regional lakes: these are relatively larger, deep and the primary receiving waters of the headwater drainages, including Judge Sissons Lake and Skinny Lake.

Generally, the lakes in the study area tend to be relatively small and shallow and only provide limited fish habitat in many locations. The sub basins of the project study area have well defined stream channels, which makes it possible for fish to move between lakes. Appendix V includes current and historical figures of the waterbodies in the study area.

5.5.2.1 Lower Lake Sub Basin

The Lower Lake sub basin is within the Sissons lease and is located to the east of the Sissons Lake sub basin. Similar to the Pointer Lake sub basin, it is composed of ten lakes. It is made up of Lower, Bear Island, Shack, Andrew, Cigar, End Grid, Smoke, Knee, Lunch, and Mushroom lakes.

These lakes were studied in August 1990 and 1991, and were again surveyed in August and September of 2007. In 2007, habitat mapping was completed of the shoreline and littoral zone of Shack, Andrew, End Grid and, Lower lakes.

The lakes in this sub basin are mostly small, shallow tundra lakes and they are the shallowest lakes in the Project area (Table 5.5-3). With the exception of Mushroom, Cigar, and Smoke lakes, which have mean water depths of 2.6 m, 1.5 m, and 1.3 m respectively; the lakes in Lower Lake sub basin have a mean water depth of less than 1 m. Since ice thickness during winter often reaches 2 m, all the lakes in the sub basin except for Mushroom Lake freeze to the bottom resulting in no winter habitat for fish (BEAK 1987). Based on winter water quality sampling done in 1991, lakes less than 2.5 m to 3.0 m deep are unlikely to have overwintering habitat.

The Lower Lake sub basin has five fish species; Arctic grayling, lake trout, lake cisco, round whitefish, and burbot. Each lake sampled in the Lower sub basin contained fish. Cigar, Lunch, and Mushroom lakes have four species each, Andrew Lake has three species, and End Grid Lake has only one species. The remainder of the lakes all have two species. The most common species captured were Arctic grayling (found in each lake) and lake trout.

Knee Lake

Knee Lake is one of the shallowest lakes sampled, with a mean depth of 0.2 m (similar to Andrew Lake), and a surface area of 34.9 ha. It is larger than eight of the 30 sampled lakes (Table 5.5-3). Knee Lake drains directly into Lunch Lake, a much larger lake to the southwest, via a 100 m to 200 m long interconnecting stream channel.

Lake trout and Arctic grayling were captured in Knee Lake. Arctic grayling prefer shallow habitats for spawning, and both YOY and adults are associated with shallow water. Although lake trout spawn in shallow to deep waters, the adults, YOY, and juveniles prefer deep waters (5+ m).

Knee Lake probably freezes during winter because it is shallow (1.0 m maximum depth), and therefore it is possible that it is only used seasonally or repopulated annually by fish from Lunch Lake where there is overwintering habitat.

Mushroom Lake

Mushroom is located in the Sissons lease. There is an esker to the south of the lake that has been identified as a possible temporary landing area. An ore body has been identified about 500 m south of Mushroom Lake. Mushroom Lake is not only the deepest lake in Lower Lake sub basin, it is also one of the deepest lakes in the study area. Mushroom Lake has a mean depth of 2.6 m, a maximum depth of 8.0 m, and a surface area of 40 ha.

Four species of fish were captured in Mushroom Lake; lake trout, Arctic grayling, round whitefish, and lake cisco. As a deep lake, it is able to provide habitat for lake cisco and round whitefish, which prefer deep habitats in their adult life stages. Mushroom Lake is unlikely to freeze to the bottom during winter and therefore provides critical over-wintering habitat.

Lunch Lake

Lunch Lake is 77.8 ha in size and has a mean depth of 0.6 m. For a shallow lake it has a high number of species present, including: lake trout, Arctic grayling, lake cisco, and round whitefish. The fish species found in Lunch Lake show a high preference for spawning in shallow waters. Cigar and Knee lakes flow into Lunch Lake and all three lakes have the same species present. Therefore, it seems likely that Lunch Lake does not support over wintering fish due to the shallow natural of the lake and it is used seasonally by fish from other lakes.

Cigar Lake

Cigar Lake is a tundra plain lake that is located west of Judge Sissons Lake and flows into Lunch Lake. Cigar Lake is 113 ha in size and has a mean water depth of 1.5 m.

Cigar Lake has the same number and types of fish as Lunch Lake: lake trout, Arctic grayling, lake cisco, and round whitefish. Each of these species spawns in very shallow waters; however, it is unlikely that fall spawners (e.g., round whitefish) would utilize the Cigar Lake, since it will freeze to the bottom in the winter. At other life history stages, lake cisco and lake trout adult then show a preference for deep waters (10+ m). Therefore, it is likely that these species are only using the lake on a seasonal basis and likely move back into Mushroom Lake to over winter.

Bear Island Lake

Bear Island Lake is a small and shallow lake with a mean depth of 0.5 m and an area of 36.5 ha. Bear Island Lake drains into Lower Lake. Arctic grayling and lake trout were captured from Bear Island Lake. Both fish species are known to spawn in shallow waters; however, since lake trout spawn in the fall it is unlikely that they utilize the lake for spawning. Arctic grayling may spawn in the lake or its tributaries in the early spring, but lake trout probably move into the lake for seasonal feeding opportunities.

Shack Lake

Shack Lake is located between Andrew Lake and Lower Lake. Shack Lake is 60 ha and has a mean depth of 0.6 m and a maximum depth of 1 m. Two fish species, Arctic grayling and lake trout, were caught in the lake. Due to the shallow nature of the lake, it is likely used for feeding and rearing during the open water season.

Andrew Lake

Andrew Lake is located west of Judge Sissons Lake in the Sissons lease area. Andrew Lake is a potential water source for drilling water and an ore body is located near it. A proposed core storage site would be located between Andrew and Shack Lakes about 500 m from either lake.

Andrew Lake is a small shallow tundra plain lake covering 54 ha and with a mean depth of 0.2 m. Andrew Lake receives waters from Lunch Lake and the outlet stream flows eastwards into Shack Lake, another shallow lake of a similar size. Andrew Lake has the shallowest mean depth in the Project area.

Andrew Lake has Arctic grayling, lake trout and burbot (recall that Judge Sissons, Sik Sik and Scotch lakes are the only other lakes where burbot were captured). The maximum depth of the lake is unknown. Therefore, it is not known if the lake can support over wintering fish populations. Although adult burbot show a preference for deep waters (10+ m), they have a high preference for spawning in shallow waters (0 m to 2 m). Burbot juveniles and YOY also show a high preference for shallower waters

(0 m to 5 m). As burbot spawn in the late winter (January to March) it is unlikely that they can access this lake for spawning, unless they can over winter in the lake.

End Grid Lake

End Grid Lake is a tundra plain lake located in the Lower Lake sub basin, in the Sissons lease area just south of Mushroom Lake. End Grid Lake drains into Shack Lake to the south. Habitat mapping and other data collection activities were carried out for the first time in 2007. Arctic grayling was the only fish species captured in End Grid Lake.

Although there is still no information on the exact size of End Grid Lake, it appears similar in size to Sik Sik Lake (16 ha), making it the smallest lake in Lower Lake sub basin. Initial water depth measurements indicate that the mean depth is likely in the range of 1.0 m (Golder 2008). Given the estimated size and depth, End Grid Lake is unlikely to provide overwintering habitat for fish. It is also unlikely to provide habitat for fish species that prefer deep waters.

Smoke Lake

Smoke Lake is located west of Cigar Lake and drains directly into Cigar Lake. Approximately half of the lake occurs within the Sissons lease area. It is a tundra plain lake that is 63.5 ha in area and has a mean water depth of 1.3 m.

Arctic grayling and lake cisco were captured in the lake. Smoke Lake probably does not provide over wintering habitat for fish due to the shallow depth. But it does provide habitat for spawning and other life history stages. For instance, lake cisco adults prefer deep waters (10+ m), but they will spawn in depths of 0 m to 5 m. YOY lake cisco show a preference for shallow water.

Lower Lake

With an area of 49 ha, Lower Lake is one of the larger lakes in Lower Lake sub basin. It is shallow, having a maximum depth of 1.0 m and a mean depth of 0.4 m. Lower Lake is located outside the Sissons and Kiggavik lease areas.

Lower Lake probably doesn’t provide over wintering habitat for the three fish species captured in the lake (Arctic grayling, round whitefish, and lake cisco). Based on the interconnected streams, Lower Lake is probably recolonized by fish from Judge Sissons Lake in the spring and summer, with seasonal use by the fishes (BEAK 1992). It also provides an important migratory pathway to seasonal fish habitat in the lakes of the upper part of the basin.

5.5.2.2 Caribou Lake Sub Basin

The Caribou Lake sub basin is composed of Ridge, Cirque, Crash, Fox, and Caribou lakes. Fox Lake and Caribou Lake are located on the Sissons lease; whereas, Crash Lake is located on the Kiggavik lease. Ridge and Cirque lakes are not located in either lease area.

The lakes in this sub basin are primarily small shallow tundra lakes with mean depths ranging from 1.1 m (Crash Lake) to 2.6 m (Cirque Lake). The Caribou Lake sub basin has two of the smallest lakes in the study area, Cirque and Crash lakes, which are 5.6 ha and 8.1 ha, respectively.

Bathymetry surveys for these lakes were completed in 1979, 1980 and 1986. Three fish species were captured in this sub basin. Each sampled lake had fish, with a maximum of two species found within a single lake. Arctic grayling was the most common species in this sub basin, as it was found in four of the five lakes sampled. Lake trout were found in three of the lakes, whereas ninespine stickleback were only found in one lake.

Crash Lake

Crash Lake is located in the northwestern portion of the project site, almost directly west of Meadow Lake. With a surface area of 8.1 ha, a mean depth of 1.1 m and a maximum depth of 2 m, it is a rather small and shallow lake.

Only one species, Arctic grayling, was captured in the lake. Crash Lake is shallow and probably freezes to the bottom during winter. Therefore, the lake provides seasonal fish habitat during the open water period.

Ridge Lake

Ridge Lake is an escarpment headwater lake located in the northern portion of Caribou Lake sub basin, draining south into Crash Lake. At 16.7 ha, Ridge Lake is one of the smaller lakes in the Caribou sub basin; however, it is also the deepest lakes in the sub basin with a mean depth of 2.3 m and a maximum depth of 6 m. A bathymetry map for Caribou Lake is included in Appendix V.

Lake trout are the only species that has been captured in Ridge Lake to date. For the depth and size of Ridge Lake, fish abundance and diversity is low, presumably because it is relatively isolated at the headwaters of the Caribou Lake sub basin.

Since the lake is more than 2 m deep, it should be capable of supporting over wintering fish. It is likely that the lake has the habitat necessary to support all life stages of lake trout, although this has can not be confirmed with the available data.

Cirque Lake

Cirque Lake is an escarpment headwater lake and it is the smallest lake in the study area, covering only 5.6 ha. It is also one of the deepest lakes in the sub basin, with a maximum depth of 4 m and mean depth of 2.6 m. Therefore, it may provide over wintering habitat. Arctic grayling and ninespine stickleback were captured in the lake during the 2007 survey.

Fox Lake

Fox Lake drains into Caribou Lake to the south. It is 128 ha in size and has a mean depth of 1.7 m and a maximum depth of 2.0 m. Arctic grayling and lake trout were captured in the lake. Fox Lake offers spawning habitat for the resident fish species but probably offers limited overwintering habitat due to the shallow depth.

Caribou

Caribou Lake drains southeast into Judge Sissons Lake. It is located almost entirely within the Sissons lease. The surface area of Caribou Lake is 341 ha. It has a mean depth of 1.4 m and a maximum depth of 2 m. Fish species captured in the lake included lake trout and Arctic grayling. Caribou Lake may not support over wintering fish due to the limited depth of the lake; however, it is provides an important migratory corridor for fish moving upstream from Judge Sissons Lake.

5.5.2.3 Willow Lake Sub Basin

The Willow Lake sub basin is composed of Escarpment, Felsenmeer, Meadow, Drum, Lin, Scotch, Jaeger, Sik Sik, Pointer, and Willow lakes. Bathymetric surveys were carried out in 1979 and 1986. Some of these lakes were found to be small deep escarpment headwater lakes, others were small shallow tundra plain lakes.

Pointer, Sik Sik, and Rock lakes are located in the Sissons lease. Escarpment Lake is partially located on the Kiggavik lease. The remaining lakes are outside the Project leases. One of the three proposed sites for core storage is at or near Pointer Lake. The Kiggavik camp will also be located in the Willow Lake sub basin.

Except for Jaeger, Meadow, and Rock lakes, which have no records of fish captured, six fish species were captured in the rest of the lakes. Similar to their distribution in the other sub basins, Arctic grayling and lake trout were the most common species and were captured in over 50% of the lakes in the sub basin. Lake cisco was captured in only one lake.

Meadow Lake

Meadow Lake is a typical tundra plain, headwater lake located at the north end of Willow Lake sub basin. It is very small at 14.0 ha and relatively shallow (mean depth of 0.8 m and a maximum depth of 2 m). A bathymetry map is provided in Appendix V.

No fish were captured in Meadow Lake. This may be explained as it is in the headwaters and is only connected to the downstream part of the watershed through a relatively long tributary, which runs dry in the summer.

Felsenmeer Lake

Felsenmeer Lake is as an escarpment headwater lake located east of Meadow Lake. It drains into Jaeger Lake and is outside the lease area. Felsenmeer Lake is small, covering just 20.8 ha, and has a mean depth of 2.0 m and a maximum depth of 6.0 m. Due to its depth, it is able to provide some over wintering habitat for fish, as well as habitat for fish that prefer deep waters.

Three species of fish were captured in the lake, including lake trout, Arctic grayling and round whitefish. It is assumed that the habitat present supports all life-stages of fish species captured in the lake.

Escarpment Lake

Escarpment Lake is an escarpment headwater lake located southwest of Felsenmeer Lake. Like Meadow and Felsenmeer lakes, it too drains south into Jaeger Lake. Escarpment Lake is the smallest lake in Willow Lake sub basin at 13 ha; however, it has a mean depth of 2.2 m. It is the deepest lake in the sub basin with a maximum depth of 8 m.

Escarpment Lake supports lake trout, Arctic grayling and round whitefish, similar to Felsenmeer Lake. It is assumed that the habitat present supports all life-stages of fish species captured in the lake.

Drum Lake

Drum Lake is 25 ha in size, with a mean depth of 1.3 m and a maximum depth of 2 m. Drum Lake flows south into Lin Lake.

Arctic grayling was the only fish species captured in Drum Lake. As the lake does not have sufficient depth to support over wintering, Arctic grayling are likely only using the lake on a seasonal basis.

Lin Lake

Lin Lake is 48 ha in size and has a mean depth of 1.3 m. There is no information available on the maximum depth of the lake. Lin Lake flows southwest into Jaeger Lake.

Like Drum Lake, Arctic grayling is the only fish species that has been captured in Lin Lake. This is may be due to the limited over wintering habitat provided by Lin Lake.

Jaeger Lake

Jaeger Lake is the second largest lake (after Pointer Lake) in the Willow Lake sub basin at 281 ha. It has a mean depth of 1.6 m and a maximum depth of 4.0 m. Jaeger Lake is located outside of the Sissons lease. Jaeger Lake flows south into Pointer Lake. A bathymetry map of Jaeger Lake is included in Appendix V.

Arctic grayling is the only fish species that has been captured in Jaeger Lake. Given the depth of the lake, it is likely that Arctic grayling can over winter in the lake.

Pointer Lake

Pointer Lake is located entirely within the northeastern portion of the Sissons lease. One of the three proposed core storage sites is near Pointer Lake. Pointer Lake flows south into Willow Lake. Pointer Lake is the largest lake in the Willow Lake sub basin. At 374 ha, it is larger than all the lakes in the Andrew and Caribou Lake sub basins as well; however, it is relatively shallow having a mean depth of 1.5 m and a maximum depth of 2.9 m. A bathymetry map of Pointer Lake is provided in Appendix V.

Pointer Lake has the third highest fish community diversity within the study area. Fish species captured in the lake include lake cisco, round whitefish, Arctic grayling, lake trout, and ninespine stickleback. Pointer Lake is the only lake in the sub basin where lake cisco were found. As some over wintering habitat is present, it is assumed that the lake can support over wintering fish populations and that the fish species captured in the lake are resident to the lake.

Sik Sik Lake

Sik Sik Lake is located in the Sissons lease area and drains south into Willow Lake. At 16 ha, it is one of the smallest lakes in the study area. It is also shallow with a mean depth of 0.8 m and a maximum depth of 2.0 m. A bathymetry survey of Sik Sik Lake was completed during earlier baseline studies and the resulting bathymetric map is included in Appendix V. During the 2007 Golder fish survey, ninespine stickleback were captured in Sik Sik Lake.

Rock Lake

Rock Lake is located just south of Sik Sik and Pointer lakes in the Sissons lease area. Rock Lake drains south through Willow Lake into Judge Sissons Lake. Rock Lake is small (26.9 ha) and shallow (mean depth of 1.4 m). A bathymetry survey was completed of Rock Lake (see Appendix V).

No fish have been captured in Rock Lake during the various studies. Fish may not have been captured in Rock Lake due to its small size and shallow depth. However, lakes upstream and downstream of Rock Lake are fish bearing. It is likely that the lake provides migratory pathways to lakes further upstream. As other lakes, upstream and downstream, with similar size and depth profiles had at least one species of present, additional effort and variety of fishing methods may result in fish captured in the future for Rock Lake.

Willow Lake

Willow Lake is located just south of Rock Lake and is outside of the Sissons lease area. The surface area of Willow Lake is 54.9 ha, and it has a mean depth of 1.4 m and a maximum depth of 2.0 m. Nine of the sampled lakes in Willow Lake sub basin eventually drain through Willow Lake and subsequently to Judge Sissons Lake. The bathymetry map of Willow Lake is provided in Appendix V.

Three species of fish were captured in Willow Lake, including lake trout, Arctic grayling and ninespine stickleback. Due to its shallow depth, Willow probably doesn’t provide over wintering habitat. However, it does provide an important migratory corridor for fish moving upstream from Judge Sissons Lake.

5.5.2.4 Kavisilik Lake Sub Basin

Skinny Lake

Skinny Lake is located to the northeast of the lease area, on the St. Tropex claim. Kavisilik Lake drains into Skinny Lake, which in turn drains into Siamese Lake to the south east. During the 1990 and 1991 field studies, habitat conditions around the perimeter of Skinny Lake were documented and the figures showing transects of aquatic habitat across the lake are presented in Appendix V.

Skinny Lake is one of the regional mainstream lakes with a surface area of 197 ha. The lake has a mean depth of 3.1 m and a maximum depth of 12 m. Lake cisco, round whitefish, Arctic grayling and lake trout are present in Skinny Lake. The perimeter of the lake is primarily a cobble/rock, which extends to approximately 3 m depth contour, which is suitable for spawning, as well as rearing habitat for many of the resident species. The lake bottom has a sand and sandy-silt substrate. Skinny Lake is sufficiently deep to provide over wintering habitat for fish.

Kavisilik Lake

Kavisilik Lake is one of the largest lakes in the study area (564 ha). It is also one of the deepest lakes with a mean depth of 4.2 m and a maximum depth of 12 m. Together with Skinny Lake; it is the third deepest lake in the study area. A bathymetry map is included in Appendix V.

Four fish species were captured from Kavisilik Lake, including: Arctic grayling, lake trout, round whitefish and lake cisco. The size and depth of the lake would provide good over wintering habitat.

5.5.2.5 Judge Sissons Sub Basin

Judge Sissons Lake

This sub basin is composed of Judge Sissons Lake and is located southeast of the Sissons lease area. Judge Sissons Lake is the largest lake in the project area covering 9,550 ha, with a mean depth of 4.6 m and a maximum depth of 20 m. The capacity of Judge Sissons Lake (440 million cubic metres) is ten times that of Squiggly Lake (the third largest lake in the project site). It is one of the regional mainstream lakes and the primary receiving waters of several local headwater drainages. Lower Lake, Boulder Lake, Caribou Lake, and Willow Lake sub basins all drain into Judge Sissons Lake.

Judge Sissons Lake discharges to the Anigaq River, which flows southeast into Baker Lake. The bathymetry map of the lake is in Appendix V.

Seven fish species have been captured from Judge Sissons Lake to date. The fish captured in Judge Sissons Lake represent the full compliment of species from the lakes that eventually drain into Judge Sissons Lake, including lake trout, arctic grayling, round whitefish, lake cisco, burbot, ninespine stickleback, and slimy sculpin. The only fish species not captured from Judge Sissons Lake that have been found in the regional study area are Arctic char and the three species found in Baker Lake (i.e., longnose sucker, lake whitefish and fourhorn sculpin).

Given the size and depth of the lake, it is assumed that the lake provides habitat that supports all life-stages of the species captured in the lake. Detailed habitat mapping of the lake has not yet been conducted, therefore, critical habitat areas (e.g., spawning areas) have not yet been identified.

5.5.2.6 Boulder Lake Sub Basin

Boulder Lake

This sub basin is composed of Boulder Lake, which is located between the Lower Lake and Caribou Lake sub basins. Boulder Lake drains into Judge Sissons Lake. Part of Boulder Lake falls within the Sissons lease area.

A bathymetry survey was not conducted on Boulder Lake. Information about the lake regarding the size, mean depth, maximum depth and fish populations is currently lacking.

5.5.2.7 Squiggly Lake Sub Basin

Squiggly Lake

This sub basin is composed of Squiggly Lake and is located to the northwest of the Project site. It is the only lake in the Project area that drains northward into the Thelon River sub basin. Squiggly Lake is outside the Kiggavik or Sissons lease areas, but has been identified as a potential source of process water. It is one of the regional mainstream lakes. It is large and deep; with a surface area of 638 ha and a mean depth of 6.0 m. A bathymetry map of Squiggly Lake is included in Appendix V.

Squiggly Lake has rocky shoals that can provide suitable spawning habitat for many species of fish. The mean depth of 6 m provides habitat for species of fish that prefer a range or greater water depths. Because of the depth, the lake can provide habitat for fish to over winter. In addition, the lake has relatively high species diversity with five of the nine fish in the study area found in it. The fish species known to occur in the lake include Arctic grayling, lake trout, round whitefish, burbot, and Arctic char.

5.5.2.8 Baker Lake Sub Basin

Baker Lake

The Baker Lake sub basin is composed of Baker Lake. All waters from the Project site drain through the Aniguq River into Baker Lake. The Thelon River also drains into Baker Lake. It is a large regional water body covering 189,000 ha with a mean depth of 15 m. The western portion of Baker Lake was surveyed in 1975; however, a bathymetry survey of the lake wasn't completed at that time (McLeod et al. 1976).

Eleven fish species were captured during the survey of the western portion of Baker Lake. Three of the fish species (longnose sucker, lake whitefish and fourhorn sculpin) were not captured in any of the other lakes in the project site. Baker Lake offers a wide variety of habitats for many fish species and their life history stages.

5.6 Benthic Invertebrate Community

Benthos are considered significant as defined by the FEARO impact statement guidelines, due to their ability, to an certain degree, to bioaccumulate stable and radioactive trace elements that could be associated with a mining operation. In addition, the reliance of fish on benthos as a food resource base renders these aquatic organisms significant to the aquatic ecosystem as a whole and the local communities that rely on them.

Benthic Invertebrate Community (BIC) samples were collected between 1979 and 1991 in the Project area. The field studies conducted between 1979 and 1989 were general in scope, and the objectives were to collect baseline information on BIC communities within the Project area. The 1990 to 1991 sampling program objectives were to fulfill the FEARO (1990) request for replicate BIC samples from the Project area lakes. Several lakes were also sampled in 2007 in the Project area to obtain information on natural variability and BIC composition.

5.6.1 Benthic Invertebrate Community Data Collection Methods

Benthic communities were sampled within the Project area in 1979, 1980, 1989, 1990, and 1991 BEAK (1990; 1992a). Lake samples were collected in 1979, 1980, 1990, and

1991 from Kavisilik, Scotch, Pointer, Sissons, Shack, Cigar, Knee, Lunch, Mushroom, and Squiggly lakes; and from lakes located 1 km and 2 km upstream of Lower Lake. Samples were also collected in 2007 by Golder. Table 5.1-1 shows the sampled lakes and years that BIC studies occurred in throughout the Project area.

5.6.1.1 Sampling Methods in Lakes: 1979-1991

BIC samples were generally collected from deep basins of lakes using a standard Ponar grab (1979 and 1980) or an Ekman grab (1990 and 1991), and sieved through a 500 µm sieve (BEAK 1990; BEAK 1992a). In 1979 and 1980, the number of stations within a lake varied from one to six. In 1990 and 1991, triplicate samples were collected per lake. A single grab sample was collected per station (BEAK 1990; BEAK 1992a). Samples were preserved with 10% buffered formalin (BEAK 1992).

Attempts were made to collect samples from the deep basin of Judge Sissons Lake in 1991 (BEAK 1992a); however, the sediment in the vicinity of the deep basin was comprised of hard packed clay and after considerable effort, no samples were recovered.

5.6.1.2 Sampling Methods in Streams: 1989-1991

Stream samples were collected in triplicate using a standard Surber sampler equipped with a 500 µm mesh collection bag (BEAK 1990; BEAK 1992). Samples were preserved with 10% buffered formalin (BEAK 1992).

5.6.1.3 Sampling Methods in Lakes: 2007

The BIC survey was conducted concurrently with the sediment and water chemistry sampling. BIC samples were collected using a standard 6 inch Ekman grab. Two stations per lake were sampled: one deep water location and one shallow water location (approximately 1 m deep). At each station, five subsamples were collected and combined into a single composite sample. BIC samples were sieved using a 500 µm mesh sieve bag, and preserved with 10% buffered formalin.

Only one BIC sample was collected from Willow Lake due to absence of soft sediment at the deepest station (possibly cobble and boulder). In addition, the shallow station comprised six subsamples due to the small amount of sediment available at the sampling station. Figure 5.6-1 shows the lakes that were sampled for BIC in 2007.

5.6.2 Benthic Invertebrate Community Baseline Results: 1979 - 1991

Benthic communities in the Project area lakes are characterized by low density and diversity. They are dominated by various chironomids (midge flies) and the pea clam, *Pisidium* (Table 5.6-1). Benthic communities in Arctic lakes are typically dominated by chironomids, including Saqvaqjuac lakes and high Arctic lakes (Welch 1985). Other benthic fauna, found in the stomachs of fish taken in the 1986 gill netting program include stoneflies, caddisflies and amphipods (BEAK 1990). In general, densities of benthic organisms in the Project area lakes are similar to densities reported in ELA Canadian Shield lakes in northwestern Ontario (Hamilton 1971).

Benthic communities collected during 1990 and 1991 in lakes of the Andrew Lake sub basin were typically low in number and dominated by various chironomids, nematodes and the pea clam, Pisidium. Other benthic fauna, found in the stomachs of fish taken in the 1991 netting program, include stoneflies, caddisflies, amphipods and snails.

Table 5.6-1
Benthic Invertebrate Community Data in the Kiggavik Area, 1979 to 1991

Waterbody	# of Species	Density #/m^2	SDI
1979			
Pointer Lake	4-8	533.8-1,799.9	1.62-2.36
Judge Sissons Lake	3-16	11.4-3,375.5	1.59-3.20
Scotch Lake	13	1,825.5	3.29
1980			
Pointer Lake	4-8	459.2-1,550	1.20-2.41
Judge Sissons Lake	0-5	0-10,639	0-1.89
Scotch Lake	10	11,289	2.53
Squiggly Lake	7	2,105	2.12
Kavisilik Lake	3	344.4	1.58
1989			
Jaeger Lake outlet	18-23	1,411-3,522 [a]	-
Ridge Lake outlet	15-20	2,044-15,111[a]	-
Skinny Lake outlet	11-17	333-3,111[a]	-
Pointer Lake outlet	14-20	5,778-32,489 [a]	-
1990			
Knee Lake	12-16	2304-4478	-
Lunch Lake	1-10	87-3,087	-
Shack Lake	7-9	565-1,696	-
Pond 1 km upstream of Lower Lake	14-16	10,043-13,478	-
Pond 2 km upstream of Lower Lake	8-13	2,000-7,478	-
Knee Lake inlet	9-20	215-1,290	-
Lunch Lake inlet	14-20	344-6,516	-
Shack Lake inlet	11-15	215-398	-
Inlet 1 km upstream of Lower Lake	14-19	538-1,226	-
Inlet 2 km upstream of Lower Lake	12-16	624-3,742	-
1991			
Cigar Lake	14-19	15,304-18,957	-
Mushroom Lake	9-13	1,913-5,913	-
Andrew Lake outlet	26-30	10,419-13,269	-
Pointer Lake outlet	11-18	505-1,753	-
Judge Sissons Lake outlet	14-21	2,258-18,957	-

Notes: # = number; m^2 = square meters; SDI = Shannon-Weaver Diversity Index
a = Total number of organisms, no information provided on surface sampled.
Source: BEAK 1990

Figure 5.6-1 Benthic Invertebrate Community Sampling Locations

Stream benthic communities (Table 5.6-1) include an assemblage of various groups. As in the lakes, chironomids tended to be the most common and diverse group of organisms in the outlet streams, although other organisms including Hydra, nematodes, ostracods, snails (*Valvata sp.*) and oligochaetes were also abundant in some samples. Benthic stream communities may provide a useful biomonitoring tool to evaluate any effects of site development on aquatic systems. Variation among replicates at individual survey stations was reasonably large in the baseline collection data, indicating that variance must be accounted for in any benthic monitoring program at the Project site.

5.6.3 Benthic Invertebrate Community Baseline Results: 2007

5.6.3.1 Density

Detailed taxonomic results for the BIC data are presented in Golder (2008). Invertebrate density was highest in the Caribou sub basin during the 2007 survey, ranging from 534 organisms per m^2 in Crash Lake to 112,224 organisms per m^2 in Cirque Lake. Within this sub basin, Cirque Lake Station 2 had the largest number of organisms per metre squared (m^2) (112,224) followed by Fox Lake, which had a density of 12,259 organisms per m^2. Density in the Willow sub basin ranged from 273 to 4,405 organisms per m^2. Willow Lake had the lowest density (273 and 810 organisms per m^2) at Station 1 and 2, respectively. Lower Sub basin density ranged from 198 to 6,853 organisms per m^2. Lower Lake was noted to be the highest density of benthic organisms (3,578 and 6,853 organisms per m^2). Results are presented in Table 5.6-2.

5.6.3.2 Species Richness

Mean taxa richness at individual sampling stations ranged from 6 to 21 taxa and was similar within different sub basins. Within the Willow Lake sub basin, richness varied from eight taxa in Willow Lake to 20 taxa in Sik Sik Lake. Within the Caribou Lake Sub basin, taxa richness varied from six taxa in Crash Lake to 17 taxa in Ridge Lake. Richness values in the Lower Lake Sub basin had the greatest range from six taxa in Crash Lake to 21 taxa in Lower Lake.

Table 5.6-2
Biotic Indices Summary for the Benthic Invertebrate Communities, Kiggavik 2007

Sub Basin	Waterbody	# of Taxa	Density #/m²	SDI
Willow	Willow Lake	8-16	273-810	0.4-0.43
	Sik Sik Lake	17-20	3560-4405	0.43-0.67
	Pointer Lake	13-15	3319-3603	0.38-0.59
Caribou	Fox Lake	12-14	2466-12259	0.53-0.74
	Crash Lake	6	534-1422	0.41-0.55
	Cirque Lake	8	11741-112224	0.06-0.49
	Ridge Lake	13-17	948-5293	0.5-0.53
Lower	Lower Lake	14-21	3578-6853	0.37-0.66
	Shack Lake	9-10	431-1233	0.11-0.56
	Andrew Lake	6-8	509-802	0.32-0.68
	End Grid Lake	7-8	198-784	0.16-0.23

Notes: # = number; m^2 = square meters; SDI = Shannon-Weaver Diversity Index
Source: Golder 2008

The majority of taxa within the fall 2007 samples were represented by four taxonomic families: Chironomidae (Dipterans), Sphaeriidae, Lumbriculidae, and Tubificidae. Chironomidae were found in all waterbodies sampled in 2007. There were only a few occurrences of Planorbidae, Chydoridae and Naididae. Two species belonging to the Orthocladiinae group (Diptera), could not be identified by the taxonomist.

The BIC of the Willow Lake sub basin was mainly comprised of chironomidae, sphaerid clams and tubificid. In Willow Lake, the BIC was dominated by chironomids (45.7%) and tubificid (44.0%). Within Sik Sik Lake, 51.3% of organisms were chironomids 23.2% were tubificid worms and 20.5% were sphaerid clams. Chironomids represented 56.4% of all organisms captured in Pointer Lake, whereas 26.0% were sphaerid clams. Chironomids (65.5%) and tubificid worms (14.3%) were the numerically dominant families represented in capture in Lower Lake.

In the Caribou Lake sub basin, chironomids were the dominant family in all waterbodies during the 2007 BIC survey with the exception of Fox and Ridge lakes. Chironomidae were found in every waterbody sampled during the 2007 BIC survey in the Lower Lake sub basin. Other taxonomic families commonly encountered included Tubificidae, Sphaeriidae, and Lumbriculidae. Several families were found in only one waterbody including, Leptoceridae (Lower Lake), Muscidae (Andrew Lake), Naididae (Shack Lake) and Notostraca (End Grid Lake).

5.6.3.3 Simpson's Diversity Index

On average, Simpson's Diversity Index (SDI) values ranged from a low of 0.20 in End Grid Lake to a high of 0.63 in Fox Lake. Within the Willow Lake sub basin diversity values ranged from 0.38 in Pointer Lake to 0.67 in Sik Sik Lake. SDI values within the Lower Lake sub basin ranged from 0.11 in Shack Lake to 0.68 in Andrew Lake. The lowest Simpson's Diversity Index (SDI) values were seen in Shack Lake Station 1 (0.11), End Grid Lake Station 1 (0.16) and End Grid Lake station 2 (0.23), indicating that the communities are dominated by only a few groups (Table 5.6-2).

5.7 Phytoplankton

Field studies were carried out in August of 1979 and August 1989 to document the existing baseline conditions and evaluate the effectiveness of monitoring plankton communities as a measure of environmental change. Aquatic environmental studies were commenced in the Andrew Lake area in August 1990 to collect additional baseline data (BEAK 1990).

Baseline studies were continued into the Kiggavik Project area in 1991 in order to tie in the new data from the Andrew Lake area into the existing baseline database, as well as to address the FEARO requests for additional information (BEAK 1990). The 1991 program included a winter phytoplankton sampling survey, which was conducted in early March 1991. This survey was timed in order to assess the under-ice phytoplankton community. See Figure 5.7-1 for phytoplankton sampling locations.

5.7.1 Data Collection Methods

5.7.1.1 Sampling Period 1979 to 1989

In 1979, phytoplankton samples were collected from four Project area lakes including: Pointer Lake, Jaeger Lake, Scotch Lake, and Judge Sissons Lake. Sampling in 1989 was conducted on five Project area lakes including: Ridge Lake, Pointer Lake, Jaeger Lake, Judge Sissons Lake, and Cirque Lake.

Figure 5.7-1 Phytoplankton and Zooplankton Community Sampling Locations

Samples were collected as whole water samples from mid-depth of each lake in 1979, and from the outlets of each waterbody in 1989. Phytoplankton samples were preserved in the field with Lugol's iodine solution. Phytoplankton biomass was calculated by measuring cell dimensions to then calculate cell volumes, which were used to calculate biomass based on an assumed density of 1 g/cm^3 (BEAK 1990). Phytoplankton were identified and enumerated using an inverted microscope and by following the Utermohl technique.

5.7.1.2 Sampling Period 1990 to 1991

During August of 1990, phytoplankton samples were collected from five lakes from the Lower Lake sub basin: Cigar Lake, Shack Lake, Bear Island Lake, Mushroom Lake, and Lower Lake. Samples were collected as subsurface grabs from lake outlets, and were preserved in Lugol's iodine solution in the field immediately after collection (BEAK 1992).

During the winter sampling in March of 1991, phytoplankton communities were collected at Judge Sissons Lake and Ridge Lake. Water quality samples were gathered as subsurface grabs at the hole cut in the ice over the deep basin of each lake (BEAK 1992). Phytoplankton samples were colleted in June of 1991 as subsurface grabs from the outlets of Judge Sissons Lake, Pointer Lake, and the Andrew Lake. The deep basins of Judge Sissons Lake, Pointer Lake, Cigar Lake and Mushroom Lake were sampled in July of 1991.

Biomass was determined by measuring the cell dimensions to calculate cell volumes, which were then used to calculate biomass based on an assumed density of 1 g/cm^3 (BEAK 1992). Phytoplankton were identified and enumerated using an inverted microscope following the Utermohl technique (BEAK 1992).

5.7.2 Results

5.7.2.1 Sampling Period 1979 to 1989

Phytoplankton communities in the Project area lakes for 1979 and 1989 showed characteristics typical of unproductive Canadian Shield lakes (BEAK 1990). Total phytoplankton biomasses were low, and generally ranged between 100 mg/cm^3 and 300 mg/cm^3.

Chrysophyceae were dominant in every lake sampled in 1979 and 1989 (with the exception of Ridge Lake in 1989) with Chlorophyceae, Chlorophyta and Cryptophyceae being present in lesser quantities. The phytoplankton community of Ridge Lake in 1989 was dominated by the diatom *Tabellaria floculosa* (BEAK 1990).

Biomasses of 200 to 2,000 mg/cm^3 are typical of Shield lakes within the Experimental Lakes Area (northwestern Ontario), with Chrysophyceae also numerically dominant (Schindler and Holmgren 1970 as presented in BEAK 1990).

Phytoplankton communities surveyed in 1979 and 1989 were very dynamic, responding over short time periods (days to weeks) to changing environmental conditions. Due to their dynamic nature, it is very difficult to measure substantial changes in the community structure without intensive (i.e., daily or weekly) sampling through the summer season. Plankton communities in the area were extremely variable in terms of species composition and numbers of organisms, offering little potential for operational monitoring with the exception of identifying gross changes over time.

Detailed results from the 1989 sampling events are presented in Appendix VII. Detailed results from the 1979 phytoplankton sampling events were not available at the time this document was being prepared.

5.7.2.2 Sampling Period 1990 to 1991

August 1990

All samples collected in August of 1990 were very rich in species, and contained species typical of shallow tundra pond habitats (BEAK 1992). A large range in biomass (65 mg/m^3 to 783 mg/m^3) indicated high inter-lake variability.

Communities sampled in 1990 were generally reflective of the habitats from which they were collected. Phytoplankton samples collected from the Cigar Lake outflow were dominated by green algae, mainly due to the presence of *Euastrum*, which is not normally planktonic (BEAK 1992). The large number of small unicellular and colonial chrysophytes is typical of tundra ponds or littoral zones, which was the habitat that comprised most of Cigar Lake.

Phytoplankton sampled from the Shack Lake outflow had the lowest biomass and species richness of the five lakes sampled in August 1990. The community in Shack Lake was indicative of a shallow waterbody that is subjected to wind mixing, and was comprised of far fewer chrysophytes than that from Cigar Lake (BEAK 1992).

Bear Island Lake was dominated by cyanobacteria, chlorophytes and chrysophytes.

Mushroom Lake was dominated by true planktonic diatoms and chrysophytes. The large amount of diatoms reflected the much deeper main basin, which consisted of fewer littoral or pond algae than the other waterbodies sampled.

Detailed results from the August 1990 sampling events are presented in Appendix VII.

Winter 1991

In the March 1991 winter sampling, there was a large difference between the planktonic communities of Ridge and Judge Sissons lakes. The sample collected from Judge Sissons Lake had a very low biomass and relatively sparse flora, whereas the sample from Ridge Lake was the opposite (BEAK 1992). Both lakes had many typical winter species indicating that the spring bloom had not yet occurred at the time of sampling.

Detailed results from the winter 1991 sampling events are presented in Appendix VII.

July 1991

Planktonic communities sampled from the deep basins of Judge Sissons, Pointer, Cigar and Mushroom lakes in July of 1991 were very diverse in species. The flora and biomass of all the lakes were typical of summer collections from Arctic or subarctic lakes, with specific assemblages affected by lake depth (BEAK 1992).

The phytoplankton communities in the Andrew Lake study area were similar to the communities previously described in the Kiggavik area lakes (BEAK 1990). Dominant species from the July 1991 sampling included: *Aphanocapsa delicatissima*, *Dinobryon bavaricum*, *Chromulina* sp,. *Ochromonas* sp. and *Rhodomonas minuta* (BEAK 1992). These communities showed characteristics typical of unproductive tundra lakes and ponds as known in general from the Canadian Arctic (BEAK 1992).

Detailed results from the July 1991 sampling events are presented in Appendix VII.

5.8 Zooplankton

Field studies were carried out in July and August of 1979 as well as August 1989 to determine baseline conditions and evaluate the effectiveness of monitoring the 300 plankton communities in order to measure environmental change (BEAK 1990). Aquatic environmental studies commenced in the Andrew Lake area in August 1990 and July 1991 to collect additional baseline data. Figure 5.6-1 shows zooplankton sampling locations.

5.8.1 Data Collection Methods

5.8.1.1 Sampling Period 1979 to 1989

Zooplankton communities were sampled in the Project area lakes in 1979 and 1989. Pointer Lake zooplankton were sampled on nine separate occasions during the 1979 ice-free season. Zooplankton communities in Judge Sissons Lake were sampled three times, and Jaeger and Scotch Lake were each sampled once in the 1979 ice-free season (BEAK 1990).

Samples were collected by a vertical haul using a 60 micron mesh Wisconsin net in 1979. Zooplankton samples from the 1989 survey were sampled by filtering a measured volume through a 60 micron mesh plankton net that was situated at a stationary location in the lake outlet streams (BEAK 1990).

5.8.1.2 Sampling Period 1990 to 1991

During the August 1990 sampling events, zooplankton communities were sampled from the outlet streams of five waterbodies located within the Lower Lake sub basin including: Cigar Lake, Shack Lake, Bear Island Lake, Mushroom Lake and Lower Lake. Samples were also collected from the deep basins of Judge Sissons Lake, Pointer Lake, Cigar Lake, and Mushroom Lake during the July 1991 sampling period (BEAK 1992).

Zooplankton samples were collected by filtering a measured volume through a 60 µm mesh plankton net at a stationary location established in the lake outlet streams or from the deep basins of the lakes (BEAK 1992). Samples collected were preserved in the field using a 10% buffered formalin solution.

5.8.2 Results

5.8.2.1 Sampling Period 1979 to 1989

During the 1979 sampling events, crustacean densities in Pointer, Jaeger, Scotch and Judge Sissons lakes ranged between 0.4 and 9.6 organisms per litre (BEAK 1990). Densities of crustaceans sampled in 1989 varied more widely, ranging from 0.04 to 20.5 organisms per litre.

Common species encountered during the two sampling events were *Diaptomus minutus*, *Cyclops scutifer*, *Holopedium gibberum*, *Bosmina longirostris* and *Daphnia longiremis* (BEAK 1990). Most of these species were reported to occur at similar low densities in the Saqvaqjuac lakes (BEAK 1990). Relative to other Canadian Shield lakes, the densities of crustacean zooplankton were low, reflecting a relatively low biological productivity of Kiggavik area lakes.

Rotifers were identified during the 1989 sampling events, but were not analyzed in 1979. The fairy shrimp (*Brachinecta* sp.) was observed in abundance in lakes lacking large bodied fish such as Sik Sik Lake and Meadow Lake during the summer months (BEAK 1990). This species was not identified in the deeper lakes that provide winter habitat for fish, most likely due to the high susceptibility of the species to fish predation (BEAK 1990).

Zooplankton communities sampled in the area in 1979 and 1989 were found to be extremely variable in terms of species composition and numbers of organisms, and would likely offer little potential for operations monitoring with the exception of identifying gross changes (BEAK 1990). Detailed results from the 1979 and 1989 sampling events are presented in Appendix VII.

5.8.2.2 Sampling Period 1990 to 1991

During the 1990 sampling events, crustacean densities in Cigar, Shack, Bear Island, Mushroom and Lower lakes ranged from 0.04 to 0.8 organisms per litre (BEAK 1992). Densities of zooplankton from the July 1991 sampling events were higher, ranging between 3.3 and 8.4 organisms per litre.

Common species encountered in the 1990 and 1991 surveys included *Epishura lacustris*, *Bosmina longirostris*, and *Holopedium gibberum*. Additional species encountered that were common only to the 1990 sampling events included *Acroperus harpae*, *Chydorus sphaericus*, and *Pleuroxus* sp. Species commonly encountered during the July 1991 sampling included *Cyclops scutifer*, *Bosmina longispina*, and *Daphnia longeremis*.

Of the rotifers identified during the 1990 and 1991 surveys, *Conochilus* sp. was found to be abundant in the outlets of Cigar Lake and Lower Lake during the 1990 survey. *Kellicottia* sp. and *Conochilus* sp. were abundant in the deep basins of Judge Sissons, Pointer and Mushroom lakes in the July 1991 survey.

Detailed results from the 1990 and 1991 sampling events are presented in Appendix VII.

5.9 Aquatic Organisms and Habitat Data Gaps

5.9.1 Background to Data Gap Identification

Baseline data should be collected from waterbodies in the Project area that may be impacted by various components of the proposed project, as well as those that are not likely to be influenced in order to provide a measure of reference conditions. The location and intensity of the baseline data collection program is specific to each waterbody and depends on its future utilization during the project (e.g., water source, effluent discharge location, and retention ponds) and the utility of previously collected information. Baseline information should be collected in all waterbodies where there is a potential for direct impacts (e.g., mine pit development, effluent discharge, and water supply). When possible, baseline information should be collected upstream (reference) and downstream (exposure) of the proposed activity. The downstream area should include near-field and far-field stations. Indirect and/or cumulative impacts should also be considered in the monitoring and assessing future development.

The Project comprises two large groups of mining leases and mineral claims subdivided into Kiggavik lease to the north and Sisson leases to the south. Mine development plans for the Kiggavik area include two or three open-pit mines, a mill, and camp infrastructure. At this point in development planning, there is the potential for project infrastructure to have an impact on Pointer Lake and Sik Sik Lake. Both lakes flow into Judge Sissons Lake via Rock Lake. The discharge of the effluent could affect water and sediment quality, BIC, phytoplankton and zooplankton communities, fish habitat, and fish health. The mine pits may be located near the headwater of the Willow Lake sub basin. One of the inlet streams to Pointer Lake (east tributary) may be diverted to facilitate mine pit development.

The Sissons lease mining activities would include two open pits or underground mines. End Grid Lake and Andrew Lake (Lower Lake sub-basin) will probably be directly affected by mining activities (e.g., dust transport, erosion, and habitat loss). The proposed open pits are located close to the tributary of Crash Lake, and the system could also receive dust from the open pits. In addition, the dewatering water (e.g., groundwater) from the open pit and underground mine will likely be discharged into the system.

Field camp infrastructure was constructed in 2007, southeast of Cirque and Ridge Lakes. Consequently, the system from Ridge Lake down to Judge Sissons Lake (Caribou Lake sub basin) will also need to be studied.

Skinny Lake, Siamese Lake, and Squiggly Lake are potential water sources, and water quality and sediment chemistry information will be collected from the lakes. Squiggly Lake is less likely to be used, as it occurs in the Thelon River sub basin. Based on experience during the Mackenzie Valley Gas Pipeline, the fish species in lakes that will be used as sources of water will also have to be assessed.

Ultimately, all the discharges from the Project will enter Judge Sissons Lake. Consequently, studies will need to be conducted on Judge Sissons Lake, since it will be the receiving environment for discharges from both mining leases.

5.9.2 Fish Data Gaps

As the project description has not been finalized, fish data gap analysis will be based largely on general baseline data needs. Fish health, population and habitat information which are required for a baseline include:

- fish presence/absence;
- relative abundance;
- fish health (weight, length, age, sex, sexual maturity, and diet);
- habitat use (for spawning, rearing, juvenile, YOY, and overwintering uses); and
- tissue chemistry.

Although fish data has been collected from thirty one of the thirty three lakes in the study area (Table 5.1-1), the baseline data still contains several gaps. The data gaps are presented in the following subsections:

- fish health and population;
- fish chemistry; and
- fish habitat.

5.9.2.1 Fish Health and Population Data Gaps

Except for the Siamese sub basin, fish health and population data has been collected from all sub basins in the project area; however, the following data gaps still exist:

- There is little or no information on small bodied fish as fish population surveys have focused on large-bodied fish species (e.g., lake trout, Arctic grayling, Arctic char). There is very little information on small bodied fish presence, absence, diet, habitat use, or relative abundance.

- Relative abundance: differences in data collection methods over the last 30 years make it difficult to compare population data between lakes and across time. With the existing data, it is not possible to assess the population size or structure.

- Lack of fish health information: Although fish population surveys focused on large bodied fish, the information does not provide sufficient information regarding population structure (e.g., age-at-length, size distribution, etc.).

- Lack of sampling on some lakes and rivers: Some of the lakes that may be affected by the current development plan have not been previously assessed and these include Aniguq River, Siamese, Rock and Boulder lakes.

- Old information: With the exception of the 11 lakes which were sampled in 2007, the rest of the lakes were surveyed at various times between 1979 to 1991. Therefore, most of the data is out dated. Given climatic changes affecting the Arctic and current regulatory requirements for environmental assessments, the fisheries baseline information needs to be updated.

5.9.2.2 Fish Chemistry Data Gaps

Fish tissue chemistry analysis has been done for fish captured from Felsenmeer, Lin, Pointer, Willow, Ridge, Caribou, Judge Sissons, Lower, Andrew, Cigar and Mushroom lakes.

The following data gaps still exist:

- tissue chemistry for small bodied fish;
- analysis of additional parameters; and
- fish tissue chemistry information for lakes that may be affected by current project design.

5.9.2.3 Fish Habitat Data Gaps

Bathymetry surveys were carried out in all sub basins (except for Siamese) and bathymetric maps were produced for the lakes (see Appendix V). There are a number of information gaps:

- With the exception of Skinny Lake, and the lakes which were surveyed by Golder in 2007 (Section 5.4.6) fish habitat was never assessed beyond bathymetry surveys.

- Lake habitat substrate description missing for most of the lakes except Skinny Lake.

- There is no information on fish habitat information for Siamese Lake and Boulder Lake (no records of bathymetric surveys).

- All the fish surveys were done during summer and fall, so there is a limited amount of information on fish habitat usage during winter and spring seasons.

5.9.3 Aquatic Vegetation Data Gaps

There is no information documenting the aquatic vegetation in the waterbodies in the Project area, with the exception of the vegetation documented in the 2007 Golder study (Golder 2008). Future sampling efforts will be needed to further document existing conditions.

5.9.4 Benthic Invertebrate Data Gaps

Several data gaps were identified pertaining to BIC as most of the information was more than 15 years old. In 1990 the Kiggavik FEARO panel indicated the need for more data on benthic macroinvertebrates present in the depositional area of lakes where contaminants might accumulate (Ecometrix 2006). As recommended in the Ecometrix report (2006), a number of lakes from each sub basin should be monitored for most aquatic components. Limited sampling was conducted during the 2007 field program. More stations need to be sampled within each lake as well as at stream sites to assess variability of the benthic invertebrate communities.

BIC information is missing from the following lakes and streams:

Willow Lake Sub Basin:

- Pointer Lake, inflows and outflow;
- Sik Sik Lake and outflow;
- Rock Lake and outflow; and
- Willow Lake and outflow.

Caribou Lake Sub Basin:

- Ridge Lake and outflow;
- Cirque Lake and outflow;
- Crash Lake;
- Fox Lake and outflow;
- Caribou Lake and outflow; and
- Calf Lake and outflow.

Lower Lake Sub Basin:

- Cigar Lake;
- Knee Lake;
- Lunch Lake;
- Andrew Lake and outflow;
- Mushroom;
- End Grid Lake and outflow;
- Shack Lake and outflow; and
- Lower Lake and outflow.

5.9.5 Phytoplankton and Zooplankton Data Gaps

Data are available for phytoplankton and zooplankton as presented in previous documents compiled by BEAK (1990) and BEAK (1992). Lakes in all key sub basins were represented with data from the two previous baseline studies (Ecometrix 2006).

In 1990 the Kiggavik FEARO panel indicated the need for more data on benthic macroinvertebrates present in the depositional area of lakes where contaminants might accumulate (Ecometrix 2006). The panel did not indicate any requirement for additional data on zooplankton or phytoplankton.

It was recommended in 2006 that due to the age of the data presented in BEAK (1990) and BEAK (1992), phytoplankton and zooplankton data should be updated in a number of key locations to determine if existing data is still representative of the current baseline conditions. Ecometrix (2006) has recommended that phytoplankton and zooplankton community samples should be collected once during a summer sampling event. One sample should be collected per lake, and should be analyzed for species composition, density, and biomass (Ecometrix 2006).

6.0 SURFICIAL GEOLOGY AND SOILS

6.1 Data Sources

Table 6.1-1 is a compilation of the work previously conducted in the proposed the Project Study Area that was reviewed for this Technical Information Document (TID).

Table 6.1-1
Work Previously Conducted in the Kiggavik Project Study Area*

Project Type	Year	Work completed for Terrain, Permafrost and Soils
Ecological Land Survey of the District of Keewatin, Northwest Territories	1987	Physiography, bedrock geology and soils were described for each Ecodistrict and Ecoregion in the Kiggavik area using Northern Land Use Information Series (NLUIS) Maps. The maps were jointly developed by Environment Canada and Indian and Northern Affairs Canada (1978-1984) at a 1:250,000 scale.
Kiggavik Preliminary Environmental Study Report	1987	An exploratory Ecological Land Survey (ELC) using aerial photography and field ground truthing to delineate areas that may be sensitive to disturbance. Helicopter surveys were flown to determine surficial deposits as well as bedrock geology. Areas of bedrock exposure were mapped, and descriptions of permafrost types were also noted.
Helicopter Reconnaissance	1988	A visual reconnaissance of the terrain and vegetation of the proposed Kiggavik winter road route and the dock facility at Baker Lake.
Field Condition Reconnaissance	1989	A brief field program to examine conditions at the proposed infrastructure sites associated with the development of the Kiggavik mine.
Desk-top Study – Supporting Document No. 2 Soils and Vegetation (Wickware 1990)	1990	Landsat Thematic Mapper^{TM} satellite data, as well as various scales of aerial photography were used to create a terrain, surficial deposit and soils environmental baseline description and map. The baseline description included mapping of bedrock, geomorphology, permafrost, rock/soil instability and soil types.
Terrestrial Inventory	1990	An exploratory vegetation, terrestrial and terrain inventory for an extension of the Kiggavik area that had not been previously assessed.
Summer Surveys for Kiggavik and Andrew Lake	1990	A field program was conducted in the Kiggavik and Andrew Lake areas to: replicate vegetation and soil descriptions and sampling of all vegetation-soil-landform site types, survey the preferred and alternate winter roads from Kiggavik to Aberdeen Lake and from Aberdeen Lake to the limestone outcrop to identify sensitive area; survey the winter road route from Kiggavik to Baker Lake to identify sensitive areas; and undertake vegetation and landform studies at the proposed Baker Lake dock site and collect lichen samples to determine background radiation characterization.

* information compiled from Ecometrix Inc. 2006

6.2 Spatial Boundaries

6.2.1 Historical Study Area

The information for the historical soil baseline studies are reported in Wickware (1990). The initial Project study area extended from Baker Lake in the east, to a proposed limestone quarry in the northwest, with the proposed Kiggavik mine site in the approximate geographic centre (Figure 6.2-1). The original Project study area included not only the area of potential infrastructure development, but also a 1,113 square kilometres (km^2) area centered on the Kiggavik exploration camp. The current (2007) regional study area (RSA) overlaps parts of the earlier Project study area; however, some areas of the current RSA were not included in the previous studies.

Surveys have been conducted for the Kiggavik Project (the Project) since 1986. Terrain, permafrost and soils information has been compiled from existing information, including reports that have been previously written for the Project.

6.2.2 Current Study Area

In 2007, AREVA began collecting aquatic and terrestrial baseline data, in anticipation of preparing an Environmental Impact Statement (EIS). The RSA for the 2007 terrestrial baseline studies is centered on the anticipated location of the Project, and is in the vicinity of the southern extent of the calving grounds for the Beverly caribou herd. The study area is 90 km long and 80 km wide (7,200 km^2), and includes all of Judge Sissons Lake, and parts of Aberdeen, Schultz, Mallory, and Princess Mary lakes (Figure 6.2-2). The spatial extent of the RSA was selected based on current study areas for caribou and other large mammals (muskoxen, grizzly bears, wolves) for other mining projects in Nunavut (i.e., the Jericho and Doris North projects [Tahera 2000; Miramar 2005]) and the NT (i.e., the Ekati, Diavik, Snap Lake, and Gahcho Kué projects [BHPB 1995; DDMI 1998; De Beers 2002; MVEIRB 2007]), along with logistical constraints, the anticipated mine plan for the Project and avoidance of the calving grounds for the Beverly caribou herd, and known location of caribou water crossings along the Thelon River basin.

Figure 6.2-1 Original Kiggavik Project Study Area

Figure 6.2-2 Regional Study Area for the 2007 Terrestrial Baseline Studies

6.3 Setting

6.3.1 Ecoregions

Ecoregions (sites of similar slope, aspect, topographic position, and soil texture) have been described in previous documents for the Project study area (BEAK 1987a, 1987b) and compiled into a description and discussion in Wickware 1990. The following text has been extracted from that report.

The Project study area is located within three major Ecoregions (Wiken *et al.* 1987):

- Black River Plains;
- Dubawnt Lake Plain/Uplands; and
- Maguse River Uplands.

6.3.1.1 Back River Plain Ecoregion

The Black River Plain Ecoregion (previously known as the Garry Lake Plains Ecoregion) is dominated by level-to-hilly plains consisting primarily of deep to shallow morainal deposits (Wicken *et al.* 1987). Many areas within the ecoregion are mantled by fine deposits of glaciomarine or glaciolacustrine origin. This ecoregion is characterized by:

- broadly sloping lowlands and plateaus consisting of massive rock, glacial moraine and marine sediments;
- young and slightly weathered soils, which are typically frost-churned;
- patterned ground, continuous permafrost and a shallow depth of thaw (less than 100 cm);
- abundant small lakes and ponds often isolated or linked by a poorly-organized drainage system, with the larger rivers flowing northerly or easterly; and
- short, cool summers with nearly continuous sunshine, and long cold winters with little daylight.

6.3.1.2 Dubawnt Lake Plain/Upland Ecoregion

The Dubawnt Lake Plain/Upland Ecoregion (previously known as the Dubawnt Plains Ecoregion) is dominated by a low-lying, rolling plain comprised primarily of deep to shallow morainal deposits in elongated to fluted northwesterly trending ridges (Wiken *et al.* 1987). The ecoregion is characterized by:

- infrequent rocky outcrops, wetlands and eskers found in limited areas;
- young and slightly weathered soils, which are frost-churned;

- patterned ground, continuous permafrost and a shallow depth of thaw (less than 100 cm);
- abundant small lakes and ponds often isolated or linked by a poorly-organized drainage system, with the larger rivers flowing northerly or easterly; and
- short, cool summers with nearly continuous sunshine and long cold winters with little daylight.

6.3.1.3 Maguse River Uplands Ecoregion

The Maguse River Uplands Ecoregion (previously known as Rankin Plains Ecoregion) is dominated by a gently rolling morainal plain, partly modified by marine submergence. The coastal portion consists of deep silt and sand deposits, whereas the inland portion is characterized by extensive areas of marine and alluvial deposits, which have been reworked by marine action (Wiken *et al.* 1987). There are numerous raised beaches and eskers. This ecosystem is characterized by:

- broadly sloping lowlands and plateau consisting of massive rock, glacial moraine and marine sediments;
- low relief with gentle slopes towards the Hudson Bay coastal plain (elevations under 50 m);
- young and slightly weathered soils, which are frost-churned;
- patterned ground, continuous permafrost and a shallow depth of thaw (less than 100 cm);
- abundant small lakes and ponds often isolated or linked by a poorly-organized drainage system, with the larger rivers flowing northerly or easterly; and
- short, cool summers with nearly continuous sunshine and long, cold winters with little daylight.

6.4 Surficial Geology

Six major surficial deposits were identified in the region (BEAK 1987a):

- Morainal deposits,
- Glaciofluvial deposits,
- Glaciolacustrine deposits,
- Glaciomarine deposits,
- Peat/organic deposits, and
- Bedrock.

These surficial deposits are described in the following subsections with text extracted from BEAK (1987a and 1987b).

6.4.1 Morainal Deposits

Moraine is glacial material deposited at, or close to, ice margins, without modification by any other agents of transport. Moraines consist of a mixture of clay, silt, sand, cobbles and boulders. In the Project area two types of morainal deposits were identified (BEAK 1987a).

In general, due to the fine texture of the morainal soils and poor drainage conditions they typically have a high ice content. Ice-rich morainal sediments are susceptible to geomorphic processes associated with permafrost. These sediments are sensitive to changes in the thermal regime following the removal of surface vegetation, inundation, or forest fires. These sediments may be susceptible to frost heaving, surface subsidence, gullying and drainage network disruption and slope instability. Also, active-layer detachment slides and retrogressive-thaw flows slides or slumps can occur.

6.4.2 Glaciofluvial Deposits

Glaciofluvial deposits occur when material is deposited by glacial meltwater streams either directly in front of, or in contact with, glacial ice. The material is typically comprised of non-sorted and unstratified, moderately to well sorted and stratified gravel and sand.

Ice content in glaciofluvial deposits is typically low. Most commonly, the deposits either have a very thick active layer or are unfrozen. These deposits generally form stable unconsolidated deposits and may offer a major source of aggregate where the material is gravel rather than sand.

6.4.3 Glaciolacustrine Deposits

Glaciolacustrine deposits occur where materials are deposited in or along the margins of ice-dammed glacial lakes. They may include sediments released by the melting of floating ice on the glacial lakes.

It has been observed that glaciolacustrine sediments generally have high susceptibility to frost heaving, surface subsidence, gullying and drainage network disruption by combined hydraulic and thermal erosion, even on gentle slopes following vegetation removal. Sensitive slopes may be prone to active-layer detachments and consequent development of retrogressive-thaw flows or slides.

6.4.4 Glaciomarine Deposits

Glaciomarine deposits occur where materials released from the glacial ice come in contact with marine water and deposits are typically thin and contain various forms of permafrost including ice wedgy polygons surface patterns.

6.4.5 Organic Deposits

Organic deposits are composed predominantly of organic materials resulting from accumulation of vegetative matter and contain at least 30% organic matter by weight. Organic deposits form a dominant terrain either as a veneer or blanket overlying the predominantly fine grained soils of moraine and glaciolacustrine plains. They are highly compressible and have low strength when thawed. When frozen, they may contain up to 100% ice by volume.

Changes in surface drainage conditions may result from warming and thawing of permafrost. Local flooding will significantly decrease the insulating value of the peat, thus increasing the permafrost degradation process as saturated peat is ten times more thermally conductive than dry peat. Disturbance of near surface seepage in peat terrain may lead to erosion on sloping approaches to streams, particularly where the peat forms a blanket over flat surfaces into which streams and major tributaries are disturbed. In areas where frost may build up as a result of construction or operation methods, near surface seepage may be disrupted.

6.4.6 Bedrock

Bedrock forms prominent ridges, scarps, and hills in the Project Study Area. Typically bedrock is generally freely drained with some poorly drained depressions. No records of segregated ice within the bedrock are available at this time, but the presence of ice is possible in joints and fracture zones. Segregated ice may be present in silt-filled depressions within the region.

6.5 Historical Baseline Studies

Surveys have been conducted for the Project since 1986. There have been a number of different project areas defined over this time, thus, for the purposes of this section, the RSA defined for wildlife in 2007 will be defined as the Project study area. A local study area is not applicable to terrain, permafrost and soils at this time as there were no surveys conducted in 2007.

6.5.1 Aerial Photography and Landsat Mapping

In 1986, 1:63,360 scale aerial photography (unknown flight line year) was used to delineate and describe ecosites (units of land that develop under similar environmental influences [e.g., climate, moisture and nutrient regime]) for a 1,113 km^2 area centered on the proposed Kiggavik development (Wickware 1990). Using these airphotos, BEAK (1987a) developed a comprehensive environmental database to describe the ecological characteristics (landforms, soil and vegetation) of the area identified for potential development and a buffer that may either directly or indirectly be affected by the proposed Project. The ecological characteristics were outlined on a preliminary map of the area at an ecosection (a subdivision of ecoregion characterized by relatively homogeneous biophysical and climatic conditions) and ecosite level (nominal scale of 1:50,000).

In 1986, Urangesellschaft Canada Limited commissioned aerial photographs for much of the Project area at various scales. This included photos at 1:40,000 scale for the entire area between Baker Lake and the east end of Aberdeen Lake, as well as photos at two scales (1:25,000 and 1:6,000) for the Project site area.

Wickware (1990) used the existing mapping, as well as Landsat Thematic MapperTM, to map selected areas in the Project study area at a scale of either 1:40,000 or 1:25,000 (1986).

6.5.2 Surficial Deposits in the Project Study Area

Table 6.5-1 provides areas of the surficial deposits identified during the 1987 and 1990 mapping completed for the Project study area (Wickware 1990). They are mapped for the study area in Figure 6.5-1.

Table 6.5-1
Surficial Deposit Areas in the Kiggavik Project Study Area*

Surficial Deposit	Area (km^2)
Ground Moraine	669
Glaciofluvial	206
Organic	41
Bedrock	140
Lakes	57
Total Area	1,113

* numbers compiled from Wickware 1990

Figure 6.5-1 Surficial Deposits in the Kiggavik Study Area

6.5.2.1 Moraine Deposits

The first type of moraine deposit identified in the Project study area (BEAK 1987a) was a buff-coloured, sandy-textured till. This till is common in the following areas:

- north of the east-west trending escarpment in the Project area;
- between the Project area and Baker Lake (where the hill has been extensively modified by post-glacial marine activity), and
- north of Aberdeen Lake to the limestone quarry (BEAK 1987a).

This till is the result of an early east-west trending ice movement through the area. Typically it is hard and compact and contains materials greater than 2 mm in size (30%) and a smaller percentage (5%) of finer materials like silt and clay (BEAK 1987a). The deposits vary in thickness from deep blankets (tens of meters thick) to veneers (less than one metre thick) with bedrock knobs protruding.

The second type of moraine deposit identified (BEAK 1987a) was a reddish-coloured, coarse loamy-textured till with a relatively high clay and silt component (1% to 13% clay and 17% to 37% silt). This till is common in the area below the escarpment and was deposited by a late northwestward flow of ice through the Project area (BEAK 1987a).

6.5.2.2 Glaciofluvial Deposits

Sandy glaciofluvial deposits occur most extensively on the east end of Aberdeen Lake and the south and west shores of Skinny Lake. Small, scattered deposits are found in the vicinity of the Lone Gull exploration camp and southeast of the Kiggavik site. Ice wedge polygon surface patterns are typical of these landforms (Wickware 1990).

6.5.2.3 Glaciolacustrine Deposits

Glaciolacustrine deposits occur primarily as the result of modification of previously developed landforms along the shores of Aberdeen and Squiggly Lakes (BEAK 1987a). Terraces developed in the sandy glaciofluvial deposits at the east end of Aberdeen Lake and the wave-washed surfaces of the drumlins along the north shore of the lake are evidence of this activity (BEAK 1987a).

6.5.2.4 Glaciomarine Deposits

In the Project study area, these form the sandy beach and foreshore deposits and sandy-gravelly raised shorelines around bedrock hills characteristic of the terrain between Aniguq River and Baker Lake (BEAK 1987a).

6.5.2.5 Organic Deposits

Organic deposits occur frequently throughout the Project study area, but are particularly associated with seepage zones along the escarpment (BEAK 1987a). Poorly-drained depressions and drainageways between lakes and ponds are other typical locations for organic material to occur. The area between Aniguq River and Baker Lake, particularly west of the Qinguq River, exhibit extensive development of poorly-drained peaty terrain (Wickware 1990).

6.5.2.6 Bedrock

In the Project Study Area, bedrock forms prominent ridges, scarps and hills.

6.5.3 Permafrost

The Project Study Area is located within the continuous permafrost zone of Canada (NRC 2007). Geomatics International (1991) noted that the permafrost was very dynamic in the Kiggavik and Andrew Lake area as permafrost was reflected in well developed patterned ground at most sites. Patterning was identified primarily as sorted circles, sorted stripes, sorted nets, sorted steps and sorted polygons depending on slope and materials. Sorted circles, nets and steps appeared to occur on the glacial till material where there was sufficient fine material. Sorted polygons were confined to glaciofluvial deposits likely due to the high proportion of material of stone and cobble size (Geomatics International 1991). No ice wedges were identified during the survey. Evidence of active cryoturbation was particularly visible in the form of stone thrusting. In several locations, platy stones were observed to have been thrust upward through the moss-heath tundra. This was assumed to have occurred within the previous season, as it was noted that there was fresh matrix material surrounding both the stone and the covering live vegetation.

6.5.4 Physiographic Units

The Project Study Area was mapped to consist of four distinct physiographic units:

- area below the escarpment including Pointer Lake (Escarpment south);
- escarpment zone;
- area above escarpment (escarpment north); and
- Skinny Lake (Wickware 1990).

6.5.4.1 Escarpment South

The area below the escarpment is strongly influenced by the escarpment itself. The coarse loamy-textured till has been modified by drainage (seepage) from the escarpment over much of the area between Pointer Lake and the base of the escarpment. Along the base of the escarpment, late-lying snow, together with seepage water from the escarpment itself, combine to supply moisture throughout much of the summer season, and feed the diffuse drainage channels characteristic of this area. Boulder pavement develops as a result of washing finer matrix material from the till by vigorous fluvial activity during the spring melt. Immediately west of Pointer Lake, the relief is greater and the till is not affected by escarpment drainage. Small, scattered, sandy, well-drained glaciofluvial or glaciolacustrine deposits with lichen steppe vegetation occur in the area between Pointer Lake and the most easterly proposed pit site.

6.5.4.2 Escarpment Zone

The escarpment zone itself is characterized by exposed bedrock pavements with extensive areas of frost shattered, angular rock debris. Numerous draws along the escarpment provide opportunity for moisture to seep out of the escarpment and escape to the Pointer Lake-Judge Sissons Lake drainage system. Organic materials typically accumulate in these draws and are characterized by sedge and tussock-sedge meadows. A large lobe of soliflucting organic material was observed on a slope near Cirque Lake, indicating potential instability of organic deposits occupying slopes along the escarpment.

6.5.4.3 Escarpment North

The zone above the escarpment is characterized by the gently undulating coarse loamy textured till covered by Lichen-Heath vegetation. Occasional small outcropping of bedrock occur, but they are not spatially dominant.

6.5.4.4 Skinny Lake

The Skinny Lake physiographic unit was characterized by extensive well drained, sandy glaciofluvial deposits. These deposits occur as valley train material in a narrow re-entrant along the escarpment. The deposits flank the valley slopes and have been extensively dissected by fluvial action. High-centered, ice wedge polygons characterize the surface of these deposits.

6.5.4.5 Baker Lake Dock Facility

The dock facility is located approximately 10 km east of the hamlet of Baker Lake along the north shore of Baker Lake. The area has a relatively narrow and abruptly rising shoreline, which has been extensively terraced by gradually declining lake levels since deglaciation. A series of gravel beach ridges characterizes the slope, which rises from the upper beach zone to a bedrock pavement at the crest of the hill overlooking the beach zone. The gravel beaches are typically sparsely vegetated.

The area between the proposed dock facility and Baker Lake is characterized by gradually sloping gravelly/sandy beach deposits, which grade more steeply up a bedrock slope covered by a veneer of terraced marine sand and gravel. Numerous creeks and seepage zones occur along the base of the bedrock slop and run across the beach slope towards Baker Lake. These seepage zones and small creeks are nourished by late-laying snow beds near the base of the bedrock slope and runoff from upper slopes.

6.5.4.6 Terrain

Winter Road Corridor: Baker Lake to the Kiggavik Site

The winter road corridor between the Project site and Baker Lake is characterized by two distinct physiographic types. Between the Project mine site and Aniguq River the terrain is dominated by a flat to very gently undulating, moderately well drained, sandy, glacial till and lichen-heath vegetation. Organic terrain is typically associated with lower landscape positions and in association with diffuse drainage and lake margins. Occasional well drained, sandy marine deposits occur frequently in association with bedrock exposures and lake shorelines. An imperfectly drained, coarse, loamy-textured till in the immediate Project site development area has been molded into a distinct drumlin landform.

Between Aniguq River and Baker Lake the terrain is characterized as a flat, poorly-drained, sandy glacial till typically covered by organic deposits and by extensive and well developed sandy, marine materials. These latter materials are most characteristic of the southern sections of the mapped area, whereas organic deposits occur most extensively in central and northern parts of the Project study area. In the vicinity of Qinguq River and Baker Lake, gravelly marine deposits occur frequently on the flanks of bedrock hills. Abandoned shorelines, a result of declining post-glacial marine levels, characterize their landforms.

Winter Road Corridor: Kiggavik Site to Limestone Quarry Site

The winter road corridor between the Project site and the limestone quarry site is also characterized by two distinct landscape assemblages. Between the Project site and the east arm of Aberdeen Lake, the terrain is dominated by a well-drained, gently undulating, coarse loamy-textured till. At the east end of Aberdeen Lake a large, fluvially dissected, glaciofluvial delta with raised beach ridges dominates the landscape. A minor component of an east-west trending sandy till occurs immediately north and south of Aberdeen Lake.

The section of road between Aberdeen Lake and the limestone quarry is relatively uniform and characterized by well drained sandy/gravelly rolling hills, interspersed with numerous lakes and ponds. Near Aberdeen Lake, where the terrain is somewhat more strongly rolling, well defined glaciolacustrine terraces occur along the flanks of hills. According to the Wickware (1990) there is some uncertainty surrounding the dominant surficial deposit along this section of the road and further investigation is required to resolve any concerns.

Organic deposits occur in lower landscape positions and along diffuse drainages. A number of rivers and streams occur in the area, including a major east-west flowing river (Qinguq River) which has eroded the flanks of hills creating steep, exposed gravel banks along much of its length. At the limestone site, exposed bedrock accounts for much of the surface condition.

Sensitive Terrain

There were areas identified that would be sensitive to construction activities in the Project area. The following areas have been identified as highly sensitive to disturbance (Urangesellschaft Canada Limited 1990):

- a major drainage/wetland originating from Crash Lake and Sauna Lake, which may be crossed by a proposed access road between the Pointer Lake airport and the proposed living quarters (north of Ridge Lake); and
- a major drainage/wetland from Meadow Lake, which may be crossed by a proposed access road between the proposed mill site and Skinny Lake.

The same document identified areas of moderate sensitivity including:

- a diffuse zone of seepage and escarpment hill slopes of coarse, loamy textured (silt content up to 36%) parent materials immediately above and below the proposed mine site;

- hill slopes and poor drainage sites along the escarpment near Escarpment Lake;
- a zone of diffuse drainage from the escarpment along the south end of Skinny Lake; and
- a zone of cross slope drainage northwest of Skinny Lake which has resulted in significant dissection of the glaciofluvial deposits in the area.

Urangesellschaft Canada Ltd. (1990) also discussed extensive areas of organic terrain between Aniguq River and Qinguq Bay and a deeply-incised stream half-way between Aberdeen Lake and the proposed quarry.

Three sensitive areas have been identified in the vicinity of Baker Lake (BEAK 1990):

- a tussock-sedge meadow in a draw near the top of the bedrock ridge above the proposed dock site;
- the stream originating from the tussock-sedge meadow and flowing into Baker Lake; and
- areas along the bench adjacent to the base of the bedrock ridge between the dock site and the Hamlet of Baker Lake (Urangesellschaft Canada Limited 1990b).

6.6 Soils

6.6.1 Soil Surveys

Soils for the Project study area (as well as for the region) were originally described by BEAK 1987a, 1987b, Wickware 1990 and Geomatics International 1991. Soils within the Project study area are primarily Cryosols (permafrost affected soils); one Regosol was documented. Soils found within the study area include:

6.6.1.1 Cryosolic Order

Cryosolic soils (permafrost affected soils) are defined as soils that have been formed in either mineral or organic materials that have permafrost either within 1 m of the surface or within 2 m if the soil has been strongly cryoturbated laterally within the active layer, as indicated by disrupted, mixed, or broken horizons. The mean annual soil temperature for Cryosols is 0°C (Soil Classification Working Group 1998).

Cryosols are divided into three great groups, Static Cryosol, Turbic Cryosol and Organic Cryosol, based on the degree of cryoturbation and the nature of soil material, mineral or organic, as defined by the Canadian System of Soil Classification (Soil Classification Working Group 1998).

Static Cryosols

Static Cryosols have permafrost within 1 m of the surface, but show either little or no evidence of cryoturbation. They generally develop on coarse-textured mineral parent material. They may also form in a wide textural range of recently deposited or disturbed sediments where evidence of cryoturbation is still largely absent. They may contain surface organic horizons less than 40 cm thick (Soil Classification Working Group 1998).

Orthic Static Cryosol

The typical profile for the Orthic Static Cryosol in the Project study area was described in BEAK 1987b and is presented in Figure 6.6-1. It was observed that these soils are typically associated with earth hummocks, have thin (less than 10 cm) Bm horizon, and are well to imperfectly drained, depending on the landscape and/or slope position. Frost circles, mud boils and stripes (i.e., slopes of drumlins) are characteristic of this soil type. Depending on slope position, mottling may or may not occur in the upper active layers of the soil (BEAK 1987a).

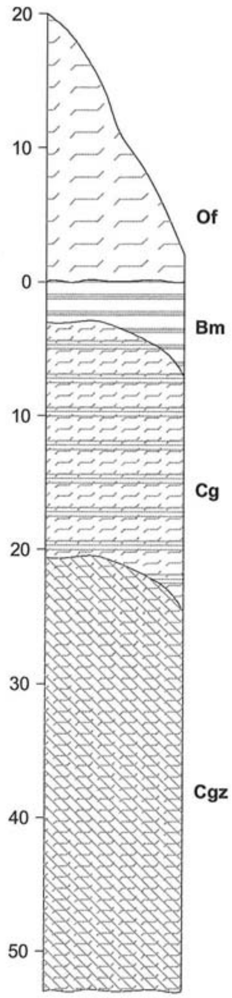
Brunisolic Static Cryosol

Brunisolic Static Cryosols are associated with crest and upper slope landscape positions on coarse loamy textured parent materials. A typical profile for the Project study area was described in BEAK 1987b and is presented in Figure 6.6-2. Moss hummocks ranging between 10 cm and 30 cm in height and frostboils are characteristic of these sites. The Bm horizons are greater than 10 cm thick, and the soils are generally acid in nature.

Gleysolic Static Cryosol

Gleysolic Static Cryosols are associated with lower slope and depressional landscape positions with coarse loamy and coarse-textured parent materials. The sites were characterized by strong surface microtopography with large moss hummocks often up to 1 m^2, and smaller grass and/or sedge tussocks up to 20 cm by 20 cm in size. Soils are gleyed and/or mottled to the surface, and the active layer is typically deeper (90 cm to 100 cm) than better drained sites. These sites generally receive a constant supply of water from upslope melting snowbanks, causing them to be supersaturated throughout the short summer period. A profile of this soil was described in BEAK 1987b and is presented in Figure 6.6-3.

Figure 6.6-1 Profile and Description of an Orthic Static Cryosol



Of 20 to 0 cm, moderately decomposed moss peat; hummocky; clear, smooth boundary.

Bm 0 to 3 cm, reddish brown (2.5YR4/2), acid, coarse loamy, vesicular pore structure, sticky, plastic, diffuse boundary.

Cg 3 to 30 cm, weak red (2.5YR4/2), acid, coarse loamy, sticky, plastic, diffuse boundary, mottles (10YR5/6).

Cgz 30 to 53 cm, weak red (2.55YR4/2), neutral, coarse loamy, sticky, plastic, frozen, mottles (10YR5/6).

Description:

Occurs on upper-middle slope positions with mid-slope more likely to show evidence of mottling in the profile.

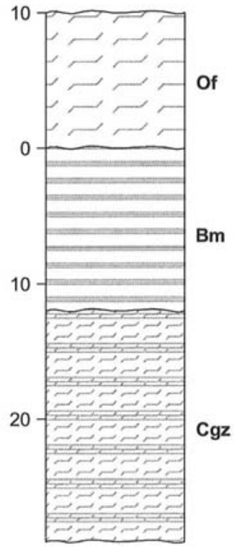
Surface material is typically hummocky with hummocks 10 to 30 cm in height.

Frost heaved angular rocks frequently occur immediately below the moss layer and in the upper 10 to 15 cm of the mineral soil. Rock may often be thrust through the organic surface by cryoturbian processes.

Active layer typically 90 to 100 cm in depth.

Vesicular soil structure in upper soil profile due to micoscale ice lens formation.

Figure 6.6-2 Profile and Description of a Brunisolic Static Cryosol



Of 10 to 0 cm, moderately decomposed moss peat; hummocky; clear, smooth boundary.

Bm 0 to 12 cm, reddish brown (2.5YR4/2), acid, coarse loamy, vesicular pore structure, sticky, plastic, diffuse boundary.

Cgz 12 to 29 cm, pinkish grey (5YR6/2), acid, coarse loamy, sticky, plastic, frozen, mottles (10YR5/8).

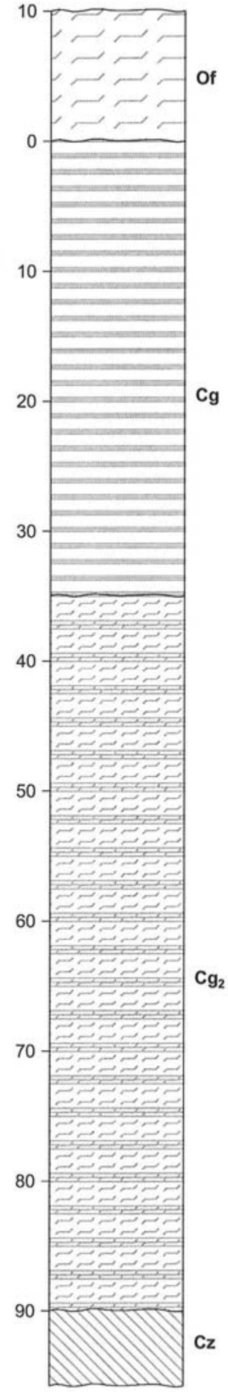
Description:

Occurs on well drained slopes with upper slope landscape positions more likely to show evidence of mottling.

Surface material is typically hummocky with hummocks 10 to 30 cm in height. Mudboils frequently occur on these soil conditions.

Surface soils characteristically have a lag of fragmental angular rocks.

Figure 6.6-3 Profile and Description of a Typical Gleysolic Static Cryosol



Of 10 to 0 cm, moderately decomposed moss and sphagnum moss; hummocky diffuse boundary.

Cg 0 to 35 cm, reddish grey (10R5/1), mottled (10YR5/8), acid, coarse loamy, sticky, plastic, diffuse boundary.

Cg_2 35 to 90 cm, weak red (10R5/3), mottled (10YR5/8), acid, coarse loamy, sticky, plastic, diffuse boundary.

Cz 90 cm +, frozen.

Description:

Located in a seepage track, downslope characterized by strong microtopography with large hummocks (up to 100 cm by 100 cm) and grass/sedge tussocks (20 cm by 20 cm).

Soils are typically thawed to a greater depth than better drained sites and are extremely spongy.

Typically, these soils are located in downslope positions which are fed throughout much of the summer period by meltwater from upslope snowbanks.

Turbic Cryosols

Turbic Cryosols are mineral soils that have been strongly affected by cryoturbation or frost churning that generates various forms of patterned ground.

Gleysolic Turbic Cryosol

Gleysolic Turbic Cryosols have developed in poorly drained areas under reducing conditions. They have evidence of gleying in the form of mottling to the mineral surface. Their uppermost mineral horizon, Bgy or Cgy may be overlain by organic layers less than 40 cm thick, or a combination of surface and subsurface horizons >15 cm. A frozen horizon must be found within 2 m of the surface (Soil Classification Working Group 1998), see Figure 6.6-4 for a typical profile.

Orthic Turbic Cryosol

Orthic Turbic Cryosols have a Bmy horizon and may have a Bm horizon less than 10 cm thick (Soil Classification Working Group 1998). The horizons are strongly disrupted by cryoturbation and a frozen horizon must be found within 2 m of the surface. Tongues of mineral and organic horizons, organic and mineral intrusions and oriented stones commonly occur. The surface horizons are not strongly gleyed, but there is usually a gleyed horizon immediately above the permafrost (Soil Classification Working Group 1998), see Figure 6.6-5 for a typical profile.

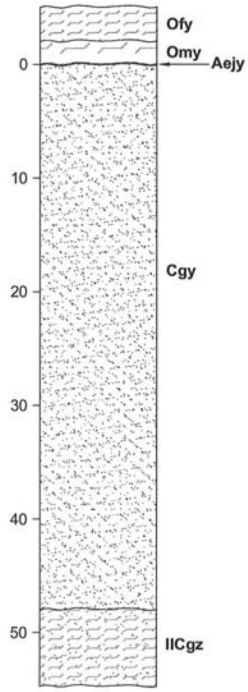
Brunisolic Turbic Cryosol

These soils have a Bm horizon of at least 10 cm thick, which is continuous over the imperfectly to well-drained part of the pedon that is relatively unaffected by cryoturbation (Soil Classification Working Group 1998). The horizons, other than the Bm, are strongly disrupted by cryoturbation. Tongues of mineral and organic horizons, organic and mineral intrusions, and oriented stones commonly occur. Surface horizons are not strongly gleyed, but there is usually a gleyed horizon immediately above the permafrost table (Soil Classification Working Group 1998), see Figure 6.6-6 for a typical profile.

Organic Cryosols

Organic Cryosols have developed primarily from organic material containing more than 17% organic carbon by weight and are underlain by permafrost within 1 m of the surface. Presence of at least 40 cm of organic material overlying mineral soil and permafrost within 1 m of the surface (Soil Classification Working Group 1998).

Figure 6.6-4 Profile and Description of a Gleysolic Turbic Cryosol



Ofy 5 to 2 cm, undecomposed plant structure showing signs of cryoturbation.

Omy 2 to 0 cm, moderately decomposed plant structure broken into layers in hummock.

Aejy Trace, in hummock only, very thin.

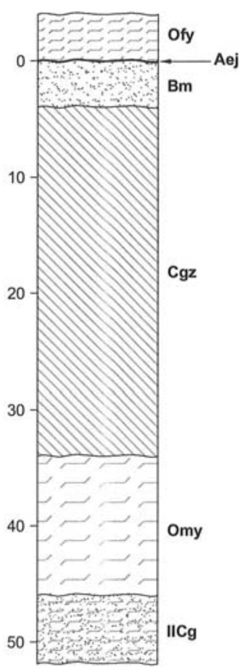
Cgy 0 to 48 cm, yellowish brown (10YR5/4) matrix colour, mottled (10YR4/6 and 10YR5/8), medium textured sand.

IICgz 48 cm +, reddish brown (2.5YR5.5/4 and 2.5YR4/6), mottled (10YR5/8) sandy loam.

Description:

Pit dug below marine shoreline sequence at junction of lake and drainage-way. Earth hummocks without stone sorting. IICgz upper 2 to 3 cm weakly frozen.

Figure 6.6-5 Profile and Description of an Orthic Turbic Cryosol



Ofy 4 to 0 cm, undecomposed plant structure.

Aej Trace, diffuse boundary.

Bm 0 to 4 cm, brown to yellowish brown (10YR5/4 to 7.5YR 4/6), mottled (7.5YR5/6) sandy loam.

Cgz 4 to 34 cm, pale brown (10YR6/3), mottled (7.5YR5/6 to 7.5YR 4/6) sandy loam, slightly frozen.

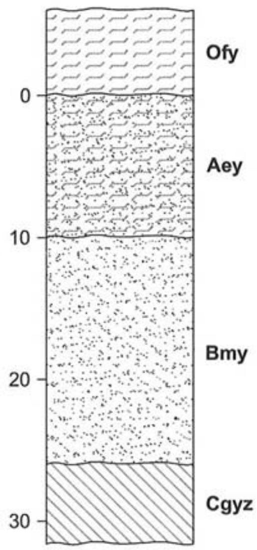
Omy 34 to 46 cm, moderately decomposed plant structure.

IICg 46 to 100 cm +, light yellowish brown (10Y6/4), sandy loam.

Description:

Site across solifluction lob of sorted step. Till material sorting evident. Water table is below mineral surface. The Omy has ribbons of IICg.

Figure 6.6-6 Profile and Description of a Brunisolic Turbic Cryosol



Ofy 6 to 0 cm, undecomposed moss, diffuse boundary.

Aey 0 to 10 cm, light gray (10YR7/2), loamy fine sand.

Bmy 10 to 26 cm, yellowish brown (10YR 5.5/4) fine sand.

Cgyz 26 cm plus, light reddish brown (5YR 6/3), mottled (5YR 5/8), frozen sandy loam.

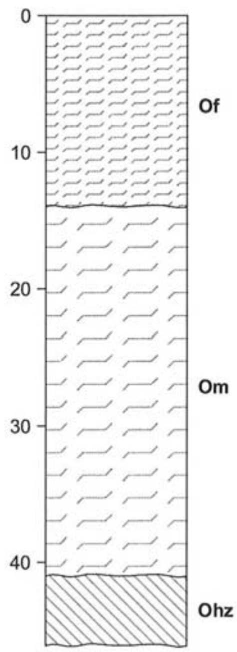
Description:

Site located in sorted net moss heath halfway up a slope. Description was at a hummock.

Terric Humic Organic Cryosol

Terric Humic Organic Cryosols have a mineral horizon within 1 m of the surface, or the mineral layer is greater than 30 cm thick with an upper boundary within 1 m of the surface (Soil Classification Working Group 1998). They are composed dominantly of humic material above the mineral contact, see Figure 6.6-7 for a typical profile.

Figure 6.6-7 Profile and Description of a Terric Humic Organic Cryosol



Of 0 to 14 cm, almost undecomposed sedge peat; hummocky.

Om 14 to 41 cm, strongly decomposed sedge peat.

Ohz 41 cm+, very strongly decomposed frozen sedge peat. Ice crystals are visible and several mm thick.

Description:

This profile occurs in sedge meadow between lakes in a deeper pocket. Surface material grades immediately into sedge and moss hummock with exposed boulder.

6.6.1.2 Regosolic Order

Regosolic soils are defined as soils that do not contain a recognizable B horizon at least 5 cm thick, and are therefore referred to as weakly developed. These soils tend to form on recent alluvium, colluvium on slopes, unstable materials, and in cold and dry climatic conditions which limit soil development. They do not have permafrost within 1 m of the soil surface.

Regosolic soils are divided into two great groups, Regosol and Humic Regosol, based on the depth of A horizon development, as defined by the Canadian System of Soil Classification (Soil Classification Working Group 1998).

Regosol

Soils in the Regosol great group do not have an Ah or dark-coloured Ap horizon at least 10 cm thick at the mineral soil surface. They can have buried mineral-organic layers and organic surface horizons, but no B horizon at least 5 cm thick (Soil Classification Working Group 1998).

Orthic Regosol

Orthic Regosols are typically weakly developed and are common in the rock barrens (Wickware 1990). They also do not have permafrost within 1 m of the surface. Several boulders were up to 1 m in diameter (Wickware 1990).

6.6.2 Soil Chemistry

Cryosolic soils have a low buffering capacity and respond to changes in air temperature quickly (Wickware 1990). This is due mainly to the shallow active layer, which provides only a small amount of stored energy. The underlying permafrost acts as a heat sink and continuously removes energy from the thawed layer of the soil. The slightest decrease in air temperature (due to storms or reduced photoperiod) quickly lowers the soil temperature at all depths. This cooling causes the permafrost table to rise long before the surface freezes (Tarnocai 1977).

Five soil samples (three Orthic Static Cryosols, one Brunisolic Static Cryosol and one Gleysolic Static Cryosol) were collected during the BEAK 1987b survey and analyzed. The results are shown in Tables IX-1 to IX-3 in Appendix IV. From these results, it was observed that the Cryosols in the Project study area had low cation exchange capacities (CEC) or were low in bases (calcium [Ca], magnesium [Mg] and potassium [K]). This capacity may be further reduced because of the shallow active layer associated with these soils and the short thaw season.

Wickware 1990 provided a general summary of the natural radionuclide levels in soils in the Project study area. Composite soil samples were collected along two perpendicular transects (N-S and E-W) that intersected at the Project site. It was noted that the drainage of the area sampled was to the south towards the wet, hummocky terrain. It was also noted that the terrain along the east-west transect had a gentle slope to the west. The main mechanism of mineral dispersion within the Project Study Area is likely snowmelt runoff as there have been large pulses of meltwater in a short period documented for the area. The meltwater has a pattern of extensive surface flow not confined to a stream channel and is likely to entrain and transport soluble and particulate radionuclide down the topographic gradient.

The samples revealed distinct anomalies of the natural radionuclide at the Main Showing (0 m) and Centre Zone (750 m E) (i.e., two ore bodies at Kiggavik) (Figures 6.6-8 and 6.6-9). U-238, Ra-226, and Bi-214 activities were three to four orders of magnitude greater at the Main Showing compared to the transect average. In the Centre Zone, which was lightly buried under glacial drift, the activities were about 100 times that of the average. Activities fell, however, to very low levels about 200 m from the Main Showing. Patterns of activity of Cs-137 did not resemble the U radionuclides pattern, and showed considerable fluctuation.

The substrates at the Main Showing and Centre Zone contained elevated levels of the uranium-family radionuclides, but their activities were localized to an area not greater than 100 m in radius about the showing. The substrate also revealed a detectable dispersion pattern of U-238 and Ra-226. The average levels of these nuclides were highest in the south and lowest in the north, reflecting down gradient hydrologic transport mechanisms.

6.6.3 Current Baseline Studies

6.6.3.1 Soil Surveys

No surveys of terrain, permafrost and soils were conducted in 2007.

6.6.3.2 Soil Chemistry

Permanent sample plots (PSPs) were established within the Project Area to measure baseline radionuclide and trace metal concentrations in soil. Three PSPs were established within the Kiggavik lease area and three within the Sissons lease area (near the ore bodies; Figure 6.6-10). Mineral and organic soil samples (peat) were collected from the PSPs. Soil samples from each sampling location were sent to SRC Analytical Laboratories (Saskatoon, SK) for chemical analysis. Mineral soil samples were analysed for basic soil chemistry (i.e., pH, SAR), cations and anions, metals, and radionuclides. Organic soil samples (peat) were analysed for metals and radionuclides.

Figure 6.6-8 The Radionuclide Activity Profiles of the Soil Along the N-S Transect of the Kiggavik Site

Figure 6.6-9 The Radionuclide Activity Profiles of the Soil Along the E-W Transect of the Kiggavik Site

Figure 6.6-10 Permanent Sample Plot Locations for Vegetation and Soil Chemistry, 2007

The results of the soil chemical analysis of mineral and organic soils samples are presented in Table 6.6-1. The basic soil chemistry, cation, and anion values are typical of the tundra, where mineral soils are generally low in nutrients and acidic (pH ~5). Mineral soils in the study area have low soluble salts as indicated by low electrical conductivity.

For the metal and radionuclide analyses in mineral and organic soils (peat) collected from within the study area, results were similar for all sampling locations, regardless of soil type (Table 6.6-1). For mineral soils, analyte concentrations were compared to Canadian Soil Quality Guideline levels for industrial land use areas (CCME 2006), and none of the concentrations were over levels indicated in the guidelines.

Variations in analyte concentrations found between sampling locations is due to the heterogeneous nature of soil in the environment. Higher variation between samples is expected when fewer representative samples are taken from an area. It is recommended that additional PSPs be established within the lease areas (potential exposure), as well as outside the lease areas (reference), to obtain better representation of potential impact of the project as activities proceed.

Table 6.6-1
Soil Chemistry Results for Soil Samples Collected from Sissons and Kiggavik Lease Areas, 2007

Analyte	Units	CCME Guidelines[(a)]	Sissons Lease Area											Kiggavik Lease Area											
			Mineral Soil[(b)]						Peat					Mineral Soil[(b)]						Peat					
			DL	SIS1	SIS2	SIS3	Mean	SD	DL	SIS1PE	SIS2PE	Mean	SD	DL	KIG1	KIG2	KIG3	Mean	SD	DL	KIG1PE	KIG2PE	KIG3PE	Mean	SD
Basic Soil Chemistry																									
pH	pH units	6 to 8	0.07	5.47	4.85	6.45	5.59	0.81	N/A	N/A	N/A	N/A	N/A	0.07	4.86	4.96	4.97	4.93	0.06	N/A	N/A	N/A	N/A	N/A	N/A
SAR	--	12	0.05	0.1	0.1	0.2	0.1	0.1	N/A	N/A	N/A	N/A	N/A	0.05	0.05	0.1	0.1	0.1	0.0	N/A	N/A	N/A	N/A	N/A	N/A
Electrical conductivity	dS/m	4	0.001	0.478	0.588	0.477	0.514	0.064	N/A	N/A	N/A	N/A	N/A	0.001	0.592	0.594	0.463	550	75	N/A	N/A	N/A	N/A	N/A	N/A
Saturation	%	N/A	0	29	26.4	19.1	24.8	5.1	N/A	N/A	N/A	N/A	N/A	0	38	30.8	32.7	33.8	3.7	N/A	N/A	N/A	N/A	N/A	N/A
Other																									
Calcium	mg/L	N/A	1	76	79	68	74	6	N/A	N/A	N/A	N/A	N/A	1	100	100	75	92	14	N/A	N/A	N/A	N/A	N/A	N/A
Chloride	mg/L	N/A	1	10	11	8	10	2	N/A	N/A	N/A	N/A	N/A	1	13	10	11	11	2	N/A	N/A	N/A	N/A	N/A	N/A
Magnesium	mg/L	N/A	1	21	28	18	22	5	N/A	N/A	N/A	N/A	N/A	1	22	22	27	24	3	N/A	N/A	N/A	N/A	N/A	N/A
Potassium	mg/L	N/A	1	4	4	6	5	1	N/A	N/A	N/A	N/A	N/A	1	8	3	6	6	3	N/A	N/A	N/A	N/A	N/A	N/A
Sodium	mg/L	N/A	1	4	4	6	5	1	N/A	N/A	N/A	N/A	N/A	1	3	4	4	4	1	N/A	N/A	N/A	N/A	N/A	N/A
Sulfate	mg/L	N/A	2	51	50	59	53	5	N/A	N/A	N/A	N/A	N/A	2	85	87	71	81	9	N/A	N/A	N/A	N/A	N/A	N/A
Metals																									
Aluminum	µg/g	N/A	20	7300	19700	7300	11433	7159	5-50	4400	37200	20800	23193	20	9400	11100	10300	10267	850	50	22600	32000	28200	27600	4729
Antimony	µg/g	40	0.2	<0.2	<0.2	<0.2	<0.2	0.0	0.1	<0.1	<0.1	<0.1	0.0	0.2	<0.2	<0.2	<0.2	<0.2	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Arsenic	µg/g	12	0.1	2.9	7	2.1	4.0	2.6	0.05	1.2	3.8	2.5	1.8	0.1	5.5	4.8	4.9	5.1	0.4	0.05	2.3	3.4	3.8	3.2	0.8
Barium	µg/g	2000	0.5	84	130	60	91	36	5-50	260	560	410	212	0.5	300	210	240	250	46	50	760	910	750	807	90
Beryllium	µg/g	8	0.1	0.5	1	0.5	0.7	0.3	0.01	0.4	0.83	0.62	0.30	0.1	0.6	0.7	0.8	0.7	0.1	0.01	0.69	0.87	2.1	1.22	0.77
Boron	µg/g	—	1	<1	6	<1	2.0	3.4	1	10	41	26	21.9	1	<1	<1	<1	<1	0.0	1	24	41	54	40	15
Cadmium	µg/g	22	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.01	0.31	0.76	0.54	0.32	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.01	0.81	0.89	0.48	0.73	0.22
Chromium	µg/g	87	0.5	9.6	44	16	23.2	18.3	0.5	4.6	30	17.3	18.0	0.5	25	21	25	23.7	2.3	0.5	24	23	31	26	4.4
Cobalt	µg/g	300	0.2	3.4	8.9	2.9	5.1	3.3	0.01	1.3	4	2.7	1.9	0.2	5.4	4.1	6.4	5.3	1.2	0.01	2	3.3	2.5	2.6	0.7
Copper	µg/g	91	0.5	4.8	18	6.2	9.7	7.3	0.05-5	11	96	54	60	0.5	16	7.7	19	14.2	5.9	5	96	80	42	73	28
Iron	µg/g	N/A	20	9400	25000	10600	15000	8681	5-50	8000	11700	9850	2616	20	15800	11900	16600	14767	2515	50	5700	11800	9800	9100	3110
Lead	µg/g	600	0.1	4.8	5.4	4.8	5.0	0.3	0.01-1	0.74	8	4.37	5.13	0.1	16	7.4	8.9	10.8	4.6	1	8	13	85	35	43
Manganese	µg/g	N/A	0.5	110	280	100	163	101	0.1-10	11	210	111	141	0.5	200	140	230	190	46	10	150	150	70	123	46
Mercury	µg/g	50	0.05	<0.5	<0.5	<0.5	<0.5	0.00	0.05	0.1	0.05	0.08	0.04	0.05	<0.5	<0.5	<0.5	<0.5	0.0	0.05	0.12	0.08	0.07	0.09	0.03
Molybdenum	µg/g	40	0.1	0.2	0.2	0.2	0.2	0.0	0.1	0.7	0.8	0.75	0.07	0.1	0.4	0.2	6.9	2.5	3.8	0.1	1.5	1.1	2	1.5	0.5
Nickel	µg/g	50	0.1	9.7	34	9.3	17.7	14.1	0.05-5	7.4	25	16.2	12.4	0.1	17	15	16	16.0	1.0	5	19	24	25	23	3.2
Selenium	µg/g	10	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.05	0.37	0.62	0.50	0.18	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.05	0.76	0.61	0.49	0.62	0.14
Silver	µg/g	40	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.01	0.06	0.25	0.16	0.13	0.1	<0.1	0.4	<0.1	0.2	0.2	0.01	0.22	0.22	0.11	0.18	0.06
Strontium	µg/g	N/A	0.5	61	74	55	63	10	5	47	62	55	10.6	0.5	75	99	73	82	14	5	110	80	70	87	21
Thallium	µg/g	1	0.2	<0.2	<0.2	<0.2	<0.2	0.00	0.05	<0.05	0.38	0.20	0.25	0.2	<0.2	<0.2	<0.2	<0.2	0.0	0.05	0.28	0.34	0.25	0.29	0.05
Tin	µg/g	300	0.1	<0.1	<0.1	<0.1	<0.1	0.00	0.05	<0.05	<0.05	<0.05	0.00	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.05	<0.05	<0.05	0.12	0.06	0.05
Titanium	µg/g	N/A	0.5	300	410	230	313	91	5	54	280	167	160	0.5	350	340	320	337	15	5	350	310	390	350	40
Uranium	µg/g	N/A	0.1	0.7	0.8	0.7	0.7	0.1	0.01-1	0.65	4	2.33	2.37	0.1	1	1	1.6	1.2	0.3	1	5	6	6	6	0.6
Vanadium	µg/g	130	0.1	16	47	17	27	18	0.1-10	4.3	30	17.2	18.2	0.1	25	21	24	23	2	10	20	20	40	27	12
Zinc	µg/g	360	0.5	14	35	16	22	12	0.5-50	6.2	50	28	31	0.5	38	21	26	28	9	0.5	25	35	19	26	8.1

Table 6.6-1
Soil Chemistry Results for Soil Samples Collected from Sissons and Kiggavik Lease Areas, 2007 (continued)

Analyte		Units		CCME Guidelines[a]		Sissons Lease Area											Kiggavik Lease Area								
						Mineral Soil[b]						Peat					Mineral Soil [b]						Peat		
						DL	SIS1	SIS2	SIS3	Mean	SD	DL	SIS1PE	SIS2PE	Mean	SD	DL	KIG1	KIG2	KIG3	Mean	SD	DL	KIG1PE	KIG2PE
Radionuclides																									
Lead-210	Bq/g	N/A	0.02	<0.02	<0.02	<0.02	<0.02	0.00	0.005-0.006	0.01	0.08	0.05	0.05	0.02	<0.02	<0.02	<0.02	<0.02	0.00	0.005-0.006	0.04	0.13	<0.006	0.058	0.065
Polonium-210	Bq/g	N/A	0.005	0.02	0.02	0.02	0.020	0.000	0.001-0.002	0.016	0.058	0.037	0.030	0.005	0.03	0.02	0.03	0.027	0.006	0.001	0.058	0.47	0.004	0.177	0.255
Radium-226	Bq/g	N/A	0.01	0.03	0.02	0.05	0.03	0.02	0.001-0.005	0.048	0.09	0.069	0.030	0.01	0.07	0.04	0.06	0.06	0.02	0.005	0.06	0.14	0.06	0.09	0.05
Thorium-230	Bq/g	N/A	0.02	0.04	0.04	0.02	0.03	0.01	0.01-0.002	0.017	0.049	0.033	0.023	0.02	0.06	0.03	0.05	0.05	0.02	0.01	0.06	0.05	0.06	0.06	0.01

Notes: N/A = not available; DL = detection limit; SD = standard deviation; µg/g = micrograms per gram; Bq/g = Becquerel per gram; mg/L = milligram per liter; µS/cm = microSiemens per cm; % = percent; < = less than
a = CCME 2006 - Canadian Environmental Quality Guidelines for soil in industrial land use areas
b = CCME guidelines only apply to mineral soils data

7.0 VEGETATION

7.1 Introduction

Vegetation refers to the plant species of an area and their successive grouping into communities and associations characteristic of the district. Plants are important, as they supply oxygen to the atmosphere, can modify the local environment, such as stabilize or add organic matter to the soil, or provide protection for other plants or animals. They are also the foundation of the food web, and provide food for herbivores that can be subsequently eaten by carnivores and by humans. “Vegetation baseline studies” are detailed research into what plant species populate a region, and their association with the landscape. These studies are a fundamental section of the environmental impact assessment (EIA), as they depict the area as it was at a specific time. Any disturbance of the land surface can remove vegetation of the area and related wildlife habitat; descriptions of the plant communities preceding any disturbances are crucial for the appropriate development of mitigation and reclamation strategies. These studies are also used for determining biological diversity (total variety of all living things) in an area. The main feature of biodiversity is the protection of “species at risk” (EC 2008a).

7.2 Data Sources

Nine reports have been written on various aspects of vegetation in the Project area based on pre-development baseline data collections:

- Kershaw et al. (1983). The Pattern of Uranium, Companion Elements and Radioisotopes in Lichen Heath Associated with the Uranium Deposits near Baker Lake, Northwest Territories (NT) prior to Mining Operations;
- Svoboda et al. (1985). Environmental Studies, No. 41, Survey of the Keewatin uranium Mineralization Areas with Respect to Natural Occurrence of Radionuclides in Vegetation, Soils and Sediments;
- Wicken et al. (1987). Ecological Land Survey of the District of Keewatin, Northwest Territories;
- BEAK (1987a). Kiggavik Environmental Pre-feasibility Study 1986;
- BEAK (1987b). Kiggavik Preliminary Environmental Study Report 1986-1987;
- Wickware (1989). Kiggavik Uranium Project, Baker Lake, Northwest Territories, Canada, Environmental Assessment. Supporting Document No. 2 Soils and Vegetation;
- Geomatics International (1990). Kiggavik Uranium Project Reconnaissance Biological Survey and Terrestrial Studies Draft Field Report 1990. December 1990;
- Geomatics International Inc. (1991). Preliminary Results of Summer Survey 1991 Kiggavik and Andrew Lake Vegetation and Soils; and

- Ecometrix Inc. (2006) Kiggavik Environmental Baseline Data Summary and Potential Data Gaps. Terrestrial Environment.

7.3 Spatial Boundaries

7.3.1 Historical Study Area

The information for the historical soil baseline studies are reported in Wickware (1990). The initial Project study area extended from Baker Lake in the east, to a proposed limestone quarry in the northwest, with the proposed Kiggavik mine site in the approximate geographic centre (Figure 6.2-1). The original Project study area included not only the area of potential infrastructure development, but also a 1,113 square kilometres (km^2) area centered on the Kiggavik exploration camp. The current (2007) regional study area (RSA) overlaps parts of the earlier Project study area; however, some areas of the current RSA were not included in the previous studies.

7.3.2 Current Study Area

In 2007, AREVA began collecting aquatic and terrestrial baseline data, in anticipation of preparing an Environmental Impact Statement (EIS). The RSA for the 2007 terrestrial baseline studies is centered on the anticipated location of the Project, and is in the vicinity of the southern extent of the calving grounds for the Beverly caribou herd. The study area is 90 km long and 80 km wide (7,200 km^2), and includes all of Judge Sissons Lake, and parts of Aberdeen, Schultz, Mallory, and Princess Mary lakes (Figure 6.2-2). The spatial extent of the RSA was selected based on current study areas for caribou and other large mammals (muskoxen, grizzly bears, wolves) for other mining projects in Nunavut (i.e., the Jericho and Doris North projects [Tahera 2000; Miramar 2005]) and the NT (i.e., the Ekati, Diavik, Snap Lake, and Gahcho Kué projects [BHPB 1995; DDMI 1998; De Beers 2002; MVEIRB 2007]), along with logistical constraints, the anticipated mine plan for the Project and avoidance of the calving grounds for the Beverly caribou herd, and known location of caribou water crossings along the Thelon River basin.

7.4 General Setting

7.4.1 Ecozones

The Project study area is located in the Keewatin lowland ecoprovince of the Southern Arctic ecozone (EC 2008b, Figure 7.4-1), previously referred to in older reports as the low arctic (Polunin 1951). The Project encompasses, from north west to south, portions of three major ecoregions: Black River Plain in the north; Dubawnt Lake Plain/Upland in the central area and Maguse River Upland in the southeast corner (EC 2008b, Figure 7.4-1). These ecoregions generally coincide with the three formerly named Ecoregions: Garry Lake Plains, Dubawnt Plains, and Rankin Plains referred to in older literature (Wiken et al. 1987) (Figure 7.4-2).

7.4.2 Ecoregions

7.4.2.1 Back River Plain

The Back River Plain ecoregion is located in central District of Keewatin, from the Back River south to Aberdeen Lake (EC 2008b). Shrub tundra is the dominant vegetation consisting of dwarf birch (*Betula glandulosa*), willows (*Salix* spp.), northern Labrador tea (*Ledum decumbens*), avens (*Dryas* spp.), and blueberry (*Vaccinium* spp.). Vegetative cover is patchy on the well-drained upper slopes; however, tall dwarf birch (*Betula nana*), willow, and alder (*Alnus* spp.) characterize mid-slope, warmer sites. In wetter areas, sedge (*Carex* spp.) tussocks with moss and willow species are prevalent. Clumps of dwarf black (*Picea mariana*) and white spruce (*P. glauca*) and tamarack (*Larix laricina*) occur at lower elevations along the Thelon River in the southwest portion of the ecoregion.

Figure 7.4-1 Ecozones, Ecoregions and Ecodistricts of Nunavut, Canada

Figure 7.4-2 Ecoregions of the District of Keewatin

7.4.2.2 Dubawnt Lake Plain/Upland

The Dubawnt Lake Plain/Upland ecoregion lies south and west of Chesterfield Inlet and incorporates the terrain around Mallery, Wharton and Dubawnt lakes (EC 2008b). It is characterized by a nearly continuous cover of shrub tundra vegetation, consisting of dwarf birch, willows, northern Labrador tea, avens, and blueberry. Tall dwarf birch, willow, and alder occur on warm sites; willows, sedges, and moss dominate wet sites.

7.4.2.3 Maguse River Upland

The Maguse River Upland ecoregion covers the uplands south of Chesterfield Inlet, extending as far south as Churchill, and includes much of the northwest coast of Hudson Bay (EC 2008b). A cover of shrub tundra vegetation characterizes this ecoregion. Dwarf birch, willow, and alder occur on warm, dry sites; poorly drained sites are dominated by willow, sphagnum moss, and sedge. Wetlands make up 25 percent (%) to 50% of the land area, and are characteristically lowland low- and high-centered polygon fens.

7.4.3 Ecodistricts

Each of the three ecoregions described for the Project area are divided into ecodistricts (Table 7.4-1). No detailed vegetation description for the current ecodistricts could be obtained; however, vegetation descriptions were available for previously delineated ecodistricts based on work completed in the mid-1980s (Wiken et al. 1987). These are used for general descriptions of the Project area (Table 7.4-1).

Table 7.4-1
Ecoregions, Ecodistricts and Vegetation Descriptions of the Project Study Area

Ecoregion	Ecodistrict Number	Ecoregion* (previous classification)	Ecodistrict* (previous classification)	Vegetation Description*
Back River Plain (43)	174	Garry Lake Plains	Deep Rose Lake (AL05)	Black lichens with some heath colonized hillcrests. On downward slopes, there was an increase in mixed lichens and low shrubs. In wet depressions or drainage ways sedge communities dominated.
Back River Plain (43)	174	Garry Lake Plains	Marjorie Hills (AL06)	The lower and mid slopes were colonized by mixed complex of lichens and low to medium height shrubs. This deceased progressively to thin and sporadic lichen cover with increasing altitude and rocks.
Dubawnt Lake Plain/Upland (44)	175 & 176	Dubawnt Plains	Mallery Lake (DL06)	The vegetative cover was continuous and comparatively abundant. Lichen associations with medium to low height shrubs predominated. Wetlands colonized with sedge-moss vegetation.
Maguse River Upland (45)	178	Rankin Plains	Kaminuriak Lake (CT01)	Unbroken and dense vegetative cover was widespread, with the exception of eskers and boulder barrens. The dominant vegetation was lichens with low height shrub and heath associations. A sedge-moss community occupied wet depressions while a dark lichen-heath community dominated on the drier exposed regions.

*Source: Wiken et al. 1987

7.5 Historical Baseline Studies

7.5.1 Methods

Early botanical studies in the Project area were qualitative, and used the physiognomy (general appearance) of the vegetation for classification and not species groupings (BEAK 1987a). To facilitate comparison with these primary data, similar approaches were used for all subsequent studies (Wickware 1989; Geomatics International Ltd. [GIL] 1990; Geomatics International Inc. 1991). Physiognomic categories were used either singly (e.g., graminoid, lichen) or more frequently as combinations to describe the dominant physiognomic associations (e.g., lichen-heath, moss-lichen).

The information for the initial baseline studies are reported in Wickware (1989). The initial Project study area extended from Baker Lake in the east, to a proposed limestone quarry in the northwest, with the proposed Kiggavik mine site in the approximate geographic centre (Figure 7.5-1). The original Project study area included not only the area of potential infrastructure development, but also a 1,113 km^2 area centered on the Kiggavik exploration camp. The current (2007) RSA overlaps parts of the earlier Project study area; however, some areas of the current RSA were not included in the previous studies.

The initial Project study area was divided into five main zones, with a sixth encompassing zone (Figure 6.2-1):

- Zone 1 - the dock facility near Baker Lake (referred to as Qinguq Bay in some reports);
- Zone 2 - the winter road corridor between Baker Lake and the Kiggavik mine site (encompassing a corridor extending from Qinguq Bay to Audra Lake [also known as Aniguq Lake, Long Lake]);
- Zone 3 - Kiggavik site development area;
- Zone 4 - the winter road corridor between the Kiggavik site and Aberdeen Lake;
- Zone 5 - the winter road corridor between Aberdeen Lake and the Limestone Quarry; and
- Zone 6 – the initial Project study area, including Zone 3 (Kiggavik site development area), Zone 4 (the corridor between Kiggavik and Aberdeen Lake) and the surrounding areas.

The five main zones of Project area and the ecoregions they are located in are listed in Table 7.5-1.

Table 7.5-1
Ecoregion Within the Project Study Area

	Facility	Current Ecoregion	Ecodistrict
Zone 1	proposed dock facility	Dubawnt Lake Plain/Upland	175
Zone 2	winter road corridor between Baker Lake and Kiggavik site	Dubawnt Lake Plain/Upland	175
Zone 3	Kiggavik Site Development Area	Dubawnt Lake Plain/Upland	175
Zone 4	winter road corridor from the Kiggavik site to Aberdeen Lake	Eastern part Dubawnt Lake Plain/Upland Western part Black Plain	175 174
Zone 5	winter road corridor from the Aberdeen lake to the limestone quarry	Black River Plain (43)	174

A supplemental vegetation study was completed following the discovery of a second uranium ore body near Andrew Lake (approximately 16 km southwest of Kiggavik). The discovery necessitated the expansion of the study area south to assess the potential impacts of ore extraction. These data are reported in GIL (1990).

The new ore body was located in the southwest corner of Zone 6, which was discussed in Wickware (1989). This supplemental study excluded most areas covered in the original study, but extended approximately 10 km east, south and west of Andrew Lake (Figure 6.2-1). This area is referred to as Zone 7.

The objectives of the supplemental survey (GIL 1990) were to:

1. provide reconnaissance level terrestrial inventory information for Zone 7 (referred to as Sissons in some reports);
2. compare the more detailed information from the Wickware (1989) report to determine if there were any differences between Zone 7 (Sissons) and the original Kiggavik north site; and
3. determine specific studies required to bring Zone 7 into agreement with the existing environmental assessment (EA) report.

Geomatics International Inc. (1991) carried out an additional study more detailed plant field surveys of the proposed uranium mine areas to provide supplementary data for concerns raised during the preliminary FEARO hearings (CEAA 1990).

The objectives of the Geomatics International Inc. (1991) survey were to:

1. undertake detailed vegetation studies at the proposed dock site on Baker Lake (Zone 1);
2. survey the winter road route from Baker Lake to Kiggavik to identify sensitive areas (Zone 2 and addition areas);
3. survey the preferred and alternate winter roads from Kiggavik to Aberdeen Lake (Zone 4) and from Aberdeen Lake to the limestone outcrop (quarry) to identify sensitive areas;
4. undertake detailed, replicate vegetation description and sampling of all vegetation-soil-landform site types within the area of the Kiggavik and Andrew Lake ore bodies; and
5. collect lichen samples near the ore bodies to determine background radiation levels.

This study concentrated on the previously defined Project zones, and did not expand its mandate.

7.5.1.1 Ecological Land Survey

An Ecological Land Survey (ELS) was prepared as part of the original baseline description for the EIA for the Project. The ELS provides an integrated information base (EC 1980), principally for projects which have numerous development aspects, and are situated in isolated areas with limited information on the properties and dynamics of land, water and climate of the area. Due to its hierarchical approach to land classification, ELS information can be organized into a range of detail as required by the proponent.

The ELS data was inputed into a Geographic Information System (GIS) program for spatial data and impact assessment analyses. This provided a summary of the Ecological Land Classification (ELC) units found within the Project area. In addition, the setting described the baseline biodiversity, which used ELC mapping to measure and quantify landscape, ecosystem, and species level biodiversity indices.

Most of the information used in the ELS (BEAK 1987a) was acquired by satellite imagery and aerial photograph interpretation, or from previous reports and other documentation. These included data for the Kiggavik site and local area, collected during studies in the late 1970's and early 1980's by Urangesellschaft Canada Limited, from pertinent reports written for the Polar Gas study in the Baker Lake area (e.g., Thompson and Klassen 1980), and other information obtained from studies in similar environments in the northern Keewatin. In addition, several field surveys were conducted to ground truth and expand the ELS data (Wickware 1989).

An ELS approach was used following the guidelines published by the FEARO (EC 1980). Table 7.5-2 describes the levels of ecological generalization associated with the ELS.

Table 7.5-2
Levels of Ecological Generalization Proposed by the Canada Committee on Ecological Land Classification

Level of Generalization	Common Map Scale	Vegetation
Ecodistrict	1:500,000 to 1:125,000	Plant districts or assemblages thereof
Ecosection	1:250,000 to 1:50,000	Plant associations or assemblages thereof
Ecosite	1:50,000 to1:10,000	Plant association or community
Ecoelement	1:10,000 to 1:2,500	Parts of a plant association or subassociation

Source: modified and reduced from Environment (1980)

7.5.1.2 Remote Sensing Data

ELS, because of its focus on landscape and landscape patterns, makes extensive use of remote sensing data, including satellite imagery and aerial photography (BEAK 1987a). Landsat Thematic Mapper (TM) satellite data as well as various scales of aerial photography were employed at each of the levels of ELS generalization described.

7.5.1.3 Landsat TM Data

On June 22, 1988, Landsat TM data for the general region centering on the Kiggavik site were obtained from the NT Department of Renewable Resources in Yellowknife, and used to evaluate terrain conditions at different locations and scales (Wickware 1989). Image enhancement procedures were used to highlight both regional and local resource patterns and distribution. All procedures were carried out using a micro-based image analysis system (EASI-PACE) developed by PCI Inc. Results are used both as stand-alone products and with other spatial data in a micro-based GIS (SPANS).

7.5.1.4 Aerial Photography

In 1986, as part of an initial baseline study, 1:63,360 scale aerial photography was used to delineate and describe complex landscape polygons (ecosections) for a 1,113 km^2 area centered on the proposed Project (Wickware 1989). Subsequently, Urangesellschaft Canada Limited commissioned new aerial photography for much of the area at various scales. Photographic scales acquired included: A) 1:40,000 for the entire area between Baker Lake and the east end of Aberdeen Lake; and B) 1:25,000 and 1:6,000 for the Kiggavik site area. This photography has been used for all baseline studies since 1986.

In addition to Landsat evaluation, the winter road corridor between Baker Lake and the Kiggavik site was mapped using 1:40,000 scale (1986) photography. The Kiggavik site development area was mapped using 1:25,000 scale (1986) photography. This mapping scale provided greater spatial resolution of the landscape (hence more homogeneous mapping polygons) required for more detailed site planning and development. The scale is more refined than the mapping scale used during the pre-feasibility environmental study when 1:63,360 scale photography was used. The winter road corridor between the Kiggavik site and Aberdeen Lake utilized existing ecological mapping (1:50,000) (BEAK 1986), which was done using 1:63,360 scale photography obtained through the National Air Photo Library (NAPL). The area between Aberdeen Lake and the limestone quarry site was also mapped at a scale of 1:63,360 using photography obtained through NAPL.

7.5.1.5 Field Surveys

Field surveys for the ELS mapping were carried out in July 1986, July 1988 and August 1989 (Wickware 1989). Comprehensive ground truthing was carried out from July 12 to 16, 1986 surrounding the Kiggavik Base camp (Lone Gull) and Skinny Lake (Zone 3). From a review of small-scale 1:63,360 aerial photography, field sampling covered representative terrain of the area and identified potentially sensitive areas near the Kiggavik site.

Vegetation sampling plots (10 metre [m] x 10 m) were established on the major landforms in the Project area. The number and specific locations of the sampling plots were not documented in the Wickware (1989) report. At each sampling location, a list of all species occurring within the plots were recorded and estimates of percentage cover were made. Identification of all collected species followed Hulten (1968), Fernald (1950), and Porsild (1964) for vascular plants, and Crum and Anderson (1981), Hale (1969), Conrad and Redfearn (1979) and Brodo (1981) for mosses and lichens.

Helicopter reconnaissance flights over sections of the Project area were made for annotation of black and white aerial photographs (1:63,360). Observations on the vegetation and general relationships between landforms and vegetation were recorded to facilitate air photo interpretation during the initial mapping phase of the Project.

In late July, 1988, three days of helicopter reconnaissance surveys of the proposed winter road routes (Zones 2, 4, and 5) and the dock facility area (Zone 1) were completed. Preceding the field reconnaissance, preliminary air photo interpretation of the proposed winter road corridors was undertaken, and areas of possible concern marked for field surveys.

During August, 1988, repositioning of the winter road routes, chiefly the routing between Baker Lake and Audra Lake, resulted in parts of the new road route occurring outside the previously assessed corridor. For these new areas, and the winter road corridor to the limestone quarry, only photo interpretation was carried out. In addition, five sites were selected for use as long-term monitoring stations of airborne particulate matter, in the Kiggavik site development area (Zone 3). No actual locations of these sites were documented in the report (Wickware 1989). Typical caribou summer forage (sedges and grasses) (Thompson et al. 1978) were collected for subsequent laboratory analysis.

In late August, 1989, a two-day ground field survey of the proposed infrastructure location for the mine was carried out. As well, the road access routes at the Kiggavik site were traversed, and all facility development sites examined. The proposed airstrip and waste rock dumpsites were also examined.

Field surveys of Zone 7 were carried out from August 14, 1990 to August 16, 1990 and the results reported in GIL (1990). Study sites were accessed by helicopter, and drop-off sites and routes were pre-selected to cover a range of terrain and vegetation types. Routes were surveyed on foot describing the vegetation on a continual basis. Major physiognomic vegetation types of the Project area were initially identified using aerial photography. Representative examples of each of the vegetation types were then field surveyed. Fieldwork was carried out throughout the Project area to encompass a variety of environments.

Eight 10 m x 10 m plots were selected to cover a range of vegetation types. No documentation of locations was included in the report (Wickware 1989). At each plot, vegetation (vascular plants, bryophytes and lichens) was identified to species and visual estimates of percent cover were recorded. Voucher specimens of mosses, lichens and some vascular plants were collected for identification confirmation. The vegetation type defined by Wickware (1989) was determined for each plot.

A cumulative species list was maintained during the field sampling and voucher specimens of most taxa were collected. All vascular plant specimens were submitted to the University of Toronto, Erindale Campus (TRTE) herbarium. Bryophyte and lichen specimens were submitted to the Canadian National Museum of Nature (CNMN) in Ottawa for identification.

Preliminary data collection in 1990 was used facilitate initial vegetation classification using aerial photography, and the design of an efficient field program for the proposed 1991 field season. Eight days of field surveys were carried out from August 12, 1991 to August 19, 1991 and reported in Geomatics International Inc. (1991). Transects and sampling plot locations were pre-selected using air photos and existing interpretative maps of the Kiggavik-Andrew Lake area. These were selected so that the sampling areas:

- provided complete coverage of the variation in vegetation-soil-landform conditions; and
- provided replicate sampling for statistical analysis of the data.

Survey transects were established to maximized different terrain coverage, with decreased distance to minimize walking time. Air photos and interpreted maps were consulted to ensure the sampling sites were representative of the area. Thirty-five plots were established throughout the Project area (Figure 7.5-1). At each site, corners of the 10 m x 10 m plot were marked. Vegetation was identified to species, and visual estimates of percent cover were recorded by stratum (shrub, herb, moss, lichen). Percent bare ground estimates were also included. Voucher samples were collected for taxonomically difficult species. Dr. W. Crins of the Ontario Ministry of Natural Resources (OMNR) confirmed vascular species identification. Bryophytes and lichens were sent to the CNMN for identification. Data from the preliminary results of the summer survey 1991 (Geomatics International Inc. 1991) were tabulated (see Appendix X, Table X-4), and subsequently summarized in this report.

Zone 1 - Dock Site - Baker Lake

Detailed vegetation descriptions for the Dock Site were undertaken at two sites representing the variability between the shoreline and the uppermost sequence of raised beach ridges (Table X-4 plots 36 and 37).

Zone 2 - Winter Road - Baker Lake to Kiggavik

This portion of the winter road was not surveyed due to logistical constraints on helicopter availability.

Zone 4 - Winter Road - Kiggavik to Aberdeen Lake

Both the alternate (north) and preferred (south) routes from Kiggavik to Aberdeen Lake were flown. Sensitive areas were considered based on drainage and slope stability. Aerial photos were annotated with locations of road intersections with seepage zones, streams (major and minor), wet depressions and steep slopes. The routes from Kiggavik to Aberdeen Lake passed through the Project area (Zone 6), and several of the 35 vegetation sites sampled, coincided with the proposed winter road routes.

Zone 5 - Winter Road – Aberdeen Lake to the Limestone Quarry

Both the preferred (west) and alternate (east) routes from Aberdeen Lake to the limestone outcrop (quarry) were flown. Vegetation was sampled at three plots along the route from Aberdeen Lake to the limestone quarry following previously detailed methods (Figure 7.5-2).

Figure 7.5-1 Locations of Vegetation Survey Plots and Lichen Sample Plots, 1991

Figure 7.5-2 Locations of Vegetation Survey Plots, for Zone 5, 1991

7.5.1.6 Lichen Collections

Cetraria spp. were collected from three locations to determine pre-development radiation levels in lichen at ground level. The three sites included the area at the main ore body at Kiggavik, an area approximately 1 km in the dominant downwind direction (southeast) from the ore bodies, and an area approximately 1 km upwind of the ore bodies. These locations are referred to as Kig1, Kig2 and Kig3 on Figure 7.5-2.

7.5.1.7 Photo Interpretation and Mapping

Winter road corridors and the Kiggavik site development plans proposed by I.D. Group Inc. (1988), were used as a geographic framework to focus the ELS and EA. Using photographs previously discussed in the “Aerial Photography” section, detailed photo interpretation of landscape patterns reflecting different ecological communities and processes was conducted for each of Zones 2 to 6. Patterns were delineated on air photos as polygons. Each polygon was homogeneous, with respect to pattern and process, as scale permitted. At scales of 1:40,000 and 1:63,360, most polygons reflected recurring patterns of diverse ecological communities. Dominant ecological processes within polygons were more similar than with those of adjacent polygons.

Following polygon delineation, annotations for each of the polygons were prepared using photo interpretation. During the field reconnaissance, terrain features (e.g., vegetation types, landforms, surficial deposits, and hydrologic character) were noted on 1:63,360 scale photos, and were used for the mapping (Wickware 1989). Terrain attributes for each polygon used in the mapping are tabulated in Table X-1. Baseline resource description maps were prepared for each zone using the ELS approach (Wickware 1989).

Thirty-five millimetre (mm) photos were used to obtain appropriate scale and detail for the dock site and subsequently were used for resource description purposes (Wickware 1989). The ELS base maps were later used for thematic resource mapping and EA (Wickware 1989).

The vegetation classification was based on physiognomic appearance (Wickware 1989), and vegetation associations previously described by BEAK (1987a) were used in the initial pre-feasibility study for the Project. Descriptions of the vegetation associations were updated for the Wickware study (1989), and integrated work by Thompson et al. (1978) for the Polar Gas Project. Coding for the vegetation complexes used in ELS (Table 7.5-3), was based in part on the polygon attributes (Table X-1).

Table 7.5-3
Coding for Vegetation Complexes Used in the ELS

Code	Vegetation Complex Description
Uhn	Low shrub boulder/lichen-heath
Ul	Lichen steppe
Ulg	Lichen steppe/sedge meadow
Uln	Lichen steppe/lichen-heath
Ulr	Lichen steppe/rock barrens
Uls	Lichen steppe/low shrub
Um	Moss-heath
Umh	Moss-heath/low shrub boulder
Umn	Moss-heath/lichen-heath
Un	Lichen-heath
Ung	Lichen-heath/sedge meadow
Unh	Lichen-heath/low shrub boulder
Unl	Lichen-heath/lichen steppe
Unm	Lichen-heath/moss-heath
Unr	Lichen-heath/rock barrens
Uns	Lichen-heath/low shrub
Ur	Rock barrens
Urh	Rock barrens/low shrub boulder
Url	Rock barrens/lichen steppe
Urn	Rock barrens/lichen-heath
Ush	Low shrub/low shrub boulder
Wgs	Sedge meadow/low shrub
Whsg	Low shrub boulder/low shrub/sedge meadow
Wsg	Low shrub/sedge meadow
Wshg	Low shrub/low shrub boulder/sedge meadow

Source: BEAK 1987b

7.5.1.8 Geographic Information System Analysis

Subsequent to the original mapping efforts, it was decided to incorporate all ELS data into a GIS platform (Wickware 1989). Data used for the ELS are tabulated in Table X-2. Maps were digitized, and data analyzed and modeled using Spatial Analysis System (SPANS) GIS software (Wickware 1989). All Project facilities, including each of the winter road corridors, were digitized and stored for use as part of the EA. Summary area statistics for major vegetation and complexes were synthesized, as were habitat loss statistics resulting from infrastructure development.

7.5.1.9 Vegetation Chemistry

Due to the general concern and potential consequences of radionuclide/heavy metals bioaccumulation from the development of the Project, it is important to have a detailed understanding, for the various pathways and components (including vegetation) of the ecosystems in the Project area. Over the last three decades, several radiation and heavy metal vegetation baseline collections have been carried out at the Kiggavik site and surrounding environments. The first vegetation survey was undertaken by Kershaw et al. (1983), which included collection and analysis of lichens to obtain background levels of radionuclides and trace metals. In Svoboda et al. (1985), various taxa of vegetation at the Project site and surrounding area were sampled to provide additional baseline radionuclide information. BEAK (1988) also provided additional trace metal concentrations for the vegetation of the Project area.

The purpose of this section of the report is to provide a general summary of natural radionuclide and trace metal levels in vegetation in the Project area. Most of the following information is taken from the Wickware (1989) report, which summarized the reports of Kershaw et al. (1983) and Svoboda et al. (1985). The Wickware report (1989) did not reference specific data, tables and figures to its origin, therefore, it was difficult to determine which of the two studies was the source of the information. The two original reports could not be located by the author, for verification of the Wickware (1989) summary, and clarification of some of the original sampling procedures, analysis methods and results. In addition, some tables from the original reports may have been omitted in the summary, causing confusion for the discussion. Additional information comes from collections by BEAK (1988), reported in Threader and Wilcox (1991).

Kershaw et al. (1983) collected three species of common lichens: glove lichen *(Dactylina arctica);* crinkle snow lichen (*Cetraria cucullata*); and, ballroom dervish lichen (*Cetraria nivalis*). The lichens were collected along four transects radiating several kilometres from the Main showing in north, east, south and west directions, The lichens were analysed for uranium and cesium-137 (Cs-137) content. Other analyses included sulphur and iron, titanium, copper and nickel concentrations.

Svoboda et al. (1985) collected vegetation samples along two perpendicular transects (N-S and E-W) intersecting at the Main showing at the Project site (Figures 7.5-3). They sampled mosses, grasses, sedges, willows, dwarf birch, Maydell's oxytrope, alpine bearberry, bilberry, cranberry (*Vaccinium vitis-idaea*), white arctic mountain heather, northern Labrador tea, black crowberry, and entire leaf mountain-avens. A composite vegetation sample was also collected. Vegetation samples were analysed for the concentrations of following radionuclides: Uranium-238 (U-238), and Radium-226 (Ra-

226), and Bismuth-214 (Bi-214). Some analyses only compared composite vegetation samples.

Svoboda et al. (1985) also collected composite plant samples from 19 locations in the Project area (both in areas with and without uranium mineralization) to determine natural concentrations of radionuclides (Figure 7.5-4). At each location, samples were taken in three different habitats; dry, mesic, and wet.

BEAK (1988) collected composite vegetation samples at five locations in the Project area including: Meadow Lake, Skinny Lake, Centre Zone Pit, Ridge Lake West, and Pointer Lake North Lowland. These samples were analysed for mineral and metal concentrations (aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, sodium, sulphur, vanadium, and zinc).

Figure 7.5-3 Location of Lichen Sample Plots Along the North, South, East, and West Transect, 1983 and1985

Figure 7.5-4 Composite Vegetation Sampling Sites for Radioactivity, 1985

7.5.2 Results

7.5.2.1 Ecosections

In 1986, using 1:63,360 scale black and white aerial photography, a 1,113 km^2 area centered on the Kiggavik ecodistricts were further subdivide into ecosections (BEAK 1987a). Six ecosections were delineated, each representing distinctive land areas with similar landforms, soils, vegetation and hydrology, based on groupings of the 177 identified ecosites (Figure 7.5-5 and Figure X-1). General descriptions for each of the ecosections based on Wickware (1989), which were slightly modified from the original versions in BEAK (1987a), are provided in the following subsections. All plant species referred to in previous studies or found during the field surveys within the Project area were compiled into a comprehensive list (Table X-2).

Aberdeen Lake North Ecosection

The Aberdeen Lake North ecosection covers an area of approximately 230 km^2 and includes 42 ecosites. Two distinct tundra vegetation communities predominate (Figure X-1). Lichen-heath communities occur most frequently on sandy tills, whereas lichen-steppe communities dominate on the well-drained, coarse-textured sandy deposits. The vegetation cover on these latter deposits is frequently sparse, sporadic and unstable.

Aberdeen Lake South Ecosection

Aberdeen Lake South is dominated by lichen-heath and heath vegetation in association with rock barrens, and thin veneers covering the bedrock scarps. Late-lying snowbeds provide local moisture supply zones, which give rise to local wetlands, which are dominated by graminoid and shrub communities.

Kiggavik Ecosection

The Kiggavik ecosection is the largest ecosection in the Project area at 385 km^2, and is comprised of 52 ecosites. The Kiggavik ecosection comprises approximately 80% of the Project area. Shrub vegetation colonizes the rills (small drainage features, i.e., gulley or rivulet, which are caused by erosion). Coarse, loamy-textured till is generally moderately well to imperfectly drained and supports moss-heath vegetation (Figure X-1). The moss forms substantial hummocks, up to 20 cm to 30 cm in height, and gives the terrain a rough, micro-topographic appearance. Graminoid tussocks and shrubs dominate wetlands and peat soils. Shrub vegetation frequently overlays a boulder pavement.

Figure 7.5-5 Ecosections and Ecosites of the Kiggavik Study Area

Squiggly Lake Ecosection

The Squiggly Lake ecosection is approximately 145 km^2 in area, and includes 23 ecosites. This ecosection is characterized by moss-heath in the southern portions, and lichen-heath vegetation in the northern parts, where a higher surface cover of boulders and better drained till occur (Figure X-1).

Skinny Lake Ecosection

The Skinny Lake ecosection covers approximately 150 km^2, with 15 ecosites. Lichen-heath vegetation dominates on the till deposits, whereas lichen-steppe vegetation dominates the coarse well-drained sediments (Figure X-1). Graminoid and graminoid-heath vegetation occur in wetlands, which are found in small pockets along lakeshores.

Sissons Lake Ecosection

The Sissons Lake ecosection covers approximately 100 km^2, and is comprised of 18 ecosites. Moss-heath vegetation occurs on coarse, loamy till and lichen-heath is found on sandy till (Figure X-1). Tussocky graminoid vegetation and taller willow shrubs characterize small wetlands along lake shorelines.

7.5.2.2 Major Vegetation Associations

The environmental pre-feasibility study (BEAK 1987a) found that vegetation varied throughout the Project area. Generally, the edaphic environment (specifically moisture) controls the type of vegetation. Soil moisture is controlled by the topography of area, texture of soil, and depth of the active layer. Additionally, local microclimates affects soil moisture levels, such as the vertical change in moisture on hummocks.

Surveys completed by BEAK (1987a) categorized vegetation in the Project area into seven major associations according to the main physiognomy of the vegetation: rock barrens, lichen steppe, lichen-heath, moss-heath, dwarf shrub, sedge meadow and tussock meadow. All vegetation association descriptions provided below are based on information from BEAK (1987a), Wickware (1989) and Geomatics International Inc. (1991), with additional comments from the summarization and review of raw data (Table X-4).

Rock Barrens

Rock barrens occur on drier exposed upper slopes, ridge tops and large boulder flats. The visual appearance is a rocky barren, hence the name of the vegetation type. Vegetation cover is low (less than 50%), and is primarily composed of crustose lichens (greater than 70%), such as map lichens (*Rhizocarpon* spp.), rim lichens (*Lecanora* spp.) and lecidea lichens (*Lecidea* spp.). Both *Cetraria* spp. and *Stereocaulon* sp. were common. Foliose lichens, such as elegant orange wall lichen (*Xanthoria elegans*), also occur on larger rocks and boulders. The drying effects of wind and absence of soil results in little or no vascular plants. Vascular plants appear only in protected cavities when soils are present and snow can accumulate. The species in these sheltered areas include ericaceous shrubs, such as black crowberry (*Empetrum nigrum*) northern Labrador tea, and alpine azalea (*Loiseleuria procumbens*), grasses, like alpine sweetgrass (*Hierochloe alpina*) and forbs (e.g., pincushion plant, *Diapensia lapponica*).

Lichen Steppe

Lichen steppe associations occur on well-drained soils; however, strong winds and the flat, exposed location produces typically patchy lichen distribution. Fruticose lichens dominate these areas, and include the northern fox hair (*Cornicularia divergens*), green witch's hair (*Alectoria ochroleuca*), foam (*Stereocaulon* spp.), star reindeer (*Cladina alpestris*), lesser green reindeer (*Cladina mitis*), gray-green reindeer (*Cladina rangiferina*), crinkle snow (*Cetraria cucullata*) and ballroom dervish (*Cetraria nivalis*) lichens. Graminoids such as Alpine sweetgrass and arctic woodrush (*Luzula nivalis*) are also common. Scattered forbs include pincushion plant, three toothed saxifrage (*Saxifraga tricuspidata*), cinquefoil (*Potentilla* spp.), locoweed (*Oxytropis* spp.) and milkvetch (*Astragalus* spp.) species.

Lichen-Heath

Lichen-heath is the major vegetation association occurring throughout the Project area. It usually occurs on well-drained upland sites with finer soils that could support ericaceous shrub growth. Little bare or exposed ground occur in these areas. Fruticose lichens dominate the lower layer, with a high occurrence of green witch's hair, northern fox hair and ballroom dervish lichen. Other lichen species present include foam lichens, (*Cetraria* spp., *Cladonia* spp., *Cladina* spp.), white-worm lichen (*Thamnolia vermicularis*) and glove lichen (*Dactylina arctica*). Woolly-fringed moss (*Racomitrium lanuginosum*) and turgid aulacomnium moss (*Aulacomnium turgidum*) occur frequently. The shrub layer is dominated by northern Labrador tea, white arctic mountain heath (*Cassiope tetragona*), black crowberry, bilberry (*Vaccinium uliginosum*) and cranberry (*Vaccinium* *vitis-idaea*). Small frost-related moss hummocks that are colonized by shrub and moss species also characterize the lichen-heath association.

The quantitative data from the Geomatics International Inc. (1991) study showed that average richness (number of species) within lichen-heath plots was 19. On average there were 11 lichen species found in the sample plots and the lichen cover was substantial (e.g., double that found in moss-heath plots). The dominant moss species in decreasing order were, elongated dicranium and turgid aulaomnium moss. The shrub group averaged four species per plot, with black crowberry and entire leaf mountain-avens being most abundant.

Moss-Heath

Moss-heath vegetation is associated with well to imperfectly drained soils in the Project area. The majority of the sites are hummocky with the relief ranging between 20 cm and 40 cm. In low-lying areas there is standing water around hummocks in mid-summer, whereas at well-drained sites, hummocks are surrounded by bare, gravely soil. Hummocks are dominated by mosses such as turgid aulacomnium moss, Schreber's big red stem moss (*Pleurozium schreberi*), and elongated dicranium moss. Lichens are also prominent on the hummocks, with species such as ballroom dervish, Iceland moss (*Cetraria. Islandica*), gray green reindeer lichen, mealy lichen (*Stereocaulon albicans* on rocks embedded in the hummocks), whiteworm lichen and *Cornicularia* spp. Frequently occurring graminoids are tussock cottongrass (*Eriophorum vaginatum*), northern single-spike sedge (*Carex scirpoidea*) and northern woodrush (*Luzula confuse*). Heath species are dominated by entire-leaf mountain-avens (*Dryas integrifolia*), cranberry, white arctic mountain heath, dwarf birch (*Betula glandulosa*), andromeda (*Andromeda polifolia*) and alpine bearberry (*Arctostaphylos alpina*). On the drier sites, the mossy hummocks still retaine adequate moisture to sustain plants such as Scotch false asphodel (*Tofieldia pusilla*), water sedge (*Carex aquatilis*) and tall cottongrass (*Eriophorum angustifolium*), all of which are usually found in wet areas.

The areas between hummocks showed greater species variability than the hummocks (Geomatics International Inc. 1991). In all cases, they were more sparsely vegetated than hummocks, often containing no plants at all. At wetter sites, the inter-hummock areas supported water and rock sedges and tufted bulrush (*Scirpus caespitosus*). Drier areas tended to be those with only bare soil, however, there were often prostrate willows such as arctic (*Salix arctica*) and diamond-leaf (*S. planifolia*) willows and arctic marsh and sheathed sedges growing there (Geomatics International Inc. 1991).

From the air, this association often produce a distinctive striping pattern, particularly at wetter sites. The darker bands were heath species, situated on the hummocks, and the lighter bands consisted of sedges located in the lower, inter-hummock depressions. This patterning was not visible at ground level.

The quantitative data from the Geomatics International Inc. (1991) study showed that the average richness at moss-heath sites was 32 species. On average, there were five moss species within the sampled plots. Mosses were the dominant taxa with respect to aerial cover. As in the lichen-heath plots, the top species were elongated dicranium and turgid aulaomnium moss. The next most dominant complex was the shrub-heaths and on average, there were eight shrub species per plot. Dwarf birch, bilberry and northern Labrador tea were the dominant shrub species. The average number of lichen species was 11, which was more than any other physiographic group; however, the overall importance of this group in terms of cover was low. Crinkled snow and ballroom dervish were the most common lichens.

Dwarf Shrub

Dwarf shrub vegetation occupies a range of terrains and locations in the Project area. It commonly occurs along branching channels where thickets of shrubs up to 50 cm to 70 cm in height can be found. Characteristic species include the white arctic mountain heather, alpine bearberry, red bearberry (*Arctostaphylos rubra*), cranberry, bilberry, river willow (*Salix alaxensis*) and dwarf birch. Shrub communities of similar composition also occur in sheltered locations, such as the lee-side of rock outcrops, or on lower and toe slopes with increased moisture. This vegetation association has low (20 cm), narrowly spaced hummocks, which are covered with a dense and reasonably abundant growth of dwarf birch. These sites are usually on flat, well-drained ground, or occur as a narrow band at the boundary between moss-heath and wetter sedge meadows around small lakes. Inter-hummock areas generally contain bare soil with some cobbles and/or coarse gravel. Mosses constitute a large part of the understorey vegetation, with the species composition similar to that of the moss-heath sites. Lichens are often less abundant at these sites.

Sedge Meadow

The sedge meadow association occurs around pools and lakes, throughout low, poorly drained areas, along drainage swales, and on gentle slopes beside streams. This type of vegetation is associated with organic soils where standing water is commonly found. The vegetation is composed of almost homogeneous stands of water or rock sedge. The low hummocks are dominated by *Sphagnum* sp. Lichens are not common in this vegetation association. The few forbs present are typically wetland species, such as alpine bistort (*Polygonum viviparum*), yellow marsh saxifrage (*Saxifraga hirculus*), arctic sweet coltsfoot (*Petasites frigidus*), lousewort (*Pedicularis* spp.), and cloudberry (*Rubus* *chamaemorus*). Shrubs are limited to the dryer edges of the wetlands or on *Sphagnum* mounds.

Tussock Meadow

The tussock meadows occur on higher ground than the sedge meadow, but it still have a fairly wet or moist environment (e.g., drainage/seepage zones). This vegetation is characterized by small graminoid tussocks (10 cm to 20 cm) colonized by cottongrasses and sedges. Specific dominant species vary in this vegetation association. Tussock cottongrass, tall cottongrass, water sedge, and spikerush (*Eleocharis* sp.) are all often dominant in tussock meadows. Heath and shrub species, such as northern Labrador tea, black crowberry and dwarf birch occur intermittently.

7.5.2.3 Vegetation Complexes

After identifying the major vegetation associations, combinations of these were used to form vegetation complexes that were incorporated in the ELS. Vegetation complex descriptions were originally discussed in BEAK (1987a). Wickware (1990) based their results on the BEAK report, and added further information. From the Wickware (1990) ELS results, it was determined that three main vegetation complexes dominated the Project area: moss-heath/lichen-heath (15.4%, 171.81 km^2,), lichen-heath/low shrub (14.1%) and lichen steppe/lichen-heath (11.7%) (Table 7.5-4). Lichen-heath and lichen steppe dominate the north and west portions of the Project area, whereas the moss-heath and low shrub communities dominate in the south and east (Figure X-3 [codes for Figures X-3 to X-7 are presented in Figure X-2]). The vegetation trends are related to the edaphic conditions. Lichen-dominated complexes occur on sandy well-drained soils to the north and west, and moss-heath and low shrub associations are found on poorly drained till in the south and east (Figure X-3). Each of the five zones in the Project area represented different environments as noted by the different amounts of the vegetation complexes (Table 7.5-4).

Table 7.5-4
Area Summary for the Major Vegetation Complexes Mapped for the Initial Project Study Area*

Vegetation Complex	Baker Lake to Audra Lake		Audra Lake to Kiggavik		Kiggavik Site Development Area		Kiggavik to Aberdeen Lake		Aberdeen Lake to Limestone Quarry		Kiggavik Study Area	
	Zone 2		Zone 2		Zone 3		Zone 4		Zone 5		Zone 6	
Geographic Area	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Lichen steppe	7.36	2.2	1.21	0.5	1.88	1.9	15	13.8	224	40	14.97	1.3
Lichen steppe/lichen-heath	43.9	13.4	5.79	2.4	4.64	4.6	3.33	3.1	77.4	13.8	130.19	11.7
Lichen steppe/low shrub	13	4	20.2	8.5	0	0	0	0	0	0	4.79	0.4
Lichen steppe/moss-heath	0	0	3.12	1.3	0	0	0	0	0	0	0	0
Lichen steppe/rock barrens	0	0	0	0	0	0	7.26	6.7	0	0	12.93	1.2
Lichen steppe/sparsely vegetated	0	0	0	0	0	0	0	0	53.6	9.6	0	0
Lichen steppe/sedge meadow	0	0	0	0	0	0	0	0	0	0	1.43	0.1
Lichen-heath	12.7	3.9	9.02	3.8	10.8	10.7	29.2	26.7	0	0	46.84	4.2
Lichen-heath/lichen steppe	27.5	8.4	0	0	0	0	7.03	6.4	0	0	70.11	6.3
Lichen-heath/tussock meadow	4.66	1.4	0	0	0	0	0	0	0	0	0	0
Lichen-heath/sedge meadow	0	0	0	0	0	0	0	0	0	0	13.86	1.2
Lichen-heath/moss-heath	0	0	5.86	2.5	15.8	15.7	2.29	2.1	0	0	7.81	0.7
Lichen-heath/low shrub	12.3	3.8	27.8	11.7	0	0	14.2	13	0	0	28.58	2.6
Lichen-heath/low shrub (boulders)	0	0	0	0	0	0	2.39	2.2	0	0	157.08	14.1
Lichen-heath/rock barrens	0	0	0	0	1.11	1.1	8.08	7.4	0	0	45.44	4.1
Moss-heath	0	0	2.12	0.9	18.8	18.7	2.84	2.6	0	0	13.41	1.2
Moss-heath/lichen-heath	0	0	11.3	4.7	15.2	15.1	3.85	3.5	0	0	171.81	15.4
Moss-heath/low shrub	0	0	51.9	21.8	8.67	8.6	0	0	0	0	0	0
Moss-heath/low shrub boulder	0	0	0	0	0	0	0	0	0	0	24.29	2.2
Moss-heath/lichen steppe	0	0	0	0	0	0	3.41	3.1	0	0	0	0
Low shrub/lichen-heath	9.63	2.9	0	0	0	0	0	0	0	0	0	0
Low shrub/moss-heath	0	0	1.39	0.6	0	0	0	0	0	0	0	0
Low shrub/sedge meadow	2.03	0.6	1.67	0.7	0	0	0	0	0	0	6.64	0.6
Low shrub/tussock moss meadow	28.8	8.8	0	0	0	0	0	0	0	0	0	0

Table 7.5-4
Area Summary for the Major Vegetation Complexes Mapped for the Initial Project Study Area (Continued)

Vegetation Complex	Baker Lake to Audra Lake		Audra Lake to Kiggavik		Kiggavik Site Development Area		Kiggavik to Aberdeen Lake		Aberdeen Lake to Limestone Quarry		Kiggavik Study Area	
	Zone 2		Zone 2		Zone 3		Zone 4		Zone 5		Zone 6	
Low shrub/low shrub boulder	0	0	0	0	0	0	0	0	0	0	3.51	0.3
Low shrub boulders/sedge meadow	31	9.4	0	0	5.13	5.1	0	0	0	0	3.88	0.3
Low shrub boulder/lichen-heath	0	0	0	0	0	0	0	0	0	0	5.38	0.5
Low shrub/low shrub boulder/sedge meadow	0	0	0	0	0	0	0	0	0	0	4.87	0.4
Tussock meadow/lichen-heath	1.2	0.4	13.8	5.8	0	0	0	0	0	0	0	0
Tussock meadow	4.31	1.3	5.88	2.5	0	0	0	0	0	0	0	0
Tussock meadow/low shrub	2.84	0.9	0	0	0	0	0	0	0	0	0	0
Sparsely vegetated	0	0	0	0	0	0	1.02	0.9	0	0	0	0
Sparsely vegetated/lichen steppe	0	0	0	0	4.21	4.2	0.3	0.3	0	0	0	0
Sedge meadow	0	0	0	0	0	0	3.2	2.9	0	0	0	0
Sedge meadow/low shrub	0	0	0	0	0	0	0	0	60	10.7	5.95	0.5
Sedge meadow/tussock moss meadow	0	0	0	0	0	0	0	0	55	9.8	0	0
Tussock moss meadow/sedge meadow	34.8	10.6	0	0	0	0	0	0	0	0	0	0
Tussock moss meadow/low shrub	10.4	3.2	0	0	0	0	3.47	3.2	0	0	0	0
Tussock moss meadow/moss-heath	2.67	0.8	8.41	3.5	0	0	0	0	0	0	0	0
Tussock moss meadow	3.43	1	2.29	1	0	0	0	0	0	0	0	0
Rock barrens	0	0	0.67	0.3	0	0	0	0	0	0	1.02	0.1
Rock barrens/lichen-heath	0	0	16.7	7	0	0	0	0	0	0	73.53	6.6
Rock barrens/lichen steppe	0	0	0	0	0	0	0	0	0	0	37.42	3.4
Rock barrens/low shrub boulder	0	0	0	0	0	0	0	0	0	0	61.31	5.5
Rock barrens/moss-heath	0	0	1.04	0.4	3.86	3.8	0	0	0	0	0	0
Lakes	75.8	23.1	47.7	20	10.8	10.7	2.27	2.1	90.2	16.1	166.28	14.9
TOTAL AREA	**328**	100	**238**	100	**101**	100	**109**	100	**560**	100	**560**	100

* this only include the initial project study areas and omits zone 7 which was added in a subsequent study (GIL 1990), No data of this sort was produce in the GIL (1990) study.

Source: Wickware 1989

km^2 = square kilometres

% = percent

Zone 1

The proposed dock facility was located along the north shore of Baker Lake, approximately 10 km east of the hamlet of Baker Lake. The site was characterized by a sequence of sandy/gravely raised beaches bordering a rock outcrop. The lower sandy beach shore was sparsely vegetated with clumps of American dunegrass (*Elymus mollis*) and three toothed saxifrage. The upper beach was characterized by lichen-heath vegetation and clumps of willows up to 1 m in height, which helped stabilize the coarse sediments. A series of gravel beaches were sparsely vegetated with lichen-heath vegetation on the inter-ridge benches.

The northeast area of the zone was dominated by a wet tussock-sedge meadow. Willow and dwarf birch shrubs, and patches of lichen-heath vegetation occupied moderate slopes, and portions of a stream channel, which originated from a wetland. The area between the proposed dock facility and Baker Lake had a gradually sloping beach, which transitioned up to a rock slope. The shore zone vegetation was similar to that found at the dock site, while lichen-heath vegetation colonized the upper slope and crest.

Zone 2

The area of the winter road corridor between Baker Lake and the Project covered an area of 566 km^2 and encompassed two distinct physiographic terrains. The terrain between Baker Lake and Audra (Aniguq) Lake was characterized by low, flat terrain and poorly drained soils dominated by wet sedge and low shrub meadows and by drier beach and foreshore areas with sporadic lichen steppe vegetation cover (Figure X-3). Between Audra Lake and the Kiggavik site, lichen-heath vegetation cover characterized the upland, moderately well drained terrain.

Zone 3

The Kiggavik site development area was 101 km^2 in size and was composed of four distinct physiographic sections (Escarpment North, Escarpment, Escarpment South and Skinny Lake), each with different vegetation communities (Figure X-4). The section above the escarpment was characterized by lichen-heath vegetation that colonized gently undulating till. Sedge and tussock-sedge vegetation occurred in poorly drained depressions.

The escarpment had cryptogramic (plants that reproduce by spores) communities associated with rock barrens, and lichen-heath communities in areas with soil (Figure X-4). Sedge and tussock-sedge meadows were located on accumulated organics in numerous moist draws along the escarpment leading to the Pointer Lake-Judge Sissons Lake drainage system.

The northern part of the escarpment influenced the southern portion below it, including Pointer Lake. Along the foot of the escarpment, late-lying snowbeds and seepage water supplied moisture throughout the summer and fed drainage channels that were usually surrounded by sedge and tussock-sedge meadows. Shrub associations occurred on boulder flats. Directly west of Pointer Lake, moss-heath and lichen-heath associations were common where the relief was greater and the sites better drained. Shrub associations occurred on protected slope sites, and on parallel strips associated with drumlins. Lichen Steppe vegetation colonized small-scattered sandy, well-drained deposits between Pointer Lake and the easterly proposed pit site. Lichen steppe vegetation also occurred on the flat exposed surfaces around Skinny Lake, whereas shrub associations colonized sheltered channels and stream banks.

Zone 4

The winter road corridor between the Project and the east end of Aberdeen Lake was 109 km^2 in size, and consisted of a series of beach ridges within an outwash delta that provided well-drained deposits. These deposits were often colonized by lichen-steppe vegetation. A large dissected delta with raised beach ridges occurred at the east end of Aberdeen Lake (Figure X-5). Moss-heath and lichen-heath vegetation was associated with the till. The moss-heath complex occurred on poorly drained sediments, whereas the lichen-heath was in well-drained areas (Figure X-5).

Zone 5

The winter road corridor between Aberdeen Lake and the limestone quarry site covered an area of 560 km^2, and was characterized by rolling sandy/gravely hills interspersed with a myriad of lakes (Figure X-6). Vegetation was relatively uniform throughout the zone, with lichen steppe being characteristic. Exposed crests and upper hill slopes were dominated by lichen steppe vegetation. Poorly drained areas were colonized by sedge and shrub meadows. Exposed sand and gravel was common on these landforms, with lichen steppe vegetation often covering 50% or less on crests. Sedge and tussock-sedge meadows occurred in lower slope and poorly drained sites. Shrub associations occurred infrequently. At the proposed limestone quarry site, exposed bedrock accounted for much of the ground surface.

Zone 6

Zone 6 had an area of 1,113.33 km^2 and encompassed Zone 3 and Zone 4, as well as areas north, south, east and west of these zones (Figure X-7). Generally the sandy well-drained soils of the north and west sections of the zone were dominated by lichen-heath and lichen steppe, whereas the poorly drained till in the south and east where dominated by the moss-heath and low shrub vegetation. A more detailed discussion of the vegetation was given in the Zone 3 and 4 discussions.

Zone 7

GIL (1990) found 62 species of vascular plants, six mosses and seven lichens during the field surveys within Zone 7 (Table X-3). Six of the seven vegetation types described by Wickware (1989) were identified including rock barrens, lichen-heath, moss-heath, dwarf shrub, sedge meadow and tussock meadow. Lichen steppe, an association found at the drier end of the moisture gradient, did not occur. Similar to Zone 6 to the north, the dominant association in Zone 7 was moss-heath. The lichen-heath association was rare in Zone 7, occurring on dry, well-drained upper slopes with boulder fields. The floristic composition was analogous to the moss-heath association, but differed greatly in the relative abundances of mosses and lichens (GIL 1990).

7.5.2.4 Vegetation Chemistry

Kershaw et al. (1983) concluded that significant distributional patterns of lichen concentrations of U, Cs-137, iron and titanium were closely associated with the Main showing (0 m on the transect) (Figures 7.5-6 to 7.5-9). The levels of these decreased with distance from the Main showing. Concentrations for sulphur, nickel and copper are shown in Figures 7.5-10 and 7.5-11.

The measured concentrations of iron (25 μg/g to 200 μg/g), titanium (3 μg/g to 35 μg/g), sulphur (80 μg/g to 300 μg/g), lead (1 μg/g to 14 μg/g) and nickel (1 μg/g to 6 μg/g) in *Cetraria nivalis* and *C. cucullata* were similar to those reported for the same lichen species from the Mackenzie Valley, NT (Nieboer et al. 1978). The relatively high concentrations of the same parameters close to the Main showing do suggest some contribution from a mineral-enriched substratum (Kershaw et al. 1983). The copper concentrations (4 μg/g to 7 μg/g) are characteristic of Arctic sites without mineralization of the substratum (Kershaw et al. 1983). The low concentrations of U found (less than 1 μg/g) in the three lichen species are comparable with other reported natural background concentrations of this metal (Beckett et al. 1982).

Figure 7.5-6 Concentration of Uranium in Lichen Samples Collected from the North, South, East and West Transects, 1983

Figure 7.5-7 Concentration of Cesium^{137} Content in Lichen Samples Collected from the North, South, East and West Transects, 1983

Figure 7.5-8 Concentration of Iron and Titanium in Lichen Samples Collected from the North, East and West Transects, 1983

Figure 7.5-9 Iron:Titanium Ratio in Lichen Samples Collected from the South and West Transects, 1983

Figure 7.5-10 Concentration of Sulphur in Lichen Samples Collected from the North and West Transects, 1983

Figure 7.5-11 Concentrations of Copper and Nickel in Lichen Samples Collected from the East and West Transects, 1983

In the Svoboda et al. (1985) study, the composite vegetation samples collected along the transects revealed distinct anomalies of the natural radionuclides at the Main showing (0 m) and Centre Zone (750 m E) (Figures 7.5-12 and 7.5-13). Activities of U-238, Ra-226 and bismuth (Bi-214) were three to four orders of magnitude greater at the Main showing compared to the transect average. At the Centre Zone, which was slightly covered by glacial drift, the activities were about 100 times the average. Activities decreased to very low levels about 200 m from the Main showing. The levels of activity were higher in the southern portion of the N-S transect which was assumed to be due to drainage south from the Main showing, to a wet, hummocky area. Patterns of activity of Cs-137 did not follow the uranium radionuclides pattern, and showed extensive fluctuation.

The plants at the Main showing and Centre Zone contained relatively high levels of U-238 and Ra-226 (Table 7.5-5), but the spatial extent of the high levels was limited. High levels of U-238 and Ra-226 were contained within a 100 m radius around the showing. The highest levels of U-238 at the Main showing were found in sedges (1190 ppm), grasses (550 ppm), and mosses (408 ppm). Ra-226 concentrations were similar to the U-238 results (Table 7.5-5). Mosses at the 30 m east location had the highest levels found in the entire area.

Figure 7.5-12 The Radionuclide Activity Profiles of the Composite Vegetation Collected Along the North and South Transects, 1985

Figure 7.5-13 The Radionuclide Activity Profiles of the Composite Vegetation Collected Along the East and West Transects, 1985

Table 7.5-5
Radionuclide Levels in Plants Collected from Three Sampling Points at the Kiggavik Main Showing Area (mean ± S.D.).

		Main Showing			30 m East			125 m West		
		U-238 (ppm)	Ra-226 (Bq/g)	Cs-137 (Bq/g)	U-238 (ppm)	Ra-226 (Bq/g)	Cs-137 (Bq/g)	U-238 (ppm)	Ra-226 (Bq/g)	Cs-137 (Bq/g)
lichens		-	2.22±0.27	0.64±0.07	-	NP	-	-	NP	-
mosses		408.0	11.41±1.31	0.32±0.03	16,000	3.29±0.38	0.42±0.05	31.1	1.27±0.19	0.17±0.02
grasses		550.0	6.68±0.77	0.04±0.01	-	132.61±15.1	0.13±0.03	-	5.18±0.59	0.01±0
sedges	*Carex* spp.	1190.0	13.01±1.50	0.16±0.03	298	34.52±3.96	0.07±0.02	-	0.09±0.09	0.07±0.01
willows	*Salix* spp.	71.6	5.56±0.64	0.04±0.01	-	19.94±2.26	0.04±0.01	-	4.44±0.52	0.01±0.01
dwarf birch	*Betula glandulosa*	-	4.38±0.50	0.05±0.01	-	3.06±0.35	0.11±0.01	26.0	2.9±0.33	0.01±0
Maydell's oxytrope	*Oxytropis maydelliana*	87.6	3.97±0.47	0.11±0.01	-	- NP -	-	-	0.82±0.12	0.04±0.01
alpine bearberry	*Arctostaphylos alpina*	-	4.91±0.57	0.1±0.01	-	2.84±0.33	0.07±0.01	33.7	5±0.56	0.01±0
bilberry	*Vaccinium uliginosum*	84.0	1.52±0.19	0.07±0.01	-	20.05±2.29	0.13±0	-	1.4±0.17	0.02±0
Cranberry	*V. vitis-idaea*	97.0	6.24±0.72	0.07±0.01	-	NP	-	-	NP	-
white arctic mountain heather	*Cassiope tetragona*	-	NP	-	-	NP	-	-	0.24±0.06	0.09±0.01
northern Labrador tea	*Ledum decumbens*	235.0	7.35±0.84	0.08±0.01	-	NP	-	-	1.49±0.19	0.04±0.01
black crowberry	*Empetrum nigrum*	-	2.47±0.28	0.11±0.01	-	1.5±0.19	0.11±0.01	21.6	1.91±0.23	0.03±0.01
entireleaf mountain-avens	*Dryas integrifolia*	-	NP	-	-	NP	-	-	3.98±0.47	0.06±0.01

NP - not present; m = metres; ppm = parts per million; Bq/g = Becquerels per gram
Source: Svoboda et al. 1985

Composite vegetation U-238/Ra-226 ratios along the two transects are shown in Figure 7.5-14. The maximum ratios occurred at the Main showing, and at the Centre Zone (700 m and 900 m east of the Main showing). The composite vegetation along the transects, except in the vicinity of the maxima, generally had values close to zero, suggesting that U-238 was almost avoided by plants. It appears that secular equilibrium (i.e., activity of U-238/activity of Ra-226 = 1) only existed in areas of uranium showing and points of the hummocky terrain. The presence of U-238 within the low-lying area south of the Main showing indicated a considerable relocation of uranium in the area. Marmont et al. (1978) traced this incongruity 600 m down the slope, while Svoboda et al. (1985) detected higher levels at about 500 m south of the Main showing.

The chief mechanism of mineral movement within the Kiggavik study area is probably snowmelt runoff (Woo and Drake 1983; BEAK 1989b). These studies documented a large widespread surface pulse of melt water in a short period, and a pattern of flow not restricted to stream channels. The chemical data reflects that these melt waters probably transport soluble and particulate radionuclides down the slope.

Additional work by BEAK Consultants Ltd. (1988) provides baseline heavy metal concentrations in vegetation throughout the Kiggavik study area (Table 7.5-6). Overall, the concentrations of minerals and metals in the vegetation collected in the Project area did not vary greatly between collection sites (Table 7.5-6). Arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, lead, magnesium, manganese, mercury, nickel, sodium, selenium, sulphur, vanadium and zinc concentrations at the Centre Zone Pit were consistent with background levels found at the Meadow Lake, Skinny Lake, Ridge Lake West and Pointer Lake North Lowland sites. Composite vegetation iron concentrations at the Centre Zone Pit were at the lower range of the background levels. However, aluminium and potassium concentrations of the composite vegetation samples were slightly lower at the Centre Zone pit compared with the background levels of the other four sampling sites. In contrast, only molybdenum concentrations (11 µg/g) in composite vegetation samples of the Centre Zone pit were higher than the background levels at the other sites.

Regional Vegetation Chemistry

Regional site locations, where plant samples were collected for chemical analysis, are shown in Figure 7.5-4. Ra-226 and Cs-137 levels over the northern, central and southern portions of the area are shown in Figures 7.5-15 to 7.5-17, respectively. The legend for these figures is given in Figure 7.5-18. Highlights of the data are described below.

Table 7.5-6
Concentrations of Minerals and Metals (μg/g) in Vegetation Collected in the Project Study Area

	Composite Vegetation Sample				
	Meadow Lake	Skinny Lake	Centre Zone Pit	Ridge Lake West	Pointer Lake North Lowland
Aluminum	150	187	87/81	152	114
Arsenic	<0.2	<0.2	<0.2/<0.2	<0.2	<0.2
Barium	0.5	0.5	<0.5/<1.0	2.5	0.5
Berylium	<0.5	<0.5	<0.5/<1.0	<0.5	<0.5
Calcium	8,900	8,400	10,000/6,100	7,900	7,000
Cadmium	0.15	0.2	0.20/0.20	0.35	0.15
Cobalt	1	1	1.0/0.5	1	1
Chromium	1	1.5	1.0/1.0	1.5	1
Copper	7.2	6	8.4/8.6	8.6	10.5
Iron	112	115	98/114	161	184
Mercury	0.08	0.08	0.06/0.10	0.12	0.06
Potassium	18,300	12,400	11,000/10,300	11,200	17,700
Magnesium	1,120	760	940/860	1,300	650
Manganese	380	950	620/610	490	380
Molybdenum	<1.0	<1.0	11/11	1	4
Sodium	155	85	110/110	140	100
Nickel	3.5	2.5	2.5/2.5	2	3
Lead	0.6	1	<0.2/1.0	2	1.2
Selenium	<0.2	<0.2	<0.2/<0.2	<0.2	<0.2
Sulphur	22	19	22/16.5	21	21
Vanadium	<0.5	<0.5	<0.5/<1.0	0.5	<0.5
Zinc	41	44	48/48	59	86

Source: BEAK 1988

Figure 7.5-14 Profiles of U/Ra Values (both converted to pCi/g) in the Composite Vegetation and the Substrates Along the two Main Transects of Kiggavik Camp.

Figure 7.5-15 Concentrations of Ra-226 and Cs-137 in Composite Vegetation Samples Collected from the Northern Region of the Study Area, 1985

Figure 7.5-16 Concentrations of Ra-226 and Cs-137 in Composite Vegetation Samples Collected from the Central Region of the Study Area, 1985

Figure 7.5-17 Concentration of Ra-226 and Cs-137 in Composite Vegetation Samples Collected from the Southern Region of the Study Area, 1985

Figure 7.5-18 Legend for Figures 7.5-15 to 7.5-17.

Northern Sites

- Sand Lake was a non-uranium showing site, however, detectible amounts of Ra-226 were present in the composite vegetation of the wet habitat. Cs-137 activity ranged between 7.3 (0.27) and 11.8 (0.44) pCi/g (Bq/g) in the composite vegetation.
- Dragon Point was a non-uranium showing site and there was no detectible Ra-226 in the composite vegetation. Cs-137 levels were similar to those found at Sand Lake.
- Whalebone Hill was a uranium showing plateau, of barren rocks with dry habitat. There was no Ra-226 activity in the composite vegetation. Cs-137 levels were similar to those found at Sand Lake.
- Whalebone East was located on another uranium showing plateau, 6 km east-northeast of Whalebone Hill. Both the dry plateau and mesic habitat had elevated levels of Ra-226 in composite vegetation (1.9 pCi/g [0.7 Bq/g]). The Cs-137 levels in the vegetation were comparable to those found at Sand Lake.
- Grant Lake was a non-uranium showing site. There was a decrease in the vegetation levels of Ra-226 from the dry to the wet habitat. Cs-137 was similar to those found at Sand Lake.
- Tundra Rose was a non-uranium showing site that had low amounts of Ra-226 present. The Cs-137 levels in the vegetation were comparable to those found at Sand Lake.
- Baker Lake North was a locality about 10 km northwest of the Hamlet of Baker Lake. Natural radionuclides were similar to those found at Dragon Point however, the Cs-137 levels were higher.

Central Sites

- Forde Lake was a uranium showing site located 26 km northwest of the western shore of Forde Lake. Anomalous levels of Ra-226 were detected in all samples. In the dry habitat vegetation, Ra-226 was 30 times the activity found in the mesic habitat.
- Kazan River I was a uranium showing site. All samples contained less than 2.5 pCi/g (0.9 Bq/g) of Ra-226. Cs-137 in the composite vegetation of the three habitats was consistent (7.4 pCi/g to 10.3 pCi/g [0.27 Bq/g to 0.38 Bq/g]).
- Kazan River II was 3 km south of Kazan River I, with similar radioactive and ecological characteristics. Elevated levels of Ra-226 were detected in the composite vegetation of the mesic habitat. The pattern of distribution for Cs-137 was quite similar to that observed at Kazan River I.
- Kazan Falls South was a uranium showing site. Anomalous Ra-226 activities were detected in the mesic and wet habitats, while background conditions prevailed at the dry habitat.

- Bissett Lake was a uranium showing site with elevated levels of Ra-226 in the samples of the dry site. The activity pattern of Cs-137 in the samples closely resembled the activity pattern of samples from Kazan River I.
- Christopher Island was a uranium showing site. Only composite vegetation of the mesic habitat showed elevated levels of Ra-226. Cs-137 activities were similar to other sites.

Southern Sites

- Nuturawit Lake was a uranium showing site. All composite vegetation samples had higher Ra-226 activity.
- Kamilukuak South was a uranium showing site. Slightly elevated levels of Ra-226 were detected only in the dry habitat. The patterns of Cs-137 distribution were similar to other sites.
- Banks Lake was a non-uranium showing site. However, detectable amounts of Ra-226 were found in the composite vegetation of dry and mesic habitats, indicating the presence of a uranium-bearing fraction in the esker material.
- Nowleye Lake was a uranium showing site northeast of Kamilukuak, which exhibited reduced shrub growth. Low levels of Ra-226 were detected. Cs-137 activity was within the range of other sites.
- Kaminuriak Lake was a non-uranium showing site that had low Ra-226 levels. Cs-137 in the composite vegetation of the dry habitat was higher than the average.
- Rankin Inlet (non-uranium showing) was the most easterly site. Samples were collected about 1.5 km west of the Town of Rankin Inlet on the east side of the airstrip. Ra-226 was lower than the average for the non-U sites, however, Cs-137 activities were comparable to other sites.

7.6 Current Baseline Studies

7.6.1 Methods

7.6.1.1 Ecological Landscape Classification

An Ecological Landscape Classification (ELC) for the RSA was completed in August 2007 by Golder Associates Ltd. (Golder) (Figure 7.6-1). The extent of the ELC was based on the RSA defined for the 2007 wildlife baseline studies, and is centered on the anticipated location of the Project. The RSA is 90 km long and 80 km wide (7,200 km^2), and includes all of Judge Sissons Lake, and parts of Aberdeen, Schultz, Mallory, and Princess Mary lakes (Figure 6.2-2).

Figure 7.6-1 Ecological Landscape Classification for the Regional Study Area, 2007

The task involved acquiring a Landsat Thematic Mapper image (28 m x 28 m pixel size), collecting training areas, and then classifying the image into vegetation polygons. Polygons (habitat patches) from the vegetation classification were digitized and then transferred into an ArcView/GIS platform. The incorporation of habitat data into a GIS platform is expected to facilitate future study designs, and determine sampling locations, habitat assessments for wildlife, and the analysis of species distribution and probability of occurrence. The information on habitat availability and habitat use (i.e., from aerial surveys, ground surveys, winter track counts) could be used to develop habitat suitability indices to help assess and predict impacts from the Project. The ability to produce several thematic or spatial layers in the GIS database also increases the efficiency and quality of map production (i.e., GPS points for aquatic and terrestrial sample plots, nest locations, wildlife observations, and soil data could be quickly and accurately transferred to the study area map).

7.6.1.2 Vegetation Chemistry

The accumulation of metals and radionuclides by plants is important because of the potential food chain transfer to wildlife and humans. As such, permanent sample plots (PSPs) were established to measure baseline radionuclide and trace metal concentrations in soil and vegetation. Three PSPs were established within the Kiggavik lease area and three within the Sissons lease area in 2007 (near the ore bodies; Figure 6.3-10). Plant species selected for collection were primary forage for herbivorous mammals and birds such as caribou, small mammals, hares, and ptarmigan. Plant species selected for chemical analysis included: lichen, willow (*Salix* spp.), dwarf birch (*Betula nana*), fruit and foliage from blueberry plants (*Vaccinium myrtilloides*), and sedge (*Carex* spp.). Vegetation samples were collected from the same area the soil samples were collected. Vegetation samples were sent to SRC Analytical Laboratories (Saskatoon, SK) for chemical analysis.

7.6.2 Results

7.6.2.1 Ecological Landscape Classification

The purpose of the vegetation classification was to map the vegetation communities within the RSA, focusing on important habitats and plant species for wildlife utilization. Using the most current satellite imagery (2007) of the RSA and ground-truthing, nine ELC units were identified (Figure 7.6-1; Table 7.6-1).

The primary ELC unit within the area is tussock-hummock, which accounts for approximately 30% of the surface area of the RSA. Riparian areas (1.8%) typically represent the most diverse communities and are primarily associated with streams and creeks, as well as with lake shorelines. The sedge wetland areas (9.7%) are composed primarily of sedge species, in addition to sparsely distributed shrub species.

The mosaic of ELC units within the RSA provides a broad range of habitats for wildlife. Lakes and streams are suitable foraging sites for eagles, osprey, and water birds (*e.g.,* loons, ducks, and shorebirds). Sedge wetlands and tussock-hummock vegetation provide important foraging areas for barren-ground caribou (Mathews et al. 2001). Streams and riparian areas contain forage for grizzly bears. These areas also provide suitable habitat for aquatic mammals and waterbirds. Bedrock lichen areas contain abundant lichen, which is an important food source for caribou. All habitat types provide a broad range of niches for song birds.

Table 7.6-1
Area and Proportion of Ecological Landscape Classification Units within the Regional Study Area

Ecological Landscape Classification Unit	Area (ha)	Proportion of RSA (%)
bare ground	2,425	0.3
bedrock lichen	30,648	4.3
heath boulder	29,380	4.1
heath tundra	161,777	22.5
riparian low shrub	13,071	1.8
sedge wetland	69,805	9.7
tussock-hummock	212,979	29.6
water	199,593	27.7
willow-boulder	321	0.0
Total	**720,000**	**100**

Bare Ground

Areas with very low, vascular plant cover as a result of anthropogenic disturbance, or areas of open tundra conditions (i.e., esker complexes) are classified as bare ground.

Bedrock Lichen

The Bedrock Lichen ELC is typical of bedrock outcrops that have undergone little weathering. The nutrient regime is very poor, and the moisture regime is very xeric. Vegetation cover is sparse. Microsites that support vegetation growth are uncommon, but vascular plants, such as boreal fescue (*Festuca hyperborean*), Baffin fescue (*Festuca baffinensis*), and alpine sweetgrass are present. Moss species, such as awned haircap moss (*Polytrichum piliferum*) grow in the rock cracks, whereas other mosses such as Hedwig's rock moss (*Hedwigia ciliate)* can be found on rock surfaces. Crustose lichens, such as green map lichen (*Rhizocarpon geographicum*) and frosted rocktripe (*Umbilicaria vellea*) are also common inhabitants of rock surfaces.

Heath Boulder

Heath with boulder fields is also an open mat plant community class. It can be distinguished from the heath/bedrock class because of the spectral differences between bedrock and boulders (Mathews et al. 2001). Differences in lichen composition and cover on boulders and bedrock outcrops also contribute to the identification of these separate classes (Mathews et al. 2001).

Heath Tundra

This class of heath tundra is a closed mat plant community that grows on moderate to well drained soils, covering most of the upland areas (Mathews et al. 2001). Plants generally belong to the heath family, the Ericaceae. The vegetation layer forms a mat of low shrubs dominated by dwarf birch and Labrador tea (Mathews et al. 2001). Other common plant species include cranberry, blueberry, crowberry, alpine milkvetch (*Astragalus alpinus*) and alpine azalea. Herb and moss layers are not well developed (Mathews et al. 2001). Typical lichens include several species of *Cetraria, Cladina, Cladonia* and others. As a closed mat community, vegetation covers at least 70% of the surface of the ground (Mathews et al. 2001).

Riparian Low Shrub

This ELC unit occurs in areas of active water seepage through boulder fields and boulder streams. Birch species are the dominant vegetation, but willow species are also present in smaller amounts. Blue joint (*Calamagrostis canadensis*) and water sedge are common plant species occurring in the understory along with crowberry, northern Labrador tea, and mosses.

Sedge Wetland

Wetland complexes are typically wet sedge meadows and other sedge associations of non-tussock plant species (Mathews et al. 2001). Sedge species such as water sedge and Bigelow's sedge (*C. bigelowii)*, and tall cotton grass (*Eriophorum angustifolium*) are the dominant vegetation types. Plant species occupy wet, low lying sites where standing water is present throughout much of the growing season. The substrate is usually organic or silty soils (Mathews et al. 2001).

Tussock-Hummock

Plants belonging to the sedge family (Cyperaceae) are also dominant in this vegetation unit (Mathews et al. 2001). Tussock cotton grasses such as *Eriophorum vaginatum* and *E. russeolum* are common. These sites are drier and less frequently flooded than sedge wetlands. Tussocks produce hummocks or mounds of 0.4 m to 1 m in diameter (Mathews et al. 2001). Hummocks are typically composed of old tussocks invaded by bog rosemary (*Andromeda polifolia*), cloudberry, Labrador tea, blueberry, and cranberry (Mathews et al. 2001). Sphagnum moss typically occupies the troughs between hummocks. Dwarf birch and willow tend to become established on the older hummocks (Diavik Diamond Mines Inc. 1998).

Willow-Boulder

The willow-boulder ELC follows active stream courses, usually with a cobble or boulder substrate. The ELC is dominated by willow species, but dwarf birch is also common. Understory plant species include dwarf raspberry (*Rubus arcticus* ssp. *acaulis)*, dwarf marsh violet (*Viola epipsila)*, cloudberry, grasses, sedges, club mosses and common horsetail.

Water

All water body-types present within the Project area landscape, including “lakes”, “ponds”, “rivers”, and “creeks” are categorized as “water”. Approximately 27.7% of the RSA is covered with water (Table 7.6-1).

7.6.2.2 Vegetation Chemistry

The results of the vegetation chemical analysis are presented in Table 7.6-2, 7.6-3. A total of 25 metals and four radionuclides were assessed for vegetation. Generally, analyte concentrations from vegetation collected from both Sissons and Kiggavik lease areas were similar to each other, regardless of plant type (Table 7.6-2 and 7.6-3). The exceptions to this were lichen and blueberry foliage in the Sissons lease area, and lichen, willow, and birch in the Kiggavik lease area. Lichen was found to have higher concentrations of Aluminum (~320 µg/g) and Iron (~220 µg/g) in the Sissons lease area as compared to other plants tested. Aluminum (~180 µg/g) was also higher in lichen in the Kiggavik lease area. Manganese concentrations found in blueberry foliage (~1030 µg/g) in the Sissons site was higher than in all other plant species tested (~300 µg/g), and was not elevated in foliage samples collected from within the Kiggavik lease area. Barium levels were elevated in willow and birch samples in the Kiggavik lease area as compared to other plant samples tested.

Overall, radionuclide levels were very low in all vegetation types from both lease areas (Table 7.6-2 and 7.6-3). The standard deviation for some of the analytes tested (i.e. Iron in *Carex*, Table 7.6-2) were very large due to very high levels in one of the replicate samples tested. This is related to the heterogeneous nature of soils, and thus the concentrations of compounds in soils in the environment. It is recommended that additional PSPs are established within the lease areas (potential exposure), as well as outside the lease areas (i.e., reference) to better assess the effect of the Project on metal and radionuclide concentrations in vegetation as activities proceed.

Table 7.6-2
Chemical Analysis of Vegetation Samples Collected from the Sissons Lease Area, 2008

Analyte	Units	Sissons Lease Area																	
		Lichen						Willow						Dwarf Birch					
		DL	SIS1L	SIS2L	SIS3L	Mean	SD	DL	SIS1WI	SIS2WI	SIS3WI	Mean	SD	DL	SIS1BI	SIS2BI	SIS3BI	Mean	SD
Metals																			
Aluminum	µg/g	5	440	380	130	317	164	0.05-5	8.6	16	16	14	4	0.05-5	34	11	32	26	13
Antimony	µg/g	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Arsenic	µg/g	0.05	0.2	0.08	0.06	0.11	0.08	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Barium	µg/g	5	52	49	28	43	13	5	91	79	70	80	11	5	88	69	68	75	11
Beryllium	µg/g	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0
Boron	µg/g	1	3	3	2	2.7	0.6	1	15	14	21	17	3.8	1	12	9	9	10	1.7
Cadmium	µg/g	0.01	0.11	0.08	0.13	0.11	0.03	0.01	1.7	2.1	1.6	1.80	0.26	0.01	0.08	0.2	0.18	0.15	0.06
Chromium	µg/g	0.5	0.6	<0.5	<0.5	0.37	0.2	0.5	<0.5	<0.5	<0.5	<0.5	0.0	0.5	<0.5	<0.5	<0.5	<0.5	0.0
Cobalt	µg/g	0.01	0.13	0.3	0.11	0.18	0.10	0.01	0.97	0.39	1	0.79	0.34	0.01	0.23	0.44	0.53	0.40	0.15
Copper	µg/g	0.05	2.3	2.2	2.6	2.4	0.2	0.05	7.6	6.7	6	6.8	0.8	0.05	4.9	4.4	5	4.8	0.3
Iron	µg/g	5	310	250	78	213	120	5	25	22	30	26	4	0.05-5	33	23	26	27	5
Lead	µg/g	0.01	2.5	0.53	0.3	1.11	1.21	0.01	0.06	0.05	0.07	0.06	0.01	0.01	0.2	0.04	0.11	0.12	0.08
Manganese	µg/g	10	240	160	370	257	106	10	400	350	430	393	40	10	130	300	410	280	141
Mercury	µg/g	0.05	0.06	0.07	0.08	0.07	0.01	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Molybdenum	µg/g	0.1	0.2	<0.1	<0.1	0.10	0.09	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Nickel	µg/g	0.05	0.94	0.99	0.69	0.87	0.16	0.05	1	0.57	1.1	0.89	0.28	0.05	1.2	1.7	2.2	1.7	0.5
Selenium	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Silver	µg/g	0.01	0.03	0.13	<0.01	0.06	0.07	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	0.03	<0.01	<0.01	0.01	0.01
Strontium	µg/g	0.05	8	6.7	6.4	7.0	0.9	0.05-5	29	20	26	25	4.6	0.05-5	13	5	8.2	8.7	4.0
Thallium	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Tin	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Titanium	µg/g	0.05-5	11	5	3.2	6.40	4.08	0.05	0.3	0.31	0.36	0.32	0.03	0.05	1.1	0.35	0.71	0.72	0.38
Uranium	µg/g	0.01	0.33	0.02	0.01	0.12	0.18	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	0.01	<0.01	<0.01	0.01	0.0
Vanadium	µg/g	0.1	0.8	0.4	0.2	0.5	0.3	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Zinc	µg/g	0.5-50	26	60	29	38	19	50	120	290	130	180	95	0.5-50	120	56	100	92	33
Radionuclides																			
Lead-210	Bq/g	0.005-0.006	0.29	0.26	0.32	0.29	0.03	0.001	0.09	0.088	0.079	0.086	0.006	0.0009-0.001	0.14	0.11	0.12	0.12	0.02
Polonium-210	Bq/g	0.001-0.002	0.31	0.15	0.29	0.25	0.09	0.0003	0.088	0.06	0.064	0.071	0.015	0.0002-0.0003	0.13	0.071	0.11	0.10	0.03
Radium-226	Bq/g	0.0002	0.0059	0.0024	0.0034	0.0039	0.0018	0.0003	0.0022	0.0012	0.0021	0.0018	0.0006	0.0002	0.0025	0.0027	0.005	0.0034	0.0014
Thorium-230	Bq/g	0.0004-0.0005	0.0031	<0.0005	0.0004	0.0013	0.0016	0.0006	<0.0006	<0.0006	<0.0006	<0.0006	0.0	0.0004	0.0006	0.0005	0.0008	0.0006	0.0002

Table 7.6-2
Chemical Analysis of Vegetation Samples Collected from the Sissons Lease Area, 2008 (Continued)

Analyte	Units	Sissons Lease Area																	
		Blueberry Foliage						Blueberry Fruit						Carex					
		DL	SIS1BB	SIS2BB	SIS3BB	Mean	SD	DL	SIS1BY	SIS2BY	SIS3BY	Mean	SD	DL	SIS1CA	SIS2CA	SIS3CA	Mean	SD
Metals																			
Aluminum	µg/g	5	86	100	48	78	27	5	16	63	12	30	28	0.05-5	38	14	3.4	18	18
Antimony	µg/g	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Arsenic	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Barium	µg/g	5	58	110	57	75	30	5	13	18	20	17	4	5	69	52	35	52	17
Beryllium	µg/g	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0
Boron	µg/g	1	9	11	15	12	3.1	1	16	60	14	30	26	1	15	8	5	9	5.1
Cadmium	µg/g	0.01	0.58	0.52	0.43	0.51	0.08	0.01	0.19	0.19	0.18	0.19	0.01	0.01	0.03	0.03	0.06	0.04	0.02
Chromium	µg/g	0.5	<0.5	<0.5	<0.5	<0.5	0.0	0.5	0.6	<0.5	<0.5	0.4	0.2	0.5	<0.5	<0.5	<0.5	<0.5	0.0
Cobalt	µg/g	0.01	0.49	0.22	0.36	0.36	0.14	0.01	0.04	0.06	0.04	0.05	0.01	0.01	0.17	0.02	0.07	0.09	0.08
Copper	µg/g	0.05	6.3	6.7	7.8	6.9	0.8	0.05	4.3	4.9	7	5.4	1.4	0.05	1.9	4.4	3.6	3.3	1.3
Iron	µg/g	0.05-5	34	31	35	33	2	5	17	16	13	15	2	5	300	91	16	136	147
Lead	µg/g	0.01	0.16	0.09	0.05	0.10	0.06	0.01	<0.01	0.04	0.01	0.02	0.02	0.01	0.11	0.03	0.02	0.05	0.05
Manganese	µg/g	10	880	900	1300	1027	237	10	140	310	290	247	93	10	160	150	390	233	136
Mercury	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Molybdenum	µg/g	0.1	0.2	<0.1	<0.1	0.10	0.09	0.1	0.3	<0.1	0.2	0.2	0.1	0.1	3.5	1.2	0.2	1.6	1.7
Nickel	µg/g	0.05	4.1	3.4	2.1	3.2	1.0	0.05	1.2	1.9	1	1.4	0.5	0.05	0.52	0.24	1.2	0.65	0.49
Selenium	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Silver	µg/g	0.01	0.01	<0.01	0.04	0.02	0.02	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	0.02	0.02	0.02	0.01
Strontium	µg/g	0.05	7.2	9	7.3	7.8	1.0	0.05	2.5	2.4	3.4	2.8	0.6	0.05	22	8.1	5	11.7	9.1
Thallium	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Tin	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Titanium	µg/g	0.05	0.54	0.76	0.76	0.69	0.13	0.05	0.07	0.33	0.17	0.19	0.13	0.05	0.45	0.25	0.11	0.27	0.17
Uranium	µg/g	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	0.24	<0.01	<0.01	0.08	0.14
Vanadium	µg/g	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Zinc	µg/g	0.5	39	51	32	41	10	0.5	21	21	19	20	1	0.5	20	49	22	30	16
Radionuclides																			
Lead-210	Bq/g	0.001	0.16	0.1	0.11	0.12	0.03	0.001-0.002	0.003	0.005	<0.002	0.003	0.002	0.001	0.072	0.069	0.054	0.065	0.010
Polonium-210	Bq/g	0.0003	0.1	0.08	0.087	0.089	0.010	0.0003-0.0005	0.0036	0.002	0.002	0.0025	0.001	0.0002	0.058	0.042	0.038	0.046	0.011
Radium-226	Bq/g	0.0002	0.0042	0.0044	0.0046	0.0044	0.0002	0.0005-0.002	0.004	0.001	0.0005	0.0018	0.0019	0.0004	0.052	0.002	0.012	0.022	0.026
Thorium-230	Bq/g	0.0004-0.0005	0.0006	0.0005	<0.0005	0.0005	0.0002	0.0004-0.001	<0.001	<0.001	<0.0004	0.0004	0.0002	0.0007-0.0008	0.002	<0.0008	<0.0007	0.0009	0.0009

Notes: DL = detection limit; SD = standard deviation; µg/g = micrograms per gram; Bq/g = becquerel per gram; < = less than

Table 7.6-3
Chemical Analysis of Vegetation Samples Collected from the Kiggavik Lease Area, 2008

Analyte	Units	Kiggavik Lease Area																	
		Lichen						Willow						Dwarf Birch					
		DL	KIG1L	KIG2L	KIG3L	Mean	SD	DL	KIG1WI	KIG2WI	KIG3WI	Mean	SD	DL	KIG1BI	KIG2BI	KIG3BI	Mean	SD
Metals																			
Aluminum	µg/g	5	220	140	170	177	40	5	13	15	21	16	4	5	25	36	24	28	7
Antimony	µg/g	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Arsenic	µg/g	0.05	0.08	0.12	0.12	0.11	0.02	0.05	<0.05	<0.05	0.13	0.060	0.061	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Barium	µg/g	5	97	23	73	64	38	5	160	87	110	119	37	5	140	110	94	115	23
Beryllium	µg/g	0.01	<0.01	<0.01	0.02	0.01	0.009	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0
Boron	µg/g	1	2	2	3	2.3	0.6	1	15	15	19	16.3	2.3	1	10	11	10	10	0.6
Cadmium	µg/g	0.01	0.28	0.1	0.22	0.20	0.09	0.01-1	5	4.1	3.1	4.07	0.95	0.01	0.35	0.14	0.1	0.20	0.13
Chromium	µg/g	0.5	<0.5	<0.5	<0.5	<0.5	0.0	0.5	<0.5	<0.5	<0.5	<0.5	0.0	0.5	<0.5	<0.5	<0.5	<0.5	0.0
Cobalt	µg/g	0.01	0.26	0.04	0.15	0.15	0.11	0.01	0.53	0.66	0.89	0.69	0.18	0.01	0.35	0.06	0.35	0.25	0.17
Copper	µg/g	0.05	1.7	1.2	3	2.0	0.9	0.05-5	12	4.4	7.3	7.9	3.8	0.05	4.9	4.3	5.9	5.0	0.8
Iron	µg/g	5	100	83	140	108	29	5	33	23	28	28	5	5	23	33	24	27	6
Lead	µg/g	0.01	1	0.37	0.71	0.69	0.32	0.01	0.2	0.11	0.19	0.17	0.05	0.01	0.09	0.21	0.11	0.14	0.06
Manganese	µg/g	10	310	60	220	197	127	10	390	300	430	373	67	10	560	100	140	267	255
Mercury	µg/g	0.05	0.09	0.1	0.08	0.09	0.01	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Molybdenum	µg/g	0.1	<0.1	<0.1	0.9	0.33	0.49	0.1	<0.1	<0.1	0.5	0.20	0.26	0.1	<0.1	<0.1	0.2	0.1	0.09
Nickel	µg/g	0.05	0.81	0.21	0.73	0.58	0.33	0.05	1.4	0.6	1.7	1.23	0.57	0.05	2.4	0.83	1.7	1.64	0.79
Selenium	µg/g	0.05	<0.05	0.06	<0.05	0.04	0.02	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Silver	µg/g	0.01	<0.01	0.03	<0.01	0.01	0.01	0.01	0.05	<0.01	<0.01	0.02	0.03	0.01	<0.01	<0.01	0.01	0.007	0.003
Strontium	µg/g	5	24	6.4	25	18.5	10.5	0.05-5	46	35	47	43	6.7	5	13	16	15	15	1.5
Thallium	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Tin	µg/g	0.05	0.07	<0.05	<0.05	0.040	0.026	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	0.06	0.04	0.02
Titanium	µg/g	5	5	4.5	10	6.5	3.0	0.05-5	0.33	0.49	49	16.61	28.05	0.05	0.79	1.4	2.8	1.7	1.0
Uranium	µg/g	0.01	0.01	0.02	0.02	0.02	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0
Vanadium	µg/g	0.1	0.2	0.2	0.5	0.30	0.17	0.1	<0.1	<0.1	1.8	0.6	1.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Zinc	µg/g	0.5	44	25	35	35	10	50	380	120	300	267	133	50	150	120	170	147	25
Radionuclides																			
Lead-210	Bq/g	0.005	0.5	0.41	0.58	0.50	0.09	0.001	0.076	0.095	0.11	0.094	0.017	0.001	0.086	0.12	0.16	0.12	0.04
Polonium-210	Bq/g	0.001	0.38	0.4	0.47	0.42	0.05	0.0002-0.0003	0.066	0.1	0.12	0.095	0.027	0.0002-0.0003	0.085	0.1	0.13	0.11	0.02
Radium-226	Bq/g	0.0002-0.0008	0.014	0.016	0.006	0.0120	0.0053	0.0003	0.014	0.007	0.0028	0.0079	0.0057	0.0002-0.0004	0.0055	0.0019	0.0055	0.0043	0.0021
Thorium-230	Bq/g	0.0006-0.002	0.0008	0.001	0.002	0.0013	0.0006	0.0007	0.001	0.001	0.0007	0.0009	0.0002	0.0004	<0.0004	0.001	0.002	0.0011	0.0009

Table 7.6-3
Chemical Analysis of Vegetation Samples Collected from the Kiggavik Lease Area, 2008 (Continued)

Analyte	Units	Kiggavik Lease Area																	
		Blueberry Foliage						Blueberry Fruit						Carex					
		DL	KIG1BB	KIG2BB	KIG3BB	Mean	SD	DL	KIG1BY	KIG2BY	KIG3BY	Mean	SD	DL	KIG1CA	KIG2CA	KIG3CA	Mean	SD
Metals																			
Aluminum	µg/g	5	44	28	36	36	8.0	0.05	6.5	6.6	26	13.0	11.2	0.05-5	10	8.6	27	15	10
Antimony	µg/g	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Arsenic	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Barium	µg/g	5	55	57	59	57	2.0	5	21	27	26	25	3	5	97	88	87	91	6
Beryllium	µg/g	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	0.02	0.01	0.01
Boron	µg/g	1	9	9	11	10	1.2	1	15	29	25	23	7.2	1	9	8	9	9	0.6
Cadmium	µg/g	0.01	0.8	0.59	0.57	0.65	0.13	0.01	0.31	0.36	0.16	0.28	0.10	0.01	0.02	0.08	0.02	0.04	0.03
Chromium	µg/g	0.5	<0.5	<0.5	0.6	0.4	0.2	0.5	<0.5	<0.5	0.6	0.4	0.2	0.5	<0.5	<0.5	0.6	0.37	0.20
Cobalt	µg/g	0.01	0.06	0.06	0.05	0.06	0.01	0.01	0.02	0.02	0.06	0.03	0.02	0.01	0.1	0.04	0.05	0.06	0.03
Copper	µg/g	0.05	9.1	9.1	9.6	9.3	0.3	0.05	3.1	4.9	4	4.0	0.9	0.05	2.8	3.4	3.5	3.2	0.4
Iron	µg/g	5	37	22	23	27	8.4	5	12	15	30	19	10	5	120	32	110	87	48
Lead	µg/g	0.01	0.06	0.06	0.08	0.07	0.01	0.01	0.01	<0.01	0.05	0.02	0.02	0.01	0.03	0.04	0.06	0.04	0.02
Manganese	µg/g	10	640	480	640	587	92	10	220	230	150	200	44	10	560	390	40	330	265
Mercury	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Molybdenum	µg/g	0.1	<0.1	<0.1	0.6	0.2	0.3	0.1	<0.1	0.1	1.5	0.6	0.8	0.1	1.7	0.6	4.8	2.4	2.2
Nickel	µg/g	0.05	1.2	2.1	2.9	2.1	0.9	0.05	1.9	1.4	1.6	1.6	0.3	0.05	0.27	0.43	0.44	0.38	0.10
Selenium	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Silver	µg/g	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	0.01	0.09	0.035	0.048
Strontium	µg/g	0.05-5	8.2	11	12	10	2.0	0.05	4.8	5.1	7.2	5.7	1.3	5	20	15	14	16	3.2
Thallium	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Tin	µg/g	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0	0.05	<0.05	<0.05	<0.05	<0.05	0.0
Titanium	µg/g	0.05-5	0.64	0.37	14	5.00	7.79	0.05	0.06	0.1	0.79	0.32	0.41	0.05	0.24	0.3	2.7	1.08	1.40
Uranium	µg/g	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0	0.01	<0.01	<0.01	<0.01	<0.01	0.0
Vanadium	µg/g	0.1	<0.1	<0.1	0.3	0.13	0.14	0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.1	<0.1	<0.1	<0.1	<0.1	0.0
Zinc	µg/g	0.5-50	70	49	70	63	12	0.5	25	23	20	23	3	0.5-50	100	50	31	60	36
Radionuclides																			
Lead-210	Bq/g	0.001	0.078	0.12	0.057	0.085	0.032	0.001-0.002	0.002	<0.002	0.011	0.005	0.006	0.001	0.058	0.014	0.007	0.026	0.028
Polonium-210	Bq/g	0.0003	0.058	0.11	0.045	0.071	0.034	0.0003-0.0005	0.0041	0.003	0.009	0.0054	0.0032	0.0002	0.037	0.017	0.012	0.022	0.013
Radium-226	Bq/g	0.0002	0.0039	0.0056	0.0023	0.0039	0.0017	0.0002-0.0005	0.0006	<0.0005	0.002	0.0010	0.0009	0.0002-0.0004	0.0036	0.0076	0.0019	0.0044	0.0029
Thorium-230	Bq/g	0.0004-0.0005	0.0005	0.0006	<0.0004	0.0004	0.0002	0.0004-0.001	<0.0004	<0.001	0.001	0.0006	0.0004	0.0005-0.0009	<0.0009	<0.0005	<0.0007	0.0004	0.0001

Notes: DL = detection limit; SD = standard deviation; µg/g = micrograms per gram; Bq/g = becquerel per gram; < = less than

8.0 WILDLIFE AND WILDLIFE HABITAT

8.1 Introduction

The Project is located approximately 80 kilometres (km) northeast of Baker Lake, Nunavut, in the Keewatin lowland ecoprovince of the Southern Arctic ecozone (Figure 8.1-1). Formal and informal wildlife studies have been completed periodically since 1978 to study habitat and fauna in the local and regional areas surrounding the Project. More recently, AREVA Resources Canada Inc. (AREVA) began collecting terrestrial baseline data in the Project area in 2007 to supplement the data from the earlier studies. In general, the principal objectives of the 2007 terrestrial baseline studies were:

- to collect information on the current physical conditions (e.g., soils), wildlife species, and habitats in the study area, including the identification of federal and provincial listed and uncommon species, and critical terrestrial habitats (i.e., sensitive ecological attributes); and
- to obtain estimates of natural variation in biophysical variables, and wildlife species presence, richness, abundance, and distribution.

Documentation of baseline conditions facilitates the EA process such that it will be possible to:

- implement environmental design features and management plans (mitigation measures) during the design of the Project to avoid or limit disturbance to biophysical variables and habitats, particularly sensitive ecological attributes;
- predict effects from the Project on current ecological conditions, wildlife species, and habitats; and
- test impact predictions (i.e., before-after-control-impact studies), and the effectiveness of environmental design features and management plans by way of comparison of baseline data to monitoring program data collected during mine construction and operation.

This section of the TID report provides qualitative and quantitative information on the population status and distribution of valued components (VCs), local habitats, seasonal habitat use, and seasonal movement corridors or high use areas. Where data are available, descriptions of other species occurring in or near the Project area also are provided (e.g., muskoxen).

Figure 8.1-1 Location of the Kiggavik Project

8.2 Species at Risk

Species at risk lists created by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007) and the Nunavut Wild Species 2000 Report (Government of Nunavut [GN] 2001) were reviewed, and species known to occur or likely occur within the regional study area (herein referred to as the RSA) were identified (Table 8.2-1). Species considered ‘sensitive’ by the Nunavut Wild Species Report (GN 2001) or endangered, threatened, or of special concern by COSEWIC (2007) or Species at Risk Act (SARA) (2007, internet site) were included as VCs. No species listed under Schedule 1 of SARA are known to reside within the Project area. Schedule 1 classifies species as being extirpated, endangered, threatened, or of a special concern. Once listed on Schedule 1, measures to protect and recover a listed species are implemented.

Of the species that potentially occur within the Project area, the tundra peregrine falcon (*Falco peregrinus tundrius*) and short-eared owl (*Asio flammeus*) are currently listed under Schedule 3 of SARA (SARA 2007, internet site). Schedule 2 and Schedule 3 are species that were designated at risk by COSEWIC prior to October 1999 and must be reassessed using revised criteria before they can be added to Schedule 1 of SARA (SARA 2007, internet site).

Table 8.2-1
Species at Risk Observed or Expected in the Kiggavik Wildlife Regional Study Area

Species	Scientific Name	Nunavut Status[(a)]	COSEWIC Status[(b)]	SARA Category of Concern[(c)]
Grizzly bear (northwestern population)	*Ursus arctos*	sensitive	special concern	no status
Wolverine (western population)	*Gulo gulo*	sensitive	special concern	no status
Peregrine falcon	*Falco peregrinus tundrius*	may be at risk	special concern	special concern, Schedule 3
Short-eared owl	*Asio flammeus*	sensitive	special concern	special concern, Schedule 3
Northern pintail	*Anas acuta*	sensitive	no status	no status
Common eider	*Somateria mollisima*	sensitive	no status	no status
King eider	*Somateria spectabilis*	sensitive	no status	no status
Least sandpiper	*Calidris minutilla*	sensitive	no status	no status
Rock ptarmigan	*Lagopus mutus*	sensitive	no status	no status
Wilson's Snipe	*Gallinago gallinago*	sensitive	no status	no status
American pipit	*Anthus spinoletta*	sensitive	no status	no status
Semipalmated sandpiper	*Calidris pusilla*	sensitive	no status	no status
Red-necked phalarope	*Phalaropus lobatus*	sensitive	no status	no status
Horned lark	*Eremophila alpestris*	sensitive	no status	no status
American tree sparrow	*Spizella arborea*	sensitive	no status	no status
White-crowned sparrow	*Zonotrichia leucophrys*	sensitive	no status	no status
Snow bunting	*Plectophenax nivalis*	sensitive	no status	no status

a = Nunavut Wild Species 2000 (GN 2001).
b = Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2007.
c= Species at Risk Act (SARA) 2007, internet site.

8.3 Spatial Boundaries

Early baselines studies completed in the Project area were not conducted within a defined spatial boundary. Instead, several sites designated as important to wildlife were surveyed to gather data on wildlife in the region containing the Project (BEAK 1990a; Urangesellschaft 1990a; Urangesellschaft 1990b).

During the initial EA process for the Project (1978 to 1980), studies were carried out in four locations to document caribou in the area surrounding the Project (Figure 8.3-1). The Marjorie Lake and Sandhill locations were selected because they fell within the "primary calving area and post-calving aggregation area" for the Beverly herd, and the Sissons and Schultz Lake locations were chosen because they fell within an area of "potential calving and post-calving aggregation" (BEAK 1990a). The remaining three sites were included to provide a regional context.

In 2007, AREVA began collecting aquatic and terrestrial baseline data, in anticipation of preparing an Environmental Impact Statement (EIS) for the Project. The RSA for the 2007 wildlife baseline studies is centered on the anticipated location of the Project, and is in the vicinity of the southern extent of the calving grounds for the Beverly caribou herd. The study area is 90 km long and 80 km wide (7,200 square kilometres [km^2]), and includes all of Judge Sissons Lake, and parts of Aberdeen, Schultz, Mallory, and Princess Mary Lakes (Figure 6.2-2). The spatial extent of the RSA was selected based on current study areas for caribou and other large mammals (muskoxen, grizzly bears, wolves) for other mining projects in Nunavut (i.e., the Jericho and Doris North projects [Tahera 2000; Miramar 2005]) and the NT (i.e., the Ekati, Diavik, Snap Lake, and Gahcho Kué projects [BHPB 1995; DDMI 1998; De Beers 2002; MVEIRB 2007]), along with logistical constraints, the anticipated mine plan for the Project and avoidance of the calving grounds for the Beverly caribou herd, and known location of caribou water crossings along the Thelon River basin.

Figure 8.3-1 Environmental Study Areas for the Project, 1979

8.4 Data Sources

This Technical Information Document (TID) provides a historical and regional perspective on wildlife populations gleaned from available literature and existing knowledge. The objective of this section is to compile the data from wildlife surveys and to provide a summary of the wildlife and wildlife habitat present in the Project area. Historical data was supplemented with ecological information from regional wildlife studies, and where available, data from the 2007 baseline studies. These data will be used within the environmental planning and assessment of potential effects from the proposed Project, and provide a basis for developing wildlife mitigation and monitoring plans during the Project.

The following documents were reviewed as part of the preparation of this section:

- Supporting Document No. 3. The Terrestrial Wildlife Resource Description: Kiggavik Uranium Facility, Bake Lake, NT (BEAK 1990a);
- Kiggavik Uranium Mine and Associated Transportation Corridors. A Review of Existing Documentation on Avifaunal Resources and Discussion of Potential Impacts. Draft Report November 1990 (Geomatics International Ltd. [GIL] 1990);
- Kiggavik Uranium Project, Baker Lake, NT Canada, Environmental Assessment. Summary Report (BEAK 1990b);
- Kiggavik Uranium Project, Baker Lake, NT, Canada, Environmental Assessment. Part 2. Environmental Assessment/ Safety Report (BEAK 1990c);
- Results of Spring Survey 1991. Kiggavik and Andrew Lake (BEAK 1991);
- Results of Spring Survey 1991. Kiggavik and Andrew Lake. Mammals and Birds. July 1991 (GIL 1991);
- Kiggavik Uranium Mine Environment Assessment Terrestrial Wildlife (Threader and Wilcox 1991);
- Terrestrial Wildlife Impact Responses to Fearo Questions (BEAK 1992); and
- Kiggavik Environmental Baseline Data Summary and Potential Data Gaps. Terrestrial Environment (Ecometrix Inc. 2006).

8.5 Barren-Ground Caribou

8.5.1 Population and Distribution

Barren-ground caribou (*Rangifer tarandus groenlandicus*) are a vital species for subsistence and are of cultural importance to Aboriginal peoples and other residents of the NT. There are three barren-ground caribou herds whose ranges may overlap with, or occur near the Project area: the Beverly herd, Qamanirjuaq herd (formerly known as the Kaminuriak and Qamanirjuac), and Ahiak herd (Figure 8.5-1).

Figure 8.5-1 Caribou Herd Annual Ranges Based on Satellite-Collared Cows

Current estimates suggest that five of the eight barren-ground caribou herds have declined during the past ten years (Porcupine, Cape Bathurst, Bluenose East, Bluenose West, and Bathurst) (Working Group on General Status of NT Species 2006). For example, from 1996 to 2003, the Bathurst herd declined by approximately 53% (BHPB 2004), and a recent analysis indicated that the population has decreased further from 2003 to 2006 (Boulanger 2006). The status of the Ahiak, Beverly, and Qamanirjuaq herds since the mid-1990s is unknown, but given the synchronicity in population cycles of barren-ground caribou, population decreases in these herds is suspected.

Variation in barren-ground caribou movement and distribution occurs within and among years, and for different populations. Although the precise timing and location of caribou movements between winter ranges and calving grounds are unpredictable, general corridors and the broad timing of movements are known (ENR 2008, internet site). One technique for monitoring the movement of barren-ground caribou is the use of satellite collars on individual animals (ENR 2008, internet site). This technology has been employed in the NT since 1996. The collars are placed on cows during the winter (when they are least sensitive to disturbance) and then the animals movements are tracked throughout the year.

Barren-ground caribou movements during their annual cycle are generally classed into six periods (biological seasons) based on satellite-collared caribou data (ENR 2008, internet site):

- northern migration (May 1 to 31);
- calving (June 1 to 15);
- post-calving aggregation (June 16 to July 1);
- summer dispersal (July 2 to August 31);
- rut and fall migration (September 1 to October 31); and
- winter dispersal (November 1 to April 30).

Northern Migration

Pregnant cows and yearlings are the first to start the northern migration to the traditional calving grounds on the tundra, followed by non-breeding cows and young bulls (BEAK 1990a; Beverly and Qamanirjuaq Caribou Management Board [BQCMB] 2007a; ENR 2008, internet site). The cows reach the tree line around the beginning of May, arriving at the calving grounds in early to mid June (BEAK 1990a; BQCMB 2007a). Mature bulls are the last to leave the winter range, up to one month after the pregnant cows, and generally stop their journey short of the calving grounds (BQCMB 2007a).

Calving

Most cows arrive on the calving grounds in the last week of May or early June. Bulls, some yearlings, and non-pregnant females tend to lag behind during the northern migration and generally do not migrate as far as the calving grounds (ENR 2008, internet site). The majority of calving takes place in the first two weeks of June. Within this period, there is a five-day interval when most calves are born (Fleck and Gunn 1982).

Calving grounds are often located in high, rocky areas where there is little shelter from wind and driving snow (ENR 2008, internet site). These conditions are favourable as they provide patches of bare ground that allow the cows to feed. Most wolves remain within or near the treeline to den and are a reduced threat to cows and newborns during the calving season (ENR 2008, internet site). As well, these high, rocky areas of the calving grounds are difficult for wolves to access. However, the calving grounds are occupied by grizzly bears that prey on newborn calves.

Post-Calving Aggregation

The post-calving period (late June to early July) begins soon after calving occurs, and is characterized by an aggregation of individuals into larger groups. Initially, these groups include cows and calves, which are gradually joined by non-calving cows, yearlings, and adult bulls (BQCMB 2007a). The large groups are formed in an attempt to minimize insect harassment from mosquitoes, warble flies and nose-bot flies (ENR 2008, internet site), as well as reducing the risk of predation by wolves and grizzly bears (BQCMB 2007a).

Summer Dispersal

In late August and early September, the decrease in insect populations allows for the dispersal from the large aggregates into smaller groups (ENR 2008, internet site). Barren-ground caribou then begin to focus on feeding to gain weight prior to fall migration and rut. This period is particularly critical for cows that need to gain enough weight to be in good condition for breeding in the fall (ENR 2008, internet site).

Rut and Fall Migration

The rut occurs in October, after which the fall migration takes the caribou back below the tree line (BQCMB 2007a). The rut can last up to three weeks, although most cows are bred within days of each other (ENR 2008, internet site). Because of the variability in timing of the fall migration, the rut may take place before, during, or after the main migration (Banfield and Jakimchuk 1980). The rut typically peaks in late October

(Gunn 1984b). Sparring may begin by the end of September, with sporadic rutting activity occurring through early November (ENR 2008, internet site). Following the rut, the cows and bulls will segregate and disperse over the wintering grounds.

Winter Dispersal

Barren-ground caribou generally disperse throughout their winter range from November through March. The distribution of barren-ground caribou changes constantly during the winter as they search for places where the food is abundant and the snow is shallow (ENR 2008, internet site). By April, animals begin to gather into small groups for the migration to the calving grounds in the north (Pruitt 1960).

8.5.1.1 Seasonal Occurrence of Caribou Herds in Relation to the Project Regional Study Area

Seasonal home ranges based on satellite collar locations were created to assess distribution of the Beverly, and Ahiak herds in relation to the Project RSA. The government of NWT has been monitoring the distribution of the Qamanirjuaq herd since 1993, however, current satellite-collared caribou data could not be acquired at the time of this report. Movements of the Beverly herd have been tracked using satellite collars from January 1, 1995 to October 31, 2007, whereas data for the Ahiak herd is based on satellite collar data from January 1, 2001 to October 31, 2007. The average distance from the Beverly herd range to the Project RSA varies from 36 km during the calving and post-calving periods to 275 km during winter period (Table 8.5-1). Based on the 2001 to 2007 satellite-collar data, the seasonal range of the Ahiak herd for the summer dispersal and fall migration periods overlaps the Project area. The average distance from the Ahiak herd range to the Project area for the remaining seasonal periods varies from 62 km during calving to 216 km in the winter (Table 8.5-1).

Table 8.5-1
Average distance of Beverly, Ahiak, and the Qamanirjuaq herds seasonal range based on satellite collar locations to the Project Regional Study Area, 1995–2007

Season	Distance to Kiggavik (km)		
	Beverly Herd	Qamanirjuaq Herd	Ahiak Herd
Calving	36	N/A	61.7
Post-calving	36	N/A	215.8
Summer	57	N/A	0
Northern Migration	59	N/A	93.6
Rut	152	N/A	0
Winter	275	N/A	121.1

N/A = not available

The Beverly Herd

Satellite-collared caribou data indicated the range of the Beverly herd extends from the boreal forests of Saskatchewan and Manitoba, across the subarctic taiga of the NT, to the Arctic tundra of west-central Nunavut (Figure 8.5-2). Wakelyn (1999a) stated that the Beverly herd historical range was approximately 600 km from east to west, ranging from Great Slave Lake, NT to just east of Dubawant Lake, Nunavut across the north and from Slave River, Alberta to Nueltin Lake, Manitoba across the south end of the range, covering approximately 1000 km from north to south. The estimated area of the annual home range (based on satellite-collared caribou data from 1995 to 2007 [Figure 8.5-2]) of the Beverly herd is 282,000 km^2.

The last population survey of the Beverly herd was completed in 1994, which estimated the number of caribou at 276,000 (ENR 2008, internet site). The population estimate obtained in 1994 is consistent with other data and indicates that the population of the Beverly herd had remained stable since 1984. In 1984 the herd size was about 264,000 animals (ENR 2008, internet site).

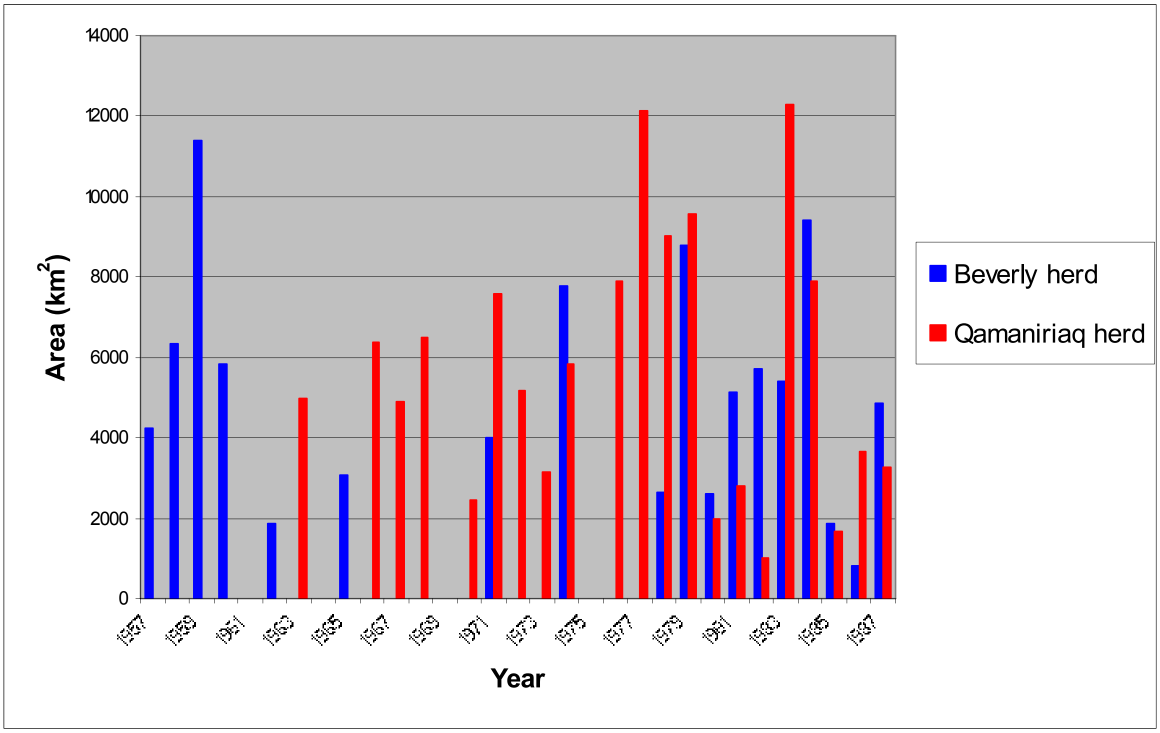
Figure 8.5-2 Annual and Seasonal Distribution of Satellite-Collared Caribou for the Beverly Herd 1995 to 2007

The Beverly herd range overlaps with the Bathurst caribou in the west, the Qamanirjuaq herd in the east, and the Ahiak herd to the north. Satellite-collared caribou data suggest that the Beverly herd remains inland year-round as they travel between their calving grounds northwest of Baker Lake to their winter range in north-central Canada (ENR 2008, internet site). BEAK (1990a) reported two traditional winter areas that the Beverly herd inhabits. The first is located south of Christie Bay, Great Slave Lake and the lower Taltson River valley as far east as Lake Nonacho, NT, and the second is located along the north shore of Lake Athabasca and south to Wollaston Lake, Saskatchewan. Satellite-collared caribou data from the Beverly herd during 1995 to 2007 indicate that the winter range of these animals is concentrated 275 km to the west of the Project area (Figure 8.5-2).

Traditionally, the Beverly herd calves northwest of the Project area, near Beverly Lake and the Thelon River system. From 1957 to 1987 these traditional calving grounds covered an area from 810 km^2 to 11,409 km^2 (Figure 8.5-3) (BEAK 1990). Wakelyn (1999a) reported that the Beverly herd used the southeast portion of these traditional grounds from 1957-1974, however, from 1980 to 1999, the northern portion was primarily used by the herd. Traditional calving areas for the Beverly herd (1986 to 1989) are shown in Figure 8.5-4. More recently, the Beverly calving ground has moved north, near Gary, Sand, and Deep Rose Lake in Nunavut (ENR 2008, internet site). Satellite-collared caribou data for the Beverly herd (1995 to 2007) indicate that the calving range of these animals is concentrated to the west of the Project area (Figure 8.5-2). The estimated average distance of the Beverly calving range to the Project area is approximately 36 km (Table 8.5-1).

Based on government surveys completed from 1948 through 1990, the Project area has historically been used by the Beverly herd during post-calving movements (Figure 8.6-5). Recent satellite-collared caribou data suggest that the average distance of the Beverly herd’s post-calving movement to the Project area is approximately 36 km (Figure 8.6-2).

Figure 8.5-3 Total Calving Ground Area Occupied by the Beverly and Qamanirjuaq Caribou Herds



Source: BEAK 1990a

Figure 8.5-4 Annual Calving Areas for the Beverley Caribou Herd (1986–1989)

Figure 8.5-5 Post-Calving Range for the Beverly and Qamanirjuaq Caribou Herds

The summer movements of the Beverly herd cover a large area and involve the aggregation of thousands of animals by mid-July (BQCMB 2007a). Based on government surveys completed from 1957 through 1981, the Project area has historically been used by the Beverly herd during summer movements (Figure 8.5-6). Both historical (1957 to 1983) and recent (1995 to 2007) fall migration locations for the Beverly herd indicate that the fall migration range of these animals is concentrated 152 km south and west of the Project area (Figure 8.5-7).

Water crossings play an important role in many periods of the annual cycle for caribou. For the Beverly heard, water crossings are frequent, as there are numerous waterbodies through their range, especially the winter range (BQCMB 2007a). During migration, caribou follow natural geographic features, which cause them to concentrate at traditional water crossings (William and Gunn 1982). The 1982 study listed the Beverly herd water crossings in descending order of current use frequency, as crossing numbers 22-26, 19-21, 27 and 13-18. Crossing sites are illustrated in Figure 8.5-8, with details and historical observations on each crossing found in Tables XI-1 and XI-2 (Appendix XI). BEAK (1990a) stated that crossings 17 and 18 at Aberdeen Lake, which are 40 km west of the proposed Project, were used heavily in the early 1900's, but that neither crossing had been used extensively since 1960. However, William and Gunn (1982) stated that crossing 17 is of high importance to the herd and is protected by Territorial Land Use Regulations under the Territorial Lands Act (BQCMB 2000; BQCMB 2007a).

At times, caribou will gather in large numbers for hours before they attempt a water crossing. Once a few animals have successfully made it across, the remainder of the herd are more likely to follow (BQCMB 2007a). If disturbed during this gathering time, the herd may disperse and move away from the crossing area. Hunters in the Baker Lake area are aware of this and will allow the caribou to make the water crossing before beginning their hunt (BQCMB 2007a).

The Qamanirjuaq Herd

BEAK (1990a) stated that the Qamanirjuaq herd range included southeast Kewaitin (now known as Kivalliq region of Nunavut), as far north as Chesterfield Inlet, northern Manitoba and northeast Saskatchewan. Wakelyn (1999a) also stated that their range was approximately 500 km from east to west, from the shores of Hudson Bay across the southern Kivillaq region, and approximately 1000 km north to south from north of Baker Lake, Nunavut to south of Brochet, Manitoba. However, the range use and movement patterns of the Qamanirjuaq herd are neither consistent nor predictable (Wakelyn 1999b).

Figure 8.5-6 Late Summer Range of the Beverly and Qamanirjuaq Caribou Herds

Figure 8.5-7 Range used by the Beverly and Qamanirjuaq Caribou Herds during Fall Migration and Rut (1957–1983)

Figure 8.5-8 Water and Ice Crossings used by the Beverly and Qamanirjuaq Caribou Herds in the Eastern Northwest Territories

The western boundary of the Qamanirjuaq herd range is not well defined, and there is a considerable overlap with the Beverly herd, especially in their winter range (BEAK 1990a). BEAK (1990a) reported two traditional winter areas that the herd inhabits, one at the very north end of their range, the other at the south. The northern area is located to the north and east of Baker Lake, Nunavut and the southern area is located in the Taiga regions of northern Manitoba and northeast Saskatchewan.

The traditional calving grounds for the Qamanirjuaq herd are located southeast of the Project area, near Qamanirjuaq Lake (Figure 8.5-9) (BEAK 1990b; BEAK 1990a; Wakelyn 1999b). BEAK (1990a) estimated the calving grounds ranged from 994 km^2 to 12,292 km^2 in size (Figure 8.5-3). Post-calving movements begin soon after calving occurs (late June to early July), and cows and calves begin moving to the northern edge of the calving grounds and gather south of Baker Lake and east of the Kazan River (BEAK 1990a). Based on government surveys completed from 1948 through 1990, the historical post-calving ground for the Qamanirjuaq herd, is southeast of the Project area (Figure 8.5-10).

The rut occurs in October, after fall migration takes the Qamanirjuaq herd to the area between Edehon and South Henik Lake (BEAK 1990a). Historical (1979, 1981, and 1985) locations for the Qamanirjuaq herd indicate that the fall migration range of these animals is concentrated to the south and east of the Project area (Figure 8.5-11).

For the Qamanirjuaq herd, summer dispersal water crossings occur at numerous major sites in the lower Kazan River between Thirty Mile Lake and Baker Lake. including crossings 9, 10, 105 and 106 (Figure 8.5-8) (Jakimchuk 1979). None of these crossings were rated by the BQCMB (Tables XI-1 and XI-2; Appendix XI). Crossings 9 and 10 are protected by Territorial Land Use Regulations under the Territorial Lands Act (BQCMB 2000; BQCMB 2007a); however, crossings 105 and 106 are not. During fall migration there is a major crossing (12) at the east end of Baker Lake in the area of Christopher and Bowell Islands for the portion of the herd that winters north of Baker Lake (Inter-Disciplinary Systems Ltd. 1978). This crossing is protected by Territorial Land Use Regulation, however, it has not yet been rated by the BQCMB (BQCMB 2000).

Figure 8.5-9 Annual Calving Areas for the Qamanirjuaq Caribou Herd (1963–1994)

Figure 8.5-10 Post Calving Range of the Qamanirjuaq Caribou Herd (1948–1990)

Figure 8.5-11 Range used during Fall Migration and Rut by Qamanirjuaq Caribou Herds (1979, 1981 and 1985)

The Ahiak Herd

Satellite-collared caribou data suggest that the Ahiak caribou herd (also known as the., Queen Maud herd) have a range from the Queen Maud Gulf to south of the Thelon Game Sanctuary, and as far west as Great Slave Lake (Figure 8.5-12). The Ahiak herd was estimated at 200,000 animals in 1996, and was the third largest barren-ground caribou herd in Nunavut and the NT at that time (ENR 2008, internet site). The estimated area of the annual home range (based on satellite-collared caribou data from 2001 to 2007) of the Ahiak herd is 345,000 km^2 (Figure 8.5-12).

Although satellite-collared caribou data indicated that the Ahiak caribou formed a discrete herd during calving and the rut, their range has been known to overlap with other caribou herds. In the past, the calving grounds overlapped with the traditional calving grounds of the Bathurst herd (ENR 2008, internet site); however, the current calving grounds of the two herds are separate. Satellite-collared caribou data collected from 1996 to the present confirmed that the Ahiak herd calving grounds are parallel to the coastline of the Queen Maud Gulf in Nunavut (Figure 8.5-12).

Post-calving and summer distributions are largely within the Queen Maud Gulf Migratory Bird Sanctuary (Figure 8.5-12). The fall and spring migration leads them through, and to the south of, the Thelon Game Sanctuary, extending their winter range into the NT. In most years the herd winters on the barrens, but satellite-collared caribou data revealed that, in some winters, the herd has moved into the boreal forests in the area northwest of the Saskatchewan border, to the north side of Great Slave Lake (ENR 2008, internet site). The Ahiak herds southern wintering ranges may overlap with the ranges of the Beverly and Bathurst herds, whereas their northern winter ranges overlap with the Dolphin and Union herd’s mainland winter ranges (ENR 2008, internet site).

8.5.2 Habitat Selection and Foraging

As barren-ground caribou move through their annual migration cycle, habitats and food sources are not predictable. The food and habitats available to the caribou can be altered by a combination of many factors, including weather (snow, wind, rain and temperature) and weather-related variables (timing of snow melt and plant growth), availability of forage, predator and insect avoidance and traditional range use and patterns can all play a part in determining the specific habitat and range used (BQCMB 1999).

Figure 8.5-12 Annual and Seasonal Distribution of Satellite-Collared Caribou for the Ahiak Herd 2001 to 2007

Lichens are the primary food source for the barren-ground caribou winter diet, although sedges and evergreens are also foraged (ENR 2008, internet site). In summer and late fall they feed on shrubs, grasses, lichens and mushrooms, and they gain weight relatively quickly. Females in particular need to gain enough weight to be able to breed during the rut (ENR 2008, internet site). The most heavily used winter vegetation communities in order of preference are lichen steppes, lichen heath tundra, dwarf shrub-lichen tundra, and dwarf shrub-sedge tundra (Thompson et al. 1978). With the increase in consumption of green vegetation in summer, forage preference is towards tussock tundra and dwarf shrub-lichen tundra communities (Thompson et al. 1978).

8.5.2.1 Historical Baseline Studies

The ecological studies carried out within these areas documented caribou use, and past caribou use (using fecal pellet counts) (BEAK 1990a). Caribou observation surveys from 1978-1980 are summarized in Table 8.5-2 and Table 8.5-3. The data summarized in the tables represent the numbers of caribou observed within a 15 km radius of each study area (BEAK 1990a). Caribou use within each area was estimated using a pellet-group counting technique. At the time of the study, this method was used extensively for estimating numbers and distribution of big game animals and for defining habitat preference (BEAK 1990a). Mean weekly caribou use within each study area and total caribou days were greater in the Sissons Lake area in 1980 than in 1979, but similar to 1978 (Table 8.5-2). There were higher numbers of caribou at Schultz Lake in 1980 than in the previous years, and Marjorie Lake sightings were down slightly in 1980 from 1979 (BEAK 1990a).

According to the pellet-group counts listed in Table 8.5-3, the Sissons Lake area had greater caribou use than the other study areas in all three years. This area has an escarpment with late-lying snow beds and an upland exposed position, both of which act to reduce insect harassment (BEAK 1990a). Also, the extensive wetlands in the area provide a good food source in the sedge meadows. These data may also reflect elevated caribou use due to a group of bulls in the Sissons Study area that followed the Urangesellschaft Canada Limited biologists during the sampling periods (BEAK 1990a).

Table 8.5-2
Summary of Caribou Observations in the Project Area, 1978 to 1980

Location	Number of Weeks[(a)]	Mean Weekly[(b)] Caribou Use ±.1 S.D.	Total Caribou Days[(c)]	Male: Female[(d)]
1978				
Sissons Lake	13	8.5±13.5	110	12:1
Schultz Lake	11	3.8±17.9	42	9:1
Sandhills	9	32.9±41.4	296	1:9.8
1979				
Sissons Lake	11	3.8±3.8	42	14:1
Schultz Lake	10	4.2±5.5	52	1:1.6
Sandhills	10	952.3±716.9	10,000**	1:24
Marjorie Lake	11	17.0±23.8	187	32:1
1980				
Sissons Lake	12	8.6±	103	8:1
Schultz Lake	9	16.8±	151	1.3:1
Marjorie Lake	12	14.6±	175	4.3:1

Source: BEAK (1990a)

S.D. = standard deviation

a = Number of weeks = the number of weeks observations were recorded

b = Mean weekly use = estimated using fecal pellet counts

c = Total Caribou Days = total number of days caribou were observed
This information is useful as an index of usage, not absolute numbers of caribou.

d = Ratio refers only to adult animals. Solitary yearlings and calves, unsexed animals and groups of caribou are not included in this ratio.

Table 8.5-3
Summary of Caribou Pellet Counts and the Resulting Caribou Day Estimates

Location	Total Area Sampled (m^2)	Number of Transects	Pellet Groups/ Hectare[(a)]	Estimated Caribou Days[(b)]	
				5	8
1978 Data[(c)]					
Sissons Lake	19,026	9	57.71±43.45	0.37±	0.23±
Schultz Lake (crossing peninsula)	121,980	9	6.72±4.17	0.04±	0.03±
1979 Data[(c)]					
Sandhills	36,800	14	28.8±20.1	0.18±	0.12±
Sissons Lake	4,000	4	120.5±67.5	1.16±	0.48±
Marjorie Lake	28,800	18	8.7±6.1	0.05±	0.03±
Schultz Lake (total)	36,910	20	45.7±?		
(north of crossing Shultz Lake Island crossing peninsula)	13,600 3,810 19,500	8 8 4	12.5±19.4 30.1±35.4 3.1±1.7	0.08± 0.19± 0.02±	0.05± 0.12± 0.01
1980 Data					
Sissons Lake	123,010	15	16.4±13.0	0.11±	0.07±
Marjorie Lake	87,748	16	6.7±5.3	0.04±	0.03±
Schultz Lake	64,200	9	9.27±6.0	0.06±	0.04±

Source: BEAK (1990a)
m^2 = square metres
a = Mean estimate of pellet groups present on claim area per hectare ± S.D.
b = Estimated caribou days per year per hectare when pellet group durability is five and eight years.
c = 1979 and 1978 caribou day calculations have been corrected from the original calculation where one pellet group was considered to equal one defecation, rather than 2.6 groups per defecation.

8.5.2.2 2007 Baseline Surveys

On August 26, 2007 a systematic aerial survey was flown by Golder Associates Ltd. (Golder) to determine the number, distribution, and group composition of caribou and muskoxen in the RSA. The survey was conducted on 11 transect lines flown in a north-south direction following a predetermined flight path using global positioning system (GPS) co-ordinates (Figure 8.5-13). Transects 1 and 2, and 10 and 11 are spaced 8 km apart, whereas the remaining transects are separated by a distance of 6 km. The survey was designed to provide good coverage of the main RSA, while maintaining data quality by limiting observer fatigue. An important aspect of the survey design was to capture the natural variation in movement and abundance (frequency of use) of caribou along the Thelon River basin (i.e., crossings at Aberdeen and Schultz Lakes) as they enter the RSA during the post-calving migration.

All caribou and muskoxen within 600 m of either side of the helicopter were counted, amounting to approximately 15% coverage of the RSA. The survey was conducted by helicopter at 150 m above ground level (agl), moving at a speed of 130 km to 150 km per hour (km/hour). The GPS location of caribou and muskoxen groups, group size, group composition, dominant behaviour, and habitat type were recorded. The composition of the groups was classified as nursery (groups with calves) or non-nursery (groups without calves). Dominant behaviour was classified as feeding, bedded, standing, walking, trotting, or running. Incidental observations of all wildlife, including grizzly bears and bear dens, wolves and wolf dens, wolverines, raptors and raptor nests, and groups of caribou off-transect or out of the survey block were also recorded during the aerial survey. Detailed results of the survey are presented in Appendix XI.

Twenty-four groups of caribou, totalling 37 individuals, were observed in the RSA during the survey (Figure 8.5-13). Group size ranged from one to eight animals, and 23 of the 24 groups did not contain calves (i.e., non-nursing). The majority of the caribou observed were found in heath tundra habitat (46%), and were observed to be either standing (8%), feeding (71%), or walking (17%). Caribou were also frequently found in tussock hummock (21%) and sedge wetland (17%) habitats.

As part of the monitoring program, independent wildlife monitors completed aerial and ground-based caribou surveys to determine the presence of caribou near exploration activities for the Project. Daily and weekly aerial surveys were completed within the Project area from July to September, 2007. Daily, high-level (greater than 300 m agl) reconnaissance surveys were completed in June and July to determine the presence of wildlife within 3.5 km of drilling activities. For the remainder of the field season, daily reconnaissance surveys were conducted during regular air transport of field personnel.

Weekly aerial surveys were flown by helicopter to determine the number, distribution, and group composition of caribou and muskoxen within the Project area. Surveys were completed within two survey blocks (20 km by 20 km) centered on the Kiggavik Lease and Sissons Lease (Figure 8.5-14). To limit the disturbance from aircraft on caribou, surveys were only completed in the block containing drilling operations (i.e., only one block was surveyed at any one time). From July to September, a total of eight surveys were completed, which were typically flown at 150 m agl. Five of these surveys were flown in a north-south direction following a predetermined flight path using GPS co-ordinates (i.e., systematic survey), whereas the remaining three surveys were flown in a circular pattern within the survey block (i.e., non-systematic survey).

Figure 8.5-13 Observations of Caribou and Muskoxen During the 2007 Aerial Survey within the Regional Study Area

Figure 8.5-14 Aerial Survey Blocks for Weekly Caribou Monitoring, 2007

All caribou and muskoxen within 600 m of either side of the helicopter were counted and the GPS location of groups, group size, group composition, dominant behaviour of the group, and habitat type were recorded. Incidental observations of all wildlife, and groups of caribou and muskoxen off-transect or out of the survey block were also recorded during each aerial survey. Weekly aerial survey results for the five systematic surveys are presented in Table XI-5 in Appendix XI. Because weekly surveys completed on July 21, July 27, September 9, 2007 were completed in a non-systematic manner (i.e., circular pattern), the results are considered as incidental observations (Table XI-5; Appendix XI).

Nineteen groups of caribou, totalling 66 individuals, were observed during the weekly surveys (Table XI-5; Appendix XI). Group size ranged from one to nine, and 18 of the 19 groups did not contain calves (i.e., non-nursing). Where it was recorded, the majority (67%) of the caribou observed were either standing, feeding or resting, whereas 33% were moving (i.e., walking, trotting or running).

Ground-based monitoring completed by the independent wildlife monitors recorded the presence of caribou in the vicinity of the camp and drilling operations from June to September, 2007. These incidental observations provided information regarding the location of individuals or groups, group size, group composition, and dominant behaviour. A log of wildlife observed within the RSA was also maintained by AREVA staff and contractors. Incidents are defined as any wildlife interaction that requires a response by Project personnel, and may include simple deterrent measures, to the injury or death of an animal. In 2007, there were no wildlife incidents associated with the Project.

A total of 213 incidental observations were recorded from June to September, 2007. This includes incidental observations from systematic and non-systematic aerial surveys, ground-based monitoring, as well as those documented in the camp logbook. During this time there were many sightings of caribou, muskoxen, wolves, foxes, waterfowl, and upland birds. Of these observations, 115 were caribou groupings. Caribou group size ranged from 1 to 275, and 87% of the groups were non-nursing.

8.6 Barren Ground Grizzly Bear

8.6.1 Population and Distribution

Barren-ground grizzly bears (*Ursus arctos*) inhabit all but the south-western tip of mainland Nunavut, including the Project area (GN 2007, internet site). The barren-ground grizzly bear is currently listed as “sensitive” in Nunavut (GN 2000), and is listed federally as a species “of special concern” due to the risk posed to its habitat by expanding industrial, residential and recreational developments (COSEWIC 2007). This species currently has no status under the SARA (SARA 2007, internet site). EC (EC 2007, internet site) estimates the grizzly population in Nunavut to be between 800 and 2,000 bears.

Barren-ground grizzly bears are solitary animals and require large home range areas (GN 2007, internet site; Threader and Wilcox 1991). The typical ranges of individual males and females are approximately 7,000 km^2 and 2,000 km^2, respectively (Nunavut Planning Commission [NPC] 2004). Barren-ground grizzly bears spend approximately seven months of the year in hibernation in dens. Denning usually coincides with the first inclement weather of the winter (ENR 2008, internet site). Females generally enter dens earlier than males, and pregnant females may den as early as late September (ENR 2008, internet site). Breeding occurs in late spring to early summer, with cubs being born in January or February during the denning period. The average female bear in Nunavut does not commence breeding until eight years of age, has a litter every three years, and has a life expectancy of 25 years (GN 2007, internet site). Due to late age of maturity, low productivity rates, and long interbirth intervals, grizzly bears maintain very low rates of population growth (McLoughlin et al. 2003). Due to these life history traits, barren-ground grizzly populations are not resilient to disturbance. Additive mortalities from over-harvesting or nuisance kills associated with increased development have the potential to cause population declines (McLoughlin et al. 2003; GN 2007, internet site; ENR 2008, internet site).

Although no direct studies were performed during previous baseline studies, grizzly bears were observed within the vicinity of the Project in 1979 and 1991 (BEAK 1992; GIL 1991), sign of a sow and a cub was observed by “Operation Raleigh Arctic Expedition” (BEAK 1992).

Although no formal surveys were completed for grizzly bears during the 2007 baseline studies, grizzly bears and bear signs were observed incidentally on eight occasions. These observations included sightings of four bears, as well as tracks, digs for arctic ground squirrels (sik-siks), willow chews and one inactive den site (Table XI-6; Appendix XI).

8.6.2 Habitat Selection and Foraging

Barren-ground grizzly bears are omnivores and their main diet consists of roots, horsetail, sedge, arctic cotton grass and various berries, as well as small mammal species, such as ground squirrels, lemmings and voles (GN 2007, internet site; Threader and Wilcox 1991; BEAK 1992). Bears are opportunistic hunters, and will kill large mammal prey, such as caribou or muskoxen, as the opportunity arises (ENR 2008, internet site). Recent studies in the central Canadian Arctic have found that barren-ground grizzly bears are more reliant on caribou in spring and fall than previously thought, but that green vegetation and berries were also important throughout the summer (Gau et al. 2002).

The habitat that the barren-ground grizzly bear occupies changes seasonally. Because their diet consists primarily of a variety of plants, their habitat and movements are largely dependent on the local plant community available at the time (EC 2007, internet site). The preferred home-range of grizzly bears contains eskers, tundra, and areas rich in lichen (NPS 2004). The primary sites for denning are locations with soil soft enough for digging, but not prone to slumping (ENR 2008, internet site).

Grizzly bears are sensitive to the disturbance and habitat loss that can be associated with industrial development and human activity (EC 2007; ENR 2008, internet site). Bears will avoid these areas, including a buffer zone, which can force them into less productive habitat, affecting their survival, as well as reproduction rates (ENR 2008, internet site).

Alternatively, bears, as opportunistic omnivores can be attracted to sites with human development and activity if a potential food source exists (e.g., garbage) (Johnson et al. 2005). Bears that interact with humans can become habituated, pose a threat to human safety and are often destroyed. These deaths, additive to natural mortality levels, can cause severe impacts to bear populations which are already naturally low (COSEWIC 2002).

8.7 Wolf

8.7.1 Population and Distribution

Grey wolves (*Canis lupus*) are found throughout Nunavut, including the Project area, and populations are considered to be “sensitive” in Nunavut (GN 2000). Federally, the grey wolf is considered ‘not at risk’ (COSEWIC 2007), and is not listed under SARA (SARA 2007, internet site).

As predators of migratory caribou, wolves in the arctic have larger home ranges and less territorial behaviour than other wolf populations of North America (ENR 2008, internet site). Wolf ranges may closely resemble that of the caribou herds they prey upon, and vary with pack size. Range sizes in Alaska have varied from 100 km^2 to 12,000 km^2 (ENR 2008, internet site). At the local scale, wolves select areas with suitable den habitat, such as eskers, creeks and riverbanks (ENR 2008, internet site). Wolves restrict movements to smaller summer ranges, near the den site after the pups arrive, until the pups can travel with the adults in the fall.

Direct studies of wolves were not performed during the previous baseline studies; however, wolves were observed within the vicinity of the Project during field surveys in 1979, and spring and winter surveys in 1991 (BEAK 1990a; BEAK 1991; GIL 1991).

Although no formal surveys were completed for wolves during the 2007 baseline studies, wolves and wolf signs were observed incidentally in the RSA. Three wolves were observed in the RSA, one feeding on a caribou kill and two travelling. Also, one active den site was documented, as well as one inactive and one temporary den site (Table XI-6; Appendix XI).

8.7.2 Habitat Selection and Foraging

The grey wolf is an opportunistic hunter, primarily targeting weak, young, or old animals. However, wolves are capable of bringing down healthy prey. The main diet of wolves in Nunavut consists of caribou, although muskoxen are also hunted by wolves when available (GN 2007; ENR 2008, internet site). Depending on the area and season, a wolf's diet may also include Arctic hare, Arctic fox, Arctic ground squirrel, lemmings, voles, ptarmigan, and waterbirds and their eggs (ENR 2008, internet site).

Although considered a habitat generalist, wolves in the tundra appear to select habitat based on the availability of food resources and den site locations. Wolves that den on the tundra are thought to do so almost exclusively in eskers, creeks and riverbanks because of the ease of digging and lack of permafrost (ENR 2008, internet site). Active wolf dens may be located in slightly raised and well-drained mounds of sand and gravel that can serve as a lookout (ENR 2008, internet site).

8.8 Arctic Fox

8.8.1 Population and Distribution

The Arctic fox (*Alopex lagopus*) is found throughout Nunavut, including in the Project area. The Arctic fox is currently listed as secure within Nunavut (GN 2001), and is not listed federally under COSEWIC (2007, internet site) or SARA (2007, internet site). No discrete population estimates are available. Although harvest rates have diminished in recent years, they are still a highly sought-after fur-bearing species. Fox are harvested by both Aboriginals and local residents, and are a valuable subsistence and non-traditional resource in Nunavut (GN 2007).

Arctic fox live in dens, with a home range size that varies between 16 km^2 and 25 km^2 (GN 2007; ENR 2008, internet site). Fox populations in northern tundra environments fluctuate in response to the three to four year cycle in lemming populations (ENR 2007, internet site). In the year following a crash in the lemming population, the survival rate of fox kits is reduced drastically, and a large number of adult foxes will starve and may not breed the following spring (ENR 2007, internet site).

Although no direct studies were performed during the previous baseline studies, Arctic fox were observed within the vicinity of the Project during field surveys in 1979, and spring and winter surveys in 1991 (BEAK 1990a; BEAK 1991; GIL 1991). During the 2007 baseline studies, one incidental observation of an Arctic fox was recorded in the RSA (Table XI-6; Appendix XI).

8.8.2 Habitat Selection and Foraging

Arctic fox feed primarily on lemmings and voles throughout the winter, although they will consume birds, squirrels, hares, and caribou (when available) (ENR 2008, internet site). In the summer, this diet is supplemented with squirrels, hares, eggs, fish, flightless geese and ducks (ENR 2008, internet site). During this time of abundant supply, foxes will cache any food surplus in their dens (ENR 2008, internet site).

Fox dens are most often found in gently sloping, sandy soil near rivers or lakes or on elevated areas free of permafrost (GN 2007; ENR 2008, internet site). They consist of complex tunnels, and have numerous entrances (ENR 2008, internet site). Optimal den sites are not easily found. As a result, when a good one is found it is used for successive years and becomes more complex with time (ENR 2008, internet site).

8.9 Wolverine

8.9.1 Population and Distribution

The wolverine (*Gulo gulo*) is the largest member of the weasel family, and is found throughout Nunavut, including the Project area. The wolverine is currently listed as sensitive within Nunavut (GN 2001), and is listed federally by COSEWIC (2007) as a species “of special concern” due to habitat fragmentation caused by expanding industrial, residential and recreational developments, and decreasing populations, with no decrease in harvest levels (COSEWIC 2007). The species currently has no status under the SARA (SARA 2007, internet site). Although no discrete population estimates are available, population are monitored through local knowledge and harvest monitoring programs (COSEWIC 2007; GN 2007, internet site).

Male wolverines have much larger home ranges than females (ENR 2008, internet site). Males occupy territories from about 230 km^2 to 1,580 km^2, and females from about 50 km^2 to 400 km^2 (Mulders 2000; SARA 2007, internet site). Long-range movements usually occur during dispersal, and juvenile wolverines can travel over 200 km (SARA 2007, internet site). The kits are born in March and April and juveniles disperse sometime after their first winter (reports vary from dispersing in the spring through to fall) (SARA 2007; GN 2007, internet site).

No focused studies for wolverine were performed in the RSA during the initial EA process, and no wolverine were observed during the 2007 baseline studies. However, harvest estimates indicate that an average of 12 wolverine (1996 to 2001) were trapped annually in the Baker Lake area (Nunavut Wildlife Management Board 2004).

8.9.2 Habitat Selection and Foraging

Wolverines are omnivores and scavengers, as well as predators. They are opportunistic hunters and their main diet consists of fresh or scavenged caribou, muskox, Arctic ground squirrel and various roots and berries (Pasitschniak-Arts and Lariviere 1995; COSEWIC 2003; SARA 2007, internet site). Wolverines have been found to be particularly dependant on caribou, which accounts for more than 50% of their diet (Mulders 2000).

Wolverines require large undisturbed areas to maintain viable populations due to a low reproductive rate, low population density, and large home range (SARA 2007, internet site). Wolverines occur more frequently where large ungulates are common and where carrion is abundant from hunter kills, predation, and natural mortality (COSEWIC 2003).

8.10 Muskoxen

8.10.1 Population and Distribution

The Project falls within the southern limits of the muskoxen (*Ovibos moschatus*) range. The muskoxen is currently listed as ‘secure’ in Nunavut (GN 2001), and is not listed federally (COSEWIC 2007).

Muskoxen live in loosely organized herds, with the herd size and composition varying with season, range conditions and the number of bulls in the population (ENR 2008, internet site). The average herd consists of approximately 15 animals, with one dominant bull (ENR 2008, internet site). In summer months, the herds increase in size as smaller herds join together (ENR 2008, internet site). This aggregating behaviour can be the result of harassment by wolves. Some groups join together to feed, but during severe winters when food is scarce, herds may fragment in search of forage (ENR 2008, internet site).

Muskoxen do no carry out long migrations like caribou, although there are some herds that have defined summer and winter grounds as far as 160 km apart (ENR 2008, internet site). Calving occurs from late April to early May (ENR 2008, internet site). Both males and females gain weight rapidly after new plant growth emerges during the summer. The rut occurs in July and August, and reaches its peak in late August (ENR 2008, internet site).

Although no formal studies for muskoxen were performed during the initial baseline studies, muskoxen were observed within the vicinity of the Project during field surveys in 1979, 1989, 1990 and 1991 (BEAK 1992; GIL 1991). An additional 25 herd sightings were observed by "Operation Raleigh Arctic Expedition", with 20% of the animals recorded being calves (BEAK 1992). BEAK (1992a) stated that an unstratified muskoxen survey in the vicinity of Baker Lake by Case and Graf (1986) indicated a density of 0.06 animals per km^2. Gunn et al. (1984) noted that there were no significant land features to hinder their continued expansion eastward from the Thelon Game Sanctuary, where the majority of the muskoxen were located in 1980. Ecometrix Inc. (2006) stated that muskoxen appear to be abundant in the local and regional environment around the Project area.

8.10.1.1 2007 Muskoxen Surveys

On August 26, 2007 a systematic aerial survey was flown to determine the number, distribution, and group composition of caribou and muskoxen in the RSA (refer to Section 8.2.3.2 for details on methods). During the systemic aerial survey, ten groups of muskoxen, totalling 130 individuals, were documented (Figure 8.5-13; Table XI-4; Appendix XI). Group size ranged from 1 to 28 individuals, and 25% contained calves. Similar to caribou, the majority (90%) of muskoxen groups were feeding or standing in heath tundra (44%) and tussock hummock (31%) habitats.

During the weekly and daily surveys in 2007, ten groups of muskoxen, totalling 54 individuals were documented (Table XI-5; Appendix XI). Group size ranged from 1 to 28 individuals, and 20% contained calves. Similar to caribou, the majority (90%) of muskoxen groups were feeding, standing, or resting. Incidental observations of muskoxen represented 26% of the total incidental observations recorded (Table XI-6; Appendix XI). Group size ranged from 1 to 50, and approximately 31% of the groups contained calves.

8.10.2 Habitat Selection and Foraging

Muskoxen are herbivores and their main diet consists of willows, sedges, grasses, rushes, horsetails, forbs, and seeds (GN 2007, internet site; BEAK 1992). In the winter, muskoxen prefer browse such as heath, willow and birch (Banfield 1974). Muskoxen habitat consists primarily of barren tundra, and can be found in river valleys, lake shores and seepage meadows in the summer months (GN 2007, internet site; Banfield 1974). In winter, muskoxen can be found on hill tops, slopes and plateaus, where vegetation can be exposed by wind (GN 2007, internet site).

8.11 Upland Breeding Birds

8.11.1 Population Status and Distribution

Upland breeding birds (i.e., passerines, ptarmigan, and upland breeding shorebirds) are commonly used in baseline and monitoring programs because they represent an abundant and diverse group of species that are relatively easy to observe and monitor. During the initial baseline studies (1979 and 1980) bird population surveys were carried out in the Project area, as well as in the Schultz Lake, Marjorie Lake and the Sandhills areas (BEAK 1990a).

A total of 29 species of songbirds, shorebirds, and ptarmigan were detected along the survey transect through the Project area during the 1979 and 1980 studies (BEAK 1990a) (Table 8.11-1). The mean breeding bird density per km of transect was 2.8 birds or 47.2 birds per 100 ha (BEAK 1990a). Of the ten most commonly occurring species in the Project area, seven were upland birds including the Lapland longspur (*Calcarius lapponicus)*, ptarmigan (*Lagopus sp.*), horned lark (*Eremophila alpestris)*, dunlin (*Calidris alpine)*, golden plover (*Pluvialis dominica)*, Baird's sandpiper (*Calidris bairdii*), and sandhill crane (*Grus canadensis*) (BEAK 1990a; BEAK 1990c).

In the Shultz Lake area, the transect began in a low area of sedge meadow near several ponds, continued through drier upland of lichen-heath, dwarf shrub-heath and dwarf shrub-sedge to the lake shore, then continued along the shoreline (BEAK 1990a). Observations on this transect were replicated three times. A total of ten species were observed during the 1979 and 1980 studies, however, only three species were recorded on-transect (BEAK 1990a). Species recorded were the Pacific loon (*Gavia pacifica*), Lapland longspur and least sandpiper (*Calidris minutilla)* (BEAK 1990a). The mean breeding density was 1.2 birds per km or 20.8 birds per 100 ha (BEAK 1990a).

Table 8.11-1
Summary of Birds Observed Along Survey Transects During the 1979 and 1980 Studies

Common Name	Scientific Name	1980		1979	
		On Transect	Off Transect	On Transect	Off Transect
Pacific loon	*Gavia pacifica*	-	√	√	-
Snow goose	*Chen caerulescens*	-	-	√	-
Canada goose	*Branta Canadensis*	-	√	√	√
Greater scaup	*Aythya marila*	-	√	-	-
Long-tailed duck (Oldsquaw)	*Clangula hyemalis*	√	√	√	√
Rough-legged hawk	*Buteo lagopus*	√	√	√	√
Gyrfalcon	*Falco rusticolous*				
Peregrine falcon	*Falco peregrinus*	√	√		
Willow ptarmigan	*Lagopus lagopus*	-	-	√	-
Rock ptarmigan	*Lagopus mutus*	√	√	-	-
Sandhill crane	*Grus canadensis*	√	√	√	√
Black-bellied plover	*Pluvialis squatarola*	√	-		
Golden plover	*Pluvialis dominica*	√	√	√	√
Least sandpiper	*Calidris minutilla*	-	-	√	-
Baird's sandpiper	*Calidris bairdii*	√	-	-	-
Pectoral sandpiper	*Calidris melanotos*	√	-	-	√
Dunlin	*Calidris alpine*	√	-	-	-
Parasitic jaeger	*Stercorarius parasiticus*	√	√	-	-
Long-tailed jaeger	*Stereorarius longicandus*	√	√	√	√
Herring gull	*Larus argentatus*				
Glacous gull	*Larus hyperboreus*	-	-	√	√
Arctic tern	*Sterna paradisaes*	-	-	-	-
Snowy owl	*Nyctea scandiaca*	-	-	-	√
Short-eared owl	*Asio flammeus*	-	√	-	-
Horned lark	*Eremophila alpestris*	√	√	√	√
(American) water pipit	*Anthus spinoletta*	√	√	√	√
(American) tree sparrow	*Spizella arborea*			√	-
Savannah sparrow	*Passerculus sandwichensis*	√	-	√	√
Lapland longspur	*Calcarius lapponicus*	√	√	√	√
(Common) redpoll	*Carduelis flammea*	√	-		

Source: BEAK 1990a; BEAK 1990c

The transect in the Marjorie Lake area passed over areas of rocky outcrops that rose above surrounding lichen heath, dwarf shrub heath, dwarf shrub-sedge, and tussock communities (BEAK 1990a). Twelve bird species were observed, and all occurred within the actual transect (BEAK 1990a). The mean breeding density per km was 2.8 birds or 45.8 birds per 100 ha for the 1979 and 1980 studies (BEAK 1990a).

In the Sandhills area, two transects were established (BEAK 1990a). One transect passed through flat terrain covered in lichen, heath, dwarf shrub n the dry areas and tussocks in the wet areas (BEAK 1990a). The second transect passed through gently rolling land, consisting of predominantly dry uplands (BEAK 1990a). Sedge-heath communities around frost boils and large patches of *Dryas saxifraga* covered the rest of the uplands, with tussocks and sedge meadows covering the lower wet areas (BEAK 1990a). On the second transect, nine bird species were observed, and eight species occurred on-transect (BEAK 1990a). The mean breeding density per km during the 1979 and 1980 studies was 3.0 birds, or 50 birds per 100 ha, with the Lapland longspur being the most common breeding species (BEAK 1990a). The mean breeding density per km on the first transect was 2.1 birds and 35.4 birds per 100 ha (BEAK 1990a).

McLaren and Holdsworth (1978) studied the Baker Lake area in 1977 and found that the lake was a focal point for shorebirds breeding in the area. Dunlin, stilt sandpiper, semipalmated sandpiper and red-necked phalarope all nest in the Piz-Baker lowlands in small numbers (McLaren and Holdsworth 1978). The American golden plover has been observed nesting near the community of Baker Lake, and has also been seen in suitable nesting habitat (open, dry tundra) along the southeast shore of Baker Lake (McLaren and Holdsworth 1978).

8.12 Waterbirds

8.12.1 Population Status and Distribution

Waterbirds are species of birds that are ecologically dependent on wetlands for at least part of their annual cycle, and include loons, grebes, geese, ducks, gulls and terns. Waterbirds observed during the 1979 and 1980 breeding bird transects included the Pacific loon (Gavia pacifica), Canada goose (*Branta Canadensis)*, snow goose (*Chen caerulescens*), long-tailed duck (*Clangula hyemalis*), greater scaup (*Aythya marila*), herring gull (*Larus argentatus*), glacous gull (*Larus hyperboreus*) and Arctic tern (*Sterna paradisaes*) (Table 8.11-1). The long-tailed duck and the Canada goose were the most common species observed (BEAK 1990a).

8.12.1.1 Regional Bird Communities

Chesterfield Inlet

Four aerial, fixed-wing surveys were completed along the coasts of Chesterfield Inlet between July 28, 1977 and September 11, 1977 (BEAK 1990a). These surveys were discussed in the original EA, as there was potential for the waterfowl populations to be impacted by mining activities at the Project (BEAK 1990c). The survey route was from Finger Point, near the town of Chesterfield Inlet, along the south coast of the inlet to Cross Bay (BEAK 1990a). On average, 87% of the total birds seen were waterbirds, with the remainder being shorebird species (BEAK 1990a). The total average bird density for the four surveys was 11.4 birds/km^2 (BEAK 1990a). The most common species observed was the long-tailed duck, although, large numbers of Canada geese were observed in late August (BEAK 1990a).

Waterfowl that nested along and in the vicinity of the shoreline of Chesterfield Inlet included the Pacific loon, tundra swan (*Cygnus columbianus*), Canada goose, northern pintail (*Anas acuta*), long-tailed duck, common eider (*Somateria mollissima*) and king eider (*Somateria spectabilis*) (Savile 1951). These species are known to begin nesting almost immediately upon their arrival to the inlet (Savile 1951). Spring thaw and fall freeze-up determine the times that Chesterfield Inlet can be used by waterfowl, confining its use to early June through late August (Hohn 1968; Savile 1951; Sutton 1931). The southern shore of the inlet was used as the main breeding range for the king eider in the region (McLaren et. al 1976). McLaren et al. (1976) considered Chesterfield Inlet to be the most important moulting and staging area for long-tailed ducks in the southern Keewatin District (now known as the Kivaliq Region). Chesterfield Inlet was also used by post-breeding waterfowl for moulting, and migrants use the inlet as a staging area (McLaren et al. 1976).

Baker Lake

Baker Lake is located approximately 80 km east of the Project and is approximately 1,887 km^2 in area. The Pitz-Baker lowlands extend southwest from Baker Lake towards Pitz Lake. This area was noted by McLaren and Holdsworth (1978) to be important to migratory and nesting birds. The shoreline of Baker Lake is an important summering area for several waterbirds. Nests of tundra swan, Canada geese, snow geese and sandhill cranes have all been found within 200 m of the shoreline (BEAK 1990a).

A literature review performed by GIL (1990) identified the south shore of Baker Lake to be more important to birds than its north shore. In particular, the southwest shore between the Thelon and Kazan rivers was found to support the highest densities of breeding birds and migrants of any other section of Baker Lake's shoreline (McLaren and Holdsworth 1978). Species nesting in this region of Baker Lake included the tundra swan, Canada goose and snow goose, as well as other waterfowl, including the Pacific loon, red-throated loon (*Gavia stellata*), northern pintail, long-tailed duck, red-breasted merganser (*Mergus serrator*), sandhill cranes, and shorebirds (GIL 1990). However, both GIL (1990) and BEAK (1992b) stated that information regarding the birds of Baker Lake was extremely limited. Recognizing this, the following relies heavily on data obtained during the Polar Gas Project by McLaren and Holdsworth (1978).

The red-throated loon was the most frequently recorded loon on Baker Lake (McLaren and Holdsworth 1978). The Pacific loon was relatively uncommon on the lake; however, small numbers were seen in the summer near the north and southwest shores (McLaren et al. 1976; McLaren and Holdsworth 1978).

Tundra swans breeding at Baker Lake are at the extreme southern limit of their breeding range. In 1977 McLaren and Holdsworth (1978) observed two nests and 52 birds between June 30 and July 5 along the shore of Baker Lake, as well as in the Pitz-Baker lowlands. The tundra swan is also known to stage along the shores of Baker Lake and on September 11, 1977, 77 tundra swans were observed (McLaren and Holdsworth 1978).

The Canada geese that occur in the Baker Lake area are comprised of two distinct groups, the nesting population and the staging population (McLaren and Holdsworth 1978). The nesting population is comprised of two of the smaller subspecies, *hutchinsii* (now known as the cackling goose [*Branta hutchinsii hutchinsii*]) and *parvipes*. The staging population is comprised of three of the larger bodied subspecies, *interior*, *maxima* and *moffiti*. McLaren and Holdswoth (1978) noted that few Canada geese moult on Baker Lake (McLaren and Holdsworth 1978). The highest densities of staging Canada geese were observed at the east end of Baker Lake, along the southwest shore (BEAK 1992).

Snow goose colonies are found at the mouth of the Kazan River, and in a bay along the Aniguq River, along the southwest shore of Baker Lake (BEAK 1992). Isolated nests have been found scattered along this portion of the shoreline (McLaren and Holdsworth 1978). Snow geese are known to stage along the shores of Baker Lake, generally leaving the Lake by mid September (BEAK 1992). The number of snow geese using the Lake as a staging area varies widely year to year, which McLaren and Holdsworth (1978) suggest reflects reproductive success achieved further north.

Most ducks occur on Baker Lake in small numbers (BEAK 1992). In general, they arrive in mid June and begin departing in late August or early September (BEAK 1992).

The long-tailed duck is the most common and widespread duck in the vicinity of Baker Lake (BEAK 1992). The local centre of abundance is the Pitz-Baker lowlands, especially south of the Aniguq River (BEAK 1992). Males moult in areas distant from Baker Lake, while the females and young remain in the vicinity of their nesting grounds (McLaren and

Holdsworth 1978). A few groups of long-tailed ducks have been observed on Baker Lake itself (McLaren and Holdsworth 1978).

Northern pintails are rare breeders in the Pitz-Baker lowlands, and most of the birds seen were most likely non-breeding moulting males (BEAK 1992). The greater scaup was also uncommon in the area (BEAK 1992). All of the 19 species observed during the 1977 survey were seen along the southwest shore of Baker Lake or in ponds south and southwest of the lake (McLaren and Holdsworth 1978). No evidence of nesting was found by McLaren and Holdsworth (1978). The red-breasted merganser was found scattered along the shores of Baker Lake in 1977 (McLaren and Holdsworth 1978). Once again, no evidence of nesting was obtained; however, most birds seen were in pairs, suggesting that nesting was most likely occurring in the area (McLaren and Holdsworth 1978).

Other species of ducks that have been observed in small numbers on Baker Lake, include the mallard (*Anas platyrhynchos*), green-winged teal (*Anas crecca*), king eider and the white-winged scoter (*Melanitta deglandi*) (BEAK 1992). McLaren and Holdsworth (1978) found no evidence that any of these species were breeding in the area, and that they were most likely non-nesting wanderers or groups of moulting males.

The herring gull was a common and widespread breeder in the Pitz Lake and Baker Lake area (BEAK 1992). In 1975, 0.9 birds/mi^2 were recorded along the north shore of Baker Lake and 1.6 birds/mi^2 were recorded along the south shore during the same period (McLaren et al. 1976).

The Arctic tern has been recorded in small numbers in the summer along the shores of Baker Lake. BEAK (1992b) stated that it probably nested in the area, however, no evidence of breeding was found.

The Beverly and Aberdeen Lakes Area

The bird populations of the Beverly and Aberdeen Lakes areas were studied in 1984 for the Canadian Wildlife Service (CWS) by McCormick and Adams (1984). Waterfowl observed included the Canada goose, white-fronted goose (*Anser albifrons*), tundra swan, and the lesser snow goose. Sterling and Dzubin (1967) stated that the Thelon River and Beverly and Aberdeen Lakes were major moulting areas for non-breeding Canada geese from mid-continental breeding grounds.

8.13 Raptors

Raptors are birds of prey and include falcons, eagles, hawks, and owls. Falcon and owl production is known to be variable and highly dependent upon small mammal and bird populations, favourable weather and the availability of suitable nesting habitat (Alliston and Patterson 1978; BEAK 1992; Bradley and Oliphant 1991; Bradley et al. 1997).

Five species of raptors were observed in the Project area during previous baseline surveys (BEAK 1990a). In order of abundance, these raptors were rough-legged hawk (*Buteo lagopus*), peregrine falcon, short-eared owl, gyrfalcon (*Falco rusticolus*) and snowy owl (*Bubo scandiacus*). The peregrine falcon and the short-eared owl are currently listed federally as ‘species of special concern’ under COSEWIC (2007) and SARA (SARA 2007, internet site).

Chesterfield Inlet supported an abundance of nesting habitat for peregrine falcons and Baker Lake was known to provide excellent nesting habitat for gyrfalcons, rough-legged hawks and peregrine falcons (McLaren 1978). Peregrine falcons used three types of cliff habitat for nesting in the northwestern Hudson Bay area, escarpments, rock outcrops and cliffs and embankments along rivers (Alliston and Patterson 1978). The Canadian Wildlife Service (CWS 1972a, b, c) identified several zones from Baker Lake west to Aberdeen Lake as critical areas for peregrine falcons, and in some cases, also the gyrfalcon. These included a region along the north shore of Baker Lake near its west end, along the Thelon River and the north shore of Shultz Lake to the northeast end of Aberdeen Lake, the south shore of Aberdeen Lake and three small areas south and southwest of Baker Lake. In 1977, eleven active nests were found in the Baker Lake area (Alliston and Patterson 1978; McLaren and Holdsworth 1978). Peregrine falcons were also observed in studies done by McCormick and Adams (1984) in the Beverly/Aberdeen Lakes area (BEAK 1990a). An active nest was observed on an escarpment to the east of the south end of Skinny Lake, approximately 2 km from the proposed pumphouse location (BEAK 1990a). However, suitable nesting sites were generally lacking within the immediate vicinity of the Project (BEAK 1990a; GIL 1990).

On the Shultz Lake transect, four occupied peregrine falcon nests were found in the area, along with six active rough-legged hawk nests (BEAK 1990a). On the Marjorie Lake transect, seven occupied peregrine falcon nests were found, along with fifteen occupied rough-legged hawk nests and one gyrfalcon nest (BEAK 1990a). There was no mention of raptors in the Sandhills area.

The short-eared owl is an extremely rare but regular breeder in the area. A few were observed in the area southwest and west of Baker Lake between 1975 and 1977

(McLaren and Holdsworth 1978). In 1979 Urangesellschaft Canada Limited located one nest at Schultz Lake and in 1980 another nest was located at Pointer Lake.

The snowy owl has varied from completely absent in 1975 to fairly numerous in 1976 and 1977 in the Pitz Lake and Baker Lake areas (McLaren et al. 1976; McLaren and Holdsworth 1978). One snowy owl nest was found at Schultz Lake in 1979 and snowy owls were also seen at Sandhills and Marjorie Lake the same year (BEAK 1979). In 1979, a pair of aggressive snowy owls were found on one of the exploration grids, suggesting that a nest was nearby (BEAK 1980).

During the 2007 baseline studies, one active falcon nest, three inactive nests and seven birds in flight were observed. Of those seven birds, three were confirmed as peregrine falcons (Table XI-6; Appendix XI).

8.14 Wildlife Tissue Chemistry

To determine whether metals and radionuclides accumulate in wildlife as the result of mine activity/operations, it is necessary to measure baseline metal and radionuclide concentrations. During the summer of 1989, various small animals were collected for baseline chemical analyses (BEAK 1990a). In total, five Arctic ground squirrels (*Sermophilus parryii*), six ptarmigan (*Lagopus mum),* and two Arctic hares (*Lepus arcticus*) were collected. In addition, two barren-ground caribou samples and one wolf sample were provided by the local Royal Canadian Mounted Police and wildlife officer, respectively (BEAK 1990a).

Chemical analyses (heavy metal and uranium-series radionuclides) were conducted by the Saskatchewan Research Council (SRC) on the following samples:

- Arctic ground squirrel (squirrel) - stomach contents, muscle, bone and- carcass;
- Arctic hare (hare) - stomach contents, muscle and bone; and
- caribou and wolf - muscle and bone.

These data, together with regional data from other sources (Smith and Armstrong 1975; Shaw and Gunn 1981), are presented in Table 8-14.1.

Table 8.14-1
Trace Metal and Radionuclide Concentrations (Wet Weigh Basis) in Wildlife Tissues from the Project and the Eastern Keewatin, 1989

Parameter	Wolf Muscle	Wolf Bone	Ptarmigan Muscle	Ptarmigan Bone	Ptarmigan SC	Ptarmigan Carcass	Hare Muscle	Hare Bone	Hare SC	Caribou Muscle	Caribou Bone	Squirrel Muscle	Squirrel Bone	Squirrel Carcass	Squirrel SC	Caribou Tissue[(a)]	Caribou Liver[(a)]	Wolf Muscle[(b)]	Wolf Muscle[(b)]	Arctic Fox Muscle[(b)]
Zinc (µg/g)	4.51E+01	1.04E+02	1.4E+01	8.1E+01	-	5.74E+01	1.9E+01	9.58E+01	-	3.61E+01	4.8E+01	2.81E+01	8.14E+01	2.70E+01	-	28.8	28.8	-	-	-
Cadmium (µg/g)	L 2E-02	L 4E-02	7.8E-02	6.3E-02	-	2.6E-01	L 1E-02	L 2E-02	-	L 1E-02	L 3E-02	6.2E-02	L 2E-02	1.1E-01	-	-	-	-	-	-
Cobalt (µg/g)	L 3E-01	L 8E-01	L 3E-01	L 4E-01	-	L 4E-01	L 2E-01	L 4E-01	-	L 3E-01	L 5E-01	L 2E-01	L 4E-01	L 3E-01	-	ND	0.76	-	-	-
Copper (µg/g)	2.8E+00	4E-01	2.74E+00	1.1E+00	-	4.46E+00	1.4E+00	8.7E-01	-	1.6E+00	5.3E-01	2.47E+00	7.3E-01	2.83E+00	-	5.19	17.2	-	-	-
Lead (µg/g)	2E-01	5E-01	6.8E+00	1.1E+00	-	1.4E+01	1.6E+01	7.0E-01	-	2E-01	4E-01	3.26E+00	4.4E-01	1.27E+01	-	2.80	3.0	-	-	-
Chromium (µg/g)	4.0E+00	2E+00	L 3E-01	4E-01	-	1E+00	L 2E-01	1E+00	-	L 3E-01	1E+00	L 2E-01	7E-01	8E-01	-	2.46	2.7g	-	-	-
Nickel (µg/g)	6.7E+00	8E-01	L 3E-01	L 4E-01	-	1E+00	L 2E-01	4E-01	-	L 3E-01	L 5E-01	L 3E-01	4E-01	8E-01	-	0.20	ND	-	-	-
Mercury (µg/g)	1.2E-01	L 7.7E-03	2.4E-02	L 4.2E-03	-	1.1E-01	4.2E-02	8.7E-03	-	4.7E-02	L 5.3E-03	2.0E-02	5.5E-02	3.5E-02	-	-	-	0.051	0.24	0.31
Arsenic (µg/g)	L 2E-01	L 4E-01	L 1E-01	L 2E-01	-	8.5E-01	2.2E-01	L 2E-01	-	L 1E-01	L 3E-01	L 1E-01	L 2E-01	6.7E-01	-	-	-	-	-	-
Selenium (µg/g)	1.2E+00	L 4E-01	6.5E-01	2E-01	-	8.5E-01	2.2E-01	2E-01	-	7.8E-01	L 3E-01	4.9E-01	5.5E-01	5.4E-01	-	-	-	-	-	-
Uranium (µg/g)	L 5.0E-04	L 3.8E-02	1.8E-03	L 2.21E-02	5.20E+00	1.25E-01	5.79E-03	1.50E+00	5.03E-01	1.0E-03	2.09E-02	2.97E-01	2.84E+00	3.83E-01	7.75E+00	-	-	-	-	-
Th-230 (Bq/g)	L 5.0E-05	L 3.8E-03	L 8.9E-05	L 2.2E-03	4.53E-02	1.6E-03	L 1.7E-04	L 2.3E-03	6.27E-03	L 1.0E-04	L 2.1E-03	7.4E-04	1.3E-03	4.3E-04	2.92E-02	-	-	-	-	-
Ra-226 (Bq/g)	5.0E-05	1.13E-02	L 4.4E-05	2.2E-03	8.48E-02	2.6E-03	4.2E-04	2.34E-01	4.27E-03	5.2E-05	2.09E-02	1E-03	1.06E-02	3.48E-03	3.09E-02	-	-	-	-	-
Pb-210 (Bq/g)	1E-03	1.1E-01	9.7E-04	7.74E-02	1.42-02	9E-03	1.08E-03	1.1E-01	1.38E-02	2.1E-03	4.2E-01	1E-03	2E-02	1E-02	9.0E-02	-	-	-	-	-
Po-210 (Bq/g)	5.3E-03	2.5E-02	-	-	-	5.1E-03	-	2.0E-02	-	-	8.9E-02	5E-04	4.7E-03	8E-03	-	-	-	-	-	-
Th-232 (Bq/g)	L 5.0E-05	L 3.8E-03	L 8.9E-05	L 2.2E-03	2.82E-02	5.1E-04	L 1.7E-04	L 2.3E-03	7.4E-04	L 1.0E-04	L 2.1E-03	L 1E-04	L 1.3E-03	L 4.3E-04	L 8.1E-04	-	-	-	-	-
Th-228 (Bq/g)	L 5.0E-05	L 3.8E-03	L 8.90-05	2.2E-03	1.13E-02	5.1E-04	L 1.7E-04	L 2.3E-03	1.5E-03	L. 1.0E-04	6.26E-03	L 1E-04	L 1.3E-03	L 4.3E-04	L 1.6E-03	-	-	-	-	-
Dry Solids (%)	33.4	77.0	26.1	42.1	77.8	42.5	22.2	43.5	22.4	26.1	52.6	24.7	36.3	27.0	16.9					

Source: BEAK 1990a
a = From: Shaw and Gunn (1981). Samples from Prince of Wales Island
b = From: Smith and Armstrong (1975). Samples from Victoria Island
L = less than; SC - stomach contents; "-" = not available
Wolf - tissues from one animal, from Baker Lake traplines
Ptarmigan - tissues from six animals (composite), Kiggavik site
Hare - tissues from two animals (composite), Kiggavik site
Squirrel - tissues from live animals (composite), Kiggavik site
Caribou - tissues from one animal, from Baker Lake hunters
Carcass - remainder after removal of muscle (flesh), bone and stomach content samples

8.15 DATA GAPS

Since the 1970's, a wide range of pre-development baseline data have been collected for the Project. While much of this data were used to assess potential environmental effects from the Project in the early 1990's, the information is not sufficient to make an informed assessment of the potential effects of the Project on the existing local environment. However, this historical data provides background values to compare against future measurements of environmental endpoints obtained during the 2008 baseline studies. Data gaps are presented for mammals (muskoxen, grizzly bear, wolverines, wolves and foxes) and birds (breeding birds, water birds and raptors).

8.15.1 Caribou

The Beverly, Qamanirjuak, and Ahiak caribou herds have annual ranges that overlap the Project. The Project is considered to be within the post-calving grounds and along known migration routes. Current estimates suggest that five of the eight barren-ground caribou herds are declining. The declining trend in most barren-ground caribou herds, and recent results from local and cumulative effects studies indicate that new projects will likely be viewed as an issue of concern for all stakeholders in Nunavut. The location of the project in relation to both calving and post-calving grounds for the Beverly caribou herd will likely be the overriding issue should the Project proceed to EA.

Data should be collected during baseline studies at the Project to provide estimates of the natural variation for the following variables:

- group size, number, density, and distribution of caribou within the study area during the northern and post-calving migration periods;
- composition of caribou groups (*i.e.*, groups with calves and groups without calves) within the study area during the post-calving migration;
- caribou behaviour (e.g., time spent foraging, resting, walking) within the study area; and
- group size, group composition, number, density, and distribution of muskoxen in the study area.

8.15.2 Muskoxen

Muskoxen are harvested for subsistence use, sport hunts, as well as commercial hunts for the sale of meat to southern destinations. Therefore, the potential for Project-related effects to muskoxen will likely be viewed as an issue of concern for stakeholders in Nunavut. Data should be collected during baseline studies at the Project to provide estimates of the natural variation for the following:

- group size, number, density, and distribution of caribou within the study area;
- composition of caribou groups (i.e., groups with calves and groups without calves) within the study area; and
- muskoxen behaviour (e.g., time spent foraging, resting, walking) within the study area.

8.15.3 Grizzly Bears

Grizzly bears are listed as a species of special concern under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2007). The sensitivity of the grizzly bear populations to changes in survival and recruitment rates, cultural significance, and federal listing of the species (COSEWIC listed) indicate that new projects will be viewed as an issue of concern for all stakeholders in Nunavut.

Data should be collected during baseline studies at the Project to determine:

- the natural variation in the relative activity level and distribution of grizzly bears within the study area; and
- the presence and distribution of grizzly bear dens in the study area.

8.15.4 Wolverines

Wolverines are currently listed as a species of special concern under COSEWIC (2007), and are proposed to be listed under Schedule 1 of the Species at Risk Act (SARA 2007). Populations appear stable, but there is concern regarding the cumulative impacts of hunting/trapping pressure and direct and indirect effects associated with industrial development.

Impacts to wolverine occur mostly through mine-related mortality. Indirect effects from the Project associated with disturbance and changes in behaviour should have a low impact on the wolverine population in the Project area. However, because of the historical mine-related loss of wolverine in the Lac de Gras region (NWT), any new projects will be viewed as an issue of concern for all stakeholders in Nunavut. As a mitigation measure, the government of Nunavut are expected to push hard to implement the hair sampling program at the Project. Data should be collected during baseline studies at the Project to determine the natural variation in the relative activity level and distribution of wolverine in the study area.

8.15.5 Wolves and Foxes

In tundra environments, wolves exhibit specialist behaviour in prey selection and den site location. The Arctic and red fox are harvested by both Aboriginals and local residents, and are a valuable subsistence and non-traditional resource. Impacts to wolves and foxes occur mostly through mine-related mortality. Indirect effects from the Project associated with disturbance and changes in behaviour should have a low impact on the wolf and fox population in the Project area. However, the potential increased mortality of carnivores has been an important issue in previous environmental assessments of diamond mines.

Data should be collected during baseline studies at the Project area to determine:

- the natural variation in the distribution, occupancy, and productivity of wolf dens; and
- the distribution and activity of fox dens.

8.15.6 Upland Breeding Birds

Upland breeding birds (passerines, ptarmigan, and shorebirds) are commonly studied in baseline and monitoring programs as they represent an abundant and diverse group of species that are relatively easy to observe. Birds are also an important resource for aboriginals in Nunavut, and have provided food and important materials, such as feathers, which were used to make blankets and pillows. During the breeding period, natural and human-induced (e.g., mining activities) disturbances can be associated with changes in density and species richness. Therefore, the potential for Project-related effects to upland breeding birds will be viewed as an issue of concern for stakeholders in Nunavut. Data should be collected during baseline studies at the Project and used to determine the natural variation in bird density (species and community), and species richness, as they relate to habitat types.

8.15.7 Water Birds

The lakes and wetlands of the tundra host a large number of migratory waterbird species, comprising a breeding assemblage of swans, loons, cranes, geese, and ducks. Species richness of waterbirds is considered a valuable indicator of the quality of wetlands habitat. Therefore, the potential for disturbances from the Project during nesting, rearing, molting, staging, and migration will be viewed as an issue of concern for stakeholders in Nunavut.

Data collected during baseline studies will be used to determine the natural variation in species density and richness in the Project area during the northern migration/establishment of nesting territories, brood rearing period, and southern migration.

8.15.8 Raptors

Raptors are birds of prey and include falcons, eagles, hawks, and owls. Impacts on raptor populations can be reflected throughout the ecosystem because they occupy a top trophic level (Kennedy 1980a). As such, raptors are commonly used as indicators of ecosystem health in baseline and monitoring programs. Raptors are known to be sensitive to disturbances during the breeding season, and declines in raptor populations have been attributed to human activities and developments (Craighead and Mindell 1981). Therefore, the potential for Project-related effects to the occupancy rate, success rate and productivity of raptors will be viewed as an issue of concern for stakeholders in Nunavut.

Data should be collected during baseline studies at the Project that will be used to determine the natural variation in nest site distribution, occupancy, success, and productivity of raptors in the Project area.

9.0 ARCHAEOLOGY

9.1 Culture History

As a result of the archaeological work conducted in the study region since the mid 20th century it is possible to develop an brief outline of the regional culture history. It should be observed that throughout the millennia, peoples who lived in the Barrenlands relied almost exclusively on the caribou for subsistence. As a result the annual migration patterns of the Beverly and Qamanirjuaq caribou herds would dictate the seasonal round of the highly mobile hunting and gathering populations that inhabited the region.

Occupation of the Barrenlands of Nunavut began shortly after the recession of the glaciers approximately 9,000 years before present (BP). The earliest recognized archaeological tradition is Northern Plano (8,000 to 6,500 BP), which is characterized by projectile points similar in form to Agate Basin points found in the plains of North America (Gordon 1996). These long lancelate points with tapered and ground bases were manufactured largely out of quartzite. Radiocarbon dates from the Migod site (KkLn 4) on Grant Lake (southwest of the project site) suggest that Northern Plano dates from at least 8,000 years BP (Gordon 1975). The concentration of Northern Plano materials at Grant Lake further suggest the Dubawnt and Thelon Rivers were major caribou migration corridors exploited by Northern Plano peoples (Gordon 1996:219).

Approximately 6,500 years ago, Northern Plano evolved into Shield Archaic (6,500 to 3,500 BP) (Gordon 1996:199). This cultural development coincided with a warming period that resulted in the expansion of the boreal forest as far north as Dubawnt Lake. Projectile points were also manufactured primarily out of quartzite, but differed from the preceding Northern Plano Tradition in that they were “side-notched lanceheads with ground, rocker [convex] bases” (Gordon 1996:201).

The Shield Archaic Tradition is followed by the Pre-Dorset Tradition, which lasted from approximately 3,450 to 2,650 BP (Gordon 1996:149). Pre-Dorset is part of the Arctic Small Tool Tradition, well known in the high arctic. The migration of these early Pre-Inuit groups corresponded with a cooling trend that adversely affected maritime hunting. As a result, these arctic adapted people were forced further south in their quest for food. They were able to exploit migrating caribou herds on the Barrenlands as a result of the southward retreating forest edge. The Pre-Dorset Tradition is characterized archaeologically by very small, finely retouched tools manufactured from fine grained, banded chert. Distinct tools include end and side blades used for harpoons and arrows, burins, and micro-cores.

The Taltheilei Tradition is the latest precontact archaeological culture identified in the study area, and dates from approximately 2,600 to 200 BP (Gordon 1996). People representing this tradition moved into the region from the west after the preceding cooling period ended, and are generally regarded as ancestral Dene. The material culture of the Taltheilei Tradition is characterized by a continuum of lancelate and notched points, distinct discoidal hide-working tools known as chithos, and a variety of scraping tools. This archaeological culture has been divided into three Periods based on projectile point style: the Early Period (2600 to 1800 BP) is characterized by long stemmed points; the Middle Period (1800 to 1300 BP) by unshouldered lancelate points; and the Late Period (1300 to 200 BP) by small side and corner-notched points (Gordon 1996).

The Historic Period begins with the establishment of fur trade posts on the western shore of Hudson's Bay in 1670. Early traders eager to make contact with more distant aboriginal groups ventured into the Barrenlands of Nunavut. The most notable was Samuel Hearne who made two expeditions between 1769 and 1772 from Fort Prince of Wales, through the interior and eventually to the mouth of the Coppermine River (Tyrell 1911), near the community of Kugluktuk. It was sometime during this early historic period that Dene groups, decimated by European disease, abandoned the Barrenlands in favour of the forests to the south to more effectively engage in the fur trade (Gordon 1996:51).

Following this migration, the historic Caribou Inuit moved into the region, either from the central arctic or the east coast of Hudson's Bay (Burch 1979; Gordon 1996; Linnamae and Clarke 1976). Their descendents have occupied much of the interior of Nunavut ever since, including the Kazan, Dubawnt and lower Thelon drainage basins. The margins of these major rivers and lakes are dominated by Inuit sites, which are characterized by stone features including Inuksuit, tent rings, caches, hunting blinds and kayak stands (Friesen 1989:4.7). The precontact origins of the Caribou Inuit ultimately lie in the Thule Tradition, which spread across the central and eastern arctic approximately 1000 BP. Throughout the 1950's with further development of the north, the Canadian Government began a policy of settling the local Inuit into communities such as Baker Lake, Chesterfield Inlet and Rankin Inlet (Stager 1977). Although year-round occupation of the Barrenlands no longer occurs, seasonal caribou hunting and fishing is still an important activity of local residents.

9.2 Previous Research in the Region

Formal scientific exploration and mapping of the Barrenlands began in the late 19th Century, and this early work would set the stage for future archaeological research in the study area. James Tyrell (1898) of the Geological Survey of Canada set out on a number of expeditions between 1893 and 1900. In 1893 he travelled north from Lake Athabasca, eventually ascending the Dubawnt River to the Thelon River, then eastward through Aberdeen and Baker Lakes to Chesterfield Inlet. In 1900 Tyrell embarked on another expedition, this time travelling eastward from Great Slave Lake along a series of rivers and lakes to the Thelon River, then on to Chesterfield Inlet. David Hanbury (1900; 1903) also explored and mapped the rivers of the Barrenlands at the turn of the century in two separate expeditions. He travelled westward through the region by canoe in 1898-99 from Chesterfield Inlet, along the Thelon River to Great Slave Lake. In the second expedition of 1901, he travelled eastward along a similar route, this time embarking from Great Slave Lake. In 1922 Knud Rasmussen entered the region as part of the Fifth Thule Expedition (Rasmussen 1926). Members of his party travelled inland from Chesterfield Inlet to Baker Lake, then south along the Kazan River to Yathkyed Lake to conduct geographic and ethnographic research.

The earliest archaeological research of the Nunavut Barrenlands, however, began with artifact collections by the Moffat Canoe expedition of 1955 (Harp 1955). Members of the expedition travelled from Black Lake, Saskatchewan along the Chipman and Dubawnt rivers to Baker Lake. A total of nine archaeological sites were recorded along this route south of Aberdeen Lake. This expedition was followed by an archaeological survey conducted by Elmer Harp in 1958 along Beverly, Aberdeen and Schultz lakes, as well as the lower Thelon River (Harp 1961). A total of 42 new sites were recorded as a result of this survey. Harper proposed the first culture history of the region based on the data obtained from these sites. Subsequent research by Irving (1968) on the Upper Kazan River and in the North Henik and Dubawnt Lake areas would result in a revision of Harp's proposed cultural chronology.

Archaeological investigations continued in the region in the 1970's with more controlled excavations conducted at a number of sites first recorded by Harp. Wright (1972a,b; 1976) excavated at the Aberdeen (LdLl 2) and Grant Lake (KkLn 2) sites. Gordon (1976) conducted excavations at the Migod (KkLn 4) site located north of Dubawnt Lake. These multi-component sites were significant in further refining the continuum of precontact occupation in the region. Additional surveys were also conducted by Gordon (1974) in the vicinity of the Baker Lake settlement. Five of Elmer Harp's sites were revisited and four new sites were recorded.

The first archaeological research related to Heritage Resources Impact Assessment (HRIA) projects occurred in 1977, with archaeological surveys conducted along the proposed Polar Gas pipeline route (Schledermann and Nash 1977; Schledermann 1978). A total of 33 sites were recorded in the Thirty Mile Lake area on the lower Kazan River and southwest of Baker Lake.

In the 1990’s, Stewart et al. (2000) conducted research south of Baker Lake with an archaeological survey of the Fall Caribou Crossing National Historic Site, an area covering a 30 km stretch of the lower Kazan River from Kazan Falls to the east end of Thirty Mile Lake. A combination of oral history and archaeology was used to interpret recent Inuit land use of the area. A total of 1,554 features were recorded (including dwellings, inuksuit, caches, hearths, kayak related structures etc.), with clusters representing at least seven recognized sites.

Archaeological assessments related to the Meadowbank Gold Mine project were conducted in the Baker Lake region in 1999 and 2003 under Permit No. 03-012A (Cumberland Resources Ltd. 2005). This included assessments of the mine site area located approximately 70 km north of the Hamlet of Baker Lake, a winter road route to the mine site, and a storage and marshalling area east of the Hamlet of Baker Lake. A total of 42 new sites were recorded and eight sites were revisited. The majority were interpreted as relatively recent, temporary campsites. Stone features observed included tent rings, hearths, inuksuit, markers, blinds, shelters, caches and graves.

9.3 Site Specific Assessments

9.3.1 1988-89 Heritage Assessment of Kiggavik Uranium Project

Archaeological impact assessments for areas affected by the proposed Kiggavik Project (the Project), located approximately 80 km west of Baker Lake, were first conducted in the late 1980’s by Max Friesen (1989). A total of 53 sites were recorded, the vast majority located on Aberdeen (n=20) and Skinny lakes (n=23) (Figure 9.2-1). Areas assessed under Permit Nos. 88-646 included: 1) a limestone quarry and associated winter access road north of Aberdeen Lake; 2) deep water harbour sites located in Chesterfield Narrows; 3) a barge dock and road to the town of Baker Lake; 4) the winter road from Baker Lake to the Kiggavik Project area; and 5) the main mine site located north of Pointer Lake. Most relevant to the current study is the assessment of the mine site area and associated infrastructure on Skinny Lake, and the winter road leading to the limestone quarry.

Assessments conducted at the mine site included proposed open pit locations, camp areas, mill, airstrip (west of Pointer Lake), roads and other related infrastructure. No heritage resources were observed at these locations. However, assessment of water intake and gravel source areas at the south end of Skinny Lake resulted in the identification of 11 heritage resources (LcLe 1 to 11). During assessment of the winter road to the limestone quarry, two lithic scatter sites (LcLf 1 and 2) were recorded on an esker east of Aberdeen Lake, and 12 sites were recorded along the north shore of the east arm of Aberdeen Lake (LcLg 1 to 12).

Figure 9.2-1 Existing Heritage Sites Within the Kiggavik Study Area

Fieldwork conducted the following year under Permit No. 89-664 focused on additional surveying of Aberdeen Lake, and excavating sites located on the south end of Skinny Lake. Eight more sites were identified along the north shore of Aberdeen Lake (LcLg 13 to 20). These sites consisted of stone features associated with lookouts, caribou drive systems, campsites, food storage and some burials. All were attributed to precontact and historic Inuit occupations. A survey was also conducted around the entire circumference of Skinny Lake, where an additional 12 sites were identified (LcLe 12 to 17; LdLe 1 to 7). Of the 17 sites excavated, 11 were lithic scatters and six were stone feature sites consisting primarily of tent rings. Excavation was carried out on features at three of the latter sites (LcLe 2, 5, and 7) and systematic surface collection were conducted at the remaining lithic scatter sites. Projectile points dating to the Middle or Late Taltheilei Tradition were recovered from two campsites (LcLe 2 and 7) and one lithic scatter site. The lithic scatter sites were located on points of high ground overlooking Skinny Lake and were interpreted as lookouts for hunters monitoring caribou migration.

Friesen (1992) returned to conduct further archaeological investigations in the vicinity of the proposed Kiggavik Uranium Mine under Permit No. 91-704. One of the sites recorded during this investigation, LcLg 22, a mid-twentieth century cache site, was the focus of a subsequently publication (Friesen 2001).

9.3.2 2007 Heritage Assessment of Kiggavik Project Site

In August of 2007, Golder Associates Ltd. conducted an archaeological survey on behalf of AREVA Resources Canada Inc. (AREVA) at the Kiggavik Project (the Project). The archaeological survey was completed under Class 2 Permit 2007-015A issued by the Department of Culture, Language, Elders and Youth (CLEY), Nunavut. The primary purpose of the survey was to address the immediate infrastructure needs of the current drilling program and camp. Secondly, a general reconnaissance was completed to determine heritage resource potential of the region.

The reconnaissance focused on several main areas of interest. These included an existing runway located approximately 12 km west of the main camp, an alternate runway north of this location, the Sissons and Kiggavik ore body areas, a fuel cache, and the area surrounding the camp. Four potential permanent runways were also investigated, as well as the south end of Skinny Lake, where it is proposed that the water intake for the mill may be located. A reconnaissance was also completed on a stretch of significant archaeological sites at the east arm of Aberdeen Lake. Finally, a brief helicopter survey was completed of the proposed all-season road corridor to Baker Lake. During the archaeological reconnaissance, a total of 17 previously unrecorded sites were identified (LcLe 19-22, LcLf 12-22, and LdLe 8-9) (Figure 9.2-1).

Survey of Existing Runway

The field survey began on August 7, 2007 with an examination of a set of elevated ancient Aberdeen Lake strandlines located approximately 12 km west of the Kiggavik camp. Aberdeen Lake is currently located 4 km to the west of the camp. These strandlines had been in use as a landing strip by AREVA and others for a number of years. In total, 3.7 km of strandlines were surveyed. Six previously unrecorded sites (LcLf 12 to 17) were identified and two previously recorded sites were revisited (LcLf 1 and 2).

LcLf 12 is a small artifact scatter located at the north end of the strandlines surveyed. It is situated at the southwest corner of a small pond. Three pieces of lithic debitage were observed over a distance of 40 m on the west edge of the strandline. These were collected to obtain a sample of lithic material.

LcLf 13 is an artifact scatter located 50 m east of the portion of strandline used that had been used as a runway. Observed over a 70 m by 30 m area was a lithic scatter consisting of approximately 20 artifacts. Two lithic bifaces were collected indicating the area likely served as a camp location. These tools, however, are not temporally diagnostic. A low wet area separates the runway from the artifact scatter.

LcLf 14 is a large lithic scatter consisting of over 200 artifacts observed on the surface. The site is located 70 m west of LcLf 13 and measures 60 m by 45 m. Several formed lithic tools were collected in addition to a sample of flaking debris. Collected tools include the tip of a broken spear point and two quartzite bifaces.

LcLf 15 is a lithic scatter located along the south end of the runway on the strandline. LcLf 14 is approximately 375 m north of this location. Observed over a 120 m by 30 m area were an estimated 150 to 200 artifacts. No formed tools were observed, but a sample of flaking debris was collected.

LcLf 16 is a tent boulder outline site located at the north end of LcLf 15 at the eastern edge of the strandline. The boulder alignment was rectangular, measured 3 m by 4 m and consisted of 16 cobbles. A second cluster of cobbles 16 m north of the tent outline may be related to this site. A piece of wire is wrapped around one of the rocks. No other historic items were observed.

LcLf 17 is located approximately 100 m northwest of LcLf 15 and LcLf 16. The site consists of a stone spear point. The artifact was found on the western edge of the strandline, several metres off the edge of the runway. The artifact is complete with the exception of the tip, which had been broken. The artifact was collected for further analysis.

LcLf 1 and 2 were previously recorded sites identified during an archaeological survey conducted in 1988 by Friesen (1989). These lithic scatter sites are located on the strandline north of the portion used for a runway.

Survey of Sissons Site Area

The survey of the Sissons Site area was completed on August 8, 2007 through helicopter reconnaissance and pedestrian survey. Overall, the general area where the ore bodies are located is considered to have low potential to contain significant heritage resources. The terrain is characterized by low, flat wet areas. A pedestrian survey was completed from Andrew Lake to Mushroom Lake. Three previously unrecorded sites, LcLf 18, 19 and 20, were found in the vicinity of Mushroom Lake. In addition, within the uplands east and southeast of Mushroom Lake there are eight previously recorded sites: LcLf 3-9, 11.

LcLf 18 is a marker observed at the east edge of Mushroom Lake at the tip of a lobe of land extending into the lake. The marker consists of five large cobbles placed on an outcrop. The marker has collapsed. LcLf 18 is located approximately 800 m northwest of the north Sissons ore body.

LcLf 19 is a small lithic scatter located on an outcrop at approximately 90 m northeast of Mushroom Lake. Observed over a 3 m area were 23 pieces of flaking debris. No diagnostics or formed tools were noted and no artifacts were collected. LcLf 19 is approximately 370 m northeast of LcLf 18.

LcLf 20 is a marker located on a boulder outcrop at the north edge of Mushroom Lake. The marker was constructed by placing two small boulders at the edge of the lake. The two rocks were placed 11 m apart. Travis Mannik, field assistant from Baker Lake, suggested that the marker may indicate a good fishing spot on the lake.

Previously recorded sites LcLf 3-9 and 11 were flown over by helicopter, but were not revisited on foot. According to the site database, these sites contain both small lithic scatters and boulder alignments found within the upland east and southeast of Mushroom Lake.

Kiggavik Project Area Survey

The survey of the Project area included the camp, existing fuel cache, possible landing strip, and around ore body areas. These areas were surveyed on August 8 and 9, 2007. Overall, the heritage potential of the region was considered moderate with the upland features around the camp and north of the ore bodies receiving the most attention. The low, wet areas were considered to be low potential. Five previously unrecorded sites were recorded during the survey: LcLf 21, LcLe 19 to 22.

LcLf 21 is a small site containing boulder outlines of two tents. The site was discovered during helicopter reconnaissance of the Project Area. The two boulder features are located on a sandy outcrop at the north end of a small lake. They are square and rectangle in outline and measure 3.5 m by 3.5 m and 3.5 m by 4 m respectively. The site is located 725 NNE from the existing fuel cache and 3 km WSW from camp.

LcLe 19 is a prominent marker located 1.6 km southeast of camp on the edge of an upland feature. Pointer Lake is prominently viewed to the south and is located 1.8 km away. The markers consist of a large linear boulder placed upright on top of a small stack of flat rocks. Surrounding this large marker are three small rocks placed on boulders.

LcLe 20 is a small marker located on the prominent upland feature 770 m northeast of camp. The marker has collapsed. This location has a prominent view to the south.

LcLe 21 is the location of an old cache. This site was identified by Travis Mannik and he stated that it was likely used to cache caribou until it could be retrieved at a later date. The cache had been opened, however, and no faunal remains were present. The cache measures 1.5 m long, 70 cm wide and 40 cm deep. An old scrap of paper was found under a rock at the bottom of the cache which suggests it is of more recent vintage. The site is located 1250 m northeast of camp.

LcLe 22 is a small collapsed marker found along the south edge of a prominent upland feature 2 km northeast of camp. Jaeger Lake can be seen to the south and is located 3.1 km away. It was noted that a large quartzite vein was present in the vicinity of the marker.

Proposed Airstrip Surveys

Four proposed airstrips were surveyed for their potential to contain significant heritage resources. These included the following locations:

- Pointer Lake Airstrip – located along the west side of Pointer Lake.
- Jaeger Lake Airstrip – located north of Jaeger Lake.
- Drumlin Airstrip – located along a low ridge between Jaeger and Siamese Lakes.
- Skinny Lake Airstrip – located along west side of Skinny Lake.

Each potential airstrip was examined by low level helicopter survey. The Jaeger Lake and Drumlin Airstrips are situated in an area that is generally low, flat, and featureless and contains low potential to contain significant heritage sites. As such, a pedestrian survey was not completed at these two locations. A pedestrian survey was completed for the Pointer Lake airstrip and no sites were discovered. Two previously unrecorded sites were discovered during the Skinny Lake airstrip survey: LdLe 8 and LdLe 9. In addition, 22 previously recorded sites are known from previous surveys in the vicinity of Skinny Lake (LcLe 1-8, 10, 12-17, LdLe 1-7).

LdLe 8 is a small lithic scatter located on the south side of a small drainage valley on the west side of Skinny Lake. The site is located on a level sandy plain 780 m west of the lakeshore. Included with the scatter was a fragment of a large biface. This artifact plus a sample of the flaking debris was collected for further analysis.

LdLe 9 is a small lithic artifact scatter located along the same sandy plain as LdLe 8 west of Skinny Lake. LdLe 9 is located 1.2 km south of GAL 15 and is 380 west of the shore of Skinny Lake. The scatter consists of approximately 20 flakes of debitage along with a quartzite cobble that was likely used as an anvil in the knapping process.

The previously recorded sites documented by Friesen (1989) are located along both shores of Skinny Lake, but are concentrated at the southern end. Numerous stone features were observed and artifacts recovered by Friesen including several temporarily diagnostic projectile points indicating use of the area over the last 1,300 years. The area surrounding Skinny Lake is unusually rich in archaeological resources compared to the other areas examined.

Aberdeen Lake Reconnaissance

On August 10, 2007 a reconnaissance survey was made to the north shore of the east arm of Aberdeen Lake. Here, a number of archaeological sites were recorded by Friesen (1989) in the 1988 and 1989 archaeological survey for the proposed winter road to the limestone quarry. In all, 21 sites were recorded. These sites are large and highly significant and contain features such as inuksuit, kayak stands, qarmats, burials, hunting blinds, fox traps and tent rings. Due to the high density of heritage resource artifacts and features at Aberdeen Lake it is considered a valuable resource for comparison to other sites and materials in the region.

One previously unrecorded site was noted during a low level helicopter survey. LcLf 22 is located near the east terminus of Aberdeen Lake on the north shore. Observed at this site was a tent ring and two small clusters of boulders.

All Weather Road Reconnaissance

Also on August 10, 2007 a helicopter reconnaissance was completed along the general corridor of one of the all weather road options to Baker Lake. Areas of high heritage potential were noted along the route and archaeological sites were observed from the air at locations in close proximity to the Thelon River. In addition, a brief helicopter survey was made over the island at Baker Lake that is proposed to be utilized as a docking station for a barge. Potential archaeological features were observed on the surface of the island and ground reconnaissance is recommended.

Public Meetings

Golder archaeologists Dr. David Blower and Brad Novecosky traveled to Baker Lake on August 6, 2007. That evening they attended the Kiggavik Community Liaison Committee meeting at AREVA's office where Mr. Novecosky gave a presentation on the planned archaeological field work to be carried out that week. The meeting was well attended and Mr. Novecosky and Dr. Blower answered questions from the committee.

On August 10, following the field work, a public meeting was advertised and held at the community centre in Baker Lake. Brad Novecosky gave a PowerPoint presentation describing the results of the fieldwork and showed images of recorded sites. Maps and artifacts from the project area were also available for the public to view. Again, there were several questions that Mr. Novecosky and Dr. Blower were able to address from the public.

On November 14, 2007 Barry McCallum, Manager of Nunavut Affairs for AREVA gave a presentation to the Inuit Heritage Trust. This meeting was also held in Baker Lake and consisted of a summary of the results of the 2007 archaeological field season.

9.4 Archaeology Data Gaps

Data gaps identified for this component include an archaeological survey of the roads and remaining infrastructure of the mine yet to identified. If archaeological sites are found in conflict with any of the proposed project components, further archaeological work including salvage excavation may be required.

10.0 CLOSURE

We trust that this report is sufficient for your present needs. Please contact Golder Associates Ltd. at your convenience if you have any questions or comments.

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APPENDIX I

HYDROLOGY

Table I-1
Estimated Monthly Precipitation [mm] Measured at Baker Lake Climate Station (1971 to 2000)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1971	9.9	9.7	2.0	12.4	9.4	21.3	43.4	43.9	34.3	42.4	19.1	2.0	249.8
1972	3.6	3.6	7.6	19.1	23.4	10.2	13.2	38.1	33.8	11.7	18.3	0.8	183.4
1973	9.9	4.1	14.0	13.2	11.7	11.9	1.5	57.7	79.0	27.4	5.6	7.4	243.4
1974	18.8	4.8	3.8	8.9	3.6	23.4	49.8	17.5	27.2	54.9	30.0	21.1	263.8
1975	10.4	3.0	3.6	2.5	20.1	22.6	68.6	68.8	37.3	79.8	8.9	8.4	334.0
1976	7.1	4.3	5.8	17.0	34.3	26.2	22.6	13.5	51.6	20.3	17.3	16.0	236.0
1977	23.4	2.5	14.8	40.6	26.5	22.3	24.3	41.9	36.8	57.1	57.9	14.5	362.6
1978	11.5	11.9	7.3	21.0	6.4	41.6	72.1	19.4	7.0	44.6	17.1	6.2	266.1
1979	8.3	2.2	6.0	9.0	41.0	51.0	29.5	38.3	15.9	24.0	14.0	6.7	245.9
1980	2.1	2.4	9.2	22.0	11.4	9.7	54.0	77.2	22.7	10.1	19.0	10.1	249.9
1981	2.4	16.3	11.3	9.7	9.8	32.2	41.8	8.6	25.0	44.1	21.8	6.3	229.3
1982	0.0	6.7	8.7	5.8	15.6	21.0	42.3	38.3	85.2	62.8	14.1	13.9	314.4
1983	13.1	6.0	10.2	11.2	12.9	10.6	6.8	74.2	57.1	50.7	3.9	8.1	264.8
1984	8.2	20.0	9.4	28.2	3.0	16.1	38.9	64.7	30.6	22.0	12.9	3.1	257.1
1985	6.2	11.4	20.8	17.5	11.2	6.2	90.8	87.7	72.6	27.7	10.7	6.3	369.1
1986	8.6	6.2	5.2	13.7	32.3	44.8	6.3	90.9	31.2	31.0	22.2	19.2	311.6
1987	13.4	11.8	22.5	24.7	5.4	31.7	45.8	65.2	31.0	15.6	27.9	18.2	313.2
1988	1.2		8.5	14.8	18.4	45.6	38.4	43.3	51.0		17.0	14.6	252.8
1989	11.0	5.6		16.2	21.3	20.6	59.0	23.8	31.5	14.5	11.6	2.3	217.4
1990	7.4	10.7	35.7	6.1	11.4	12.6	77.7	40.6	31.1	16.1	23.5	14.2	287.1
1991	2.6	3.5	17.1	22.6	11.5	23.8	27.6	37.2	38.7	20.5	16.5	13.2	234.8
1992	9.8	8.0	12.9	13.2	31.6	7.4	10.2	52.4	78.2	32.2	25.1	12.5	293.5
1993	16.9	10.2	16.0	6.9	16.4	17.8	68.8	39.0	13.8	17.1	17.6	17.3	257.8

Table I-1

Estimated Monthly Precipitation [mm] Measured at Baker Lake Climate Station (1971 to 2000) (Continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1994	0.2	1.6	9.7	8.6	3.2	10.2	80.2	40.2	60.2	18.0	13.8	13.8	259.7
1995	5.6	0.6	10.2	3.6	1.2	8.6	17.0	57.9	21.9	31.7	6.0	11.4	175.7
1996	3.8	6.0	4.0	15.2	3.5	23.4	45.6	80.3	86.2	24.2	10.1	2.0	304.3
1997	0.4	7.0	3.6	4.4	16.2	42.0	18.8	19.9	16.3	70.2	8.6	22.0	229.4
1998	1.4	15.2	3.8	4.6	18.3	45.9	54.1	45.6	77.2	7.6	12.4	8.8	294.9
1999	5.2	8.8	8.0	8.8	21.4	59.8	75.0	48.8	47.8	21.6	8.8	9.7	323.7
2000	0.8	5.8	11.4	5.7	15.0	0.6	28.6	34.6	58.1	21.4	13.4	6.0	201.4
Mean	7.4	7.2	10.5	13.6	15.6	24.0	41.8	47.0	43.0	31.8	16.8	10.5	267.6

Source: Environment Canada 2006a

Table I-2
Monthly Precipitation (Adjusted) Estimated for Baker Lake Climate Station (1971 to 2000) (mm)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1971	16.3	18.2	6.5	21.0	14.2	26.3	49.0	50.8	41.4	56.4	28.2	5.6	334.0
1972	8.3	7.1	14.5	30.6	33.0	13.9	17.7	43.4	43.2	21.6	36.7	3.8	273.8
1973	17.5	8.8	28.5	20.1	18.2	15.5	2.9	65.0	85.9	42.3	10.9	13.1	328.6
1974	29.5	8.6	7.4	14.5	7.8	27.4	55.7	23.5	39.0	83.2	47.1	31.5	375.3
1975	15.8	6.2	6.4	5.1	28.8	28.9	74.8	74.5	47.1	114.5	16.0	14.6	432.8
1976	14.4	8.7	9.4	26.5	41.0	31.5	25.6	18.7	62.2	31.3	25.9	25.2	320.5
1977	34.2	5.9	22.5	55.6	33.0	26.4	29.0	46.3	41.7	76.0	82.9	22.6	476.0
1978	18.9	19.4	12.5	30.5	12.5	52.5	77.2	23.3	10.9	62.7	26.3	11.3	358.0
1979	11.5	6.5	11.0	15.5	46.3	64.0	32.3	48.4	23.5			12.7	
1980	6.2	6.9	21.8	34.3	19.3	12.9	59.2	81.1	30.0	18.2	32.5	16.8	339.4
1981	7.2	25.3	21.1	14.7	15.3	40.4	46.0	13.6	28.5	61.2	36.9	12.7	322.7
1982	3.8	13.0	15.4	10.9	23.4	26.2	46.7	47.6	84.5	76.4	22.7	25.8	396.4
1983	22.8	11.5	16.7	16.6	20.9	14.4	10.5	79.6	65.7	73.8	10.1	14.4	356.9
1984	14.6	30.4	16.6	42.2	6.6	19.4	42.3	69.7	38.8	33.4	20.3	6.4	340.8
1985	12.4	17.5	31.2	25.8	18.5	9.7	96.0	95.1	79.3	40.4	21.8	15.7	463.3
1986	18.3	14.4	10.4	26.8	37.1	55.7	9.0	95.1	46.5	56.5	38.5	32.9	441.2
1987	27.0	21.6	47.4	50.8	13.0	36.2	49.0	70.2	33.8	36.1	69.8	51.8	506.7
1988	6.8	8.3	32.0	40.2	55.1	49.6	41.6	46.9	55.3	77.3	45.1	37.3	495.6
1989	19.2	10.9	6.9	31.7	38.5	24.9	62.0	25.7	42.5	31.6	34.7	8.3	336.9
1990	19.7	20.7	59.4	17.2	19.6	16.4	81.4	44.6	36.8	29.0	36.2	22.1	403.0
1991	6.9	7.8	26.8	38.3	17.6	26.8	30.4	40.3	52.9	31.5	26.5	21.3	327.2
1992	16.2	14.0	21.5	20.5	45.6	12.4	12.5	57.5	96.7	47.8	36.8	20.5	401.8
1993	26.3	17.0	24.5	11.8	29.0	21.4	72.7	42.9	20.8	26.3	25.6	28.7	347.0

Table I-2
Monthly Precipitation (Adjusted) Estimated for Baker Lake Climate Station (1971 to 2000) (mm) (Continued)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1994	4.5	5.5	19.5	13.3	6.6	13.8	82.9	44.4	64.9	27.5	23.8	24.9	331.4
1995	12.2	4.6	22.5	10.1	5.2	9.7	20.6	61.2	30.4	46.4	13.0	22.2	258.2
1996	11.4	14.7	9.1	27.6	7.3	25.3	47.9	84.3	91.3	44.0	21.3	10.0	394.3
1997	5.2	18.2	10.4	9.1	23.5	44.5	21.3	22.7	22.2	113.6	18.0	37.7	346.3
1998	5.9	35.9	8.6	12.5	26.9	48.7	56.4	49.1	83.8	14.8	32.1	23.7	398.4
1999	15.0	24.6	21.6	17.6	37.8	66.8	80.1	53.3	53.2	59.4	63.1	30.9	523.5
2000	11.5	19.7	30.9	20.4	23.0	3.6	30.3	39.9	63.8	32.6	26.9	14.2	316.8
Mean	14.7	14.4	19.8	23.7	24.2	28.8	45.4	52.0	50.6	50.5	32.1	20.6	377.5

Source: Environment Canada 2006a

Table I-3
Estimated Average Daily Discharge at SF2, 2007 [m^3/s]

Day	Jun	Jul	Aug	Sep
1		0.324	0.005	0.139
2		0.268	0.010	0.117
3		0.223	0.013	0.104
4		0.185	0.013	0.106
5		0.136	0.011	0.100
6		0.116	0.010	0.089
7		0.104	0.009	0.076
8		0.093	0.019	0.073
9		0.081	0.019	0.063
10		0.064	0.018	0.058
11		0.054	0.018	0.037
12		0.046	0.016	0.043
13		0.041	0.015	0.046
14		0.036	0.014	0.051
15	0.557	0.030	0.017	0.051
16	1.110	0.026	0.018	0.046
17	1.090	0.023	0.016	0.048
18	1.042	0.021	0.015	
19	1.323	0.017	0.014	
20	1.041	0.015	0.014	
21	0.955	0.016	0.015	
22	1.259	0.016	0.018	
23	1.576	0.013	0.025	
24	1.130	0.011	0.081	
25	1.003	0.009	0.317	
26	1.093	0.009	0.538	
27	1.135	0.009	0.458	
28	0.680	0.007	0.358	
29	0.512	0.006	0.276	
30	0.362	0.005	0.215	
31		0.005	0.167	
Average	0.992	0.065	0.089	0.073

Table I-4
Estimated Average Daily Discharge at SF6, 2007 [m^3/s]

Day	Jun	Jul	Aug	Sep
1		0.982	0.081	0.361
2		0.883	0.087	0.362
3		0.845	0.093	0.363
4		0.790	0.095	0.388
5		0.711	0.093	0.361
6		0.622	0.089	0.352
7		0.558	0.082	0.335
8		0.519	0.103	0.337
9		0.480	0.102	0.328
10		0.448	0.096	0.330
11		0.416	0.092	0.304
12		0.373	0.089	0.277
13		0.342	0.087	0.269
14		0.315	0.086	0.309
15		0.283	0.091	0.287
16		0.253	0.093	0.246
17	5.984	0.225	0.091	0.238
18	7.660	0.212	0.088	
19	5.815	0.191	0.084	
20	5.045	0.168	0.082	
21	4.490	0.155	0.083	
22	4.039	0.170	0.087	
23	3.493	0.156	0.102	
24	2.822	0.146	0.149	
25	2.357	0.123	0.184	
26	1.976	0.119	0.190	
27	1.603	0.122	0.258	
28	1.402	0.116	0.325	
29	1.221	0.103	0.352	
30	1.094	0.093	0.382	
31		0.084	0.370	
Average	3.500	0.355	0.138	0.320

Table I-5
Estimated Average Daily Discharge at SF7, 2007 [m^3/s]

Day	Jun	Jul	Aug	Sep
1		10.912	3.907	2.267
2		10.224	3.843	2.278
3		9.773	3.826	2.326
4		9.423	3.740	2.444
5		9.002	3.601	2.034
6		8.645	3.689	2.055
7		8.370	3.724	2.197
8		8.187	3.583	2.063
9		7.979	3.750	2.040
10		7.634	3.498	1.867
11		7.230	3.307	1.823
12		6.702	3.138	2.024
13		6.539	2.951	1.816
14		6.180	2.799	1.642
15		5.953	2.599	1.660
16		5.807	2.662	1.475
17		5.652	2.713	
18	8.561	5.648	2.670	
19	9.882	5.569	2.658	
20	11.505	5.455	2.389	
21	12.857	5.474	2.139	
22	13.499	5.616	1.467	
23	13.887	5.424	1.643	
24	13.930	5.244	2.208	
25	13.756	4.939	2.396	
26	13.317	4.911	2.533	
27	12.827	4.823	2.497	
28	12.282	4.656	2.550	
29	11.910	4.614	2.481	
30	11.419	4.475	2.334	
31			2.350	
Average	12.279	6.702	2.892	2.001

Table I-6
Estimated Average Daily Discharge at SF9, 2007 [m^3/s]

Day	Jun	Jul	Aug	Sep
1		1.536	0.222	0.537
2		1.186	0.226	0.489
3		1.062	0.215	0.473
4		0.896	0.207	0.458
5		0.796	0.201	0.448
6		0.724	0.193	0.416
7		0.654	0.203	0.390
8		0.603	0.251	0.387
9		0.552	0.218	0.368
10		0.515	0.212	0.347
11		0.478	0.211	0.341
12		0.448	0.207	0.317
13		0.427	0.204	0.321
14		0.399	0.206	0.310
15		0.376	0.225	0.398
16		0.358	0.232	0.313
17		0.342	0.219	0.307
18		0.324	0.211	0.321
19	2.294	0.311	0.204	
20	2.317	0.297	0.201	
21	2.352	0.293	0.214	
22	3.207	0.277	0.230	
23	5.279	0.275	0.273	
24	4.719	0.267	2.168	
25	4.081	0.266	2.809	
26	3.814	0.253	1.354	
27	3.416	0.247	1.033	
28	3.011	0.235	0.848	
29	2.277	0.229	0.722	
30	1.771	0.223	0.652	
31		0.214	0.583	
Average	3.211	0.486	0.489	0.386

APPENDIX II

WATER QUALITY

APPENDIX III

SEDIMENT

APPENDIX IV

FISH POPULATION AND HEALTH

Table IV-1
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Smoke Lake, August 1991 Net Set Duration 25 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Arctic Grayling	16.5	38	Imm		
Arctic Grayling	17	40	Imm		
Arctic Grayling	18.5	58	Imm		
Arctic Grayling	18	45	Imm		
Arctic Grayling	18	58	Imm		
Arctic Grayling	17	40	Imm		
Arctic Grayling	17	40	Imm		
Arctic Grayling	19	55	Imm		
Arctic Grayling	27.5	238	F	Snails	
Arctic Grayling	29.5	325	M	BM	
Arctic Grayling	26.5	280	M	BM	
Arctic Grayling	27	300	M	BM	
Arctic Grayling	28.5	325	F	BM	
Arctic Grayling	27	300	M	BM	
Arctic Grayling	25.5	250	M	BM	
Arctic Grayling	25	172	F		
Arctic Grayling	24	132	M		
Arctic Grayling	26	190	M		
Arctic Grayling	20	180	M		
Arctic Grayling	25.5	175	F		
Arctic Grayling	28	300	F		
Arctic Grayling	24.5	155	M		
Arctic Grayling	26	175	M	M, OI	
Arctic Grayling	23.5	135	M		
Arctic Grayling	23	138	M		
Arctic Grayling	30	410	F		
Cisco	37.5	750	F	S, BM	
Cisco	34	500	M		
Cisco	27.5	280	F		
Cisco	27	300	F	Empty	
Cisco	28.5	350	M	Empty	
Cisco	25.5	185	M		

Note: cm = centimetre; gm = grams; S = Snails; M = Midge Larvae; OI = Other Insects; BM = Bottom Material.
Source BEAK 1992.

Table IV-2
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Cigar Lake, August 1991 Net Set Duration 12 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Net#1					
Lake Trout	78.5	>5000			Released
Lake Trout	42.5	700			Released
Lake Trout	77.5	5000	F	Empty	CLT-1
Lake Trout	42.5	700	F	Snails	CLT-2
Lake Trout	40	650	M	Snails	CLT-2
Lake Trout	37.5	500	F	Empty	
Lake Trout	42	775	F	Empty	CLT-2
Lake Trout	50	1150	M	Empty	
Lake Trout	40	600	Imm	Empty	
Lake Trout	39.5	650	Imm	Empty	
Lake Trout	38.5	525	Imm	Empty	
Lake Trout	35.5	425	Imm	Empty	
Arctic Grayling	34	475	M	A,S,M	CG-1
Arctic Grayling	33	400	M	Beetle	CG-1
Arctic Grayling	31.5	370	M	A,S	CG-2
Arctic Grayling	28	250	F	A,S	CG-2
Round Whitefish	30	300	F	Zooplankton	
Round Whitefish	30.5	250	M	Zooplankton	
Round Whitefish	34	350	F	Zooplankton	
Round Whitefish	33	350	M	Zooplankton	CRW-1
Round Whitefish	33.5	400	F	Snails	CRW-1
Round Whitefish	37	400	F	Zooplankton	
Round Whitefish	36.5	350	F	Snails	
Round Whitefish	35	325	F	Empty	
Round Whitefish	33.5	325	F	Z,M	
Round Whitefish	34	350	M	Empty	
Round Whitefish	32.5	350	F	Z,M	CRW-1
Round Whitefish	33	300	F	Empty	
Round Whitefish	30	250	F	Zooplankton	
Round Whitefish	34	350	F	Empty	
Round Whitefish	30	300	F	Zooplankton	
Round Whitefish	33.5	325	M	Snails	
Round Whitefish	32	250	F	Empty	
Round Whitefish	30.5	250	F	Zooplankton	
Round Whitefish	22.5	60	Imm		
Cisco	27.5	200	M	Zooplankton	
Cisco	26.5	175	M	Z,S,C	
Cisco	19	45	Imm		

Note: cm = centimetre; gm = grams; S = Snails; C = Clams; M = Midge Larvae; Z = Zooplankton.
Source BEAK 1992.

Table IV-3
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Cigar Lake, August 1991 Net Set Duration 12 Hours

Species (Net#2)	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Lake Trout	84.5	~10000			Released
Lake Trout	42.5	800			Released
Lake Trout	39.5	650			Released
Lake Trout	61.5	2200	F	Empty	
Lake Trout	66	3500	M	Empty	CLT-1
Lake Trout	68.5	3600	F	Empty	
Lake Trout	60.5	3000	M	DF	
Lake Trout	42.5	750	F	DF	
Lake Trout	32	350	F		
Lake Trout	39.5	650	F	DF	
Lake Trout	51	1800	F	Empty	
Arctic Grayling	30	350	M	BM	
Arctic Grayling	32.5	425	M	BM	
Arctic Grayling	32	425	M	BM	
Arctic Grayling	31	400	M	BM	
Arctic Grayling	26.5	300	F	BM	
Arctic Grayling	30	350	M	BM	
Arctic Grayling	31	425	M	BM	
Arctic Grayling	30.5	400	M	BM	
Round Whitefish	30	350	F	Zooplankton	
Round Whitefish	29.5	350	M	Zooplankton	
Round Whitefish	32	400	M	Zooplankton	
Round Whitefish	32.5	400	M	Zooplankton	
Round Whitefish	30	400	F		
Round Whitefish	35.5	475	M	Zooplankton	
Round Whitefish	36	500	M		CRW-1
Round Whitefish	29	300	F		
Round Whitefish	35	500	M		
Round Whitefish	34	475	M		
Round Whitefish	33	425	M		
Round Whitefish	32.5	450	F		
Round Whitefish	30	350	F		
Round Whitefish	31	375	F		
Round Whitefish	31	400	M		
Round Whitefish	31	375	M		
Round Whitefish	31	400	F		
Round Whitefish	29.5	350	F		
Round Whitefish	32.5	400	F		
Round Whitefish	31.5	375	M	Zooplankton	
Round Whitefish	29.5	325	M		
Round Whitefish	31	375	F		
Round Whitefish	31	375	M		

Table IV-3
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Cigar Lake, August 1991 Net Set Duration 12 Hours

Species (Net#2)	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Round Whitefish	30	350	M		
Round Whitefish	34	400	F		
Round Whitefish	32	375	M		
Round Whitefish	32.5	400	M		
Round Whitefish	33	425	M		
Round Whitefish	34	375	F		
Round Whitefish	32	375	M		
Round Whitefish	33	425	M		
Round Whitefish	32	350	M		
Round Whitefish	34	475	M		
Round Whitefish	34	425	F		
Round Whitefish	29.5	325	M		
Round Whitefish	30	375	F		
Cisco	28.5	325	M	Zooplankton	
Cisco	19	150	Imm		
Cisco	19	150	Imm		
Cisco	21	175	Imm		
Cisco	27.5	325	F		
Cisco	27	250	M		
Cisco	27	300	F		
Cisco	28	300	F	Zooplankton	
Cisco	23	175	Imm		
Cisco	25.5	250	F		
Cisco	20	125	Imm		
Cisco	27.5	275	M		

Note: cm = centimetre; gm = grams; BM = Bottom Material; DF = Decomposed Fish.
Source BEAK 1992.

Table IV-4
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Mushroom Lake, August 1991 Net Set Duration 16.5 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Lake Trout	55	[illegible]			Released
Lake Trout	36	550	M	DF	MLT-1
Lake Trout	43	850	F	Empty	MLT-2
Arctic Grayling	28.5	375			Released
Arctic Grayling	25	170	M	S,C,M,OI	
Arctic Grayling	26	170	M	S,C,M,OI	
Arctic Grayling	30	400	F	S,C,M,OI	
Arctic Grayling	30	375	F	S,C,M,OI	
Arctic Grayling	29	350	F	S,C,M,OI	MG-1
Arctic Grayling	29	350	F	S,C,M,OI	
Arctic Grayling	28.5	350	F	S,C,M,OI	
Arctic Grayling	26	200	F	S,C,M,OI	
Arctic Grayling	29.5	400	F	S,C,M,OI	
Arctic Grayling	30	375	M	S,C,M,OI	MG-1
Arctic Grayling	30	375	M	S,C,M,OI	MG-1
Arctic Grayling	28.5	130	F	S,C,M,OI	
Round Whitefish	31	375	M	Empty	
Round Whitefish	29	275	F	Empty	
Round Whitefish	30	325	M	Empty	
Round Whitefish	32.5	400	M	Empty	
Round Whitefish	31	375	M	BM	
Round Whitefish	31.5	375	M	BM	
Round Whitefish	31.5	425	M	BM	
Round Whitefish	32.5	425	F	BM	
Round Whitefish	31	375	M	BM	MRW-1
Round Whitefish	29	275	M	BM	
Round Whitefish	29.5	350	F	BM	MRW-1
Round Whitefish	30	350	M	BM	
Cisco	33	450	F	BM	
Cisco	29	360	F	BM	
Cisco	30	350	F	BM	
Cisco	33	450	F	BM	
Cisco	30	375	M	BM	

Notes: cm = centimetre; gm = grams; BM = Bottom Material; DF = Decomposed Fish; S = Snails; C = Clams; M = Midge Larvae; OI = Other Insects.
Source BEAK 1992.

Table IV-5
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Mushroom Lake, August 1991 Net Set Duration 16.5 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Lake Trout	67.5	3500	M	Empty	
Lake Trout	43	925	F	Empty	
Arctic Grayling	31	400	F	BM	
Arctic Grayling	33.5	500	M	BM	
Arctic Grayling	32.5	550	F	BM	
Arctic Grayling	30.5	400	F	BM	
Arctic Grayling	32	500	F		
Arctic Grayling	34	550	F	BM	
Arctic Grayling	31.5	400	M		
Arctic Grayling	32	450	M		
Arctic Grayling	32.5	475	F		
Arctic Grayling	32	450	M		
Arctic Grayling	22.5	140	F		
Arctic Grayling	22	115	M		
Arctic Grayling	23	145	F		
Arctic Grayling	19.5	95	F		
Arctic Grayling	23	140	M		
Arctic Grayling	19.5	75	Imm		
Arctic Grayling	19.5	85			
Arctic Grayling	19.5	75			
Arctic Grayling	21	110			
Arctic Grayling	18	60			
Arctic Grayling	20	100			
Arctic Grayling	15	35			
Arctic Grayling	16	40			
Arctic Grayling	16	40			
Arctic Grayling	16.5	50			
Arctic Grayling	15.5	30			
Arctic Grayling	17	50			
Arctic Grayling	17.5	50			
Arctic Grayling	18.5	60			
Arctic Grayling	16	30			
Arctic Grayling	16	40			
Arctic Grayling	15.5	30			
Arctic Grayling	13.5	15			
Arctic Grayling	22	110			
Arctic Grayling	19.5	80			
Arctic Grayling	16	40			

Table IV-5
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Mushroom Lake, August 1991 Net Set Duration 16.5 Hours (Continued)

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Arctic Grayling	16.5	35			
Arctic Grayling	17	40			
Arctic Grayling	15	25			
Arctic Grayling	14.5	25			
Arctic Grayling	15.5	35			
Arctic Grayling	15	28			
Including 7 more small grayling torn apart					

Notes: cm = centimetre; gm = grams; BM = Bottom Material.
Source BEAK 1992.

Table IV-6
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Andrew Lake, August 1991 Net Set Duration 16.5 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Arctic Grayling	18.5	65			
Arctic Grayling	16	30			

Notes: cm = centimetre; gm = grams.
Source BEAK 1992.

Table IV-7
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Shack Lake, August 1991 Net Set Duration 16.5 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Arctic Grayling	34	550	F		
Arctic Grayling	34	575	F	Z,S	
Arctic Grayling	33.5	575	F	Z,M,OI	
Arctic Grayling	30.5	450	F	Z,M,OI	
Arctic Grayling	35	650	F	Z,M,OI	
Arctic Grayling	24.5	180	M	Z,M,OI	
Arctic Grayling	20.5	105	Imm		
Arctic Grayling	22.5	140	M	Empty	
Arctic Grayling	22	130	M	Z,M,OI	
Arctic Grayling	24	175	M	Z,M,OI	
Arctic Grayling	20	90	Imm	Z,M,OI	
Arctic Grayling	21	100	Imm	Z,M,OI	
Arctic Grayling	21	85	Imm	Z,M,OI	
Arctic Grayling	15	30	Imm		
Arctic Grayling	14.5	24			
Arctic Grayling	16	32			
Arctic Grayling	17	50			
Arctic Grayling	15.5	25			
Arctic Grayling	15.5	30			
Arctic Grayling	15	25			
Arctic Grayling	17.5	50			
Arctic Grayling	16.5	40			
Arctic Grayling	16	30			
Including 6 more small grayling, released or torn apart					

Notes: cm = centimetre; gm = grams.
Source BEAK 1992.

Table IV-8
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Bear Island Lake, August 1991 Net Set Duration 17 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Arctic Grayling	21	125	M		
Arctic Grayling	15.5	30	Imm		
Arctic Grayling	15.5	30	Imm		

Notes: cm = centimetre; gm = grams.
Source BEAK 1992.

Table IV-9
Fork Length, Weight, Sex and Stomach Contents of Fish Collected from Lower Lake, August 1991 Net Set Duration 17 Hours

Species	Fork Length (cm)	Weight (gm)	Sex	Stomach Contents	Tissue Sample
Arctic Grayling	34	510	F	Zooplankton	
Arctic Grayling	36	600	M	Z,S,M,OI	
Arctic Grayling	36	580	M	Z,S,M,OI	
Arctic Grayling	30	375	M	Z,S,M,OI	
Arctic Grayling	26.5	240	M	Z,S,M,OI	
Arctic Grayling	14	20	Imm		
Arctic Grayling	24	500		Released	
Round Whitefish	41.5	800	F	BM	
Round Whitefish	31	400	M	BM,M,OI	
Round Whitefish	18	480	Imm		
Round Whitefish	19.5	52			
Round Whitefish	19.5	60			
Round Whitefish	18	38			
Cisco	16	30			
Cisco	16.5	38			

Notes: cm = centimetre; gm = grams; S = Snails; M = Midge Larvae; OI = Other Insects; BM = Bottom Material.
Source BEAK 1992.

Table IV-10
Standardized Catch per Unit Effort* for Fish Stocks in Study Area Lakes

Lake	Species	Number	Biomass (kg)		Total Biomass of All Species (kg)
			Total	Mean	
Ridge	Lake Trout	17	26.5	1.6	26.5
Escarpment	Lake Trout	8	13.4	1.7	28.0
	Grayling	4	1.4	0.4	
	Round Whitefish	26	13.2	0.5	
Felsenmeer	Lake Trout	8	13.2	1.7	19.7
	Grayling	8	4.2	0.5	
	Round Whitefish	7	2.3	0.3	
Skinny	Lake Trout	9	27.6	3.1	31.5
	Round Whitefish	8	3.4	0.4	
	Cisco	1	0.5	0.5	
Kavisilik	Lake Trout	11.3	36.6	3.2	39.3
	Cisco	10.0	2.4	0.2	
	Round Whitefish	1.0	0.3	0.3	
Lin	Grayling	62	13.3	0.2	13.3
Cirque	Grayling	11	2.6	0.2	2.6
Caribou	Lake Trout	1	1.2	1.2	2.2
	Grayling	4	1.0	0.3	
Pointer	Lake Trout	2	7.2	3.6	4.1
	Cisco	6	1.1	0.2	
	Grayling	1	0.3	0.3	
Sissons	Lake Trout	9.8	26.5	2.7	27.8
	Cisco	1.7	0.5	0.3	
	Round Whitefish	1.4	0.5	0.4	
	Grayling	0.3	0.2	0.6	
	Burbot	0.2	0.1	0.5	
Scotch	Lake Trout	11.0	24.3	2.2	28.9
	Round Whitefish	7.3	4.6	0.6	

One standard unit of effort represents an 18-hour set of index monafilament gill nets of 45.7 m total length, consisting of 7.6 m panels of the following stretch mesh sizes: 3.8 cm , 5.1 cm 6.4 cm, 7.6 cm, 10.2 cm and 12.7 cm.
Source : BEAK 1992.

Table IV-11
Lake Characteristics and Fish Yields, Based on the Morphoedaphic Index, in Kiggavik and Andrew Lake Study Area Lakes

	Lake Area (ha)	Mean Depth (m)	TDS[a] (mg/L)	MEI[b] (ppm/m)	Yield (kg/yr)
Escarpment	12.7	2.2	9	4.1	13
Felsenmeer	20.8	2	34	17	21
Ridge	16.7	2.3	7	3	17
Cirque	5.6	2.6	16	5	6
Crash	8.1	1.1	(15)	14	8
Drum	25	1.3	(30)	23	25
Lin	48	1.3	30	23	48
Fox	128	1.7	(33)	19	130
Caribou	341	1.4	33	24	340
Willow	54.9	1.4	(28)	20	55
Pointer	374	1.5	28	19	370
Scotch	195	3.6	13	3.6	200
Jaeger	281	1.6	20	13	280
Judge Sissons	9,550	4.6	33	7.2	9,600
Skinny	197	3.1	6	1.9	200
Kavisilik	564	4.2	(6)	1.4	560
Squiggly	638	6	(20)	3.3	640
Mushroom	40	2.6	23	8.8	40
Lunch	78	0.6	(23)	38.3	78
Knee	35	0.2	(23)	115	35
Smoke	63.5	1.3	(28)	21.5	64
Cigar	113	1.5	28	18.7	110
Andrew	54	0.2	25	125	54
Shack	60	0.6	(25)	41.7	60
Bear Island	36.5	0.5	(28)	56	37
Lower	49	0.4	28	170	49

a = TDS = total dissolved solids. Assumed values are in parenthesis. b) MEI = morphoedaphic index (TDS(ppm)/mean depth (m)). Source BEAK 1992.

Table IV-12
2007 Fisheries Study CPUE Results for Gill Nets, Minnow Traps, and Angling.

Location	Species	Gill Net		Minnow Trap		Angling	
		Total Fish	CPUE (# fish/hr/100 m net)	Total Fish	CPUE (# fish/ trap hr)	Total Fish	CPUE (# fish/ angler hr)
Pointer Lake System							
Pointer Lake	Arctic grayling	2	2.7E-01	-	-	-	-
	cisco	1	1.4E-01	-	-	-	-
	lake trout	1	1.4E-01	-	-	-	-
	ninespine stickleback	-	-	5	9.6E-03	-	-
Sik Sik Lake	-	0	0.0E+00	-	-	-	-
	ninespine stickleback	-	-	3	1.7E-02	-	-
Willow Lake	Arctic grayling	1	2.3E-01	-	-	-	-
	-	-	-	0	0.0E+00	-	-
Fox Lake System							
Ridge Lake	-	0	0.0E+00	-	-	-	-
	-	-	-	0	0.0E+00	-	-
	-	-	-	-	-	0	0.0E+00
Cirque Lake	-	0	0.0E+00	-	-	-	-
	ninespine stickleback	-	-	7	1.7E-01	-	-
Crash Lake	-	0	0.0E+00	-	-	-	-
	Arctic grayling	-	-	2	4.6E-02	-	-
Fox Lake	-	0	0.0E+00	-	-	-	-
	-	-	-	0	0.0E+00	-	-
Shack Lake System							
Andrew Lake	-	0	0.0E+00	-	-	-	-
	burbot	-	-	1	2.4E-02	-	-
End Grid Lake	-	0	0.0E+00	-	-	-	-
	Arctic grayling	-	-	3	1.0E-01	-	-
Shack Lake	-	0	0.0E+00	-	-	-	-
	-	-	-	0	0.0E+00	-	-
Lower Lake	Arctic grayling	2	2.1E-01	-	-	-	-
	-	-	-	0	0.0E+00	-	-

Note: # = number; hr = hour; m = metres; CPUE = Catch-per-Unit-Effort Source Golder 2008.

Table IV-13
2007 Fisheries Study Length, Weight and Condition Factor Results

Lake	Species	Total Body Weight (g)	Length (mm)	Condition Factor (*k*)
Pointer Lake	Arctic grayling	20	126	1.00
		250	260	1.42
	cisco	425	304	1.51
	lake trout	4000	712	1.11
	ninespine stickleback	2	49	1.70
		2	56	1.14
		2	63	0.80
		2	56	1.14
		2	62	0.84
Sik Sik Lake	ninespine stickleback	2.3	56	1.31
		2.1	64	0.80
		1.9	67	0.63
Willow Lake	Arctic grayling	200	240	1.45
Cirque Lake	ninespine stickleback	2	50	1.60
		4	65	1.46
		2	52	1.42
		2	60	0.93
		4	55	2.40
		2	55	1.20
		1	45	1.10
Crash Lake	Arctic grayling	4	70	1.17
		4	72	1.07
Andrew Lake	burbot	4	70	1.17
End Grid Lake	Arctic grayling	2.8	65	1.02
		3.5	66	1.22
		2.5	57	1.35
Lower Lake	Arctic grayling	14	118	0.85
		16	116	1.03

Source: Golder 2008

Table IV-14
2007 Fisheries Study External Health Results

Species	Category	Pointer Lake	Sik Sik Lake	Willow Lake	Cirque Lake	Crash Lake	Andrew Lake	End Grid Lake	Lower Lake
Arctic Grayling	**Total # of Fish Surveyed**	**2**	**0**	**1**	**0**	**2**	**0**	**3**	**2**
	Total # of Fish with Abnormalities[(a)]	0	0	0	0	0	0	0	0
	Body Deformities	0	0	0	0	0	0	0	0
	Eyes	0	0	0	0	0	0	0	0
	Gills	0	0	0	0	0	0	0	0
	Pseudobranchs	0	0	0	0	0	0	0	0
	Thymus	0	0	0	0	0	0	0	0
	Skin	0	0	0	0	0	0	0	0
	Fins	0	0	0	0	0	0	0	0
	Opercula	0	0	0	0	0	0	0	0
	Hindgut	0	0	0	0	0	0	0	0
Cisco	**Total # of Fish Surveyed**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Total # of Fish with Abnormalities[(a)]	0	0	0	0	0	0	0	0
	Body Deformities	0	0	0	0	0	0	0	0
	Eyes	0	0	0	0	0	0	0	0
	Gills	0	0	0	0	0	0	0	0
	Pseudobranchs	0	0	0	0	0	0	0	0
	Thymus	0	0	0	0	0	0	0	0
	Skin	0	0	0	0	0	0	0	0
	Fins	0	0	0	0	0	0	0	0
	Opercula	0	0	0	0	0	0	0	0
	Hindgut	0	0	0	0	0	0	0	0
Ninespine stickleback	**Total # of Fish Surveyed**	**5**	**3**	**0**	**7**	**0**	**0**	**0**	**0**
	Total # of Fish with Abnormalities[(a)]	0	0	0	0	0	0	0	0
	Body Deformities	0	0	0	0	0	0	0	0
	Eyes	0	0	0	0	0	0	0	0
	Gills	0	0	0	0	0	0	0	0
	Pseudobranchs	0	0	0	0	0	0	0	0
	Thymus	0	0	0	0	0	0	0	0
	Skin	0	0	0	0	0	0	0	0
	Fins	0	0	0	0	0	0	0	0
	Opercula	0	0	0	0	0	0	0	0
	Hindgut	0	0	0	0	0	0	0	0
Lake trout	**Total # of Fish Surveyed**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Total # of Fish with Abnormalities[(a)]	1	0	0	0	0	0	0	0
	Body Deformities	0	0	0	0	0	0	0	0
	Eyes	1	0	0	0	0	0	0	0
	Gills	0	0	0	0	0	0	0	0
	Pseudobranchs	0	0	0	0	0	0	0	0
	Thymus	0	0	0	0	0	0	0	0
	Skin	1	0	0	0	0	0	0	0
	Fins	0	0	0	0	0	0	0	0
	Opercula	0	0	0	0	0	0	0	0
	Hindgut	0	0	0	0	0	0	0	0
Burbot	**Total # of Fish Surveyed**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**
	Total # of Fish with Abnormalities[(a)]	0	0	0	0	0	0	0	0
	Body Deformities	0	0	0	0	0	0	0	0
	Eyes	0	0	0	0	0	0	0	0
	Gills	0	0	0	0	0	0	0	0
	Pseudobranchs	0	0	0	0	0	0	0	0
	Thymus	0	0	0	0	0	0	0	0
	Skin	0	0	0	0	0	0	0	0
	Fins	0	0	0	0	0	0	0	0
	Opercula	0	0	0	0	0	0	0	0
	Hindgut	0	0	0	0	0	0	0	0

a = An individual fish could have more than one incidence of an external abnormality.

Source Golder 2008.

Figure IV-1 Injured Lake Trout Captured in Golder 2007 Field Program

APPENDIX V

HABITAT AND BATHYMETRY MAPS

APPENDIX VI

BENTHIC INVERTEBRATE

APPENDIX VII

PHYTOPLANKTON

APPENDIX VIII

ZOOPLANKTON

APPENDIX IX

SURFICAL GEOLGOY AND SOILS

Table IX-1
Summary of the Chemical and Physical Characteristics of Three Orthic Static Cryosols in the Kiggavik Project Study Area*

	Site LG001 Horizon		Site LG002 Horizon			Site LG003 Horizon		
	Bm	**Cg**	**Bm**	**C**	**Cz**	**Bm**	**Cg**	**Cgz**
Horizon Thickness (cm)	0 to 8	8 to 27	0 to 7	7 to 30	30 to 53	0 to 7	7 to 42	42 to 81
Soil Chemistry								
pH ($CaCl_2$)	5.4	5.4	5.3	5.9	6.1	5.3	4.7	6.4
Ca (Meq/100g)	2.75	1.65	2.40	2.20	2.90	4.90	1.60	2.55
Mg (Meq/100g)	0.65	0.39	0.56	0.42	0.49	1.64	0.53	0.69
K (Meq/100g)	0.08	0.06	0.09	0.08	0.14	0.16	0.08	0.13
Na (ppm)	10	10	10	20	<10	<10	40	10
Fe[(a)] (%)	0.035	0.024	0.033	0.022	0.018	0.118	0.063	0.015
Al[(a)] (%)	0.015	0.011	0.018	0.012	0.013	0.035	0.025	0.011
% base saturation[(b)]	67.2	63.6	60.4	67.5	71.6	63.2	44.1	73.7
Cation Exchange Capacity (CEC)[(c)]	5	2	3	3	4	11	5	4
Soil Physical Analysis								
% Sand	68.2	63.8	70.4	63.8	62.0	69.3	64.3	54.7
% Silt	25.6	32.1	23.9	29.2	29.0	17.0	28.3	35.9
% Clay	6.2	4.1	5.8	7.0	9.0	13.7	7.4	9.4
Soil Texture[(d)]	Silty sand	Silty sand	Silty sand	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam

*BEAK 1987b

a = Pyrophosphate extractable Fe and Al.
b = Proportion of CEC occupied by bases is termed % base saturation.
c = CEC calculated value: Ca+Mg+K/Ca+ Mg+K+Al.
d = Sand, silt and clay fractions based on Canadian System Soil Classification standards where: sand = 2.0 to 0.05 mm; silt = 0.05 to 0.002 mm; clay = <0.002 mm.

Table IX-2
Summary of the Chemical and Physical Characteristics of a Brunisolic Static Cryosol in the Kiggavik Project Study Area*

	Site LG005 Horizon	
	Bm	**Cgz**
Horizon Thickness (cm)	0 to 12	12 to 29
Soil Chemistry		
pH ($CaCl_2$)	5.4	4.5
Ca (Meq/100g)	1.9	0.7
Mg (Meq/100g)	0.53	0.29
K (Meq/100g)	0.05	0.04
Na (ppm)	30	40
Fe[a] (%)	0.033	0.038
Al[a] (%)	0.015	0.009
% base saturation[b]	59.3	50.7
Cation Exchange Capacity (CEC)[c]	3	1
Soil Physical Analysis		
% Sand	64.8	66.9
% Silt	30.7	31.5
% Clay	4.6	1.6
Soil Texture[d]	Silty sand	Silty sand

*BEAK 1987b
a = Pyrophosphate extractable Fe and Al.
b = Proportion of CEC occupied by bases is termed % base saturation.
c = CEC calculated value: Ca+Mg+K/Ca+ Mg+K+Al.
d = Sand, silt and clay fractions based on Canadian System Soil Classification standards where: sand = 2.0 to 0.05 mm; silt = 0.05 to 0.002 mm; clay = <0.002 mm.

Table IX-3
Summary of the Chemical and Physical Characteristics of a Gleysolic Static Cryosols in the Kiggavik Project Study Area*

	Site LG004 Horizon	
	Cg	**Cg2**
Horizon Thickness (cm)	0 to 35	35 to 90
Soil Chemistry		
pH ($CaCl_2$)	4.0	5.4
Ca (Meq/100g)	0.37	1.45
Mg (Meq/100g)	0.16	0.49
K (Meq/100g)	0.05	0.09
Na (ppm)	<10	20
Fe[(a)] (%)	0.025	0.024
Al[(a)] (%)	0.008	0.012
% base saturation[(b)]	39.2	61.0
Cation Exchange Capacity (CEC)[(c)]	<1	2
Soil Physical Analysis		
% Sand	75.1	72.8
% Silt	24.1	21.5
% Clay	0.8	5.7
Soil Texture[(d)]	Loamy sand	Loamy sand

*BEAK 1987b
a = Pyrophosphate extractable Fe and Al.
b = Proportion of CEC occupied by bases is termed % base saturation.
c = CEC calculated value: Ca+Mg+K/Ca+ Mg+K+Al.
d = Sand, silt and clay fractions based on Canadian System Soil Classification standards where: sand = 2.0 to 0.05 mm; silt = 0.05 to 0.002 mm; clay = <0.002 mm.

APPENDIX X

VEGETATION

Table X-1
Polygon Attributes used in the Kiggavik Mapping Program as Listed in dbase III File

1	ECO SEC	eco section
2	POLYGON NUMBER	
3	LANDFORM	
	Parent Material Modifiers	
		b: bouldery
		g: gravelly
		s: sandy
		c: silty/clayey
		p: peat/muck
		t: till
	Genetic Parent Material	
		M: Morainal
		G: Glaciofluvial
		T: Modified Morainal Material
		L: Lacustrine
		0: Organic
		R: Bedrock
4	TOPOGRAPHY	
	Relief Modifiers	
		c: channelled
		d: dissected/gullied
		f: felsenmeer
		h: hummocky
		j: jagged, rugged, cliffed
		l: level
		m: terraced
		n: stripes, polygons, frost boils
		r: ridged (drumlinoid)
		s: sloping
		t: tussocky
		u: undulating/rolling
		v: veneer

Table X-1
Polygon Attributes used in the Kiggavik Mapping Program as Listed in dbase III File (Continued)

5	UPLAND VEGETATION	
	U: Upland	
	Physiognomic Modifier	
		g: graminoid
		h: heath (less than 30 cm)
		s: shrub (greater than 30 cm)
		1: lichen steppe
		m: moss-heath
		n: lichen-heath
		r: rock barrens
6	WETLAND VEGETATION	
	W: Wetland	
	Physiognomic Modifier	
		g: graminoid
		h: heath (less than 30 cm)
		s: shrub (greater than 30 cm)
		t: tussocky
7	RELIEF	
	Local Relief	
		H: mainly high local relief (greater than 50 m)
		M: mainly moderate local relief (20 to 50 m)
		L: mainly low local relief (0 to 20 m)
	HYDROLOGY	
8	% Cover Water	
		1: 0-10
		2: 10-25
		3: 25-50
		4: 50+
9	Hydrologic Type	
		1: lake, pond, pool
		s: river, stream, creek
10	AREA (ha)	
Source: BEAK 1987a		

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes*

ECO SEC	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	AREA (ha)
ALN	1	bstM	gsG	p0	dc	Unlr	Wsg	L	1	s	70.3
ALN	2	bstM	gsG	p0	dc	Unlr	Wsg	L	1	s	162.5
ALN	3	bstM	gsG	p0	nst	Un	Wsg	L	1	s	78.5
ALN	4	bstM	gsG	p0	dc	Unlr	Wsg	L	1	s	599.7
ALN	5	p0	bstM		v	Un	Wsg	L	3	s	204.0
ALN	6	stM	p0		ru	Uns	Wsg	L	1	s	397.3
ALN	7	bstM			lv	Urn		L	1	s	27.1
ALN	8	bstM			sl	Urn		L	1	s	71.6
ALN	9	bstM	p0		svt	Unr	Wsg	L	3	ls	183.7
ALN	10	bstM			lv	Urn		L	1	s	28.0
ALN	11	bstM	bvr	p0	rdc	Unr	Wsg	M	2	ls	76.5
ALN	12	sgG	p0		uv	Urn	Wsg	L	1	s	601.8
ALN	13	sgG	bgG	p0	ndt	Urn	Ws	M	1	sl	652.2
ALN	14	stM	p0	R	rnc	Urnh	Wsg	M	1	ls	1211.1
ALN	15	stM	p0	R	usj	Urnh	Wsg	M	1	ls	1464.6
ALN	47	stM	bgG		uc	Un		L	1	s	35.5
ALN	48	sgG	bgG	p0	ndt	Urn	Ws	M	1	sl	119.8
ALN	49	bstM	bvR	p0	rdc	Unr	Wsg	M	2	ls	1014.6
ALN	51	bstM	byR	p0	dut	Url	Wgs	L	2	l	763.3
ALN	52	ctM	stM		du	Uln		L	2	l	442.3
ALN	53	bstM			nu	Uns		L	1	s	299.5
ALN	54	bstM	ctM	p0	dut	Uls	Wgs	L	2	ls	477.0
ALN	55	bstM	p0		tu	Urn	Wsg	L	3	ls	254.8

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes* (Continued)

ECO SEC	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	AREA (ha)
ALN	56	bstM	p0		ut	Unr	Wsg	L	1	s	801.0
ALN	57	bstM	gsG	p0	nst	Un	Wsg	L	1	s	1832.1
ALN	58	gstM			ls	Unr		L	1	s	145.3
ALN	59	gstM	bR		is	Unr	Ws	L	1	s	112.4
ALN	60	bstM	p0		dt	Urln	Wsg	M	1	s	215.0
ALN	61	bstM	p0	sgG	rdt	Urln	Wsg	M	1	s	708.4
ALN	62	bstM	p0		mst	Urln	Wsg	M	1	s	569.5
ALN	63	bstM	p0	sgG	rdt	urln	Wsg	M	1	sl	143.0
ALN	64	bstM	p0	sgG	rdt	Urln	Wsg	M	1	sl	1259.8
ALN	65	gstM	p0		dc	Unh	Wsg	M	1	s	794.7
ALN	66	gstM			du	Unh		M	1	s	125.6
ALN	67	bstM	p0		ud	Unh	Wsg	L	1	s	164.5
ALN	68	bstM	p0		rdt	Ung	Wsg	M	3	ls	1468.2
ALN	69	gstM	p0		dct	Uns	Wsg	M	1	s	451.5
ALN	70	gsG	gstM	p0	dnt	Uns	Wsg	M	1	ls	844.8
ALN	71	gsG	gsA	p0	cd	Ul	ws	M	1	s	452.3
ALN	72	gsG	gsA		cdn	Ul	Wsg	M	1	ls	1055.7
ALN	73	gsG	bcth	p0	uv	Uns	Ws	L	1	sl	286.5
ALN	74	bstM	sgG		su	Unh		M	1	s	609.6
ALS	108	bstM	bvR	p0	lu	Urh		L	1	s	573.7
ALS	109	bctM	p0		nst	Urh	Wg	L	1	s	680.6
ALS	110	bgsG	gsA	p0	scd	Ulr	Wsg	M	1	s	1083.1
ALS	111	gstM	bvR		ls	Urh		L	1	s	478.4

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes* (Continued)

ECO SEC	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	AREA (ha)
ALS	112	gstM	p0	bvR	ls	Urh		L	1	sl	578.8
ALS	113	gstM	p0		nst	Urh	Wgs	L	1	ls	1073.4
ALS	114	bstM	R		ns	Umh		L	1	l	251.7
ALS	115	bstM			us	Urn		M	1	s	156.1
ALS	116	gsG			ds	Uln		H	1	s	195.5
ALS	117	bstM	gsG		dcs	Ulrs		M	1	s	20.9
ALS	118	bstM			dst	Uirs		L	1	s	75.3
ALS	119	bstM	gsG		ds	Ulrs		M	1	s	108.1
ALS	120	bstM	gsG	p0	dr	Uln		M	1	l	365.5
ALS	121	bstM	gsG		dcs	Urln		M	1	s	143.9
ALS	122	bstM	p0		dsn	Umh	Ws	L	1	s	745.9
ALS	123	bstM	gsG		d	Uln		M	2	l	305.9
ALS	124	gstM	p0		rsnt	Urhl	Wgs	L	1	ls	702.1
ALS	125	gstM			sn	Umhl		L	1	ls	133.4
ALS	126	bstM	p0		ns	Umh	Ws	L	1	ls	60.5
ALS	127	gstM			is	Unh		L	1	l	54.3
ALS	128	bstM			nrs	Unh		L	1	ls	573.8
ALS	129	bstM	p0		nsut	Unrs	Ws	L	1	ls	1308.3
ALS	130	bstM	p0		ls	Urh		L	1	s	166.6
ALS	131	bstM			nrs	Unh		L	1	l	57.5
ALS	135	bstM	p0		st	Urhl	Wgs	L	1	s	202.1
ALS	136	bstM	byR	p0	vt	Urhl	Wgs	L	1	ls	1218.2

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes* (Continued)

ECO SEC	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	AREA (ha)
ALS	137	R	bstM		js	Urns		M	1	l	206.7
SQL	25	R	ctM		jfs	Unh		M	1	ls	331.8
SQL	30	bR	ctM		jfs	Unh		M	1	s	97.9
SQL	32	bstM	p0		sh	Umnh	Ws	L	1	sl	317.1
SQL	33	bR			jfs	Unh		M	1	sl	543.9
SQL	34	ctM	stM	p0	nrs	Unhr	Ws	M	1	ls	4757.9
SQL	36	bstM	R	p0	jcy	Urnh	Ws	M	1	ls	33.3
SQL	37	p0			st		Whsg	L	1	s	128.9
SQL	38	p0	bcth		std	Unh	Whsg	L	1	s	177.5
SQL	39	bctM			ru	Unh		L	1	l	269.8
SQL	40	p0			vlt			L	3	l	315.8
SQL	41	bctM			ru	Unh		L	1	l	668.3
SQL	42	p0			vtl		Wgs	L	4	l	188.9
SQL	43	p0			st		Whsg	L	1	s	79.6
SQL	44	bctM	bstM	p0	st	Unhs	Wsh	L	1	sl	370.5
SQL	45	p0			st		Whsg	L	1	ls	170.5
SQL	46	bstM	bstM		us	Uhn		L	1	ls	100.2
SQL	50	ctM			u	Unh		L	1	s	882.2
SQL	75	ctM	vR	sgG	dsu	Unhr		M	1	sl	788.8
SQL	76	ctM	p0		ut	Umnh	Wth	L	2	l	563.8
SQL	77	R	p0		jt	Ur	Wts	H	1	ls	103.2
SQL	78	p0			lt		Wgs	L	0		88.8

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes* (Continued)

ECO SEC	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	AREA (ha)
SQL	79	ctM	R	p0	ujhf	Umns	Wsh	M	1	ls	968.9
SQL	139	bctM			uth	Unm		L	1	s	59.1
SKL	16	bstM	R	p0	jcy	Urnh	Ws	M	1	ls	2092.1
SKL	17	sgG	po		ndl	Uln	Wsg	L	1	ls	82.1
SKL	18	stM	p0		nud	Uln	Wsg	L	1	ls	936.2
SKL	19	stM	p0		dr	Uln	Wsg	L	2	ls	635.2
SKL	20	stM			ru	Uln		L	1	ls	223.1
SKL	21	stM	p0		ru	Uln	Ws	L	2	ls	2380.4
SKL	22	stM			ru	Uln		L	1	ls	22.2
SKL	23	sgT			sn	Ulns		M	1	l	3836.5
SKL	24	sgT	R		njs	Unl		L	1	l	680.7
SKL	26	sgT			dnr	Uln		M	1	ls	831.8
SKL	27	stM	p0		nud	Uln	Wsg	L	1	ls	48.1
SKL	28	sgG	p0		ns	Uln	Wsg	L	1	l	145.8
SKL	29	sgG			nd	Ulgn		L	1	ls	141.1
SKL	31	sgG	p0		ndl	Uln	Wsg	L	1	ls	266.8
SKL	35	sgt	p0		s	Uln	Wsg	L	1	s	184.2
KIG	80	ctM	bR		jfs	Urn		M	1	s	119.5
KIG	81	ctM	p0		rn	Umn	Wsg	M	1	ls	1761.6
KIG	82	bsgT	bG	p0	lnt	Uln	Wsg	L	1	ls	1912.8
KIG	83	bctM	sgG		nr	Unls		L	1	l	3991.2
KIG	84	bR			vs	Un		L	1	s	99.1
KIG	89	ctM	p0		rtun	Uln	Wsg	L	1	l	2477.3

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes* (Continued)

ECO SEC	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	AREA (ha)
KIG	90	bp0	bl	ctM	vtl	Umn	Wsg	L	2	sl	749.4
KIG	91	p0	bp0		ts		Wsg	L	3	sl	253.7
KIG	92	ctM			sn	Umn		L	1	l	362.1
KIG	93	ctM	p0		ut	Umn	Wsg	L	1	l	114.2
KIG	94	p0	ctM		tl	Umn	Wsg	L	4	ls	247.9
KIG	95	ctM	p0		ut	Umn	Wsg	L	1	l	213.8
KIG	96	p0	ctM	R	tlvf	Um	Wshg	L	1	s	512.5
KIG	97	ctM	p0	sgG	udht	Umnh	Wshg	M	1	ls	248.3
KIG	98	p0			lt		Wshg	L	2	ls	385
KIG	99	bctM	sgG		usd	Unhl		M	1	ls	910.1
KIG	100	p0	sgG		ltd	Un	Whsg	L	2	sl	89.4
KIG	101	ctM	sgS		us	Umhl		L	1	ls	347.2
KIG	102	bctM	p0		sl	Unh	Wsg	L	1	ls	446.5
KIG	103	ctM			us	Unh		L	1	l	145.6
KIG	104	ctM	p0		ut	Unh	Wsg	L	1	ls	2556.7
KIG	105	ctM	bctM		dv	Umh	Ws	L	1	sl	377.9
KIG	106	bctM	p0		v	Urh	Wsg	L	1	sl	140.6
KIG	107	bctM	p0		b	Urh	Wsg	L	1	sl	308.4
KIG	132	bctM	p0		nsut	Uns	Ws	L	1	ls	358.9
KIG	133	ctM	p0	bstM	slt	Unr	Wgs	L	2	ls	59.2
KIG	134	ctM	p0	bstM	slt	Unr	Wgs	L	2	ls	912.9
KIG	138	bR	p0	ctM	vj	Urn	Wsg	M	2	ls	336.1
KIG	140	bctM	p0	R	ruth	Umn	Wsg	L	1	s	784.2

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes* (Continued)

ECO SEC	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	AREA (ha)
KIG	141	bctM	p0		utnh	Umn	Wsg	L	1	ls	89.9
KIG	142	ctM	p0		uhvt	Umn	Wsg	L	1	s	373.8
KIG	143	bp0			vl		Wsg	L	1	s	33.7
KIG	144	bctM			rsh	Um		L	1	s	211.2
KIG	145	bp0			tvl		Wsg	L	4	ls	154.5
KIG	146	bp0	bctM		tvl		Wsg	L	2	ls	128.8
KIG	147	ctM			urn	Umns		L	1	sl	853.2
KIG	148	ctM			ut	Unm		L	1	ls	718.4
KIG	149	bp0		ctM	svt	Um	Wsg	L	1	sl	303.4
KIG	150	bp0			l		Wshg	L	3	sl	115.6
KIG	151	bp0		ctM	svt	Um	Wsg	L	1	sl	318.6
KIG	152	bR			jsv	Urn		M	1	l	171.2
KIG	153	bctM		p0	uvt	Umn	Wsg	L	1	ls	531.2
KIG	154	bctM		p0	ltn	Umn	Wsg	L	1	s	442.4
KIG	155	bctM		p0	rns	Umn	Wsg	L	1	s	581.0
KIG	156	bctM		p0	nl	Umn	Wsg		1	s	332.9
KIG	157	bp0		bctM	tlv	Un	Wsg	L	1	sl	124.6
KIG	158	bp0		bctM		Umn	Wsg	M	1	ls	336.9
KIG	159	ctM			rns	Umn		M	1	l	487.0
KIG	160	bctM		p0	rnsh	Umn	Wsg	M	1	ls	1018.9
KIG	162	bctM			urn	Umn		L	1	l	511.9
KIG	163	p0			vlt		Wsg	L	2	l	167.9
KIG	166	ctM	gsT		un	Umnl		L	1	s	238.1

Table X-2
Kiggavik Study Area ELS Map Ecosite Polygon Attributes* (Continued)

Eco Sec	Polygon #	Primary landform	Secondary landform	Tertiary landform	Topol	Upland vegetation	Wetland vegetation	Relief	Hy	dro	Area (ha)
SIL	85	bR	sgT		js	Unl		M	2	l	771.7
SIL	86	sgT	p0		dtn	Unl	Wsg	L	1	ls	587.0
SIL	87	bR		p0	njs	Unl	Wsg	L	1	ls	557.3
SIL	88	gsT	R	p0	ln	Ulns	Wsg	L	1	sl	583.8
SIL	161	gsT	ctM		un	Umn	Wsg	L	2	ls	259.4
SIL	164	gsT	p0		unr	Umn	Wsg	L	2	l	485.8
SIL	165	ctM	gsT	p0	shn	Unsm	Wsg	L	1	s	169.8
SIL	167	ctM	gsT		unh	Umnh		L	1	s	370.9
SIL	168	ctM	gsT		snh	Umnh		L	1	s	162.3
SIL	169	ctM	gsT		sln	Ushn	Wsh	L	1	ls	179.7
SIL	170	gsT	p0		ud	Unh	Wsg	L	1	ls	431.2
SIL	171	ctM	p0		ln	Ushn	Wshg	L	1	s	172.1
SIL	172	p0	sgT		nl	Un	Wsg	L	2	ls	1475.9
SIL	175	bcT	R		ns	Umn		L	1	s	294.6
SIL	174	R	sgT		nsj	Un	Wsg	L	1	ls	381.7
SIL	175	bcT	p0		sn	Umns	Ws	L	1	ls	1062.0
SIL	176	p0	sgL		tv		Wgs	L	3	s	56.0
SIL	177	bcT	p0		sn	Umns	Ws	L	1	ls	689.3

Source: BEAK 1987b

* see Table A6.1 for coding explanations

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form)

Scientific Name	Common Name	Study*					Synonyms
Shrubs and Heaths							
Andromeda polifolia	andromeda		2	3		5	
Arctostaphylos alpina	alpine bearberry		2	3	4	5	
Arctostaphylos rubra	red bearberry	1	2	3			
Betula glandulosa	dwarf birch	1	2	3	4	5	
Cassiope tetragona	white arctic mountain heather	1	2	3	4	5	
Dryas integrifolia	entire-leaf mountain-avens	1	2	3	4	5	
Empetrum nigrum	black crowberry	1	2	3	4	5	
Kalmia polifolia	bog laurel				4	5	
Ledum decumbens	northern Labrador tea	1	2	3	4	5	
Loiseleuria procumbens	alpine azalea	1	2	3			
Phyllodoce caerulea	blue mountain heather	1	2				
Rhododendron lapponicum	Lapland rosebay	1	2		4	5	
Rubus chamaemorus	cloudberry				4	5	
Salix alaxensis	river willow	1	2				
Salix arctica	arctic willow	1	2	3	4	5	
Salix cordifolia	gray willow	1	2				*Salix glauca* ssp. *callicarpaea*
Salix fuscescens	Alaska bog willow			3	4	5	
Salix herbacea	snowbed willow	1	2	3	4	5	
Salix planifolia	diamond leaf willow			3	4	5	
Salix reticulata	net leaf willow	1	2	3	4	5	
Salix richardsonii	Richardson's willow	1	2		4	5	*Salix lanata* ssp. *richardsonii*
Salix spp.	willow	1	2				
Shepherdia canadensis	russet buffaloberry				4		
Vaccinium uliginosum	bilberry; bog blueberry	1	2	3	4	5	
Vaccinium vitis-idaea	lingonberry	1	2	3	4	5	
Forbs							
Antennaria ekmaniana	Fries's pussytoes				4	5	*Antennaria friesiana* ssp. *friesiana*
Arabis arenicola	rock-cress	1	2				
Arenaria spp.	sandwort	1	2				
Armeria maritima	thrift seapink		2	3	4	5	
Artemisia borealis	field sagewort				4	5	*Artemisia campestris* ssp. *borealis* var. *borealis*
Artemisia spp.	wormwood		2				
Aster spp.	aster						
Astragalus alpinus	alpine milkvetch		2	3			
Astragalus eucosmus	elegant milkvetch		2				
Astragalus sp.	milkvetch			3			

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Braya purpurascens	smooth northern rockcress	1	2				*Braya glabella* ssp. *purpurascens*
Cardamine bellidifolia	alpine bittercress	1	2		4	5	
Cardamine digitata	Richardson's bittercress			3			
Caryophyllaceae	pink family	1	2				
Castilleja elegans	elegant Indian paintbrush			3	4		
Castilleja pallida	Indian paintbrush		2				
Castilleja raupii	Raup's Indian paintbrush					5	
Cerastium arcticum	arctic mouse-ear chickweed	1	2				
Cerastium spp.	mouse-ear chickweed	1	2				
Cochlearia officinalis	scurvygrass	1	2				
Brassicaceae	mustard family		2				
Draba alpina	alpine draba	1	2				
Draba bellii	flat-top draba	1	2				
Draba lactea	milky draba	1	2				
Draba nivalis	yellow arctic draba				4	5	
Draba oblongata	Canadian arctic draba	1	2				
Draba sp.	draba	1	2				
Epilobium latifolium	dwarf fireweed		2		4	5	*Chamerion latifolium*
Erigeron humilis	arctic alpine fleabane				4		
Eutrema edwardsii	Edwards' mock wallflower	1	2	3			
Hedysarum alpinum var. *americanum*	liquorice-root				4		
Hedysarum mackenziei	Mackenzie's sweetvetch		2				*Hedysarum boreale* ssp. *mackenziei*
Hippuris vulgaris	common mare's-tail				4		
Matricaria ambigua	false mayweed				4	5	*Tripleurospermum maritimum* ssp. *phaeocephalum*
Melandrium apetalum	apetalous catchfly	1	2				*Silene uralensis* ssp. *uralensis*
Minuartia rubella	beautiful sandwort				4	5	
Minuartia stricta	bog stitchwort				4	5	
Oxyria digyna	alpine mountainsorrel	1	2		4		
Oxytropis arctica	arctic locoweed		2		4	5	
Oxytropis bellii	Bell's locoweed			3	4		
Oxytropis maydelliana	Maydell's oxytrope		2	3	4	5	*Oxytropis maydelliana* ssp. *maydelliana*
Oxytropis sp.	oxytrope; crazyweed			3		5	
Papaver radicatum	rooted poppy	1	2		4	5	
Parrya arctica	arctic false wallflower	1	2				

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Parrya nudicaulis	nakedstem wallflower	1	2				
Parrya spp.	parrya	1	2				
Pedicularis arctica	arctic lousewort		2				*Pedicularis langsdorffii* ssp. *arctica*
Pedicularis lanata	woolly lousewort		2				
Pedicularis lapponica	Lapland lousewort		2				
Pedicularis sudetica	sudetic lousewort		2	3	4	5	
Pedicularis sp.	lousewort			3			
Pinguicula vulgaris	common butterwort				4	5	
Polygonum viviparum	alpine bistort	1	2	3	4	5	
Potentilla hyparctica	arctic cinquefoil		2				*Potentilla nana*
Potentilla palustris	purple marshlocks			3	4	5	*Comarum palustre*
Potentilla rubricaulis	Rocky Mountain cinquefoil				4	5	
Potentilla vahliana	Vahl's cinquefoil		2				
Potentilla spp.	cinquefoil		2				
Pyrola grandiflora	large-flowered wintergreen		2	3	4	5	
Ranunculus sabinei	Sabine buttercup	1	2				
Ranunculus sulphureus	sulphur buttercup	1	2				
Sagina intermedia	snow pearlwort	1	2				*Sagina nivalis*
Saussurea angustifolia	narrow-leaf sawwort			3	4	5	
Saxifraga aizoides	yellow mountain saxifrage			3			
Saxifraga caespitosa	tufted bulrush		2		4		
Saxifraga cernua	nodding saxifrage		2	3			
Saxifraga flagellaris	Saxifraga flagellaris		2				
Saxifraga foliolosa	leafy-stem saxifrage		2		4	5	
Saxifraga hieraciifolia	hawkweed-leaved saxifrage		2				
Saxifraga hirculus	yellow marsh saxifrage		2				
Saxifraga nivalis	alpine saxifrage		2				
Saxifraga oppositifolia	purple mountain saxifrage		2				
Saxifraga tenuis	Ottertail Pass saxifrage		2				
Saxifraga tricuspidata	three toothed saxifrage		2	3	4	5	
Sedum lanceolatum	spear-leaf stonecrop				4	5	
Silene acaulis	moss campion	1	2	3	4	5	
Stellaria longipes	long-stalk starwort	1	2	3	4	5	

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Graminoids							
Arctagrostis latifolia	wide-leaf polargrass	1	2	3	4	5	
Agropyron latiglume	Alaskan wheatgrass	1	2				*Elymus alaskanus* ssp. *latiglumis*
Alopecurus alpinus	boreal alopecurus	1	2				
Calamagrostis lapponica	Lapland reedgrass			3	4		*Calamagrostis lapponica* var. *nearctica*
Carex aquatilis	water sedge		2	3	4	5	*Carex aquatilis* var. *stans*
Carex bigelowii	Bigelow's sedge		2	3	4	5	
Carex capillaris	hair-like sedge				4	5	
Carex chordorrhiza	creeping sedge				4	5	
Carex glacialis	alpine sedge		2				
Carex holostoma	arctic marsh sedge			3	4	5	
Carex membranacea	fragile sedge				4	5	
Carex misandra	short-leaved sedge		2				
Carex nardina	spike sedge				4	5	
Carex norvegica	Norway sedge				4	5	
Carex rariflora	loose-flower alpine sedge		2		4	5	
Carex rostrata	beaked sedge		2				
Carex rotundata	round sedge				4	5	
Carex rupestris	curly sedge				4	5	
Carex saxatilis	rock sedge			3	4	5	
Carex scirpoidea	northern single-spike sedge		2				
Carex stans	tundra sedge		2				
Carex vaginata	sheathed sedge			3	4	5	
Carex williamsii	Williams' sedge				4	5	
Colpodium vahlianum	Vahl's alkaligrass	1	2				*Puccinellia vahliana*
Dupontia fisheri	Fisher's tundragrass	1	2				
Elymus arenarius ssp. *mollis*	American dunegrass				4	5	*Elymus mollis*
Eriophorum angustifolium	tall cottongrass		2	3	4	5	
Eriophorum scheuchzeri	white cottongrass		2				
Eriophorum spp.	cottongrass		2				
Eriophorum vaginatum	tussock cottongrass		2		4	5	*Eriophorum vaginatum* ssp. *spissum*
Eriophorum triste	tall cottongrass		2				*Eriophorum angustifolium* ssp. *triste*
Festuca baffinensis	Baffin fescue	1	2				
Festuca brachyphylla	alpine fescue	1	2				

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Hierochloe alpina	alpine sweetgrass	1	2	3	4	5	*Anthoxanthum monticola* ssp. *alpinum*
Juncaceace spp	rush family		2				
Juncus albescens	northern white rush				4	5	
Juncus biglumis	two-flowered rush		2				
Juncus castaneus	chestnut rush				4	5	
Kobresia myosuroides	Bellardi bog sedge				4	5	
Luzula confusa	northern woodrush		2	3	4	5	
Luzula nivalis	arctic woodrush		2	3			*Luzula arctica* ssp. *arctica*
Luzula sp.	woodrush				4	5	
Luzula spicata	spiked woodrush				4	5	
Luzula wahlenbergii	Wahlenberg's woodrush		2		4	5	
Phippsia algida	icegrass	1	2				
Pleuropogon sabinei	false semaphoregrass	1	2				
Poa abbreviata	short bluegrass	1	2				
Poa alpigena	northern meadow grass	1	2				*Poa pratensis* ssp. *alpigena*
Poa arctica	arctic bluegrass	1	2				
Poa glauca	glaucous bluegrass				4	5	
Poa spp.	bluegrass	1	2				
Poaceae	grass family	1					
Puccinellia bruggemannii	Prince Patrick alkaligrass	1	2				
Scirpus caespitosus	tufted bulrush				4	5	*Trichophorum cespitosum*
Tofieldia pusilla	Scotch false asphodel				4	5	
Trisetum spicatum	spike trisetum	1	2				
Ferns and allies							
Equisetum arvense	field horsetail			3		5	
Equisetum variegatum	variegated scouring-rush		2				
Lycopodium clavatum	running clubmoss				4	5	
Lycopodium selago	fir clubmoss	1	2	3	4	5	*Huperzia selago* var. *selago*
Lycopodium sp.	clubmoss				4	5	
Woodsia ilvensis	rusty woodsia				4		

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Bryophytes							
Aulacomnium sp.				3		5	
Aulacomnium turgidum	turgid aulacomnium moss		2			5	
Bryophyta	unknown mosses	1					
Calliergon sarmentosum	sarmenthypnum moss					5	*Sarmenthypnum sarmentosum*
Calliergon sp.	watermoss					5	
Campylium stellatum	star campylium moss					5	
Cinclidium latifolium	wideleaf cinclidium moss					5	
Dicranum acutifolium	acute-leaf dicranum moss					5	
Dicranum elongatum	elongate dicranum moss		2			5	
Dicranum sp.	dicranum moss			3		5	
Dicranum spadiceum	dicranum moss					5	
Grimmia affinis	grimmia dry rock moss					5	
Hylocomium splendens	step moss					5	
Limprichtia revolvens	limprichtia moss					5	
Loeskypnum badium	loeskypnum moss					5	*Sarmenthypnum sarmentosum*
Oncophorus wahlenbergii	Wahlenberg's oncophorus moss					5	
Physconia muscigena	frosted lichen					5	
Pleurozium schreberi	Schreber's big red stem moss					5	
Pleurozium sp.	big red stem moss			3			
Polytrichum sp.	haircap moss					5	
Polytrichum strictum	polytrichum moss					5	
Ptilidium ciliare	northern naugehyde liverwort					5	
Racomitrium lanuginosum	woolly fringe moss		2			5	
Racomitrium sp.	racomitrium moss			3			
Rhytidium rugosum	rhytidium moss					5	
Sphagnum fuscum	rusty peat moss			3			
Sphagnum russowii	Russow's sphagnum					5	
Sphagnum spp.	sphagnum moss	1	2	3		5	
Sphagnum subsecundum	slender cow-horn bog-moss					5	

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Lichens							
Alectoria nigricans	gray witch's hair lichen					5	
Alectoria ochroleuca	green witch's hair lichen	1	2		4		
Allantoparmelia alpicola	allantoparmelia lichen					5	
Arctoparmelia centrifuga	sunburst lichen					5	
Arctoparmelia incurva	arctoparmelia lichen					5	
Arctoparmelia separata	arctoparmelia lichen						
Arctoparmelia separata	bryocaulon lichen					5	
Cetraria andrejevii		1	2			5	*Arctocetraria andrejevii*
Cetraria cucullata	crinkled snow lichen				4		*Flavocetraria cucullata*
Cetraria delisei	snow bed Iceland lichen	1	2			5	
Cetraria islandica	Iceland moss	1	2	3			
Cetraria islandica ssp. *crispiformis*	brown island moss					5	
Cetraria islandica ssp. *islandica*	island cetraria lichen					5	
Cetraria laevigata	cetraria lichen				4		
Cetraria nigricans	cetraria lichen					5	
Cetraria nivalis	ballroom dervish	1	2	3	4		*Flavocetraria nivalis*
Cetraria tilesii		1	2				*Vulpicida tilesii*
Cladina alpestris	star reindeer lichen	1	2			5	*Cladina stellaris*
Cladina mitis	lesser green reindeer lichen					5	
Cladina rangiferina	grey green reindeer lichen	1	2	3	4		
Cladina sp.	reindeer lichen			3			
Cladonia amaurocraea	cup lichen	1	2		4		
Cladonia arbuscula						5	
Cladonia bellidiflora	toy soldiers lichen	1	2				
Cladonia chlorophaea	mealy pixie-cup	1	2				
Cladonia coccifera	cup lichen	1	2			5	
Cladonia gracilis ssp. *gracilis*	cup lichen					5	
Cladonia laevigata	cup lichen					5	
Cladonia phyllophora	cup lichen					5	
Cladonia pleurota	red-fruited pixie-cup					5	
Cladonia pocillum	cup lichen					5	
Cladonia sp.	cup lichen				4		
Cladonia stricta	cup lichen					5	
Cladonia uncialis	cup lichen					5	

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Cladonia verticillata	cup lichen	1	2				*Cladonia cervicornis* ssp. *verticillata*
Collema ceraniscum	jelly lichen					5	
Cornicularia divergens	bryocaulon lichen	1	2				*Bryocaulon divergens*
Cornicularia sp.				3			
Dactylina arctica	glove lichen	1	2		4		
Dactylina sp.	dactylina lichen				4		
Icmadophila ericetorum	peppermint drop lichen					5	
Lecanora rupicola	rim lichen					5	
Lecidea auriculata	lecidea lichen					5	
Lecidea lapicida	lecidea lichen					5	
Ochrolechia frigida	cold crabseye lichen					5	
Ochrolechia sp.	crabseye lichen					5	
Parmelia omphalodes ssp. *omphalodes*	shield lichen					5	
Peltigera aphthosa	latex pelt, freckle pelt					5	
Peltigera rufescens	felt lichen					5	
Peltigera sp.	pelt lichen				4		
Pertusaria coriacea	leathery pore lichen	1	2			5	
Pertusaria dactylina	white finger lichen	1	2			5	
Pertusaria panyrga	pore lichen					5	
Porpidia flavicunda	porpidia lichen					5	*Porpidia flavocaerulescens*
Porpidia thomsonii	Thomson's porpidia lichen					5	
Rhizocarpon badioatrum	map lichen					5	
Rhizocarpon eupetraeoides	map lichen					5	
Rhizocarpon geminatum	map lichen					5	
Rhizocarpon geographicum	world map lichen					5	
Rhizocarpon grande	big map lichen					5	
Rock crustose lichens		1	2				
Siphula spp.	whitefingers lichen	1	2				
Solorina bispora	chocolate chip lichen					5	
Solorina crocea	chocolate chip lichen	1	2				
Sphaerophorus globosus	globe ball lichen	1	2		4		
Spilonema revertens	spilonema lichen		2				
Stereocaulon albicans	mealy lichen	1	2				*Leprocaulon albicans*
Stereocaulon alpinum	alpine snow lichen					5	
Stereocaulon rivulorum	snow lichen				4		
Stereocaulon sp.	foam lichens			3		5	

Table X-3
A Compiled Plant Species Encountered in the Regional Study Area During the Various Studies (grouped by growth form) (Continued)

Scientific Name	Common Name	Study*					Synonyms
Thamnolia sp.	whiteworm lichen			3	4		
Thamnolia vermicularis	whiteworm lichen	1	2			5	
Toninia sp.	bruised lichen					5	
Tortella tortuosa	tortured tortella moss					5	
Umbilicaria proboscidea	navel lichen					5	
Umbilicaria sp.	navel lichen					5	
Umbilicaria torrefacta	navel lichen					5	
Verrucaria nigrescens	wart lichen					5	
Verrucaria nigrescens var. *laeviascula*	wart lichen					5	
Xanthoria elegans	elegant orange wall lichen					5	

* The number coincides with the following reports of the area.
1 BEAK 1987b. Summary of plant species compiled from existing studies of area (pre 1987) and during that study.
2 Wickware 1989. Summary of plant species compiled from existing studies of area (pre 1989) and during that study.
3 Geomatics International. 1990. Plants noted on the study site.
4 Geomatics International Inc. 1991. Preliminary results of species found in the study area. Lichens were preliminary pending confirmation.
5.Geomatics International Inc. 1991. List of raw species from data sheets - identification not confirmed

Table X-4
Study 3 Tabulated Raw Vegetation Survey Data for the Kiggavik Study Area

Plot Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	LST1	LST3	LST4
Habitat*		LS	SM	MH	LH RB	MH	LH	MH	LMH RB	MH Sh	ShH	MH	MH	SM	MH Sh	CM Sh	ST	MH	LH	LH RB	SM	MH	MH	MH SM	LH	MH RB	LH	MH SM	MH	Sh	SM	LMH	LH	LH	SH RB	MH SM	LMH	CB	MH	LH	LS
% bare earth / rocks		10	5	10	15	1	0	3	40	1	0	1	5	0	5	0	0	1	40	20	3	0	20	<5	60	10	90	10	1	0	10	0	20	2	0	0	0	75	0	20	0
richness		15	15	7	23	35	15	31	28	31	25	34	35	25	33	22	16	29	24	19	12	34	37	31	22	41	24	25	32	11	11	38	15	13	26	30	31	18	18	13	12
Andromeda polifolia	S							+																+					+										+		
Arctostaphylos alpina	S					+		+	+				+		+			+		+			+	+	0.5				+								+				
Betula glandulosa	S		+			+		1	0.5	2	7	0.5	2		4	3		2		+		3	+			1		0.5	0.5	9	+	0.5	0.5		6	+					
Cassiope tetragona	S				1.5	0.5	+	+	+		0.5	+			0.5					+		+	+	+		+		0.5	1			1		+			1			1	
Dryas integrifolia	S					0.5		+	+		+		+		+	+		+	+			+	+	+	0.5	+		+	+			0.5			+	+	2			6	
Empetrum nigrum	S	1			+	+	2		+				+		+	+			2	2			+		0.5	+	+						3	1	+		+	+			
Kalmia polifolia	S		+									+														+															
Ledum decumbens	S	+			+		+		+			+	+					+		+	+		+		+	+							+		+				2		+
Rhododendron lapponicum	S					+																							+			+					+			+	
Rubus chamaemorus	S																																						1		
Salix arctica	S		+			+		+	+	0.5	+	+	+	+	+	+		+	+	+		+	+	+	+	+		+	+			+			+	+	0.5				
Salix fucescens	S																				+										+										
Salix herbacea	S					+					+																														
Salix lanata	S																															+				+					
Salix planifolia	S										+		+	+				+					+			+															
Salix reticulata	S					+		+					+		+							+	+	+				+	+			+			+		+				
Vaccinium uliginosum	S					0.5		0.5		+	+	+	0.5		0.5	+	+	0.5	+	+		0.5	+	+	+	+	+		0.5			+			+	+	0.5			+	
Vaccinium vitis-idaea	S	+			+					+		+	+		+		+			+		+	+		+	+							0.5	+					+		+
Armeria maritima	F											+	+		+				+					+				+	+			+						+			
Antennaria ekmanniana	F																																					+			
Artemesia borealis	F																		+													+						+			
Cardamine bellidiflora	F							+																																	
Castilleja raupii	F					+																																			
Draba nivalis	F																								+		+											+			
Matricaria ambigua	F																															+									
Minuartia rubella	F																								+																
Minuartia stricta	F																		+																						
Oxytropis arctica	F																		+										+								+			+	
Oxytropis maydelliana ssp. maydelliana	F					+		+	+	+			+		+	+			+			+		+	+		+	+	+			+			+			+			
Oxytropis sp.	F																															+									

Table X-4
Study 3 Tabulated Raw Vegetation Survey Data for the Kiggavik Study Area (Continued)

Plot number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	LST1	LST3	LST4
Habitat*		LS	SM	MH	LH RB	MH	LH	MH	LMH RB	MH Sh	ShH	MH	MH	SM	MH Sh	CM Sh	ST	MH	LH	LH RB	SM	MH	MH	MH SM	LH	MH RB	LH	MH SM	MH	Sh	SM	LMH	LH	LH	SH RB	MH SM	LMH	CB	MH	LH	LS
Papaver radicatum	F														+																										
Pedicularis sudetica	F		+			+		+			+		+	+	+	+		+				+	+			+		+	+			+			+	+					
Pinguicula vulgaris	F																																							+	
Polygonum viviparum	F		+			+		+	+				+	+	+	+		+			+	+	+	+	+	+		+			+	+			+		+				
Potentilla nudicaulis	F																										+														
Potentilla palustris	F																														+										
Pyrola grandiflora	F																																		+						
Saussurea angustifolia	F					+		+	+	+	+	+	+		+	+		+				+	+	+				+	+			+			+	+	+				
Saxifraga foliosa	F													+							+																				
Saxifraga tricuspidata	F																		+						0.5		+										+	0.5			
Sedum lanceolata	F																																							+	
Silene acaulis	F					+		+			+				+	+			1			+	+	1		+	0.5	+	+			+			+	+	+	+		+	
Stellaria longipes	F																													+											
Arctagrostis latifolia	G					+		+	+	+	+	+	+		+	+			+			+	+	+		+		+	+			+			+	+			+		
Calamagrostis lapponica ssp. nearctica	G																																								+
Carex (combined cover)	G											6	4			5										4										4	0.5				
Carex aquatilis	G							2	2			p		4				5			8					2					4										
Carex aquatilis var. *stans*	G		6																																						
Carex bigelowii	G					+										4						+	2	+		+		2.5	+			1									
Carex capillaris	G					+		+	+		+	p	+		0.5	+					+		+	+		+									+	1	+				
Carex chordorrhiza	G													+																	2										
Carex holostoma	G																																						1		
Carex membranacea	G		+																										+												
Carex nardina	G																								+																
Carex norvegica	G											p		+							+																				
Carex rarif lora	G													+																	1										
Carex rotundata	G		+									+		+																											
Carex rupestris	G	+												+															+											+	
Carex saxatilis	G					+			+			p		+		+			+																	+				+	
Carex sp.	G									0.5	+							+	+	+						+		+		+		+			+	1.5	+	+			
Carex vaginata	G				+	2	+	+		+	+	p			+	1		1				+	2	1	1	1		1	+			+			1	+	+				
Carex williamsii	G		+											+							+																				

Table X-4
Study 3 Tabulated Raw Vegetation Survey Data for the Kiggavik Study Area (Continued)

Plot Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	LST1	LST3	LST4
Habitat*		LS	SM	MH	LH RB	MH	LH	MH	LMH RB	MH Sh	ShH	MH	MH	SM	MH Sh	CM Sh	ST	MH	LH	LH RB	SM	MH	MH	MH SM	LH	MH RB	LH	MH SM	MH	Sh	SM	LMH	LH	LH	SH RB	MH SM	LMH	CB	MH	LH	LS
Elymus arenarius ssp. *mollis*	G																																					+			
Epilobium latifolium	G								+																												+	+			
Eriophonim angustifolium	G					+		+	+		+	+	+		+							+	+	+		+										+				+	
Eriophorum sp.	G																														+								+		
Eriophorum spissum spp. *Spissum*	G																																			+					
Eriophorum vaginatum	G											+									+																				
Hierochloe alpina	G	+			+		+												+					+	+		+					+	+	+	+						
Juncus albescens	G													+																											
Juncus casteneus	G																						+																		
Kobresia myosuroides	G													+																											
Luzula confusa	G	+			+		+	+											+				+	+		+			+				+	+		+	+		+		
Luzula sp.	G								+																																
Luzula spicata	G		+																				+																		+
Luzula wahlenbergii	G																				+																				
Poa glauca	G																																					+			
Scirpus caespitosus	G								+					+												+															
Equisetum arvense	A																												+												
Lycopodium clavatum	A					+																																			
Lycopodium selago	A		+									###		+		+		+					+																		
Lycopodium sp.	A		+																																						
Aulacomnium schreberi	B																													+											
Aulacomnium turgidum	B			+		2		1.5	1	1.5	5	2	1	+	1	+	+	+	+		+	+	1	+		+		3	2		+	4			7	1	3	+			
Calliergon sarmentosa	B											1	0.5				+	+				+				+		+								3					
Calliergon sp.	B													+																											
Campylium stellatum	B													+																											
Cinclidium latifolium	B													+																											
Dicranum acutifolium	B									+																															
Dicranum elongatum	B				+					+		2	2		1	2	+	+	+			+	2	3	+	+		+	1			1				1	0.5				
Dicranum sp.	B	+																																	+	0.5			5		+
Dicranum spadiceum	B									+																															
Grimmia affinis	B			+	+			+	+	+	+	0.5	+		+		+	+				+	+	+		+		+	+			+				0.5	+				

Table X-4
Study 3 Tabulated Raw Vegetation Survey Data for the Kiggavik Study Area (Continued)

Plot Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	LST1	LST3	LST4
Habitat*		LS	SM	MH	LH RB	MH	LH	MH	LMH RB	MH Sh	ShH	MH	MH	SM	MH Sh	CM Sh	ST	MH	LH	LH RB	SM	MH	MH	MH SM	LH	MH RB	LH	MH SM	MH	Sh	SM	LMH	LH	LH	SH RB	MH SM	LMH	CB	MH	LH	LS
Hylocomnium splendens	B			+						+																															
Limptrichtia revolvens	B											+		+																											
Loeskypnum badium	B													+																											
Mosses (combined cover)	B			6																												7				8					
Oncophorus wahlenbergii	B			+						+				+																											
Physconia muscigena	B																								+																
Pleurozium schreberi	B					+		1.5	1	0.5	1				0.5			+				+	+			+			+	+		+			2		+				
Polytrichum sp.	B				+	1	+					+						+					+	+		+	0.5					+		+		+	+				
Polytrichum strictum	B									+																															
Ptilidium ciliare	B									+																															
Rhacomitrium lanuginosum	B			+		+		+	+	+	+		2		+		+	+	+	+		+	+	+		+						+				+	+				
Rhytidium rugosum	B									+																															
Sphagnum russowii	B																													+					+						
Sphagnum sp.	B		+																		+					+					1								2		
Sphagnum subsecundum	B													+																											
Tortella tortuosa	B									+																															
Unidentified moss	B																							4																	
Alectoria nigricans	L																										+														
Alectoria ochroleuca	L	+			0.5	+	+	+	+			+			+		+		+	+		+	+		+	+	+		+			+		+			+		+		6
Allantoparmelia alpicola	L				+		+			+																	+														
Arctoparmelia incurva	L				+	+	+													+							+														
Arctoparmelia centrifuga	L																	+									+														
Arctoparmelia separata	L																			+																					
Bryocaulon divergens	L	*4*			0.5		1	+				+	+				+		+	+		+	+	+	+	+	1					+	+	0.5			0.5		1		2
Cetraria andrejevii	L				+																																				
Cetraria cucullata	L				1	0.5	1	+	1	1	+	0.5	0.5		0.5		1	+	0.5	1.5		0.5	+	+	+	0.5		+	0.5	+		1	1	1	+	+	1		1.5		
Cetraria cucullata/ C. nivalis	L																																								1
Cetraria delisei	L					+																																			
Cetraria islandica ssp. *crispiformis*	L																																					+			
Cetraria islandica ssp. *islandica*	L																																+								

Table X-4
Study 3 Tabulated Raw Vegetation Survey Data for the Kiggavik Study Area (Continued)

Plot Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	LST1	LST3	LST4
Habitat*		LS	SM	MH	LH RB	MH	LH	MH	LMH RB	MH Sh	ShH	MH	MH	SM	MH Sh	CM Sh	ST	MH	LH	LH RB	SM	MH	MH	MH SM	LH	MH RB	LH	MH SM	MH	Sh	SM	LMH	LH	LH	SH RB	MH SM	LMH	CB	MH	LH	LS
Cetraria laevigata	L							+		+	+	+				+	+	+				+	+	+		+		+				+	1	0.5	+	+	+	1	1		
Cetraria nigricans	L	+			+																						+														
Cetraria nivalis	L	+	+		1	+	1	+	1	1	+	0.5	0.5		0.5		1		0.5	1.5		0.5	+	+	+	0.5	+	+	0.5	+		1	1	1	+	+	1	+	1.5	1	
Cladina mitis	L								+		+											+											+						+		
Cladina rangiferina	L					+		+	+	+	+	0.5	+		+	+	+	+		+		+	+	+	+	+	+		+	+		+	+		+			+	+		+
Cladina stellaris	L																																								+
Cladonia amaurocraea	L	+										+	+		+		+	+		+							+														
Cladonia arbuscula	L																									+															
Cladonia coccifera	L				+																						+														
Cladonia gracilis ssp. *gracilis*	L			+																																					
Cladonia laevigata	L					+							+																												
Cladonia phyllophora	L																	+																							
Cladonia pleurota	L				+																																				
Cladonia pocillum	L				+					+					+	+		+				+				+	+	+				+	+	+		+					
Cladonia sp.	L														+		+															+									+
Cladonia stricta	L	+											+									+							+	+											
Cladonia uncialis	L																										+														
Collema ceraniscum	L																											+													
Dactylina arctica	L	+	+		+	+	+	+	+	+	+	+	+		+		+	+		+		+	+	+		+		+	+	+		+		+		+	+		+		+
Icmadophila ericetorum	L				+																																				
Lecanora rupicola	L	+								+																															
Lecidea auriculata	L																										+														
Ledidea lapicida	L																										+														
Lichens (combined cover)	L																											5													
Ochrolechia frigida	L						+													+																					
Ochrolechia sp.	L			+																																					
Parmelia omphaloides ssp. omphaloides	L						+													+																					
Peltigera apthosa	L																					+	+							+											+
Peltigera rufescens	L																	+																							
Pertusaria coriacea	L						+								+					+																					
Pertusaria dactylina	L	+															+			+		+		+	0.5		+	+	+			+	+			+	+	+			

Table X-4
Study 3 Tabulated Raw Vegetation Survey Data for the Kiggavik Study Area (Continued)

Plot Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	LST1	LST3	LST4
Habitat*		LS	SM	MH	LH RB	MH	LH	MH	LMH RB	MH Sh	ShH	MH	MH	SM	MH Sh	CM Sh	ST	MH	LH	LH RB	SM	MH	MH	MH SM	LH	MH RB	LH	MH SM	MH	Sh	SM	LMH	LH	LH	SH RB	MH SM	LMH	CB	MH	LH	LS
Pertusaria panyrga	L																			+																					
Porpidia flavicauda	L					+																																			
Porpidia thomsonii	L	+																																							
Rhizocarpon badioatrum	L						+																																		
Rhizocarpon eupetraeoides	L																			+																					
Rhizocarpon geminatum	L					+																																			
Rhizocarpon geographicum	L	+					+																																		
Rhizocarpon grande	L	+																																							
Solorina bispora	L																											+													
Sphaerophrus globosus	L	+			+	+	+		+	+	+	+	+		+		+		+	+		+	+		+	+	+		+			+		+		+					
Spillonema revertens	L																											+													
Stereocaulon alpinum	L			+																												+									
Stereocaulon rivale	L	+			0.5								+		+								+																		
Stereocaulon sp.	L																+		+	+		+			0.5	+			+				+		+		+		+	+	+
Thamnolia vermicularis	L	+			0.5	+	+	+	+	+		+	+		+				+	+		+			+		+		+			+	+	+		+	+			+	
Tofieldia pusilla	L								+						+							+													+		+			+	
Toninia sp.	L																	+																							
Umbilicaria proboscidea	L					+	+													+							+														
Umbilicaria sp.	L	+																																							
Umbilicaria torrefacta	L						+													+																					
Unidentified lichen	L																															0.5									+
Unidentified saxicolous lichens	L																																							+	
Verrucaria nigrescens var. *laeviascula*	L																	+																							
Xanthoria elegans	L																								+																

Moss-heath (MH) Lichen-heath (LH) Lichen steppe (LS\) Sedge meadow (SM) Rock barrens (RB) Low shrub (Sh) Carex meadow (CM)

Source: Geomatics International Inc. 1991

APPENDIX XI

WILDLIFE AND WILDLIFE HABITAT

HISTORICAL WILDLIFE BASELINE DATA

Table XI-1
Summary of Observations in the Literature of Designated Water Crossings (1904 to 1978), NT

Water Crossing Number	Observation Date	Sign	Author and Date
1-3	August 1967	n/a	F.L. Miller, pers. comm.
3	July 1945	carcasses, trails	Manning (1948)
4 and 5	July 1954	2	Loughrey (1955)
4 and 5	July-August 1966	2	Parker (1972)
4 and 5	July-August 1967	2	Parker (1972)
4 and 5	July-August 1968	2	Parker (1972)
4 and 5	July 1970	caribou trails	F.L. Miller, pers. comm.
6	July-August 1966	2	Parker (1972)
7	July-August 1967	2	Parker (1972)
7	July-August 1968	2	Parker (1972)
8	July 1969	post-calving aggregation seen	Parker (1972)
10	not specified	traditional hunting area	Birket-Smith (1929)
12	not specified	traditional hunting area	Birket-Smith (1929)
12	August 1945	trails on shore	Manning (1948)
12	August 1944	reported crossing	Manning (1948)
13,14,15,17	unspecified	archaeological hunting site	Harp (1961)
13,14	unspecified	n/a	hunters in IDS (1978)
15	August 1904	hunting activity	Hanbury (1904)
15,16,17	n/a	n/a	hunters in IDS (1978)
16	July 1959	reported crossing to south	McEwan (1960)
15,16	n/a	n/a	hunters in Welland (1976)
15,16	n/a	n/a	hunters in Stager (1977)
17	July 1973	signs of recent crossing	Hawkins (1973)
18	n/a	n/a	hunters in IDS (1978)
19,20	n/a	archaeological hunting sites	Harp (1961)
19	August 1951	caribou drowning	Kelsall (1953)
19	August 1956	hunting camp	Loughrey (1956)
19,20	June-July 1960	caribou moving south	hunters in Welland (1976)
19,20	n/a	n/a	hunters in Stager (1977)

Source: Williams and Gunn, 1982 in BEAK 1990

Table XI-2
Summary of Observations of Use of Water Crossings During the Caribou Monitoring Program (1978 to 1981), NT

Water Crossing Number	Observation Date	Sign	Author and Date
2	1980	trails	this report
3	1980	trails	this report
4	June-July 1978	caribou moving north	Cooper (1981)
4	July-80	heavy trails	this report
5	Spring (?) 1980	heavy trails	Cooper (1981)
7	June-July 1978	caribou moving south	Darby (1978)
7	1980	trails	this report
8	July 1980	trails	Cooper (1981)
8	July 1980	few caribou	this report
9	July 1979	caribou moving northwest	Neigo in Darby (1980)
10	1980	trails	this report
12	May 1981	caribou moving south	C. Gates, pers. comm.
13-17	July 1980	few trails	this report
15	July 1980	few caribou	Cooper (1981)
19	July 1980	few caribou	this report
20	1980	few caribou	this report
21	1980	few caribou	this report
22	June-July 1978	caribou moving northwest	Darby (1978)
22	July-August 1979	caribou moving south	Darby (1980)
22	July 1980	caribou moving south	Cooper (1981)
22	July 1980	few trails	this report
23	July 1978	caribou moving north	Darby (1978)
23	July-August 1979	caribou moving south	Darby (1980)
23	July 1980	heavy trails	this report
24	July 1978	caribou moving south	Darby (1978)
24	July 1980	trails	Cooper (1981)
25	July 1978	caribou moving south	Darby (1978)
25	July 1979	caribou moving south	Darby (1980)
25	July 1980	caribou moving south	Cooper (1981)
25	July 1981	caribou moving south	A. Gunn field notes
26	July 1980	caribou moving south	Cooper (1981)
26	July 1981	caribou moving south	A. Gunn field notes

Source: Williams and Gunn, 1982 in BEAK 1990

Table XI-3
Species List for the Kiggavik Project Area

Common Name	Scientific Name
Barren-ground caribou	*Rangifer tarandus groenlandicus*
Barren-ground grizzly bear	*Ursus arctos*
Grey wolf	*Canis Lupus*
Arctic fox	*Alopex lagopus*
Wolverine	*Gulo gulo*
Muskoxen	*Ovibos moschatus*
Red-throated loon	*Gavia stellata*
Pacific loon	*Gavia pacifica*
(Greater) white-fronted goose	*Anser albifrons*
Snow goose	*Chen caerulescens*
Canada goose	*Branta Canadensis*
Tundra swan	*Cygnus columbianus*
Northern pintail	*Anas acuta*
Greater scaup	*Aythya marila*
King eider	*Somateria spectabilis*
Common eider	*Somateria mollissima*
(Long-tailed duck) oldsquaw	*Clangula hyemalis*
Red-breasted merganser	*Mergus serrator*
Rough-legged hawk	*Buteo lagopus*
Gyrfalcon*	*Falco rusticolous*
Peregrine falcon	*Falco peregrinus*
Willow ptarmigan	*Lagopus lagopus*
Rock ptarmigan	*Lagopus mutus*
Sandhill crane	*Grus Canadensis*
Black-bellied plover	*Pluvialis squatarola*
(American) golden plover	*Pluvialis dominica*
Least sandpiper	*Calidris minutilla*
Baird's sandpiper	*Calidris bairdii*
Pectoral sandpiper	*Calidris melanotos*
Dunlin	*Calidris alpine*
Long-tailed jaeger	*Stereorarius longicandus*
Parasitic jaeger	*Stercorarius parasiticus*
Herring gull	*Larus argentatus*
Glacous gull	*Larus hyperboreus*
Arctic tern	*Sterna paradisaes*

Table XI-3
Species List for the Kiggavik Project Area (Continued)

Common Name	Scientific Name
Snowy owl	*Nyctea scandiaca*
Short-eared owl	*Asio flammeus*
Horned lark	*Eremophila alpestris*
(American) water pipit	*Anthus spinoletta*
(American) tree sparrow	*Spizella arborea*
Savannah sparrow	*Passerculus sandwichensis*
Lapland longspur	*Calcarius lapponicus*
(Common) redpoll	*Carduelis flammea*

2007 WILDLIFE BASELINE DATA

Table XI-4
2007 Aerial Survey Results for the Study Area

Sampling Date	Easting	Northing	Species	Number	Group Composition	Habitat	Behaviour
26-Aug-07	517306	7166967	Caribou	1	nursing	TH	feeding
26-Aug-07	525118	7144351	Caribou	1	non-nursing	TH	walking
26-Aug-07	524628	7168480	Muskoxen	1	non-nursing	TH	feeding
26-Aug-07	532874	7096143	Caribou	1	non-nursing	TH	feeding
26-Aug-07	524387	7122186	Muskoxen	13	nursing	HT	feeding
26-Aug-07	524708	7117966	Caribou	1	non-nursing	HT	feeding
26-Aug-07	544735	7181962	Muskoxen	1	non-nursing	TH	feeding
26-Aug-07	545014	7181374	Muskoxen	1	non-nursing	TH	feeding
26-Aug-07	545320	7160507	Caribou	1	non-nursing	SW	feeding
26-Aug-07	545341	7159828	Caribou	1	non-nursing	TH	feeding
26-Aug-07	545453	7153188	Muskoxen	1	non-nursing	TH	feeding
26-Aug-07	545307	7139439	Caribou	1	non-nursing	HT	feeding
26-Aug-07	551371	7093578	Muskoxen	18	non-nursing	LS	standing
26-Aug-07	551127	7099022	Muskoxen	2	non-nursing	HT/BE	standing
26-Aug-07	550734	7144910	Caribou	1	non-nursing	SW	feeding
26-Aug-07	550486	7148320	Caribou	1	non-nursing	SW	feeding
26-Aug-07	550778	7159705	Muskoxen	16	non-nursing	HT	feeding
26-Aug-07	550783	7159935	Caribou	4	non-nursing	HT	feeding
26-Aug-07	550926	7164684	Muskoxen	1	non-nursing	TH	feeding
26-Aug-07	550937	7164910	Caribou	1	non-nursing	LV	feeding
26-Aug-07	556857	7158025	Caribou	1	non-nursing	SW	feeding
26-Aug-07	556447	7152447	Caribou	8	non-nursing	HT	feeding
26-Aug-07	556863	7147952	Caribou	2	non-nursing	HT	feeding
26-Aug-07	557145	7132652	Caribou	1	non-nursing	HT	feeding
26-Aug-07	563415	7096116	Muskoxen	2	non-nursing	SW	feeding
26-Aug-07	563183	7133156	Muskoxen	1	non-nursing	HT	walking
26-Aug-07	563183	7133156	Caribou	2	non-nursing	HT	walking
26-Aug-07	562932	7172067	Caribou	1	non-nursing	LV/BO	feeding
26-Aug-07	569470	7171632	Muskoxen	17	nursing	LS/BO	feeding
26-Aug-07	569679	7166682	Caribou	1	non-nursing	LV	standing
26-Aug-07	569485	7157365	Muskoxen	44	nursing	HT/LV	feeding
26-Aug-07	569485	7157365	Caribou	1	non-nursing	LAKE	swimming
26-Aug-07	574845	7167078	Caribou	2	non-nursing	HT/BE	walking
26-Aug-07	574873	7168430	Caribou	1	non-nursing	HT/BE	feeding
26-Aug-07	575103	7176683	Caribou	1	non-nursing	TH	feeding
26-Aug-07	581289	7174424	Caribou	1	non-nursing	HT	walking
26-Aug-07	581124	7139473	Muskoxen	1	non-nursing	HT	feeding
26-Aug-07	588734	7148632	Muskoxen	10	nursing	SW	feeding
26-Aug-07	597845	7134111	Muskoxen	1	nursing	LV/HT	feeding
26-Aug-07	598431	7122140	Caribou	1	non-nursing	HT/BE	standing

TH = tussock hummock; HT = heath tundra; SW = sedge wetland; LV = lichen veneer; BE = bedrock; BO = boulder; LS = low shrubs.
Easting and Northing coordinates are in NAD83, Zone 14W

Table XI-5
Weekly Aerial Survey Results for Caribou and Muskoxen

Sampling Date	Location	Easting	Northing	Species	Number	Behaviour
28-Aug-07	Kiggavik	563555	7137735	Caribou	1	standing
28-Aug-07	Kiggavik	565830	7138316	Muskoxen	28	feeding
28-Aug-07	Kiggavik	567850	7145302	Caribou	2	standing
28-Aug-07	Kiggavik	569895	7153394	Caribou	3	feeding
28-Aug-07	Kiggavik	573907	7152001	Muskoxen	1	standing
10-Aug-07	Kiggavik	559335	7156968	Muskoxen	1	walking
10-Aug-07	Kiggavik	559620	7148801	Muskoxen	2	feed
10-Aug-07	Kiggavik	561647	7157405	Muskoxen	14	feeding
10-Aug-07	Kiggavik	565662	7137500	Muskoxen	2	feeding
19-Aug-07	Kiggavik	561561	7156684	Muskoxen	1	standing
19-Aug-07	Kiggavik	573539	7149991	Caribou	1	running
5-Sep-07	Sissons	nr	nr	Muskoxen	1	standing
5-Sep-07	Sissons	nr	nr	Muskoxen	1	standing
5-Sep-07	Sissons	nr	nr	Muskoxen	3	resting
5-Sep-07	Sissons	nr	nr	Caribou	2	standing
5-Sep-07	Sissons	nr	nr	Caribou	1	walking
21-Sep-07	Sissons	546522	7127294	Caribou	9	nr
21-Sep-07	Sissons	545737	7133842	Caribou	3	nr
21-Sep-07	Sissons	546471	7145829	Caribou	1	nr
21-Sep-07	Sissons	548202	7144159	Caribou	5	nr
21-Sep-07	Sissons	548026	7129773	Caribou	5	nr
21-Sep-07	Sissons	550373	7125975	Caribou	1	nr
21-Sep-07	Sissons	550301	7129072	Caribou	4	nr
21-Sep-07	Sissons	550584	7129950	Caribou	1	nr
21-Sep-07	Sissons	550296	7132986	Caribou	9	nr
21-Sep-07	Sissons	552001	7141940	Caribou	2	nr
21-Sep-07	Sissons	552233	7134118	Caribou	9	nr
21-Sep-07	Sissons	554323	7134764	Caribou	2	nr
21-Sep-07	Sissons	558246	7141451	Caribou	2	nr

Nr= not recorded

Easting and Northing coordinates in NAD83, Zone 14W

Table XI-6
2007 Incidental Wildlife Observations

Date	Easting	Northing	Species	Number	Behaviour/Observation Type	Habitat
21-Jul-07	559550	7144991	Arctic Fox	1	running	na
21-Jul-07	561714	7145787	Bear	1	tracks on edge of pond	edge of pond
21-Jul-07	567129	7141395	Muskoxen	1	feeding	edge of water
27-Jul-07	559159	7145684	Caribou	2	running	na
27-Jul-07	563984	7141165	Muskoxen	17	walking	na
27-Jul-07	570613	714492	Muskoxen	1	sitting	na
10-Aug-07	573260	7151279	Falcon	1	nest	rock
19-Aug-07	558777	7157763	Muskoxen	22	bedded	na
25-Aug-07	577757	7152338	Caribou	1	carcass	sedge wetland
25-Aug-07	580043	7170620	Caribou	2	standing	heathbedrock
25-Aug-07	566469	7170777	Caribou	1	feeding	lichen veneer
25-Aug-07	566469	7170777	Caribou	1	standing	sedge wetland
25-Aug-07	541497	7176323	Caribou	6	walking	tussock tundra
25-Aug-07	548082	7150227	Caribou	1	feeding	tussock hummock
25-Aug-07	551502	7149396	Caribou	1	bedded	heath tundra
25-Aug-07	552228	7149808	Caribou	2	feeding	tussock hummock/ lichen veneer
25-Aug-07	552345	7149246	Caribou	1	feeding	lichen veneer
25-Aug-07	554922	7147223	Caribou	1	bedded	sedge wetland
25-Aug-07	565682	7145331	Caribou	1	feeding	heath tundra
25-Aug-07	564569	7146896	Caribou	2	walking	heath tundra
25-Aug-07	595439	7153163	Falcon	1	flying	boulder assoc
25-Aug-07	595597	7153081	Falcon	1	visual/inactive nest	bedrock assoc
25-Aug-07	559944	7184988	Falcon	2	visual/inactive nest	bedrock assoc
25-Aug-07	559105	7184349	Falcon	1	visual/inactive nest	bedrock assoc
25-Aug-07	580752	7169955	Grizzly bear	1	sik sik digs	low shrub heath tundra
25-Aug-07	586791	7169589	Grizzly bear	1	sik sik digs	heath tundra
25-Aug-07	554922	7147223	Grizzly bear	1	standing	low shrub
25-Aug-07	595439	7153163	Hare	2	running	boulder assoc
25-Aug-07	566605	7169558	Muskoxen	18	feeding/standing	heath tundra
25-Aug-07	559215	7183565	Muskoxen	1	feeding	heath boulder/ lichen venner
25-Aug-07	550453	7183371	Muskoxen	1	standing	heath bedrock/ lichen veneer
25-Aug-07	544664	7182404	Muskoxen	2	feeding	heath tundra
25-Aug-07	543626	7170855	Muskoxen	4	feeding	tussock tundra
25-Aug-07	548246	7156105	Muskoxen	1	feeding	sedge wetland
25-Aug-07	569843	7151429	Muskoxen	50	feeding	lichen veneer

Table XI-6
2007 Incidental Wildlife Observations (Continued)

Date	Easting	Northing	Species	Number	Behaviour/Observation Type	Habitat
25-Aug-07	567207	7169584	Peregrine falcon	1	flying	bedrock assoc
25-Aug-07	559105	7184349	Peregrine falcon	2	flying	bedrock assoc
25-Aug-07	579382	7152565	Wolf	1	feeding on caribou kill	heath tundra
26-Aug-07	541832	7164720	Caribou	1	feeding	tussock hummock
26-Aug-07	541319	7145383	Caribou	1	feeding	sedge wetland
26-Aug-07	540593	7145518	Caribou	5	walking	heath tundra
26-Aug-07	548245	7092233	Caribou	1	feeding	tussock hummock
26-Aug-07	575714	7171702	Caribou	1	bedded	heath tundra
26-Aug-07	575266	7171580	Grizzly bear	1	walking	low shrub/tussock hummock
26-Aug-07	530367	7187928	Muskoxen	1	feeding	tussock hummock
26-Aug-07	527310	7184417	Muskoxen	18	standing	lichen veneer
26-Aug-07	539197	7124387	Muskoxen	1	standing	heath tundra
26-Aug-07	545299	7144538	Muskoxen	1	feeding	heath tundra
26-Aug-07	556446	7152446	Muskoxen	2	feeding	heath tundra
26-Aug-07	562331	7093405	Muskoxen	1	standing	heath tundra
26-Aug-07	588784	7141520	Muskoxen	11	standing	tussock hummock
26-Aug-07	598762	7109905	Muskoxen	7	bedded	heath tundra
26-Aug-07	545218	7099456	Swan	2	swimming	lake
26-Aug-07	563255	7110872	Swan	2	bedded	heath tundra
26-Aug-07	588964	7127627	Swan	2	swimming	lake
26-Aug-07	588755	7144694	Swan	2	swimming	lake
26-Aug-07	597430	7159726	Swan	2	swimming	lake
26-Aug-07	598040	7131322	Swan	2	bedded	heath tundra
26-Aug-07	598113	7129148	Swan	2	bedded	heath tundra
26-Aug-07	598266	7123894	Swan	2	swimming	lake
26-Aug-07	516995	7113864	Wolf	1	trotting	sedge wetland
26-Aug-07	550988	7117776	Wolf	1	trotting	lichen veneer
26-Aug-07	556997	7138799	Wolf	1	inactive den	heath tundra
26-Aug-07	597637	7153082	Wolf	1	active den	heath tundra
28-Aug-07	575201	7138276	Caribou	2	standing	lichen veneer
28-Aug-07	576174	7152384	Caribou	4	feeding	heath tundra bedrock
28-Aug-07	550469	7105198	Caribou	1	walking	heath tundra
28-Aug-07	553411	7134426	Caribou	2	feeding	sedge wetland
28-Aug-07	565160	7148122	Caribou	2	feeding	heath tundra

Table XI-6
2007 Incidental Wildlife Observations (Continued)

Date	Easting	Northing	Species	Number	Behaviour/Observation Type	Habitat
28-Aug-07	564569	7146895	Caribou	4	feeding	heath tundra
28-Aug-07	565561	7137844	Grizzly bear	1	inactive den	heath tundra
28-Aug-07	564569	7146895	Hare	1	running	heath tundra
28-Aug-07	558250	7157105	Muskoxen	16	standing	heath tundra
28-Aug-07	572303	7151024	Muskoxen	45	feeding	heath tundra bedrock
28-Aug-07	566102	7151661	Muskoxen	8	standing	sedge wetland
28-Aug-07	572953	7152048	Muskoxen	12	standing	sedge wetland
28-Aug-07	550476	7104874	Peregrine falcon	1	flying	bedrock assoc
30-Aug-07	564464	7147107	Grizzly bear	1	chew on willow	heath tundra bedrock
30-Aug-07	564431	7147010	Wolf	1	temporary den	heath tundra bedrock
5-Sep-07	557045	7132778	Grizzly bear	1	walking	na
5-Sep-07	na	na	Grizzly bear	1	walking	na
9-Sep-07	na	na	Bald Eagle	1	flying	na
9-Sep-07	548189	7135140	Caribou	1	walking	na
9-Sep-07	na	na	Caribou	5	visual	na
21-Sep-07	555072	7131696	Caribou	7	visual	na

East and Northing coordinates are in NAD83, Zone 14W