Blachford Lake had relatively low chlorophyll *a* values in June and September (0.626 and 1.42 μg/L), while Dinosaur showed high values. Dinosaur also had the highest chlorophyll *a* across the study area in September (14.60 μg/L), increasing nearly three-fold from June (4.90 μg/L).

Phytoplankton richness, diversity and predominant taxa were similar in both lakes, with slight differences in species composition. In Blachford Lake, one blue-green species (*Lyngbya limnetica*) was predominant and in Dinosaur Lake, two blue-green species (*Lyngbya contorta* and *L.* cf. *limnetica*) were predominant. *Dinobryon* spp. (yellow-brown algae) were common in both lakes.

Zooplankton richness and diversity were relatively high in both lakes, though higher in Blachford than Dinosaur. Rotifers were predominant in both lakes, with four main species in Blachford and two species in Dinosaur.

Benthic invertebrate taxon richness and diversity were higher in Blachford than in other lakes of the study area samples in 2009. Richness and diversity values were moderate in Dinosaur, and evenness was moderately low in both lakes. Amphipoda and Chironomidae were predominant in Blachford and Dinosaur lakes.

No fish sampling was conducted in Dinosaur or Blachford lakes during the Stantec (2010c) studies. Sampling in the south bay of Blachford Lake in June 1998 resulted in the capture of 55 fish by gill netting and angling. Fish species captured were: northern pike, lake cisco, lake whitefish, and lake trout.

2.8.6 Great Slave Lake

2.8.6.1 General Description

Great Slave Lake is the second largest lake in the Northwest Territories (behind Great Bear Lake), the deepest lake in North America at 616 m (2,027 ft.), and the sixth largest lake in the world. It is 456 km long and 19 to 109 km wide. It covers an area of 28,400 km^2 and has an approximate volume of 2,090 km^3 (Herbert 2007).

Figure 2.8-36 presents the general bathymetry of Great Slave Lake as derived from available Canadian Hydrographic Service charts. The main western portion (central basin) of the lake forms a moderately deep bowl with a surface area of 18,500 km^2. This basin has a maximum depth of 187.7 m. A large area of the central basin is less than 60 m in depth and the average depth of the basin is 32.2 m. To the east, McLeod Bay and Christie Bay in the East Arm are much deeper, with a maximum recorded depth in Christie Bay of 614 m (Herbert 2007).

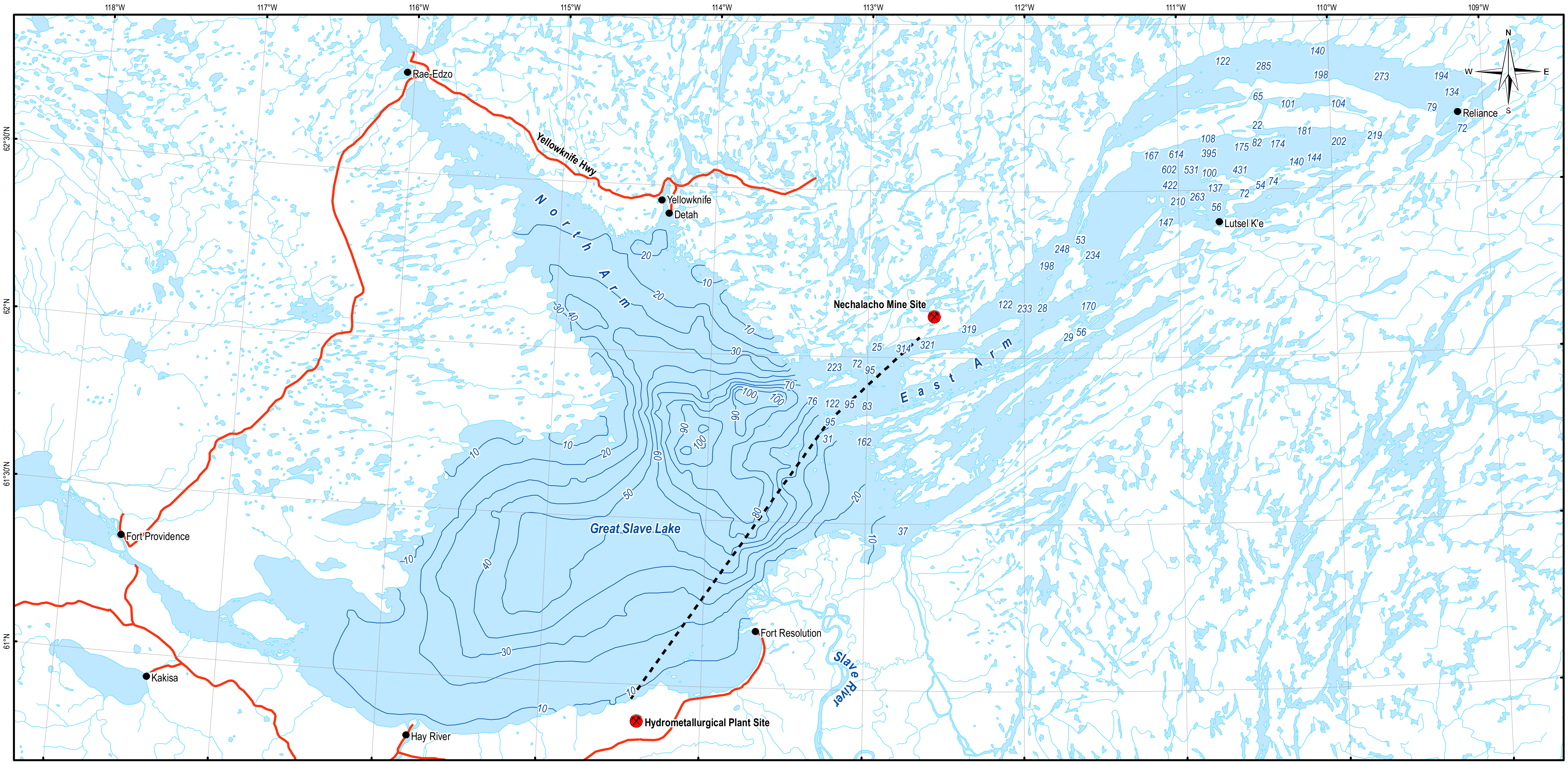
Directly offshore of the Nechalacho Project area, the water is also deep (315 m) but, within about 15 km of the proposed barging corridor, the water depth shallows to 95 m and shallower as the corridor crosses the central basin heading towards the Pine Point area.

During the recently completed MVEIRB scoping sessions, a number of community members expressed concerns about the apparent lower water levels observed in Great Slave Lake during the past year. To place the current water level condition in a longer term perspective, Figure 2.8-37 presents Great Slave lake water level data recorded continuously in Yellowknife Bay by the federal government since 1934 (Environment Canada 2010a). As illustrated by these data, water levels in Great Slave Lake have been varying from year to year for the period of record within a range of approximately 0.5 m to 1 m.

The Slave River contributes the majority of the annual inflow of water to Great Slave Lake (77%) The Slave River has a very large basin area (606,000 km^2) and a mean annual flow volume of almost 108 billion m^3 (Kokelj 2003). One of the primary tributaries to the Slave River is the Peace River, on which construction and filling of the Bennett Dam were completed by 1971.

Although research has been ongoing to determine some of the effects specific to this basin, the average annual peak flow on the Slave River has decreased approximately 18%, while average annual low flow has increased about 92% since 1971 (Kokelj 2003).

The Slave River's majority inflow contribution to the lake means that: management of the Williston Reservoir upstream on the Peace River and precipitation received in northern Alberta and British Columbia can potentially influence water levels on Great Slave Lake; and precipitation received in most of the North and South Slave regions has little impact on Great Slave Lake water levels.



LEGEND

- Site Location
- Community
- Bathymetric Contour (10m)
- Approximate Barging Route
- All Weather Road
- Watercourse
- Waterbody

NOTES

Base data sources: Canadian Hydrographic Service Nautical Chart 6341 (2004); Leon et al (2005).

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Great Slave Lake Bathymetry

PROJECTION	DATUM
NWT Lambert	NAD83

Scale: 1:1,300,000

0 25 50

Kilometres

FILE NO.
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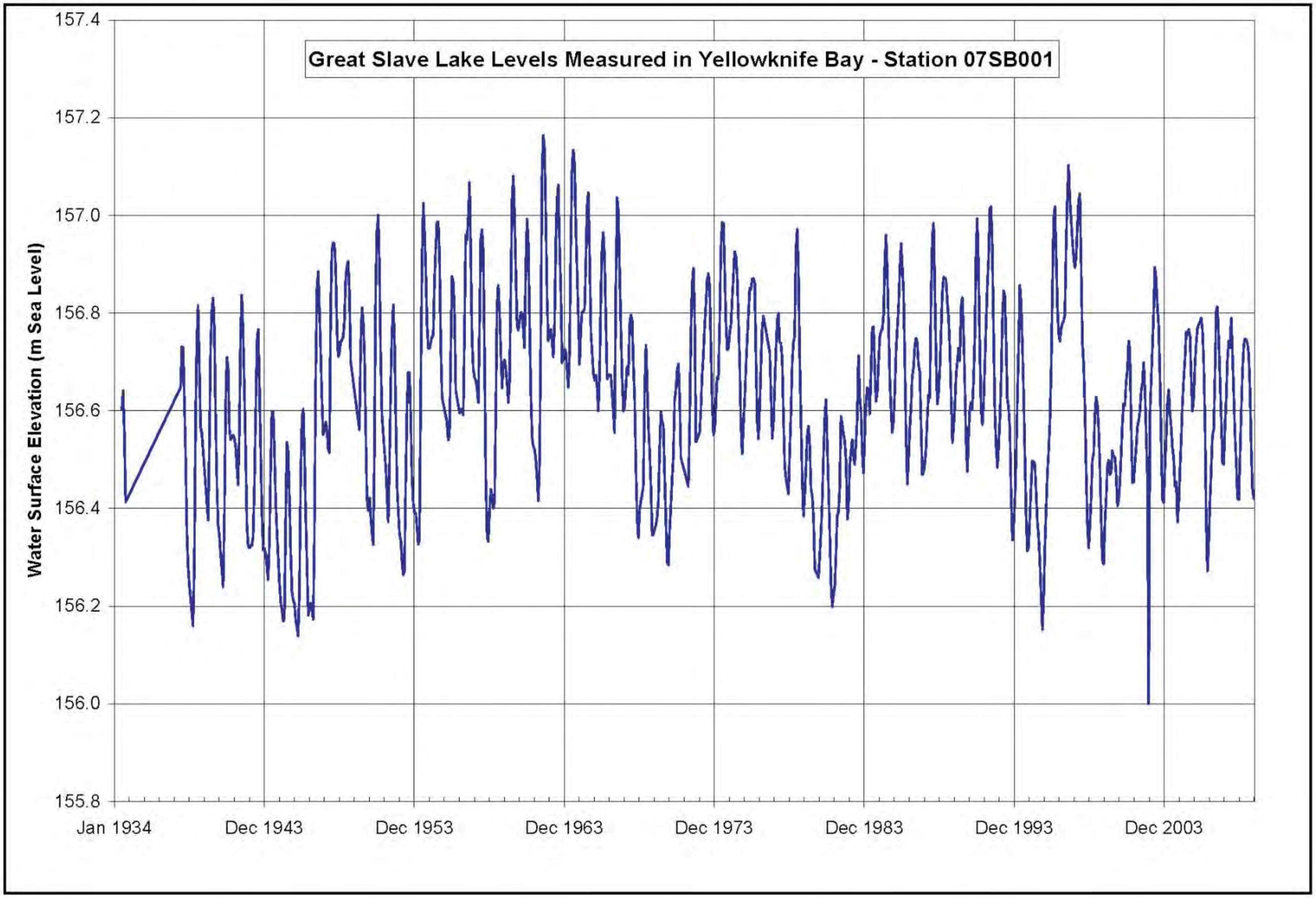
Figure 2.8-36



NOTES
1. Figure Source: Environment Canada, Station 07SB001

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Great Slave Lake Water Levels 1934-2009

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Figure 2.8-37

2.8.6.2 Fisheries Resources

At least 27 species of fish are known to occur in Great Slave Lake (Scott and Crossman 1973; Stewart 1999). The common and scientific names of these fish are presented in Table 2.8-22. Great Slave Lake is the second largest lake in the Northwest Territories (behind Great Bear Lake), the deepest lake in North America at 616 m (2,027 ft), and the sixth largest lake in the world.

TABLE 2.8-22: FISH OF GREAT SLAVE LAKE

Common Name	Scientific Name
lake trout	*Salvelinus namaycush*
lake whitefish	*Coregonus clupeaformis*
Northern pike	*Esox lucius*
pickerel (walleye)	*Stizostedion vitreum*
Inconnu	*Stenodus leucichthys*
chum salmon	*Oncorhynchus keta*
lake cisco (lake herring)	*Coregonus artedii*
round whitefish	*Prosopium cylindraceum*
Shortjaw cisco	*Coregonus zenithicus*
goldeye	*Hiodon alosoides*
Arctic grayling	*Thymallus arcticus*
Arctic lamprey	*Lampetra japonica*
lake chub	*Couesius plumbeus*
flathead chub	*Hybopsis gracilis*
emerald shiner	*Notropis atherinoides*
spottail shiner	*Notropis hudsonius*
longnose dace	*Rhinichthys cataractai*
longnose sucker	*Catostomus catostomus*
white sucker	*Catostomus commersoni*
trout-perch	*Percopsis omiscomaycus*
Burbot	*Lota lota*
brook stickleback	*Culaea inconstans*
ninespine stickleback	*Pungitius pungitius*
yellow perch	*Perca flavescens*
slimy sculpin	*Cottus cognatus*
spoonhead sculpin	*Cottus ricei*
fourhorn (deepwater) sculpin	*Myoxocephalus quadricornis*

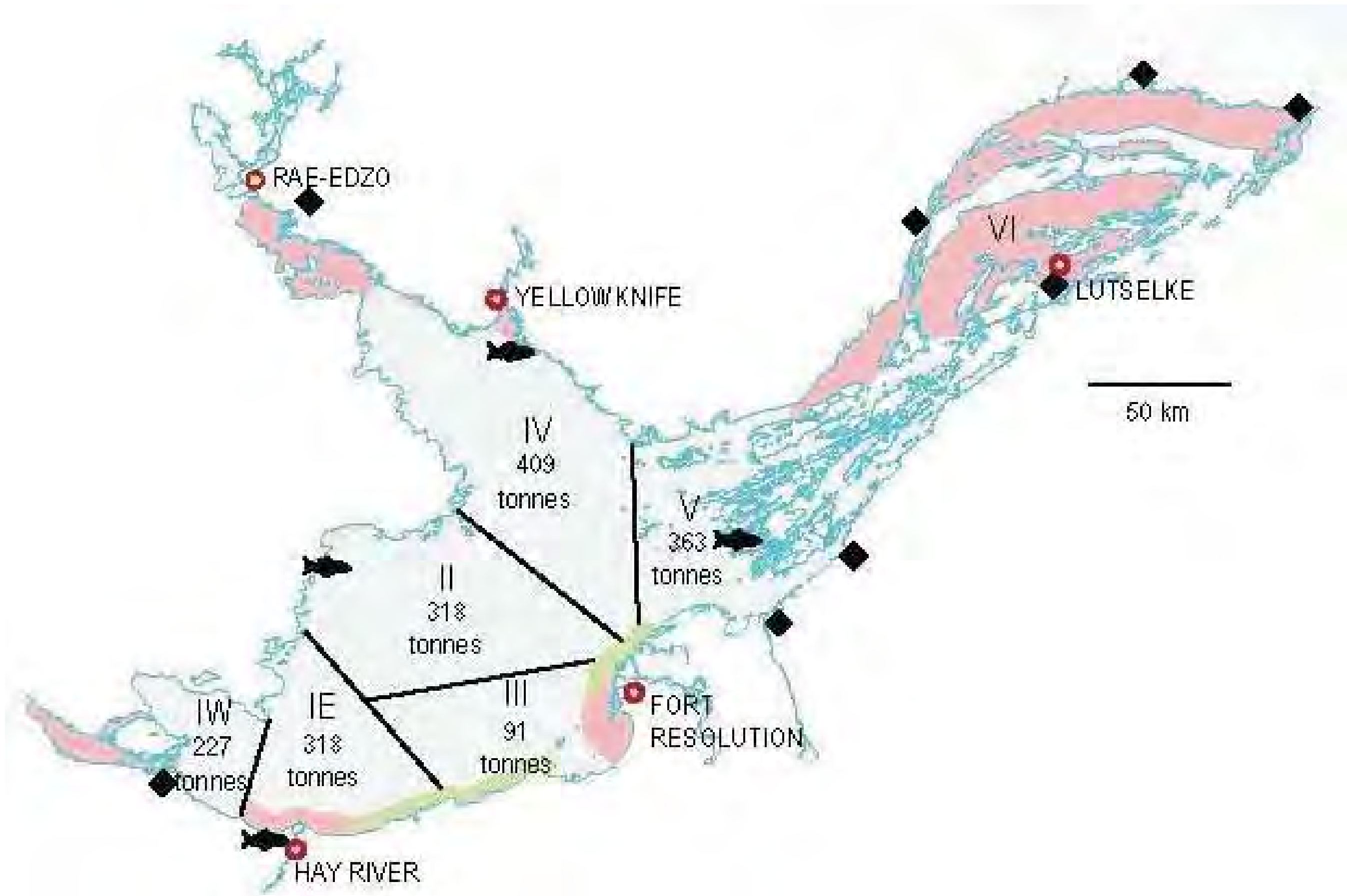
Sources: Scott and Crossman 1973; Stewart (DFO) 1999

The management of fish in Great Slave Lake has been directed towards balancing subsistence, sport and commercial fishing so that all fish stocks are sustained (Mackenzie River Basin Board 2004). There are six fish management areas in Great Slave Lake. Each area has its own management plan (Figure 2.8-38). Commercial fishing occurs in the western and central portions of Great Slave Lake; however, Area VI in the East Arm and certain inshore areas are closed to commercial fishing. The East Arm is managed for a trophy lake trout fishery and the other areas are important for the Aboriginal subsistence fishery.

The commercial gillnet fishery in the West Basin has been managed primarily for lake whitefish after the collapse of lake trout stocks in the mid-1960s. The commercial fish harvest has declined over time and there are fewer licensed boat operators on the lake, but the number of commercial fishing licences has increased.

All communities on Great Slave Lake and its major tributaries have subsistence fisheries that are dependent on Great Slave Lake stocks. These fisheries are poorly monitored and current harvest statistics are only available for Fort Resolution and Fort Smith. In those communities, whitefish make up 68% of the overall subsistence catch.

There is a trophy lake trout fishery in the East Arm of Great Slave Lake, especially in Area VI, which is closed to commercial fishing. The sport fisheries on Great Slave Lake involve fishing lodges, outfitters, and unguided anglers. There are seven sport fishing lodges and eight outfitters licensed to operate on Great Slave Lake.



LEGEND

- Areas closed to Commercial Fishing
- Spring Closures (Inconnu Protection)
- Fish Plants
- Fishing Lodges

NOTES

1. Figure Source: Mackenzie River Basin Board Report 2004 (Figure 6-8) Department of Fisheries and Oceans.

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Map of Administrative Fishing Areas in Great Slave Lake

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Figure 2.8-38

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2.8.6.3 Water/Environmental Quality

Nechalacho Dock Site Area

Water quality data were collected by Stantec (2010c; Appendix A) from the vicinity of the proposed seasonal dock site on the north side of Great Slave Lake from October 2008 to September 2009, as previously discussed in Section 2.6. Low values for mean conductivity, hardness, dissolved solids, nutrients and metals were reported. However, nitrate levels were relatively high, similar to those of Cressy and South Tardiff lakes.

Since the sediment in this nearshore area of Great Slave Lake was relatively hard and difficult to sample with the ponar grab; only one sample was obtained. Sediment chemistry showed low values for organic carbon, Total Kjeldahl Nitrogen, phosphorus and most metals; nickel was higher than the CCME ISQG (22.6 mg/kg).

Benthic invertebrate data collected in 2009 are discussed in Section 2.8 above and are reported in Stantec (2010c; Appendix A). Due to the hard silt and sand substrate at the Great Slave Lake station, only three grabs were obtained (instead of nine), resulting in a lower volumes of benthic material analyzed compared to the other lakes in the study area. Taxon richness and abundance were relatively low, perhaps related to the reduced sample volume analyzed. Diversity and evenness were intermediate, suggesting a moderately heterogeneous benthic community. Fingernail clams (Sphaeriidae) and amphipods (freshwater shrimp) were predominant and Chironomidae (fly) larvae were common.

As previously discussed in Section 2.8 above, more species of fish were caught in Great Slave Lake than any other lake, as is to be expected given the high known species and habitat diversity in Great Slave Lake. These included the largest lake whitefish (542 mm) and lake cisco (405 mm) in the Stantec fisheries study. Catch rates were within the normal range for northern pike and lake whitefish, but were very high for lake cisco (8.4 fish/hour and 4.1 fish/hour in 2009 and 2008 respectively) compared to the study average (1.1 fish/hour). Parasite frequencies in Great Slave Lake were very low for all species (internal parasites were observed in one lake cisco of 20 dissected, and no other parasites were observed).

Total mercury levels in muscle of lake whitefish from Great Slave Lake were generally low. However, levels of metals (particularly cadmium and thallium) in livers of some lake whitefish and lake cisco were higher than in the other study lakes. Selenium and arsenic levels were also elevated in Great Slave Lake compared with the other lakes.

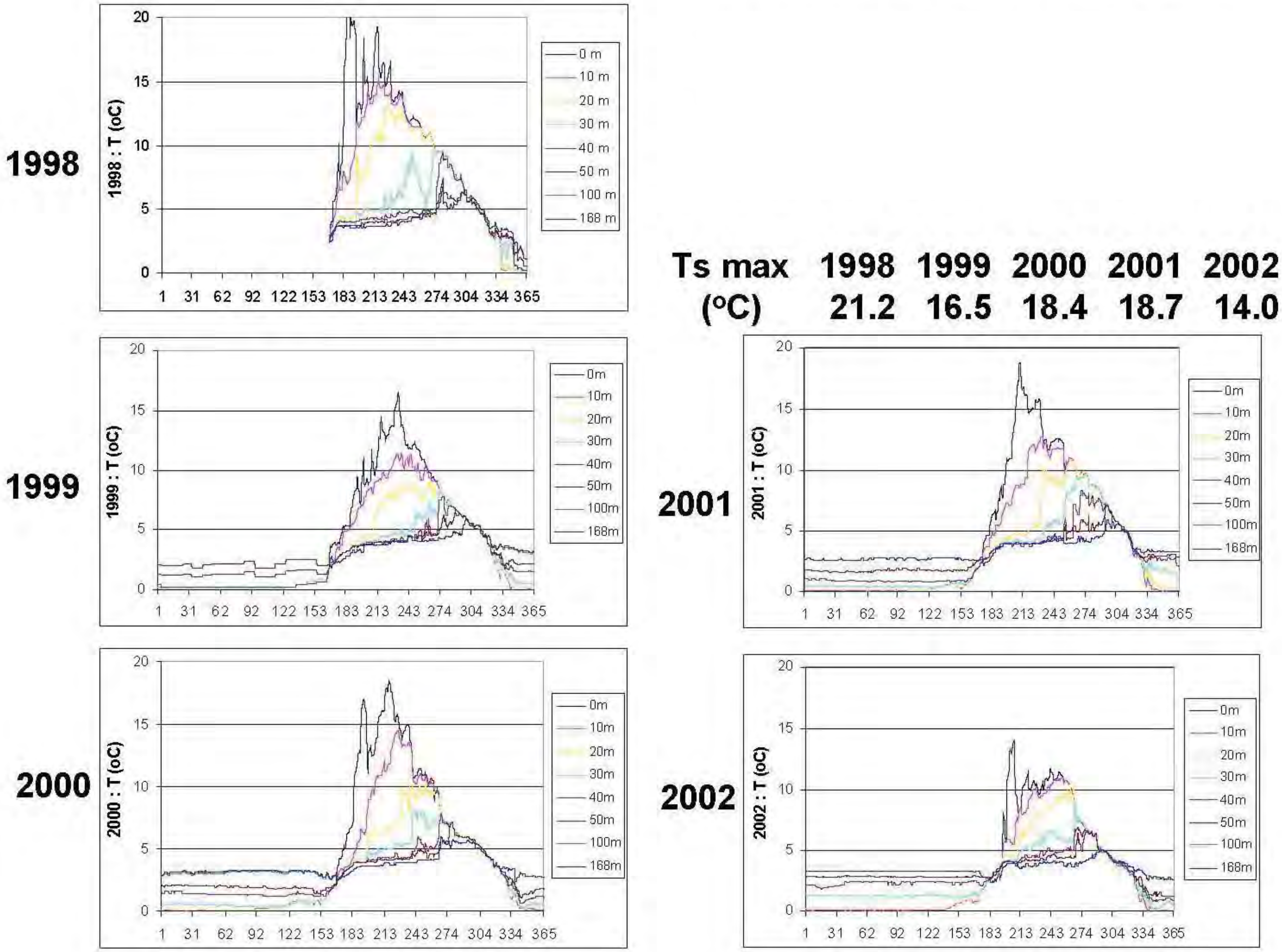
Central Great Slave Lake Area

Intensive field observations and modelling research undertaken during the Global Energy and Water Cycle Experiment on the Mackenzie Basin (GEWEX-MAGS) over the period 1998 to 2003 has contributed to the quantification of the interannual variability of key over-lake meteorological variables, the lake thermal structure, heat content and heat exchange (Schertzer et al. 2004).

Cross-lake measurements of the West Basin of Great Slave Lake using meteorological buoys and thermistor moorings were conducted during summer and winter field programs throughout the study period. This multi-year study maintained the basic measurement configuration throughout. This facilitated examination of interannual variability.

As reported by Schertzer et al (2004), the study determined that the colder deeper portion of the lake was less responsive to diurnal changes than the upper mixed layer during the stratified summer period. The isotherm time-series (Figure 2.8-39) shows the variation in timing of the beginning and end of the thermally stratified period on a lake-wide mean basis.

For the ice-covered months, at the deepest station measured (168 m), the water temperature generally remained stable at about 3°C, rising gradually to about 5°C during the brief open-water period (June to October). The temperature of the water column below 30 m depth generally remained below about 10°C during the open water period. The temperature of the shallower portion of the water column (0-30 m) was observed to rise relatively rapidly during the open-water period, reaching maximum surface water temperatures ranging from 14.0°C in 2002, to 21.2°C in 1998.



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Seasonal Temperature Characteristics of Great Slave Lake, 1998 to 2002

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Figure 2.8-39

NOTES

1. Figure Source: Schertzer et. al, 2004. Department of Fisheries and Oceans.

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In 1987, Mudroch et al. (1992) carried out a study to determine the geochemistry and distribution of trace elements and other parameters in the sediments of selected areas in Great Slave Lake. A total of five stations were sampled in the western basin of Great Slave Lake, two of which were located in the vicinity of the proposed barging corridor.

Sediment cores were collected at three sampling stations in the west basin of the lake on a transect from the Slave River delta to the outlet of the Mackenzie River. The geochemical composition of the sediments showed the deposition of similar material at all sampling stations. Sediment dating indicated a very high sedimentation rate (46.6 g/cm^2 per year) at a 110 m water depth in the vicinity of the Slave River delta and mixing of bottom sediments at the southwestern part of the lake (Mudroch et al. 1992).

The unusually high sedimentation rate recorded at Station 4 and sediment mixing at Station 3 were determined to be most likely due to the input of great quantities of suspended sediments from the Slave River and strong currents at the bottom of the west basin of the lake. The estimated mean sediment inflow from the Slave River into the lake is 30 x l0^6 tons per year, of which 10% is sand and the rest is fine-grained material (Mudroch et al. 1992; Mackenzie River Basin Committee 1981).

Generally, the sediments from all sampling stations consisted of very fine grey-brown silty clay, with a surface layer (1 -5 cm) less consolidated than the underlying material. The samples contained 77-92% clay-size particles (<2μm). The rest of the particles were silt (particle size 2-63 μm). Major minerals were quartz, illite, chlorite, kaolinite, and feldspars. Other minerals in the sediments were calcite and small quantities of many different minerals originating from the complex bedrock geology of the lake drainage basin (Allan 1979).

The concentrations of major elements (Cu, Ni, Co, Cr, V, Pb and Zn), were uniform from the surface to the bottom of each sediment core and similar for all three coring stations indicating a continuous deposition of geochemically similar material. However, surficial sediments were enriched by arsenic. Low concentrations of organic carbon in the sediment profile indicated the deposition of mineral particles and limited contributions of naturally produced in-lake organic matter to the sediments in this oligotrophic (nutrient poor) lake (Mudroch et al. 1992).

Mudroch et al. (1992) also reported that a few amphipods (freshwater shrimp) were typically found at the sediment surface at each sampling station. Other biota likely to live in the fine sediments of the deeper waters (>100 m) of Great Slave Lake would include several species of bivalves (clams/mussels), snails, worms and mysid shrimp. Fish species that are like to live in >100m water depth in Great Slave Lake would include deep water lake trout and bottom feeding fish such as burbot, suckers, lamprey and sculpins.

Pine Point Dock Site Area

The community of Fort Resolution has long been concerned about possible contamination of the environment and its natural resources in the Pine Point area since the beginning of mining operations in 1965. In response to community, and subsequently, resource agency concerns, beginning in the 1970's a number of environmental assessment studies were conducted to investigate the possible impact of mining operations on the land and natural resources in the nearshore region of Great Slave Lake (Evans et al. 1998).

Stein and Miller (1972) of the Department of Fisheries conducted the first such study on the fish, water and sediments of Great Slave Lake in the vicinity of the Pine Point mine operation. This study was followed by further studies conducted by BC Research on related subjects in 1977 and 1978 on behalf of Pine Point Mines Ltd (BC Research 1978), Allan in 1979 (Allan 1979), DIAND in 1992 and 1993 (Lafontaine 1997), Klavercamp and Baron (1996) in 1994 and the most recent study results collected in 1996 and reported by Evans et al. (1998).

The key results and conclusions of all of these studies were reviewed, along with the most recent results, as reported in a National Hydrology Research Institute (NHRI) report co-authored by M.S. Evans of NHRI and the Department of Fisheries (Evans et al. 1998).

The Evans et al. (1998) study was supported by DIAND and was initiated in 1996 after receiving inputs from Patrick Simon and Maurice Boucher, Environmental Officers with Deninu Ku'e First Nation. Lloyd Norn (Fort Resolution) assisted with sampling in Great Slave Lake and Tom and Darwin Unka (Fort Resolution) assisted with fish and river sampling. Gabriel Lafferty (Fort Resolution) and Pamela Taylor (Hay River) helped with the collection of burbot in December 1996 (Evans et al. 1998).

Since all of the earlier results and the status of existing knowledge on the health of the environment of Great Slave Lake in the Pine Point area were summarized in the report by Evans et al. (1998) the following updated information was drawn directly from this report.

In September 1996, water and surficial sediment samples were collected from 7 sites (5 in Great Slave Lake; one in each of the Slave River and Little Buffalo River). Limnological data (temperature, conductivity, pH, oxygen, water clarity, turbidity, suspended sediments and particulates, chlorophyll, bacteria and plant nutrients) were also collected to provide insight into water movement and dilution in the eastern side of Resolution Bay, Great Slave Lake.

The Evans et al. (1998) study determined that the Slave River was an enriched source of iron, manganese and possibly nickel. The Slave River was also identified to be a significant source of suspended sediments, particulates and various plant nutrients. The Little Buffalo River was identified as an enriched source of salinity (salt), dissolved nitrogen, ammonia and possibly iron and manganese during the study.

Other key findings of Evans et al. (1998) were the following (cited from the report abstract):

> *"There was no evidence that water in the study area was being contaminated by the decommissioned mine. A review of the documentation on the operation and decommissioning of the mine site provided*

no indication of any mechanism by which water flowing through the study region could be significantly contaminated by the decommissioned mine.

Metal concentrations in surficial sediments were determined at the same sites where the water column was sampled. Metal concentrations in the sediments sampled were similar to concentrations observed in suspended sediments in the Slave River, and, overall, similar to average concentrations in the earth's crust. There was no evidence of contaminated sediments offshore of the decommissioned mine site.

A review of the documentation on the operation and decommissioning of the mine site provided no indication of any mechanism by which the mine could have significantly contaminated sediments in the study region. While decanted water from the tailings pond was released into the muskeg, this water was apparently rapidly diluted (and adsorbed) into the muskeg. There was no mechanism to transport large, concentrated volumes of suspended sediments to Great Slave Lake.

A sediment core collected in a depositional area offshore of the decommissioned mine site was examined for metals. The time period extended from the late 1880s to the early 1990s. There was no evidence of an increase in metal concentrations in this core during the period in which the mine was operational.

Pike from the Little Buffalo River, and burbot from the Slave River were examined for metals (muscle, liver and kidney) and metallothionein (liver, kidney) concentrations. A small number of inconnu (3) from the Slave River and walleye (1) from each river were also examined.

Metal concentrations were similar to those observed in fish collected from the Slave River, Yellowknife Bay and Leland, Alexie and Trout lakes. Overall there was no evidence that fish in the Resolution Bay area, including the Little Buffalo and Slave rivers, were contaminated with metals by the decommissioned Pine Point Mine.

Metallothionein and arsenic concentrations in burbot kidney were similar to values reported from the Northern River Basin Study (Klavercamp and Baron 1996) for all study sites except the 1994 sampling of the Slave River delta. Thus, we were unable to verify the elevated metallothionein values in burbot kidney, which were observed in 1994 for the Slave River sampling.

The reasons for the elevated metallothionein concentration in burbot kidney (and gills) in 1994 cannot be explained. We have, however, determined that these elevated values could not be due to the decommissioned Pine Point Mine. Other studies have determined that Outlet Creek and the Peg Creek outflow in Yellowknife Bay are contaminated with metals from the gold mines at Yellowknife. However, it is very unlikely that the burbot collected in the Slave River in 1994 originated from these outflows".

Since the subjects of contaminant concentrations in Great Slave Lake fish, water and sediments remain of ongoing concern to residents of the area and resource management agencies, Avalon suggests that a complete copy of the National Hydrology Research Institute (NHRI) report, co-authored by M.S. Evans of NHRI and the Department of Fisheries (Evans et al. 1998) be placed on the public record with the MVEIRB.

2.9 SURFICIAL GEOLOGY AND SOILS

2.9.1 Nechalacho Mine Site

2.9.1.1 Study Area and Physiography

The following description is drawn primarily from Stantec (2010d; Appendix A) and references incorporated into the Stantec report. The Nechalacho Project Regional Study Area (RSA), Mine Lease 3178, is located within NTS 85I/SE, near the northeast shores of the Hearne Channel, Great Slave Lake, Northwest Territories. The area falls within the Bear Slave Uplands of the physiographic Kazan Region (Bostock 1970). This region consists of vast areas of massive rocks that form flat, broad, sloping uplands, plateaus and lowlands (Stantec 2010d).

2.9.1.2 Quaternary History

The Nechalacho Project area was covered by the Laurentide Ice Sheet during the last glaciation, in the Late Wisconsinan. During glacial maximum, about 18,000 years ago, the dominant ice flow direction was southwest, flowing from the Keewatin Ice Divide (Dyke and Dredge 1989; Lemmen et al. 1994; Fulton 1995, Stantec 2010d)).

The Laurentide Ice Sheet retreated to the northeast of the Project area, leaving the area free of ice between 10,000 and 9,000 years before present (Dyke and Dredge 1989; Dyke et al. 2003). Glacial meltwater impounded along this margin, forming Glacial Lake McConnell (Dyke et al. 2003; Lemmen, et al. 1994; Smith 1995). Great Bear Lake (NWT), Great Slave Lake (NWT) and Lake Athabasca (AB/SASK) are remnants of this lake, though it wasn't until around 8,000 years before present that the lakes completely separated to their modern configurations.

Glacial Lake McConnell covered approximately 240 000 km^2. Former lake shores of glacial Lake McConnell reached elevations between 245 and 295 metres above sea level (masl) (Craig 1965). Observation in the Yellowknife area showed material reworked by wave action as far as 70 km inland from the actual location of Great Slave Lake (Kerr and Wilson 2000). This implies that glacial Lake McConnell reached elevations averaging 275 to 285 masl.

2.9.1.3 Landforms and Surficial Geology

The bedrock of the region is covered by a thin and discontinuous veneer of glacial till material (Fulton 1995). Great Slave Lake was far more extensive in the past, as part of Glacial Lake McConnell, but very little sediment seems to have been deposited in this lake (Dyke and Dredge 1989; Kerr and Wilson 2000).

The regional landscape and surficial geology in the vicinity of Yellowknife was described by Kerr and Wilson (2000) as a vast terrain of low relief with topographic variations usually ranging between 10 and 30 m. The earth's surface consists mostly of bare rocky outcrops intersected by generally thin accumulation of glacial and glaciolacustrine sediments. The most common surficial deposit consists of till and commonly shows signs of reworking by glacial meltwater and glaciolacustrine processes, resulting in a variety of material facies and textures (Stantec 2010d).

The landforms and surficial geology within the Nechalacho Project area show strong evidence of glacial and post-glacial activity. The landscape consists of a gently undulating relief that gradually decreases in elevation towards Great Slave Lake. Elevation ranges from 235 m along the shore of Thor Lake, to about 265 m on top of the highest bedrock knobs. Elevations progressively drop to approximately 160 m along the north shore of Great Slave Lake.

2.9.1.4 Exposed Bedrock

Bedrock outcrops are dominant landscape elements throughout the Northwest Territories and within the Nechalacho Project area, bedrock accounts for 43.2% of the mapped area (Photo 2.9-1). Areas between the outcrops are mostly characterized by washed out tills and thin organic accumulations. Several bedrock outcrops show glacial striations, grooves and scratches, all evidence of glacial erosion and ice flow directions. Those abrasion marks are formed by debris-carrying ice and represent some very good indicators of former ice-flow patterns (Photo 2.9-2). Several were recorded throughout the Project area by Stantec (2010d) and all were displaying a southwest orientation.

A similar ice-flow pattern is reported in the literature for this general area. A series of large-scale indicators such as glacially smoothed bedrock outcrops, and roche moutonnées were also observed. At the Nechalacho site, glacially profiled bedrock outcrops are aligned NE-SW which is consistent with the glacial striaes. These low elevation outcrops are separated by longitudinal glacial troughs and glacial overdeepening depressions now occupied by lakes (e.g., Thor Lake).

Slopes were measured throughout the Project area and usually ranged from 5 to 15% with slope lengths ranging from 100 to 500 m. Short slopes between 15 and 30% are present but less common. Steep slopes are rare, although a series of bedrock outcrops show some escarpments up to 70% steep with a maximum height of 15 m. Maximum elevation difference between topographic highs and lows average 30 m. Bedrock outcrops show variable degree of weathering in relation with processes such as geological decompression, frost action and thermal expansion.

Photo 2.9-1
Extensive bedrock outcrops located within the Project area

Photo 2.9-2
Glacially smoothed and striated bedrock surface showing a southwest ice flow

2.9.1.5 Glacial Deposits

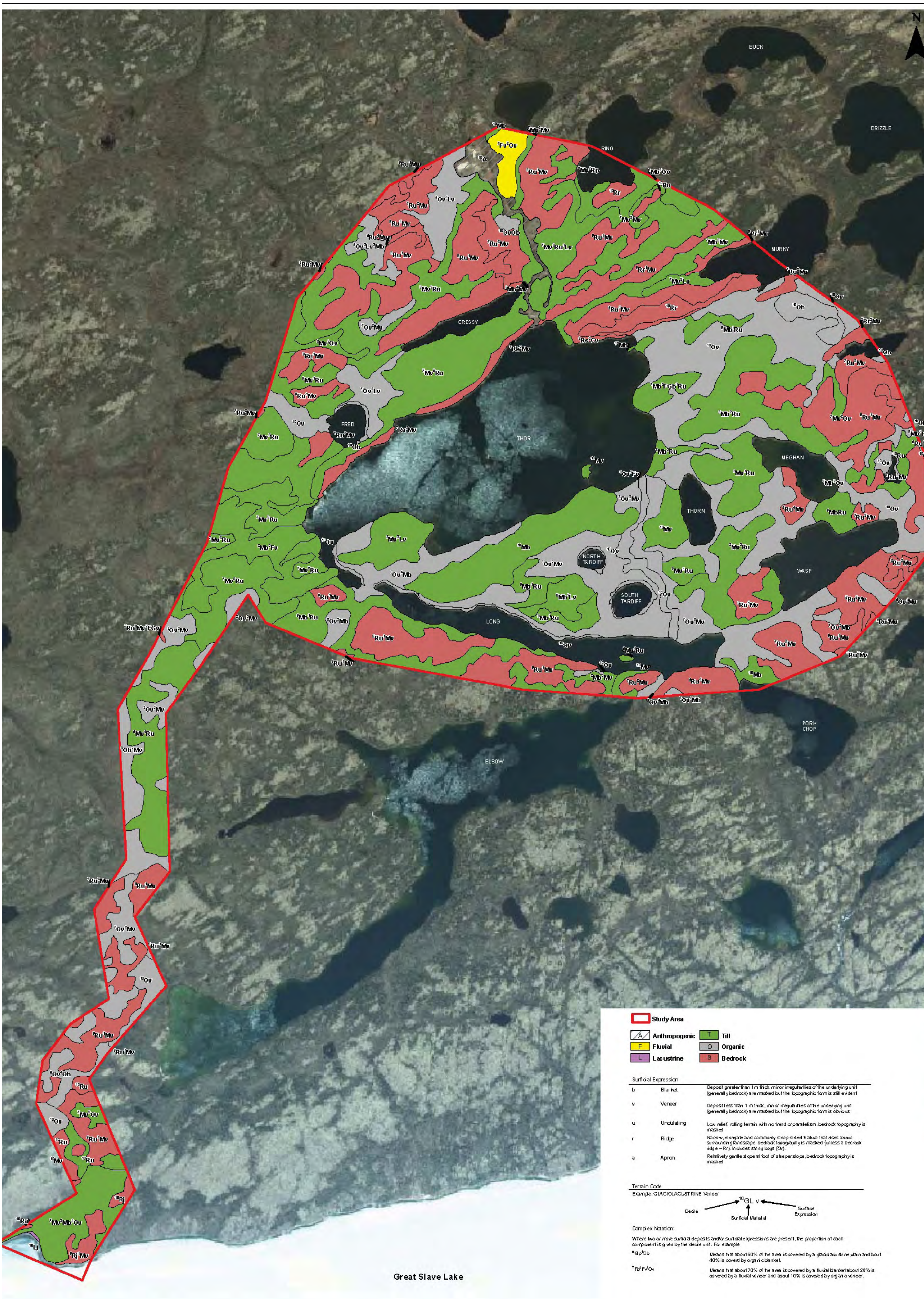
Figure 2.9-1 shows the distribution of parent materials throughout the Nechalacho Mine site area. The colors displayed on the map correspond to the dominant parent material only (Stantec 2010d).

Till Deposits

Till is the dominant surficial deposit found within the Project area accounting for 24.5% (Stantec 2010d). It consists of material deposited directly by ice by lodgement, melt out, or post-melt out gravity flow. Till deposits are generally found as discontinuous veneers (<1 m in thickness) and blankets (>1 m in thickness but not masking the underlying bedrock surface) directly overlying the bedrock. The surface topography is generally flat to very gently undulating.

Till facies vary considerably throughout the Project area but generally consist of a poorly compact, stony, matrix supported diamicton (Photos 2.9-3 and 2.9-4). Depending on the location and the degree of reworking of the material, the matrix ranges from silty clay to medium sand with minor amount of silt. Clasts range in size from pebbles to boulders and are sub-rounded to angular. Several erratics are found throughout the area, with diameters up to 1.5 m. Clast content is generally high, averaging 30 to 50%, but observation pits and coring have showed till material with clast content below 10%. The material lithology reflects the underlying bedrock type or the bedrock found in up-ice areas of the Project area. The drainage of the till deposits range for moderate to poor (Stantec 2010d).

Some till deposits contain lenses and beds of reworked material. In some cases, till facies shows evidence of reworking by glacial meltwaters and wave action (former glacial lake McConnell and present-day Great Slave Lake). Similar observations have been made in the Yellowknife area, where wave-washed bouldery till surface was found up to 100 m (275-280 masl) above the present Great Slave Lake level (Kerr and Wilson 2000). These tills are generally coarser, in relation with the fine sediment being removed.



NOTES
Figure Source: Figure 2-2. Stantec 2010d.

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Surficial Geology of the Nechalacho Mine Site Area

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Photo 2.9-3
Till Material
(ST21)

Photo 2.9-4
Observation pit showing coarse till material with approximately 50% coarse fragments in a silty sand matrix

Glaciofluvial Deposits

Glaciofluvial deposits consist of well-sorted sediment deposited by glacial meltwaters (subaerial or outwash deposits) and also includes material deposited in proglacial lakes in contact with glacier ice (ice-contact deposits) and material deposited at the margins of glaciers. They are very uncommon within the study area (0.3% of the study area) and are mostly found as a minor polygon component. No glaciofluvial landforms (e.g., esker, kame, outwash, etc.) were observed within the Nechalacho Project area.

Glaciofluvial materials within the Project area consist of medium- to coarse-textured sand with variable amount of gravels and pebbles (Photo 2.9-5). The clasts are for the most sub-rounded to round, with minor sub-angular. Glaciofluvial sediments are generally massive or vaguely horizontally bedded. Most observed deposits were forming discontinuous veneers, and generally located in topographic lows. Drainage of this type of material was usually good to moderate.

Photo 2.9-5
Glaciofluvial material found at Site ST25

Glaciolacustrine Deposits

This type of material is generally well-sorted and consists of heavy clay to silty clay, deposited by suspension into the former glacial lake basin (Stantec 2010d). The sediments are compact, firm and generally massive; although in some areas they are finely laminated (rhythmic beddings). Dropstones released by melting ice may be present. Buried organic horizons are not associated with glaciolacustrine sediments due to the limited amount of vegetation that existed in glacial times.

Glaciolacustrine material occupies former topographic depressions. No glaciolacustrine deposits were found exposed at the surface. A shallow borehole drilling revealed the presence of such material at 2.5 metres below the surface. The material consisted of silt and clay but the bottom of the units was not reached during the drilling.

2.9.1.6 Post-Glacial Deposits

Lacustrine Deposits

Lacustrine deposits were mapped over only 1.5% of the Nechalacho Project area (Stantec 2010d). Most lacustrine deposits were found underlying organic accumulations. Lacustrine sediment consists of massive to poorly laminated silt and clay with minor amount of sand (Photo 2.9-6). They also include sandy to gravelly beach deposits formed by currents wave action along Great Slave Lake. Most lacustrine deposits are found in topographic low and bedrock controlled depressions. The thicknesses of lacustrine deposits are highly variable and the material was commonly found underlying organic accumulations.

Photo 2.9-6
Lacustrine material consisting of massive silt with minor clay and very fine sand found at Site ST25

Fluvial Deposits

Fluvial sediments are rare throughout the study area accounting for slightly more than one percent of all materials mapped. They consist mainly of moderately well to well sorted, fine sand and silt with a very low amount of sub-rounded to well-rounded gravels and pebbles. Fluvial deposits are generally massive, but bedding and lamination with thin buried organic layers are not uncommon. Fluvial material observed in the field was usually less than one meter thick and their drainage ranged from moderate to poor.

Colluvial Deposits

Colluvial deposits are composed of angular to very angular material, deposited by gravity-induced mass movement. They consist mainly of blocky talus, characterized by the absence of fine grained matrix. The thickness of the colluvial deposits found within the Project area is generally thin (less than 2 m). All were characterized as well to rapidly drained. Colluvial deposits are mostly derived from the weathering (gelifraction) of local bedrock and are commonly found mantling the edges of bedrock ridges. The material is generally very coarse and angular, with an average clast size in the 20 to 50 cm range (Photo 2.9-7). These types of deposits are very rare within the study area, in relation with the relatively flat topography.

Photo 2.9-7
Blocky colluvial deposit found along a bedrock ridge, east of Thor Lake

Organic Deposits

Organic accumulations are common throughout the study area and account for 17.9% of the surficial materials (Stantec 2010d). They generally occupy topographic lows, and either rest directly on bedrock or overlie poorly drained surficial deposits such as fine-grained lacustrine or glaciolacustrine material. In lesser occasions, organic material is found overlying fine-grained till deposits. Only organic accumulations greater than 40 cm thick have been mapped as 'organic'. Accumulations less than 40 cm thick have been mapped according to the underlying surficial material.

Organic accumulations form bogs and fens, which host varying amounts of grasses, sedges and sphagnum mosses. The average depth of organics is about 80 cm, however some areas only have thin veneers (<50 cm) and others are characterized by deposits over 2 m thick. Drainage of the organic deposit units is considered very poor.

2.9.1.7 Permafrost Distribution and Landforms

An understanding of the permafrost and soil characteristics of the proposed Nechalacho Mine and Flotation Plant site area was developed through the review of the historical information, detailed mapping, and field inventory. Approximately 1,097 ha of the Thor Lake Property area were mapped for both surficial geology and soils using high resolution digital imagery, and 63 field sites were visited and described in October, 2008. Manual measurements of active layer thickness were taken from several test pits using a graduated steel probe. Core samples were also collected for further analysis, including gravimetric and volumetric water content, pH, conductivity, and grain size distribution (Stantec 2010d). A thermistor cable installed at a borehole southwest of Thor Lake also provided temperature data of the active layer and upper permafrost zone. Soils were also described in the field, and samples were collected for physical and chemical characterization. Full details are provided in Stantec (2010d).

The proposed Nechalacho Mine and Flotation Plant site area is located within the discontinuous permafrost zone, which results in the spatial distribution of permafrost being highly dependent on local factors (e.g., thin snow cover, northern exposure, presence of fine-grained sediments like silt and clay) (Stantec 2010d).

Within the proposed site area, landforms associated with permafrost consist mainly of frost-shattered bedrock and frost-heaved sediments that form small raised peat plateaus (Figure 2.9-2; Stantec 2010d). Areas represented by permafrost degradation include thermokarst pits, collapsed fens and bogs, and thaw lakes.

Active Layer Thickness

Sites with surficial deposits affected by permafrost have an active layer (the zone that freezes and thaws annually) that varies between about 40 and 200 cm (Stantec 2010d). Variations in active layer thickness are related to local terrain factors, the most important being thickness of the organic cover and sediment texture. Sites with organic cover thicker than a few decimetres and underlain by fine-grained sediments (silt, clay, fine-grained till) usually have active layer in the order of 60 to 65 cm on average (n=12). In coarser sediments and in locations with thinner organic cover, the active layer will usually be thicker than 100 cm. In bedrock, the active layer can be a few metres thick

Upper Permafrost Cryostructure, Ice Content and Thaw Susceptibility

Five shallow boreholes indicate the near surface permafrost in the Nechalacho Project area is potentially very ice-rich and thus highly thaw-susceptible (Stantec 2010d). From a geotechnical point of view, permafrost with volumetric ice content over 40% are considered more problematic upon thawing as they can initiate major geomorphic and environmental changes such as thaw-settlement, soil consolidation, impeded drainage, excess pore water pressure and mass movement.

Peat Accumulation

Significant decimetre to metre thick peat cover was encountered at several locations in the Project Area. These organic accumulations usually support permafrost, the latter usually extending down in the sedimentary deposit or bedrock below. Frozen peat is generally very ice-rich with volumetric ice content over 40% (gravimetric ice content over 100% is very common). Frozen peat is highly thaw-susceptible. Degradation and erosion of frozen peat is also very problematic as peat provides an isolative cover protecting the intrasedimentary permafrost. Removal and destruction of peat cover initiates positive feedback effects which accelerate permafrost degradation.

Glaciolacustrine Deposits

Glaciolacustrine silt deposits becoming finer in texture with depth were encountered in two boreholes located west of North Tardiff Lake (Stantec 2010d). These deposits are covered by a fine to medium sand blanket a few decimeters thick and peat up to 1.7 m thick. The active layer thickness was 50 cm in borehole ST44 and 80 cm in borehole ST46. Below the active layer the peat has a porous cryostructure and is very ice-rich (60 – 70% volumetric ice content). The sediments have lenticular to reticulate cryostructures and are very ice-rich (40 – 75% volumetric ice content). Glaciolacustrine sediments are considered highly thaw-susceptible. This type of deposit is covered by either peat or various types of sediments and has not been observed directly at the surface. The extent, depth and thickness of glaciolacustrine deposits are unknown but presumably important as the area was covered by glacial Lake McConnell.

Lacustrine Deposits

A lacustrine silty sand deposit was encountered in borehole ST48 (south-west of Thor Lake) (Stantec 2010d). This deposit is covered by about 70 cm of peat. The active layer is located at the interface between the peat and the mineral sediments. The silts have lenticular to suspended cryostructures and are generally ice-rich (25 – 62% volumetric ice content). Lacustrine deposits are considered highly thaw-susceptible. This type of deposit is covered by either peat or various types of sediments and has not been observed directly at the surface. The extent and thickness of this type of deposit are unknown but presumably smaller than glaciolacustrine deposits as they are related to isolation phases of former glacial Lake McConnell

Till with Fine-grained Matrix

A till deposit with a silty matrix was encountered in borehole ST02 (east of Fred Lake) (Stantec 2010d). This deposit is covered by peat a few decimeters thick. The active layer thickness was 40 cm and located at the mineral interface. The sediments have reticulate to suspended cryostructures and are very ice-rich (>65% volumetric ice content) in the first meter but the ice content decreased with depth. This type of deposit is presumably encountered at depth in several glacial troughs in the Project area. Locally this deposit has been washed out by waves of glacial Lake McConnell (see below).

Washed-out Till

A washed-out, coarse-grained till deposit was encountered in borehole ST08 (north of Thor Lake) (Stantec 2010d). This deposit was overlaid by about 75 cm of peat. The active layer was 55 cm thick. The peat has porous to micro-lenticular cryostructures and was very ice-rich (>480% gravimetric ice content, volumetric ice content not available). The sediment has a porous cryostructure and was ice-poor (<20% gravimetric ice content, volumetric ice content not available). Washed-out till deposits are considered thaw-stable.

NOTES
Figure Source: Figure 2-7. Stantec 2010d.

CLIENT
AVALON RARE METALS INC

EBA Engineering Consultants Ltd.

ISSUED FOR USE

THOR LAKE PROJECT

Permafrost Distribution of the Nechalacho Mine Site Area

PROJECT NO.	DWN	CKD	REV
V15101007.006	SL	RH	0
OFFICE	DATE		
EBA-VANC	May 9, 2011		

Figure 2.9-2

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2.9.1.8 Soils

The Nechalacho Project area is comprised mainly of moderately well, poorly and very poorly drained soil complexes (Stantec 2010d). These soils occur in patterns of Organics, peaty Regosols, Gleyed Regosols, Brunisols, Cryosols and bedrock exposures throughout the area. The patterns of soil can be quite complex in part due to the lack of well-established drainage pathways.

The Project area is composed of 37% (402.6 ha) mineral soils, 13% (148.3 ha) organic soils and 27% (295.8 ha) bedrock. The remainder is either previously disturbed land (1%, 8.4 ha), or open water (22%, 242 ha). Within the mineral soils, fine-textured soils (23%, 248.3 ha) almost double the area covered with coarse textured soils (12%, 128.6 ha).

The rest of the mineral soil is composed of Cryosolic soils that are frozen within one meter of the surface (2%, 25.6 ha). Organic soils occupy 13% of the Project area, and 8% of these organic soils were mapped as Organic Cryosols. Soils personnel have found considerable extents of thin organic layers that are not of sufficient thickness (e.g., <40 cm) to be designated as peatlands; some of these shallow organic areas have been mapped as organics by the Terrain program.

Soil Map Units

Eight (8) soil units based on texture and soil order were found and mapped in the area sampled in 2008. Four soil orders were identified in the field, including Brunisols, Cryosols, Organics and Regosols; Luvisols, which are known to occur regionally, were not found within the Project area. A total of 17 different soil subgroups were identified from the 63 soil investigations. The dominant soil order found in the Nechalacho Study Area was Regosolic.

Mappable soil units are those occurring in extents large enough to be represented as polygons that are legible and meaningful. A total of eight soil units were identified and mapped based on soil order and texture, the distribution of which are shown in Figure 2.9-3.

Physical and Chemical Characteristics of Soil Units

Stantec (2010d) also provided a brief description of the pertinent physical and chemical characteristics of the eight soil units located in the study area. Parameters recorded included soil horizon, depth, pH, electrical conductivity, percent saturation, Sodium adsorption ratio, Total Organic Carbon, Total Kjeldahl Nitrogen and texture. For more details on the physical and chemical properties of these soil units the reviewer is directed to Stantec (2010d) which is provide in Appendix A. It should be noted however that baseline data on dioxins and furans in soils were not collected.