8.3.2.2.6 Relative Humidity

No long-term regional data set of relative humidity is available. Relative humidity results (Table 8.3-11) are based on hourly data collected at the Project climate station for the period June 2004 to September 2005.

Table 8.3-11 Relative Humidity Summary, June 2004 to September 2005

Month	Mean Relative Humidity (%)	
	2004	2005
January	no data	74.6
February	no data	76.7
March	no data	82.6
April	no data	87.8
May	no data	87.0
June	66.3	67.7
July	64.5	71.6
August	77.7	76.0
September	84.8	81.4
October	87.9	no data
November	85.8	no data
December	75.6	no data

% = percent.

8.3.2.2.7 Solar and Net Radiation

Solar-radiation is the incoming solar radiation arriving at the earth's surface from above. It is also termed global radiation to indicate that it consists of all short-wave radiation arriving from direct sunlight as well as from diffused sky radiation. Net radiation is the difference between all incoming and outgoing radiation of both short- and long-wave lengths (i.e., it is a measure of the energy absorbed at the earth's surface).

No long-term regional data set of solar or net radiation is available. Solar and net radiation results are based on data collected at the Project climate station for the period June 2004 to August 2005. Monthly data are presented in Table 8.3-12 and daily data are shown in Figure 8.3-5.

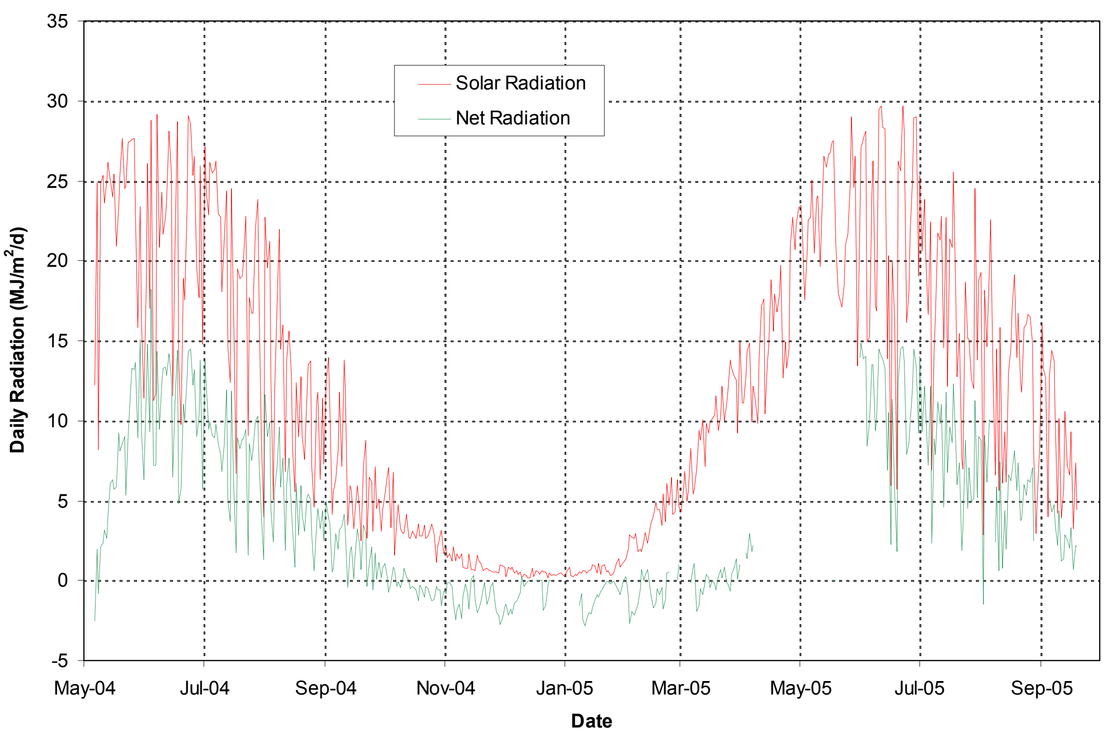
Table 8.3-12 Solar and Net Radiation Summary, June 2004 to August 2005

Month	Mean Solar Radiation ($MJ/m^2/d$)		Mean Net Radiation ($MJ/m^{2/}d$)	
	2004	2005	2004	2005
January	no data	0.67	no data	[a]
February	no data	3.65	no data	[a]
March	no data	9.41	no data	[a]
April	no data	15.56	no data	[a]
May	no data	22.66	no data	13.92
June	21.40	22.11	11.34	11.08
July	19.31	17.46	8.01	8.17
August	12.08	12.81	5.05	5.73
September	6.66	no data	1.87	no data
October	3.38	no data	-0.35	no data
November	1.06	no data	-1.16	no data
December	0.46	no data	[a]	no data

[a] Net radiation sensor data are not reliable.

$MJ/m^2/d$ = megajoules per square metre per day.

Figure 8.3-5 Project Station Daily Solar and Net Radiation, 2004 to 2005



$MJ/m^2/d$ = megajoules per square metre per day.

8.3.3 Permafrost

This following section describes the permafrost conditions and features within the Kennady Lake watershed. The Local Study Area (LSA) for permafrost corresponds to that for bedrock geology, terrain, soils, and vegetation, but the permafrost investigations focused on the Project footprint within the Kennady Lake watershed. For additional information regarding permafrost, the reader is referred to Annex D (Bedrock Geology, Terrain, Soil, and Permafrost Baseline).

8.3.3.1 Methods

The existing permafrost conditions and features for the Kennady Lake watershed were established using the following types of evaluation:

- interpretation of aerial photographs for permafrost mapping;
- geotechnical drill program and thermistor installation to measure soil temperature and active layer thickness;
- field reconnaissance program to confirm the aerial photograph interpretation;
- calculation of mean annual soil temperatures; and
- calculation[1] of the active layer and seasonal frost penetration.

8.3.3.2 Results

8.3.3.2.1 Permafrost Features

The Project is located within the Continuous Permafrost Zone (Heginbottom and Dubreuil 1995). The aerial photograph interpretation, field reconnaissance, and drill program determined that permafrost extends over approximately 90 to 95% of the on-land Project area. The following characteristics related to permafrost are described:

- landscape description and permafrost processes;
- mean annual soil temperature;
- thickness of active layer and frost penetration;
- moisture content; and
- permafrost thickness.

[1] Calculations were required for these permafrost parameters because of the limited data set obtained by the drilling program for mean annual soil temperature and thickness of the active layer. This derivation is an applicable technique when field measurements from a drilling program are not available.

8.3.3.2.2 Landscape Description and Permafrost Processes

Various earth processes and phenomena were identified during an air photo review and field reconnaissance. Some of the processes are a result of thawing or freezing, while others are a result of specific soil composition, terrain, topography, and origin of deposits.

Stone channels and polygons are considered to be erosional features that result in part from thawing of permafrost. Snowmelt water and runoff have washed out the soil matrix, leaving stony material (cobbles, boulders, and rock fragments) in the form of stone channels and stone polygons. Because the moraine deposits have a stony composition, formation of stone channels and stone polygons are widespread processes within the study area.

Mud boil polygons are encountered in moist to wet cohesive surficial soils. The formation of the mud boil polygons is a process related to frost cracking, followed by freezing of the active layer downward from the ground surface, perpendicular to the frost cracks, and upward from the active layer base. If the freezing soil is saturated or nearly saturated, the soil within the polygon under high pore water pressure bursts through the surficial frozen layer and freezes at the ground surface.

Landforms associated with ice wedges were frequently encountered in organic deposits of the study area. Formation of the ice wedges is a cyclic process of freezing and thawing. Winter cold causes the frozen soil of the active layer to shrink and crack. During warm spring days, water seeps into the cracks, freezes and expands when it is chilled by the still-frozen soil, forming wedges of ice in the soil. Each winter, cracks form again in the same places and each spring, additional water enters and enlarges the ice wedges as the freezing water expands. This cycle of cracking and freezing continues to enlarge the wedges year after year.

Thermokarst depressions and lakes were found occasionally within peat bogs and organic veneers. Formation of the thermokarst features is due to the process of thawing ice-rich permafrost and, finally, accumulation of water in the resulting subsidence. The soil subsidence can lead to formation of large thermokarst lakes, up to several tens of metres in dimension. Thermokarst processes are often accompanied with thermo-erosion, referred to as soil erosion from combined thermal and mechanical activity of running water in permafrost areas, resulting in formation of gullies.

Results of field investigations undertaken by AMEC Earth & Environmental (AMEC) in summer 2004 suggest that taliks (i.e., patches of unfrozen ground surrounded by permafrost) limited in depth could be encountered within isolated areas of glaciofluvial deposits treed with spruce, willow, and high polar birch. Taliks also can be encountered beneath numerous lakes in the study area. Depending on the size and age of the lake, sub-aquatic taliks may either be limited in depth (open to the top talik or closed talik) or penetrate through the entire permafrost thickness (through talik – open to both top and unfrozen layers beneath the permafrost). A through or open talik exists beneath Kennady Lake where water is deeper than 2 m.

8.3.3.2.3 Mean Annual Soil Temperature

The majority of the study area includes glacial veneer over bedrock. Based on thermistor temperature measurements, mean annual permafrost temperatures over the Project site ranged from -0.5°C to -2.5°C. The highest soil temperature in this range (-0.5°C) corresponded to regions that possess dense polar birch vegetation, while the lowest temperature (-2.5°C) were typically encountered within glacial veneers or blankets with minimum snow cover, which corresponded to areas with no shrub vegetation.

Wet areas within peat bogs and peat veneers have mean annual temperatures ranging from about -1.0°C to -1.5°C. The slightly warmer temperatures are mainly due to the low thermal resistance of saturated moss. Slightly cooler annual permafrost temperatures in the range of about -1.5°C could be encountered either in well-drained peat bogs and peat veneers due to the insulating effect of the moss in summer time. Cooler temperatures can also be expected at the summits of eskers and bedrock outcrops where there is minimal snow cover (low insulating effect of snow in winter time).

Areas with a mean annual soil temperature above 0°C (up to 1.5°C) could be encountered within the tall shrub terrain along creeks in the glaciofluvial deposits and at lake banks. The occurrence of the positive temperatures is a result of snow accumulation in tall shrubs.

8.3.3.2.4 Thickness of the Active Layer and Frost Penetration

The maximum thickness of the active layer (3.7 to 4.0 m) was estimated to be in exposed bedrock areas. Deep seasonal thaw is a result of low moisture content in bedrock. A deep active layer (in the range of 3.0 to 3.4 m) was also calculated for the eskers. The thickness of the active layer within the moraine veneer and blanket could vary from 2.6 to 3.2 m and 1.6 to 2.5 m, respectively. Glaciofluvial sand and silt deposits have the thinnest active layer thickness (1.0 to 2.0 m) of the mineral soils within the study area. Seasonal frost penetration within the on-land taliks likely does not exceed 1.5 m, due to a thick snow cover within tall shrubs.

Organic soils (peat) are characterized with the shallowest active layers (0.4 to 0.9 m). The main factors that determine a shallow active layer are high moisture content and the insulating effect of the moss cover. Within this range, the deepest thaw that would be expected occurs in dry peat bogs (moisture content about 500% by dry weight of peat) whereas the shallowest thaw is typical for heavy mossy patches of organic veneers.

8.3.3.2.5 Moisture Content

The mineral soils within the Project area have variable, although generally low, ice content. No visible ice was observed in the majority of boreholes advanced at the moraine blanket and glaciolacustrine plain. The moisture contents of these materials were in a range of 3 to 20%, by dry weight of solids. Higher ice contents were observed in glaciofluvial deposits. For instance, ice layers, up to 10 mm thick, were encountered in one borehole (MPV-04-206 in the depth interval from 1.8 to 2.9 m, see Annex D, Bedrock Geology, Terrain, Soil, and Permafrost Baseline for details).

Organic deposits were found to be extremely ice rich. It was estimated that volumetric ice content of the peat could be about 40 to 50% (moisture content of peat, defined as weight of water to weight of dry peat, was in a range of about 500 to 800%). Ice layers in peat were up to 3 mm thick, and were horizontal or wavy in shape. The ice layers were alternated with peat layers also several millimetres thick. Numerous ice lenses and pockets, up to 30 mm in size, were also recorded in the peat.

8.3.3.2.6 Permafrost Thickness

The thickness of the permafrost was measured in three deep boreholes (MPV-04-153, MPV-04-162, and MPV-04-165) located within the study area. At these three locations, the thickness of the permafrost was estimated to be 120, 150, and 310 m, respectively. The first two boreholes were drilled on islands within Kennady Lake at a distance of about 45 to 70 m from the shoreline. The warming effect of Kennady Lake results in the reduced permafrost thickness at these locations. The permafrost thickness of about 310 m encountered in borehole MPV-04-165 is considered a typical permafrost thickness for climate conditions associated with the Project area that are not influenced by lake taliks (Brown 1970).

8.3.4 Hydrogeology

The following section describes the hydrogeological setting within the LSA for the Project (Figure 8.3-6) used in the baseline. The baseline setting is defined from available published work and recent seasonal surveys and investigations. Figure 8.3-7 presents the Kennady Lake area and the various drillhole locations used in these surveys. For additional information regarding hydrogeology, the reader is referred to Annex G (Hydrogeology Baseline).

8.3.4.1 Methods

Baseline conditions provide a reference for identifying effects, and for qualitative and quantitative assessments of such effects. Groundwater conditions in the Project area were described in terms of geological setting, physical and chemical characterization, assessment of groundwater quality and conceptual and numerical modelling, and included the following:

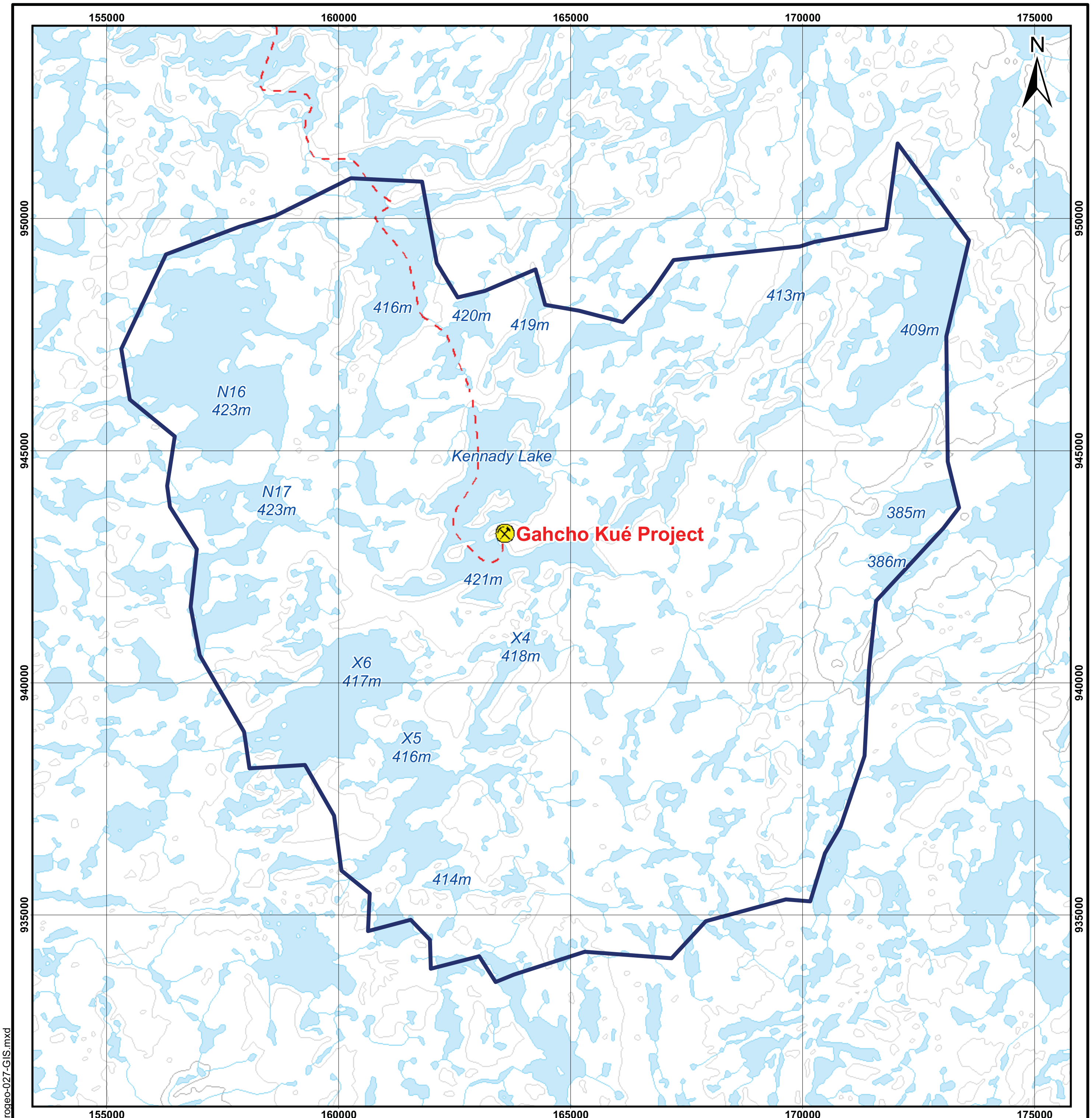
- collection and review of the pertinent information on the Project site, surrounding areas and region;
- completion of field programs in 2004 and 2005 including site reconnaissance, hydrogeological drilling and testing, and collection of groundwater samples;
- implementation of standard quality assurance and quality control procedures in the collection and analysis of field data and samples;
- performing laboratory analyses of collected groundwater samples;
- data processing and interpretation of collected information to define the conceptual hydrogeological condition, and to construct numerical flow models;
- development of a local groundwater flow model; and
- reporting.

8.3.4.2 Results

8.3.4.2.1 Groundwater Flow Regimes

The hydrogeology of the Project area is controlled by the permafrost characteristics, distribution, and spatial and temporal dynamics within the LSA. It is divided into two primary groundwater regimes:

- shallow groundwater regime; and
- deep groundwater regime.



LEGEND

- Gahcho Kué Project
- Winter Access Road
- Watercourse
- Contour (20m interval)
- Waterbody
- Local Study Area

NOTES

Base data source: The Atlas of Canada
Elevations shown are approximate (+/- 1m).
Lake elevations were derived from National Topographic Base Data (NTDB) 1:50,000 data and LiDAR data provided by the client.

GAHCHO KUÉ PROJECT

Hydrogeology Local Study Area

PROJECTION:	DATUM:	
Canadian Lambert Conf. Conic	NAD83	DE BEERS CANADA
Scale: 1:120,000 (2 1 0 2 Kilometres)		
FILE No: B-Hydrogeo-023-GIS.mxd		DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 1	Figure 8.3-6
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF

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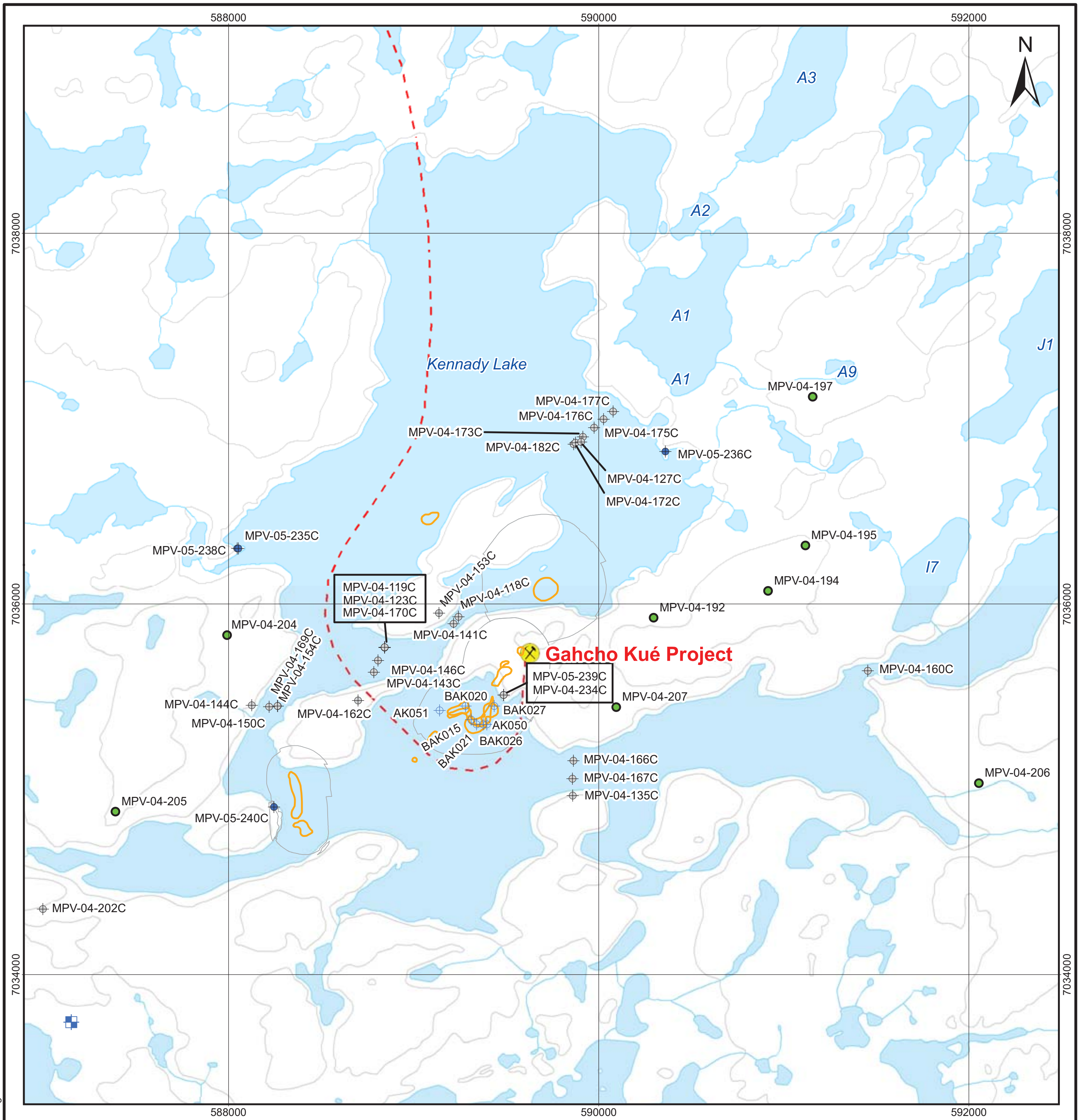

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LEGEND

- Gahcho Kué Project
- Winter Access Road
- Contour (10m interval)
- Watercourse
- Waterbody
- Shallow Groundwater Sampling Location
- Till Sampling Drillhole Location

Borehole

- 1996
- 2004
- 2005
- Kimberlite Outline
- Pit Outline

NOTES

1) Base Data Source: National Topographic Base Data (NTDB) 1:50,000
2) Borehole Data Sources:
-Hydrological Consultants Inc. December 2005. Draft Predicted Hydrologic Effects of Developing Gahcho Kué Diamond Project. Prepared for SRK Ltd. HCI-1759.
-Bruce Geotechnical Consultants. 1996. AK5034: Diamondiferous Kimberlite Pipe Geotechnical Studies, Permafrost and Ground Ice Conditions. A report prepared for Canamera Geological Ltd.

GAHCHO KUÉ PROJECT

Borehole Locations

PROJECTION:	DATUM:
UTM Zone 12	NAD83

Scale: 1:30,000

400 200 0 400

Metres

DE BEERS CANADA

FILE No:	
B-Hydrogeo-006-GIS	October 22, 2010

JOB NO:	REVISION NO:
09-1365-1004	4

OFFICE:	DRAWN:	CHECK:
GOLD-CAL	JH	DC

Figure 8.3-7

The shallow groundwater regime consists of the active layer above the permanent permafrost. This is an ephemeral system in that it is primarily frozen in winter time and is only active in the summer months. The deep groundwater regime is laterally continuous and found in bedrock below the permafrost at approximately 300 metres below ground surface (mbgs). It is anticipated that there is generally little to no hydraulic connection between the two flow regimes because of the thick, low permeability permafrost.

Groundwater in the shallow groundwater system is underlain by permanently frozen unconsolidated sediments (i.e., till, sand, and organic soils) or by frozen bedrock with low hydraulic conductivity. Groundwater in the active layer is controlled by surface topography and flows towards local lows, represented by lakes and the surface water drainage network. This conceptual framework applies to the on-land areas underlain by massive and continuous permafrost.

Taliks are found in unfrozen ground encountered within the discontinuous permafrost zone. Closed taliks exist beneath smaller lakes that possess sufficient depth such that they do not freeze to the bottom in winter, but not sufficient size for the talik below to extend through to the deep groundwater flow regime. Closed taliks can be also be encountered within isolated areas of glaciolacustrine plains, fluvial-glaciofluvial valleys, and intermittent creek channels treed with spruce, tall willow, and high polar birch.

Open taliks penetrate the permafrost completely, connecting shallow and deep groundwater (van Everdingen 1998). Open taliks may be found below large rivers and lakes and may be noncryotic (a hydrothermal talik; i.e., at temperatures above 0°C) or cryotic (a hydrochemical talik; i.e., at temperatures below 0°C due to elevated TDS concentrations). An open talik exists under Kennady Lake and other large lakes in the region measuring several hundred metres in size.

Recharge to the deep groundwater flow regime is predominantly limited to areas of open taliks beneath large, surface water bodies. Generally, deep groundwater will flow from higher elevation lakes to lower elevation lakes. To a lesser degree, groundwater beneath the permafrost is influenced by density differences due to the upward diffusion of deep-seated brines (density-driven flow).

8.3.4.2.2 Groundwater Usage

Groundwater sources from both the active layer and from the deep groundwater below the permafrost are not used for drinking water in continuous permafrost regions. Due to the presence of deep permafrost, the seasonal nature of the active layer, and the availability of good quality drinking water from surface water sources near the project site, it is unlikely that groundwater will be used as a drinking water source in the future.

8.3.4.2.3 Hydrostratigraphy

The conceptual hydrogeological model comprises six hydrostratigraphic units consisting of till, shallow exfoliated rock, deep competent rock, kimberlite, kimberlite contact zone, and enhanced permeability zones associated with sub-vertical faults (Figure 8.3-8 and 8.3-9). These units are described below.

Relatively competent bedrock is assumed to comprise the majority of the rock domain, and the hydraulic conductivity of competent rock is assumed to decrease with depth. Areas of greater fracturing associated with post-glacial rebound, faulting or along the kimberlite contact are assumed to have greater hydraulic conductivity than the less disturbed rock mass.

In developing the conceptual hydrogeological model for the Project, a reasonably conservative approach was undertaken, so that it is expected that the actual groundwater inflows to the open pits and associated impacts to the environment will be less than those predicted by the numerical hydrogeological model. Where uncertainty in parameter values exists, reasonable upper bound values of hydraulic conductivities have been selected.

Till

The till unit is located directly beneath Kennady Lake. Several lake bottom sediment samples collected below Kennady Lake contained unconsolidated sand, pebbles, cobbles, and boulders with few fines (Annex G). The mean thickness of the lake bottom sediments intersected by drill holes within Kennady Lake was 7 m. No in-situ hydraulic conductivity testing has been carried out in this unit beneath the lake; however, based on the material description, the hydraulic conductivity of this material is expected to be greater than the bedrock below, and therefore will not restrict groundwater flow from Kennady Lake.

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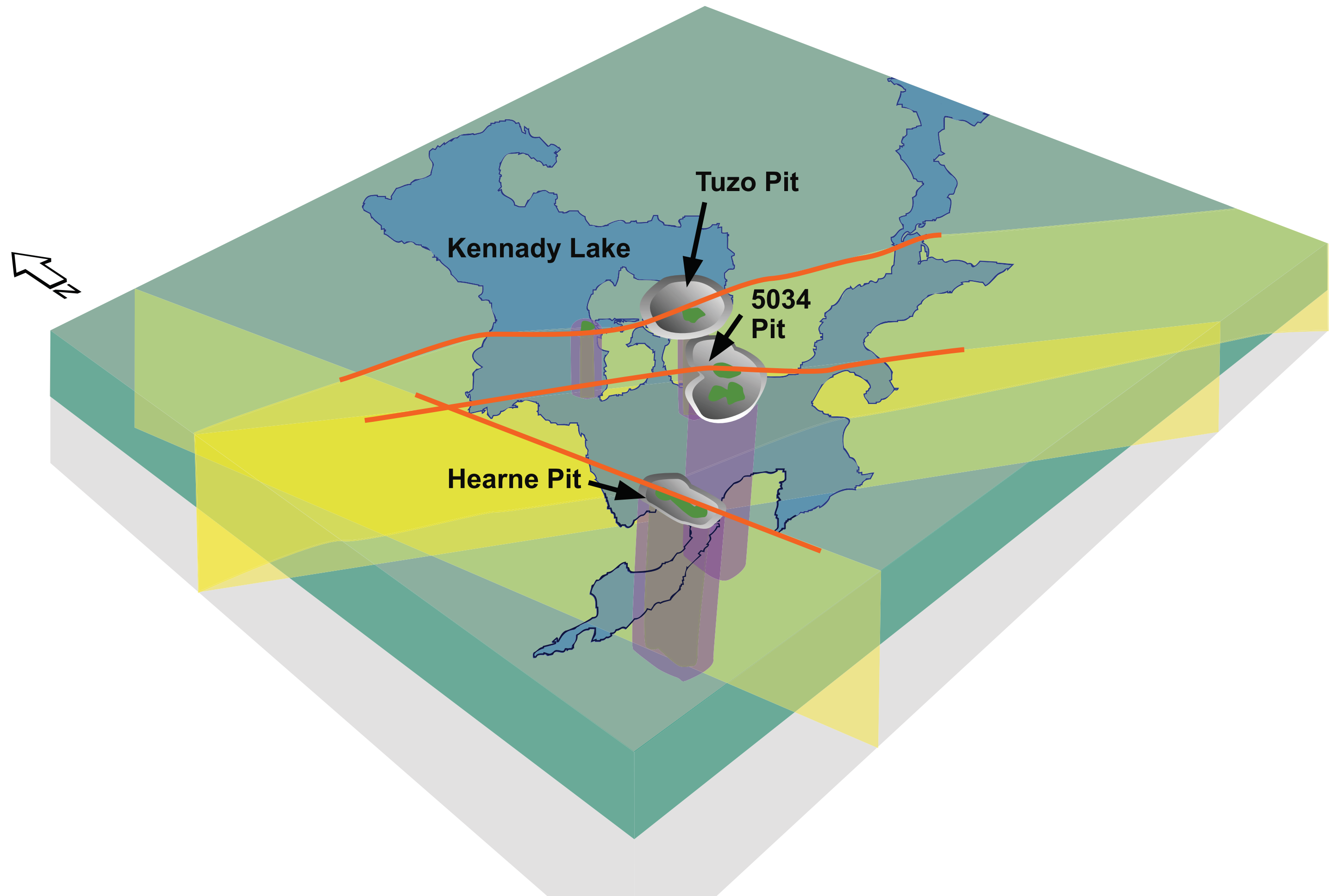


LEGEND

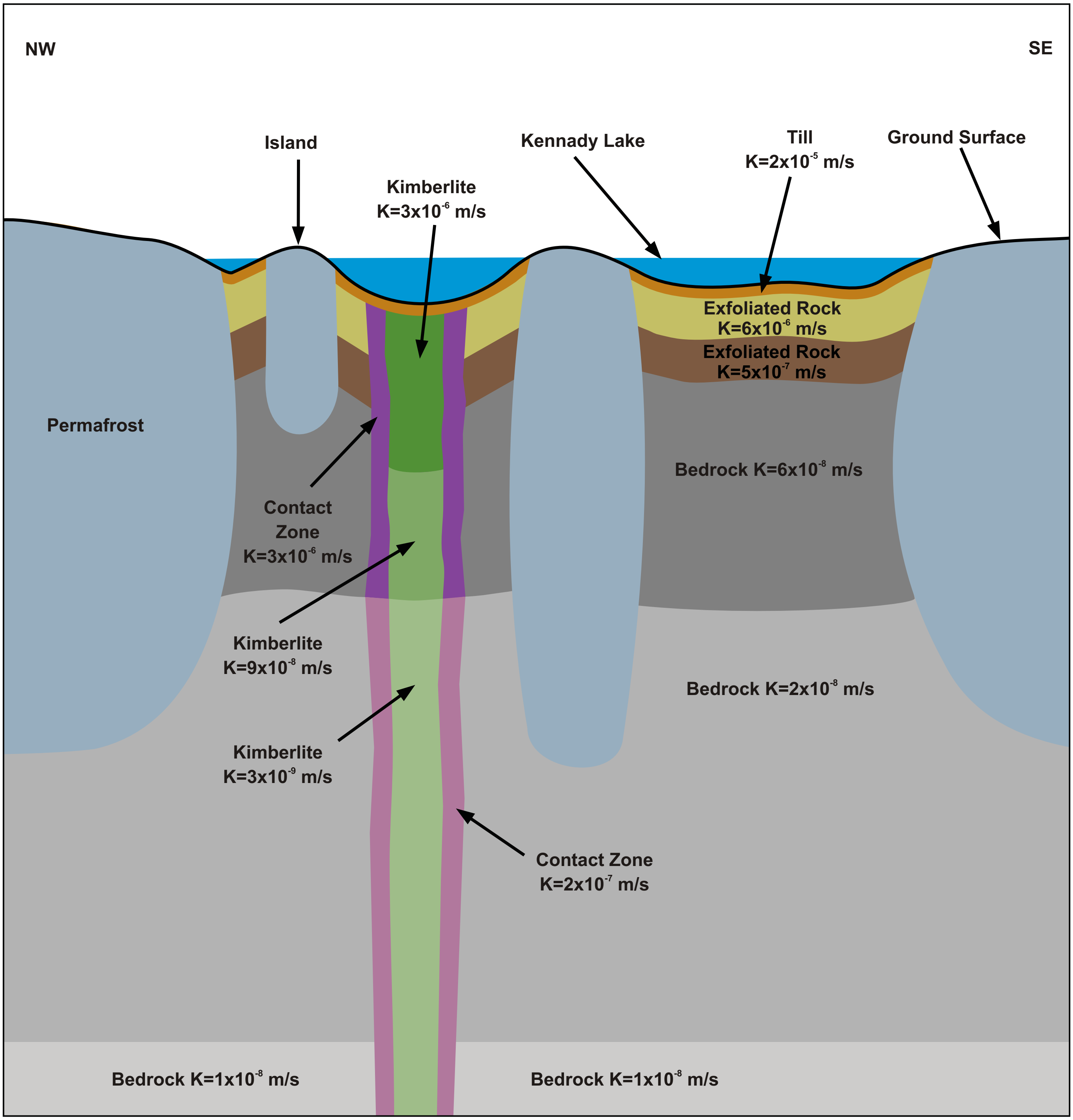
- Surface Expression of Potential Enhanced Permeability Zone
- Contact Zone
- Deep Bedrock
- Kimberlite Pipe
- Lake
- Permafrost
- Potential Enhanced Permeability Zone

Schematic Only

GACHO KUÉ PROJECT

Hydrostratigraphy of the Local Study Area

PROJECTION: N/A	DATUM: N/A	DE BEERS CANADA
SCALE: NOT TO SCALE		
FILE No: B-Hydrogeo-004-CAD		DATE: October 21, 2010
JOB No: 09-1365-1004	REVISION No: 0	**Figure 8.3-8**
OFFICE: GOLD - CAL	DRAWN: DLM	CHECK: DC



LEGEND

- Ground Surface
- Till
- Bedrock
- Contact Zone
- Exfoliated Rock
- Kimberlite Pipe
- Lake
- Permafrost

Schematic Only

NOTE

Potential enhanced permeability zones not shown in section - see Figure 5.4-1 for locations

GACHO KUÉ PROJECT

Hydrostratigraphy of the Local Study Area – Cross-Section View

PROJECTION: N/A
DATUM: N/A
SCALE: NOT TO SCALE
FILE No: SON-11.6-010-CAD
DATE: September 28, 2010
JOB No: 09-1365-1004
REVISION No: 0
OFFICE: GOLD - CAL
DRAWN: DLM
CHECK: DC

Figure 8.3-9

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Exfoliated Bedrock

The uppermost zone of bedrock typically has numerous horizontal fractures as a result of exfoliation due to rebound following deglaciation. This zone is estimated to be about 60 m thick, and can be further divided into two sub-zones. The exfoliated bedrock forms a relatively permeable unit within the taliks, but, below the land surface, it is entirely within the permafrost zone. Exfoliation planes are near horizontal; therefore, the vertical hydraulic conductivity of this unit is expected to be less than the horizontal hydraulic conductivity, and flow in this unit is expected to be primarily horizontal. The arithmetic mean of single-well response testing in this unit is considered to be most representative of the hydraulic conductivity on the scale of the open pits. Over 100 single-well response tests have been conducted in this unit. The arithmetic mean of these tests above 30 mbgs is about 6×10^{-6} metres per second (m/s), while between 30 mbgs and 60 mbgs, the arithmetic mean is about 5×10^{-7} m/s (Table 8.3-13).

Table 8.3-13 Summary of Hydrostratigraphy in EIS Model

Hydrostratigraphic Unit	Depth (mbgs)	Average Hydraulic Conductivity[a] (m/s)	Number of Tests
Exfoliated bedrock	0 to 30	6×10^{-6}	70
	30 to 60	5×10^{-7}	48
Bedrock	60 to 200	6×10^{-8}	70
	200 to 500	2×10^{-8}	24
Kimberlite pipe	0 to 100	3×10^{-6}	31
	100 to 200	9×10^{-8}	14
Contact between kimberlite pipes and bedrock	60 to 200	3×10^{-6}	26
	200 to 400	2×10^{-7}	11
Potential Enhanced Permeability Zones	60 to 400	1×10^{-6} to 3×10^{-6}	27

[a] For exfoliated rock and enhanced permeability zones, average hydraulic conductivity was calculated using the arithmetic mean of hydraulic conductivity values calculated from testing. For all other units, averages were calculated using the geometric mean. Values calculated based on the geometric mean were multiplied by a scaling factor of 3.

mbgs = metres below ground surface; m/s = metres per second.

Massive Bedrock

The massive bedrock unit is dominated by granitoids and granitic gneiss, but is not uniform; ultramafic rocks are also present. The bedrock below 60 mbgs, is generally less permeable than the overlying sediments, and the hydraulic conductivity is expected to decrease further with greater depths (Stober and Bucher 2007). Nearly 100 single-well response tests have been conducted in the bedrock below 60 mbgs with the deepest tests extending to nearly 500 mbgs. The geometric mean of single well response tests carried out from 60 mbgs to 200 mbgs is about 2×10^{-8} m/s, while the geometric mean of testing below

200 mbgs is about 5 x 10^{-9} m/s. All of these tests were of short duration and conducted within single wells.

Research has shown that these types of tests generally underestimate the hydraulic conductivity at the scale of excavations with similar dimensions to that of the open pits at the Project (Illman and Tartakovsky 2006; Niemann and Rovey 2008). The reason for this is that single-well tests investigate hydraulic conductivity over a small scale volume of rock near to the well screen or packer isolated interval of the borehole. The resulting values of hydraulic conductivity from these tests are more often representative of the lower-permeability rock composed of poorly connected and small aperture discontinuities (e.g., fractures). Testing of a larger volume of rock generally will include better connected and larger aperture discontinuities; hence, a higher permeability. It has been found that hydraulic conductivity values determined from single-well response tests generally underestimate the large-scale hydraulic conductivity by a factor of 2 to 5 times, depending on the relative scale of the disturbance to the hydrogeologic regime. Single-well response tests result in a relatively small disturbance to the hydrogeologic regime compared to the disturbance caused by the excavation of the open pit,

In the conceptual model, the hydraulic conductivity of the massive bedrock was increased by a factor of 3 to account for scaling affects related to the relative difference between the volume of rock tested in a single-well response test and the volume of the excavation at the open pits within the Project site. Accordingly, the geometric mean values of hydraulic conductivity determined from the single-well response tests were increased by a factor of 3 times in the conceptual hydrogeologic model (Table 8.3-13). Although hydraulic conductivity testing is limited to less than 500 m depth, the hydraulic conductivity of the bedrock is expected to decrease further with depth, as observed at other sites (Stober and Bucher 2007). Based on published reductions in hydraulic conductivity with depth (Stober and Bucher 2007); the hydraulic conductivity of the bedrock below 500 m is expected to decrease to less than 1 x 10^{-8} m/s.

Kimberlitic Pipe Zone

Nearly 50 single well response tests have been carried out in eight boreholes drilled into the 5034 Pipe to a maximum depth of nearly 300 mbgs. The geometric mean of hydraulic conductivity tests in the kimberlite to 100 m depth was about 9 x 10^{-7} m/s, while the geometric mean of testing from 100 mbgs to 200 mbgs was about 3 x 10^{-8} m/s. The results of three single well response tests carried out in the 5034 pipe in borehole MPV-05-239C below 200 mbgs suggest that the hydraulic conductivity of the kimberlite decreases further at greater depths with the highest hydraulic conductivity measured below 200 mbgs being 1 x 10^{-9} m/s. Similar to the massive bedrock, the geometric mean of the hydraulic conductivity of the kimberlite was increased by a factor of 3 to account for scaling effects.

Contact Zone(s)

A distinct contact zone with enhanced permeability was encountered between the 5034 kimberlite pipe and the bedrock in five boreholes: BAK020, BAK015, MPV-04-234, MPV-05-239C, and MPV-05-240C. This zone is estimated to be between 50 m and 100 m wide. The geometric mean of hydraulic conductivity tests within this zone to 200 mbgs is about 1 x 10^{-6} m/s. The geometric mean of comparable tests completed below 200 mbgs is about 7 x 10^{-8} m/s. Although the enhanced permeability indicated from testing in boreholes MPV-04-234 and MPV-05-239C could also be due to increased fracturing or larger fracture aperture associated with a linear structural feature, these results are also included in calculations of average hydraulic conductivity of the contact zone, as these structures would likely overlap.

The contact zones between other geologic formations were also tested. The contact zones between the granite and a dolerite dyke in MPV-04-127C and between the granite and ultramafic rocks in MPV-04-144C did not identify any increased hydraulic conductivity.

Enhanced Permeability Zones

Enhanced permeability zones or zones of greater fracturing or larger apertures related to structures such as faults have been found to be present at operating diamond mines in crystalline rock of the Canadian Shield. These zones have been found at Diavik, Ekati, and Snap Lake; none of which were identified during extensive field investigations at these sites prior to mining. At Diavik, in addition to the 100 m wide enhanced permeability zone referred to as Dewey's Fault, similar but thinner zones have been found: one zone parallel to Dewey's Fault and the other two perpendicular.

Higher permeability zones due to greater fracturing or larger fracture aperture associated with structural features may be present at the Project site. As discussed above, analysis of air photos, and gravity and aeromagnetic data was used by SRK (2004) to identify possible enhanced permeability zones associated with faults. Three of these zones (Figure 8.3-8), one passing through each of the three pipes, are considered to be of potential importance for governing groundwater inflow quality and quantity to the three planned open pits. These zones correspond to Fault 1A/1B, Fault 12, and the Hearne Main Fault identified on Figure 8.3-10. The results of single-well response testing across these potential enhanced permeability zones have been somewhat inconclusive. Attempts to test some of these features were unsuccessful. Where the features may have been intersected, it could not be determined if the high permeability calculated from the tests was related to these structures or to a highly permeable contact zone around the kimberlite. Nevertheless, because the zones associated with faults have been identified at three mines with similar host rocks, it was considered prudent to include these potential enhanced permeability zones in the conceptual hydrogeologic model developed for the Project. Therefore, the three zones identified in Figure 8.3-8 were assumed to have enhanced permeability.

Tests in three boreholes (i.e., MPV-04-234, MPV-05-238C, MPV-05-239C) may have measured the hydraulic conductivity of the potential enhanced permeability zone passing through the 5034 pipe. Because of the assumed enhanced permeability of these zones compared to the surrounding rock, the dominant groundwater flow pattern induced during mining will be near parallel to the features; therefore, the arithmetic mean of single-well response testing within these features provides the best approximation of the bulk hydraulic conductivity.

The arithmetic mean of the hydraulic conductivity values calculated below 60 mbgs in these wells is 3×10^{-6} m/s. The continuous and relatively high flows of water observed during purging of the three boreholes prior to groundwater sampling corroborates the high hydraulic conductivity values measured in these boreholes.

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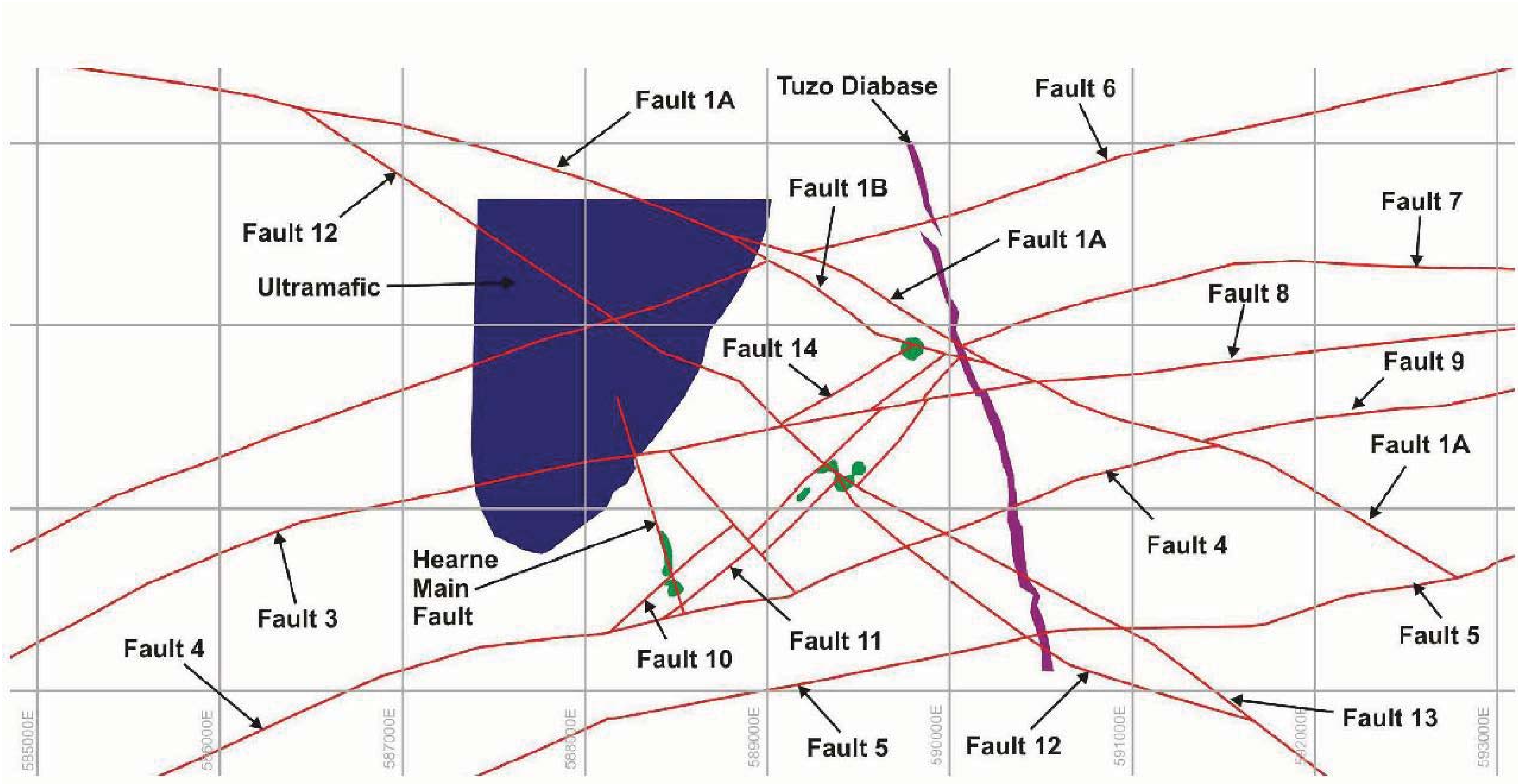


Source:
Figure 3.5, SRK (SRK Consulting (Canada) Inc.). 2004. Gahcho Kué Diamond Project - Mining Geotechnics. Prepared for De Beers Canada Ltd. November 2004.

GAHCHO KUÉ PROJECT			
Gahcho Kué Project Structural Geology Model			
PROJECTION: N/A		DATUM: N/A	DE BEERS CANADA
SCALE: NOT TO SCALE			
FILE No: B-Hydrogeo-001-CAD.dwg			DATE: October 25, 2010
JOB No: 09-1365-1004	REVISION No: 0		**Figure 8.3-10**
OFFICE: GOLD - CGY	DRAWN: RFM	CHECK: DC	

A test in borehole MPV-04-144C may have measured the hydraulic conductivity of the potential enhanced permeability zone passing through the Hearne Main Fault. Hydraulic conductivities over a zone of intense shearing at 107 to 110 mbgs, which was thought to correspond to the geophysical lineation identified by SRK (2004), were no greater than those in the competent rock. However, several pyrite-bearing fractures intersected at 130 to 150 mbgs, coincided with higher hydraulic conductivity values. The arithmetic mean of the three tests carried out from 130 to 150 mbgs is 1×10^{-6} m/s. No testing that has been carried out to date has intersected the enhanced permeability zone assumed to pass through the Tuzo pipe (Fault 1A and 1B).

Although the results of testing across potential enhanced permeability zones have been somewhat inconclusive, zones of enhanced permeability can be composed of sparsely spaced highly permeable discontinuities within a lower permeability pseudo-matrix. Depending on the orientation of a borehole drilled within such a zone, none or many permeable fractures may be intersected. Identification of enhanced permeability zones can be difficult with geotechnical logging and single-well response testing alone. Enhanced permeability zones associated with structural features have been identified at other diamond mines in the north only after mining began, and it is possible that additional enhanced permeability zones may be identified within the Project area once mining begins. Because of this difficulty in identifying such features prior to mining, and the apparent prevalence at diamond mines in the Arctic, the numerical hydrogeological model that was developed to predict mine inflows assumes that such enhanced permeable zones are present.

8.3.4.3 Groundwater Quality

8.3.4.3.1 Shallow Groundwater Flow System

The shallow groundwater system is only active in the summer season, and receives water mainly from summer precipitation, with possibly a minor contribution from snowmelt. Groundwater samples in the active layer had total dissolved solids (TDS) concentrations ranging from 44 to 544 milligrams per litre (mg/L), which is classified as fresh water (less than 1,000 mg/L TDS).

The chemistry of shallow groundwater is expected to be similar over most of the LSA. The shallow groundwater system is disconnected from the deep groundwater regime below the permafrost. Shallow groundwater can discharge to the surface drainage system. No evidence of saline seeps was reported from surface water quality, soil, or vegetation studies completed for the Project.

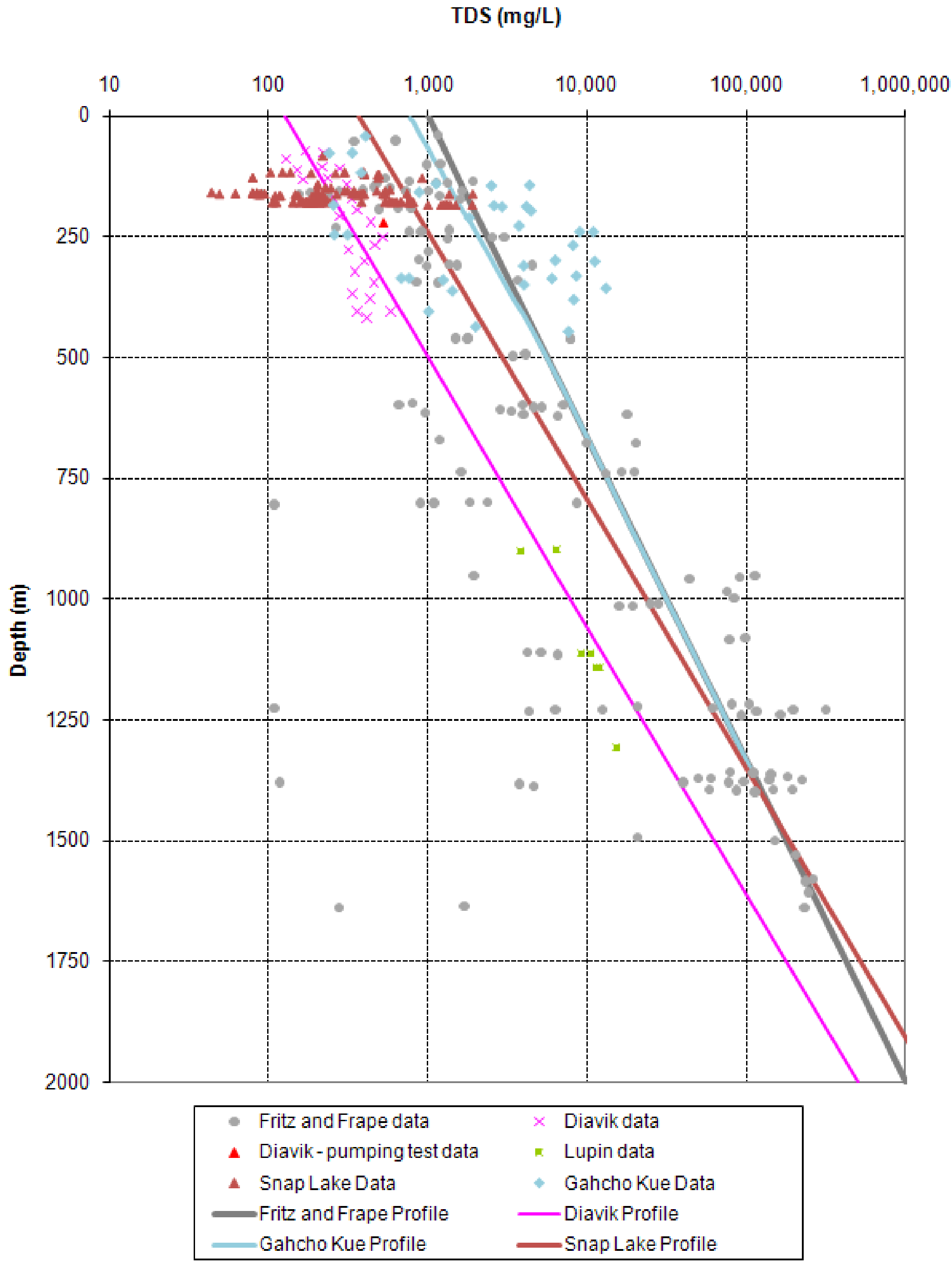
8.3.4.3.2 Deep Groundwater Flow System

Permafrost in the LSA extends to a depth of about 300 m below the surface in areas outside the influence of lakes or taliks, which can be considered as a typical permafrost thickness corresponding to permafrost formation in the Project area's climate condition (Brown 1970). In the region beneath continuous permafrost, groundwater mineralization with depth in the Canadian Shield is expected to approximate the regional relationship developed by Fritz and Frape (1987) and shown in Figure 8.3-11. Up to 50% by weight of the dissolved solids in saline samples could be attributed to chloride.

The chemistry of some of the groundwater samples collected at the site were affected by sampling difficulties resulting in dilution of the samples by drilling fluids. Five of the nearly forty groundwater samples were considered to be notably contaminated and, therefore, were removed from Figure 11.6-11. These groundwater samples were collected in boreholes MPV-04-118C, MPV-04-127C, and MPV-04-135C. The remainder of the groundwater quality data in the LSA has considerable variability for samples collected at similar depths. This variability may be due to local variations in the vertical and horizontal components of the convective flux due to variations in the hydraulic and density gradients, and hydraulic conductivity. In addition, local variations in the diffusive flux from the deep-seated saline groundwater may be present due to variations in the relative interconnection of pore space in the rock mass. Difficulties encountered during groundwater sampling that resulted in mixing of groundwater samples with drilling fluids. may also contribute to this variability. Depending on the groundwater quality and chemical composition of these fluids, results could over- or under-estimate the actual TDS Despite this variability, the TDS of groundwater samples collected for the Project is generally consistent with the TDS of groundwater observed at other sites in the Canadian Shield (Figure 8.3-11), and the data set is considered sufficient for characterization of the groundwater chemistry for the Project.

The Fritz and Frape profile (1987) shown in Figure 8.3-11 was developed using chemical analyses of deep saline water collected by various investigators from several sites in the Canadian Shield. The Diavik profile was derived from site-specific data from Diavik, supplemented by information from the Lupin mine site located about 200 km north of Diavik (Kuchling et al. 2000). The Diavik Site is located about 300 km northeast of Yellowknife, and about 150 km northwest of the Project site. Data for the Snap Lake Project, which is located about 85 km northwest of the Project, consist of site information augmented with deep groundwater data from the other data sources discussed previously.

Figure 8.3-11 Total Dissolved Solids in Groundwater versus Depth



TDS = total dissolved solids; mg/L = milligrams per Litre; m = metre

The Project TDS versus depth profile was developed based on a best fit to the TDS of groundwater samples at the site to the maximum depth of site-specific data (450 mbgs). Below this depth, the profile was assumed to follow the Fritz and Frape profile (Fritz and Frape 1987), which is the most conservative profile of TDS with depth for data collected in the Canadian Shield.

In general, groundwater below the permafrost is dominated by chloride and calcium, with sodium, magnesium, and sulphate levels increasing in step with increasing TDS levels. This trend is similar to the typical pattern observed in the deep waters from the Canadian Shield.

8.3.4.4 Groundwater Flow

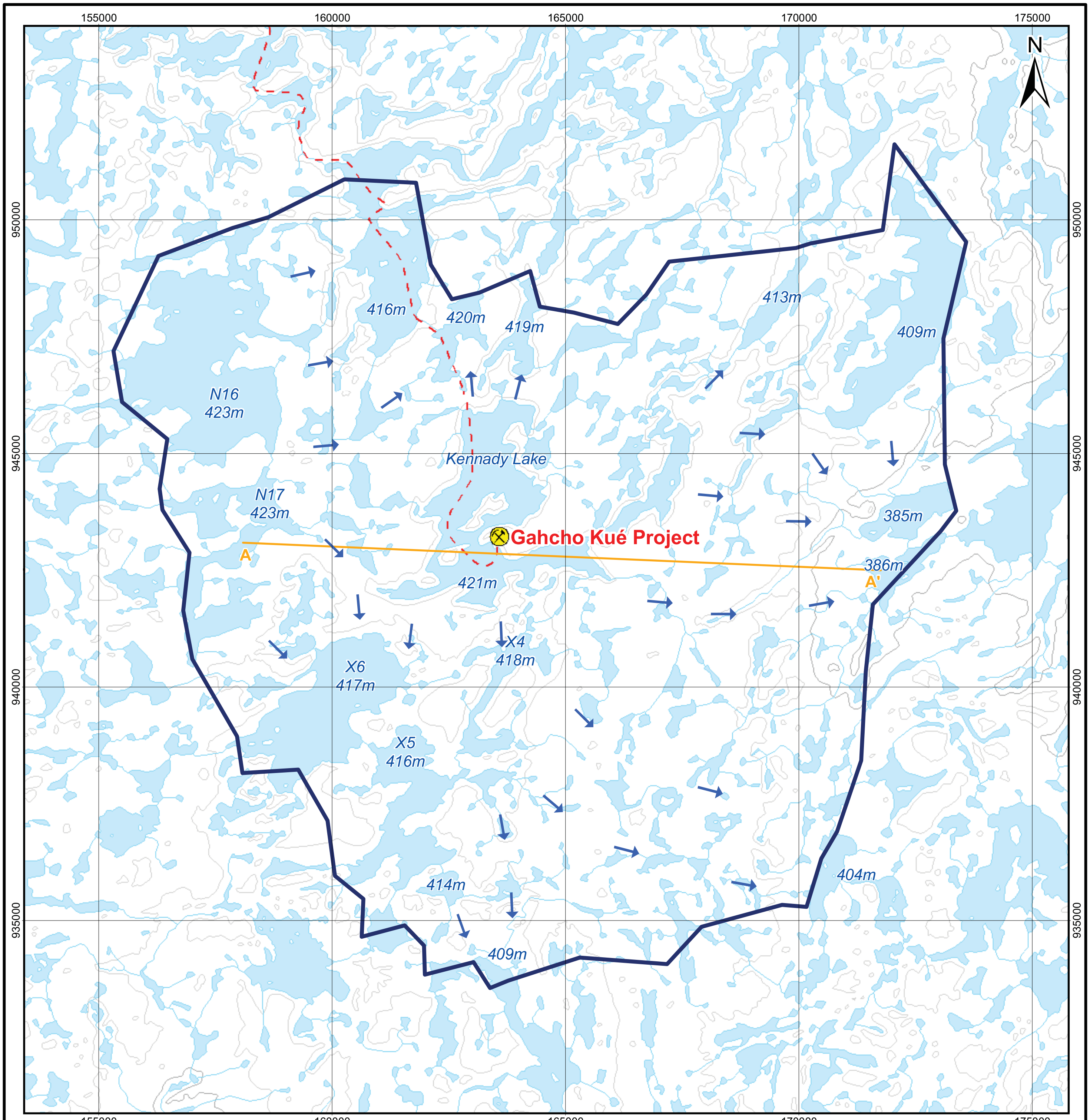
8.3.4.4.1 Shallow Groundwater Flow

In the shallow seasonally active groundwater regime, hydraulic gradients closely follow land topography. On this basis, the slope of the local terrain suggests hydraulic gradients in the active zone may range from 0.001 to 0.1 metre per metre (m/m). Based on surficial geology and vegetation mapping results, most of the elevated terrains appear to be well drained, and the groundwater table was not encountered within auger holes drilled in elevated areas during the 2004 field inspection. The auger holes never penetrated deeper than 0.4 to 0.6 m below grade due to auger refusal. In the fluvial channels, groundwater can be expected at shallower depths (less than 1 m), and in the peat bogs the groundwater table usually coincided with the ground surface. In terms of travel distance, groundwater in the till is likely to move in the range of centimetres per day, but locally faster groundwater movement may also occur. Groundwater flow in the shallow system is controlled by local topography, and, as a result, the total travel distance would usually extend only to the nearest pond, lake, or stream.

8.3.4.4.2 Deep Groundwater Flow

Open taliks play a pivotal role in controlling the deep groundwater flow, as the overlying lakes provide the driving head for the flow system beneath the zone of continuous permafrost. Generally, groundwater will flow from higher elevation lakes to lower elevation lakes.

Lakes expected to have open taliks extending to the deep groundwater flow system and their respective elevations are identified on Figures 8.3-12. Flow directions in the deep groundwater flow regime were inferred from the elevations of these lakes and are also presented on Figure 8.3-12 and Figure 8.3-13. The elevations of these lakes indicate that the groundwater flow direction in the deep groundwater flow regime in the area of the LSA is generally to the south and east.



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LEGEND

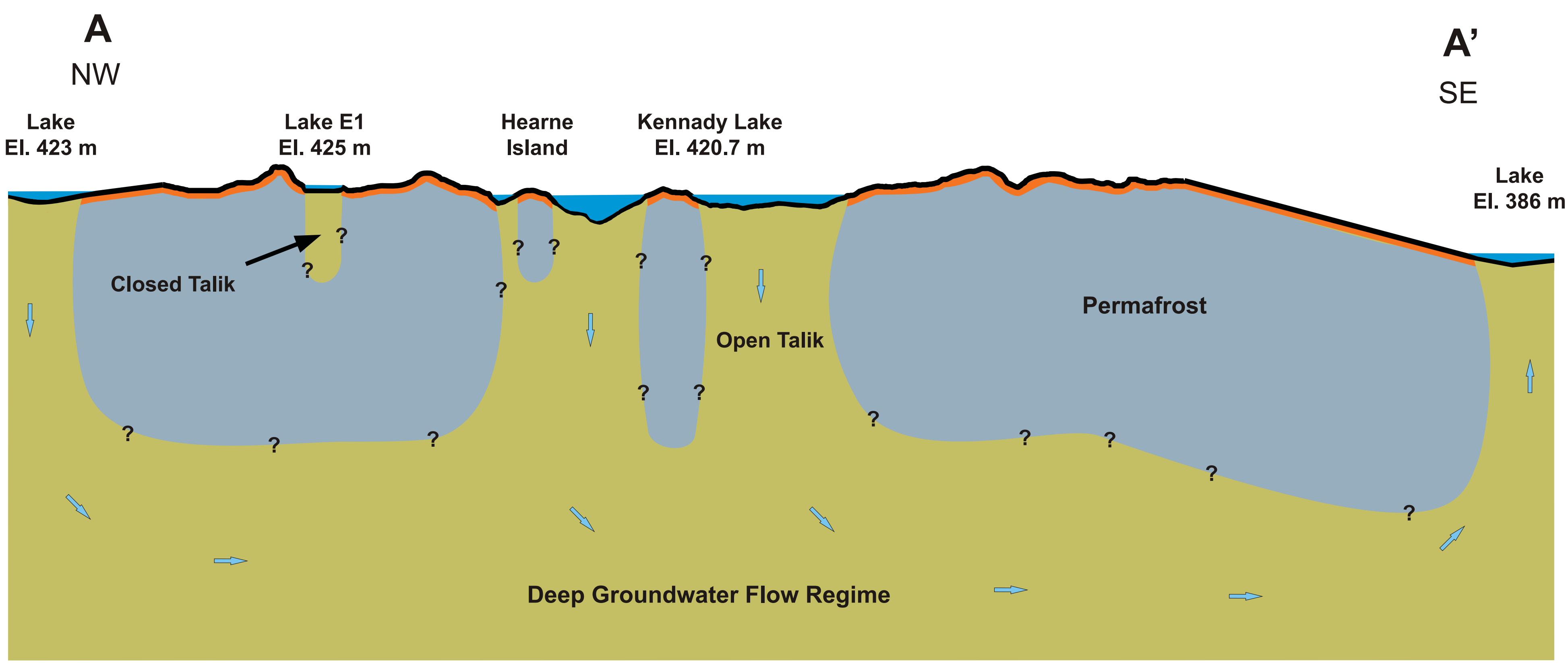
Gahcho Kué Project
Contour (20m interval)
Watercourse
Winter Access Road
Waterbody
Conceptual Cross Section
Inferred Groundwater Flow Direction Beneath Permafrost
Local Study Area

NOTES
Base data source: The Atlas of Canada
Elevations shown are approximate (+/- 1m).
Lakes labelled with elevations are assumed to have open taliks. Lake elevations were derived from National Topographic Base Data (NTDB) 1:50,000 data and LiDAR data provided by the client.

GAHCHO KUÉ PROJECT

Conceptual Model of Groundwater Flow in the Kennady Lake Area - Plan View - Pre-Mining

PROJECTION: Canadian Lambert Conf. Conic	DATUM: NAD83	DE BEERS CANADA
Scale: 1:120,000 2 1 0 2 Kilometres		
FILE No: SON-11.6-002-GIS		DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 1	**Figure 8.3-12**
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF



LEGEND

- Active Layer (Shallow Groundwater Flow Regime)
- Ground Surface
- Inferred Groundwater Flow Direction
- Deep Groundwater Flow Regime
- Permafrost

Schematic Only
Approximate vertical exaggeration of 1:8

GACHO KUÉ PROJECT

Conceptual Model of Groundwater Flow – Cross-Section View Pre-Mining

PROJECTION: N/A	DATUM: N/A	
SCALE: NOT TO SCALE		DE BEERS CANADA
FILE No: SON-11.6-011-CAD		DATE: September 29, 2010
JOB No: 09-1365-1004	REVISION No: 0	**Figure 8.3-13**
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These groundwater flow directions were inferred assuming that open taliks exist beneath lakes identified on Figure 8.3-12. On a regional scale, it was also assumed that the hydraulic conductivity of the bedrock beneath the permafrost is relatively homogeneous and isotropic.

8.3.5 Surface Water Quantity

This following section describes the hydrological conditions for Kennady Lake and the Kennady Lake watershed. For additional baseline details, the reader is referred to Annex H (Climate and Hydrology Baseline) and Addendum HH.

8.3.5.1 Methods

The description of hydrology focuses on the streamflow at lake outlets in the Kennady Lake watershed. Hydrometric data, stream geomorphology data, and ice and winter flow information were collected for baseline reporting. The baseline report examines local and regional data to develop the following estimates:

- long-term mean values of discharge and annual water yield;
- ranges of natural variability;
- dry and wet year values;
- peak discharges; and
- low flows.

A water balance model was developed to derive long-term mean characteristics and variability for key waterbodies within the Kennady Lake watershed because long-term regional hydrometric stations are sparse; regional data are not applicable to small, local watersheds with variable storage and lake outlet geometry; and there are only short periods of record for hydrometric stations at the Project.

8.3.5.2 Results

Kennady Lake is a headwater lake, receiving runoff from smaller tributary watersheds. Each such tributary watershed typically contains a series of small lakes with interconnecting channels, through which tributary runoff is conveyed before it reaches Kennady Lake. The watershed and watershed boundaries for Kennady Lake are shown in Figure 8.3-1 and characteristics of component watersheds are summarized in Table 8.3-14.

Table 8.3-14 Kennady Lake Watershed Area Summary

Watershed	Land Surface Area (km^2)	Lake Surface Area (km^2)	Total Area (km^2)	Lake Surface Fraction
A	1.59	0.645	2.24	0.288
B	1.10	0.174	1.27	0.137
C	0.323	0.018	0.341	0.053
D	3.47	1.03	4.50	0.228
E	1.15	0.244	1.39	0.175
F	0.260	0.039	0.300	0.131
G	0.765	0.090	0.855	0.105
H	0.730	0.102	0.832	0.122
I	0.594	0.152	0.746	0.204
J	1.12	0.525	1.65	0.318
Kennady Lake[(a)]	21.2	11.3	32.5	0.348

(a) Areas at Kennady Lake outlet include upstream watersheds A to J and Ka to Ke.

km^2 = square kilometres.

Stream Geomorphology

Lakes generally comprise more than 35% of the landscape within the Kennady Lake watershed, and are typically connected by short outlet channels that are steep relative to overall land slopes. Channels are typically only slightly entrenched, have high bankfull width-to-depth ratios (W/D greater than 12) and are moderately sinuous (i.e., curving). Sinuosity is greater than 1.2. Most lake outlet channels in the Kennady Lake watershed could be described as C1 or C2 channels by the Rosgen Level II classification system (Rosgen 1994), though some have side channels and very high width-to-depth ratios, and could be classified as D1 or D2 channels.

The beds of larger channels are typically armoured with bedrock or boulder layers that do not erode. Channels may include flat and steep reaches as governed by the local topography and bedrock outcrops. Channel banks typically consist of vegetated mats of organic material up to 300 mm thick, below which are found organics and fine soils within a matrix of boulders similar to the bed materials. Mid-channel islands were observed to also consist of a veneer of vegetated organic mat resting on a boulder substrate.

Erosion resistance of channel/banks is also likely enhanced by frozen conditions during spring snowmelt when peak discharges occur, as has been observed in other northern areas (Scott 1978). However, during unfrozen conditions after spring runoff, these banks may be sensitive to changes in flow regime.

Channels at the outlets of small, headwater lakes may be poorly defined and flow through organics, mostly without the cobble and boulder bed typical of the medium to larger channels described for the other watersheds. Although some cobbles and boulders may be present along the channel, the bed and banks are largely composed of easily erodible organics and fine-grained soils, which could be sensitive to changes in flow regime.

A summary of the lake outlet channel characteristics for Area 8 is provided in Table 8.3-15.

Table 8.3-15 Lake Outlet Channel Data Downstream of Kennady Lake

Outlet Channel	Watershed Area (km^2)	Length (m)	Elevation Drop (m)	Slope	Channel Type
Kennady Lake Outlet (Stream K5)	32.5	100	0.140	0.001	well-defined with boulder bed, shallow and wide, with sub- and side channels present

km^2 = square kilometres; m = metres.

8.3.5.2.1 Ice and Winter Flows

Winter Conditions

Data and observations of ice conditions and winter flows in the Kennady Lake watershed are summarized in Table 8.3-16. Ice thicknesses for the surveyed lakes appear similar for both years, with an average of about 1.7 m in 2004 and 1.8 m in 2005. Ice surface levels were also consistently about 15 cm higher than the water levels, indicating a floating ice cover with some snow load. For Kennady Lake, the January 2005 water level was only 0.004 m below the late September 2004 water level of 7.161 m (local datum), indicating that fall water levels remained stable to freeze-up, likely due to inflows approximately equalling outflows for that period.

All lake outlets that were examined were consistently observed to be completely frozen with zero flow during the winter. This appears to be the typical winter condition for all lakes in the Kennady Lake watershed.

Table 8.3-16 Lake Ice, Winter Water Levels, and Outlet Flow Conditions in the Kennady Lake Watershed, 2004 and 2005

Lake	Date	Ice Thickness (m)	Ice Level[(a)] (m)	Water Level[(a)] (m)	Outlet Condition
D7	May 2004	1.75	9.585	9.425	frozen, no flow
	Apr 2005	1.71	no data	9.607	frozen, no flow
D1	May 2004	1.64	8.252	8.092	frozen, no flow
	Apr 2005	1.79	no data	8.150	frozen, no flow
E1	May 2004	1.68	8.752	8.582	frozen, no flow
	Apr 2005	no data	no data	ice to bottom	frozen, no flow
Area 8	May 2004	1.65	7.283	7.143	frozen, no flow
	Jan 2005	1.74	7.287	7.157	frozen, no flow
	Apr 2005	1.96	no data	no data	frozen, no flow

(a) Local datum.

m = metres.

Spring Melt Conditions

During the first week or two of the runoff period, regular observations of water levels and discharge measurements were made at intervals of one to two days. Dates relating to the start of runoff for the monitoring stations for 2004 and 2005 are presented in Table 8.3-17.

Table 8.3-17 Runoff Start-up Dates in the Kennady Lake Watershed, 2004 and 2005

Location	Year	Start of Runoff	First Discharge Measurement	Runoff Peak
Lake D7	2004	June 3	June 5	June 11
	2005	June 2	June 4	June 6
Lake D1	2004	June 2	June 5	June 5
	2005	June 3	June 4	June 4
Lake E1	2004	June 2	June 3	June 5
	2005	June 2	June 4	June 5
Kennady Lake	2004	June 1	June 5	June 15
	2005	June 3	June 5	June 10

Freeze-up Conditions

On the basis of the observed winter conditions, observed start and end of season lake levels, the likely influence of watershed area, upstream lakes, and typical regional temperatures, the following estimates were made for freeze-up of the outlets:

- Lake E1 typically discharges to the end of September;
- Lakes D1 and D7 typically continue to discharge to about the middle of October; and

- Kennady Lake typically discharges to about the end of October.

8.3.5.2.2 Mean Water Balance

A mean annual water balance for a typical watershed was developed based on the mean values of the various parameters, on a hydrological year basis. The example provided in Table 8.3-18, although describing a lake in the L watershed, provides a basic characterization for mean conditions that is applicable to the Kennady Lake watershed.

Table 8.3-18 Representative (Lake L1) Watershed Mean Annual Water Balance for Natural Conditions

Component	Magnitude (mm)	Comment
Total precipitation	331.6	mean annual value
Rainfall	162.0	mean annual value
Snowfall as SWE	169.6	mean annual value
Spring SWE	117.7	mean annual value, accounting for 30% loss due to sublimation (51.9 mm)
Net precipitation input	279.7	rainfall + spring SWE
Surface runoff (at Lake L1 outlet)	141.1	mean annual value
Lake evaporation at 285 mm	93.8[a]	32.9% of watershed L is lake surface
Evapotranspiration at 66.8 mm	44.8[b]	67.1% of watershed L is land surface
Net watershed output	279.7	surface runoff + lake evaporation + evapotranspiration

[a] Total evaporation loss from lake surfaces = (285 mm) x (0.329) = 93.8 mm.

[b] Total evapotranspiration loss from land surfaces = (66.8 mm) x (0.671) = 44.8 mm.

SWE = snow water equivalent; mm = millimetres; % = percent.

The total evaporative loss from lake and land surfaces (lake evaporation and land evapotranspiration) equals 138.6 mm or 50% of the net pre-snowmelt precipitation input. When combined with sublimation of snow (51.9 mm), the total loss equals 190.5 mm or 57% of the total precipitation.

The surface runoff amount represents 43% of the total precipitation, or 50% of the net precipitation, which is the precipitation remaining after the snow sublimation loss is deducted.

8.3.5.2.3 Kennady Lake Outlet Flow Regimes

Frequency analysis of the hydrology model results (floods and droughts) for the outlet of Kennady Lake (Stream K5) was carried out for use in fisheries and water quality baseline reports and to provide a basis for environmental impact assessment and engineering design. The following parameters were examined:

- maximum, mean, and minimum daily outflow volumes for each calendar month;
- annual 7-day and 14-day mean flood discharges; and
- annual 30-day, 60-day, and 90-day low flow discharges for the period of July, August, and September.

Results for Kennady Lake outflow are presented in Table 8.3-19 (mean daily outflow volumes) and Table 8.3-20 (long-duration floods and low flow discharges).

Table 8.3-19 Derived Mean Daily Outflow Volumes at the Outlet of Kennady Lake (Stream K5)

Condition	Return Period (years)	Mean Daily Outflow Volume (m^3)					
		May	June	July	August	September	October
Wet	100	36,000	121,000	86,500	59,600	68,600	13,500
	50	21,400	114,000	76,800	52,000	53,900	11,700
	20	10,400	104,000	68,300	44,100	39,800	8,860
	10	5,790	97,600	61,900	38,100	29,200	6,640
	5	2,930	85,900	53,400	32,000	22,500	5,160
Median	2	708	65,900	39,300	22,800	13,200	3,070
Dry	5	0	47,000	28,400	16,500	8,350	1,820
	10	0	36,900	23,100	13,900	6,880	1,430
	20	0	28,500	19,000	12,100	6,010	1,190
	50	0	19,200	14,700	10,400	5,280	985
	100	0	12,900	12,000	9,420	4,910	878

m^3 = cubic metres.

Table 8.3-20 Derived Representative Discharges at the Outlet of Kennady Lake (Stream K5)

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Average Peak Q (m^3/d)	14-Day Average Peak Q (m^3/d)	30-Day (July to September) Low Flow Q (m^3/d)	60-Day (July to September) Low Flow Q (m^3/d)	90-Day (July to September) Low Flow Q (m^3/d)
Wet	100	2.51	192,000	167,000	48,900	52,500	59,000
	50	2.43	186,000	162,000	41,400	46,200	53,700
	20	2.28	176,000	153,000	32,400	38,200	46,600
	10	2.14	166,000	145,000	26,200	32,300	41,000
	5	1.96	153,000	133,000	20,300	26,500	35,100
Median	2	1.56	123,000	108,000	12,800	18,300	26,000
Dry	5	1.07	85,500	77,200	8,070	12,500	18,500
	10	0.80	65,100	60,000	6,560	10,900	16,100
	20	0.57	47,600	45,200	5,750	10,100	14,700
	50	0.32	27,900	28,400	5,210	9,550	13,700
	100	0.15	14,900	17,300	5,000	9,340	13,200

m^3/s = cubic metres per second; m^3/d = cubic metres per day; Q = discharge.

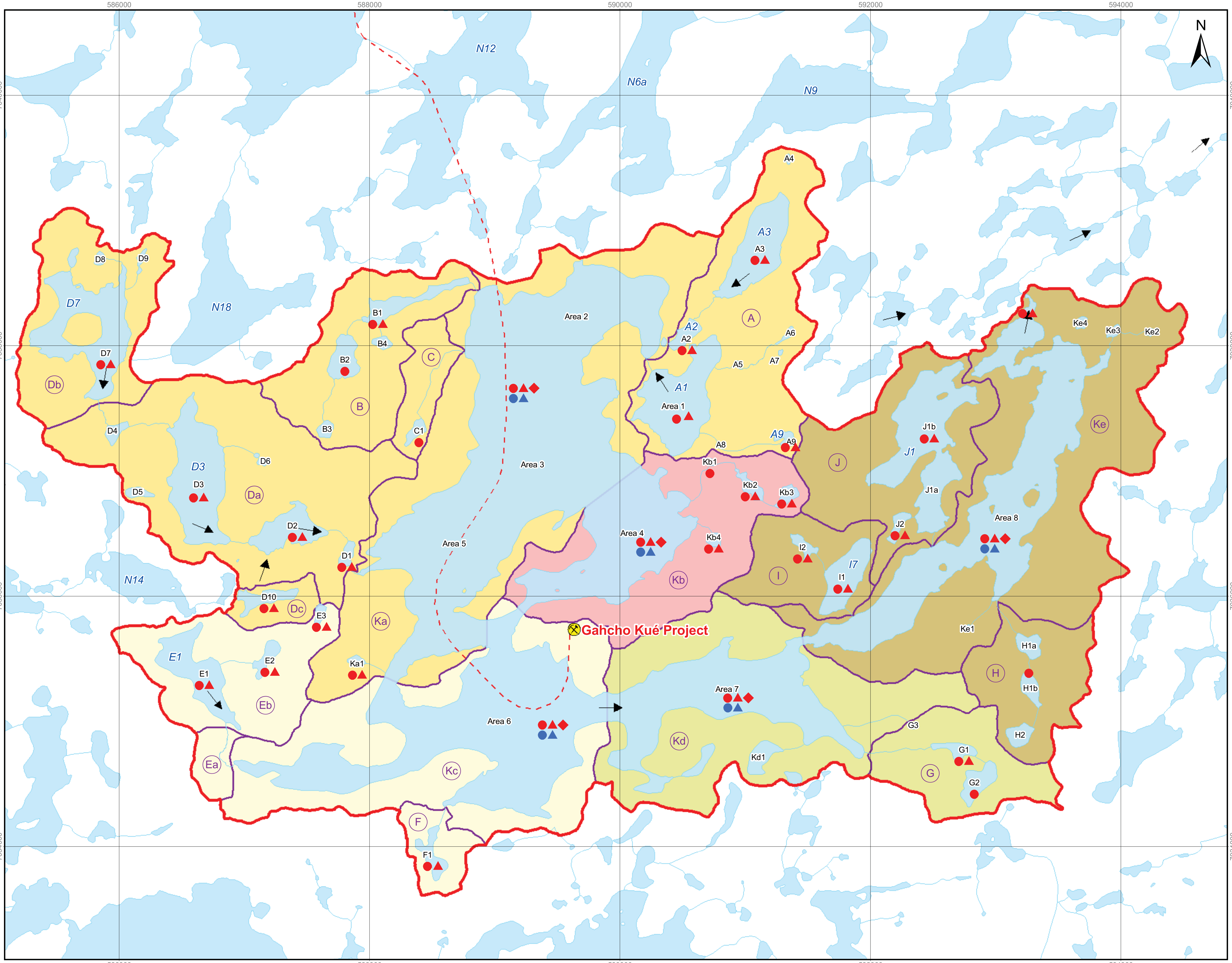
8.3.6 Surface Water and Sediment Quality

The following section provides an overview of the baseline surface water quality and sediment quality for Kennady Lake and its watershed. The baseline setting is defined from published work by others and several seasons of investigations by several consultants and consulting teams. For additional information regarding surface water quality, the reader is referred to Annex I (Water Quality Baseline) and Addendum II.

8.3.6.1 Methods

The baseline sampling programs involved the collection of water and sediment samples from Kennady Lake, and small lakes in the Kennady Lake watershed. Several baseline field programs have been conducted in the Kennady Lake watershed since 1996. The location and timing for each sampled lake is denoted for each type of water or sediment sample collected, and represented in Figure 8.3-14 using different symbols:

- in situ measurements are denoted with a circle;
- grab water samples and water samples collected as part of a vertical profile are denoted with a triangle; and
- grab sediment samples are denoted with a diamond.



LEGEND

- Gahcho Kué Project
- Winter Access Road
- Watercourse
- Waterbody
- K5 Lake Identifier
- Flow Direction

Watershed Boundary

- Kennady Lake Watershed

Watershed Boundary

- Watershed Ka
- Watershed Kb
- Watershed Kc
- Watershed Kd
- Watershed Ke
- I Watershed Identifier

Open Water

- Field Measurements
- Grab Samples/Water Column Profile Samples
- Sediment Sampling

Under-Ice

- Field Measurements
- Grab Samples/Water Column Profile Samples

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Surface Water Quality Sampling Locations in the Kennady Lake Watershed

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA	
Scale: 1:30,000 (0.5 0.25 0 0.5 Kilometres)			
FILE No: E-SWQ-003-GIS		DATE: December 16, 2010	
JOB NO: 09-1365-1004	REVISION NO: 4	Figure 8.3-14	
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	

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The colour of the symbol denotes sampling during under-ice (blue) and open water (red) conditions.

All data from the baseline study reports were classified as in situ (spot or profile measurements), grab samples, or vertical profile sampling. Summary statistics for water and sediment quality, including the median, minimum, and maximum values, as well as the range of sample sizes, were prepared for each chemical constituent analyzed and are presented in tabular format. Water quality summaries were prepared for both under-ice and open water conditions.

All data were summarized into the following three categories, based on the proportion of values below their respective method detection limits (MDL), and analyzed separately:

- data series where values below the MDL consisted of approximately one-third to one-quarter (or less) of the data series;
- data series where values below the MDL ranged from approximately one-third to two-thirds of the data series; and
- data series where values below the MDL comprised approximately two-thirds to three-quarters (or more) of the data series.

When the data series occurred in the first category, all values below the MDL were assigned a value of one-half of the most sensitive MDL and descriptive statistics (e.g., minimum, median, and maximum) were calculated. By using a value of half of the most sensitive MDL in this case, a representative statistical analysis of the natural conditions could be accomplished.

For data in the second category, descriptive statistics were calculated on values at or above the MDL only. If a value of half the most sensitive MDL was used in this case, the data series may have become skewed.

For data series in the final category, only minimum and maximum values were provided. By using a value of half the most sensitive MDL in this case, descriptive statistics may have provided a median below the most sensitive MDL.

Minimum and maximum detection limits were presented in addition to the statistical descriptors of the data range for each parameter to assist in understanding the statistical descriptors presented. The baseline data represents data collected over more than 10 years. Improvements or changes in analytical methods and procedures over the period of baseline data collection have resulted in inconsistent detection limits within the data. Generally, lower detection limits have been associated with more recent baseline field programs.

All results for the water sampling programs were compared to both the most recent Canadian Council of Ministers of the Environment (CCME) Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (CCME 2006, 2007) and Health Canada Guidelines for Canadian Drinking Water Quality (CDWQG) (Health Canada 2006, 2007). The results of the sediment sampling programs were compared to the CCME Interim Sediment Quality Guidelines (ISQG) for the protection of aquatic life (CCME 2002).

The CWQG and ISQG are intended to protect all forms of aquatic life, including the most sensitive species, for the long-term (CCME 2006). They are based on toxicity tests of the effects on sensitive aquatic species and tend to be conservative in nature.

8.3.6.2 Results

8.3.6.2.1 Kennady Lake

Physical Limnology and Vertical Structure

Under-ice Conditions

During under-ice conditions, all basins in Kennady Lake were inversely stratified. Cooler waters approaching 0°C occurred immediately below the ice with temperatures gradually increasing with increased depth. Maximum temperatures (around 4°C) generally occurred at depths greater than 6 m (Figure 8.3-15a).

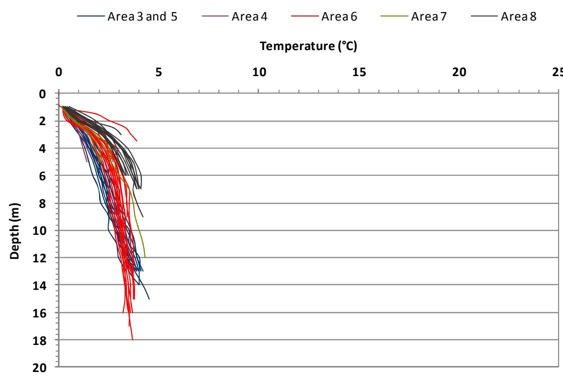
At the ice-water interface, measured conductivity in all areas of Kennady Lake ranged from 9 to 11 microSiemens per centimetre (µS/cm) (Figure 8.3-15b). Conductivity measured during under-ice conditions generally increased slightly with increasing depth in Kennady Lake.

Concentrations of dissolved oxygen (DO) ranged from 13 to 22 milligrams per litre (mg/L) in the upper 2 m of the water column and decreased rapidly with depth to near anoxia (i.e., DO concentrations less than 2 mg/L) at depths greater than 12 m during late winter (April to May) (Figure 8.3-15c). In general, DO concentrations were below the CWQG for cold water aquatic life (9.5 mg/L for early life stages and 6.5 mg/L for other life stages) at depths generally greater than 8 m in the deeper basins of Kennady Lake.

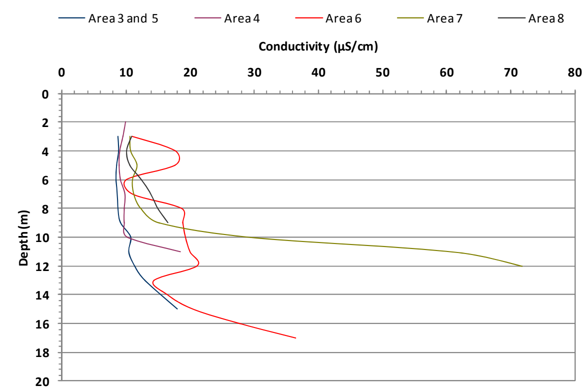
Water column profile measurements for pH in under-ice conditions were limited to water surface measurements (Figure 8.3-15d). Measured field pH values ranged between 6 and 7.

Figure 8.3-15 Physico-chemical Water Quality Profile Data in Kennady Lake During Under-ice Conditions

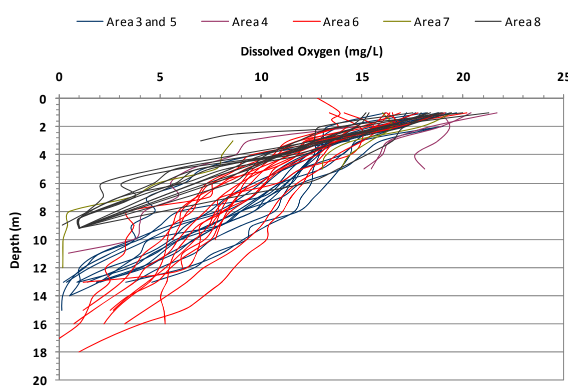
a.) Water Temperature



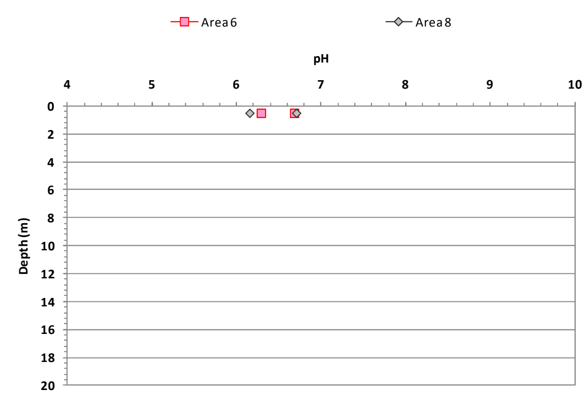
b.) Conductivity



c.) Dissolved Oxygen



d.) pH



Note: Only single surface ice-covered pH readings collected.

m = metres, °C = degrees Celsius, µS/cm = microSiemens per Centimetre, mg/L = milligrams per litre.
Individual field results not presented in field profile figures.

Open Water Conditions

Temperature profiles were vertically homogeneous during most open water sampling events, indicating that the water column in Kennady Lake was typically well mixed by temperature-related, density-driven overturn in spring and fall as well as wind-driven circulation during summer months (Figure 8.3-16a). Temperatures varied during open water conditions from 3°C to 17°C. Well-developed seasonal thermoclines (steep temperature gradients) were observed between depths of 10 and 14 m in Area 6 during sampling events in late July 1999, early August 2004 and July 2010. The temperature gradients for the 1999 and 2004 thermoclines were about 5.5°C per metre, but the July 2010 thermocline was less defined.

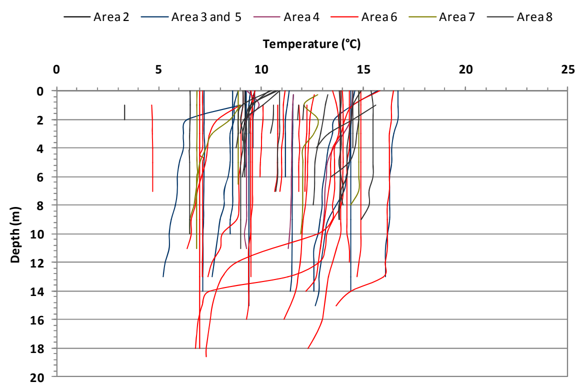
Measured conductivity during open water conditions was very low, ranging between 8 and 14 µS/cm (Figure 8.3-16b). There was very little variability throughout the water column indicating that total dissolved solids (TDS) were equally distributed throughout the lake, and that Areas 2 through 8 of Kennady Lake were well mixed during open water conditions.

Dissolved oxygen concentrations were generally uniform throughout the water column of Areas 2 to 8 of Kennady Lake during open water conditions, ranging from 9 to 16.5 mg/L (Figure 8.3-16c). Decreases in DO at depths greater than 12 m were observed in Area 6, associated with the measured temperature thermoclines. The DO concentrations measured during most sampling events were above the lowest acceptable dissolved oxygen concentrations for the protection of early life stages (9.5 mg/L) and other life stages (6.5 mg/L) of cold water aquatic life in the CWQG. There were no DO concentrations recorded below 6.5 mg/L with the exception of one result which may have been due to the probe reading pore water in the sediments.

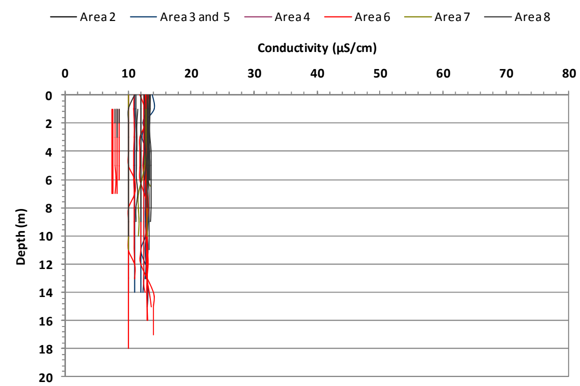
Open water pH field results ranged from 6.4 to 8.3 (Figure 8.3-16d). Field pH profiles in Kennady Lake were fairly uniform throughout the water column for each field program. Observed changes in pH between field programs are likely due to seasonal variation in addition to calibration changes in the field instrument. Several vertical profiles measured during fall field programs were below the acceptable pH range of the CWQG (6.5 to 8.5).

Figure 8.3-16 Open Water Kennady Lake Field Data (1998 to 2010)

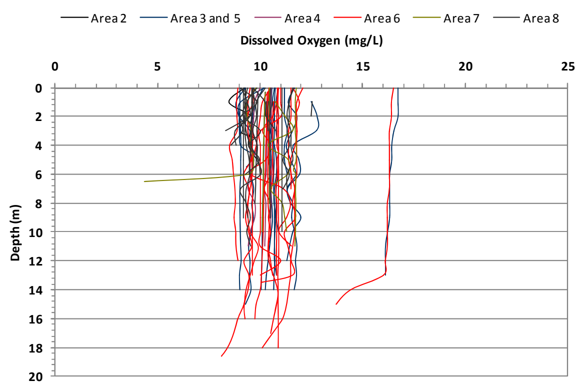
a.) Water Temperature



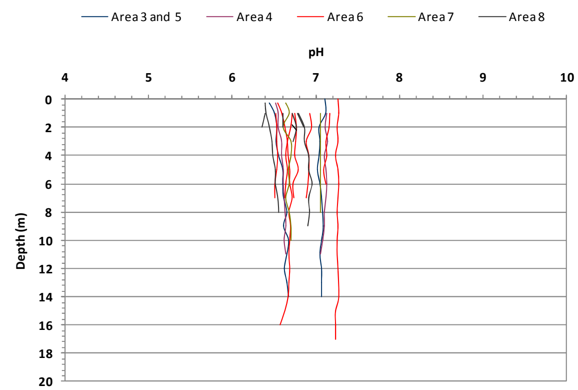
b.) Conductivity



c.) Dissolved Oxygen



d.) pH



Note: Questionable profiles from September 11 -13, 2004 removed.

m = metre, °C = degrees Celsius, µS/cm = microSiemens per centimetre, mg/L = milligrams per litre.

Individual field results not presented in field profile figures.

Water Quality

The water in Areas 2 through 8 of Kennady Lake is soft, having a median hardness of 3.8 mg/L during open water conditions and 6 mg/L during under-ice conditions (Table 8.3-21). The median alkalinity during both open water and under-ice conditions, which is also 4 and 6 mg/L respectively, is an indication of the low buffering capacity of water from Kennady Lake.

The concentrations of TDS were low during open water and under-ice conditions, (medians of 5.4 and 7 mg/L, respectively), indicating a very small amount of dissolved substances in the water (Table 8.3-21). Bicarbonate was the dominant ion surveyed during both water conditions, whereas sulphate and chloride were at or below the detection limit during most sampling events. Calcium was the major cation measured in all areas of Kennady Lake.

Total suspended solids (TSS) were generally measured at or below detection limits during under-ice conditions (78% of samples were below detection limits during under-ice conditions; Table 8.3-21), indicating that water in Kennady Lake is very clear and contains very little suspended solids. The highest measurement of TSS (27 mg/L) was reported during open water conditions. Only 67% of samples were below detection limits during open water conditions.

The concentrations of inorganic nitrogen compounds, such as ammonia, nitrate, and nitrite, generally were below detection during open water conditions (Table 8.3-21). Total Kjeldahl nitrogen (TKN) was measured above detection levels only during open water conditions, where it was generally found at low concentrations (median of 0.3 mg/L).

Total phosphorus (TP) was more variable during under-ice conditions than during open water conditions. Due to the high number of results below detection, a median TP concentration could not be calculated. Samples collected during ice-cover had a minimum concentration of <1 micrograms per litre (µg/L) and a maximum concentration of 10 µg/L. Open water concentrations had a maximum value of 6 µg/L. The observed concentrations of nutrients indicate that Kennady Lake can be classed as an oligotrophic lake, is phosphorus-limited, and has low biological productivity.

Table 8.3-21 Summary of Water Quality in Areas 2 through 8 in Kennady Lake, 1995 to 2010

Parameter Name	Unit	Method Detection Limit			Kennady Lake: Under-Ice Conditions (1996 - 2004)										Kennady Lake: Open Water (1995 - 2010)									
											Guidelines										Guidelines			
											Aquatic Life - Chronic [(a)]		Human Health - Chronic [(b)]								Aquatic Life - Chronic [(a)]		Human Health - Chronic [(b)]	
		Min	Max	Number of Method Detection Limits	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Field measured																								
pH	pH units	-	-	-	4	**6.2**[(c)]	6.5	6.7	0	0	6.5 - 8.5	2	5.0 - 9.0	0	261	**6.8**	6.8	7.3	0	0	6.5 - 8.5	85	5.0 - 9.0	13
Temperature	°C	-	-	-	567	0	2.7	4.5	0	0	-	0	-	0	561	3.3	12	18	0	0	-	0	-	0
Specific Conductivity	µS/cm	-	-	-	51	8.4	11	72	0	0	-	0	-	0	488	7.4	12	18	0	0	-	0	-	0
Dissolved Oxygen	mg/L	-	-	-	548	**0**[(c)]	9.6	22	0	0	6.5	160	-	0	528	**1.4**[(c)]	11	17	0	0	6.5	2	-	0
Conventional Parameters																								
Colour	TCU	1	-	1	0	-	-	-	0		-	0	-	0	22	0.5	10	30	4	18.2	-	0	-	0
Specific Conductance	µS/cm	-	-	0	116	12	18	27	0	0	-	0	-	0	45	10	13	23	0	0	-	0	-	0
Dissolved Organic Carbon	mg/L	1	-	1	35	2.7	3.6	5.1	0	0	-	0	-	0	28	0.5	3	6	1	3.6	-	0	-	0
Hardness	mg/L	6	-	1	129	4.3	6	10	0	0	-	0	-	0	83	1.3	3.8	5	22	26.5	-	0	-	0
pH	pH units	-	-	0	125	**5**[(c)]	6.4	6.8	0	0	6.5 - 8.5	78	5.0 - 9.0	0	47	**5.6**[(c)]	6.5	7.2	0	0	6.5 - 8.5	23	5.0 - 9.0	0
Total Alkalinity	mg/L	1	5	2	160	0.5	6	9	17	10.6	-	0	-	0	79	0.5	3.6	27	12	15.2	-	0	-	0
Total Dissolved Solids	mg/L	2	20	3	78	3	7	27	21	26.9	-	0	-	0	78	1	5.4	32	20	25.6	-	0	-	0
Total Organic Carbon	mg/L	1	3.1	2	88	1.6	3.7	8.8	1	1.1	-	0	-	0	38	0.5	3.1	4	2	5.3	-	0	-	0
Total Suspended Solids	mg/L	0.1	5	5	138	<1	-	18	107	77.5	-	0	-	0	52	<0.1	-	27	35	67.3	-	0	-	0
Major Ions																								
Bicarbonate	mg/L	1	5	2	88	2.5	9	10	2	2.3	-	0	-	0	40	0.5	4	33	12	30	-	0	-	0
Calcium	mg/L	-	-	0	150	0.65	1.4	2.5	0	0	-	0	-	0	58	0.1	1	1.8	0	0	-	0	-	0
Carbonate	mg/L	0.5	5	3	88	<5	-	<5	88	100	-	0	-	0	40	<0.5	-	<5	40	100	-	0	-	0
Chloride	mg/L	0.5	1	2	159	<0.5	-	6.3	107	67.3	230	0	-	0	78	0.25	0.6	1.7	21	26.9	230	0	-	0
Magnesium	mg/L	0.5	-	1	150	0.27	0.6	1	0	0	-	0	-	0	58	0.25	0.42	1.1	7	12.1	-	0	-	0
Potassium	mg/L	0.5	2	2	136	0.25	0.5	1	8	5.9	-	0	-	0	58	0.25	0.38	0.56	15	25.9	-	0	-	0
Sodium	mg/L	0.5	2	3	136	0.33	0.8	1.2	14	10.3	-	0	-	0	58	0.45	0.58	2.9	22	37.9	-	0	-	0
Sulphate	mg/L	0.5	1	2	157	0.5	1	11	28	17.8	-	0	-	0	76	0.46	1	2.1	38	50	-	0	-	0
Sulphide	µg/L	2	-	1	0	-	-	-	0		2.4	0	-	0	6	<2	-	<2	6	100	2.5	0	-	0
Nutrients																								
Nitrate + Nitrite	mg-NL	0.003	0.006	2	80	0.006	0.029	0.34	27	33.8	2.93	0	10	0	15	<0.003	-	0.078	14	93.3	2.93	0	10	0
Nitrogen - Ammonia	mg-NL	0.005	0.1	3	159	0.0025	0.014	0.062	42	26.4	49	0	-	0	76	0.005	0.007	0.063	44	57.9	16	0	-	0
Nitrogen - Kjeldahl	mg-NL	0.2	-	1	0	-	-	-	0	-	-	0	-	0	28	0.1	0.3	1.3	3	10.7	-	0	-	0
Phosphorus, total	µg/L	1	300	7	112	<1	-	10	80	71.4	50	0	-	0	68	<20	-	6	62	91.2	50	0	-	0
Phosphorus, dissolved	µg/L	2	300	3	48	<2	-	9	34	70.8	-	0	-	0	49	<5	-	190	37	75.5	-	0	-	0
General Organics																								
Total Phenolics	µg/L	2	-	1	0	-	-	-	0	-	5	0	-	0	6	<2	-	<2	6	100	5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	0	-	-	-	0	-	-	0	-	0	28	<0.1	-	0.2	26	92.9	-	0	-	0
Total Metals																								
Aluminum	µg/L	5	20	2	165	3.2	6.7	51	0	0	100	0	100	0	87	2.5	10	**730**[(c, d)]	21	24.1	100	2	100	2
Antimony	µg/L	0.02	1	5	165	0.015	0.08	0.72	55	33.3	-	0	5.5	0	87	<0.02	-	**15**[(d)]	60	69	-	0	5.5	1
Arsenic	µg/L	0.1	1	3	165	0.05	0.13	0.3	5	3	5	0	10	0	87	0.06	0.11	1.5	38	43.7	5	0	10	0
Barium	µg/L	1	10	3	165	0.25	2.6	8.1	3	1.8	-	0	1000	0	87	1.5	1.9	11	30	34.5	-	0	1000	0

Table 8.3-21 Summary Water Quality in Areas 2 through 8 in Kennady Lake, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Kennady Lake: Under-Ice Conditions (1996 - 2004)										Kennady Lake: Open Water (1995 - 2010)										
											Guidelines										Guidelines				
											Aquatic Life - Chronic (a)		Human Health - Chronic (b)								Aquatic Life - Chronic (a)		Human Health - Chronic (b)	
		Min	Max	Number of Method Detection Limits	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Beryllium	µg/L	0.01	5	5	165	<0.2	-	<5	165	100	-	0	4	0	87	<0.01	-	<5	87	100	-	0	4	0
Boron	µg/L	1	100	5	165	0.5	2	7	5	3	-	0	5000	0	87	1	2	9	40	46	-	0	5000	0
Cadmium	µg/L	0.002	0.2	6	165	<0.02	-	**0.05**(c)	157	95.2	0.0029	8	5	0	89	<0.002	-	**0.005**(c)	88	98.9	0.002	1	5	0
Calcium	µg/L	1000	-	1	165	170	1310	2400	0	0	-	0	-	0	87	100	940	2530	1	1.1	-	0	-	0
Chromium	µg/L	0.06	15	6	165	<0.06	-	0.78	113	68.5	1	0	50	0	87	<0.06	-	**1.5**(c)	83	95.4	1	2	50	0
Cobalt	µg/L	0.1	1	3	165	<0.1	-	1.2	141	85.5	-	0	-	0	87	<0.1	-	0.4	71	81.6	-	0	-	0
Copper	µg/L	0.6	10	4	165	0.3	0.6	**311**(c)	49	29.7	2	19	1300	0	87	0.28	0.4	**8**(c)	49	56.3	2	1	1300	0
Iron	µg/L	5	50	4	165	2.5	10	**433**(c, d)	44	26.7	300	2	300	2	87	10	27	195	37	42.5	300	0	300	0
Lead	µg/L	0.05	1	4	165	<0.05	-	0.6	152	92.1	1	0	10	0	87	<0.05	-	0.7	66	75.9	1	0	10	0
Lithium	µg/L	0.1	20	4	165	0.2	0.9	1.4	77	46.7	-	0	-	0	56	<0.1	-	6	41	73.2	-	0	-	0
Magnesium	µg/L	500	-	1	165	240	560	1020	0	0	-	0	-	0	87	250	410	1000	8	9.2	-	0	-	0
Manganese	µg/L	5	-	1	165	0.5	2.5	**378**(d)	2	1.2	-	0	50	25	87	2	3.9	36	9	10.3	-	0	50	0
Mercury	µg/L	0.0006	500	8	162	<0.01	-	0.02	155	95.7	0.026	0	1	0	75	<0.0006	-	**0.07**(c)	68	90.7	0.026	3	1	0
Molybdenum	µg/L	0.04	5	6	165	<0.04	-	0.09	162	98.2	73	0	-	0	87	<0.05	-	<5	87	100	73	0	-	0
Nickel	µg/L	0.06	8	5	165	0.03	0.27	2.2	4	2.4	25	0	340	0	87	0.18	0.25	10	20	23	25	0	340	0
Potassium	µg/L	500	2000	2	165	210	459	1000	20	12.1	-	0	-	0	87	349	380	740	32	36.8	-	0	-	0
Selenium	µg/L	0.01	10	7	165	<0.1	-	0.2	161	97.6	1	0	10	0	87	<0.01	-	**3**(c)	84	96.6	1	3	10	0
Silver	µg/L	0.0005	0.2	6	165	<0.01	-	**0.88**(c)	154	93.3	0.1	9	-	0	89	<0.0005	-	0.0036	83	93.3	0.1	0	-	0
Sodium	µg/L	500	2000	2	165	280	606	1000	20	12.1	-	0	-	0	87	440	490	700	44	50.6	-	0	-	0
Strontium	µg/L	-	-	0	165	3.5	8.6	69	0	0	-	0	-	0	65	5	6.3	20	0	0	-	0	-	0
Sulphur	µg/L	10000	-	1	0	-	-	-	0	-	-	0	-	0	9	300	300	500	6	66.7	-	0	-	0
Thallium	µg/L	0.002	100	5	77	<0.03	-	0.05	75	97.4	0.8	0	0.13	0	78	<0.002	-	0.1	77	98.7	0.8	0	0.13	0
Titanium	µg/L	0.1	100	5	77	<0.1	-	1	73	94.8	-	0	-	0	56	<0.1	-	4	55	98.2	-	0	-	0
Uranium	µg/L	0.01	0.5	4	165	<0.01	-	0.2	149	90.3	-	0	-	0	73	<0.01	-	0.25	63	86.3	-	0	-	0
Vanadium	µg/L	0.05	30	6	165	<0.05	-	0.12	164	99.4	-	0	-	0	87	<0.05	-	0.6	77	88.5	-	0	-	0
Zinc	µg/L	0.8	8	5	165	0.8	2.8	14	68	41.2	30	0	5100	0	87	0.1	1.3	**63**(c)	56	64.4	30	3	5100	0
Dissolved Metals(e)																								
Aluminum	µg/L	5	10	2	158	2.6	5	15	0	0	-	0	-	0	49	2.5	5	170	10	20.4	-	0	-	0
Antimony	µg/L	0.03	0.1	3	158	0.015	0.09	0.81	45	28.5	-	0	-	0	49	<0.05	-	0.09	43	87.8	-	0	-	0
Arsenic	µg/L	0.1	0.1	1	158	0.05	0.13	0.21	1	0.6	-	0	-	0	49	0.1	0.12	0.2	17	34.7	-	0	-	0
Barium	µg/L	3	10	2	158	1.1	2.5	7.1	0	0	-	0	-	0	49	1.8	2.1	5	27	55.1	-	0	-	0
Beryllium	µg/L	0.01	5	5	158	<0.2	-	<0.5	158	100	-	0	-	0	49	<0.01	-	<5	49	100	-	0	-	0
Boron	µg/L	1	100	4	158	0.5	2	7	2	1.3	-	0	-	0	49	<4	-	4	35	71.4	-	0	-	0
Cadmium	µg/L	0.005	0.2	4	158	<0.02	-	0.05	150	94.9	-	0	-	0	49	<0.005	-	0.07	48	98	-	0	-	0
Chromium	µg/L	0.06	15	5	158	0.06	0.12	4.2	103	65.2	-	0	-	0	49	<0.1	-	1.8	42	85.7	-	0	-	0
Cobalt	µg/L	0.05	1	3	158	<0.1	-	0.7	140	88.6	-	0	-	0	49	<0.05	-	0.7	41	83.7	-	0	-	0
Copper	µg/L	0.6	10	4	158	0.3	0.7	72	19	12	-	0	-	0	49	0.32	0.4	5.9	29	59.2	-	0	-	0
Iron	µg/L	5	30	4	158	5	9	131	95	60.1	-	0	-	0	49	<10	-	120	36	73.5	-	0	-	0
Lead	µg/L	0.05	1	2	158	<0.05	-	0.23	153	96.8	-	0	-	0	49	<0.05	-	0.47	34	69.4	-	0	-	0
Lithium	µg/L	0.1	15	3	158	0.2	0.9	1.4	73	46.2	-	0	-	0	27	<1	-	1	21	77.8	-	0	-	0

Table 8.3-21 Summary Water Quality in Areas 2 through 8 in Kennady Lake, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Kennady Lake: Under-Ice Conditions (1996 - 2004)										Kennady Lake: Open Water (1995 - 2010)									
					n	Min	Med	Max	Count Below Detection	% Below Detection	Guidelines				n	Min	Med	Max	Count Below Detection	% Below Detection	Guidelines			
											Aquatic Life - Chronic [a]		Human Health - Chronic [b]								Aquatic Life - Chronic [a]		Human Health - Chronic [b]	
		Min	Max	Number of Method Detection Limits							Value	Guideline Exceedance Count	Value	Guideline Exceedance Count							Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Manganese	µg/L	1	5	2	158	0.09	1	300	0	0	-	0	-	0	49	0.15	0.5	5	13	26.5	-	0	-	0
Mercury	µg/L	0.002	1	6	158	<0.01	-	0.02	156	98.7	-	0	-	0	49	<0.002	-	0.005	46	93.9	-	0	-	0
Molybdenum	µg/L	0.04	1	5	144	<0.04	-	0.3	142	98.6	-	0	-	0	49	<0.05	-	0.5	48	98	-	0	-	0
Nickel	µg/L	0.1	1	2	144	0.015	0.3	2.5	0	0	-	0	-	0	49	0.05	0.26	2.9	9	18.4	-	0	-	0
Selenium	µg/L	0.04	2	7	144	<0.1	-	0.1	141	97.9	-	0	-	0	49	<0.04	-	<2	49	100	-	0	-	0
Silver	µg/L	0.005	0.1	5	144	<0.01	-	0.89	136	94.4	-	0	-	0	49	<0.005	-	<0.1	49	100	-	0	-	0
Strontium	µg/L	-	-	0	144	4.2	8.4	13	0	0	-	0	-	0	27	6.1	7	11	0	0	-	0	-	0
Sulphur	µg/L	10,000	10,000	1	0	-	-	-	0	-	-	0	-	0	6	<10,000	-	<10,000	6	100	-	0	-	0
Thallium	µg/L	0.002	100	5	56	<0.03	-	0.14	53	94.6	-	0	-	0	49	<0.002	-	0.07	44	89.8	-	0	-	0
Titanium	µg/L	0.1	100	4	56	<0.1	-	0.2	53	94.6	-	0	-	0	27	<0.5	-	<100	27	100	-	0	-	0
Uranium	µg/L	0.01	0.5	3	144	<0.01	-	0.02	132	91.7	-	0	-	0	49	<0.01	-	0.01	42	85.7	-	0	-	0
Vanadium	µg/L	0.05	30	5	143	<0.05	-	<1	143	100	-	0	-	0	49	<0.2	-	<30	49	100	-	0	-	0
Zinc	µg/L	0.8	5	4	143	0.4	1.9	12	18	12.6	-	0	-	0	49	0.4	3	17	14	28.6	-	0	-	0

Note: Presented guidelines were calculated using median values for data when applicable.
Individual guidelines were calculated for each sample, to determine the number of results above guidelines when applicable.
Bold values indicate a guideline exceedance.
(a) Canadian Environmental Quality Guidelines (CCME 1999 with updates to 2010). Winnipeg, MB.
(b) The human health guideline is based on the CCME drinking water guideline, Health Canada (2008).
(c) Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
(d) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(e) Some maximum dissolved metals concentrations are higher than the maximum total metal concentration in the statistical summary.
NA = not applicable, "-" = not available; °C = degrees Celsius, µS/cm = microSiemens per centimetre, mg/L = milligrams per litre, mV = millivolts, mg-N/L = milligrams nitrogen per litre, µg/L = micrograms per litre, TCU = True colour units; % = percent, n = number of samples, < = less than; min = minimum; med = median; max = maximum.

Levels of total organic carbon (TOC) and dissolved organic carbon (DOC) were low during both open water and under-ice conditions (Table 8.3-21). The water colour was observed at levels above the CDWQG of 15 true colour units (TCU) for four sampling events during the open water season. Oil and grease, phenol, and petroleum hydrocarbons were generally not detected.

The concentrations of total and dissolved metals were low, with several metals near or below detection limits (e.g., cadmium, lead, mercury, molybdenum, selenium and thallium) (Table 8.3-21). More variability was observed during open water conditions; however, median concentrations for most metals were similar during both under-ice and open water conditions. Exceedances of applicable guidelines were observed for total aluminum, antimony, cadmium, chromium, copper, iron, manganese, mercury, selenium, silver, and zinc. The median concentrations of dissolved metals were similar to the total fraction.

Sediment Quality

Kennady Lake sediments collected for sediment quality analyses were mainly composed of sand, with some silt and clay (Table 8.3-22). The TOC ranged from 7% to 15% of the sediment composition. Inorganic carbon constituted 1.7% or less of the sediment whereas calcium carbonate content ranged between 0.1 and 0.6%.

In Kennady Lake, phosphorus was the dominant nutrient bound to the sediment, although the observed concentrations were variable (ranging from 1,390 to 2,450 micrograms per gram [µg/g]). In comparison, available phosphorus concentrations ranged from 7 to 37 µg/g, (Table 8.3-22). Nitrate concentrations were low (maximum of 0.7 µg/g), with several sediment samples yielding concentrations below the detection limit of 0.5 µg/g.

The total petroleum hydrocarbon (TPH) content in Kennady Lake sediments was detected and variable, ranging from 7 to 2,450 µg/g (Table 8.3-22). Hydrocarbons found in the sediment may be from natural sources, such as those by-products associated with the decomposition of organic matter.

The predominant metals in the sediment included aluminum, iron, and magnesium (Table 8.3-22). Concentrations of metals in the sediment were generally within the applicable aquatic life guidelines; however, arsenic exceeded the ISQG in most sediment samples, and copper was measured above the ISQG in all samples. Guideline exceedances also were observed for cadmium and zinc.

Table 8.3-22 Sediment Quality Summary for Kennady Lake, 1995 to 2010

Parameter	Unit	Method Detection Limit		Kennady Lake							Guideline
		Min	Max	Count	Min	Med	Max	Count Below Detection	% Below Detection	Number of Times a Guideline is Exceeded	Sediment Quality Guidelines (ISQG) CCME (2002)
Texture and Carbon Content											
Sand	%	1	1	1	70	-	70	0	0	0	-
Silt	%	1	1	1	28	-	28	0	0	0	-
Clay	%	1	1	1	2	-	2	0	0	0	-
Calcium Carbonate	%	0.005	0.005	5	0.115	0.155	0.52	2	40	0	-
Inorganic Carbon, Total	%	0.01	0.02	10	<0.01	0.44	1.72	2	20	0	-
Organic Carbon, Total	%	0.01	0.2	10	7.14	11.6	15	0	0	0	-
Carbon, Total	%	0.01	0.2	10	7.8	12.2	15	0	0	0	-
Nutrients and Organics											
Nitrate	µg/g	0.5	0.5	5	<0.5	0.65	0.7	3	60	0	-
Phosphorus, Available	µg/g	1	2	5	7	23	37	0	0	0	-
Phosphorus, Total	µg/g	5	5	5	1,390	1,630	2,450	0	0	0	-
Total Petroleum Hydrocarbons	µg/g	8	400	10	880	1,640	2,290	5	50	0	-
Total Metals											
Aluminum	µg/g	5	5	5	12,300	18,600	22,100	0	0	0	-
Arsenic	µg/g	0.5	1	10	3	**6.85**	**8.7**	0	0	6	5.9
Barium	µg/g	1	10	10	66	69.5	91	0	0	0	-
Cadmium	µg/g	0.1	0.2	10	0.3	0.4	**0.7**	0	0	1	0.6
Calcium	µg/g	5	5	5	2,700	3,590	4,380	0	0	0	-
Chromium	µg/g	0.5	1	10	27.8	30.9	**41**	0	0	2	37.3
Cobalt	µg/g	0.5	1	10	8	15.8	22	0	0	0	-
Copper	µg/g	0.1	5	10	**47**	**63.7**	**110**	0	0	10	35.7
Iron	µg/g	5	5	5	29,600	67,600	69,500	0	0	0	-
Lead	µg/g	0.5	1	10	2.6	5.45	9	0	0	0	35
Magnesium	µg/g	1	1	5	3,300	4,360	5,060	0	0	0	-
Manganese	µg/g	0.5	0.5	5	234	324	525	0	0	0	-

Table 8.3-22 Sediment Quality Summary for Kennady Lake, 1995 to 2005 (continued)

Parameter	Unit	Method Detection Limit		Kennady Lake							Guideline
		Min	Max	Count	Min	Med	Max	Count Below Detection	% Below Detection	Number of Times a Guideline is Exceeded	Sediment Quality Guidelines (ISQG) CCME (2002)
Mercury	µg/g	0.05	0.5	10	<0.05	-	0.09	7	70	0	0.17
Molybdenum	µg/g	0.4	0.5	10	2.6	4.15	6.1	0	0	0	-
Nickel	µg/g	0.5	1	10	26	32	48	0	0	0	-
Potassium	µg/g	2	5	10	12	978	2,000	0	0	0	-
Selenium	µg/g	0.5	0.5	10	0.5	0.8	1.3	4	40	0	-
Sodium	µg/g	1	1	5	119	133	150	0	0	0	-
Thallium	µg/g	0.3	0.5	10	<0.3	-	0.4	9	90	0	-
Vanadium	µg/g	0.2	1	10	33	36.7	46.5	0	0	0	-
Zinc	µg/g	0.5	10	10	65	99.5	**157**	0	0	2	123

Source: Canadian Environmental Quality Guidelines (CCME 1999 with updates to 2010). Winnipeg, MB.

Note: **Bolded** numbers indicate where a guideline is exceeded.

ISQG = Interim Sediment Quality Guidelines; CCME = Canadian Council of Ministers of the Environment; min = minimum; med = median; max = maximum; % = percent; µg/g = micrograms per gram (dry weight basis); - = not applicable.

8.3.6.2.2 Lakes in the Kennady Lake Watershed

Physical Limnology and Vertical Structure

Vertical profile data for physical parameters, such as temperature and DO, were collected during July and August 2002, 2004, 2007, and 2010 for lakes in the A, B, D, E, F, G, and I watersheds. In-situ measurements were not measured for lakes in the Kennady Lake watershed during under-ice conditions.

Temperature profiles measured during open water conditions in the deeper small lakes, Lakes A1, A3, I1 and J1b, had similar temperature ranges in open water conditions as the areas of Kennady Lake. The small lakes had near-surface temperatures ranging from 11°C to 18°C and were generally well-mixed (Figure 8.3-17a). A thermocline was observed in a water column profile measurement in Lake A3; the thermocline was located between approximately 10 or 12 m, where the temperature decreased from 12°C to 8°C.

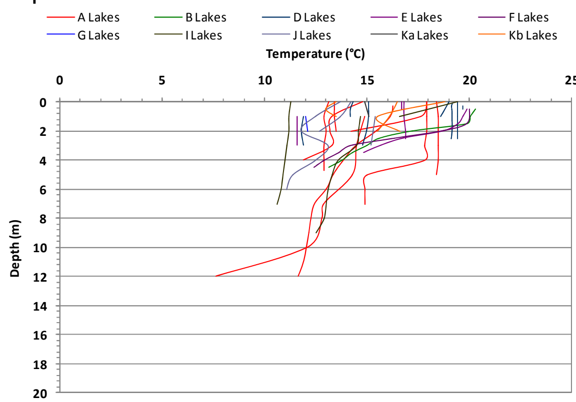
Measured conductivity during open water conditions was very low, ranging between 5 and 26 µS/cm (Figure 8.3-17b). There was very little variability throughout the water column indicating that TDS were equally distributed throughout the lakes, i.e., the small lakes were well mixed during open water conditions.

Vertical profiles of DO and conductivity had only slight variability between surface and near bottom of the small lakes, indicating that the lakes were well mixed (Figure 8.3-17c). Concentrations of DO were higher than the minimum CWQG values during most measurements, with the exception of one profile collected for Lake A3 in July 2007. Dissolved oxygen concentrations of less than 1 mg/L where measured at the near bottom depths (i.e., 6 and 7 m, respectively).

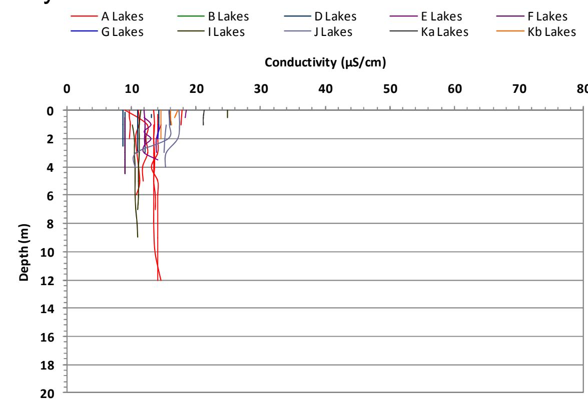
Surface pH readings for the lakes in the Kennady Lake watershed varied between 5.8 and 9.4 pH units (Figure 8.3-17d), ranging from slightly acidic to slightly alkaline. Many pH measurements were below the acceptable range of the CWQG and CDWQG during early spring, whereas measurements were above this range during certain summer observations.

Figure 8.3-17 Physico-chemical Water Quality Profile Data for Lakes in the Kennady Lake Watershed (2002 to 2010)

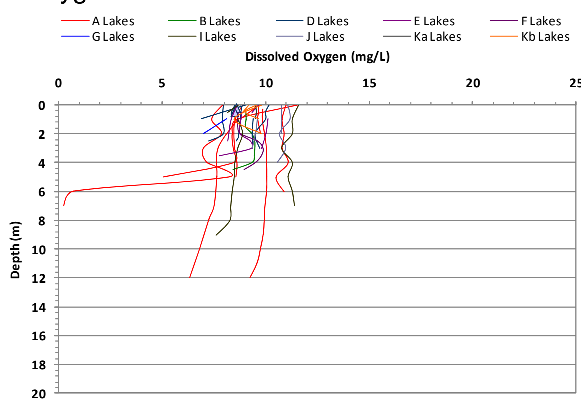
a.) Water Temperature



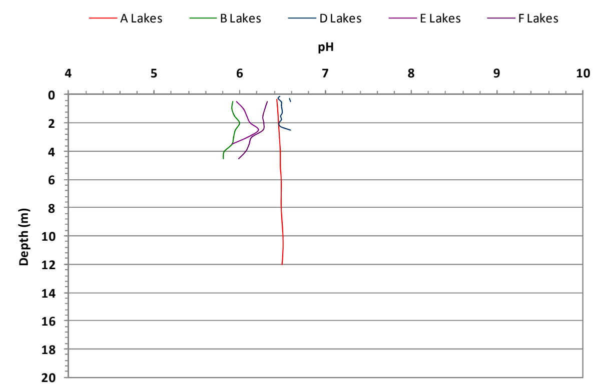
b.) Conductivity



c.) Dissolved Oxygen



d.) pH



m = metre, °C = degrees Celsius, µS/cm = microSiemens per Centimetre, mg/L = milligrams per litre.

Individual field results not presented in field profile figures.

Water Quality

Since the small lakes in the Kennady Lake watershed contribute to the loading of substances into the individual areas of Kennady Lake, the water quality similarities and differences are discussed for all surveyed lakes. The available data for all lakes in the Kennady Lake watershed are presented in Table 8.3-23. Lake E2 had a different chemistry than the other lakes in the Kennady Lake watershed and the data for this lake are presented separately in Table 8.3-23.

Hardness and alkalinity were low in most of the small lakes (Table 8.3-23), with several measurements below the detection limit. There was very little difference in concentrations among the lakes, with marginally higher concentrations of both parameters measured in Lake E2. These hardness and alkalinity results indicate that water in most of the lakes in the Kennady Lake watershed is soft and has a low buffering capacity.

Concentrations of TDS were generally low (Table 8.3-23); however, there was some variability in the amount of dissolved substances found in the different lakes, ranging from less than 5 to 64 mg/L. Lake E2 had higher TDS concentrations than most other lakes (minimum of 55 mg/L). Bicarbonate was the dominant anion in most lakes, and sulphate was below 4.2 mg/L in all lakes surveyed. Sodium was the major cation measured in most lakes, with the highest concentrations measured in Lake E2.

The TSS concentrations were generally measured slightly above the detection limit or were not detected (Table 8.3-23). The highest TSS concentrations were measured in Lake E2. The lakes in the Kennady Lake watersheds were very clear and contained low concentrations of suspended particulate matter.

The concentration of dissolved inorganic nitrogen fractions, such as ammonia nitrate, and nitrite were below the detection limit (Table 8.3-23). TKN was measured at low concentrations, with highest concentrations reported in Lake E2. Total phosphorus was not detected in over half the measurements. The measured concentrations of nutrients indicate that the lakes in the Kennady Lake watershed have an oligotrophic status, are phosphorus-limited, and are indicative of low biological productivity.

Table 8.3-23 Water Quality Summary for Lakes in the Kennady Lake Watershed, 1995 to 2010

Parameter Name	Unit	Method Detection Limit			Lakes in the Kennady Lake Watershed Excluding Lake E2 and Kennady Lake (1995 - 2010)						Lake E2 (2004)						Guidelines Exceedances for All Results within the Kennady Lake Basin including Lake E2			
																	Aquatic Life - Chronic [a]		Human Health - Chronic [b]	
		Min	Max	Number of Method Detection Limits	n	Min	Med	Max	Count Below Detection	% Below Detection	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Field measured																				
pH	NA	-	-	-	97	**5.5**[c]	6.5	**9.4**[c, d]	0	0	4	**6.2**[c]	6.6	6.9	0	0	6.5 - 8.5	59	5.0 - 9.0	4
Temperature	°C	-	-	-	176	4.8	13	20	0	0	4	10	15	22	0	0	-	0	-	0
Specific Conductance	µS/cm	-	-	-	174	4.3	12	26	0	0	4	<1	36	48	0	0	-	0	-	0
Dissolved Oxygen	mg/L	-	-	-	174	4.5[c]	9.6	13	0	0	4	8.2	9.3	13	0	0	6.5	3	-	0
Conventional Parameters[e]																				
Colour	TCU	-	-	0	23	5	20	85	0	0	2	125	-	175	0	0	-	0	-	0
Specific Conductance	µS/cm	-	-	0	36	9	16	31	0	0	3	37	40	44	0	0	-	0	-	0
Dissolved Organic Carbon	mg/L	-	-	0	29	3.3	6	20	0	0	2	20	-	36	0	0	-	0	-	0
Hardness	mg/L	6	-	1	39	3.8	6	9.7	23	59	3	9.1	12	14	0	0	-	0	-	0
pH	NA	-	-	0	36	5.3[c]	6.6	7.2	0	0	3	**6.4**[c]	6.9	7.2	0	0	6.5 - 8.5	13	5.0 - 9.0	0
Total Alkalinity	mg/L	1	5	2	45	0.5	10	35	7	15.6	3	2.5	13	14	1	33.3	-	0	-	0
Total Dissolved Solids	mg/L	10	20	2	39	5	19	64	10	25.6	2	57	-	84	0	0	-	0	-	0
Total Organic Carbon	mg/L	-	-	0	29	3	5.8	19	0	0	2	19	-	30	0	0	-	0	-	0
Total Suspended Solids	mg/L	1	2	2	29	1	2	5	19	65.5	2	3	-	55	0	0	-	0	-	0
Major Ions																				
Bicarbonate	mg/L	1	5	2	44	0.5	12	43	4	9.1	3	6	15	17	0	0	-	0	-	0
Calcium	mg/L	-	-	0	36	0.66	0.98	2.3	0	0	3	2.7	3.3	4.3	0	0	-	0	-	0
Carbonate	mg/L	0.5	5	3	44	<0.5	-	<5	44	100	3	<1	-	<5	3	100	-	0	-	0
Chloride	mg/L	0.1	1	3	45	0.1	0.2	1	23	51.1	3	0.4	0.5	1	0	0	230	0	-	0
Magnesium	mg/L	0.5	0.5	1	36	0.25	0.44	1.1	3	8.3	3	1.2	1.5	2.2	0	0	-	0	-	0
Potassium	mg/L	0.5	0.5	1	36	0.24	0.42	0.83	3	8.3	3	0.77	1.2	1.2	0	0	-	0	-	0
Sodium	mg/L	1	1	1	36	0.39	1	3.9	3	8.3	3	2.7	3	4.4	0	0	-	0	-	0
Sulphate	mg/L	0.5	1	2	45	0.00029	0.9	2	15	33.3	3	0.0057	2.6	4.2	0	0	-	0	-	0
Sulphide	µg/L	2	-	1	6	2	-	2	4	66.7	0	-	-	-	0		2.4	0	-	0
Nutrients																				
Nitrate + Nitrite	mg-N/L	0.003	0.006	2	12	<0.003	-	0.022	11	91.7	1	-	<0.006	-	1	100	2.93	0	10	0
Nitrogen - Ammonia	mg-N/L	0.05	0.1	2	39	<0.05	-	0.01	38	97.4	2	<0.1	-	<0.1	2	100	21	0	-	0
Nitrogen - Kjeldahl	mg-N/L	0.2	-	1	20	0.2	0.3	1.1	9	45	2	1.1	-	2.7	0	0	-	0	-	0
Phosphorus, total	µg/L	20	300	4	39	<20	-	**100**[c]	30	76.9	2	37	-	**83**[c]	0	0	50	3	-	0
Phosphorus, dissolved	µg/L	5	300	2	30	<5	-	16	23	76.7	2	-	6	-	1	50	-	0	-	0
General Organics																				
Total Phenolics	µg/L	2	-	1	6	<2	-	2	5	83.3	0	-	-	-	0		5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	29	<0.1	-	208	20	69	2	-	0.2	-	1	50	-	0	-	0
Total Metals[e]																				
Aluminum	µg/L	20	20	1	45	10	51	**240**[c, d]	16	35.6	3	**207**[c, d]	459	**1130**[c, d]	0	0	100	8	100	8
Antimony	µg/L	0.02	1	5	45	<0.02	-	2.1	37	82.2	3	-	0.5	-	2	66.7	-	0	5.5	0
Arsenic	µg/L	0.4	1	2	45	<0.4	-	0.5	33	73.3	3	0.7	0.9	1.1	0	0	5	0	10	0
Barium	µg/L	5	-	1	45	1.7	3.3	7.4	23	51.1	3	9	13	22	0	0	-	0	1000	0

Table 8.3-23 Water Quality Summary for Lakes in the Kennady Lake Watershed, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lakes in the Kennady Lake Watershed Excluding Lake E2 and Kennady Lake (1995 - 2010)						Lake E2 (2004)						Guidelines Exceedances for All Results within the Kennady Lake Basin including Lake E2			
																	Aquatic Life - Chronic [a]		Human Health - Chronic [b]	
		Min	Max	Number of Method Detection Limits	n	Min	Med	Max	Count Below Detection	% Below Detection	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Beryllium	µg/L	0.01	1	4	45	<0.01	-	<1	45	100	3	<0.5	-	<1	3	100	-	0	4	0
Boron	µg/L	8	20	3	45	<8	-	2	42	93.3	3	<10	-	<20	3	100	-	0	5000	0
Cadmium	µg/L	0.002	0.2	4	45	<0.002	-	**0.008**[c]	40	88.9	3	<0.2	-	<0.2	3	100	0.0031	2	5	0
Calcium	µg/L	1000	-	1	41	580	1130	2,240	14	34.1	2	3,300	-	3,500	0	0	-	0	-	0
Chromium	µg/L	0.1	5	5	45	<0.1	-	4[c]	39	86.7	3	0.45	1.7	**2.7**[c]	1	33.3	1	6	50	0
Cobalt	µg/L	0.1	0.5	2	45	0.02	0.1	0.7	28	62.2	3	0.8	1	2	0	0	-	0	-	0
Copper	µg/L	1	5	2	45	0.56	1.1	**12**[c]	29	64.4	3	**5**[c]	5	**12**[c]	0	0	2	8	1300	0
Iron	µg/L	50	-	1	41	17	132	**540**[c, d]	3	7.3	2	**626**[c, d]	-	**1,280**[c, d]	0	0	300	7	300	7
Lead	µg/L	0.05	0.5	3	45	<0.05	-	0.4	36	80	3	0.05	0.1	0.8	1	33.3	1	0	10	0
Lithium	µg/L	1	20	2	16	0.6	0.95	1.4	10	62.5	0	-	-	-	0	-	-	0	-	0
Magnesium	µg/L	500	-	1	41	310	560	6,200	16	39	2	1420	-	2,280	0	0	-	0	-	0
Manganese	µg/L	-	-	0	41	1.1	3.3	16	0	0	2	18	-	20	0	0	-	0	50	0
Mercury	µg/L	0.0006	500	7	41	<0.0006	-	0.01	36	87.8	2	<1	-	<500	2	100	0.026	0	1	0
Molybdenum	µg/L	0.05	5	4	45	<0.05	-	0.3	38	84.4	3	0.25	0.5	0.9	1	33.3	73	0	-	0
Nickel	µg/L	0.6	8	2	45	0.22	0.85	13	19	42.2	3	1.4	5.2	5.5	0	0	25	0	340	0
Potassium	µg/L	500	500	1	41	250	490	850	20	48.8	2	830	-	1310	0	0	-	0	-	0
Selenium	µg/L	0.04	10	6	45	<0.04	-	<10	45	100	3	<0.4	-	<10	3	100	1	0	10	0
Silver	µg/L	0.01	0.4	4	45	<0.01	-	**0.5**[c]	38	84.4	3	<0.2	-	<0.4	3	100	0.1	1	-	0
Sodium	µg/L	500	2000	2	41	390	568	1,190	23	56.1	2	-	2,100	-	1	50	-	0	-	0
Strontium	µg/L	-	-	0	22	4.2	7.2	14	0	0	1	-	26	-	0	0	-	0	-	0
Sulphur	µg/L	10,000	-	1	15	300	500	800	6	40	0	-	-	-	0	-	-	0	-	0
Thallium	µg/L	0.002	0.1	3	43	<0.002	-	0.003	40	93	3	<0.05	-	<0.1	3	100	0.8	0	0.13	0
Titanium	µg/L	0.5	10	4	20	<0.5	-	4	15	75	1	-	44	-	0	0	-	0	-	0
Uranium	µg/L	0.05	0.1	2	45	<0.05	-	0.024	38	84.4	3	0.09	0.1	0.3	0	0	-	0	-	0
Vanadium	µg/L	0.1	5	4	45	0.08	0.27	0.4	28	62.2	3	1.4	2.5	5.6	0	0	-	0	-	0
Zinc	µg/L	2	4	2	45	0.9	7	**55**[c]	16	35.6	3	13	15	15	0	0	30	4	5100	0
Dissolved Metals																				
Aluminum	µg/L	10	-	1	30	5	23	125	4	13.3	2	134	-	165	0	0	-	0	-	0
Antimony	µg/L	0.02	0.1	3	30	<0.02	-	0.04	25	83.3	2	<0.1	-	<0.1	2	100	-	0	-	0
Arsenic	µg/L	0.1	-	1	30	0.05	0.12	0.5	10	33.3	2	-	0.9	-	1	50	-	0	-	0
Barium	µg/L	3	-	1	30	1.6	3	4	18	60	2	8	-	8	0	0	-	0	-	0
Beryllium	µg/L	0.01	0.5	3	30	<0.01	-	0.1	29	96.7	2	<0.1	-	<0.1	2	100	-	0	-	0
Boron	µg/L	4	20	2	30	<4	-	2	29	96.7	2	<4	-	<4	2	100	-	0	-	0
Cadmium	µg/L	0.005	0.05	2	30	<0.005	-	0.12	27	90	2	<0.05	-	<0.05	2	100	-	0	-	0
Chromium	µg/L	0.1	0.5	3	30	<0.1	-	0.7	27	90	2	1	-	1.7	0	0	-	0	-	0
Cobalt	µg/L	0.05	-	1	30	0.025	0.085	1.5	9	30	2	0.3	-	0.63	0	0	-	0	-	0
Copper	µg/L	1	2	2	30	<1	-	1.2	23	76.7	2	4	-	4	0	0	-	0	-	0
Iron	µg/L	20	-	1	30	3	67	280	4	13.3	2	405	-	437	0	0	-	0	-	0
Lead	µg/L	0.05	-	1	30	<0.05	-	0.09	23	76.7	2	<0.05	-	<0.05	2	100	-	0	-	0

Table 8.3-23 Water Quality Summary for Lakes in the Kennady Lake Watershed, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lakes in the Kennady Lake Watershed Excluding Lake E2 and Kennady Lake (1995 - 2010)						Lake E2 (2004)						Guidelines Exceedances for All Results within the Kennady Lake Basin including Lake E2			
																	Aquatic Life - Chronic [a]		Human Health - Chronic [b]	
		Min	Max	Number of Method Detection Limits	n	Min	Med	Max	Count Below Detection	% Below Detection	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Lithium	µg/L	1	-	1	7	0.5	1	1.3	1	14.3	0	-	-	-	0	-	-	0	-	0
Manganese	µg/L	-	-	0	30	0.9	3	14	0	0	2	4.8	-	12	0	0	-	0	-	0
Mercury	µg/L	0.01	1	3	30	<0.01	-	0.009	24	80	2	<1	-	<1	2	100	-	0	-	0
Molybdenum	µg/L	0.05	0.3	2	30	<0.05	-	0.14	28	93.3	2	0.5	-	0.6	0	0	-	0	-	0
Nickel	µg/L	-	-	0	30	0.2	0.4	2	0	0	2	1.9	-	2.5	0	0	-	0	-	0
Selenium	µg/L	0.04	2	4	30	<0.04	-	<2	30	100	2	<2	-	<2	2	100	-	0	-	0
Silver	µg/L	0.005	0.1	3	30	<0.005	-	<0.1	30	100	2	<0.05	-	<0.05	2	100	-	0	-	0
Strontium	µg/L	-	-	0	7	4	5.7	7.4	0	0	0	-	-	-	0	-	-	0	-	0
Sulphur	µg/L	10,000	10,000	1	6	<10,000	-	<10,000	6	100	0	-	-	-	0	-	-	0	-	0
Thallium	µg/L	0.002	0.05	3	30	<0.002	-	0.15	23	76.7	2	-	0.08	-	1	50	-	0	-	0
Titanium	µg/L	0.5	10	2	7	<0.5	-	<10	7	100	0	-	-	-	0	-	-	0	-	0
Uranium	µg/L	0.01	0.05	2	30	<0.01	-	0.023	24	80	2	0.08	-	0.08	0	0	-	0	-	0
Vanadium	µg/L	0.2	1	3	30	<0.2	-	<1	30	100	1	-	1.1	-	0	0	-	0	-	0
Zinc	µg/L	2	2	1	30	0.5	2	12	8	26.7	1	-	2	-	0	0	-	0	-	0

Note: Presented guidelines were calculated using median values for data when applicable.
Individual guidelines were calculated for each sample, to determine the number of results above guidelines when applicable.
Bold values indicate a guideline exceedance.

(a) Canadian Environmental Quality Guidelines (CCME 1999 with updates to 2010). Winnipeg, MB.
(b) The human health guideline is based on the CCME drinking water guideline, Health Canada (2008).
(c) Concentration higher than the relevant chronic aquatic life guideline or beyond the recommended pH or DO concentration range.
(d) Concentration higher than the relevant human health guideline or beyond the recommended pH range.
(e) Some maximum dissolved parameter concentrations are higher than the maximum total parameter concentrations in the statistical summary.

NA = not applicable, "-" = not available; °C = degrees Celsius, µS/cm = microSiemens per centimetre, mg/L = milligrams per litre, mV = millivolts, mg-N/L = milligrams nitrogen per litre, µg/L = micrograms per litre, TCU = True colour units; % = percent, n = number of samples, < = less than; min = minimum; med = median; max = maximum.

Measured concentrations of TOC and DOC were under 20 mg/L in all lakes, with the exception of Lake E2 (Table 8.3-23). The TOC and DOC measured in Lake E2 varied between 19 and 36 mg/L. The water colour often exceeded the CDWQG guideline (median of 23 TCU), with readings from Lake E2 being much higher than in other lakes (ranging from 125 to 175 TCU). Total recoverable hydrocarbons, and total phenolics were generally not detected (Table 8.3-23); however, a total phenolic concentration of 208 mg/L was detected in one sample. The elevated concentrations of these parameters were not observed during other sampling events and may be attributed to a natural increase in hydrocarbons from the decay of vegetation borne through runoff.

The concentrations of many metals were low, with several metals measured near or below the detection limit (Table 8.3-23). There was little variability in metals concentrations measured between lakes. For metals reported above the detection limit, Lake E2 tended to have higher concentrations than other lakes in the Kennady Lake watershed. Exceedances of applicable guidelines were observed for total aluminum, chromium, copper, iron, selenium, and zinc.

Sediment Quality

Baseline sediment sampling was not conducted for the small lakes in the Kennady Lake watershed, and historical data were not available. The composition of the sediment in these lakes is undetermined.

8.3.7 Lower Trophic Levels

The following section describes the baseline information for the lower trophic level communities (e.g., plankton, benthic invertebrate communities) for the proposed Project. For additional information regarding lower trophic levels, the reader is referred to the limnology and lower trophic level sections of Annex J (Fisheries and Aquatic Resources Baseline) and Addendum JJ.

8.3.7.1 Methods

Lower trophic level studies in Kennady Lake and its watershed were initiated in 1996 and continued through 2007. Data were collected for the following lower trophic communities and supporting variables:

- Phytoplankton and zooplankton communities were sampled in Kennady Lake.
- Zooplankton communities were sampled in 14 small lakes within the Kennady Lake watershed.
- Benthic invertebrate communities were sampled in Kennady Lake.

- Sediment samples were collected from Kennady Lake for toxicity analysis.

8.3.7.2 Results

8.3.7.2.1 Plankton Communities

Phytoplankton and Chlorophyll *a*

Total phytoplankton biomass was considerably lower in 2004 than in 2007 (Figure 8.3-18). There was no consistent spatial pattern in phytoplankton biomass among areas sampled in Kennady Lake.

Phytoplankton communities in Kennady Lake consist of representatives of six major taxonomic groups: cyanobacteria (blue-green algae); Chlorophyta (green algae); Chrysophyta (golden algae); Cryptophyta (biflagellates with chloroplasts); Bacillariophyceae (diatoms); and Pyrrophyta (dinoflagellates). Phytoplankton community composition based on abundance was similar among the five basins within Kennady Lake, but differed between the two years with available data (Figure 8.3-19). Cyanobacteria and Chlorophyta were the dominant taxonomic groups in 2004, whereas cyanobacteria and Chrysophyta were dominant in 2007. Although cyanobacteria were consistently the most abundant taxonomic group in all areas of Kennady Lake in 2004, this group accounted for only a small proportion of the total phytoplankton biomass (Figure 8.3-20). In contrast, cyanobacteria accounted for 20 to 60% of total phytoplankton biomass in 2007. Chrysophyta typically dominated the phytoplankton community biomass in Areas 3 to 7 in 2004 and Area 8 in 2007, which is indicative of oligo- to oligomesotrophic conditions.

There was little variation in chlorophyll *a* concentration among areas in Kennady Lake, in both 2004 and 2007. Most concentrations were approximately 1 µg/L, within a range characteristic of oligotrophic lakes. Concentrations were consistent with those in lakes of similar trophic status in the Slave Geological Province, with lakes between southern Yukon Territory and the Tuktoyaktuk Peninsula, NWT, and with lakes between Yellowknife and Contwoyto Lake, NWT (Pienitz et al. 1997a, 1997b).

Zooplankton

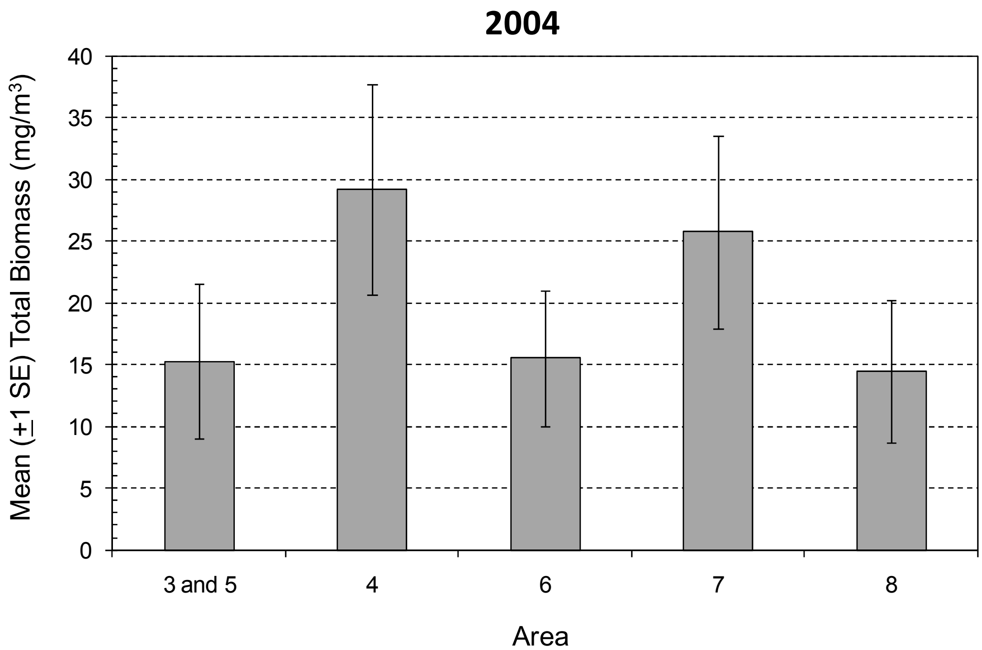
Total zooplankton biomass was highly variable between 2004 and 2007, with an up to ten-fold range between years in Area 4 (Figure 8.3-21). There was no consistent spatial pattern in zooplankton biomass among areas sampled in Kennady Lake.

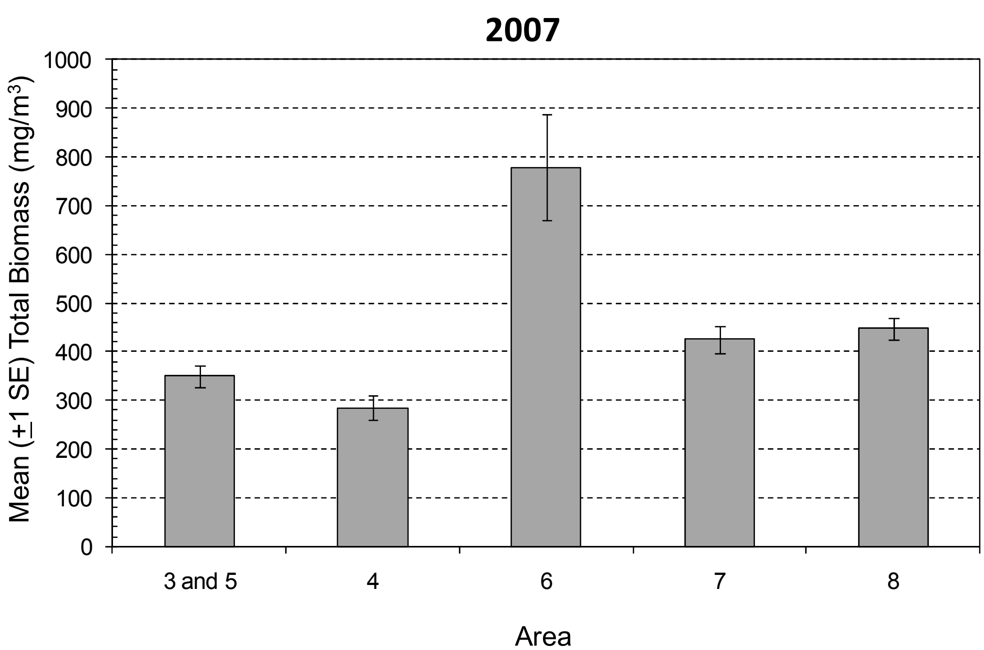
The zooplankton community of Kennady Lake consisted of representatives of four major taxonomic groups: Rotifera, Cladocera, Calanoida (calanoid copepods), and Cyclopoida (cyclopoid copepods).

Zooplankton community composition based on abundance was similar in the five areas within Kennady Lake in 2004. However, the relative abundance of copepod nauplii was slightly higher in Area 8 (Figure 8.3-22). In 2007, the Area 8 community was more strongly dominated by Rotifera compared to other areas; copepod nauplii were not enumerated in 2007 samples. Community composition based on biomass was more variable among areas in 2004, with Cladocera accounting for a lower proportion and calanoids accounting for a greater proportion of total community biomass in Area 4 compared to the other four areas sampled (Figure 8.3-23). In 2007, calanoid copepods were more strongly dominant in areas 6 and 8 compared to other areas.

Zooplankton abundance was also determined during previous small lake surveys. In August 2002 and August 2003, copepods were the most abundant zooplankton in all small lakes sampled (Jacques Whitford 2003a, 2004), consistent with the 2007 results for Kennady Lake. The combined abundance of calanoid and cyclopoid copepods ranged from 1,400 to over 18,000 individuals per cubic metre (ind/m^3) (Table 8.3-24). Cladocerans were occasionally absent from zooplankton samples from these lakes, and had more variable densities among lakes compared to copepods. They were abundant in some of small lakes sampled, with densities as high as 3,600 ind/m^3.

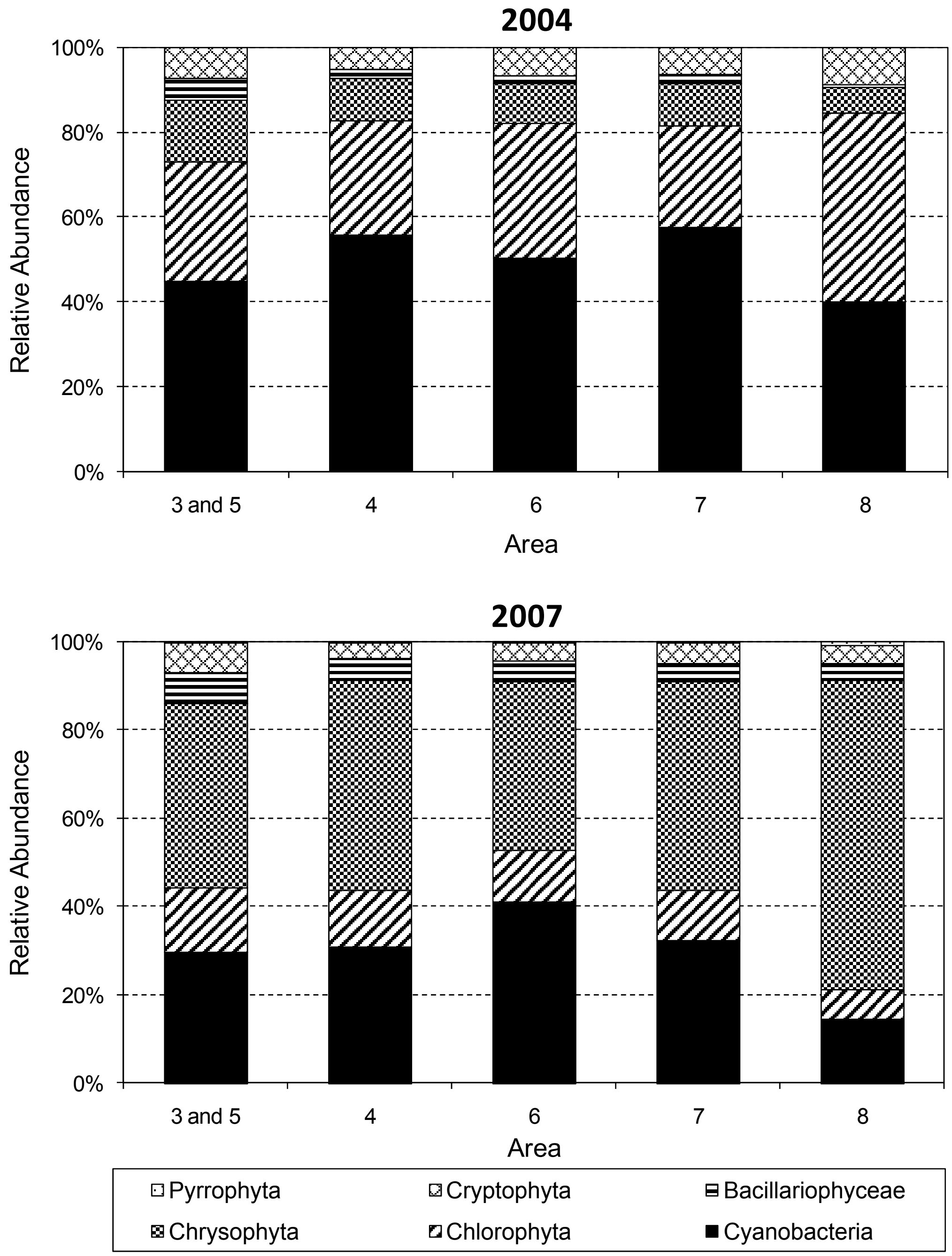
Figure 8.3-18 Total Phytoplankton Biomass in Kennady Lake, August 2004 and August 2007





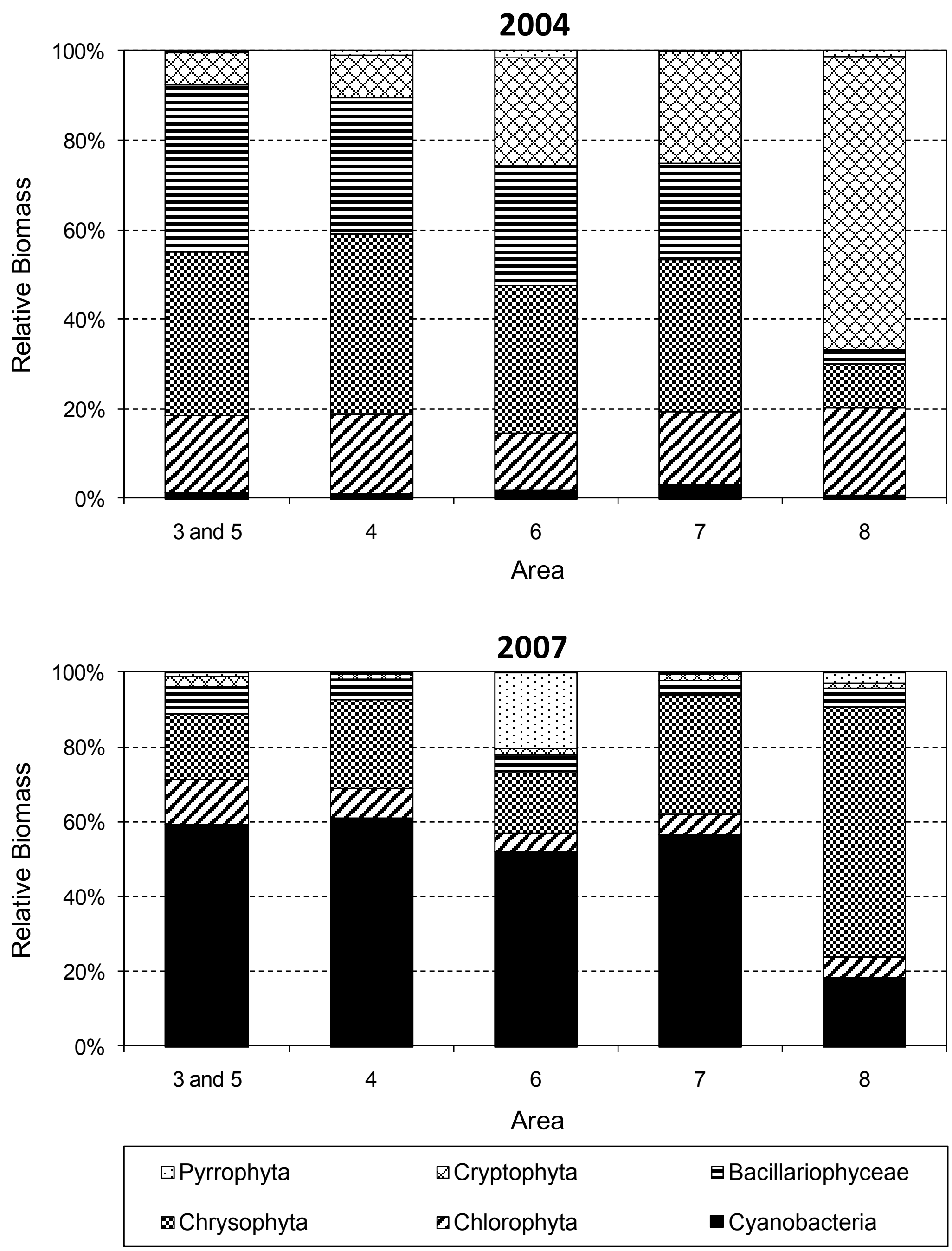
± = plus or minus; SE = standard error; mg/m^3 = milligrams per cubic metre.

Figure 8.3-19 Relative Abundances of Major Phytoplankton Taxa in Kennady Lake, August 2004 and August 2007



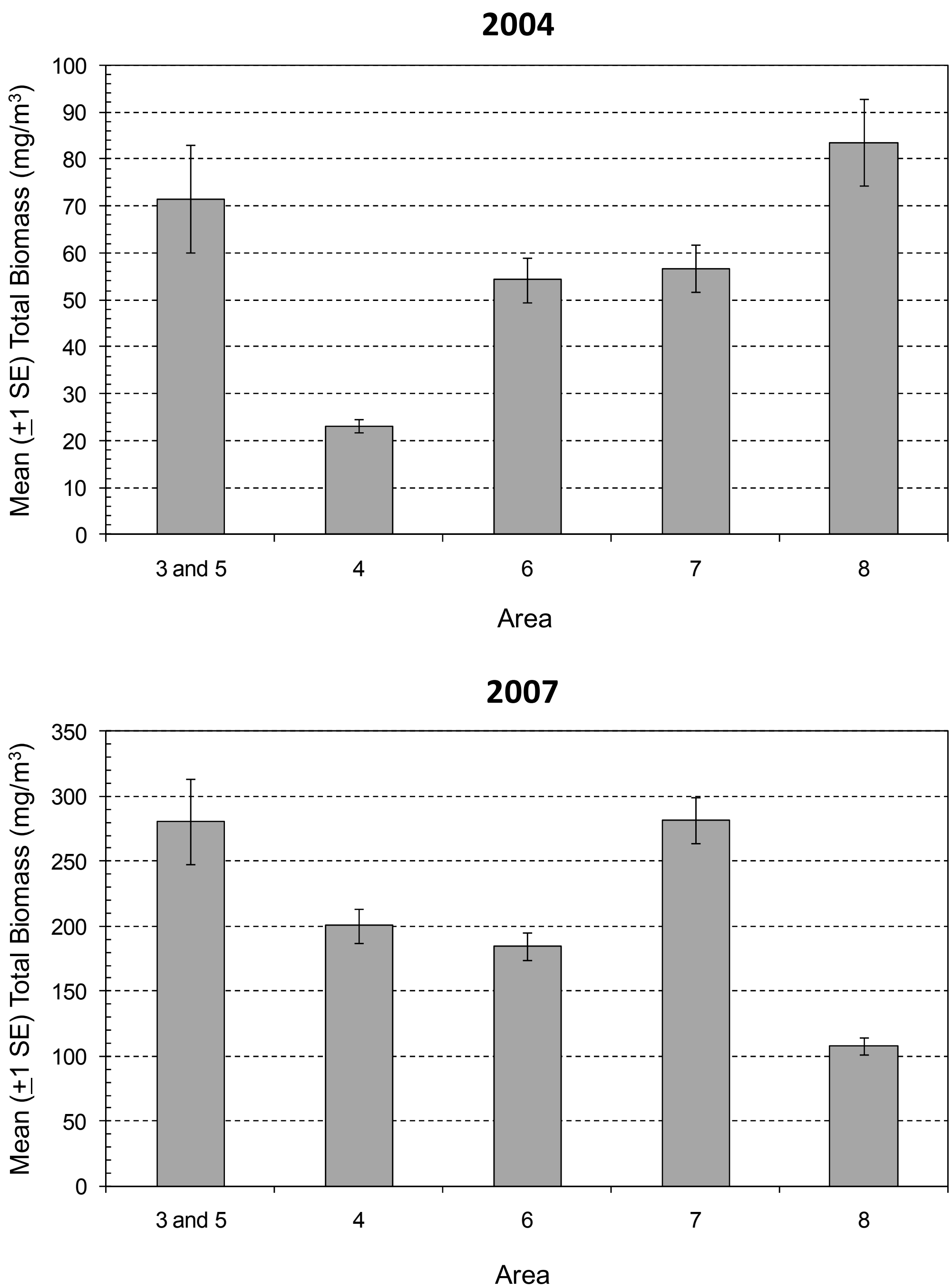
% = percent.

Figure 8.3-20 Relative Biomass of Major Phytoplankton Taxa in Kennady Lake, August 2004 and August 2007



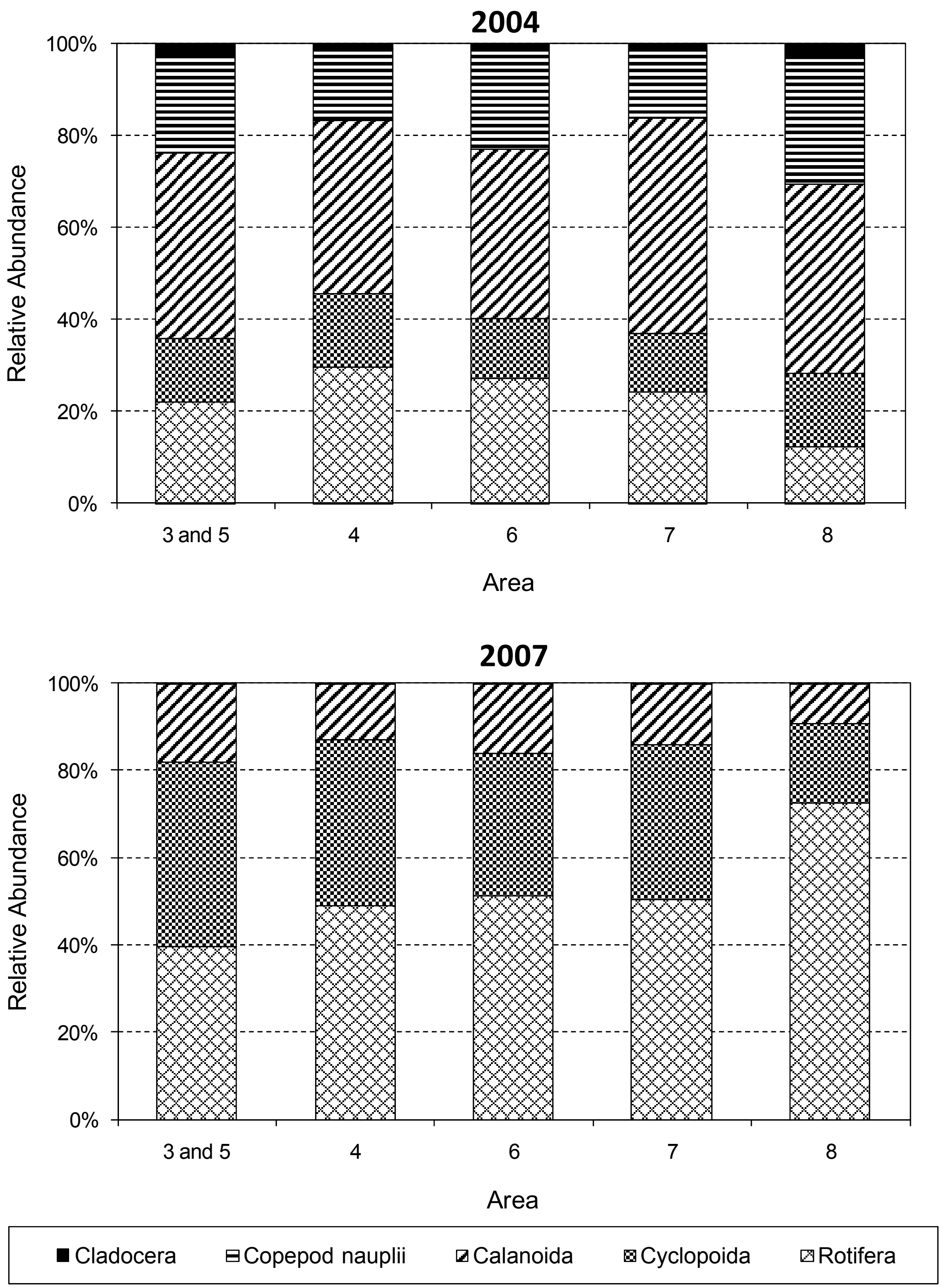
% = percent.

Figure 8.3-21 Total Zooplankton Biomass in Kennady Lake, August 2004 and August 2007



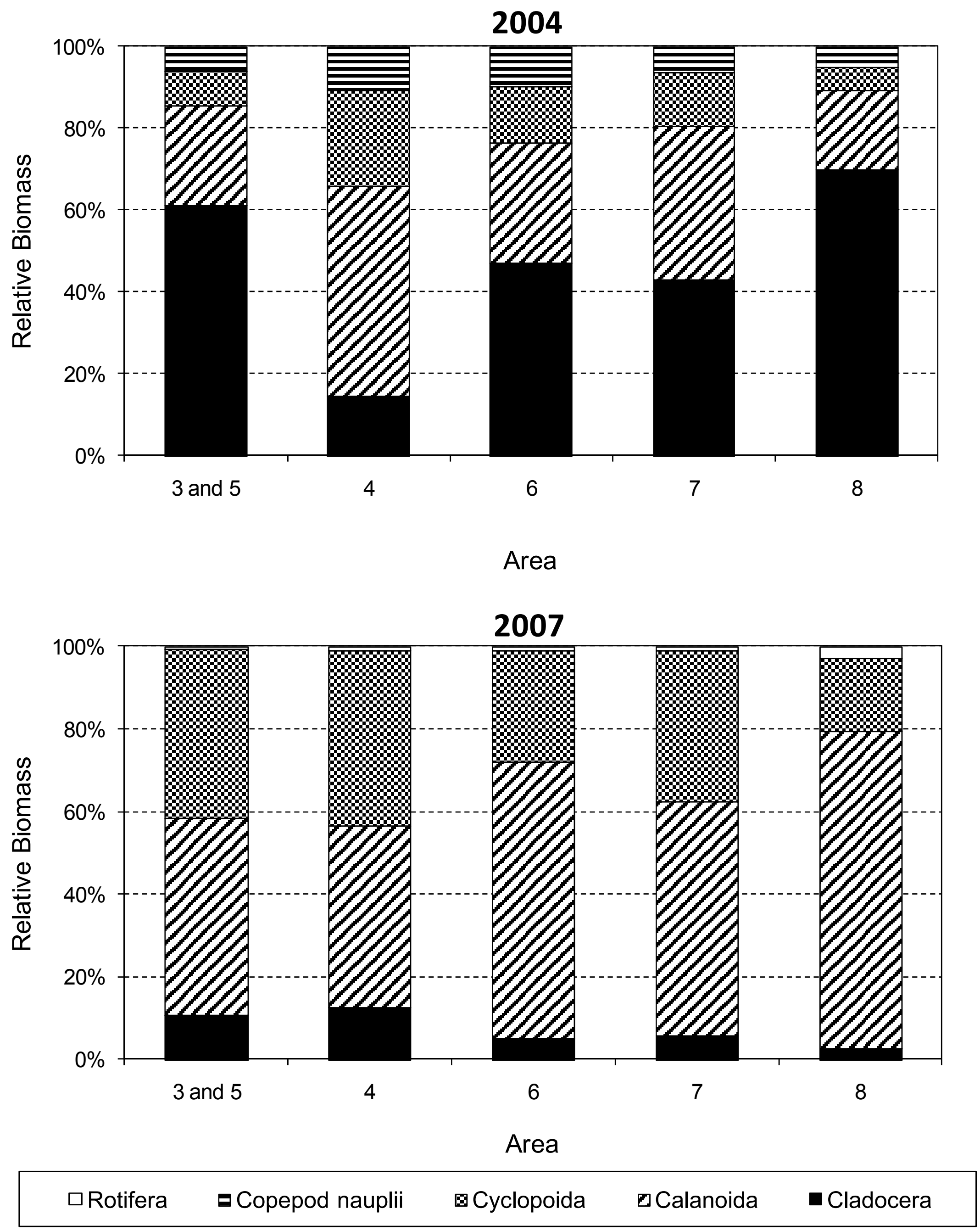
± = plus or minus; SE = standard error; mg/m^3 = milligrams per cubic metre.

Figure 8.3-22 Relative Abundances of Major Zooplankton Taxa in Kennady Lake, August 2004 and August 2007



% = percent.

Figure 8.3-23 Relative Biomass of Major Zooplankton Taxa in Kennady Lake, August 2004 and August 2007



% = percent.

Table 8.3-24 Zooplankton Abundance in Small Lakes in the Kennady Lake Watershed, August 2002 and August 2003

Lake	Copepoda			Cladocera (ind/m^3)
	Calanoida (ind/m^3)	Cyclopoida (ind/m^3)	Total Copepoda (ind/m^3)	
A1	4,205	1,113	5,318	1,268
A2	3,977	490	4,467	61
A9	4,873	4,268	9,141	3,631
D1	5,733	5,574	11,307	597
E3	13,103	364	13,467	2,548
I1	9,595	8,983	18,578	832
I2	857	551	1,408	0
J1a	3,182	61	3,243	245
J1b	5,650	61	5,711	1,632
J2	6,608	245	6,853	0
Ka1	8,174	318	8,492	425
Kb2	2,907	7,277	10,184	66
Kb3	918	734	1,652	61
Kb4	5,803	389	6,192	0

ind/m^3 = individuals per cubic metre.

8.3.7.2.2 Benthic Invertebrate Community

Benthic invertebrate densities in Kennady Lake were generally low in August and September, 2004 (Figures 8.3-24 and 8.3-25). Shallow littoral areas supported a denser benthic invertebrate community than deeper mid-lake areas. The shallow sites (4 to 6 m depth) sampled also had more diverse communities than the deep sites (8 to 18 m depth), as indicated by higher richness values at shallow sites. Dominant invertebrates in Kennady Lake included roundworms (*Nematoda*), aquatic worms (*Oligochaeta*), fingernail clams (Pelecypoda), and midges (*Chironomidae*). Compared to deep sites, relative abundances of midges were higher and relative abundances of roundworms and fingernail clams were lower at shallow sites. Part of the differences observed in benthic community characteristics between shallow and deep sites in 2004 may have been caused by the different sampling times at shallow (mid-September) and deep (early August) sites.

Benthic invertebrate densities in Kennady Lake also were low in fall (late August/early September) 2007 in shallow areas (3 to 6 m) (Figure 8.3-26). Exceptions included sites 4 and 5 in Area 8, where densities were moderate. Richness was similar to the range reported for shallow sites in September 2004. The dominant taxa in 2007 also were similar to those at shallow sites in 2004, with midges, nematodes, fingernail clams, and aquatic worms being the more abundant taxa.

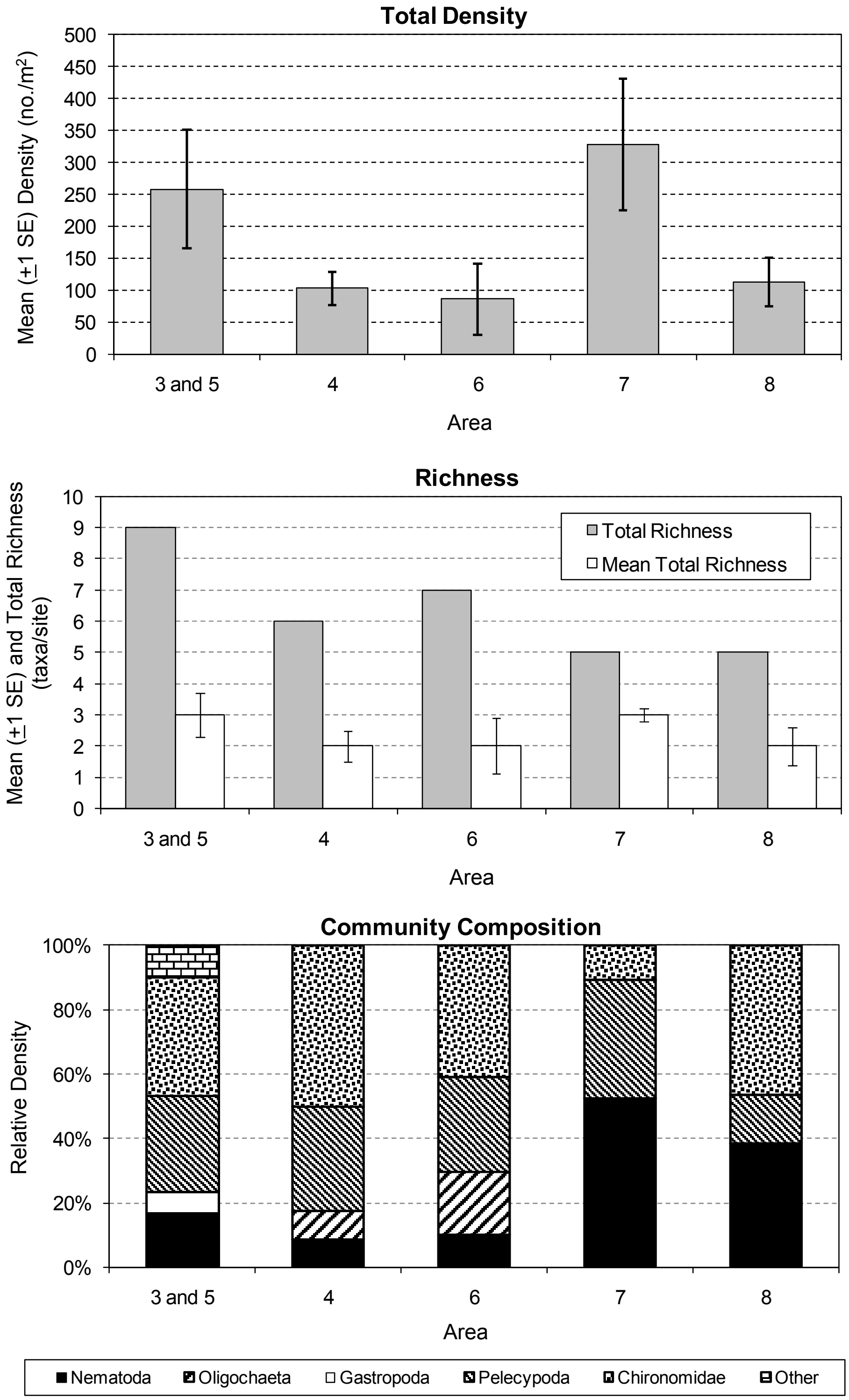
In 2007, the east section of Kennady Lake (Area 8) had the highest mean density and richness (Figure 8.3-26), potentially indicating greater benthic invertebrate productivity due to better quality habitat. Relative to other portions of Kennady Lake, the east section of Area 8 tended to have shallower waters, more abundant fine sediments at depths greater than 2 m, and higher amounts of aquatic vegetation.

Both total density and richness of Kennady Lake benthic communities were lowest in 2004 (Table 8.3-25). Among-year differences in richness and density may partly reflect varying water depth at sampling locations, mesh size differences of the sampling equipment used in different years, and varying levels of identification of invertebrates in some of the major groups. Sample collections were made with a smaller mesh size in 1996 relative to that used in subsequent years. Aquatic worms and water mites were identified to lower levels in 1996 and 2001 than in 2004.

Although some year-to-year differences were apparent in both density and richness of the benthic community in Kennady Lake, available density data indicate that Kennady Lake communities are typically characterized by generally low density (Table 8.3-25). Benthic invertebrate communities from the four studies were similar in terms of richness, with values in the range characteristic of low to moderate richness.

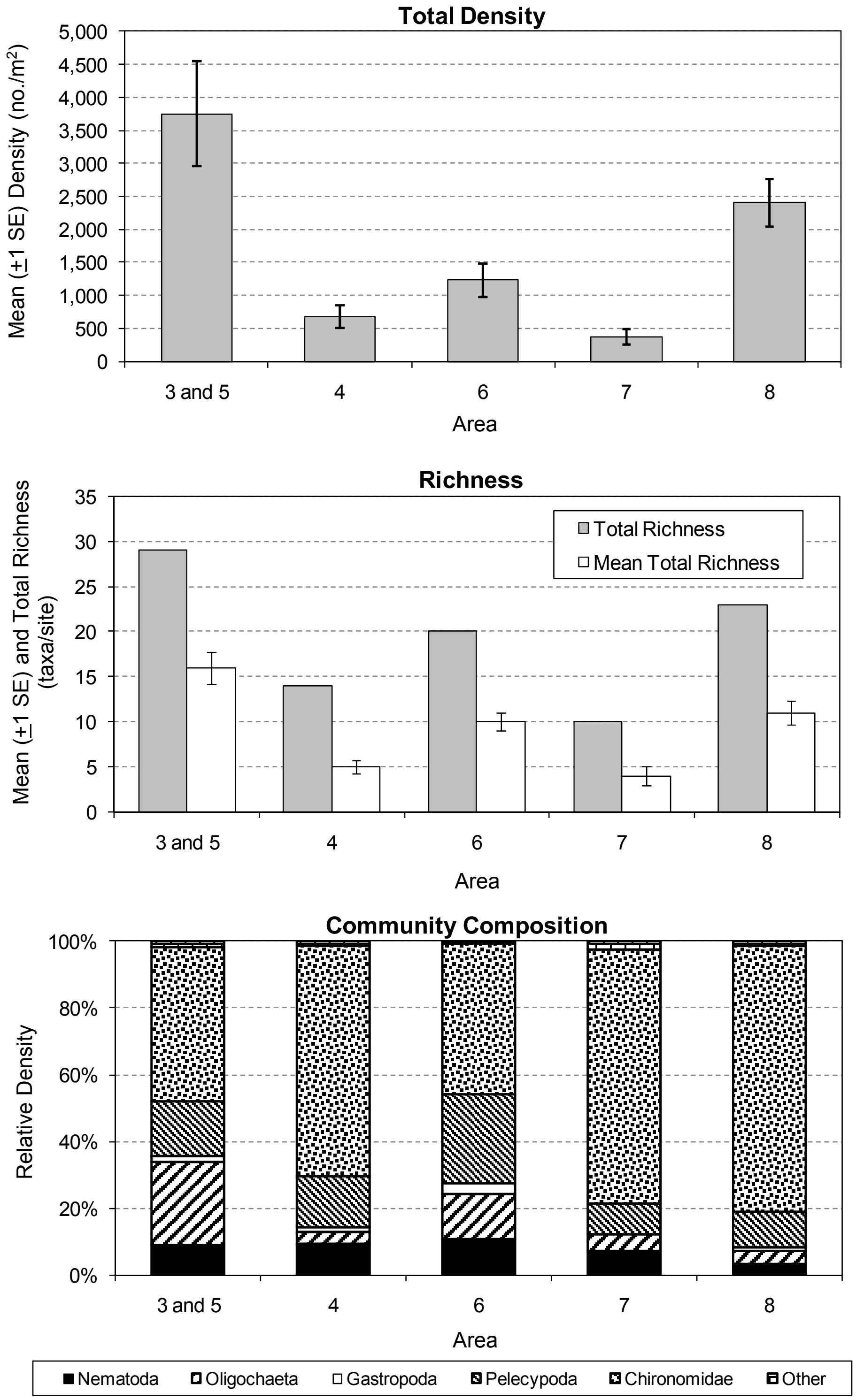
Numerically dominant invertebrate groups in Kennady Lake were similar in all years with available data, and included roundworms, fingernail clams, midges, and aquatic worms. Differences in proportions of major taxa among years were most likely due to variation in sampling locations, sampling depths, and mesh size used to process samples in the field and laboratory.

Figure 8.3-24 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Kennady Lake at Deep Water Sites, August 2004



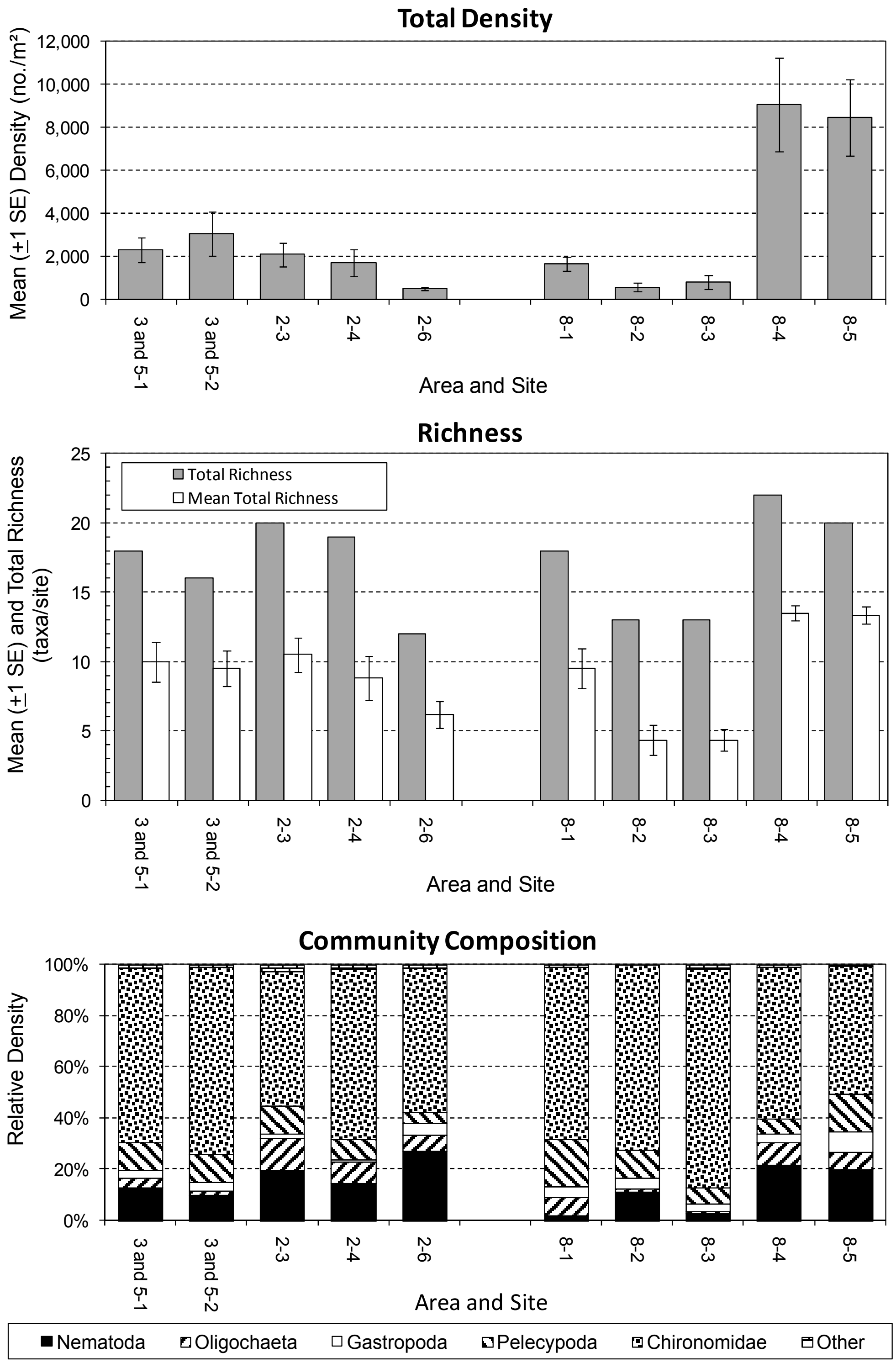
± = plus or minus; SE = standard error; no./m² = number of organisms per square metre; % = percent.

Figure 8.3-25 Total Abundance, Richness, and Community Composition of Benthic Invertebrates at Shallow Water Sites in Kennady Lake, September 2004



$\pm$ = plus or minus; SE = standard error; no./m^2 = number of organisms per square metre; % = percent.

Figure 8.3-26 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Kennady Lake, Fall 2007



± = plus or minus; SE = standard error; no./m^2 = number of organisms per square metre; % = percent.

Table 8.3-25 Summary of Benthic Invertebrate Density and Richness in Kennady Lake

Study Year	Mean Total Density (no./m² ±1 SE)				Mean Richness (no. of taxa ±1 SE)			
	North Section (Areas 2, 3, 4 and 5)	South Section (Areas 6 and 7)	East Section (Area 8)	Entire Lake	North Section (Areas 2, 3, 4 and 5)	South Section (Areas 6 and 7)	East Section (Area 8)	Entire Lake
1996	2,813 ±820	2,239 ±387	6,035 ±2,097	3,696 ±822	12 ±1.8	10 ±1.5	13 ±1.0	12 ±0.8
2001	2,051 ±365	1,282 ±224	3,162 ±565	2,060 ±186	10 ±0.8	8 ±0.9	11 ±1.0	10 ±0.4
2004	1,199 ±390	504 ±121	1,257 ±419	933 ±187	7 ±1.4	5 ±0.8	7 ±1.7	6 ±0.7
2007	1,911 ±419	-	4,099 ±1,912	-	17 ± 1.4	-	17 ± 1.8	-

± = plus or minus; SE = standard error; no./m² = number of organisms per square metre; no. = number

8.3.7.2.3 Sediment Toxicity

According to Microtox® test results, all sediment samples tested in 2004 and 2005 were non-toxic. In 2004, *Hyalella azteca* survival was significantly reduced compared to lab controls in sediment samples collected from Areas 3 and 5, Area 4, and Area 7 of Kennady Lake. *Hyalella azteca* growth was significantly reduced in the sample collected from Areas 3 and 5 (i.e., analysis by ANOVA using ToxCalc™ 1994 to 1996; p > 0.05; see Annex J Fisheries and Aquatic Resources Baseline). Reduced survival in the Area 4 sample may have resulted from a longer sample storage time compared to other samples tested in 2004. *Chironomus tentans* survival and growth were not significantly different between lab controls and lake sediments collected in 2004.

Of the 12 survival and growth tests (six *Hyalella* and six *Chironomus*) run in 2004, results were found to be significantly different from the laboratory controls (i.e., lower than controls) for only four *Hyalella* tests (three survival tests and one growth test) in 2004 and one *Chironomus* test (growth). Overall, these results indicate that bottom sediments in Kennady Lake are generally non-toxic to aquatic life.

8.3.8 Fish

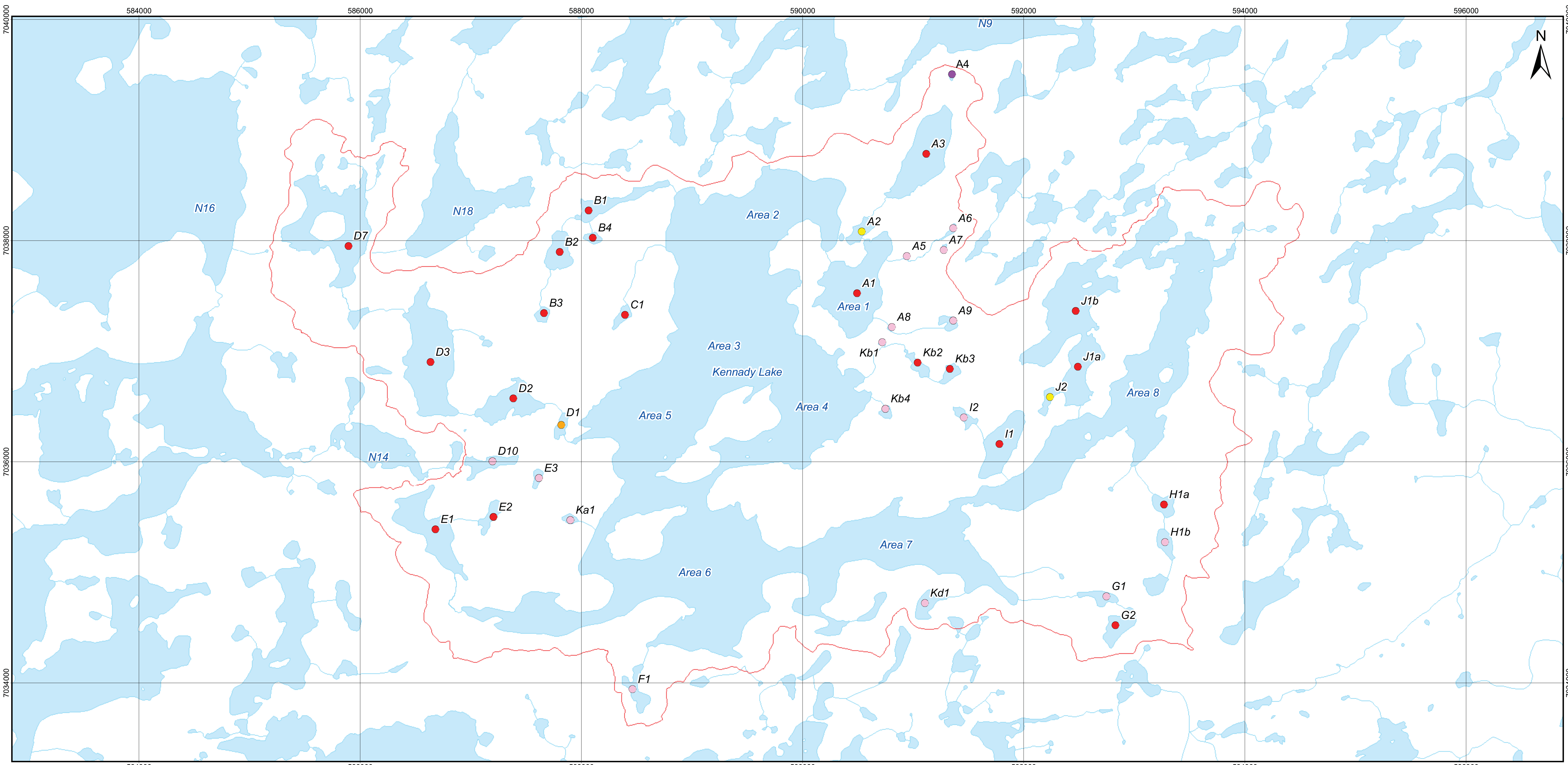
The following section describes the fish and fish habitat baseline information collected for the proposed Project. For additional information regarding fish and fish habitat, the reader is referred to Annex J (Fisheries and Aquatic Resources Baseline) and Addendum JJ.

8.3.8.1 Methods

Aquatics studies in Kennady Lake and the Kennady Lake watershed were conducted between 1996 and 2010.

The following data were collected for fisheries:

- Habitat and bathymetric surveys were conducted in Kennady Lake.
- Gillnetting surveys were conducted to characterize the large-bodied fish community in Kennady Lake.
- Minnow traps, backpack electrofishing, and boat electrofishing were used to describe the littoral fish community of Kennady Lake.
- A mark/recapture study was conducted in 2004 to calculate population estimates for the principal large-bodied fish species in Kennady Lake.
- Gillnetting and a hydroacoustic survey were conducted in 2010 to refine the population estimate.
- Spring spawning runs were assessed in Kennady Lake tributaries.
- Lake habitat assessments and fish sampling were conducted to assess the fish-bearing status of small lakes in the Kennady Lake watershed. Small lake habitat sampling locations and fish sampling locations are shown in Figures 8.3-27 and 8.3-28, respectively.
- Limnological surveys were conducted in selected lakes within the Kennady Lake watershed. Limnology sampling locations are shown in Figure 8.3-29.
- Stream habitat assessments were conducted in streams in the Kennady Lake watershed. Stream habitat sampling locations are shown in Figure 8.3-30.
- Stream utilization surveys were conducted in tributaries to Kennady Lake to determine species composition, distribution, and summer abundance of stream-dwelling fish. Stream fish sampling locations are shown in Figure 8.3-31.
- Radio telemetry was used in 2004 and 2005 to monitor movements of fish within Kennady Lake and between Kennady Lake and downstream lakes.
- Fall spawning surveys were conducted in an attempt to identify the principal spawning sites for lake trout and round whitefish in Kennady Lake.
- Fish tissue body burdens of trace metals (a measure of trace metal bioaccumulation in fish) were assessed by collecting muscle and liver samples for metals analysis from lake trout and round whitefish in Kennady Lake and Lake N16.



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LEGEND

- Watercourse
- Waterbody
- *A1* Lake Identifier

Sampling Year

- 2010
- 2005
- 2004
- 2003
- 2000
- Kennady Lake Watershed Boundary

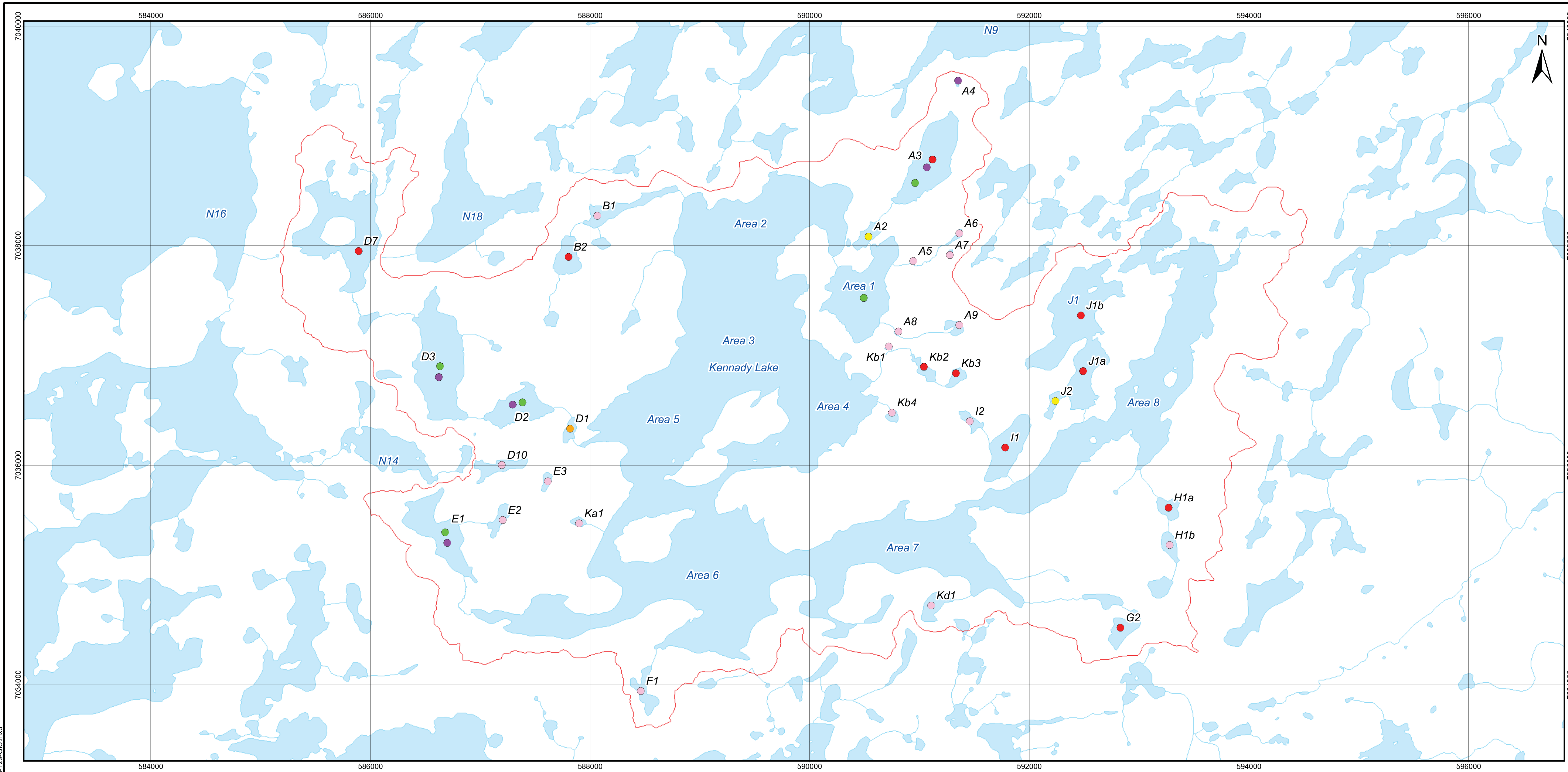
NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000
*Habitat Surveys Conducted in 1996, 1999, 2000, 2001, and/or 2005

GAHCHO KUÉ PROJECT

Fish Habitat Sampling Locations in Small Lakes in the Kennady Lake Watershed, 2000 to 2010

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
Scale: 1:35,000 — 500 250 0 500 Meters		
FILE No: E-Fish-126-GIS		DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 1	Figure 8.3-27
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF



LEGEND

Watercourse
Waterbody
A1 Lake Identifier

Sampling Year
- 2010
- 2007
- 2005
- 2004
- 2003
- 2000

Kennady Lake Watershed Boundary

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

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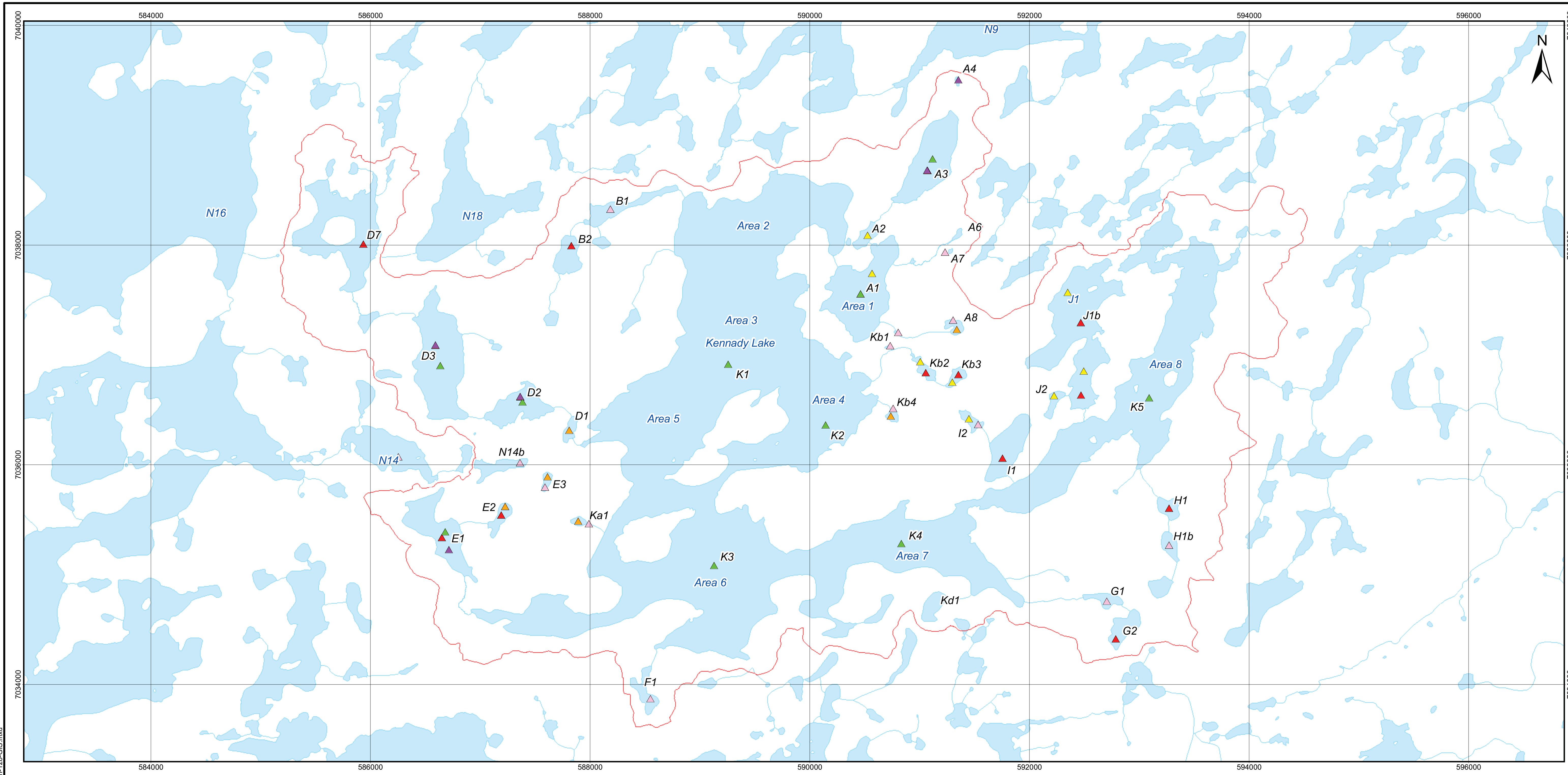
GAHCHO KUÉ PROJECT

Small Lake Fish Sampling Locations in the Kennady Lake Watershed, 2000 to 2010

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:35,000 — 500 250 0 500 Meters	DE BEERS CANADA
FILE No: E-Fish-129-GIS	DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF

Figure 8.3-28



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LEGEND

Watercourse

Waterbody

A1 Lake Identifier

Sampling Year

- 2010
- 2007
- 2005 (Limnology)
- 2004 (Limnology)
- 2003 (Limnology, Zooplankton)
- 2002 (Limnology, Zooplankton)

Kennady Lake Watershed Boundary

NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000

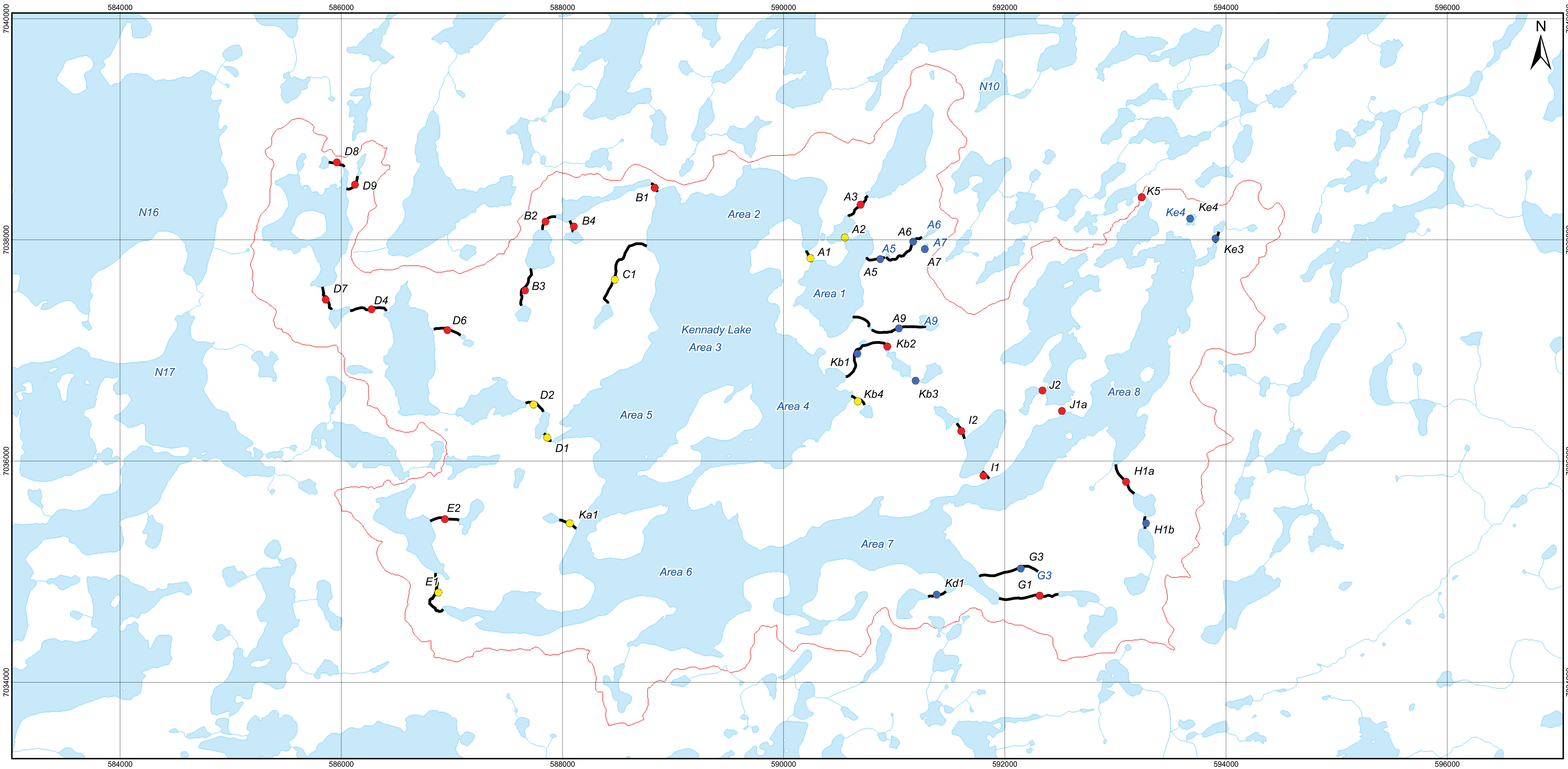
*Habitat Surveys Conducted in 1996, 1999, 2000, 2001, and/or 2005

GACHO KUÉ PROJECT

Small Lake Limnological Sampling Locations in the Kennady Lake Watershed, 2002 to 2010

PROJECTION: UTM Zone 12	DATUM: NAD83		
Scale: 1:35,000	500 250 0 500	Meters	
FILE No: E-Fish-128-GIS		DATE: December 16, 2010	
JOB NO: 09-1365-1004	REVISION NO: 1		Figure 8.3-29
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	

DE BEERS CANADA



LEGEND

Waterbody	**Sampling Year**
Watercourse	2004
A1 Lake Identifier	2000
	1996
	Habitat Survey
	Kennady Lake Watershed Boundary

NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000
Habitat Surveys Conducted in 1996, 1999, 2000, 2001, and/or 2004

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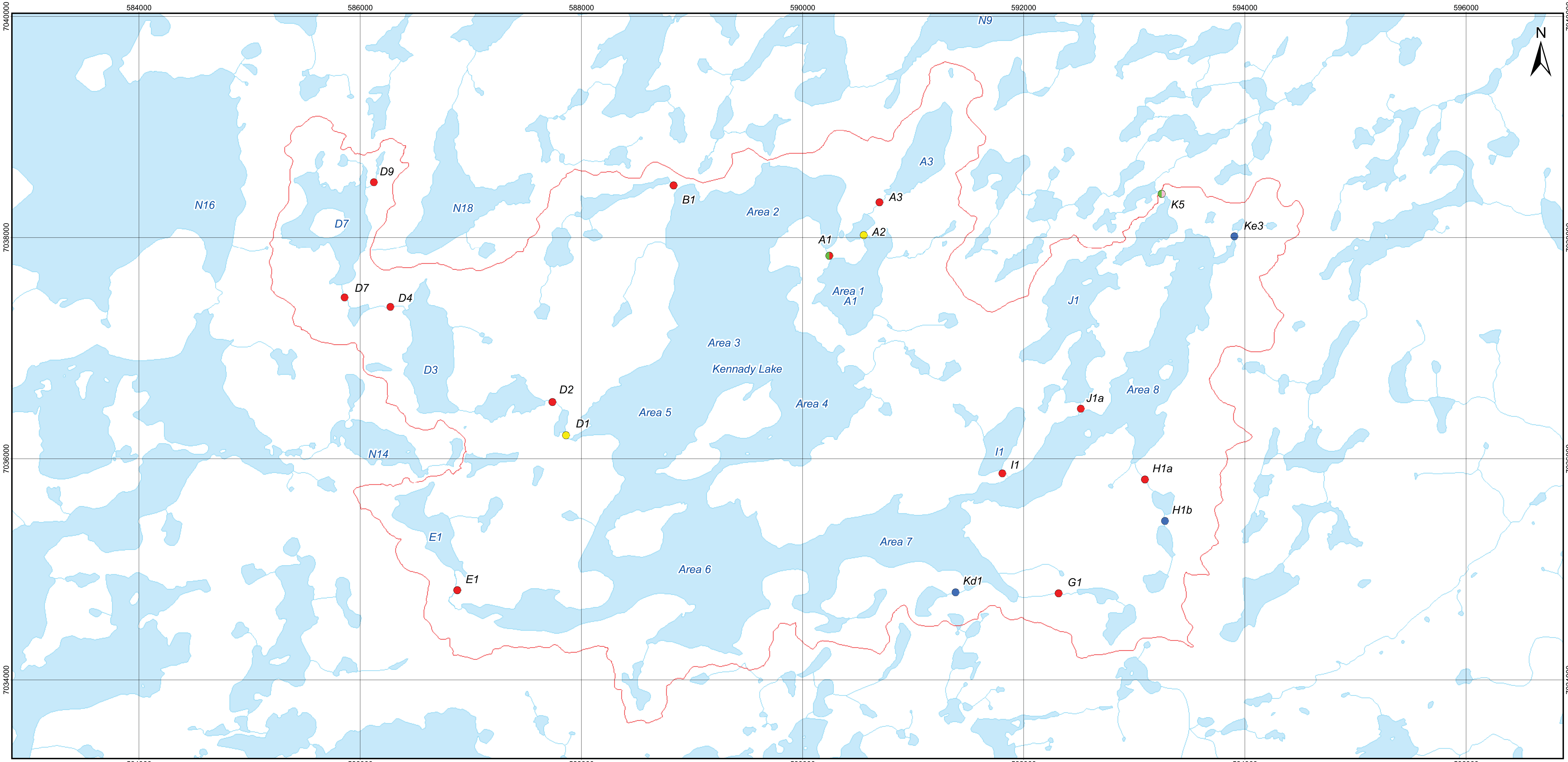
GAHCHO KUÉ PROJECT

Stream Habitat Sampling Locations in the Kennady Lake Watershed, 1996 to 2010

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
Scale: 1:35,000 500 250 0 500 Meters		
FILE No: E-Fish-127-GIS		DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 7	Figure 8.3-30
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF



LEGEND

Watercourse
Waterbody
A1 Lake Identifier

Sampling Year
- 2007
- 2005
- 2004
- 2000
- 1996

Kennady Lake Watershed Boundary

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

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GAHCHO KUÉ PROJECT

Stream Fish Sampling Locations in the Kennady Lake Watershed, 1996 to 2010

PROJECTION: UTM Zone 12	DATUM: NAD83		
Scale: 1:35,000 (500 250 0 500 Meters)			DE BEERS CANADA
FILE No: E-Fish-130-GIS		DATE: December 16, 2010	
JOB NO: 09-1365-1004	REVISION NO: 1	**Figure 8.3-31**	
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	

8.3.8.2 Results

8.3.8.2.1 Aquatic Habitat

Kennady Lake

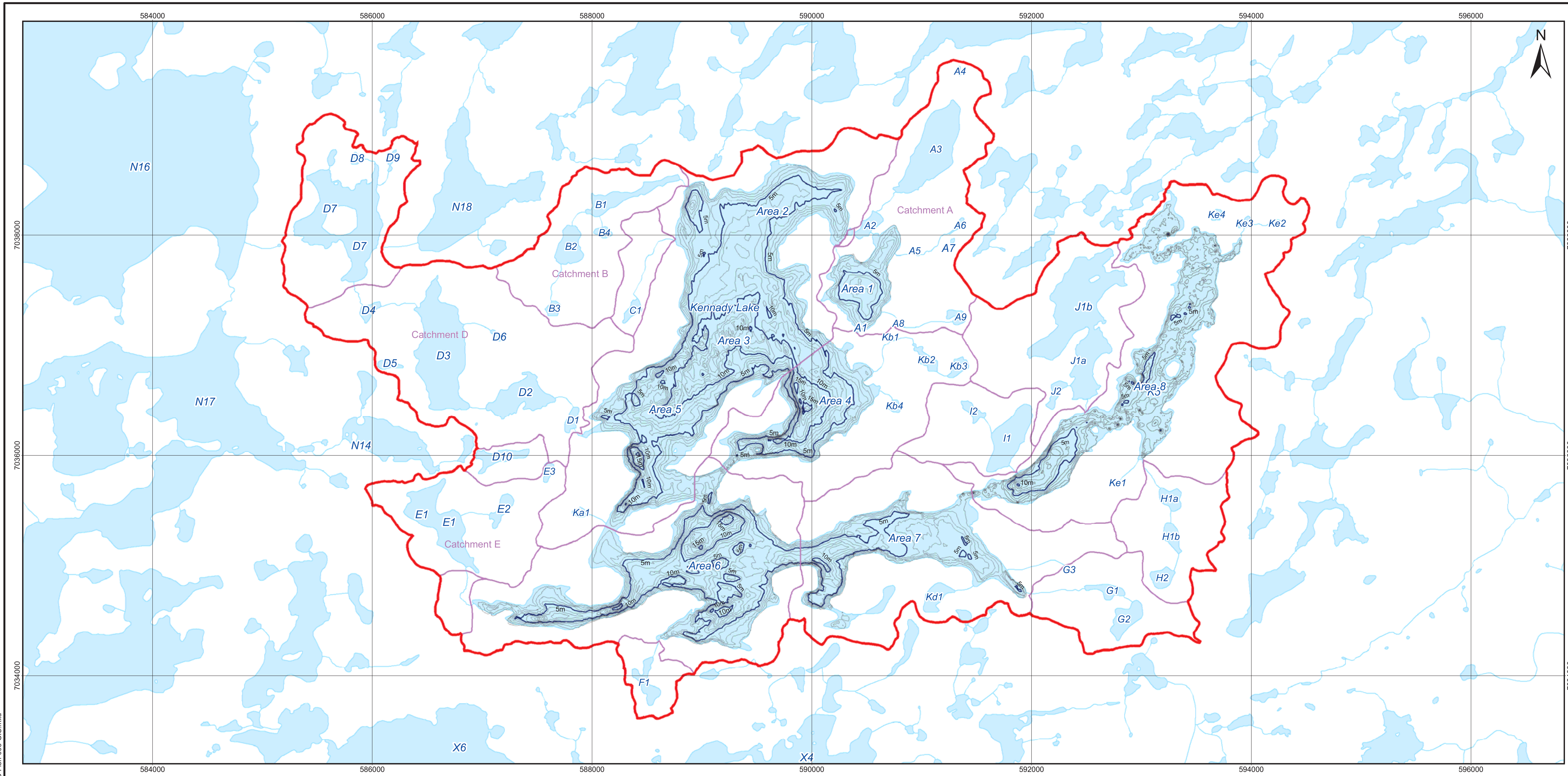
In general, habitat in Kennady Lake can be classified into three types based on depth and dominant substrate type:

- shallow, nearshore habitat within the zone of freezing and ice scour (i.e., less than 2 m deep);
- nearshore habitat deeper than the zone of ice scour but where wave action prevents excessive accumulation of sediments (i.e., greater than 2 m but less than 4 m); and
- deep (greater than 4 m), offshore habitat with substrate usually consisting of a uniform layer of loose, thick organic material and fine sediment.

A bathymetric map of Kennady Lake is presented in Figure 8.3-32.

Annual ice thickness in Kennady Lake is typically up to 2 m and substrates in nearshore areas less than 2 m deep are subjected to ice scour each winter. In Kennady Lake, 60% of all nearshore habitat falls within this ice scour zone, making it effectively unusable by fall spawning fish species such as lake trout and round whitefish for spawning and egg development.

Nearshore habitats (less than 4 m) comprise about 48% (393 ha) of the total area of Kennady Lake (Table 8.3-26). Most of this nearshore habitat (greater than 57%) has a low gradient (less than 10º) extending from the wetted edge to deeper (greater than 4 m) habitat offshore. Clean cobble and boulder substrates are the most common substrate types found in nearshore habitats and are generally found along exposed shorelines where wind and wave actions function to reduce silt accumulation.



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LEGEND

- Watercourse
- Waterbody
- *Area 1* Kennady Lake Area Identifier
- *E1* Lake Identifier
- Bathymetry Index (1m)
- Bathymetry Index (5m)
- Kennady Lake Watershed Boundary
- Sub-Watershed Boundary

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Bathymetry of Kennady Lake and Sub-watersheds within the Kennady Lake Watershed

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:35,000 (0.5 0.25 0 0.5 Kilometres)	DE BEERS CANADA
FILE No: B-Fish-003-GIS	DATE: November 24, 2010
JOB NO: 09-1365-1004	REVISION NO: 6
OFFICE: GOLD-CAL	DRAWN: SK
CHECK: AL	

Figure 8.3-32

Aquatic vegetation in Kennady Lake is extremely limited and is typically restricted to a narrow fringe of sedges in protected embayments and at tributary mouths where sediments have accumulated. A narrow band of terrestrial vegetation is typically inundated in spring when water levels in the lake rise, but this habitat usually exists for only two to three weeks during the peak spring freshet.

Deeper (greater than 4 m) offshore habitats comprise the remaining 52% (421 ha) of the lake area (Table 8.3-26). The lake bottom in this area is almost exclusively (99.8%) covered by a thick layer of loose, fine sediments. However, clean boulder/cobble substrates do exist at depths down to approximately 6 m in some areas along steep (greater than 10º), exposed shorelines where wave-generated currents are strong enough to keep silt and organic sediments from accumulating at depths deeper than most areas of the lake.

Small Lakes

Small lakes within the Kennady Lake watershed range in size from 0.09 ha (Lake A8) to 40.2 ha (Lake D7) (Table 8.3-27). Only three of these lakes are deeper than 6 m (lakes A1, A3, and I1). Most small lakes within the Kennady Lake watershed were less than 3 m deep (Table 8.3-27) and, therefore, do not provide overwintering habitat for fish. Typically 2 m of ice forms each winter and most small lakes are frozen to the bottom or have only small pockets of water in deeper areas, which likely become de-oxygenated by mid-winter. The fish-bearing status of lakes within the Kennady Lake watershed is assessed in the section on fisheries investigation below.

Most small lakes surrounding Kennady Lake are shallow depressions in the tundra with low-gradient shorelines and typically have homogenous nearshore habitats dominated by boulder substrates embedded with silt. Nearshore areas in larger lakes with sufficient fetch (i.e., the distance over open water that wind blows unobstructed from a constant direction) to create wind-generated currents typically have cleaner boulder substrates than the smaller lakes. Aquatic vegetation is rare but, where present, occurs in a narrow margin along the shoreline or in wetland areas at inlet or outlet streams. Below the 2 m depth contour, lake bottoms typically consist of fine and organic sediments.

Table 8.3-26 Summary of Nearshore and Deep Offshore Habitats in Kennady Lake

Substrate Category No.	Substrate Category	Nearshore (< 4 m) Habitat										Deep (> 4 m) Offshore Habitat								Total Area (ha)
		Depth Class I (0 m – 2 m)				Depth Class II (2 m – 4 m)				Total Area (ha)	% of Total	Depth Class III (> 4 m)						Total Area (ha)	% of Total	
		Low (L) Gradient		High (H) Gradient		Low (L) Gradient		High (H) Gradient				Low (L) Gradient		High (H) Gradient		Unknown (-) Gradient				
		Area (ha)	% of Total	Area (ha)	% of Total	Area (ha)	% of Total	Area (ha)	% of Total			Area (ha)	% of Total	Area (ha)	% of Total	Area (ha)	% of Total			
1	Bo/Co	84.7	37.6	2.2	22.0	29.1	24.1	20.7	55.6	136.7	34.8	0.0	0.0	0.7	70.0	0.0	0.0	0.7	0.2	137.4
2	Bo	39.8	17.7	3.3	33.0	2.9	2.4	2.4	6.5	48.4	12.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.4
3	Bd	3.0	1.3	1.6	16.0	0.1	0.1	0.7	1.9	5.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4
4	Bd/Bo	2.5	1.1	0.3	3.0	0.3	0.2	0.5	1.3	3.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6
5	Bd/Co	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
6	Veg/Org	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
7	Veg/Bo	8.8	3.9	0.0	0.0	0.0	0.0	0.0	0.0	8.8	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.8
8	F	7.2	3.2	0.0	0.0	34.5	28.6	0.0	0.0	41.7	10.6	0.0	0.0	0.0	0.0	420.0	100.0	421.0	99.8	462.7
9	Co/Gr	2.5	1.1	1.1	11.0	0.7	0.6	1.7	4.6	6.0	1.5	0.0	0.0	0.3	30.0	0.0	0.0	0.3	0.0	6.3
10	Bo/F	42.2	18.7	0.0	0.0	26.1	21.6	8.5	22.8	76.8	19.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.8
11	Co/F	34.1	15.1	0.2	2.0	27.0	22.4	1.4	3.8	62.7	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.7
12	Bo/Gr	0.0	0.0	1.3	13.0	0.0	0.0	1.3	3.5	2.6	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6
Total		**225.1**	**100.0**	**10.0**	**100.0**	**120.7**	**100.0**	**37.2**	**100.0**	**393.0**	**100.0**	**0.0**	**0.0**	**1.0**	**100.0**	**420.0**	**100.0**	**421.0**	**100.0**	**815.0**

Note: Substrate categories are described in Annex J, Tables J3.2-1 and J3.2-2.

Bo = boulder; Co = cobble; Bd = bedrock; Gr = gravel; F = fines/organics; Veg = vegetation; Org = organics; < = less than; > = greater than; % = percent; ha = hectare; m = metre; No. = number.

Table 8.3-27 Summary of Habitat Characteristics for Small Lakes in the Kennady Lake Watershed

Lake Identifier	Lake Area (ha)	Maximum Depth (m)	Dominant Shallow Habitat[(a)]	Lake Identifier	Lake Area (ha)	Maximum Depth (m)	Dominant Shallow Habitat[(a)]
A1	34.5	8.0	8LI	E1	20.2	3.4	10LI
A2	3.07	1.1	10L1	E2	3.02	0.4	10LI
A3	23.8	12.2	10LI	E3	1.12	0.7	10LI
A4	0.4	0.4	8LI	F1	3.93	5.0	-
A5	0.14	1.0	8LI	G1	2.86	3.0	6LI
A6	0.59	-	6L1	G2	5.90	3.2	2L1
A7	0.12	0.4	8[(b)]	H1a	3.68	1.6	12L1
A8	0.09	-	7LI	H1b	3.34	-	10H1
A9	1.81	2.0	5LI	I1	13.1	11.0	8L1
B1	8.21	4.1	2LI	I2	2.07	0.9	10LI
B2	6.55	1.1	10LI	J1a	14.0	2.2	10LI
B3	1.48	-	10LI	J1b	36.1	4.3	8LI
B4	1.16	-	8LI	J2	2.03	0.9	-
C1	1.77	-	1LI	Ka1	0.94	1.0	8LI
D1	1.87	3.8	10L1	Kb1	0.18	1.5	6LI
D10	4.40	1.7	10[(b)]	Kb2	2.53	2.5	10LI
D2	12.5	1.0	10LI	Kb3	1.95	0.9	11LI
D3	38.4	2.5	10LI	Kb4	0.99	1.2	8LI
D7	40.2	4.5	1LI	Kd1	4.26	2.9	-

(a) Habitat types:

1 Boulder/cobble - Substrates generally clean due to wave action and ice scour; on average 60% boulders, 40% cobbles. Interstitial spaces generally clean.
2 Boulder - Substrates 80% or greater boulder; remainder cobble, gravel, or fine sediments.
5 Bedrock/cobble - Bedrock overlain with cobble.
6 Vegetation/organics - Submergent, emergent, or inundated vegetation on organic substrates.
7 Vegetation/boulder - Emergent or inundated vegetation; substrates of boulder or boulder and cobble.
8 Fines/organics - Substrates predominantly fines, organics, or sand.
10 Boulder/fines - Highly embedded boulders overlain with layer of fine sediments. Substrates greater than 40% boulder.
H High gradient (>10°).
L Low gradient (<10°).
I Depth - 0 to 2 m.
II Depth - 2 to 4 m.
II Depth - >4 m.

(b) No depth/gradient category, only substrate.

ha = hectare; m = metre; - = not measured; % = percent; > = greater than; < = less than; ° = degrees.

Streams

The numerous small lakes in the Kennady Lake watershed are typically drained by small streams (less than 3 m wide) with low gradients (less than 2%) and boulder/cobble substrates (Table 8.3-28). These streams typically are either entirely dry or consist of discontinuous wetted sections in summer and fall when waters recede. In streams draining larger watersheds where summer flow persists (A, B, and D watersheds), flow is generally confined in a narrow, incised channel between and under boulders. Sedges and grasses occur in some streams, and willows and alders grow along most tributary banks. Fish passage is possible in most Kennady Lake tributaries in spring when flows are highest. However, habitat suitable for spawning and rearing of Arctic grayling and other stream-dwelling fish typically is present only in the lowest streams of the largest watersheds (i.e., A, B, and D watersheds).

Table 8.3-28 Summary of Fish Habitat Quality in Kennady Lake Tributary Streams

Stream Identifier	Reference Number[(a)]	Season Surveyed	Stream Length (m)	Map Gradient (%)	Flow duration	Overall Habitat Quality Rating	Spawning Habitat Quality[(b)]		Fish Passage
							ARGR	NRPK	
A1	3	sp	100	0.0	Perm	M-H	M	H	yes
A2	3	sp	20	0.0	Perm	M-H	M	H	yes
A3	3, 5	sp	294	0.6	Perm	M	L	L	yes
B1	3, 5	sp	94	5.1	Perm	M	M	N	yes
B2	5	su	169	0.4	Ephem	L	N	L	no
B3	5	su	332	1.5	Ephem	N	N	N	no
B4	5	su	102	0.1	Ephem	N	N	N	no
C1	3	sp	691	1.8	Ephem	N	N	N	no
D1	3	sp	118	0.3	Perm	M	M	N	yes
D2	1,3	sp, su	228	1.4	Perm	M	M	L	yes
D3	3	sp	97	2.3	Perm	M	M	L-M	yes
D4	5	su	428	0.5	Perm	M	L	L	yes
D6	5	su	255	-	Ephem	N	N	N	no
D7	5	su	206	1.7	Perm	M	L	L	yes
D8	5	su	169	2.3	Ephem	N	N	N	no
D9	5	su	188	1.9	Ephem	N	N	N	no
Ka1	3	sp	170	3.6	Ephem	N	N	N	no
Kb1	3	sp	300	1.4	Ephem	N	N	N	no
Kb2	5	su	181	2.3	Ephem	N	N	N	no
Kb4	3	sp	309	0.6	Ephem	N	N	N	no
E1	3	sp	426	1.1	Perm	L-M	M	L	yes
E2	5	su	290	1.6	Ephem	N	N	N	no
F1	3	sp	168	5.9	Ephem	N	N	N	no
G1	5	su	574	1.0	Ephem	L	N	L	yes
Kd1	1	sp, su	138	1.4	Ephem	L	-	-	unknown
I1	5	su	68	1.3	Perm	L	L	L	yes
I2	5	su	193	2.6	Ephem	N	N	N	no
H1a	1,5	sp, su	331	2.1	Perm	L	N	L	yes
H1b	1	sp, su	80	0.0	Ephem	L	-	-	yes

Table 8.3-28 Summary of Fish Habitat Quality in Kennady Lake Tributary Streams (continued)

Stream Identifier	Reference Number[(a)]	Season Surveyed	Stream Length (m)	Map Gradient (%)	Flow duration	Overall Habitat Quality Rating	Spawning Habitat Quality[(b)]		Fish Passage
							ARGR	NRPK	
H2	no reference	-	175	1.9	Ephem	not surveyed			unknown
J1a	5	su	123	1.2	Perm	L	L	N	yes
J2	5	su	22	1.9	Ephem	N	N	N	no
Ke3	1	sp, su	56	1.6	Ephem	L	-	-	unknown

(a) Sources: 1: Canamera 1998; surveyed June 4 to 9 (spring) and July 2 to 28 (summer), 1996; 2: EBA and Jacques Whitford 2000; surveyed July 16 to 27 (summer), 1999; 3: EBA and Jacques Whitford 2001; surveyed June 4 to 9 (spring), 2000; 4: EBA and Jacques Whitford 2002; surveyed July 14 (summer), 2001; 5: current baseline sampling program (Annex J); surveyed August 4 to 6, 2004.

(b) Habitat Quality Ratings: H = High; M = Moderate; L = Low; N = Nil.

ARGR = Arctic grayling; NRPK = northern pike; Perm = Permanent; Ephem = Ephemeral; sp = spring; su = summer; "-" = not applicable; m = metre; % = percent.

8.3.8.2.2 Large-bodied Fish Community

Eight species of fish are known to inhabit Kennady Lake. Round whitefish (*Prosopium cylindraceum*) are the most abundant large-bodied fish species and typically comprise more than 50% of the total large-bodied fish community (Table 8.3-29). Lake trout (*Salvelinus namaycush*) are the second most abundant species (about 20%) and are the top predator in the lake. Relative abundance of lake chub (*Couesius plumbeus*) and Arctic grayling (*Thymallus arcticus*) has varied between years but, on average, is lower (12% and 10%, respectively) than lake trout and round whitefish. The northern pike (*Esox lucius*) population in Kennady Lake is small (about 2%) due to the paucity of aquatic vegetation in the lake. A single longnose sucker (*Castostomus catostomus*) was observed in the spring of 2000 near the lake outlet (Table 8.3-33). It is believed this single fish was a stray from downstream habitats and that Kennady Lake does not support a population of longnose sucker (Annex J).

Short-duration gill netting in summer 2010 captured fewer fish than previous years. Only eight of the 72 sets captured fish and only 13 fish were captured in total (one northern pike, five lake trout, six round whitefish, and one lake chub). Overall, 85% of the catch was lake trout and round whitefish. The lake trout catch-per-unit-effort (CPUE) was 1.41 fish per 100 m^2 / 12-net hours, and the round whitefish CPUE was 1.69 fish per 100 m^2 / 12-net hours. The total (all species combined) CPUE was 3.66 fish per 100 m^2 / 12-net hours.

Burbot (*Lota lota*) are the only other large-bodied fish species in Kennady Lake but were not represented in gillnet catches. Ninespine stickleback (*Pungitius*

pungitius) and slimy sculpin (*Cottus cognatus*) are the only other fish species found in Kennady Lake and are discussed in Littoral Fish Community (Section 8.3.8.2.4). Mean length, weight, and condition factor[2] for large-bodied fish species captured by gillnetting in Kennady Lake in 1996, 1999, and 2004 are provided in Table 8.3-30.

Table 8.3-29 Species Composition, Relative Abundance, and Average Catch-Per-Unit-Effort of Fish Captured in Kennady Lake during Gillnetting Surveys, Summer Months of 1996, 1999, and 2004

Species	1996			1999			2004[(a)]		
	# of Fish	% of Catch	CPUE	# of Fish	% of Catch	CPUE	# of Fish	% of Catch	CPUE
Arctic grayling	3	0.8	0.07	39	22.7	2.11	20	7.2	2.16
Lake chub	106	29.2	2.54	9	5.2	0.46	3	1.1	0.18
Lake trout	70	19.3	1.97	36	20.9	1.98	53	19.0	4.13
Northern pike	2	0.6	0.05	5	2.9	0.28	5	1.8	0.42
Round whitefish	182	50.1	4.54	83	48.3	4.52	198	71.0	18.9
Total	**363**	**100**	**9.17**	**172**	**100**	**9.35**	**279**	**100**	**25.7**

(a) Combined results from 89 SLIN gillnet lifts and 7 experimental gillnet lifts.

CPUE = catch-per-unit-effort measured as number of fish/100 m^2/12 hours; SLIN = spring littoral index netting; # = number; % = percent; m^2 = square metre.

Table 8.3-30 Mean Length, Weight, and Condition Factor for Fish Captured in Standardized Experimental Gill Nets in Kennady Lake

Species	Length (mm)			Weight (g)			Condition Factor		
	n	Mean	Standard Deviation	n	Mean	Standard Deviation	n	Mean	Standard Deviation
Arctic grayling[(a)]	37	304	35.6	37	333	86.1	37	1.14	0.10
Lake chub[(b)]	98	94	6.6	-	-	-	-	-	-
Lake trout[(b)]	70	304	147	60	525	760	60	1.01	0.13
Northern pike[(a)]	5	699	90.0	5	2,920	1,112	5	0.81	0.05
Round whitefish[(b)]	166	244	70.8	152	195	152	152	1.01	0.24

(a) Fish captured in 1999.

(b) Fish captured in 1996.

Length = fork length; mm = millimetres; g = grams; n = number of fish; - = no fish found.

2 Condition factor is a proxy for the general health or condition of fish. It is calculated as (fish weight [g])/(fish length [mm]). This ratio measure is often multiplied by some arbitrary factor to scale the measure to something close to one. It is not necessarily comparable among species but rather may provide an indication of spatial or temporal variation within a population or species. In Environmental Effects Monitoring (EEM) programs, it is often related to energy storage, i.e., higher condition equates to more energy being stored

Lake Trout

Lake trout sampled in Kennady Lake ranged in age between 1 to 26 years old (Table 8.3-31). Although based on a limited number of aged fish, growth rates of lake trout in Kennady Lake appear slower than in Great Slave Lake (Scott and Crossman 1973).

Lake trout in Kennady Lake reach sexual maturity at a minimum size of 450 mm, when most lake trout in Kennady Lake are 8 or 9 years old (Table 8.3-31). In addition, evidence from gillnetting surveys conducted since 1996 suggests that lake trout in Kennady Lake do not spawn every year. Alternate year spawning is common in lake trout populations in the NWT (McPhail and Lindsey 1970; Richardson et al. 2001), where growing seasons are short and low nutrient availability limits productivity.

Most (62%) lake trout captured in summer 1996 were less than 300 mm in length with a modal length class of 175 to 200 mm (Figure 8.3-33). In comparison, most (92%) lake trout captured in summer 1999 were greater than 300 mm with a modal length-class distribution of 500 to 525 mm (Figure 8.3-34). The difference in length-frequencies between years is difficult to interpret but may be due to differences in sample effort. The difference may also represent the growth of a particularly strong year-class of fish from 1996 to 1999.

Table 8.3-31 Mean Length- and Weight-at-Age for Lake Trout in Kennady Lake, 1996, 1999, and 2004

Age	Length (mm)				Weight (g)			
	n	Mean	Min	Max	n	Mean	Min	Max
1+	2	114	108	120	2	52	14	90
2+	9	184	131	216	9	64	15	85
3+	4	244	204	276	4	159	88	225
4+	3	212	200	219	3	101	78	124
5+	3	263	238	289	3	211	200	218
6+	2	334	287	380	2	420	260	580
7+	1	272	-	-	1	200	-	-
8+	2	482	445	518	2	1,038	890	1,186
9+	8	498	455	534	8	1,383	920	1,975
10+	6	484	457	512	6	1,242	1,070	1,400
11+	4	477	468	486	4	1,231	1,175	1,300
12+	1	508	-	-	1	2,025	-	-
13+	3	548	497	578	3	1,808	1,198	2,600
14+	2	553	498	608	3	1,930	1,375	2,714
15+	4	571	452	659	4	2,315	1,200	3,530
16+	1	603	-	-	1	2,755	-	-

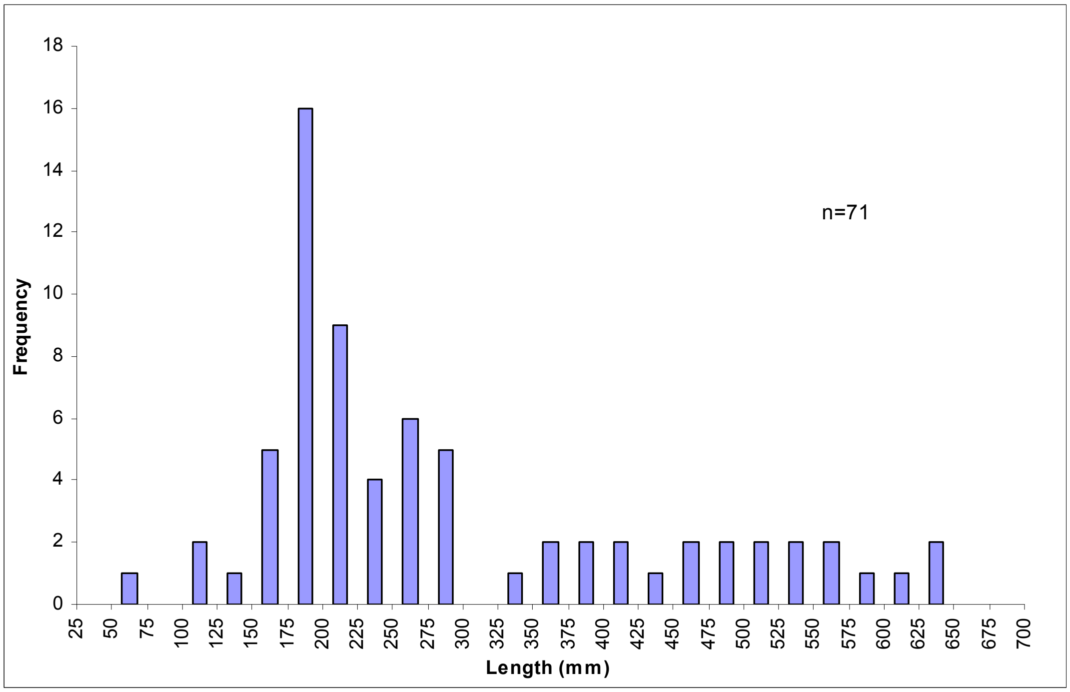
Table 8.3-31 Mean Length- and Weight-at-Age for Lake Trout in Kennady Lake, 1996, 1999, and 2004 (continued)

Age	Length (mm)				Weight (g)			
	n	Mean	Min	Max	n	Mean	Min	Max
17+	7	602	549	701	7	2,315	1,580	3,100
18+	3	632	580	780	3	2,760	2,030	5,000
19+	2	613	578	648	2	2,104	1,982	2,225
20+	-	-	-	-	-	-	-	-
21+	3	615	577	653	3	2,617	1,952	3,400
22+	1	575	-	-	1	1,940	-	-
23+	1	778	-	-	1	5,725	-	-
24+	2	690	595	785	2	3,888	1,825	5,950
25+	-	-	-	-	-	-	-	-
26+	1	658	-	-	1	4,250	-	-

Notes: 1996 (n=50); 1999 (n=2); 2004 (n=24).
mm = millimetres; g = grams; - = not applicable; n = number of fish; min = minimum; max = maximum.

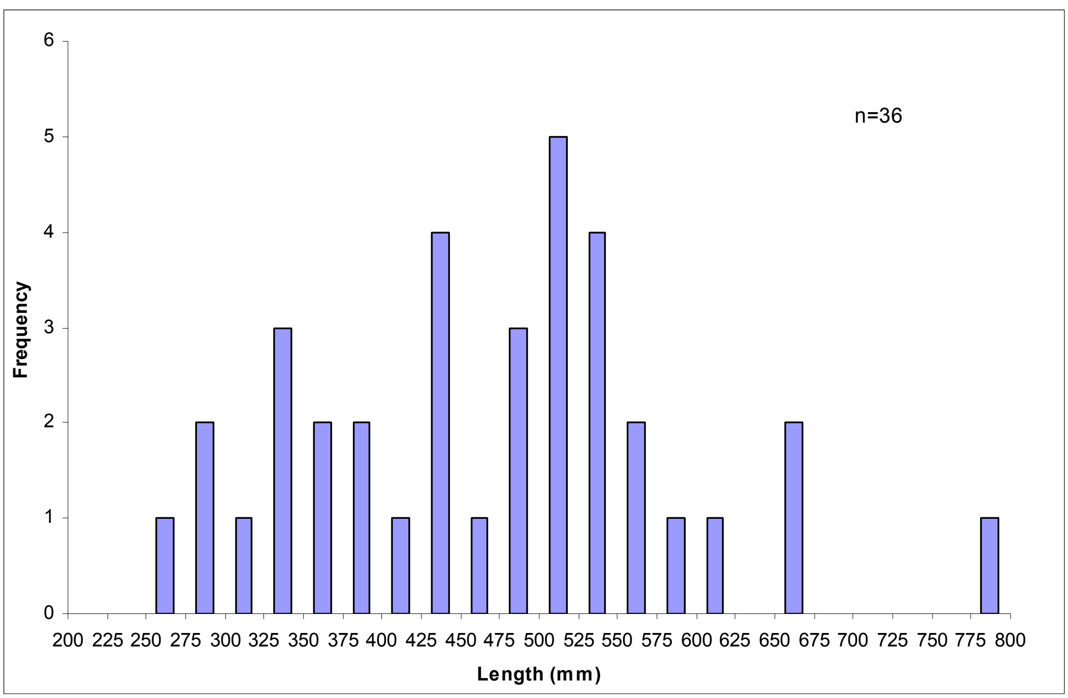
Lake trout are the top predators in Kennady Lake where they feed almost exclusively on round whitefish. In contrast, lake trout in Lake N16 in the adjacent watershed prefer lake cisco despite the relatively high abundance of round whitefish. Lake cisco are not found in Kennady Lake.

Figure 8.3-33 Length-Frequency Distribution for Lake Trout Gillnetted in Kennady Lake, Summer 1996



mm = millimetre.

Figure 8.3-34 Length-Frequency Distribution for Lake Trout Gillnetted in Kennady Lake, Summer 1999



mm = millimetre.

Round Whitefish

Round whitefish captured in gillnets in Kennady Lake ranged between 1 and 13 years old (Table 8.3-32). In Kennady Lake, most round whitefish reach sexual maturity at 250 mm in length. Round whitefish in Kennady Lake typically reach this size at five years old (Table 8.3-32). Evidence from all three years of gillnetting suggest that round whitefish in Kennady Lake spawn every year once reaching sexual maturity.

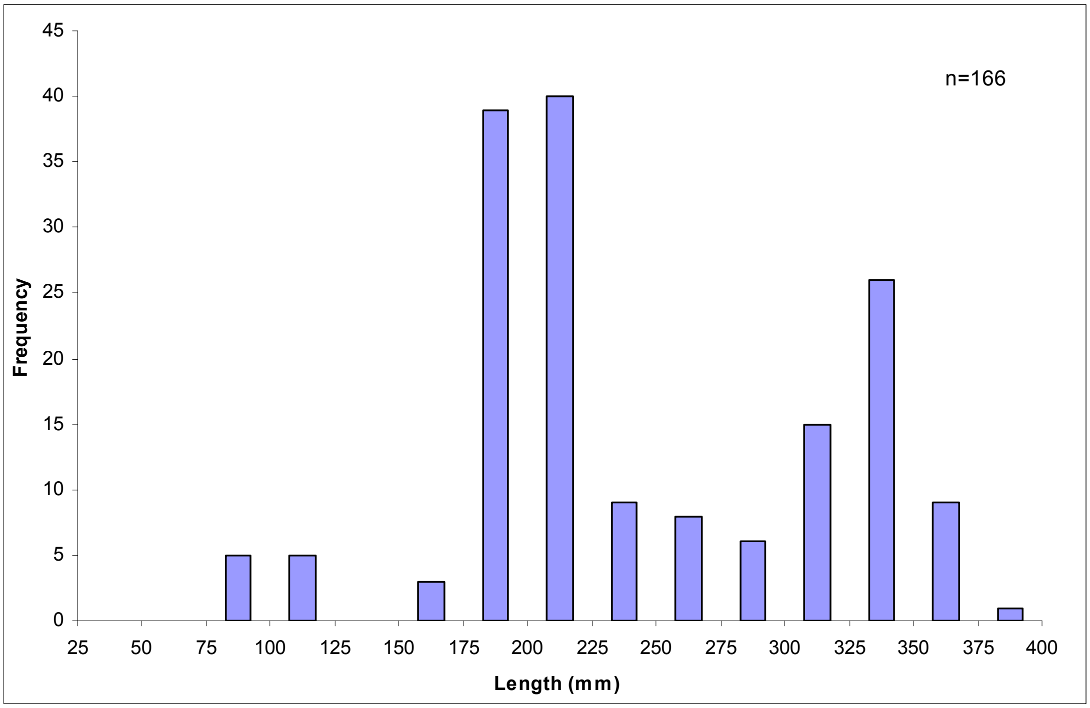
Round whitefish captured in gillnets in 1996 had a mean length of 244 mm, a mean weight of 195 g, and a condition factor of 1.01. Round whitefish ranged in length between 75 mm and 400 mm, with a modal length class of 200 to 225 mm (Figure 8.3-35); most (92%) round whitefish captured in 1996 were greater than 175 mm. Zooplankton groups were the primary prey item of round whitefish in Kennady Lake. Bivalves and gastropods were also commonly eaten.

Table 8.3-32 Mean Length-at-Age and Weight-at-Age for Round Whitefish in Kennady Lake, 1996, 1999, and 2004

Age	Length (mm)				Weight (g)			
	n	Mean	Min	Max	n	Mean	Min	Max
1+	1	118	-	-	1	14	-	-
2+	1	188	-	-	1	66	-	-
3+	19	201	184	231	19	77	55	114
4+	16	222	188	263	16	114	70	178
5+	7	273	238	298	7	225	125	325
6+	16	279	248	320	16	245	100	395
7+	25	306	265	355	25	300	200	425
8+	26	312	264	345	26	352	150	734
9+	21	334	290	365	21	422	250	558
10+	17	343	270	385	17	487	350	742
11+	8	345	330	355	8	469	425	500
12+	1	343	-	-	1	550	-	-
13+	1	348	-	-	1	525	-	-

Notes: 1996 (n=61); 1999 (n=4); 2004 (n=94).
mm = millimetres; g = grams; - = not applicable; n = number of fish; min = minimum; max = maximum.

Figure 8.3-35 Length-Frequency Distribution for Round Whitefish Gillnetted in Kennady Lake, Summer 1996



mm = millimetre.

8.3.8.2.3 Population Estimates

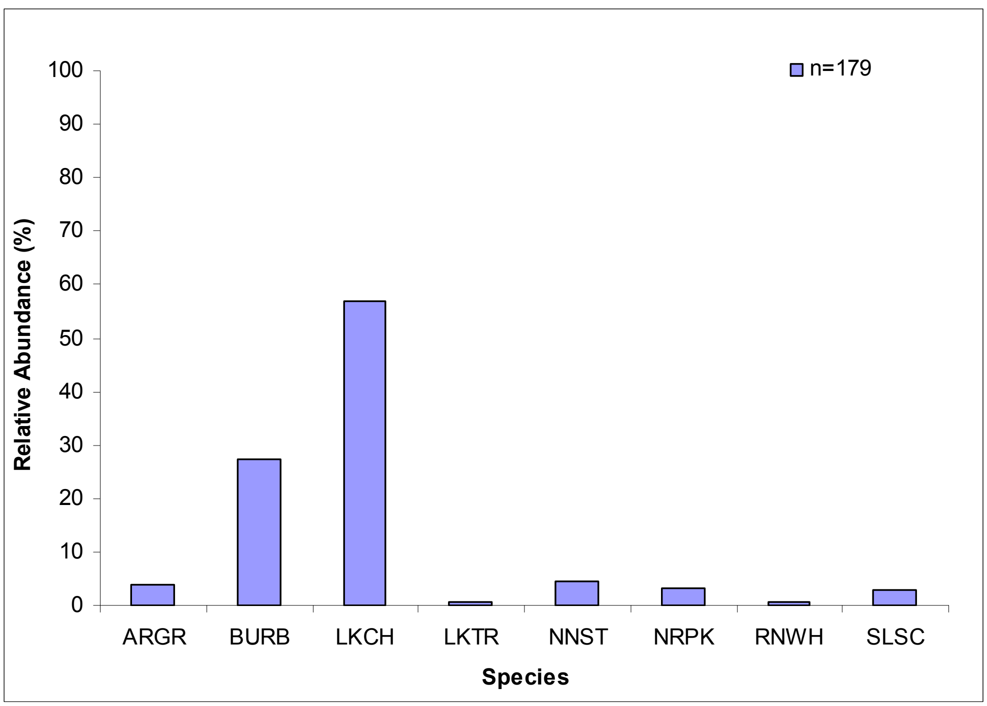
In the 2004 mark/recapture study, Peterson population estimates could not be calculated due to low numbers of recaptured fish in the fall. Instead, a Bayesian approach (Gazey and Staley 1986) was used to calculate the probability that the minimum population size was greater than a reference population level. Based on results of the 2004 mark/recapture experiment, there is a 95% probability that the lake trout population in Kennady Lake is greater than 2,300 fish. Population estimates for Arctic grayling and round whitefish could not be calculated because tagged individuals were not recaptured in the fall. A whole-lake population estimate for northern pike was not possible due to their patchy distribution and limited movement.

To further refine the Kennady Lake population estimates, a hydroacoustic survey of pelagic fish was conducted in late summer 2010. The fish density of Kennady Lake was calculated to be 23.3 fish per hectare (0 to 51.2 fish per hectare; 90% confidence interval [CI]). If considering the entire wetted surface area of Kennady Lake (i.e., 814 ha), the total fish population was estimated at 18,977 fish; however, this estimate does not include fish (e.g., young-of-year, small fish) that prefer shallow water where hydroacoustic surveys are generally ineffective. The hydroacoustic surveys showed that most of the Kennady Lake population resided in Area 6 (53%) where there was deep water (approximately 18 m in depth), and possibly, vertical thermoclines. A mean density of 13.4 lake trout per hectare was calculated (or a lake trout population of 10,925 fish).

8.3.8.2.4 Littoral Fish Community

The density of fish in the littoral areas of Kennady Lake was low (less than 2.5 fish/100 m), which is characteristic of the low productivity of Kennady Lake. Lake chub were the most abundant fish species in littoral areas comprising over 50% of the catch (Figure 8.3-36). Juvenile burbot contributed about 25% of all fish captured in the littoral areas. In contrast, few adult burbot have been captured in gillnets set offshore. The relative proportion of burbot in the Kennady Lake fish community in comparison to other large-bodied fish species is likely underestimated, as burbot are typically under-represented in gillnet catches (Jensen 1986). Small numbers of Arctic grayling, lake trout, northern pike, and round whitefish were also captured in littoral areas. Ninespine stickleback and slimy sculpin were the only other small-bodied fish species captured in the littoral areas of the lake. These two species comprised less than 5% of the littoral fish community.

Figure 8.3-36 Relative Abundance of Fish Species Captured in Littoral Areas of Kennady Lake, 1996, 1999, and 2004



ARGR = Arctic grayling; BURB = burbot; LKCH = lake chub; LKTR = lake trout; NRPK = northern pike; RNWH = round whitefish; SLSC = slimy sculpin; NNST = ninespine stickleback; n = number of fish; % = percent.

8.3.8.2.5 Spring Spawning Runs

In spring of 2000, 127 individual fish were captured in Kennady Lake tributaries and in the Kennady Lake outlet (Table 8.3-33). Arctic grayling were the most abundant species captured, followed by lake trout, burbot, and northern pike. Lake chub, ninespine stickleback, and longnose sucker were also captured in Kennady Lake tributaries in spring 2000.

Table 8.3-33 Numbers of Fish Captured, by Species, in Fish Fences Set in Kennady Lake Tributaries, Spring 2000

Species	Area 1	Area 3 and 5		Area 6	Area 7	Kennady Lake Outlet	Total
	A2[(a)]	D1[(a)]	B1[(a)]	E1[(a)]	G1[(a)]	K5[(b)]	
Arctic grayling	12	15	7	6	0	53	**93**
Burbot	1	1	0	9	0	0	**11**
Lake trout	0	0	0	0	0	12	**12**
Northern pike	7	0	0	0	0	0	**7**
Lake chub	0	0	0	0	0	1	**1**
Ninespine stickleback	0	0	0	2	0	0	**2**
Longnose sucker	0	0	0	0	0	1	**1**
Total	**20**	**16**	**7**	**17**	**0**	**67**	**127**

(a) Upstream.
(b) Downstream.

In spring 2004, 235 fish were captured in Kennady Lake tributaries and in the Kennady Lake outlet in fish fences and hoopnets (Table 8.3-34). Arctic grayling was the most abundant large-bodied species captured, followed by northern pike and lake trout. Small numbers of burbot, round whitefish, and slimy sculpin were also captured. Large numbers of ninespine stickleback were captured in Stream A1, which is likely a reflection of the smaller mesh nets (13 mm) used in Stream A1 than the absence of ninespine stickleback in other streams.

Lake trout are fall spawners and the movement of lake trout through the Kennady Lake outlet in the spring of 2000 and 2004 is most likely to feed on spawning Arctic grayling and/or their newly laid eggs.

Based on these two years of data, most adult Arctic grayling in Kennady Lake move through the Kennady Lake outlet to spawn in the series of streams immediately downstream (Figure 8.3-37). Other tributaries to Kennady Lake are also used, including streams within the A, B, D, and E watersheds, but to a smaller extent. This is primarily due to their smaller size, lower flows, and steeper gradients compared to streams downstream of Kennady Lake.

Table 8.3-34 Numbers of Fish Captured, by Species and Direction of Movement, in Fish Fences and Hoopnets Set in Kennady Lake Tributaries, Spring 2004

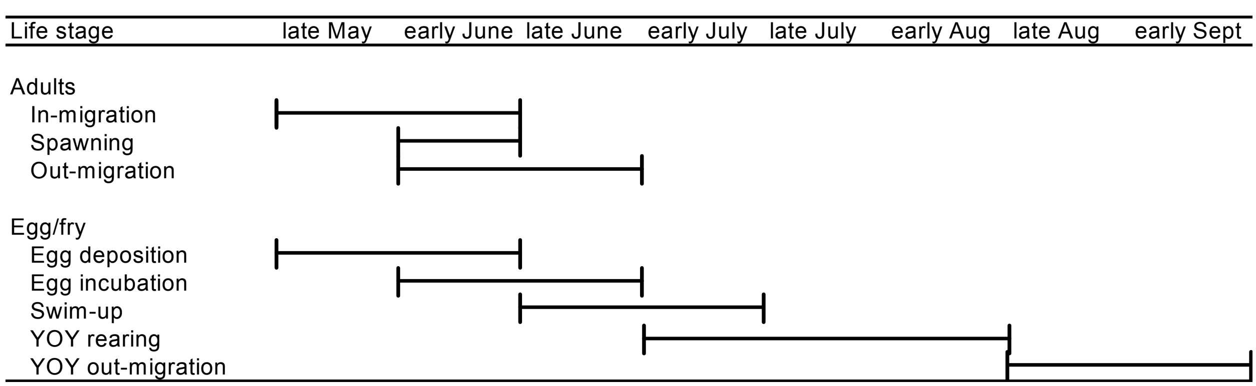
Species	Area 2		Area 1		Area 3 and 5				Area 6		Area 7		Area 8				Kennady Lake Outlet		Total
	A1		A3		B1		D2		E1		G1		H1a		J1a		K5[(a)]		
	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	U/S	D/S	
ARGR	19	1	2	0	0	12	1	1	1	1	0	0	0	0	1	0	1	48	**88**
BURB	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
LKTR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	**7**
NNST	7	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**89**
NRPK	1	3	1	0	0	0	25	2	0	1	0	0	0	0	0	0	7	6	**46**
RNWH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
SLSC	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**3**
Total	**28**	**88**	**3**	**0**	**0**	**12**	**26**	**3**	**1**	**2**	**0**	**0**	**0**	**0**	**1**	**0**	**8**	**63**	**235**

(a) Downstream count includes one Arctic grayling located in the wing of the fish fence.

ARGR = Arctic grayling; BURB = burbot; LKCH = lake chub; LKTR = lake trout; NRPK = northern pike; RNWH = round whitefish; SLSC = slimy sculpin; NNST = ninespine stickleback; U/S = upstream; D/S = downstream.

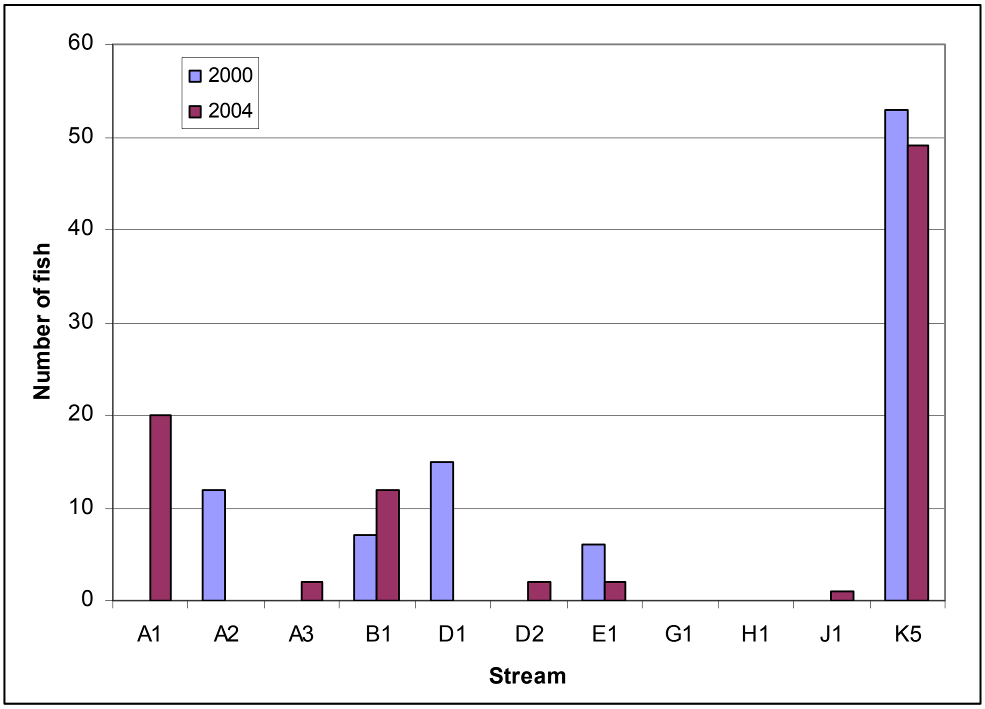
Arctic grayling in Kennady Lake exhibit an adfluvial life history (i.e., live in lakes but migrate into rivers or streams to spawn). Adults and juveniles reside in the lake for most of the year. In spring, adult Arctic grayling migrate into streams soon after ice break-up to spawn. Adults move back into the lake soon after spawning. Eggs hatch in June and young-of-the-year rear in natal streams for the summer, moving upstream to Kennady Lake or downstream to overwintering habitat in lakes by late August. Young-of-the-year Arctic grayling may move upstream or downstream depending upon their location in relation to overwintering habitat (Stewart et al. 2007).

Table 8.3-35 Timing of Stream Utilization by Adfluvial Arctic Grayling in the Northwest Territories



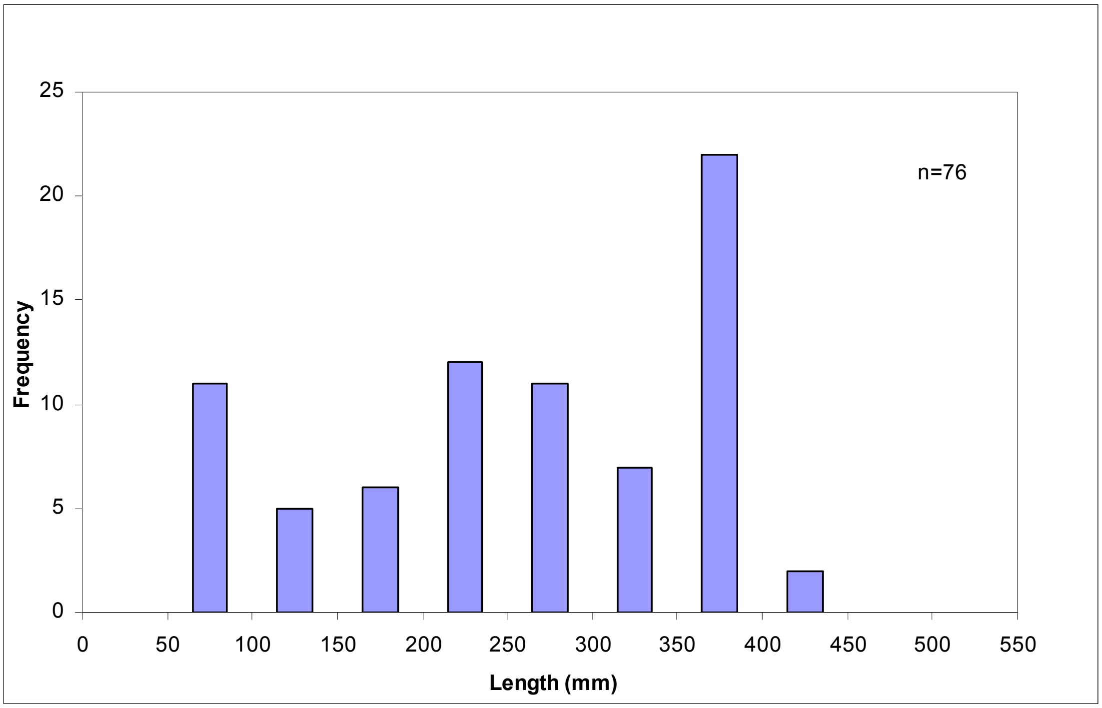
YOY = young-of-year. Adapted from Stewart et al. (2007)

Figure 8.3-37 Comparison of Arctic Grayling Movements into Kennady Lake Tributaries, Spring 2000 and 2004



Arctic grayling moving into tributaries in spring ranged in length between 50 and 450 mm but most (75%) were greater than 200 mm (Figure 8.3-38). Mean length and weight of Arctic grayling captured in tributaries in spring 2004 was 263 mm and 306 grams (g), respectively. The resulting mean condition factor for these fish was 1.1. Although aging data are limited, most Arctic grayling greater than 200 mm were three years of age or older and most Arctic grayling greater than 350 mm were six years old (Table 8.3-36). Based on the length frequency distribution, this suggests that Arctic grayling in Kennady Lake began spawning at three years of age but the majority of spawning fish were likely six years or older. Similar age structure of spawning Arctic grayling occurs in Great Slave Lake (Scott and Crossman 1973; Stewart et al. 2007).

Figure 8.3-38 Length-Frequency Distribution for Arctic Grayling Captured Moving into Kennady Lake Tributaries, Spring 2004



mm = millimetre.

Table 8.3-36 Length-at-Age and Weight-at-Age for Arctic Grayling Captured in Kennady Lake Tributaries, Spring 2004

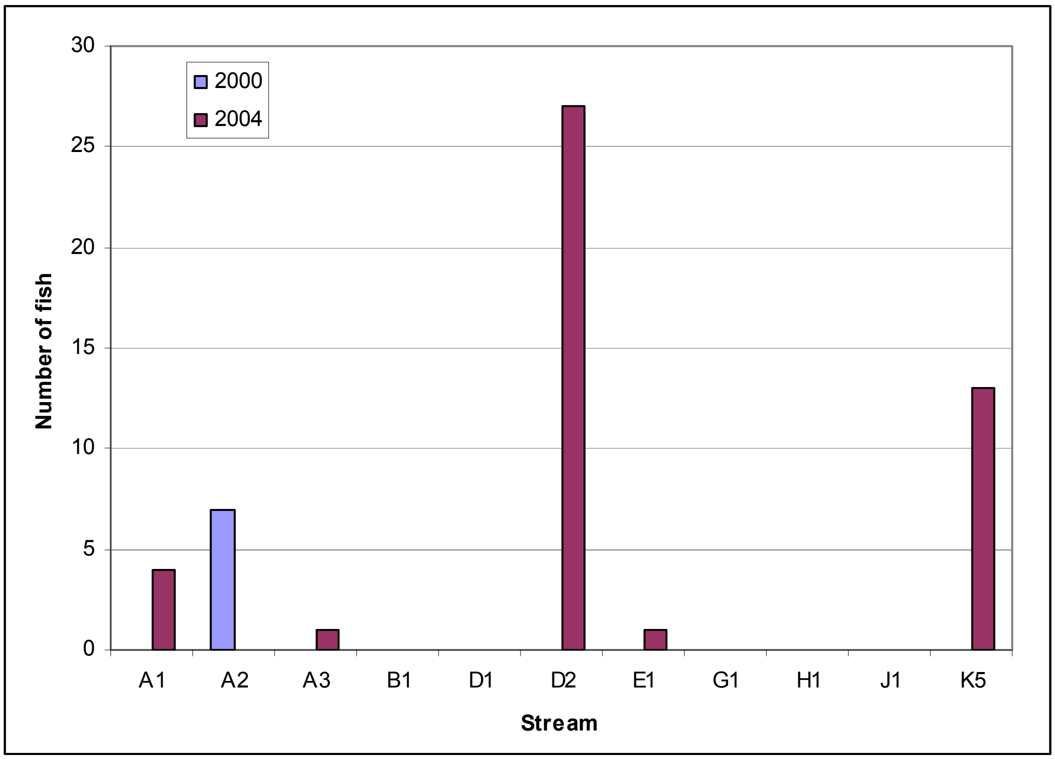
Age	Fork Length (mm)			Weight (g)		
	n	Mean	Range	n	Mean	Range
3+	5	207.4	197 to 221	5	116.0	90 to 200
4+	4	253.5	250 to 258	4	191.3	175 to 200
5+	2	211.5	201 to 222	1	126.6	-
6+	4	376.3	362 to 391	4	592.5	500 to 700
7+	1	253.0	-	1	172.5	-
8+	1	393.0	-	1	880.0	-

mm = millimetre; g = grams; n = number of fish; - = no data.

Northern pike were captured in streams of the A watershed in 2000 and 2004 and in relatively large numbers (27 fish) in the D watershed in 2004 (Figure 8.3-39). Lakes D2 and D3 on the western side of Kennady Lake appear to provide spawning habitat for a substantial proportion of northern pike in Kennady Lake. This is likely due to the abundance of aquatic vegetation in these lakes in comparison to Kennady Lake and other small lakes in the watershed.

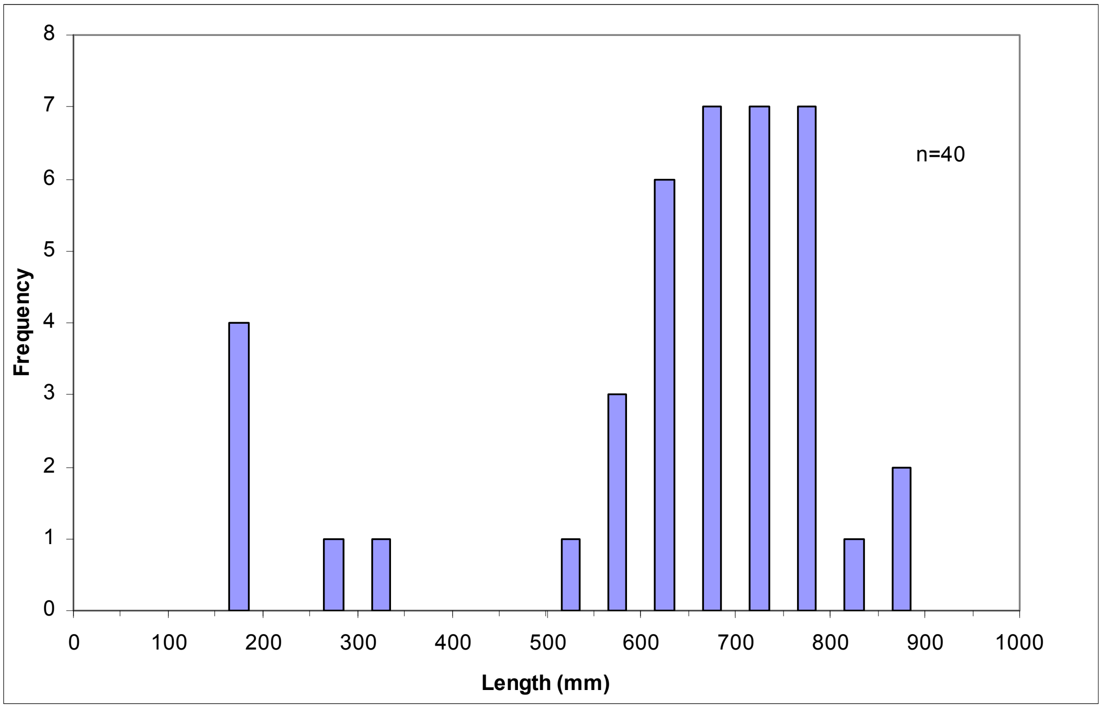
Northern pike were also observed moving out of Kennady Lake in spring (Stream K5) (Figure 8.3-39). These movements may represent spawning movements to areas of flooded aquatic vegetation along the shorelines and riparian areas of streams downstream, or may be pre-spawning feeding movements as northern pike take advantage of concentrations of Arctic grayling near the outlet of Kennady Lake.

Figure 8.3-39 Comparison of Northern Pike Movements into Kennady Lake Tributaries, Spring 2000 and 2004



Most northern pike captured in spring were large (mean length and weight of 631 mm and 2,624 g, respectively) mature fish. Northern pike ranged in length between 150 and 900 mm, but most (84%) northern pike captured in spring were greater than 550 mm (Figure 8.3-40). Although few northern pike were aged, length-at-age data indicated that most northern pike spawners in Kennady Lake are six years old or older (Table 8.3-37). This age-at-maturity is consistent with other northern pike populations at similar latitudes (Richardson et al. 2001).

Figure 8.3-40 Length-Frequency Distribution for Northern Pike Captured in Kennady Lake Tributaries, Spring 2004



mm = millimetre.

Table 8.3-37 Mean Length- and Weight-at-Age for Northern Pike Captured in Kennady Lake Tributaries, Spring 2004

Age (years)	Fork Length (mm)			Weight (g)		
	n	Mean	Range	n	Mean	Range
3+	1	340.0	-	1	150.0	-
4+	-	-	-	-	-	-
5+	-	-	-	-	-	-
6+	2	664.5	635 to 694	2	2,000.0	1,650 to 2,350
7+	3	671.3	584 to 755	3	2,641.7	1,650 to 3,875
8+	2	649.5	647 to 652	2	2,112.5	2,025 to 2,200
9+	-	-	-	-	-	-
10+	2	714.0	670 to 758	2	2,900.0	2,600 to 3,200
11+	-	-	-	-	-	-
12+	-	-	-	-	-	-
13+	1	875.0	-	1	6,700.0	-

n = number of fish; mm = millimetre; g = grams; - = no data.

8.3.8.2.6 Small Lakes Surveys

A summary of fish captured in each small lake sampled in the Kennady Lake watershed is provided in Table 8.3-38. Fish were captured in 12 of the 34 lakes sampled. Fish species captured included five sport fish (Arctic grayling, burbot, lake trout, northern pike, and round whitefish) and two forage fish species (ninespine stickleback, and slimy sculpin). For the most part, abundance of fish was low in all lakes.

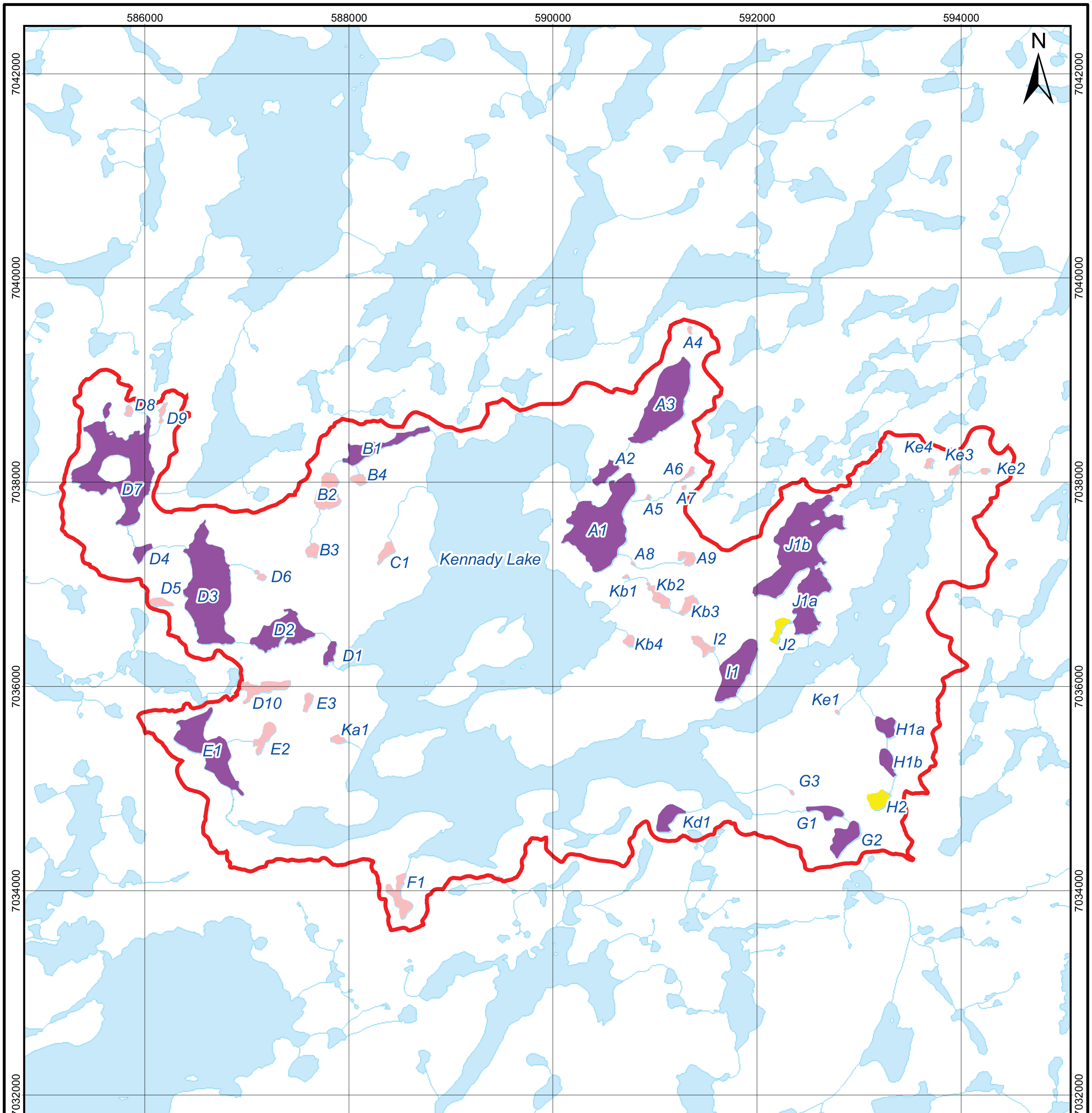
Figure 8.3-41 shows the fish-bearing status of lakes within the Kennady Lake watershed. Many of these small lakes were designated as fish-bearing, meaning fish were captured or there was a connection to another fish-bearing lake or stream. As outlined in Annex J, lakes were designated as non-fish bearing if no fish were captured, the maximum depths were too shallow for overwintering fish (i.e., less than 3 m), and there was no connection to fish-bearing lakes or streams during high flows (i.e., spring).

Lake I1 includes a self-sustaining population of lake trout; adult and juvenile lake trout were captured in this lake in 1996 and 2004. This lake has a maximum depth of 11 m and is connected to Area 8 of Kennady Lake by an ephemeral stream flowing through a shallow wetland. The presence of juvenile lake trout, the availability of cobble/boulder substrates suitable for spawning below the ice scour zone (2 m), and the ephemeral nature of Stream I1 suggests strongly that lake trout are successfully spawning and rearing in Lake I1. Arctic grayling, slimy sculpin, and ninespine stickleback were also captured in this lake in 1996.

Table 8.3-38 Fish Species Captured in Small Lakes within the Kennady Lake Watershed

Lake	Fish Species
A1	ARGR, BURB, RNWH
A2	-
A3	ARGR, BURB, LKTR, NRPK
A4	-
A5	-
A6	-
A7	-
A8	-
A9	-
B1	ARGR, LKTR, NNST, SLSC
B2	-
D1	BURB, NRPK
D2	NRPK
D3	BURB, LKTR, NRPK
D7	ARGR, BURB, NRPK
D10	-
E1	NRPK, SLSC
E2	-
E3	-
F1	-
G2	NNST
H1a	NNST, SLSC
H1b	-
I1	ARGR, LKTR, NNST, SLSC
I2	-
J1a	-
J1b	BURB
J2	-
Ka1	-
Kb1	-
Kb2	-
Kb3	-
Kb4	-
Kd1	-

ARGR = Arctic grayling; BURB = burbot; LKTR = lake trout; NRPK = northern pike; RNWH = round whitefish; NNST = ninespine stickleback; SLSC = slimy sculpin; - = no fish captured.



LEGEND

Watercourse

Waterbody

Kennady Lake Watershed Boundary

A2 Lake Identifier

Fish Presence

Fish-Bearing

Non-Fish-Bearing

Fish Presence Unknown

NOTES

Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Fish-Bearing Status of Small Lakes in the Kennady Lake Watershed

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:55,000 (1 0.5 0 1 Kilometres)	

DE BEERS CANADA

FILE No: B-Fish-057-GIS		DATE: November 24, 2010
JOB NO: 09-1365-1004	REVISION NO: 5	
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: AL

Figure 8.3-41

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8.3.8.2.7 Stream Fish Inventory Surveys

Table 8.3-39 shows the fish species captured in streams sampled within the Kennady Lake watershed. In summer sampling, juvenile Arctic grayling were very abundant in streams within the Kennady Lake watershed and typically comprised over 90% of the total catch. Ninespine stickleback were also abundant at two of the sites sampled. Juvenile burbot and northern pike, and slimy sculpin were also found in streams in summer but in substantially lower numbers.

In the Kennady Lake watershed, streams in the larger catchments (i.e., A, B, and D catchments) were used by Arctic grayling for spawning and by northern pike as access corridors to upstream lakes in spring. Smaller tributaries are used primarily by slimy sculpin and ninespine stickleback.

Table 8.3-39 Fish Captured in Streams Surveyed in the Kennady Lake Watershed

Stream	Fish Species Captured
A1	ARGR, BURB, LKCH[a], NNST, NRPK, SLSC
A2	ARGR, BURB, NRPK
A3	ARGR, BURB, LKTR, NNST, NRPK
B1	ARGR
D1	ARGR, BURB, NNST
D2	ARGR, BURB, NRPK, SLSC
D4	SLSC
D7	SLSC
E1	ARGR, BURB, NNST, NRPK
G1	-
H1a	NNST, NRPK
H1b	NNST
J1a	ARGR
Kd1	NNST
Ke3	NNST

[a] Lake chub in stream A1 originally identified as peamouth. Subsequent sampling and identification has confirmed that lake chub are present, and that the peamouth were likely misidentified.

ARGR = Arctic grayling; NRPK = northern pike; BURB = burbot; SLSC = slimy sculpin; LKCH = lake chub; LKTR = lake trout; NNST = ninespine stickleback; - = no fish captured.

8.3.8.2.8 Fish Movements

Lake trout exhibit a lacustrine life history in Kennady Lake and generally conduct all of their life history requirements in the lake. Lake trout have been observed moving through the Kennady Lake outlet in spring, presumably feeding on congregations of spawning Arctic grayling. Radio-tagged lake trout moved freely between all areas of Kennady Lake but generally avoided Area 8 in summer.

This is likely due to its shallower depth and limited cover compared to other areas of the lake.

Similar to lake trout, round whitefish in Kennady Lake exhibit a lacustrine life history, conducting all of their life history requirements (spawning, rearing, foraging, and overwintering) in the lake. Too few round whitefish were radio-tagged to confirm movements in the lake. However, no round whitefish were ever observed moving out of, or into, Kennady Lake in spring. No tagged round whitefish was ever captured downstream of Kennady Lake.

Adult Arctic grayling were found primarily in offshore areas of Kennady Lake in summer and, based on radio-telemetry, move freely between all areas of the lake. Although some populations are known to make extensive migration (up to 320 km) from overwintering areas to spawning grounds (Evans et al. 2002), Arctic grayling in Kennady Lake rarely moved more than 2 km downstream in spring. Like lake trout, Arctic grayling typically avoid the shallower Area 8. Juvenile Arctic grayling were found in littoral areas in summer but are also likely to use deeper, offshore areas as well.

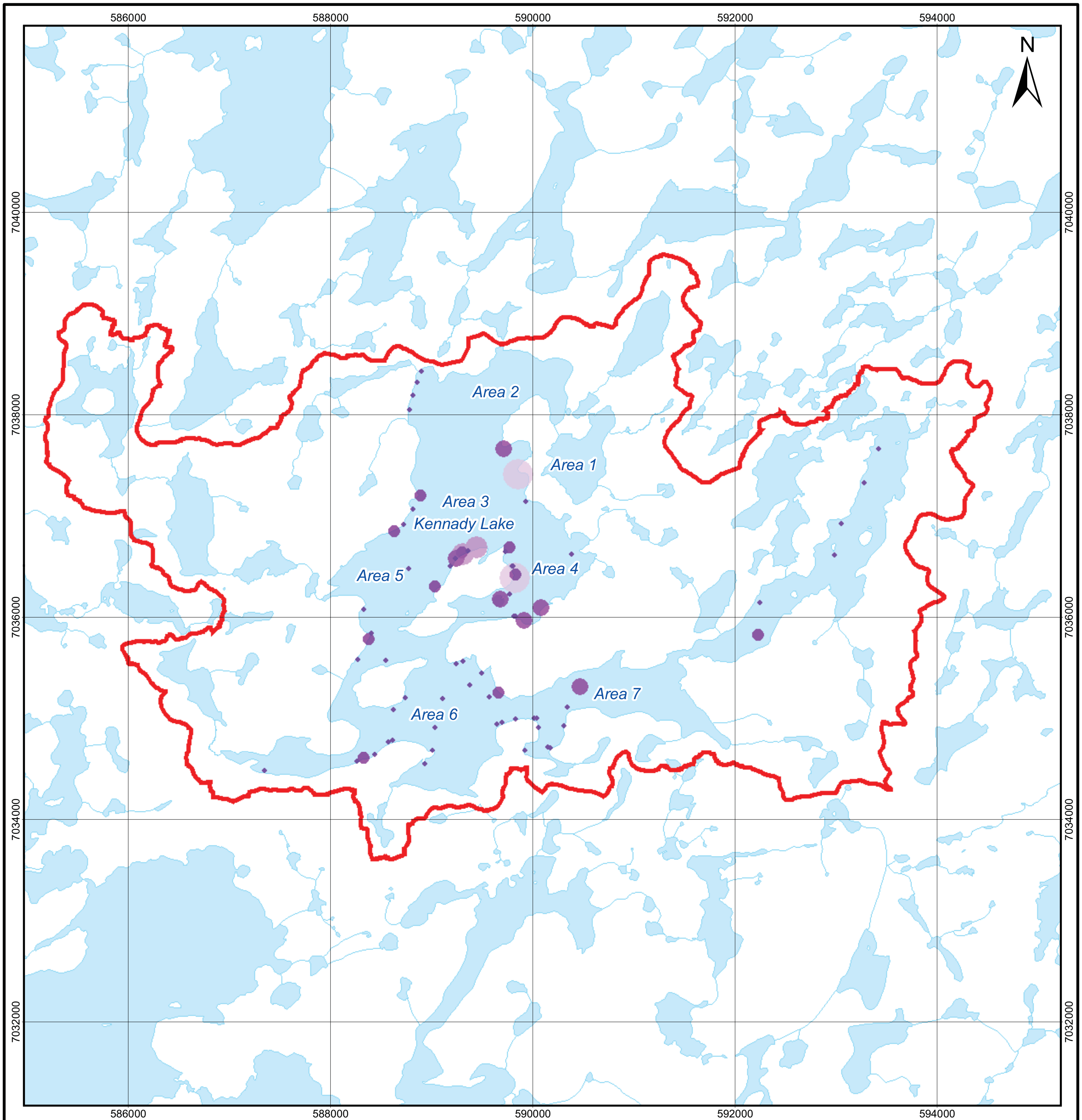
Northern pike appear to only move locally in Kennady Lake and most northern pike were located in Areas 6 and 7, where aquatic vegetation existed in protected embayments.

8.3.8.2.9 Fall Spawning Surveys

Lake trout are fall spawners and begin to congregate near spawning locations at water temperatures less than 10ºC. In Kennady Lake, this typically occurs in September or early October. Peak spawning usually occurs in late September in Kennady Lake.

The primary lake trout spawning site in Kennady Lake is the northern shore of the island separating Areas 3 and 5 from Area 4 (Figure 8.3-42). This is based on two lines of evidence:

- concentrations of ripe (pre-spawning condition) and spent (post-spawning condition) lake trout were highest in gillnets set around the northern half of this island; and
- the largest numbers of radio-tagged lake trout were also found along the Areas 3 and 5 shoreline of this island in fall.



LEGEND

- Watercourse
- Waterbody
- Kennady Lake Watershed Boundary
- *Area 1* Kennady Lake Area Identifier

Catch-Per-Unit-Effort (# of fish/100 m^2/12 hours)

- 0.0
- 0.1 - 3.0
- 3.1 - 6.0
- 6.1 - 9.0
- 9.1 - 12.0

NOTES
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Lake Trout Catch-Per-Unit-Effort, Fall 2004

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
Scale: 1:55,000 (1 0.5 0 1 Kilometres)		
FILE No: B-Fish-055-GIS		DATE: November 24, 2010
JOB NO: 09-1365-1004	REVISION NO: 5	**Figure 8.3-42**
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: AL

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Habitat along the shoreline of this island is near optimal for lake trout spawning in that it has predominantly clean boulder/cobble substrates, is located directly adjacent to deep (greater than 10 m) areas on both sides, and is exposed to the largest fetch (greater than 1.5 km) in the lake. This latter characteristic serves to keep boulder substrates clean from silt and fine organic sediment accumulation.

Lake trout are likely to use other spawning sites in Kennady Lake besides this island. Sexually mature lake trout were found in all areas of Kennady Lake during fall sampling. Most shoreline areas of Kennady Lake have boulder/cobble substrates suitable for lake trout spawning and it is likely that many of these shorelines, particularly those exposed to fetches greater than 500 m, are used by spawning lake trout.

Round whitefish spawn later in fall than lake trout, typically at water temperatures between 2 and 5.5°C (Wismer and Christie 1987) and may spawn just before lake freeze-up (Morrow 1980). This delayed spawning is the likely reason why accumulations of ripe round whitefish were not observed during fall surveys and why spawning locations in Kennady Lake could not be positively identified. However, round whitefish have similar spawning requirements as lake trout (Richardson et al. 2001) and it is likely that round whitefish in Kennady Lake use the northern shoreline of the island separating Areas 3 and 5 from Area 4 extensively for spawning.

8.3.8.2.10 Metals in Fish Tissues

The metal concentrations in the muscle tissue of lake trout from Kennady Lake and Lake N16 are summarized in Table 8.3-40. Concentrations of aluminum, antimony, beryllium, boron, silver, thallium, and tin were below analytical detection limits in 75% or more of the fish that were analyzed and are not presented here for this reason. Mean and maximum arsenic, chromium, mercury, and vanadium concentrations in lake trout muscle tissue exceeded the risk-based screening criteria for human consumption (Table 8.3-40).

Arsenic concentrations in most samples of lake trout muscle tissue were equal to or less than the analytical detection limits, which ranged from 0.01 to 0.05 milligrams per kilogram as wet weight (mg/kg ww). Arsenic concentrations reported above the detection limits ranged from 0.02 to 0.30 mg/kg ww. Although detection limits were too high to draw definitive conclusions, naturally occurring arsenic concentrations in muscle tissue of lake trout may be above the risk-based criterion of 0.021 mg/kg ww.

Chromium and vanadium were detected in more than 50% of lake trout muscle samples from Kennady Lake and Lake N16. Chromium concentrations reported above the detection limits ranged from 0.05 to 0.79 mg/kg ww, which were higher than the risk-based criterion of 0.063 mg/kg ww. Detection limits for vanadium were higher in samples from 1996 than those from 2004, and the maximum concentrations summarized in Table 8.3-40 reflect these differences in detection limits. Vanadium was only detected in the 2004 samples, at concentrations ranging from 0.008 to 0.045 mg/kg ww, with most concentrations slightly higher than the risk-based criteria of 0.019 mg/kg ww. These values suggest that naturally occurring chromium and vanadium concentrations in muscle tissue of lake trout may be higher than the risk-based criteria.

Total mercury was detected in most of the lake trout muscle samples from both lakes. Concentrations reported above the detection limits ranged from 0.06 to 1.4 mg/kg ww, which were higher than the risk-based criterion of 0.028 mg/kg ww for methyl mercury. No analysis of methyl mercury was undertaken, but it is generally accepted that total mercury levels in fish muscle are reliable indicators of methyl mercury, as methyl mercury can contribute to at least 90% of the total methyl mercury concentration values in fish tissue (Rai et al. 2002; Lasorsa and Allen-Gil 1995). Methyl mercury is the form of mercury that poses a public health risk in fish and shellfish tissue due to its tendency to bioaccumulate (US EPA 1997). The detected concentrations of total mercury in muscle tissue of lake trout suggest that naturally occurring concentrations may exceed the risk-based criterion for human consumption.

Table 8.3-40 Overall Mean and Maximum Metal Concentrations (mg/kg wet weight) in Lake Trout Muscle Tissue Samples Collected from Kennady Lake and Lake N16 between 1996 and 2007

Parameter	Kennady Lake		Lake N16		Risk-based criteria [c]
	Mean[a]	Maximum[b]	Mean[a]	Maximum[b]	
Arsenic	0.036	0.10	0.065	0.30	0.021
Barium	0.050	0.090	0.056	0.36	54
Cadmium	0.015	0.15	0.014	<0.20	0.28
Chromium	0.15	0.64	0.17	0.79	0.063[d]
Cobalt	0.050	<0.080	0.050	<0.080	0.082
Copper	0.47	1.8	0.62	2.2	11
Iron	2.6	5.0	3.8	7.4	190
Lead	0.032	0.72	0.020	0.090	nc
Manganese	0.077	<0.16	0.099	0.36	38
Mercury	0.30	<0.79	0.36	1.4	0.028[e]
Molybdenum	0.033	<0.040	0.035	0.16	1.36
Nickel	0.10	1.4	0.15	1.6	5.4
Selenium	0.31	0.43	0.28	0.40	1.4
Strontium	0.29	0.93	0.26	1.6	162
Titanium	0.45	1.4	0.33	1.2	nc
Vanadium	0.067	<0.14	0.066	<0.14	0.019
Zinc	3.2	6.5	3.1	10	82

Note: Shaded values equal or exceed the US EPA risk-based criteria.
Metal concentrations are presented as mg/kg wet weight.

(a) Detection limits were used to calculate mean metal concentrations for individuals with metal concentrations below detection limit.

(b) When indicated by a less than sign (<), the maximum concentration was reported at below the sample-specific detection limit.

(c) Risk-based criteria for fish consumption were based on a 70 kg individual consuming 54 g of fish per day over a 70-year period (US EPA 2010). The US EPA screening values were adjusted to a carcinogenic risk of 1E-5 and a hazard quotient of 0.2 for non-carcinogens (carcinogens were multiplied by 10 and non-carcinogens were multiplied by 0.2). When criteria were available for both carcinogenic and non-carcinogenic exposure scenarios, the lowest value was used.

(d) Criterion is for hexavalent chromium.

(e) Criterion is for methyl mercury.

US EPA = United States Environmental Protection Agency; nc = no criterion; mg/kg = milligram per kilogram.

The metal concentrations in the muscle tissue of round whitefish from Kennady Lake and Lake N16 are summarized in Table 8.3-41. Concentrations of aluminum, antimony, beryllium, boron, iron, manganese, silver, tin, and vanadium were below analytical detection limits in 75% or more of the fish that were analyzed and are not presented here for this reason. Mean and maximum chromium and mercury concentrations in round whitefish muscle tissue from both lakes and mean and maximum arsenic concentrations from Lake N16 exceeded the risk-based screening criteria for human consumption (Table 8.3-41).

Concentrations of all other metals were below screening criteria, when criteria were available.

Arsenic was detected in almost all muscle tissue samples from Lake N16, but was not detected in any samples from Kennady Lake. Detection limits in the Kennady Lake samples ranged from 0.01 to 0.05 mg/kg ww, and the maximum detection limit was higher than the risk-based criterion of 0.021 mg/kg ww. In muscle tissue of round whitefish from Lake N16, arsenic concentrations ranged form 0.03 to 0.49 mg/kg ww, which suggests that naturally occurring arsenic concentrations in muscle tissue of round whitefish from Lake N16 may be above the risk-based criterion of 0.021 mg/kg ww.

Chromium concentrations in most round whitefish muscle tissue samples from Kennady Lake and Lake N16 were equal to or below the detection limits. Detection limits varied among samples, and ranged from 0.11 to 0.39 mg/kg ww. The maximum concentration reported above the sample-specific detection limit was 0.17 mg/kg ww in a fish from Lake N16. Given that detection limits were higher than the risk-based criteria, and any detected concentrations were only slightly above detection limits, it cannot be determined if naturally occurring chromium concentrations in round whitefish muscle tissue are above the risk-based criterion of 0.063 mg/kg ww.

Total mercury was detected in about 50% of the round whitefish muscle tissue samples from Lake N16, but in only three samples from Kennady Lake. Detection limits also varied among samples, and ranged from 0.02 to 0.14 mg/kg ww. The concentrations reported above the sample-specific detection limits ranged from 0.05 to 0.37 mg/kg ww, which are above risk-based criterion of 0.028 mg/kg ww for methyl mercury. As stated for lake trout, it is assumed that total mercury concentrations in fish muscle are reliable indicators of methyl mercury. The detected concentrations of total mercury in muscle tissue of round whitefish suggest that naturally occurring concentrations may exceed the risk-based criterion for human consumption.

Table 8.3-41 Overall Mean and Maximum Metal Concentrations (mg/kg wet weight) in Round Whitefish Muscle Tissue Samples Collected from Kennady Lake and Lake N16 between 1996 and 2007

Parameter	Kennady Lake		Lake N16		Risk-based criteria [c]
	Mean[a]	Maximum[b]	Mean[a]	Maximum[b]	
Arsenic	0.014	<0.050	0.15	0.49	0.021
Barium	0.035	0.14	0.056	0.31	54
Cadmium	0.013	0.030	0.011	0.028	0.28
Chromium	0.12	0.19	0.17	<0.39	0.063[d]
Cobalt	0.013	0.026	0.018	0.040	0.082
Copper	0.34	0.68	0.43	0.77	11
Lead	0.016	0.088	0.011	0.013	nc
Mercury	0.088	0.17	0.10	0.37	0.028[e]
Molybdenum	0.027	0.070	0.022	0.025	1.36
Nickel	0.024	0.048	0.038	0.13	5.4
Selenium	0.30[f]	0.30	0.40[f]	0.40	1.4
Strontium	0.50	1.7	0.58	3.0	162
Zinc	2.6	5.3	3.3	5.7	82

Note: Shaded values equal or exceed the US EPA risk-based criteria.

Metal concentrations are presented as mg/kg wet weight.

[a] Detection limits were used to calculate mean metal concentrations for individuals with metal concentrations below detection limit.

[b] When indicated by a less than sign (<), the maximum concentration was reported at below the sample-specific detection limit.

[c] Risk-based criteria for fish consumption were based on a 70 kg individual consuming 54 g of fish per day over a 70-year period (US EPA 2010). The US EPA screening values were adjusted to a carcinogenic risk of 1E-5 and a hazard quotient of 0.2 for non-carcinogens (carcinogens were multiplied by 10 and non-carcinogens were multiplied by 0.2). When criteria were available for both carcinogenic and non-carcinogenic exposure scenarios, the lowest value was used.

[d] Criterion is for hexavalent chromium.

[e] Criterion is for methyl mercury.

[f] Only one fish was sampled.

US EPA = United States Environmental Protection Agency; nc = no criterion; mg/kg = milligram per kilogram.

8.4 WATER MANAGEMENT PLAN SUMMARY

8.4.1 Introduction

The following section provides a summary of the Water Management Plan that has been developed for the Gahcho Kué Project (Project). The primary purpose of this plan is to reduce the effect of the Project on the aquatic ecosystem of Kennady Lake and downstream environments during construction, operations, and closure phases.

The most significant water-related activity that will take place during the Project will be the dewatering of Areas 2 to 7 of Kennady Lake to allow access to the lake bed and underlying kimberlite pipes, and the subsequent restoration of the lake. The dewatering process will begin during the first year of construction (Year -2) and will take place during the open water season. To facilitate the dewatering process, natural drainage from the upper portion of the watershed will be diverted to the adjacent N watershed by the establishment of several earth filled dykes. Area 8 will be separated from the rest of Kennady Lake by the construction of a water retaining dyke (Dyke A).

It is expected that about half the water in Kennady Lake can be removed in the initial dewatering process. During this time, the discharge water will be partitioned between Area 8 and Lake N11, located northwest of Kennady Lake. As water levels in the lake decrease, particularly in Area 7, the concentrations of totals suspended solids (TSS) in the water are expected to increase, which will limit the period of time that water from Area 7 can be discharged to Area 8. During operations, water will be pumped from Areas 3 and 5 (the Water Management Pond [WMP]) to Lake N11; where necessary, water entering Area 5 may be treated with flocculants to reduce the TSS in the WMP.

The water management strategy developed for the Project considered economic and environmental constraints. This strategy is included in technical memoranda in Appendix 8.I, Attachment 8.I.1 for the construction and operations phases and Appendix 8.I, Attachment 8.I.2 for the closure phase. The Water Management Plan described herein is based on these technical memoranda, with emphasis placed on water quality considerations.

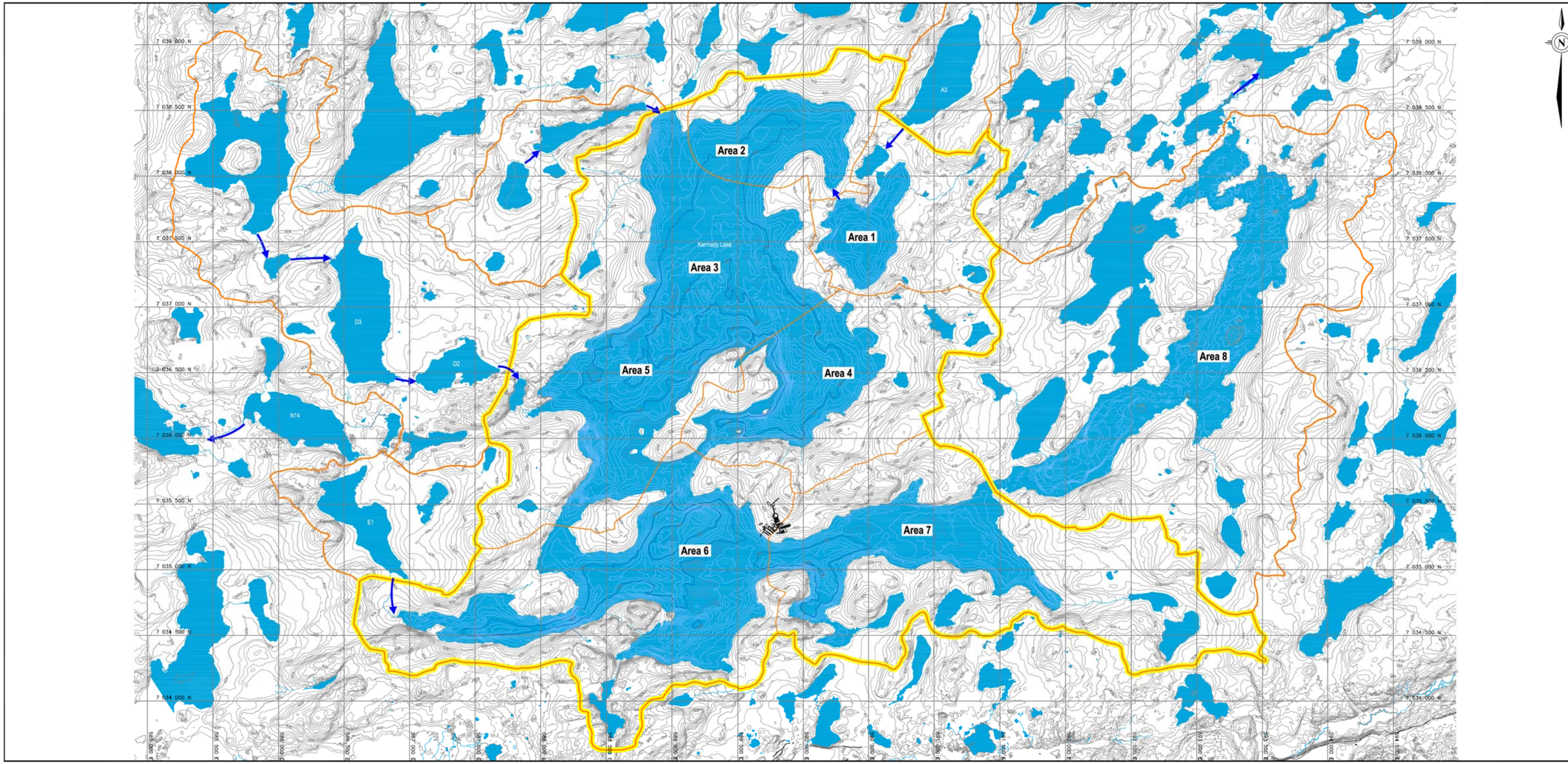
Respecting the constraints and considerations listed in Appendix 8.I, Attachments 8.I.1 and 8.I.2, the key objectives of the Water Management Plan are to:

- minimize the amount of water requiring discharge to downstream receptors during the initial dewatering period;
- manage mine water during closure to minimize water quality impacts within the WMP during closure and post-closure; and
- manage waters within the Kennady Lake catchment area until the water quality is suitable for release, marking the transition to post-closure.

To facilitate the design of the Project Water Management Plan, Kennady Lake is divided into six principal areas whose limits are truncated by impermeable, earth-filled dykes and a filter dyke, as discussed in Section 8.4.2.3. Figure 8.4-1 illustrates the areas of Kennady Lake, their distinct watersheds and the upper watersheds of Kennady Lake. Table 8.4-1 provides a brief description of each area. The Water Management Plan presented in the subsequent sections is discussed with reference to these areas.

The Water Management Plan is also discussed in terms of the following time periods:

- Construction phase (initial dewatering) – Years -2 to -1. Kennady Lake is drawn down to increase available capacity and facilitate dyke construction; water is discharged to Lake N11 and Area 8.
- Operational phase – Years 1 to 11. Water is diverted from mine pits and lake areas to the WMP; water is discharged from the WMP to Lake N11, as long as the water quality in the WMP meets specific discharge criteria.
- Closure phase – Years 12 to 20. Water is transferred from the WMP to Tuzo Pit and Kennady Lake is refilled from natural drainage and water pumped from Lake N11.
- Post-closure (i.e., beyond closure) – Years 21 onwards. Kennady Lake receives only natural drainage and releases water to Area 8.



LEGEND

Existing Ground Contours
5m Index - 1m Intermediate

Bathymetry Contours
5m Index - 1m Intermediate

Controlled Area Boundary

Marsh Area

Scrub

Sub-watershed Boundary

Drainage Flow Direction

NOTES
Base data source: EBA Figure 4.5 - Stage 2 - Water Management During Mine Operation Years 1 to 3 (2015 to 2017)

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GAHCHO KUÉ PROJECT

Kennady Lake and its Watersheds

PROJECTION: UTM Zone 12	DATUM: NAD83
SCALE 500 0 500 METRES	DE BEERS CANADA
FILE No: E-SWQ-001-CAD	DATE: December 13, 2010
JOB No: 09-1365-1004	REVISION No: 1
OFFICE: GOLD - SAS	DRAWN: TAH/AJL
CHECK: JF	Figure 8.4-1

The construction phase of the Water Management Plan is described in Section 8.4.2. During construction, the key activities related to water management will be the diversion of upper watersheds that flow into Kennady Lake, the initiation of dewatering of Kennady Lake, the construction of a dyke that separates the most downstream basin of Kennady Lake (Area 8) from Area 7, and the establishment of the WMP.

Table 8.4-1 Summary of Kennady Lake Areas

Area	Description
Areas 1 and 2 (Fine Processed Kimberlite Containment Facility)	Located in the northeast embayment of Kennady Lake (Area 2) and most of the A watershed (Area 1). Areas 1 and 2 are designated for fine processed kimberlite deposition.
Areas 3 and 5 (i.e., Water Management Pond)	This area will operate as the site Water Management Pond and will provide the primary source of process reclaim water. It is located in the northwest part of Kennady Lake.
Area 4	Located to the southeast of the Water Management Pond. Location of the Tuzo kimberlite pipe.
Area 6	Located to the south of the Water Management Pond. Location of the 5034 and Hearne kimberlite pipes.
Area 7	Truncates Area 6 to the east.
Area 8	East basin of Kennady Lake outside of controlled area boundary.

The operations phase of the Water Management Plan is described in Section 8.4.3. During operation, Project activities associated with the Water Management Plan will be designed to minimize the discharge of site water to downstream waterbodies, and to recycle process water to the greatest extent possible. During the operations phase of the Project, water for use in the processing plant will be sourced from the WMP. After the Fine Processed Kimberlite Containment (PKC) Facility has been closed, the groundwater flowing into the open pits will be the primary source of make-up water for the processing facility.

The closure phase of the Water Management Plan is discussed in Section 8.4.4. At closure, the WMP (Areas 3 and 5), and Area 7 will contain water, Area 4 will be effectively dewatered and Area 6 will be partially dewatered. After mining has been completed, the natural drainage system in the Kennady Lake watershed will be restored and refilling of the dewatered lake-beds will begin. Refilling of the lake is scheduled to start in Year 12 and is expected to take eight years. Runoff from the mine rock piles, Coarse PK Pile, Fine PKC Facility, plant site, and airstrip will flow to the lake and be used to assist in refilling the lake. Water will also be pumped from Lake N11 during the last three weeks of June and the first three weeks of July of each year. Once Areas 3 to 7 are refilled to the same elevation as Area 8, and the water quality within the refilled lake is acceptable, the in-lake portion of Dyke A will be removed, and the refilling of Kennady Lake will be complete. Flow from Areas 3 to 7 of Kennady Lake to Area 8 will then resume.

Annual inflows to and outflows from the site water management system (e.g., the Project mechanism to which all elements of site contact and mine contact water, potable and plant water supply, pumped inflows and discharges, and natural inflows and outflows are managed and facilitated) are briefly summarized in Table 8.4-2; however, the water balance in Section 8.4.5 provides a quantitative summary for the construction, operations, closure, and post-closure phases of the Project.

Table 8.4-2 Description of Inflows to and Outflows from the Water Management System

Source of Inflows	Destination of Outflows
- direct precipitation and surface runoff from the Project site and natural surface runoff from adjacent catchments - groundwater inflows to the open pits - drainage from the mine rock and Coarse PK piles, and Fine PKC Facility - freshwater drawn from Area 8 - freshwater pumped from Lake N11 to expedite refilling of Kennady Lake	- water pumped to Area 8 and Lake N11 during the dewatering of Kennady Lake - water pumped to Lake N11 during operations - natural discharge from Area 8 - evaporation and evapotranspiration losses

PK = processed kimberlite; PKC = Processed Kimberlite Containment.

The potential sources of change to water quality resulting from Project activities, including solid waste disposal, chemical storage and handling, and mine rock and PK disposal are discussed in Section 8.4.6. The potential accidents and malfunctions relevant to the Water Management Plan, including petroleum spills, ammonium nitrate spills, and dyke failures are also examined in Section 8.4.7.

For the Base Project Case assessed for the EIS, the Water Management Plan does not account for fish habitat compensation that may be constructed as part of the No Net Loss Plan. It is assumed that any environmental impacts associated with the No Net Loss Plan will be evaluated as part of the application to Fisheries and Oceans Canada (DFO).

8.4.2 Construction Phase

The following key water-related activities will take place during the construction phase of the Project:

- the majority of the upper Kennady Lake watershed (sub-watersheds A, B, D, and E) will be diverted through the construction of dykes to facilitate the dewatering of Kennady Lake and Lake A1, and to isolate the WMP during operations;
- Kennady Lake will be dewatered to allow access to the lake-bed and the underlying kimberlite pipes;
- Dyke A will be constructed to separate Area 8 from Area 7 of Kennady Lake; and
- a WMP will be established in Areas 3 and 5 to collect mine water, process water, groundwater inflow, and drainage from the mine site and surrounding area.

8.4.2.1 Diversion of A, B, D, and E Watersheds

The Fine PKC Facility will be located in the A watershed and the northeast embayment of Kennady Lake, which are identified as Areas 1 and 2, respectively. Area 1 includes the majority of the A watershed (i.e., Lakes A1 and A2) that drains into Kennady Lake in the northeast corner, but excludes Lake A3. Lake A3 will be isolated from Lakes A1 and A2 through the construction of a permanent saddle dyke (Dyke C) between Area 1 and Lake A3 to the north (Figure 8.4-2). Dyke C will serve to raise the level of Lake A3 to a point where the Lake A3 outlet will be permanently diverted into Lake N8. Lake A1 will be partially dewatered into Lake A3 after Dyke C is constructed.

To reduce surface inflows to Kennady Lake, a portion of the upper Kennady Lake watershed (watersheds B, D, and E) will be isolated or diverted, so that the runoff from these watersheds is directed away from Kennady Lake. The diversion system will rely on temporary, earth-filled dykes that will be placed across the outlets of the B, D, and E watersheds. Runoff from the B, D, and E watersheds will be diverted to lakes in the N watershed. The surface water diversions from Kennady Lake are illustrated in Figure 8.4-3.