GAHCHO KUÉ PROJECT

ENVIRONMENTAL IMPACT STATEMENT
CONFORMITY RESPONSE, ITEM 1

SECTION 9

KEY LINE OF INQUIRY: DOWNSTREAM WATER EFFECTS

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9 KEY LINE OF INQUIRY: DOWNSTREAM WATER EFFECTS

9.1 INTRODUCTION

9.1.1 Context

This section of the Environmental Impact Statement (EIS) for the Gahcho Kué Project (Project) consists solely of the key line of inquiry on downstream water effects. In the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* (Terms of Reference) issued on October 5, 2007, the Gahcho Kué Panel (2007) defined this topic as a key line of inquiry based on the following concerns:

> *"The release of large quantities of water during the dewatering of Kennady Lake may have effects on downstream creeks and lakes. Large short-term increases in water flow will be followed by a substantial decrease over a longer period of time as the tertiary pit and lake are re-filling. In addition to fluctuations in lake water volume, Aboriginal communities are concerned about possible water contamination, their experience with older mines being mainly negative."*

The potential effects of the proposed Project on the aquatic environment are spread among three key lines of inquiry presented in EIS Sections 8, 9, and 10 of the EIS, as required by the Terms of Reference. The geographic extent of effects is divided into Kennady Lake (Section 8) and the streams and lakes downstream of Kennady Lake (Section 9). The temporal extent is spread across all three key lines of inquiry. The effects of the construction, operations, and closure phases are addressed in detail in Sections 8 and 9. Section 10 provides a comprehensive summary of the long-term effects on both Kennady Lake and downstream lakes and streams during closure and reclamation, and during post-closure. Although each section can be understood on its own (i.e., it is stand-alone), a holistic understanding of the effect of the Project on aquatic resources is provided by the three key lines of inquiry together.

The Key Line of Inquiry: Downstream Water Effects includes a detailed analysis of the changes to waterbodies located downstream of Kennady Lake as far downstream as effects from the Project are expected to be discernable. Potential cumulative effects are addressed from Kennady Lake downstream to Great Slave Lake.

This key line of inquiry overlaps substantially with the Subject of Note: Impacts on Great Slave Lake presented in Section 11.2 of the EIS. Other subjects of note address topics that may slightly overlap with this key line of inquiry. Where there is overlap between this key line of inquiry and another key line of inquiry or subject of note, information will be provided in both locations. Nevertheless, the key line of inquiry on downstream water effects will contain the primary substantive analysis of the effect of the Project on the streams and lakes downstream of Kennady Lake, including effects on aquatic life.

9.1.2 Purpose and Scope

The purpose of the Key Line of Inquiry: Downstream Water Effects is to meet the Terms of Reference for the EIS issued by the Gahcho Kué Panel. A table of concordance for this key line of inquiry and the Terms of Reference is provided in Table 9.1-1. The entire Terms of Reference document is included in Appendix 1.I and the complete table of concordance for the EIS is in Appendix 1.II of Section 1, Introduction of the EIS.

Effects are included for the construction (i.e., dewatering of Kennady Lake), operation, and closure and reclamation phases. These include, but are not limited to, direct effects on water quality and quantity, riparian vegetation, fish abundance and quality, and wildlife and human health.

9.1.3 Study Areas

9.1.3.1 General Location

The Project is situated at Kennady Lake, north of the East Arm of Great Slave Lake in the Northwest Territories (NWT), at Longitude 63° 26’ North and Latitude 109° 12’ West. The Project site is about 140 kilometres (km) northeast of the nearest community, Łutselk’e, and 280 km northeast of Yellowknife (Figure 9.1-1).

Kennady Lake is a small headwater lake within the Lockhart River system that discharges to the north, via a series of small lakes, into Kirk Lake and then into Aylmer Lake. Aylmer Lake is located on the mainstem of the Lockhart River, about midway along its length. The Lockhart River system drains into the East Arm of Great Slave Lake.

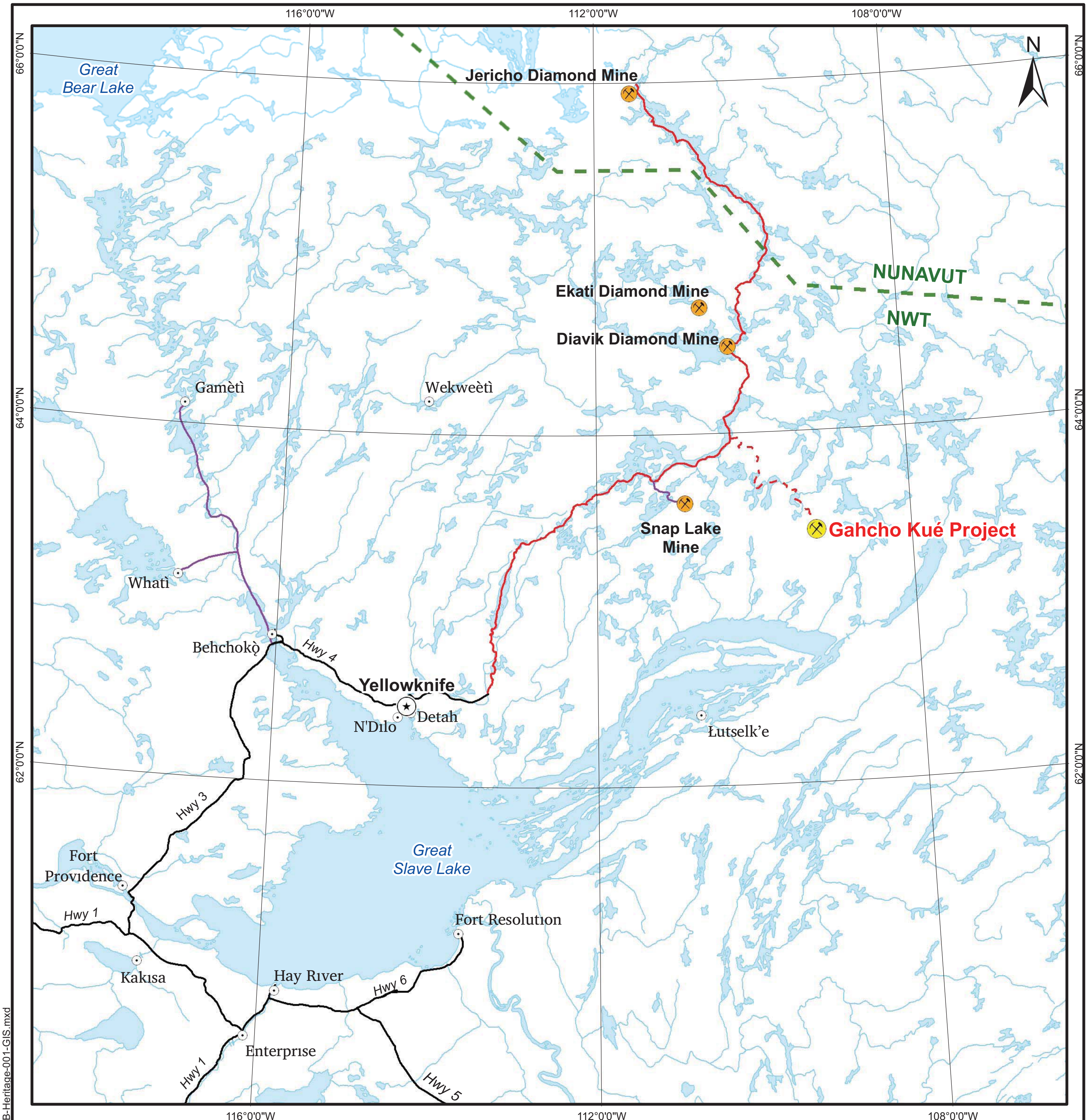
Table 9.1-1 Terms of Reference Pertaining to Downstream Water Effects

Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
3.1.3 Physical Environment: Water Quality and Quantity	Describe all water bodies, watercourses and major drainage areas and watersheds potentially affected by the proposed development	9.3.2
	Describe existing water quality for each water body identified for use in the proposed development, and those immediately downstream	9.3, Annex I, Addendum II
	Describe existing groundwater resources in the Project area, including quality and quantity, flow patterns, recharge and discharge areas, and interactions with surface water	9.3
	Identify relevant federal, provincial, or territorial guidelines, criteria, or legislation	9.8
3.1.3 Existing Environment: Fish and Aquatic Life Forms	Describe fish-bearing waterbodies and watercourses that may be affected by the proposed development	9.3
	Describe potentially affected fish species and local populations, and for each describe:	
	- seasonal and life cycle movements;	9.3.5
	- habitat requirements for each life stage;	9.3.5
	- local and regional abundance, distribution, use of habitat; and	9.3.5
	- known sensitive habitat areas, species or life stage/activity (e.g., spawning, hatching, feeding)	9.3.5, 9.10
	Describe key species used for traditional harvesting activities and any ecotourism activities.	9.5.1.3
	Describe any known issues currently affecting fish and aquatic life forms in the proposed development (e.g., contamination of food sources, parasites, disease).	9.3.5
4.1.3 Key Lines of Inquiry: Downstream Water Effects	General requirements pertaining to downstream water effects include:	
	Specific requirements pertaining to downstream water effects include:	
	- describe the physical effects of increased flows and changes to water quality on downstream water bodies	9.7
	- provide an analysis of the geographic extent of any downstream effects and a water balance for all affected water bodies	9.7
	- provide a detailed assessment of impacts on aquatic life that considers timing and levels of increased flows and changes to downstream water quality relative to sensitive life stages of fish	9.7
	- provide a detailed assessment of the potential biological impacts of changes, such as effects on riparian habitat and wildlife such as semi-aquatic fur-bearers and waterfowl that use riparian habitat	9.8, 9.9, 9.10, 9.11

Table 9.1-1 Terms of Reference Pertaining to Downstream Water Effects (continued)

Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
7 (Table 7-3) Water Issues	Remaining issues pertaining to surface water and watershed include:	
	- downstream effects of large water releases;	9.7, 9.8, 9.9, 9.10
	- reduced water flows as lake level is restored;	9.7.3, 9.7.4
	- ice quality on Kennady Lake and surrounding lakes;	9.3.2.2.2
	- cumulative effects on Hoarfrost and Lockhart rivers and Great Slave Lake; and	9.12, 11.2
	- extent of downstream effects	9.7, 9.8, 9.9, 9.10
	Remaining issues pertaining to surface water use and management include:	
	- water diversion effects; and	9.7, 9.10
	- alterations to natural drainage	9.7, 9.10
	Remaining issues pertaining to public concern include:	
	- implications of water quality on human health; and	9.8, 9.11
	- public notification of flooding events	3
3.2.7 Follow-up Programs	The EIS must include a description of any follow up programs, contingency plans, or adaptive management programs the developer proposes to employ before, during, and after the proposed development, for the purpose of recognizing and managing unpredicted problems. The EIS must explain how the developer proposes to verify impact predictions. The impact statement must also describe what alternative measures will be used in cases were a proposed mitigation measure does not produce the anticipated result.	9.13.4, 9.14, 9.15
	The EIS must provide a review of relevant research, monitoring and follow up activities since the first diamond mine was permitted in the Slave Geological Province to the extent that the relevant information is publicly available. This review must focus on the verification of impact predictions and the effectiveness of mitigation measures proposed in previous diamond mine environmental impact assessments. In particular the developer must make every reasonable effort to verify and evaluate the effectiveness of any proposed mitigation measures that have been used, or are similar to those used at other diamond mining projects in the Mackenzie Valley.	9.2, 9.3.1, 9.6.2.1.2

Source: Terms of Reference for the Gahcho Kué Environmental Impact Statement (Gahcho Kué Panel 2007).



LEGEND

- Gahcho Kué Project
- Existing Mine
- Territorial Capital
- Populated Place
- Highway
- Existing Winter Road
- Tibbitt-to-Contwoyto Winter Road
- Winter Access Road
- Watercourse
- Waterbody
- Territorial/Provincial Boundary

NOTES
Base data source: The Atlas of Canada

GAHCHO KUÉ PROJECT

Location of the Gahcho Kué Project

PROJECTION: Canadian Lambert Conf. Conic	DATUM: NAD83	DE BEERS CANADA
Scale: 1:3,500,000 (50 25 0 50 Kilometres)		
FILE No: B-Heritage-001-GIS		DATE: September 20, 2010
JOB NO: 09-1365-1004	REVISION NO: 8	**Figure 9.1-1**
OFFICE: GOLD-CAL	DRAWN: CW	CHECK: JB

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9.1.3.2 Study Area Boundaries

To assess the potential effects of the Project on downstream water effects, it is necessary to define appropriate spatial boundaries. The study area for this key line of inquiry was identified in the Terms of Reference as follows:

> *"The geographical scope of this Key Line of Inquiry includes all water bodies (and associated riparian areas) downstream of Kennady Lake up to Great Slave Lake."*

Baseline studies were completed before the Terms of Reference were issued; the boundaries for most of the baseline field work were based on two concepts:

- watersheds; and
- expected extent of the Project-related effects.

The baseline boundaries were set so that all the expected direct and indirect effects of the Project would lie within the Local Study Area (LSA) boundary. The LSA in the baseline studies extended from Kennady Lake watershed to the outlet of Kirk Lake, and included all the watersheds that could potentially be affected between these points.

The downstream extent of the LSA was based on the downstream limit of effects resulting from anticipated changes in lake levels, stream flows, or water quality (e.g., trace metals) during construction, operations, and closure. Effects were expected to be negligible beyond Kirk Lake, which would make the outflow at Kirk Lake a key node of analysis. Therefore, the baseline LSA was extended to the outflow of Kirk Lake. From the results of baseline studies, this delineation of the LSA would also encompass movement patterns of fish populations in Kennady Lake, as well as lakes and streams in its upstream and downstream watershed.

The study area identified by the Gahcho Kué Panel (2007) forms the lower part of the baseline LSA (i.e., the part below the Kennady Lake watershed). Therefore, a new LSA has been defined that is specific to the Key Line of Inquiry: Downstream Water Effects. The LSA for this key line of inquiry was selected to assess the immediate direct, and indirect, effects of the Project on downstream lakes and streams, and associated aquatic and semi-aquatic life.

Baseline survey intensity varied within each spatial boundary depending on the anticipated magnitude of the effect. The most intense effort was directed at waterbodies that would be directly affected by the Project in the baseline LSA;

existing government information summarized in the baseline was used to characterize the Lockhart River beyond Kirk Lake.

The Key Line of Inquiry: Downstream Water Effects was completed within the following spatial boundaries:

- downstream water effects Regional Study Area (RSA); and
- downstream water effects LSA.

9.1.3.3 Downstream Local Study Area

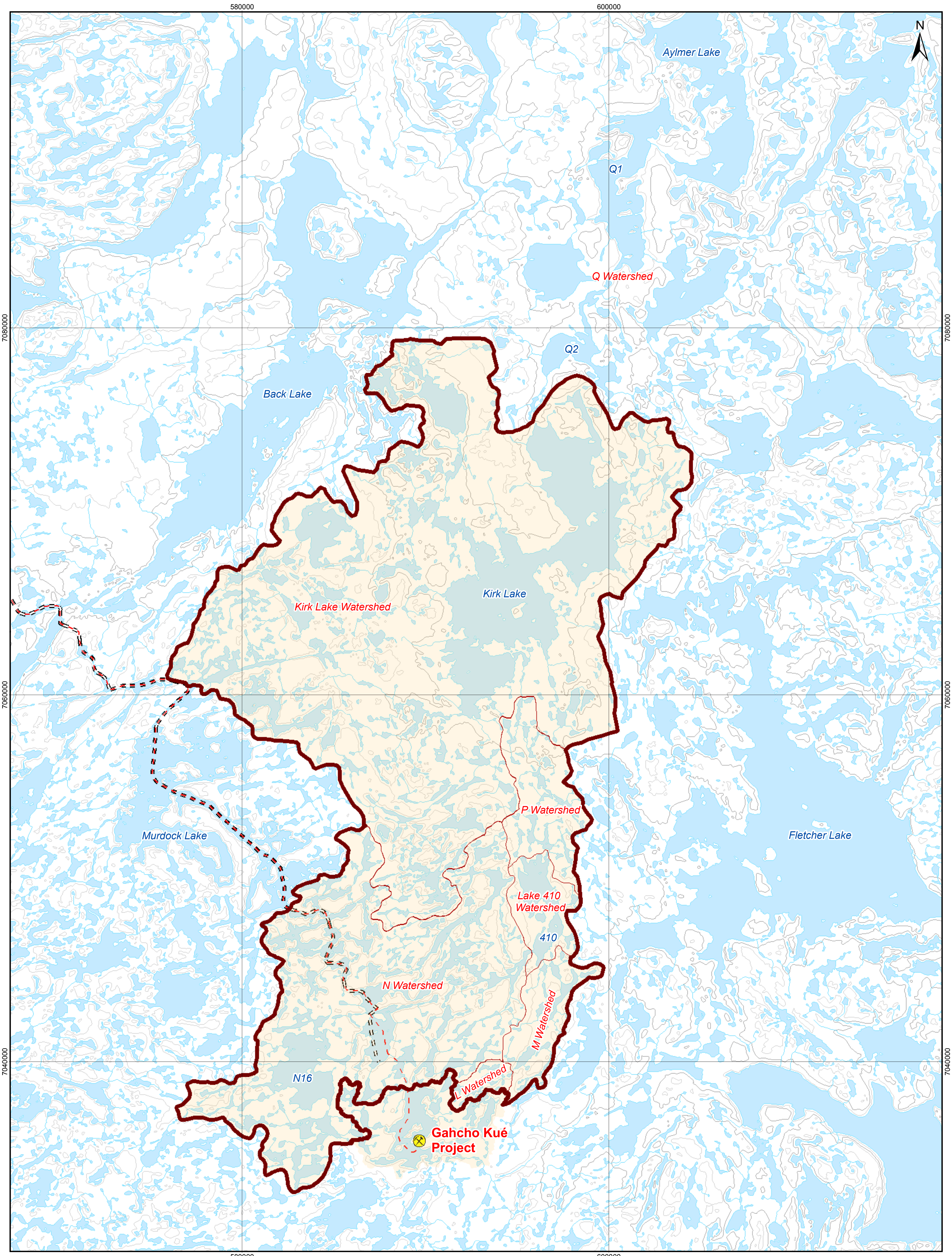
The downstream LSA (Figure 9.1-2) extends from the outlet of Kennady Lake at Area 8 (Stream K5) downstream to the outlet of Kirk Lake, and includes all the associated watersheds. The Kennady Lake watershed was assessed in the Key Line of Inquiry: Water Quality and Fish in Kennady Lake (Section 8).

The proposed Project is expected to directly affect the L and M watersheds located downstream, and north of the Kennady Lake outlet. The Project will also affect the watershed immediately adjacent to the west and north of Kennady Lake (the N watershed) during construction and operations by lowering the level of Kennady Lake (pumping to Lake N11), during operations by the diversion of the A, B, D, and E watersheds (i.e., sub-watersheds in the Kennady Lake watershed), and during closure, as water will be pumped from Lake N11 to Kennady Lake to supplement natural refilling. The drainage from the adjacent N watershed joins the natural drainage from Kennady Lake at Lake 410. The combined drainage then flows out of Lake 410 through the P watershed to Kirk Lake, and then to Aylmer Lake.

9.1.3.4 Regional Study Area

The RSA for the Key Line of Inquiry: Downstream Water Effects was selected to encompass the entire Lockhart River watershed to its outlet into Great Slave Lake. The RSA was selected to capture any effect that may extend beyond the LSA, and could potentially interact with other existing or proposed development projects to cumulatively affect hydrology, water quality, fisheries, and other aquatic resources.

The RSA for this key line of inquiry (Figure 9.1-3) is unchanged from the baseline RSA used by the surface water disciplines. Clear RSA boundaries are not possible to define for the deep groundwater component of the downstream water effects key line of inquiry.



LEGEND

- Gahcho Kué Project
- Baseline Winter Access Road
- Proposed Winter Access Road
- Watercourse
- Waterbody
- Index Contour (100m interval)
- Intermediate Contour (20m interval)
- Baseline Local Study Area
- Downstream Water Effects Boundary
- Watershed Boundary

NOTES
Base data source: National Topographic Base Data (NTDB) 1:250,000 096C

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GAHCHO KUÉ PROJECT

Downstream Water Effects Local Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:200,000 (2.5 1.25 0 2.5 Kilometres)	
FILE No: KLOI-09-002-GIS	DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 2
OFFICE: GOLD-CAL	DRAWN: SK CHECK: JF

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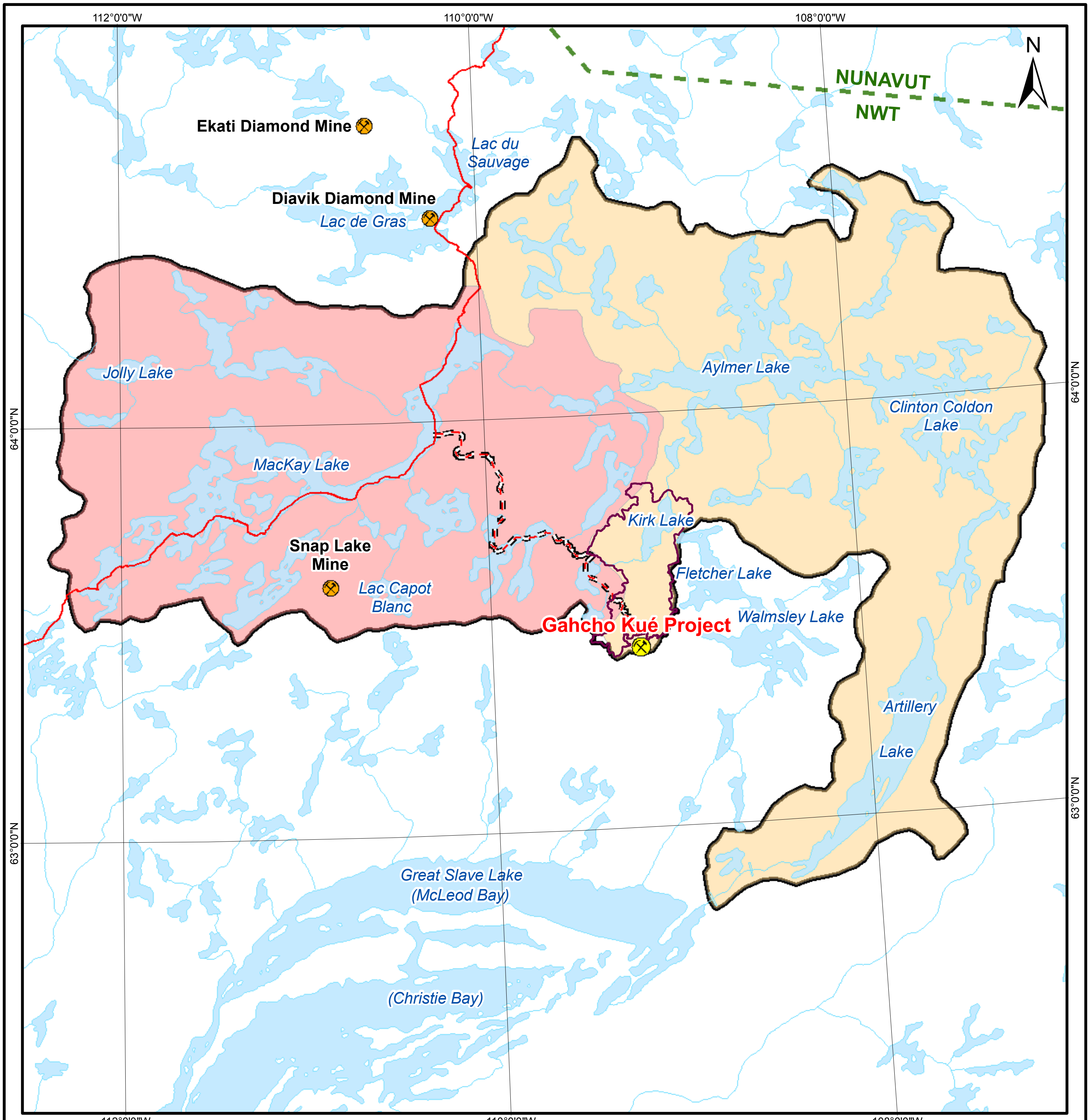
Figure 9.1-2



LEGEND

- Gahcho Kué Project
- Existing Mine
- Tibbitt-to-Contwoyto Winter Road
- Baseline Winter Access Road
- Proposed Winter Access Road
- Watercourse
- Waterbody
- Territorial/Provincial Boundary
- Downstream Watershed Boundary
- Lower Lockhart River Watershed
- Upper Lockhart River Watershed
- Regional Study Area

NOTES
Base data source: The Atlas of Canada

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GAHCHO KUÉ PROJECT

Downstream Water Effects Regional Study Area

PROJECTION: Canadian Lambert Conf. Conic	DATUM: NAD83	DE BEERS CANADA
Scale: 1:1,500,000 (30 15 0 30 Kilometres)		
FILE No: KLOI-09-001-GIS		DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 2	**Figure 9.1-3**
OFFICE: GOLD-CAL	DRAWN: SK / CHECK: JF	

9.1.4 Content

This key line of inquiry consists of details of the impact analysis and assessment related to downstream water effects. The key headings of this section are arranged according to the sequence of steps in the assessment. The disciplines relevant to this key line of inquiry are presented in a logical order with progressively longer pathways between the original sources and the receptors. The following briefly describes the content under each heading of this key line of inquiry:

- **Existing Environment** summarizes relevant baseline information for all waterbodies and associated riparian areas downstream of Kennady Lake to Great Slave Lake, beginning with the general environmental setting in which the Project occurs, which includes a summary of baseline methods and results for specific disciplines, including, surface water quantity, surface water quality, lower trophic levels, and fish and fish habitat (Section 9.3).
- **Water Management Plan Summary** presents a conceptual plan for water management during Project construction and operations, and closure, with emphasis on aspects relevant to downstream waters (Section 9.4).
- **Assessment Approach** provides details on specific aspects of the assessment approach (described in Section 6) that are particularly relevant to the assessment of effects to downstream waters (Section 9.5).
- **Pathway Analysis** identifies all potential pathways by which the Project could affect downstream waterbodies, and provides a screening level assessment of each pathway after applying environmental design features and mitigation that reduce or eliminate Project-related effects (Section 9.6).
- **Effects to Water Quantity** explains the scientific methods that were used to predict the changes to surface water quantity in downstream waterbodies; and presents the results of the analysis of effects to downstream surface water quantity as a result of the Project (Section 9.7).
- **Effects to Surface Water Quality** explains the scientific methods that were used to simulate changes to surface water quality in downstream waterbodies; and presents the results of the analysis of effects to downstream surface water quality as a result of the Project (Section 9.8).
- **Effects to Aquatic Health** explains the scientific methods that were used to assess effects to the health of aquatic life (aquatic health) in downstream waterbodies; and presents the results of the analysis of

downstream effects to aquatic health as a result of the Project (Section 9.9).

- **Effects to Fish and Fish Habitat** explains the scientific methods that were used to predict the changes to fish and fish habitat in downstream waterbodies; and presents the results of the analysis of downstream effects to fish and fish habitat as a result of the Project (Section 9.10).
- **Related Effects to Wildlife and Human Health** explains the scientific methods that were used to predict the changes to wildlife and human health in downstream waterbodies, and presents a summary of results of the analysis of effects to wildlife and human health that flow from effects to downstream waterbodies as a result of the Project (Section 9.11).
- **Residual Effects Summary** summarizes the effects to downstream waterbodies that are predicted to remain after all measures (e.g., environmental design features and mitigation) to eliminate potential pathways or reduce associated negative effects have been incorporated into the Project design (Section 9.12).
- **Residual Impact Classification** describes methods used to classify residual effects, and summarizes the classification results (Section 9.13).
- **Uncertainty** discusses sources of uncertainty surrounding the predictions of downstream water effects and how this uncertainty is addressed by the Project (Section 9.14).
- **Monitoring and Follow-up** describes proposed monitoring programs, contingency plans, and/or adaptive management strategies related to downstream water effects (Section 9.15).
- **References** list all documents and other material used in the preparation of this section (Section 9.16).
- **Glossary, Acronyms, and Units** explains the meaning of scientific, technical, or other uncommon terms used in this section. In addition, acronyms and abbreviated units are defined (Section 9.17).

9.2 SUMMARY

Background

The proposed Project is a diamond mine situated at Kennady Lake in the Northwest Territories (NWT), approximately 280 kilometres (km) northeast of Yellowknife. Kennady Lake is a small headwater lake within the Lockhart River system that drains northward about 70 km, via a series of small lakes, into Kirk Lake and then into Aylmer Lake. Aylmer Lake is located on the mainstream of the Lockhart River, about midway along its length. The Lockhart River system drains into the East Arm of Great Slave Lake. Downstream water effects were identified in the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* as a key line of inquiry because of concerns related to effects of changes in flows and water quality to downstream lakes and streams resulting from Kennady Lake dewatering, during mining operations, and after reconnection.

The downstream Local Study Area (LSA) extends from the outlet of Kennady Lake at the northeast end of Area 8 (Stream K5), downstream to the outlet of Kirk Lake, and includes all of the associated watersheds (Figure 9.1-2). The proposed Project is expected to directly affect the L and M watersheds located downstream, and north, of Stream K5. The Project will also affect the watershed immediately adjacent to the west and north of Kennady Lake (the N watershed). The drainage from the adjacent N watershed joins the natural drainage from the outlet of Kennady Lake at Lake 410. The combined drainage then flows out of Lake 410 through the P watershed to Kirk Lake, and then to Aylmer Lake.

Existing Environment

Components of the existing environment that are relevant to this key line of inquiry include surface water quantity, surface water and sediment quality, lower trophic levels, and fish and fish habitat. Where available, historical baseline data in streams and lakes in the LSA downstream of Kennady Lake were reviewed and summarized; multi-year, seasonal baseline sampling was conducted to supplement existing information.

Water Management Plan

A Water Management Plan has been developed for the Project. This plan was designed to minimize the impact of the Project on the aquatic ecosystem of Kennady Lake and downstream environments during the construction, operations, and closure phases.

The following water-related Project activities will have a substantial bearing on the downstream watersheds and waterbodies (Figure 9.1-2):

- pumping water to Lake N11 as a component of dewatering Kennady Lake during construction and operations;
- pumping water to Area 8 of Kennady Lake allowing subsequent flow downstream through Stream K5 following construction of Dyke A;
- diversion of the A, B, D, and E watersheds (i.e., sub-watersheds in the Kennady Lake watershed) to the N watershed during operations;
- reduction of inflows to Area 8 and, therefore, reduction of flows in the L and M watersheds during operations;
- pumping discharge, on an as-needed basis, to Lake N11 from the Water Management Pond (WMP) during operations;
- pumping water from Lake N11 to Kennady Lake to supplement natural refilling during closure;
- restoration of the natural drainage system in the Kennady Lake watershed, with the exception of watershed A; and
- removal of Dyke A once Areas 3 to 7 of Kennady Lake are refilled and water quality meets specific criteria, allowing Kennady Lake to discharge natural flows through Area 8 during post-closure.

Assessment Approach

The pathway analysis identified and screened the linkages between Project components or activities and the potential effects to receptors within the aquatic environment. Pathways were determined to be primary or secondary (minor), or to have no linkage. Scientific and traditional knowledge, logic, and experience with similar developments, including environmental design features and mitigation were considered. All primary pathways were carried forward in the assessment for detailed effects analysis.

The selection of Valued Components (VCs) specific to this key line of inquiry resulted from issues scoping sessions for the Project with community members, federal and territorial regulators, and other stakeholders. For this key line of inquiry, water quality and fish were identified as VCs, with the following being identified as the assessment endpoints:

- suitability of Water Quality to Support a Viable Aquatic Ecosystem;
- abundance and Persistence of Desired Population(s) of Lake Trout;
- abundance and Persistence of Desired Population(s) of Northern Pike; and

- abundance and Persistence of Desired Population(s) of Arctic Grayling.

Water Quantity

Dewatering: During construction, the dewatering of Kennady Lake will result in discharges to Area 8 and Lake N11 in the N watershed, which will be limited to prevent downstream erosion or geomorphological changes. Pumping will be timed to begin after the peak of the spring freshet, such that peak flows will not be increased.

Peak daily discharges at the Area 8 outlet (Stream K5) will be slightly reduced, with low flows increasing substantially as dewatering discharges are sustained through the open-water season. A similar trend will also occur with water levels in downstream lakes, although the magnitude of change in water level is predicted to be relatively small. Effects on downstream waterbodies and streams will be progressively reduced with increased distance from the Project as more undisturbed areas contribute to runoff, which acts to attenuate the magnitude of change.

Dewatering discharges to Lake N11 are expected to increase flows at the Lake N11 and Lake N1 outlets. Peak daily discharges for the Lake N11 and N1 outlets will be approximately equal to baseline conditions, with low flows increasing substantially as dewatering discharges are sustained through the open-water season. A similar trend will also occur with water levels in lakes N11 and N1, although the magnitude of change in water level is predicted to be relatively small.

Lake 410 and downstream waterbodies will be affected by the dewatering discharges to Area 8 and Lake N11. The peak daily discharges for the Lake 410 outlet will be approximately equal to baseline conditions, with low flows increasing substantially as dewatering discharges are sustained through the open-water season. Water levels in Lake 410 will follow a similar trend during peak and low flow periods, although the magnitude of change in water level is relatively small. The peak daily discharges for the Kirk Lake outlet are expected to increase marginally and low flows will also increase, but to a lesser extent than at upstream locations. Water levels in Kirk Lake are expected to increase slightly, although the magnitude of change in water level is relatively small.

No adverse effects on the stability of the shorelines of downstream lakes are anticipated during the dewatering phase, as limiting discharges to a 2-year flood water level will mean that the downstream lakes have the capacity to accommodate the planned discharge rates.

Operations: After construction dewatering has been completed, Kennady Lake will retain a volume of water in Areas 3 and 5 that will constitute the WMP for the remaining period of operation. Water will be pumped from the WMP directly to Lake N11 as required through operations. Pumping will be managed such that peak flows will remain similar to baseline, and low flow augmentation will not extend throughout the open-water period. Seasonal low flows will return to near baseline conditions by mid-summer and remain for the duration of the open-water period.

To reduce the amount of runoff from the upstream watersheds to Kennady Lake throughout operations, four upper tributary watersheds will be diverted to the adjacent N watershed. The diversion of the A and B watersheds will result in small increases in peak flows and low flows at the Lake N6 outlet. Water levels in Lake N6 are also expected to increase a small amount. The diversion of the D and E watersheds will result in moderate increases in peak flows and low flows at the Lake N17 outlet. Water levels in Lake N17 are also expected to increase a small amount. Increases in flows at the Lake N6 and Lake N17 outlets due to operational diversions will be mitigated to limit the potential for erosion. Changes to the flow regime in downstream channels are not expected to cause adverse impacts on channel or bank stability or erosion, as flow increases will be limited.

Dyke A will isolate Kennady Lake Areas 2 to 7 from Area 8, reducing the upstream drainage area at the Area 8 outlet (Stream K5). This will substantially reduce peak daily discharges and low flows through Stream K5 because of the reduction in upstream storage and drainage area. Effects on downstream waterbodies will be progressively reduced as additional undisturbed watersheds contribute to runoff.

Lake 410 receives inflow from both the N watershed and the M watershed. Reduced flows downstream of Area 8 through the M watershed will be offset by increased flows in the N watershed, such that the water levels and outlet discharge at Lake 410 will be similar to baseline conditions. At Kirk Lake, changes in water level and outlet discharges during operations will be negligible.

Closure: During refilling, the flow and water level regime in the Stream K5 channel and downstream to the Lake M1 outlet will be the same as during operations. The diversion of water from Lake N11 to refill Kennady Lake will result in a small reduction of monthly mean flows at the Lake N11 and Lake N1 outlets. Similarly, small changes in water levels of Lake N11 and N1 will also occur. A reduction in the monthly mean flows at the Lake 410 and Kirk Lake outlets will also be expected due to the combined effects of abstraction for lake refilling and the removal of upstream drainage areas, although the change is small. No effects on outlet channel or bank stability during operations are expected, because flows will be reduced or subject to only small increases.

Post-Closure: Watersheds downstream of Kennady Lake will return to near baseline conditions, but will be affected by the post-closure hydrological regime of the Kennady Lake watershed. This regime includes a small increase in mean annual water yield and a slight increase in flood peak discharges. The effects of these changes to downstream watersheds will be progressively reduced with increased distance downstream from Kennady Lake as more watershed areas contribute to runoff, which acts to attenuate the magnitude of change. The post-closure hydrological regimes of the N11 and upstream watersheds is expected to be almost identical to the baseline conditions, with the post-closure hydrological regime of the N1 watershed affected to a negligible extent by the permanent diversion of the A watershed.

Water Quality

As a result of the Project, water quality in the downstream waters was predicted to change in waterbodies downstream of Kennady Lake, through the Interlakes (i.e., the L and M watersheds) to Lake 410. Additionally, water quality in the N watershed, from Lake N11 through to Lake 410 was predicted to change. The modelling nodes used in this assessment included Lake N11, the Interlakes and Lake 410.

Water quality was modelled under the assumption that permafrost would not establish in the mine rock piles, Coarse PK Pile, and Fine PK Facility. Therefore, simulated concentrations of water quality parameters downstream of Kennady Lake following closure will remain elevated above background levels for the long-term. However, these projections are conservative as parameter loading to Kennady Lake from the reclaimed mine rock and PK storage facilities is expected to decrease with the establishment of permafrost. With the onset of climate change conditions that reduce or eliminate permafrost conditions at the Project site, parameter concentrations are projected to increase to modelled long-term levels.

Lake N11: During dewatering of Areas 3 and 5 of Kennady Lake to Lake N11, changes to total suspended solids (TSS) levels will be negligible, as water to be initially pumped will be surface waters. TSS levels in the WMP will be at, or similar, to background concentrations. After dewatering, any continued pumped discharge during operations from the WMP to Lake N11 will not be a source of TSS to Lake N11. At closure, active pumping from Lake N11 to Areas 3 and 5 to augment lake refilling will not be a source of additional TSS in Lake N11.

During the operations phase, concentrations of TDS and major ions in Lake N11 are projected to increase as a result of pumped discharge from the WMP. During closure, total dissolved solids (TDS) concentrations are predicted to return to background levels when pumping from the WMP ceases. During construction and operation, and in the early years of closure, concentrations of TDS and all major ions are predicted to increase above background conditions, but remain below concentrations that would affect aquatic health.

Concentrations of nutrients are projected to increase in Lake N11 over the course of operations. All modelled forms of nitrogen are predicted to increase in Lake N11 due to inputs from blasting residue in the pumped discharge from the WMP to Lake N11. Nitrate and ammonia concentrations are predicted to remain below guidelines and return to background conditions within the first few years of closure. Concentrations of phosphorus are predicted to increase from a background concentration of 0.005 mg/L to a maximum concentration of 0.009 mg/L in Lake N11 during operations. Phosphorus projections assume that mitigation strategies will be applied to the Fine PKC Facility, which is the largest contributing source of phosphorus to the WMP and, subsequently, to Lake N11. At the end of mining, pumped discharge from the WMP to Lake N11 will cease, and phosphorus concentrations will return to background concentrations. An increase in primary productivity is expected during operations; however, the lake trophic status would remain oligotrophic (i.e., low biological productivity).

During operations, pumped discharge of the WMP to Lake N11 will result in increased metals concentrations in Lake N11. Of the 23 trace metals that were modelled for this assessment:

- Seventeen metals are predicted to increase in concentration during the operations phase, following the same temporal patterns as TDS and major ions. These include antimony, arsenic, barium, boron, chromium, iron, manganese, molybdenum, nickel, lead, selenium, silver, strontium, thallium, uranium, vanadium, and zinc. Metals that are influenced more by groundwater inflows are predicted to have maximum peaks early in the operational phase (e.g., chromium). Metals that are more strongly influenced by geochemical loading sources (i.e., from PK and mine rock sources) are predicted to have the highest peaks near the end of the operational phase (e.g., strontium). Only chromium is predicted to exceed guidelines which will occur in Years 2 and 4. Within the first few years of closure, metals concentrations are expected to return to background concentrations.
- Six of the 23 modelled metals are predicted to have slight increases in concentration (i.e., less than 20 percent [%] from background) due to pumped discharge from the WMP. These metals include aluminum, beryllium, cadmium, cobalt, copper, and mercury. Of these metals, only

cadmium is predicted to exceed guidelines, and these exceedances are observed in background conditions.

The Interlakes (L and M Watersheds): Water quality in the Interlakes (the chain of lakes within the L and M watersheds) is predicted to be similar to that in Area 8 (as outlined in Section 8.8), although some attenuation is expected due to increased dilution with distance downstream.

As described in Section 8.8.4, phosphorus is predicted to increase in Area 8 during post-closure, following the removal of Dyke A and the reconnection of Areas 3 through 7 with Area 8. These concentrations are anticipated to extend downstream but decline with distance as inflows from the L and M watersheds dilute the concentrations originating from Area 8. Average long-term concentrations for lakes along the main flow path in the L and M watersheds are predicted to be 0.015 mg/L and 0.013 mg/L, respectively. Primary productivity will increase in these lakes, which will modify dissolved oxygen dynamics, particularly over winter (they will increase from oligotrophic to a mesotrophic state in the long-term). For lakes with depths greater than 6 m, which have overwintering habitat for fish (i.e., Lakes M3 and M4), dissolved oxygen concentrations will remain sufficient to support aquatic life. The small lakes in the L watershed and M watershed, upstream of Lake M3, are currently subject to low under-ice dissolved oxygen levels with nil or limited overwintering habitat for fish. Potential increases in winter oxygen depletion due to nutrient enrichment would have, therefore, no or limited effect on the overwintering capability or suitability of these small lakes.

Lake 410: During dewatering of Area 7 of Kennady Lake to Area 8, changes to TSS levels will be negligible in Area 8, and therefore through the Interlakes to Lake 410, as water to be initially pumped will be surface waters. As the water level in Area 7 is drawn down and water quality does not meet discharge criteria, pumping to Area 8 will cease so that there is no additional source of TSS to Area 8 and downstream waters. Contributions of TSS from the N watershed to Lake 410 will be negligible.

Concentrations of TDS and major ions in Lake 410 are projected to increase during the operations phase due to relative contribution of pumped discharge from the WMP to Lake N11. Temporal patterns of concentrations in Lake 410 will be similar to those in Lake N11, except that concentrations will be lower in Lake 410 due to dilution from the majority of the Lake 410 watershed, and these patterns will occur one to two years later in Lake 410, reflecting travel time. During the closure phase (i.e., refilling period), at which time no water will be released from Kennady Lake, water chemistry in Lake 410 is predicted to return to near background conditions. In post-closure, when water is released to

Area 8, TDS concentrations will increase slightly in Lake 410. Patterns of concentrations in Lake 410 will be similar to those projected for Area 8, except that these will also be lower due to dilution and offset due to travel time. TDS and all major ions are predicted to remain above background conditions but below levels that would affect aquatic health.

Concentrations of all modelled forms of nitrogen are predicted to increase in Lake 410, with operations concentrations higher than closure concentrations. Closure concentrations of nitrogen are predicted to decline to near-background concentrations, because there are no major loading sources of nitrogen. In post-closure, nitrogen concentrations will increase for several years after the removal of Dyke A and then decline to near background concentrations. Concentrations of nitrate and ammonia are predicted to remain below guidelines throughout the life of the Project and beyond.

Concentrations of phosphorus in Lake 410 are predicted to increase from a background concentration of 0.005 mg/L to a maximum concentration of 0.007 mg/L throughout operations and several years into post-closure. The projected increases in phosphorus were developed assuming that supplemental mitigation strategies for the Fine PKC Facility are in place. After the pumped discharge from the WMP to Lake N11 ceases, phosphorus loading from Lake N11 will return to near-background concentrations. Increased concentrations of phosphorus are projected for several years into post-closure following the removal of Dyke A and the reconnection of Areas 3 to 7 of Kennady Lake to the downstream lakes. A slight increase in primary productivity would be expected during operations and into post-closure; however, the trophic status would remain oligotrophic.

Of the 23 modelled trace metals:

- Twelve are predicted to have small increases in concentration (i.e., maximum concentrations less than twice as high as baseline) in Lake 410 associated with operations discharge to Lake N11 and in the early post-closure with the removal of Dyke A. These metals are aluminum, barium, beryllium, cadmium, cobalt, copper, iron, lead, manganese, mercury, nickel, and zinc. These metals are predicted to return to near-background conditions in the long-term.
- Three metals (chromium, selenium, and thallium) are predicted to increase well above baseline conditions during the operational and closure phases, but return to near-background conditions in the long-term. These metals are predicted to have similar trends to TDS and the major ions.

- Eight metals are predicted to increase and reach long-term steady state concentrations more than double baseline concentrations. These metals include antimony, arsenic, boron, molybdenum, silver, strontium, uranium, and vanadium. Concentrations of these metals are predicted to increase after closure, and reach steady state conditions in Lake 410 within about 40 years. As geochemical sources are the primary contributors of these metals, the majority of total concentrations will be in the dissolved form.

Cadmium is the only metal predicted to exceed guidelines in Lake 410, and the guideline exceedance is due to naturally elevated background concentrations.

Aquatic Health

Changes in water quality in Lake N11 and Lake 410 are predicted in constructions, operations, and closure of the Project. The potential effect of these changes on aquatic health was evaluated considering both direct waterborne exposure and accumulation within fish tissues. For direct waterborne exposure, predicted maximum concentrations for all substances of potential concern were lower than the corresponding chronic effects benchmarks (CEB). Predicted fish tissue concentrations were below tissue-based toxicological benchmarks for the substances considered in the assessment.

With respect to the interlakes, the aquatic health assessment completed for Area 8 predicted that Project activities would result in negligible effects to aquatic health, with follow-up monitoring being recommended to confirm these results (see Section 8.9). Water quality in the interlakes is predicted to be similar to that in Area 8, although parameters concentrations will gradually decline with distance downstream due to dilution. Consequently, the conclusions and recommendations put forward for Area 8 apply to the interlakes as well.

Based on the above, changes to concentrations of all substances considered in this assessment are predicted to result in negligible effects to aquatic health in waterbodies downstream of Kennady Lake.

Effects to Fish and Fish Habitat

Dewatering: Dewatering of Kennady Lake will result in augmented flows in the N watershed, and in the L and M watersheds downstream of Kennady Lake during the open-water period. Most of the pumping will occur after the peak of the spring freshet has occurred, and peak discharges will remain similar to baseline conditions. No changes to fish habitat due to changes in channel morphology are predicted. As a result of mitigation, the risk of flushing or stranding fish during the start-up and shut-down of pumping is considered to be negligible.

From the evaluation of spring (June) discharges and average June water velocities in Stream N11 and N1 during dewatering, the effect of dewatering on spawning Arctic grayling in Streams N11 and N1 is expected to be negligible. Higher summer discharges are expected to have a minor effect on any young-of-the-year (YOY) Arctic grayling rearing in these streams.

From the evaluation of spring (June) discharges and average June water velocities downstream of Kennady Lake during dewatering, Arctic grayling are likely to continue spawning successfully, and as a result, the effect of dewatering on spawning Arctic grayling in streams downstream of Kennady Lake is expected to be negligible. Given the small increases in average water velocities during dewatering, and the availability of suitable low velocity habitat for small YOY Arctic grayling, the effect of dewatering on Arctic grayling YOY in streams downstream of Kennady Lake is expected to be negligible. The density and species composition of benthic invertebrate communities and invertebrate drift are not expected to change as a result of higher summer flows in streams in the L, M, and N watersheds downstream of Kennady Lake. Dewatering is not expected to result in an increase in barriers to fish migration and may improve accessibility for some species.

Small increases in lake water levels and lake areas are predicted compared to baseline conditions in the N watershed. Water levels in the L and M lakes downstream of Kennady Lake and Lake 410 will remain near spring freshet levels longer into the summer and early fall compared to baseline conditions, which may benefit fish in these lakes during summer through increased littoral area and summer rearing habitat. Lake levels will return to baseline conditions before winter, and therefore, no changes to overwintering habitat are expected.

Operations: Flows in the N watershed during operations are similar to the dewatering phase of the Project for June and July. During operations, flows return to conditions similar to baseline in August and for the remainder of the open-water season. No changes are predicted to channel morphology. As a result of mitigation on ramp-up and ramp-down rates, effects to fish and fish habitat in the N watershed are considered to be negligible as a result of the pumped discharge from the WMP to Lake N11 during operations. Improved fish movements can be expected in the N watershed during operations. As the projected mean current velocities in N watershed streams are within the expected range of natural variation, they are therefore not predicted to influence benthic invertebrate communities or invertebrate drift.

Flow reductions in the L and M watersheds during operations will result in a reduction of available habitat. The change from baseline generally declines moving downstream, with the largest changes found in Streams K5 and L3.

During operations, flows in June are substantially reduced in streams between Kennady Lake and Lake 410. The increase in frequency of barriers preventing spring spawning migrations of Arctic grayling is likely to have a negative impact on Arctic grayling populations between Area 8 and Lake 410. The projected decreases in mean current velocity relative to baseline are small, and therefore, are not expected to alter benthic invertebrate communities or invertebrate drift. Predicted changes in wetted width and water depth are not expected to alter benthic community composition and drift density; however, the amount of invertebrate biomass and total drift are expected to be reduced in proportion to the reduction in stream width and flow.

Water levels and lake areas in the N watershed are expected to increase compared to baseline, but decrease compared to dewatering. As the changes in water level and lake area are small and within natural variability, no effects on fish and fish habitat are expected. Water levels and lake areas in lakes between Kennady Lake and Lake 410 are generally expected to decrease during operations compared to baseline conditions. However, as the changes in water levels are small, the effects on fish habitat or benthic invertebrate communities in these lakes are expected to be minor. In Lake 410, the predicted changes are small and within natural variability; no effects on fish and fish habitat would be expected to occur.

The increased nutrient concentrations in Lake N11 during operations are expected to generally increase productivity at all trophic levels, with the lake remaining oligotrophic. As a result of the increased food base, there may also be increased growth and production in the fish species of Lake N11. At closure, lower trophic communities are expected to return to those characteristic of baseline conditions.

Closure: The flow regime in the N watershed will return to near baseline conditions during closure, with small seasonal reductions in flow due to pumping to Area 3 to augment the refilling of Kennady Lake. At the outlet of Lake N1, flows will return effectively to baseline conditions. Effects on lower trophic communities will cease and communities are expected to return to those characteristic of baseline conditions.

Flows downstream of Kennady Lake to Lake 410 during closure will remain reduced, with the same flow regime from operations continuing through the refilling phase; the same conclusions for fish habitat availability, fish habitat suitability, changes to fish migrations, and changes to lower trophic communities from operations apply.

Small decreases in lake water levels and lake areas are predicted in Lake N11 and Lake N1, but as the changes are small compared to baseline conditions, they are unlikely to have a substantive effect on fish habitat or benthic invertebrate communities in these lakes. The lake levels, and associated effects on fish and fish habitat, in the L and M lakes are the same as for operations.

Post-closure: Flows return to near baseline conditions throughout the N, L, and M watersheds and the effects to fish habitat are considered to be negligible. Benthic invertebrates are expected to quickly re-colonize the re-wetted stream areas. Water levels and lake areas in lakes between Kennady Lake and Lake 410 are expected to slightly decrease, but as the changes are small compared to baseline, effects to fish and fish habitat would be negligible.

Reconnection of Area 8 to the remainder of Kennady Lake is predicted to result in a rapid increase in nutrient concentrations in the L and M watersheds, along the flow-path to Lake 410. These predictions are indicative of a gradient in trophic status from mesotrophic in the L watershed to oligotrophic in Lake 410, with a corresponding gradient of effects on lower trophic communities. In downstream lakes, increased primary and secondary productivity is expected. An increase in benthic invertebrate abundance and biomass, as well as a shift in benthic invertebrate community composition, is also likely to occur. As a result, there may also be increased growth and production of forage fish species, as well as large-bodied fish species. In downstream lakes, there may be small reductions in overwintering habitat availability or suitability at post-closure for fish species remaining throughout the winter. However, it is expected that open-water rearing and feeding habitat may be enhanced due to the increased food base. Nutrient concentrations are expected to increase slightly in Lake 410, but the lake is expected to remain oligotrophic; as a result, effects are expected to be lower in magnitude, with corresponding smaller changes in productivity, lower trophic communities, and fish production.

Streams in the L and M watersheds will also experience nutrient enrichment, with corresponding changes in lower trophic communities and fish production, reflecting the gradient in nutrient concentrations. Although there is a potential for reduced suitability and availability of spawning habitat due to increased algal growth on streambed substrates in streams close to Kennady Lake, it is expected that these streams will continue to provide Arctic grayling spawning and rearing habitat.

The Project is expected to have negligible effects on aquatic health in waterbodies downstream of Kennady Lake (i.e., Lake N11 and Lake 410) from changes in chemical constituents of water quality; therefore, no effects to fish populations or communities are expected to occur from changes in aquatic health.

Residual Impact Classification

The classification was carried out on residual impacts (i.e., impacts with environmental design features and supplemental mitigation considered). Residual impacts were classified for two time periods: from the initiation of the Project to 100 years later; and future conditions after 100 years from Project initiation. Projected impacts were then evaluated to determine if they were environmentally significant.

The projected impacts of the Project on the suitability of water downstream of Kennady Lake to support a viable and self-sustaining aquatic ecosystem are considered to be not environmentally significant for both time periods. Water quality is predicted to change, but is expected to result in negligible effects to aquatic health. After closure, phosphorus concentrations are predicted to be higher than during pre-development conditions along a gradient downstream of Kennady Lake to Lake 410. Trophic status of lakes in the L watershed may shift from oligotrophic to mesotrophic, but the trophic status of Lake 410 is expected to remain oligotrophic. The projected increases in phosphorus will not pose a health risk to a viable and self-sustaining aquatic ecosystem, though it will likely be different to the pre-development ecosystem (i.e., it will become a more productive aquatic ecosystem).

The projected impacts on the abundance and persistence of Arctic grayling, lake trout, and northern pike are considered to be not environmentally significant for both time periods. During the first time period, reduced flows and lake levels that occur downstream of Area 8 during operations and closure may affect habitat availability, suitability, and movement of the VCs between Area 8 and Lake 410. For Arctic grayling, this has the potential to affect the population size by restricting spawning migrations and reducing the area available for spawning; for lake trout and northern pike, this is not expected to result in population level changes. However, a flow mitigation plan is under development. In the second time period, flows return to near baseline conditions and the population and distribution of Arctic grayling are also expected to return to baseline conditions. Nutrient enrichment after closure may provide for improved productivity for fish, although there may some localized changes to habitat conditions. All three species are expected to continue to persist in the watershed downstream of Kennady Lake during construction, operations, closure, and post-closure.

9.3 EXISTING ENVIRONMENT

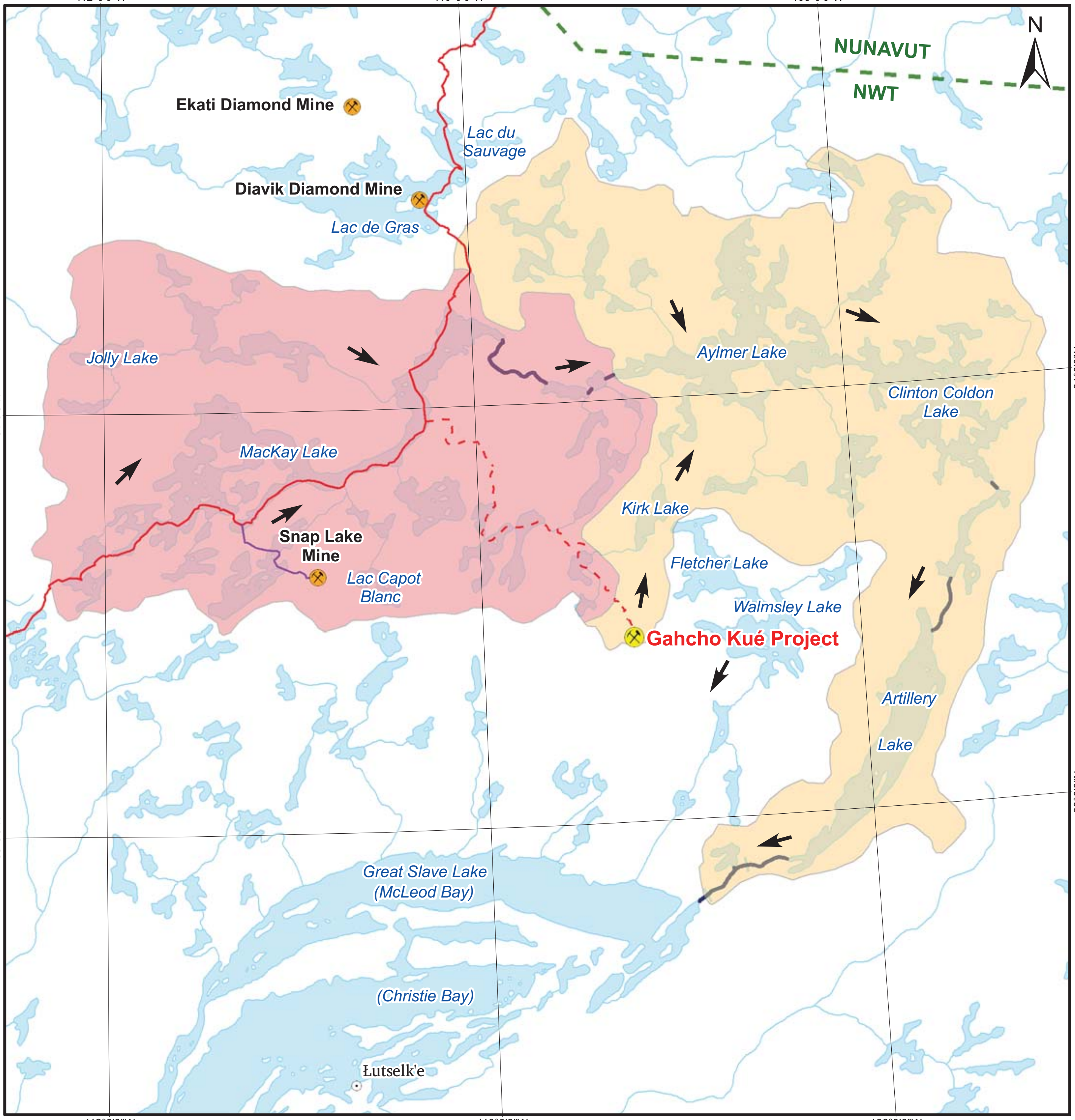
The following section provides a brief description of the existing environment downstream of the Kennady Lake watershed. Components of the existing conditions discussed herein include surface water quantity, surface water quality, physical aquatic habitat, lower trophic levels, and fish. The focus of the descriptions below is on results for each component, although methods are briefly discussed. For more details on methods or results, supplementary information regarding the existing environment downstream of the Kennady Lake watershed is provided in the following annexes of this environmental impact statement (EIS):

- Annex H (Climate and Hydrology Baseline);
- Annex I (Water Quality Baseline); and
- Annex J (Fisheries and Aquatic Resources Baseline).

9.3.1 General Setting

The Gahcho Kué Project (Project) is located within the Kennady Lake watershed at Kennady Lake (63° 26’ N; 109° 12’ W), a small headwater lake of the Lockhart River watershed in the Northwest Territories (NWT). Kennady Lake is about 140 kilometres (km) northeast of the nearest community Łutselk’e on the eastern arm of Great Slave Lake, and about 280 km northeast of Yellowknife (Figure 9.1-1). Kennady Lake is 84 km east of the Snap Lake Mine, the only other active mine in the Lockhart River watershed. The Diavik and Ekati diamond mines are located in the Coppermine River watershed, approximately 127 km and 158 km northeast of Kennady Lake, respectively. The Project site is located at an elevation of approximately 420 metres (m) above sea level.

Kennady Lake drains north for approximately 70 km through Kirk Lake and into Aylmer Lake. Aylmer Lake is located on the mainstem of the Lockhart River, approximately halfway between the Kennady lake watershed and Great Slave Lake. The Lockhart River then drains southeast from Aylmer Lake through Clinton Colden and Artillery lakes into the East Arm of Great Slave Lake. The Kennady Lake watershed (37 square kilometres [km^2]) comprises approximately 0.14 percent (%) of the 27,500 km^2 Lockhart River watershed. Regional drainage at the Project is shown in Figure 9.3-1.



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LEGEND

- Gahcho Kué Project
- Existing Mine
- Tibbitt-to-Contwoyto Winter Road
- Winter Access Road
- Existing Winter Road
- Watercourse
- Waterbody
- Lockhart River
- Territorial/Provincial Boundary
- Drainage Direction
- Lower Lockhart River Watershed
- Upper Lockhart River Watershed

NOTES
Base data source: The Atlas of Canada

GAHCHO KUÉ PROJECT

Regional Drainage

PROJECTION: Canadian Lambert Conf. Conic	DATUM: NAD83
Scale: 1:1,500,000 (30 15 0 30 Kilometres)	
FILE No: B-Hydro-011-GIS	DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 4
OFFICE: GOLD-CAL	DRAWN: JH / CHECK: NS

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Figure 9.3-1

The area downstream of the Kennady Lake watershed is located in the sub-Arctic tundra, north of the treeline, and near the southern limit of continuous permafrost. Topography downstream of the Kennady Lake watershed is characterized by low relief with occasional rocky ridges. Muskeg is the dominant vegetation, but willow shrubs exist in riparian areas and black spruce are found in valley depressions where wind exposure is reduced.

The Project is accessed in the winter by a 120 km long winter road, the Winter Access Road, which extends from the Tibbitt-to-Contwoyto Winter Road at MacKay Lake to Kennady Lake. The Winter Access Road to Kennady Lake crosses Reid, Munn, Margaret and Murdock lakes as well as a large number of smaller lakes and streams. The Winter Access Road typically operates for less than 70 days each year between November and March. The Project can also be accessed by air in winter, and by float plane in summer.

9.3.2 Surface Water Quantity

This section describes the hydrological conditions downstream of the Kennady Lake watershed.

For additional baseline details, including a summary of regional background climate conditions, the reader is referred to EIS Annex H (Climate and Hydrology Baseline) and Addendum HH (Additional Climate and Hydrology Baseline Information).

9.3.2.1 Methods

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

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

Due to the paucity of long-term regional hydrometric stations, the unreliability of applying regional data to small, local watersheds with variable storage and lake outlet geometry, and the short periods of record for hydrometric stations at the project, a water balance model was developed to derive long-term mean characteristics and variability for key waterbodies.

9.3.2.2 Results

The local drainage network from Kennady Lake to the downstream limit of the Local Study Area (LSA) at the outlet of Kirk Lake is shown in Figure 9.3-2. The general characteristics of component watersheds are summarized in Table 9.3-1. The drainage direction from Kennady Lake is northward, and passes through the L watershed, M watershed, Lake 410, P watershed, and finally Kirk Lake. The drainage from Kirk Lake passes through the Q watershed before entering Aylmer Lake. The N watershed is adjacent to the Kennady Lake watershed, and also drains to Lake 410. Watersheds within the LSA have lake surface fractions of up to 30%, and the hydrology of these watersheds is dominated by lake storage and evaporation.

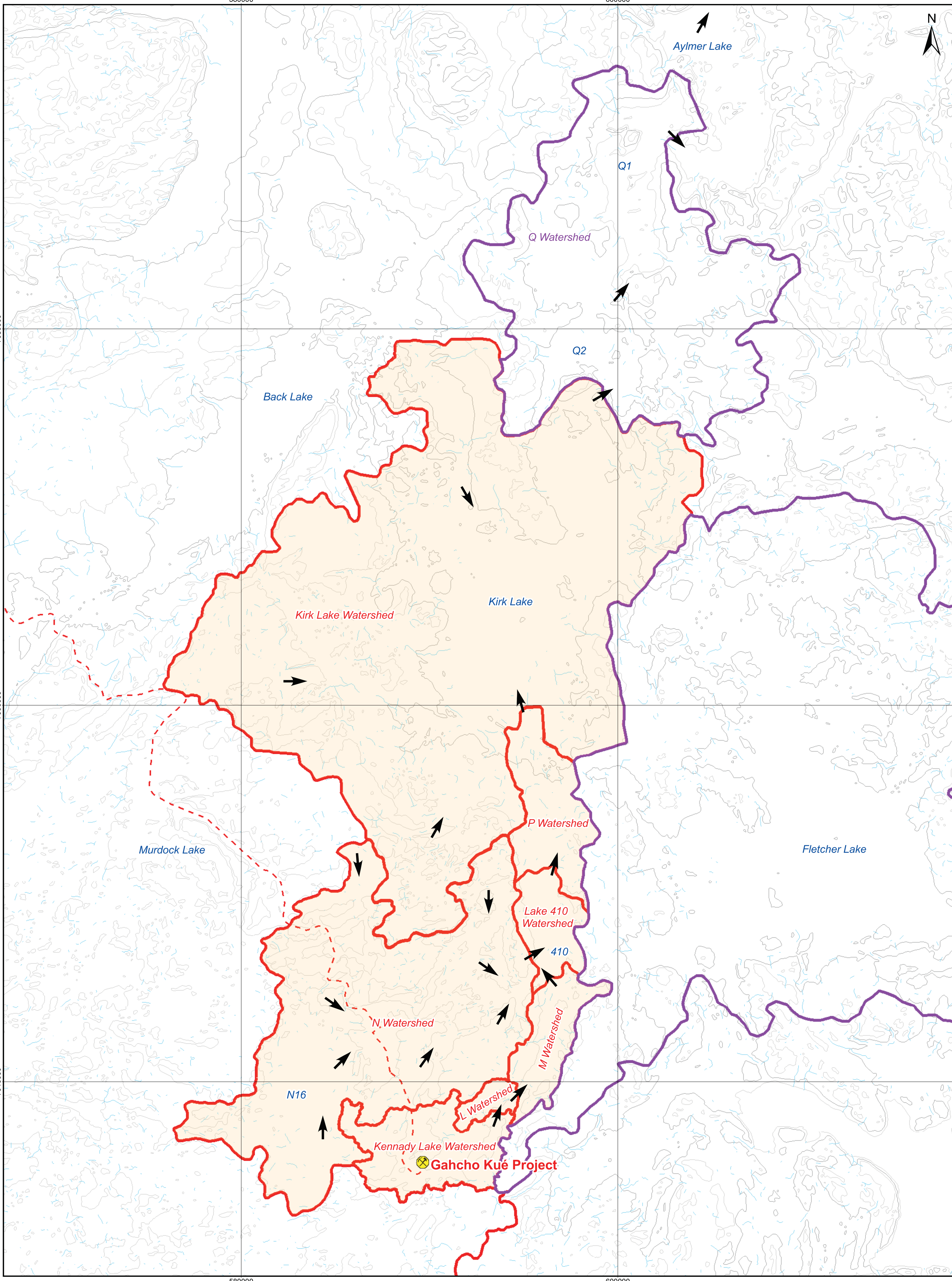
Table 9.3-1 Local Study Area Watershed Area Summary

Watershed or Sub-watershed	Land Surface Area (km^2)	Lake Surface Area (km^2)	Total Area (km^2)	Lake Surface Fraction
L	25.2	12.3	37.5	0.329
M	40.7	16.0	56.7	0.282
N2	12.2	3.64	15.8	0.230
N	129	53.9	183	0.295
Lake 410	179	76.7	256	0.300
P	203	81.9	284	0.288
Kirk Lake	527	212	739	0.286
Q	670	267	937	0.285

km^2 = square kilometres.

9.3.2.2.1 Stream Geomorphology

Lakes comprise greater than 25% of the landscape within the LSA 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 (greater than 12) and moderate sinuosity (S) (greater than 1.2). Most lake outlet channels in the LSA 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.



LEGEND

- Gahcho Kué Project
- Winter Access Road
- Watercourse
- Waterbody
- Index Contour (100m interval)
- Intermediate Contour (20m interval)
- Local Study Area
- Watershed Boundary
- Adjacent Watershed
- Drainage Direction

NOTES
Base data source: National Topographic Base Data (NTDB) 1:250,000

GAHCHO KUÉ PROJECT

Local Study Area Watersheds

PROJECTION: UTM Zone 12	DATUM: NAD83	
Scale: 1:200,000 (2.5 1.25 0 2.5 5 Kilometres)		DE BEERS CANADA
FILE No: B_Hydro-013-GIS		DATE: October 21, 2010
JOB NO: 09-1365-1004	REVISION NO: 3	**Figure 9.3-2**
OFFICE: GOLD-CAL	DRAWN: JH / CHECK: NS	

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The beds of larger channels are typically armoured with unerodible bedrock or boulder layers. 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 millimetres (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 material resting on a boulder substrate.

Erosion resistance of channel banks is also likely enhanced by frozen conditions during spring snowmelt peak discharges, 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. The Lake N11 outlet channel is an exception to this observation, where channel banks are naturally armoured with boulders, bedrock, and till.

Channels at the outlets of small, headwater lakes may be poorly defined and flow through organic substrates, mostly without the cobble and boulder bed typical of the medium to larger channels described for the other watersheds. For instance, the Lake N13 outlet has no defined channel, with discharge appearing to flow through a vegetated mat along numerous flow paths, with occasional pools of open water. Although there may be some cobble and boulder substrate 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 lake outlet channel characteristics in the LSA downstream of Kennady Lake is shown in Table 9.3-2.

Table 9.3-2 Lake Outlet Channel Data Downstream of Kennady Lake

Outlet Channel	Watershed Area (km^2)	Length (m)	Elevation Drop (m)	Slope	Channel Type
L3	32.7	463	1.360	0.003	well-defined with boulder bed, shallow and wide, with sub- and side channels present
L2	36.3	300	1.640	0.005	
L1b	37.2	85	0.655	0.008	
L1a	37.5	346	4.408	0.013	
M4	45.1	305	0.916	0.003	
M3	52.6	216	0.297	0.001	
M2	54.2	211	0.555	0.003	
M1	56.7	237	0.283	0.001	
Total/Mean	**56.7**	**2163**	**10.114**	**0.005**	–
N13	0.25	141	2.260	0.016	poorly defined
N12	3.89	481	4.160	0.009	poorly defined
N14	0.98	500	2.051	0.004	well-defined, bed and banks of organics and fine-grained soil

Table 9.3-2 Lake Outlet Channel Data Downstream of Kennady Lake (continued)

Outlet Channel	Watershed Area (km^2)	Length (m)	Elevation Drop (m)	Slope	Channel Type
N17	18.8	348	0.255	0.001	well-defined
N16	52.9	276	no data	no data	well-defined
N15	53.7	382	no data	no data	well-defined
N18	1.63	538	8.1	0.015	some well-defined channel but much flow through boulder garden and subsurface
N11	115	174	4.5	0.026	well-defined; banks armoured and bedrock bed control
Total/Mean	**115**	-[(a)]	-	-	-
Lake 410	256	193	1.615	0.008	wide with numerous small islands
Total/Mean	**256**	**193**	**1.615**	**0.008**	-
P8b	266	300	1.000	0.003	wide with numerous small islands
P8a	266	121	1.897	0.016	
P7		96	1.991	0.021	
P6b	275	200	0.535	0.003	
P6a	275	712	4.610	0.006	
P5	279	575	1.708	0.003	
P4	280	233	2.936	0.013	
P3 west (via P2)	284	1200	7.649	0.006	wide with numerous small islands; 80% of flow
P3 east (via P1)	284	1700	7.649	0.004	wide with numerous small islands; 20% of flow
Total/Mean (excl. P3 east)	284	**3630**	**23.941**	**0.007**	–
Kirk Lake	739	900	3	0.003	pool and riffle with stable boulder bed and banks

[(a)] Total not calculated, as the streams are not contiguous.

km^2 = square kilometres; m = metres; % = percent; – = not applicable.

9.3.2.2.2 Ice and Winter Flows

Winter Conditions

Data and observations of ice conditions and winter flows in the LSA are summarized in Table 9.3-3. Only limited field data collection was performed, because Project effects on winter flows are expected to be small. Data are not available for the ice thickness of most lakes surveyed in 2004 and 2005, except for Lake N1, which had 1.7 m of ice in 2004, and Lake N1 and Lake N2, both which had approximately 1.8 m ice cover in 2005. Ice surface and water levels for lakes downstream of the Kennady Lake watershed typically had no data available. However, Lake N1 had an ice surface level approximately 15 centimetres (cm) higher than the water levels, indicating a floating ice cover with some snow load.

All lake outlets that were examined, except for Lake N11 and Lake N1, were consistently observed to be completely frozen, with no measurable flow during the winter. This appears to be the typical winter condition for all lakes downstream of the Kennady Lake watershed, and also for all smaller lakes downstream to Kirk Lake. Both Lake N1, and its major tributary Lake N11, appear to have a combination of discharge volume and outlet characteristics that allows flow to be sustained over the winter. Lake N11 appears to be the lake farthest upstream within the local drainage network that flows through the winter, as evidenced by the absence of winter inflows from the upstream Lake N16.

Winter flows from Lake N1 into Lake 410 were observed to disappear under the Lake 410 ice cover rather than flowing onto the ice surface, indicating that surface icing (aufeis formation) did not occur. Most winter outflows from Lake N1 appear to be stored in Lake 410.

Table 9.3-3 Lake Ice and Winter Water Levels and Outlet Flow Conditions in the LSA, 2004 and 2005

Lake	Date	Ice Thickness (m)	Ice Level (m)[a]	Water Level (m)[a]	Outlet Condition
L1	May 2004	no data	8.384	ice to bottom	frozen, no flow
	April 2005	(>1.1)	no data	ice to bottom	frozen, no flow
M4, M3, M2	May 2004	no data	no data	no data	frozen, no flow
M2	January 2005	no data	no data	no data	aerial observation showed no open water
M1	May 2004	(>1.2)	no data	ice to bottom	frozen, no flow
	January 2005	no data	no data	no data	aerial observation showed no open water
N16	April 2005	no data	no data	no data	frozen, no flow
N7, N6, N5, N4, N3, N2	May 2004	no data	no data	no data	frozen, no flow
N6	April 2005	(>1.2)	no data	ice to bottom	frozen, no flow
N2	April 2005	1.86	no data	8.479	frozen, no flow
N11	April 2005	no data	no data	no data	aerial observation showed open water at the outlet and also collapsed and cracked ice cover at two locations at narrows in Lake N11
N1	May 2004	1.72	8.153	8.013	some open water, flow
	January 2005	no data	no data	no data	some open water, flow
	April 2005	1.80	no data	8.014	some open water, flow
P Lakes	May 2004	no data	no data	no data	aerial observation showed no open water
P3	January 2005	no data	no data	no data	aerial observation showed no open water

[a] Local datum.

m = metres; > = greater than.

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. Notable dates relating to the start of runoff for the monitoring stations for 2004 and 2005 are presented in Table 9.3-4.

Table 9.3-4 Runoff Start-up Dates in the LSA, 2004 and 2005

Location	Year	Start of Runoff	First Discharge Measurement	Runoff Peak
Lake L1a	2004	June 1	June 3	June 12
	2005	June 3	June 5	June 11
Lake N2	2004	June 10	June 11	June 12
	2005	June 6	June 8	June 8
Lake N1	2004	continuous	June 2	June 21
	2005	continuous	June 4	June 21
Lake N6	2005	June 5	June 4	June 9
Lake N16	2005	June 5	June 6	June 22
Kirk Lake	2005	continuous	June 3	July 11

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:

- Lakes L1a, N2, and N6 typically discharge to about the end of October;
- Lake N16 and Lake 410 typically discharge to the end of December;
- all lakes in the P watershed discharge to the end of December; and
- Lake N11, N1, and Kirk Lake typically discharge through the winter.

9.3.2.2.3 Mean Water Balance

A mean annual water balance for a typical watershed in the Kennady Lake area was developed based on the mean values of the various parameters, on a hydrological year basis. The example of Lake L1 is presented in Table 9.3-5 to provide a basic characterization for mean conditions.

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.

Table 9.3-5 Representative Watershed (Lake L1) 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.

9.3.2.2.4 Lake Outlet Flow Regimes

Frequency analysis of the hydrology model results (floods and droughts) for lake outflows of interest at lakes downstream of the Project site were 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 are presented for selected lakes (i.e., L1, N18, N11, N1, Lake 410, and Kirk Lake). Results for additional lakes, and for maximum and minimum daily outflow volumes, are presented in Annex H and Addendum HH.

Lake L1

Results for Lake L1 are presented in Table 9.3-6 (mean daily outflow volumes) and Table 9.3-7 (long duration floods and low flow discharges).

Table 9.3-6 Derived Mean Daily Outflow at Lake L1

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	31,500	130,000	111,000	67,700	85,000	20,600
	50	19,700	122,000	102,000	60,900	67,400	16,700
	20	10,500	112,000	90,500	52,200	49,900	12,200
	10	6,380	102,000	81,400	45,700	38,900	9,240
	5	3,370	90,600	70,300	38,400	28,300	6,650
Median	2	998	67,800	52,300	28,100	16,400	3,630
Dry	5	0	47,200	36,700	20,200	10,300	2,090
	10	0	35,700	29,300	17,100	8,310	1,620
	20	0	26,800	23,900	14,900	7,210	1,330
	50	0	16,500	18,100	12,700	6,250	1,100
	100	0	10,700	14,200	11,300	5,750	976

m^3/d = cubic metres per day.

Table 9.3-7 Derived Representative Discharges at Lake L1

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. 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	2.62	214,000	189,000	57,000	63,400	76,800
	50	2.54	208,000	184,000	48,400	55,600	69,300
	20	2.40	197,000	174,000	38,300	45,900	59,500
	10	2.25	185,000	164,000	31,300	38,900	51,900
	5	2.05	168,000	150,000	24,700	32,000	44,100
Median	2	1.59	131,000	119,000	16,100	22,400	32,500
Dry	5	1.12	93,300	85,600	9,990	15,500	23,500
	10	0.86	71,700	66,800	7,980	13,000	19,900
	20	0.63	53,500	50,800	6,870	11,500	17,700
	50	0.39	33,200	32,800	6,090	10,400	15,800
	100	0.23	20,000	21,000	5,770	9,970	15,000

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

Lake N18

Results for Lake N18 are presented in Table 9.3-8 (mean daily outflow volumes) and Table 9.3-9 (long duration floods and low flow discharges).

Table 9.3-8 Derived Mean Daily Outflow at Lake N18

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	5,020	8,440	4,240	3,380	5,600	255
	50	3,290	7,940	3,810	2,920	4,020	207
	20	1,820	7,190	3,230	2,330	2,430	148
	10	1,110	6,550	2,780	1,900	1,560	107
	5	623	5,800	2,290	1,480	902	68
Median	2	184	4,420	1,530	896	308	18
Dry	5	0	3,130	951	519	95	0
	10	0	2,490	704	378	45	0
	20	0	1,970	524	283	20	0
	50	0	1,400	344	196	3	0
	100	0	1,040	237	147	0	0

m^3/d = cubic metres per day.

Table 9.3-9 Derived Representative Discharges at Lake N18

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. 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	0.20	15,000	12,900	3,210	3,100	2,890
	50	0.19	14,200	12,100	2,410	2,570	2,570
	20	0.17	12,900	11,100	1,570	1,930	2,140
	10	0.16	11,900	10,100	1,070	1,500	1,820
	5	0.14	10,600	9,070	665	1,110	1,490
Median	2	0.11	8,390	7,130	259	620	990
Dry	5	0.09	6,300	5,330	89	351	636
	10	0.07	5,260	4,450	44	263	493
	20	0.06	4,430	3,750	19	208	393
	50	0.05	3,530	2,980	1	160	296
	100	0.04	2,950	2,490	0	136	239

Q = discharge; m^3/s = cubic metres per second; m^3/d = cubic metres per day; - = not applicable.

Lake N11

Results for Lake N11 are presented in Table 9.3-10 (mean daily outflow volumes) and Table 9.3-11 (long duration floods and low flow discharges).

Table 9.3-10 Derived Mean Daily Outflow at Lake N11

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	236,000	443,000	293,000	221,000	258,000	50,700
	50	149,000	425,000	270,000	197,000	206,000	43,300
	20	79,600	392,000	239,000	168,000	155,000	34,400
	10	48,900	359,000	215,000	147,000	123,000	28,200
	5	25,900	327,000	186,000	124,000	91,800	22,300
Median	2	7,610	257,000	141,000	91,400	56,800	14,700
Dry	5	0	191,000	101,000	68,100	39,100	10,300
	10	0	155,000	83,600	58,800	33,300	8,740
	20	0	126,000	70,200	52,600	30,100	7,750
	50	0	92,800	56,300	46,400	27,400	6,870
	100	0	71,900	46,900	42,600	25,900	6,400

m^3/d = cubic metres per day.

Table 9.3-11 Derived Representative Discharges at Lake N11

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. 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	9.77	747,000	630,000	179,000	198,000	215,000
	50	9.38	718,000	608,000	154,000	175,000	196,000
	20	8.78	672,000	572,000	124,000	146,000	171,000
	10	8.22	630,000	538,000	102,000	125,000	152,000
	5	7.50	576,000	495,000	82,000	104,000	131,000
Median	2	6.00	464,000	404,000	55,500	75,000	98,700
Dry	5	4.32	339,000	300,000	39,500	55,700	74,400
	10	3.36	269,000	240,000	33,900	48,500	64,200
	20	2.53	208,000	188,000	30,200	43,600	56,800
	50	1.54	135,000	125,000	27,000	39,100	49,600
	100	0.85	85,300	81,700	25,200	36,500	45,200

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

Lake N1

Results for Lake N1 are presented in Table 9.3-12 (mean daily outflow volumes) and Table 9.3-13 (long duration floods and low flow discharges).

Table 9.3-12 Derived Mean Daily Outflow at Lake N1

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	444,000	737,000	470,000	370,000	398,000	84,100
	50	284,000	704,000	436,000	333,000	333,000	72,300
	20	153,000	654,000	387,000	285,000	256,000	57,800
	10	91,000	609,000	348,000	248,000	204,000	47,600
	5	49,700	554,000	303,000	211,000	157,000	37,900
Median	2	13,900	444,000	229,000	156,000	99,000	25,100
Dry	5	0	331,000	166,000	117,000	67,100	17,300
	10	0	270,000	138,000	102,000	56,600	14,600
	20	0	219,000	116,000	91,400	50,100	12,800
	50	0	161,000	93,400	81,200	44,500	11,200
	100	0	121,000	79,300	75,400	41,600	10,300

m^3/d = cubic metres per day.

Table 9.3-13 Derived Representative Discharges at Lake N1

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. 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	25.90	1,250,000	1,050,000	285,000	333,000	353,000
	50	24.20	1,210,000	1,010,000	249,000	295,000	323,000
	20	21.90	1,140,000	960,000	204,000	247,000	283,000
	10	19.90	1,080,000	910,000	171,000	212,000	251,000
	5	17.60	997,000	845,000	139,000	177,000	218,000
Median	2	13.50	827,000	704,000	95,600	128,000	166,000
Dry	5	9.94	636,000	539,000	67,600	95,900	126,000
	10	8.22	527,000	441,000	57,200	83,800	109,000
	20	6.87	432,000	354,000	50,300	75,600	96,500
	50	5.43	320,000	249,000	44,000	68,000	84,400
	100	4.51	242,000	174,000	40,500	63,800	77,100

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

Lake 410

Results for Lake 410 are presented in Table 9.3-14 (mean daily outflow volumes) and Table 9.3-15 (long duration floods and low flow discharges).

Table 9.3-14 Derived Mean Daily Outflow at Lake 410

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	402,000	934,000	678,000	475,000	587,000	135,000
	50	248,000	891,000	633,000	432,000	477,000	114,000
	20	128,000	823,000	569,000	374,000	355,000	88,500
	10	73,800	759,000	514,000	329,000	278,000	70,700
	5	39,000	681,000	452,000	282,000	211,000	54,000
Median	2	10,300	537,000	344,000	210,000	135,000	32,700
Dry	5	0	399,000	249,000	155,000	91,000	20,300
	10	0	329,000	203,000	132,000	73,900	16,000
	20	0	275,000	168,000	116,000	63,200	13,300
	50	0	222,000	130,000	99,700	54,200	10,900
	100	0	190,000	106,000	90,100	49,800	9,660

m^3/d = cubic metres per day.

Table 9.3-15 Derived Representative Discharges at Lake 410

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. 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	20.00	1,420,000	1,240,000	404,000	443,000	491,000
	50	19.10	1,380,000	1,200,000	351,000	395,000	451,000
	20	17.70	1,300,000	1,140,000	285,000	333,000	398,000
	10	16.50	1,230,000	1,080,000	237,000	287,000	355,000
	5	14.90	1,140,000	1,000,000	191,000	240,000	308,000
Median	2	11.90	942,000	837,000	128,000	173,000	234,000
Dry	5	8.78	713,000	640,000	88,700	126,000	175,000
	10	7.11	580,000	523,000	74,200	108,000	150,000
	20	5.71	462,000	418,000	64,600	96,000	131,000
	50	4.11	319,000	290,000	55,800	84,200	112,000
	100	3.03	219,000	200,000	50,900	77,500	100,000

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

Kirk Lake

Results for Kirk Lake are presented in Table 9.3-16 (mean daily outflow volumes) and Table 9.3-17 (long duration floods and low flow discharges).

Table 9.3-16 Derived Monthly Mean Outflow at Kirk Lake

Condition	Return Period (years)	Monthly Mean Outflow (m^3/d)					
		May	June	July	August	September	October
Wet	100	641,000	1,850,000	1,730,000	1,250,000	1,370,000	420,000
	50	410,000	1,740,000	1,650,000	1,150,000	1,120,000	337,000
	20	220,000	1,590,000	1,530,000	1,020,000	852,000	246,000
	10	131,000	1,450,000	1,420,000	916,000	676,000	188,000
	5	72,000	1,290,000	1,290,000	796,000	520,000	137,000
Median	2	20,400	995,000	1,020,000	596,000	332,000	75,700
Dry	5	0	708,000	752,000	427,000	208,000	37,700
	10	0	562,000	607,000	349,000	161,000	24,500
	20	0	443,000	486,000	290,000	130,000	16,100
	50	0	312,000	348,000	229,000	101,000	8,710
	100	0	226,000	255,000	191,000	85,200	4,760

m^3/d = cubic metres per day.

Table 9.3-17 Derived Representative Discharges at Kirk Lake

Condition	Return Period (years)	Peak Daily Q (m^3/s)	7-Day Avg. Peak Q (m^3/d)	14-Day Avg. 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	25.50	2,160,000	2,100,000	1,050,000	1,140,000	1,290,000
	50	24.70	2,100,000	2,040,000	925,000	1,030,000	1,210,000
	20	23.40	1,990,000	1,940,000	759,000	887,000	1,080,000
	10	22.10	1,890,000	1,850,000	636,000	774,000	981,000
	5	20.50	1,760,000	1,720,000	512,000	654,000	864,000
Median	2	17.10	1,460,000	1,440,000	333,000	467,000	660,000
Dry	5	13.00	1,110,000	1,090,000	211,000	323,000	480,000
	10	10.60	902,000	884,000	163,000	262,000	395,000
	20	8.44	714,000	694,000	131,000	218,000	328,000
	50	5.83	485,000	459,000	99,700	174,000	258,000
	100	3.98	321,000	290,000	82,100	148,000	213,000

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

Lockhart River

A frequency analysis was performed on data from the Water Survey of Canada hydrometric station on the Lockhart River at the Outlet of Artillery Lake (Station 07RD001). This examined annual flood and low flow discharges (mean daily flows) and annual water yields. The results of this analysis are presented in Table 9.3-18.

Table 9.3-18 Frequency Analysis Results for Lockhart River Hydrometric Station

Condition	Return Period (years)	Annual Flood (m^3/s)	Annual Low Flow (m^3/s)	Annual Water Yield (mm)
Wet	100	301	-	217
	50	282	-	209
	20	254	-	196
	10	232	-	185
	5	208	-	172
Median	2	168	78.0	146
Dry	5	-	64.9	122
	10	-	57.9	108
	20	-	52.0	97.3
	50	-	45.3	84.9
	100	-	40.7	76.6

m^3/s = cubic metres per second; mm = millimetre; - = not applicable.

9.3.3 Surface Water and Sediment Quality

The following section provides an overview of the baseline surface water quality and sediment quality for streams and lakes downstream of the Kennady Lake 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 (Additional Water Quality Baseline Information).

9.3.3.1 Methods

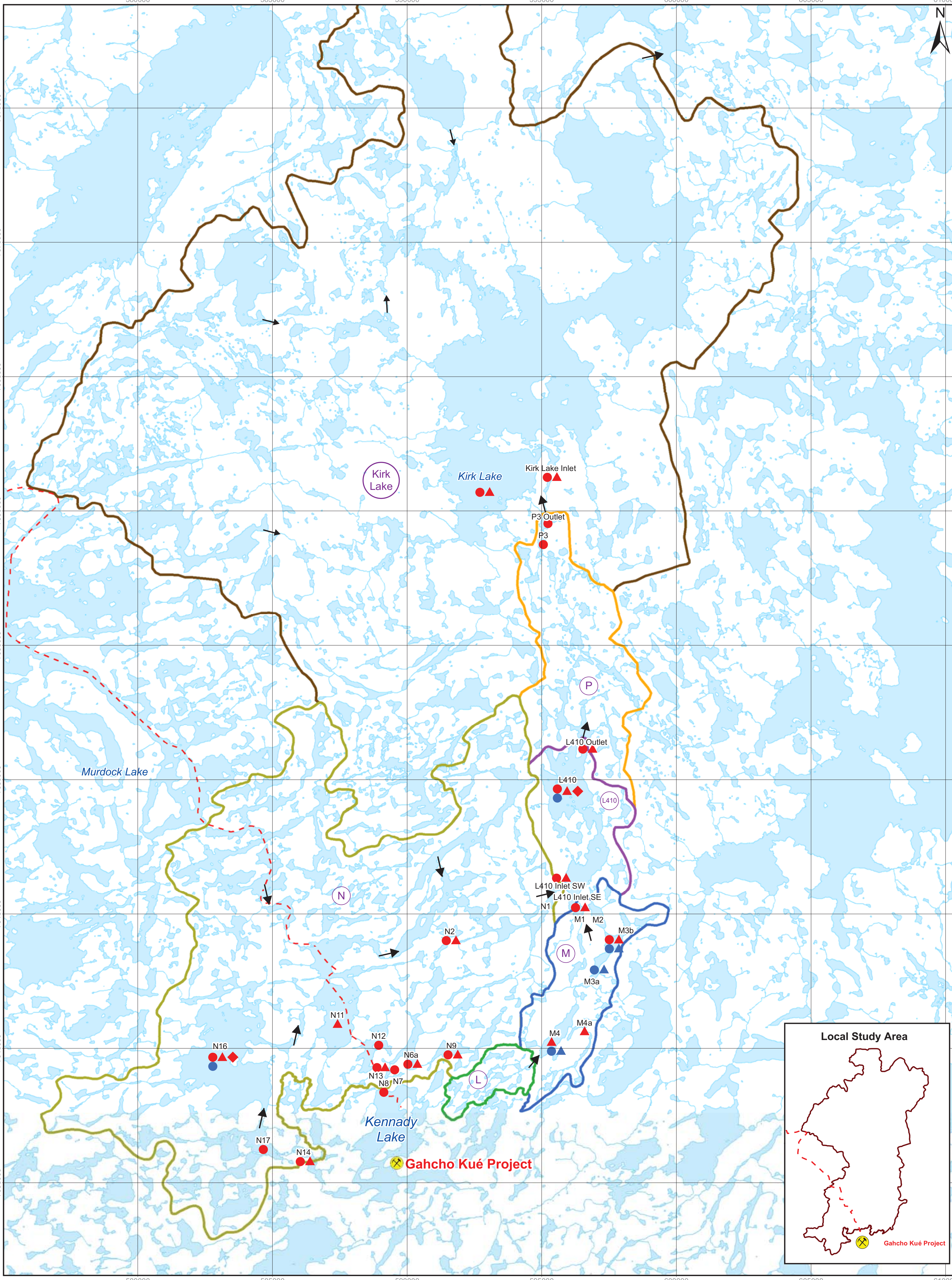
9.3.3.1.1 Location and Timing of Sampling

The baseline sampling programs involved the collection of water and sediment samples from waterbodies downstream of Kennady Lake to the inlet basin of Kirk Lake. Several baseline field programs have been conducted in areas downstream of the Kennady Lake watershed since 1998. The location and timing for each sampled stream and lake is denoted for each water or sediment sample collected. These are represented in Figure 9.3-3 using different symbols:

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

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 samples. 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.



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LEGEND

- Gahcho Kué Project
- Winter Access Road
- Watercourse
- Waterbody
- N8 Lake Identifier
- Flow Direction

Watershed Boundary

- Watershed L
- Watershed M
- Watershed N
- Lake 410 Watershed
- Watershed P
- Kirk Lake Watershed
- M Watershed Identifier

Open Water

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

SEASON, SampleType

- 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 Streams and Lakes Downstream of Kennady Lake to Kirk Lake Outlet

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:140,000 (2 1 0 2 Kilometres)	
FILE No: E-SWQ-004-GIS	DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: CW · CHECK: JF

DE BEERS CANADA

Figure 9.3-3

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 the 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 1999a, with updates to 2010) and Health Canada Guidelines for Canadian Drinking Water Quality Guidelines (CDWQG) (Health Canada 2008). The results of the sediment sampling programs were compared to the CCME Interim Sediment Quality Guidelines (ISQG) for the protection of aquatic life (CCME 1999b, with updates to 2002).

The CWQG and ISQG are intended to protect aquatic life, including the most sensitive species, for the long-term (CCME 1999a, CCME 1999b). They are based on toxicity tests of the effects on sensitive aquatic species and tend to be conservative in nature.

9.3.3.2 Results

9.3.3.2.1 The Interlakes - Lakes Immediately Downstream of Kennady Lake

Physical Limnology and Vertical Structure

Under-ice Conditions

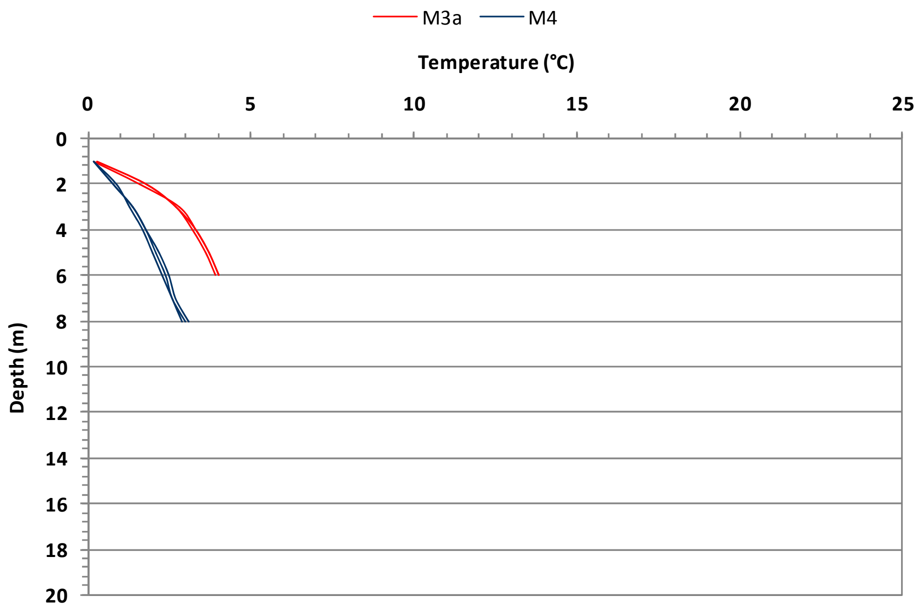
During under-ice conditions, Lakes M3 and M4 exhibited inverse thermal gradients. Cooler waters approaching 0 degrees Celsius (°C) occurred immediately below the ice, with temperatures gradually increasing with depth to a maximum temperature around 4°C (Figure 9.3-4a). The maximum temperatures occurred generally at near-bottom depths.

Concentrations of dissolved oxygen (DO) ranged from 14 to 21 milligrams per litre (mg/L) in the upper 2 m of the water column near the ice-water interface and decreased with depth to less than the lower CWQG for cold water aquatic life (i.e., 6.5 mg/L for other life stages) (Figure 9.3-4b). Water column DO trends in Lakes M3 and M4 were similar to DO profiles measured in Kennady Lake under-ice conditions. However, DO concentrations did not reach the under-ice anoxic conditions measured in the deeper waters of Kennady Lake.

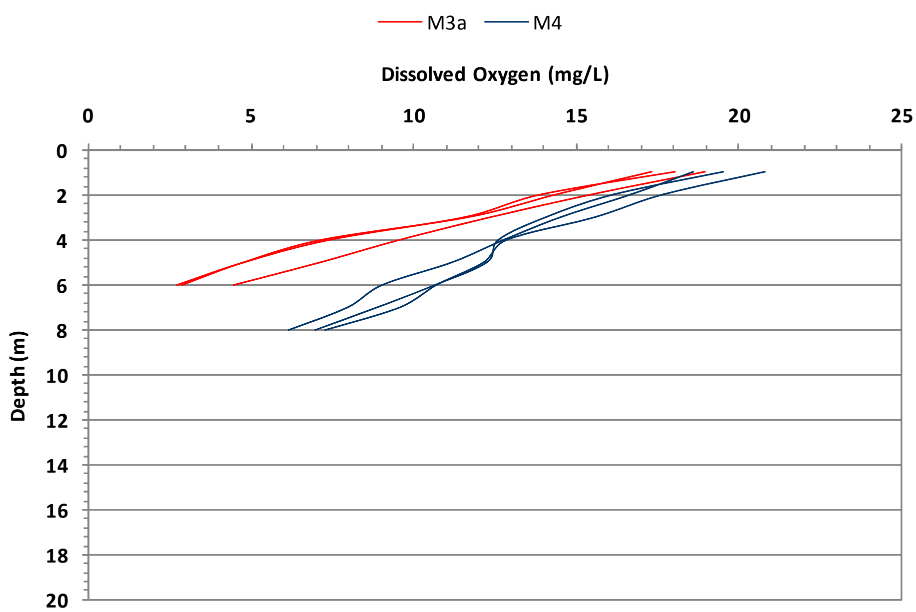
Field measurements of conductivity and pH were not collected during under-ice conditions from lakes in the L and M watersheds. Laboratory measurements of conductivity and pH for water samples collected from these lakes during under-ice conditions had conductivity values that ranged between 9 to 24 microSiemens per centimetre (μS/cm) and pH values that ranged between 6.1 to 6.6 pH units (Table 9.3-19). Some pH readings were below the acceptable CWQG and CDWQG ranges.

Figure 9.3-4 Physico-chemical Water Quality Profile Data for Water Temperature and Dissolved Oxygen for the Interlakes during Under-ice Conditions (1998 to 2010)

a) Water Temperature



b) Dissolved Oxygen



m = metre, °C = degrees Celsius.

Individual field results not presented in field profile figures.

Table 9.3-19 Water Quality Data Summary for the Interlakes Downstream of Kennady Lake, 1998 to 2010

Parameter Name	Unit	Method Detection Limit			Under-ice Conditions (1998-2004)						Guidelines				Open Water Conditions (1996-2010)						Guidelines			
											Aquatic Life-Chronic [a]		Human Health-Chronic [b]								Aquatic Life-Chronic [a]		Human Health-Chronic [b]	
		Min	Max	Number of MDL	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	-	-	0	0	-	-	-	0	-	6.5-8.5	0	5.0-9.0	0	48	**6.2**[c]	**6.4**[c]	8.3	0	0	6.5-8.5	28	5.0-9.0	0
Temperature	°C	-	-	0	54	0.2	2.2	4	0	0	-	0	-	0	85	10	13	18	0	0	-	0	-	0
Conductivity	µS/cm	-	-	0	0	-	-	-	0	-	-	0	-	0	85	10	13	14	0	0	-	0	-	0
Dissolved Oxygen	mg/L	-	-	0	54	**2.7**[c]	12	21	0	0	6.5	9	-	0	71	**0.7**[c]	9.3	12	0	0	6.5	1	-	0
Conventional Parameters																								
Colour	TCU	-	-	0	0	-	-	-	0	-	-	0	-	0	3	10	20	30	0	0	-	0	-	0
Conductivity	µS/cm	-	-	0	14	9	21	24	0	0	-	0	-	0	7	13	16	25	0	0	-	0	-	0
Dissolved Organic Carbon	mg/L	-	-	0	0	-	-	-	0		-	0	-	0	5	4	4	6	0	0	-	0	-	0
Hardness	mg/L	6	6	1	14	3.3	7	9	0	0	-	0	-	0	8	0.5	3.8	7	3	37.5	-	0	-	0
pH	pH units	-	-	0	14	**6.1**[c]	6.4	6.6	0	0	6.5-8.5	7	5.0-9.0	0	7	**6.1**[c]	6.6	6.8	0	0	6.5-8.5	3	5.0-9.0	0
Total Alkalinity	mg/L	5	5	1	14	2	8	8	0	0	-	0	-	0	10	2.5	7.5	30	2	20	-	0	-	0
Total Dissolved Solids	mg/L	10	10	1	2	22	-	39	0	0	-	0	-	0	8	24	26	35	3	37.5	-	0	-	0
Total Organic Carbon	mg/L	-	-	0	12	5	6	6.6	0	0	-	0	-	0	5	3	4.1	6	0	0	-	0	-	0
Total Suspended Solids	mg/L	1	3	3	14	<1	-	<3	14	100	-	0	-	0	5	<3	-	3	3	60	-	0	-	0
Major Ions																								
Bicarbonate	mg/L	5	5	1	12	9	10	10	0	0	-	0	-	0	10	2.5	9.4	36	2	20	-	0	-	0
Calcium	mg/L	-	-	0	14	0.73	1.7	2.1	0	0	-	0	-	0	7	1	1	1.9	0	0	-	0	-	0
Carbonate	mg/L	-	5	3	12	<5	-	<5	12	100	-	0	-	0	10	<0.5	-	<5	10	100	-	0	-	0
Chloride	mg/L	0.5	1	2	14	<0.5	-	1	11	78.6	230	0	-	0	10	0.2	0.6	1	6	60	230	0	-	0
Magnesium	mg/L	-	-	0	14	0.35	0.7	0.9	0	0	-	0	-	0	7	0.34	0.5	0.62	0	0	-	0	-	0
Potassium	mg/L	-	-	0	14	0.44	0.6	0.8	0	0	-	0	-	0	7	0.35	0.41	0.5	0	0	-	0	-	0
Sodium	mg/L	1	1	1	14	0.41	1.1	1.3	0	0	-	0	-	0	7	0.5	0.57	3	2	28.6	-	0	-	0
Sulphate	mg/L	1	1	1	14	0.5	1.3	1.4	1	7.1	-	0	-	0	10	<1	1.1	1.3	4	40	-	0	-	0
Sulphide	µg/L	2	2	1	0	-	-	-	0	-	5.6	0	-	0	2	<2	-	<2	2	100	2.3	0	-	0
Nutrients																								
Nitrate + Nitrite	mg N/L	0.003	0.006	2	12	0.02	0.037	0.14	5	41.7	2.93	0	10	0	4	<0.003	-	<0.006	4	100	2.93	0	10	0
Nitrogen-Ammonia	mg N/L	0.05	0.1	2	14	0.009	0.018	0.1	0	0	5	0	-	0	8	<0.05	-	<0.1	8	100	26	0	-	0
Nitrogen-Kjeldahl	mg N/L	0.2	0.2	1	0	-	-	-	0	-	-	0	-	0	3	<0.2	-	<0.2	3	100	-	0	-	0
Phosphorus, total	mg/L	0.02	0.3	4	2	<0.3	-	<0.3	2	100	0.05	0	-	0	9	<0.02	-	0.005	7	77.8	-	0	-	0
Phosphorus, dissolved	mg/L	0.005	0.3	2	2	<0.3	-	<0.3	2	100	-	0	-	0	5	0.003	-	0.003	3	60	-	0	-	0
General Organics																								
Total Phenolics	µg/L	2	2	1	0	-	-	-	0	-	5	0	-	0	2	<2	-	<2	2	100	5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	0	-	-	-	0	-	-	0	-	0	5	<0.1	-	<2	5	100	-	0	-	0
Total Metals[e]																								
Aluminum	µg/L	20	20	1	14	20	26	83	0	0	100	0	100	0	11	15	18	**170**[c, H]	6	54.5	100	2	100	2
Antimony	µg/L	0.02	1	5	14	0.025	0.09	0.48	2	14.3	-	0	5.5	0	11	<0.02	-	<1	11	100	-	0	5.5	0
Arsenic	µg/L	0.4	1	2	14	0.08	0.13	0.18	0	0	5	0	10	0	11	<0.4	-	0.15	8	72.7	5	0	10	0
Barium	µg/L	5	5	1	14	2.2	2.9	3.9	0	0	-	0	1000	0	11	1.6	2.5	6.7	3	27.3	-	0	1000	0
Beryllium	µg/L	0.01	1	4	14	<0.2	-	<0.5	14	100	-	0	4	0	11	<0.01	-	<1	11	100	-	0	4	0
Boron	µg/L	8	20	3	14	2	2	3	0	0	-	0	5000	0	11	<8	-	2	10	90.9	-	0	5000	0
Cadmium	µg/L	0.002	0.2	4	14	<0.05	-	<0.05	14	100	0.0034	0	5	0	13	<0.002	-	**0.017**[c]	11	84.6	0.002	2	5	0
Chromium	µg/L	0.06	5	6	14	0.08	0.095	0.1	8	57.1	1	0	50	0	11	<0.1	-	<5	11	100	1	0	50	0
Cobalt	µg/L	0.1	0.5	2	14	<0.1	-	0.8	10	71.4	-	0	-	0	11	0.025	0.11	0.3	7	63.6	-	0	-	0
Copper	µg/L	5	5	1	14	0.8	1	**48**[c]	0	0	2	2	1300	0	11	0.5	0.63	**4**[c]	6	54.5	2	1	1300	0
Iron	µg/L	50	50	1	14	18	46	260	0	0	300	0	300	0	9	25	74	184	1	11.1	300	0	300	0
Lead	µg/L	0.05	0.5	3	14	<0.05	-	0.1	13	92.9	1	0	10	0	11	<0.05	-	0.037	9	81.8	1	0	10	0
Lithium	µg/L	0.1	20	3	14	0.05	1	1.3	4	28.6	-	0	-	0	6	1	1.1	1.1	3	50	-	0	-	0
Manganese	µg/L	-	-	0	14	1.1	6.1	31	0	0	-	0	50	0	9	2	2.8	5	0	0	-	0	50	0
Mercury	µg/L	0.0006	500	6	14	<0.01	-	<0.02	14	100	0.026	0	1	0	10	<0.0006	-	0.008	8	80	0.026	0	1	0
Molybdenum	µg/L	0.05	5	4	14	<0.05	-	<0.06	14	100	73	0	-	0	11	<0.05	-	0.2	9	81.8	73	0	-	0
Nickel	µg/L	0.6	8	2	14	0.22	0.5	1.4	0	0	25	0	340	0	11	0.2	0.51	2.1	5	45.5	25	0	340	0
Selenium	µg/L	0.04	10	5	14	<0.1	-	<1	14	100	1	0	10	0	11	<0.04	-	<10	11	100	1	0	10	0

Table 9.3-19 Water Quality Data Summary for the Interlakes Downstream of Kennady Lake, 1998 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Under-ice Conditions (1998-2004)										Open Water Conditions (1996-2010)									
											Guidelines										Guidelines			
											Aquatic Life-Chronic [a]		Human Health-Chronic [b]								Aquatic Life-Chronic [a]		Human Health-Chronic [b]	
		Min	Max	Number of MDL	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
Silver	µg/L	0.01	0.4	4	14	<0.01	-	<0.1	14	100	0.1	0	-	0	13	<0.01	-	0.0028	9	69.2	0.1	0	-	0
Strontium	µg/L	-	-	0	14	4.4	8.8	11	0	0	-	0	-	0	8	5	6.4	12	0	0	-	0	-	0
Sulphur	µg/L	10000	10000	1	0	-	-	-	0	-	-	0	-	0	5	400	400	500	2	40	-	0	-	0
Thallium	µg/L	0.002	0.1	3	2	<0.05	-	<0.05	2	100	0.8	0	0.13	0	11	<0.002	-	<0.1	11	100	0.8	0	0.13	0
Titanium	µg/L	0.5	10	3	2	<10	-	<10	2	100	-	0	-	0	8	3	3	3	5	62.5	-	0	-	0
Uranium	µg/L	0.05	0.1	2	14	<0.05	-	0.06	12	85.7	-	0	-	0	10	<0.05	-	0.013	8	80	-	0	-	0
Vanadium	µg/L	0.05	5	5	14	<0.05	-	<1	14	100	-	0	-	0	11	<0.1	-	0.6	8	72.7	-	0	-	0
Zinc	µg/L	0.8	2	3	14	0.8	1.7	3	5	35.7	30	0	5100	0	11	0.5	4	30	3	27.3	30	0	5100	0
Dissolved Metals[e]																								
Aluminum	µg/L	-	-	0	14	17	24	71	0	0	-	0	-	0	5	12	13	28	0	0	-	0	-	0
Antimony	µg/L	0.05	0.1	2	14	0.025	0.09	0.32	2	14.3	-	0	-	0	5	0.03	-	0.03	3	60	-	0	-	0
Arsenic	µg/L	0.1	0.1	1	14	0.09	0.15	0.29	0	0	-	0	-	0	5	0.13	0.13	0.2	2	40	-	0	-	0
Barium	µg/L	3	3	1	14	2.2	2.8	3.9	0	0	-	0	-	0	5	2.2	-	2.2	3	60	-	0	-	0
Beryllium	µg/L	0.01	0.5	4	14	<0.2	-	<0.5	14	100	-	0	-	0	5	<0.01	-	<0.1	5	100	-	0	-	0
Boron	µg/L	4	20	2	14	1	2	3	0	0	-	0	-	0	5	<4	-	<20	5	100	-	0	-	0
Cadmium	µg/L	0.005	0.05	2	14	<0.05	-	<0.05	14	100	-	0	-	0	5	<0.005	-	<0.05	5	100	-	0	-	0
Chromium	µg/L	0.06	0.5	4	14	0.07	0.12	0.15	6	42.9	-	0	-	0	5	<0.1	-	<0.4	5	100	-	0	-	0
Cobalt	µg/L	0.05	0.1	2	14	<0.1	-	0.7	11	78.6	-	0	-	0	5	0.31	-	0.31	3	60	-	0	-	0
Copper	µg/L	2	2	1	14	0.8	1.1	39	0	0	-	0	-	0	5	0.86	-	0.86	3	60	-	0	-	0
Iron	µg/L	-	-	0	14	15	36	200	0	0	-	0	-	0	5	20	39	99	0	0	-	0	-	0
Lead	µg/L	0.05	0.05	1	14	<0.05	-	<0.05	14	100	-	0	-	0	5	0.038	0.038	0.52	2	40	-	0	-	0
Lithium	µg/L	0.1	1	2	14	0.05	1	1.3	4	28.6	-	0	-	0	2	1	-	1	0	0	-	0	-	0
Manganese	µg/L	-	-	0	14	0.4	5.7	27	0	0	-	0	-	0	5	1.2	1.3	3.7	0	0	-	0	-	0
Mercury	µg/L	0.01	1	3	14	<0.01	-	<0.02	14	100	-	0	-	0	5	0.007	-	0.007	3	60	-	0	-	0
Molybdenum	µg/L	0.05	0.3	3	14	<0.05	-	<0.06	14	100	-	0	-	0	5	<0.05	-	<0.3	5	100	-	0	-	0
Nickel	µg/L	-	-	0	14	0.18	0.58	1.3	0	0	-	0	-	0	5	0.2	0.4	0.42	0	0	-	0	-	0
Selenium	µg/L	0.04	2	3	14	<0.1	-	0.1	13	92.9	-	0	-	0	5	<0.04	-	<2	5	100	-	0	-	0
Silver	µg/L	0.005	0.1	4	14	<0.01	-	<0.1	14	100	-	0	-	0	5	<0.005	-	5	4	80	-	0	-	0
Strontium	µg/L	-	-	0	14	4.3	9	11	0	0	-	0	-	0	2	6.2	-	6.2	0	0	-	0	-	0
Sulphur	µg/L	10000	10000	1	0	-	-	-	0	-	-	0	-	0	2	<10000	-	<10000	2	100	-	0	-	0
Thallium	µg/L	0.002	0.05	3	2	<0.05	-	<0.05	2	100	-	0	-	0	5	<0.002	-	<0.02	5	100	-	0	-	0
Titanium	µg/L	0.5	10	2	2	<10	-	<10	2	100	-	0	-	0	2	<0.5	-	<0.5	2	100	-	0	-	0
Uranium	µg/L	0.05	0.05	1	14	<0.05	-	0.05	12	85.7	-	0	-	0	5	0.012	-	0.012	3	60	-	0	-	0
Vanadium	µg/L	0.05	1	4	14	<0.05	-	0.15	13	92.9	-	0	-	0	5	<0.2	-	<0.5	5	100	-	0	-	0
Zinc	µg/L	0.8	2	2	14	0.4	2	7.4	1	7.1	-	0	-	0	5	0.9	0.9	3	2	40	-	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 1999a, 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.
(H) 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, 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; MDL = method detection limits

Open Water Conditions

Water column profile measurements for temperature were collected in August of 2002 and 2005 from Lakes L4, L14, L15, L21, M3, and M4 (Figure 9.3-5a). The lakes had near surface temperatures ranging from 13 to 18°C. The lakes exhibited well mixed conditions, by temperature-related, density-driven overturn in spring and fall, as well as wind-driven circulation during summer months in some of the shallow lakes. Stratified conditions, with seasonal thermoclines (steep temperature gradients), were observed between depths of 2 and 6 m in Lakes M3, M4, and L21 (Figure 9.3-5a).

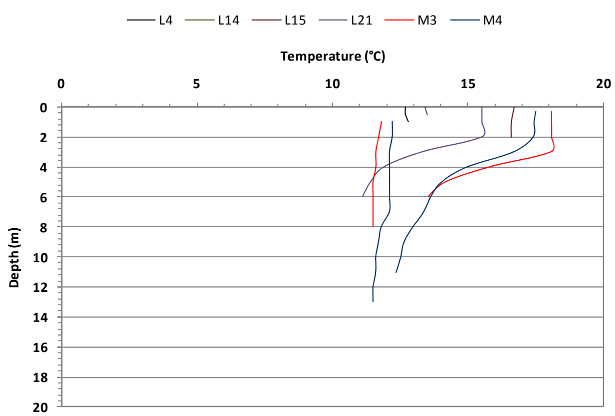
Vertical conductivity profile measurements through the water column during open water conditions were low, ranging between 11 and 14 µS/cm in the L and M lakes (Figure 9.3-5b). Despite the occurrence of a pronounced seasonal thermocline, little variability in conductivity was evident throughout the water column indicating that total dissolved solids (TDS) were equally distributed throughout the lakes.

With the exception of one lake, vertical DO concentrations through the water column in open water conditions in the L and M lakes ranged between 8.5 and 9.8 mg/L, and were generally uniform with depth (Figure 9.3-5c). The DO concentrations measured during most sampling events were above the lowest acceptable dissolved oxygen concentration for the protection of cold water aquatic life (i.e., other life stages [6.5 mg/L]) in the CWQG. The exception was Lake L21 measured in August, where DO decreased rapidly below the thermocline at 2 m to near anoxia at the bottom of the water column (i.e., 6 m).

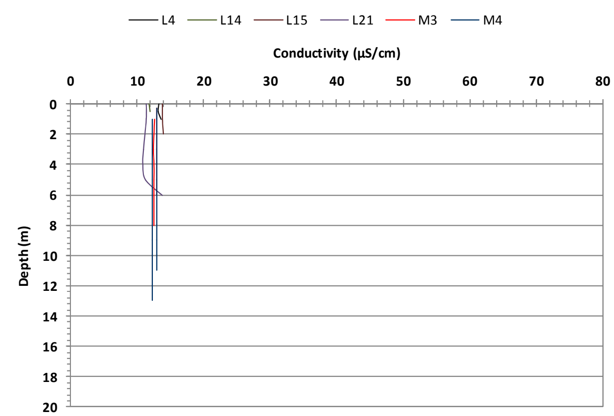
Open water pH measurements through the water column in the M lakes ranged between 6.2 and 6.6 (Figure 9.3-5d). Some of the pH values measured were below the acceptable pH range of the CWQG (6.5 to 8.5) (Figure 9.3-5d). Field water column profile data for pH were not collected for the L lakes.

Figure 9.3-5 Physico-chemical Field Data for the Interlakes (L and M Lakes) during Open Water Conditions Open Water Interlakes Field Data (1998 to 2010)

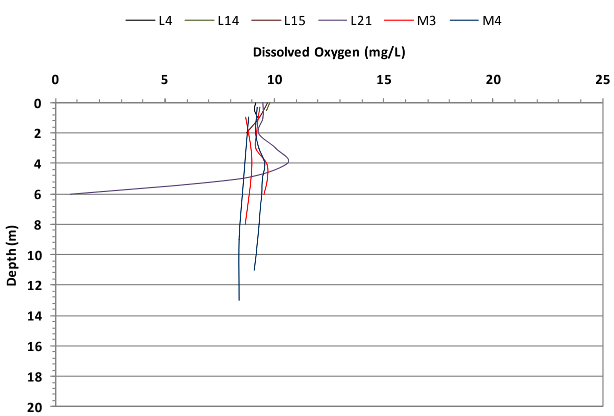
a) Water Temperature



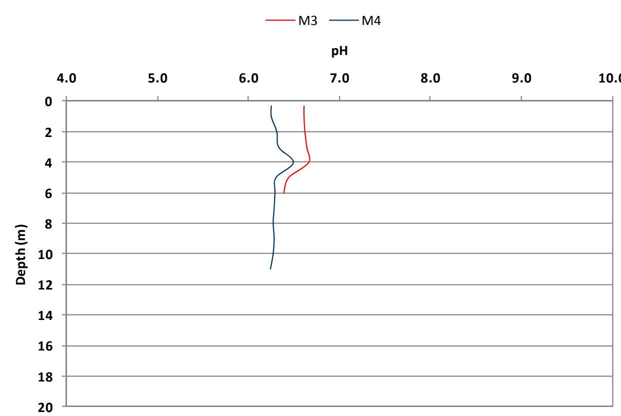
b) Conductivity



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 interlakes watershed (i.e., L and M watersheds) contribute to the loading of substances to downstream lakes, the water quality similarities and differences are discussed for all surveyed lakes. The available data for all lakes in the L and M watershed are presented in Table 9.3-19.

The water in the interlakes (the L and M lakes watersheds) is soft, having a median hardness of 7 mg/L during under-ice conditions and 3.8 mg/L during open water conditions (Table 9.3-19). The median alkalinity during both under-ice and open water conditions, which is also 8 and 7.5 mg/L, respectively, is also low and an indication of the low buffering capacity of water in these lakes.

The concentrations of TDS were low during under-ice and open water conditions, with values ranging between 22 and 39 mg/L, indicating a small amount of dissolved substances in the water (Table 9.3-19). Bicarbonate was the dominant ion measured during both seasonal sampling conditions, whereas sulphate and chloride were at or below the detection limit during most sampling events. Calcium was the major cation measured in the L and M lakes.

Water in the L and M lakes is very clear and contains very little suspended particulate matter. Total suspended solids (TSS) were not detected during under-ice conditions (Table 9.3-19), and were at, or below, detection limits during open water conditions (i.e., 60% of samples were below detection limits; Table 9.3-19).

The concentrations of inorganic nitrogen compounds, such as ammonia, nitrate, and nitrite, generally were below detection during open water conditions (Table 9.3-19). Total Kjeldahl nitrogen (TKN) was measured below detection limits during ice-covered and open water conditions. Most total phosphorus (TP) concentrations were at, or below, detection during under-ice and open water conditions; due to the limited number of samples and the number of results below detection, a median TP concentration could not be calculated. The measured concentrations of nitrogen and phosphorus nutrients indicate that the L and M lakes can be classed as oligotrophic.

Levels of total organic carbon (TOC) and dissolved organic carbon (DOC) were low (3 to 6 mg/L) during both open water and under-ice conditions (Table 9.3-19). Colour was measured in open water conditions at levels above the CDWQG of 15 true colour units (TCU). Phenol and petroleum hydrocarbons were 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 9.3-19). 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, cadmium, and copper. The median concentrations of dissolved metals were similar to the total fraction.

Sediment Quality

Baseline sediment quality for the Interlakes is limited to sediment samples collected from Lake M3 and Lake M4 in July 2010.

Sediment from the M lakes was mainly composed of sand, with some silt and clay (Table 9.3-20). The total carbon (TC) content ranged from 11 to 14% of the sediment composition, with TOC comprising the majority of the sediment carbon (i.e., 10% to 13%). Inorganic carbon constituted less than 0.9%.

Available phosphorus concentrations in the sediment samples were low, ranging from 5 to 9 micrograms per gram (µg/g) dry weight (Table 9.3-20). Total sediment phosphorus and sediment nitrogen concentrations were not available for the Interlakes.

Total petroleum hydrocarbon (TPH) compounds were not detected in the sediment samples collected from Lakes M3 and M4.

Concentrations of metals in the sediment were generally within the applicable aquatic life guidelines (CCME 1999b) (Table 9.3-20); however, arsenic, chromium, cadmium, copper and zinc exceeded the interim sediment quality guidelines (ISQG) in one or both M lakes.

Table 9.3-20 Sediment Quality Data Summary for Lakes in the M Watershed, in 2010

Parameter	Unit	Method Detection Limit		Lake M3	Lake M4	ISQG
		Minimum	Maximum			
Particle Size and Carbon Content						
Sand	%	2	2	64	51	-
Silt	%	2	2	26	36	-
Clay	%	2	2	10	13	-
Total Inorganic Carbon	%	0.02	0.02	0.89	0.6	-
Total Organic Carbon	%	0.02	0.2	13	10	-
Total Carbon	%	0.02	0.2	14	11	-
Nutrients and Organics						
Available Phosphorus	µg/g	1	2	5	9	-
Total Petroleum Hydrocarbons	µg/g	500	600	<600	<500	-
Total Metals						
Arsenic	µg/g	1	1	**10**	**7**	5.9
Barium	µg/g	10	10	84	100	-
Cadmium	µg/g	0.1	0.1	0.5	**1**	0.6

Table 9.3-20 Sediment Quality Data Summary for Lakes in the M Watershed (continued)

Parameter	Unit	Method Detection Limit		Lake M3	Lake M4	ISQG
		Minimum	Maximum			
Chromium	µg/g	1	1	**42**	**60**	37.3
Cobalt	µg/g	1	1	29	18	-
Copper	µg/g	5	5	**62**	**85**	35.7
Lead	µg/g	1	1	7	7	35
Mercury	µg/g	0.05	0.05	0.13	0.08	0.17
Molybdenum	µg/g	0.4	0.4	4.6	6.4	-
Nickel	µg/g	1	1	39	45	-
Potassium	µg/g	2	4	82	50	-
Selenium	µg/g	0.5	0.5	0.9	1.5	-
Thallium	µg/g	0.3	0.3	<0.3	<0.3	-
Vanadium	µg/g	1	1	48	65	-
Zinc	µg/g	10	10	**130**	**150**	123

Note: **Bolded** numbers identify values above guidelines.
ISQG = Interim Sediment Quality Guideline (CCME 1999b, with updates to 2002).% = percent; µg/g = micrograms per gram, dry weight;-= not applicable.

9.3.3.2.2 Lakes in the N Watershed

Physical Limnology and Vertical Structure

Vertical profile physico-chemical data were collected from Lake N16 during both open water and ice-covered conditions in 2004, 2005, and 2010. In-situ spot measurements for physico-chemical data were collected from several other lakes in the N watershed, but were limited to open water conditions.

Under-ice Conditions

A vertical temperature profile measured for Lake N16 in 2004 showed that the lake was inversely stratified in winter conditions (Figure 9.3-6). The temperature increased from 1°C at the ice-water interface to 2°C at depths of 6 m and greater.

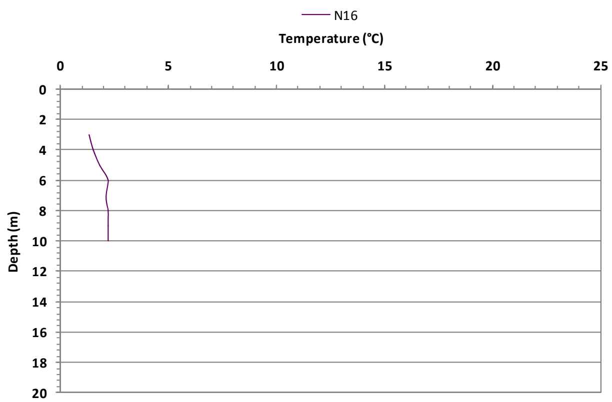
The vertical conductivity profile measurements were low, ranging from 8 µS/cm at the ice-water interface to 11 µS/cm at a depth of 10 m (Figure 9.3-6). The little variability through the water column indicated that the TDS was generally equally distributed through the water column.

The concentration of DO through the water column varied only slightly between the ice-water interface to 8 m depth, below which the DO rapidly reduced to anoxic levels (Figure 9.3-6). Above 6 m, the DO concentrations were below the lowest acceptable guideline for early life stages of cold water fish (9.5 mg/L) but above the guidelines for other life (6.5 mg/L). Low DO concentrations during under-ice conditions are a common feature of northern lakes, and have been routinely measured in other lakes within the study area.

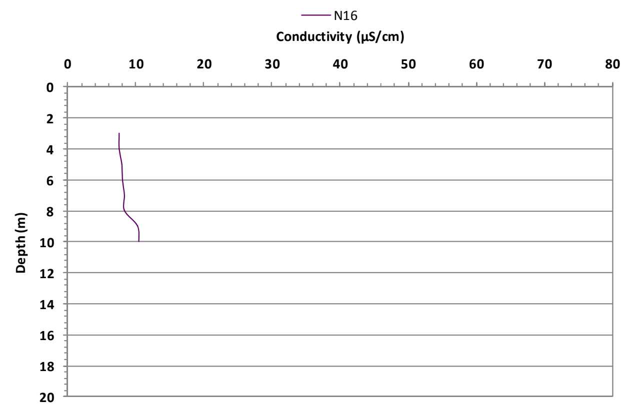
Vertical pH profile measurements and in-situ spot pH measurements were not collected during under-ice conditions from lakes in the N watershed.

Figure 9.3-6 Physico-chemical Field Data for Lakes in the N Watershed during Under-ice Conditions (2004)

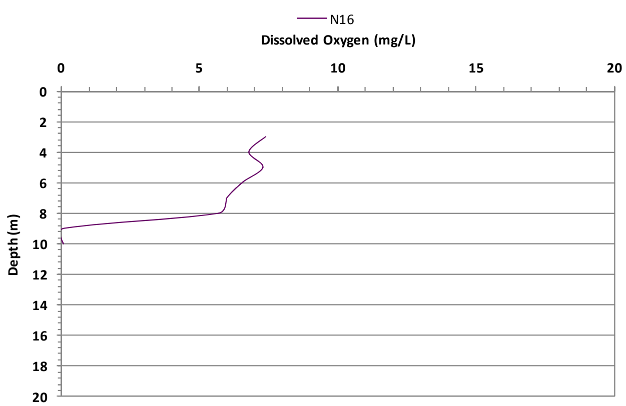
a) Water Temperature



b) Conductivity



c) Dissolved Oxygen



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

Open Water Conditions

Vertical physico-chemical profile measurements were collected from Lake N16 in August 2004 and July 2010 (Figure 9.3-7). In-situ field measurements were collected from Lakes N2, N6a, and N7.

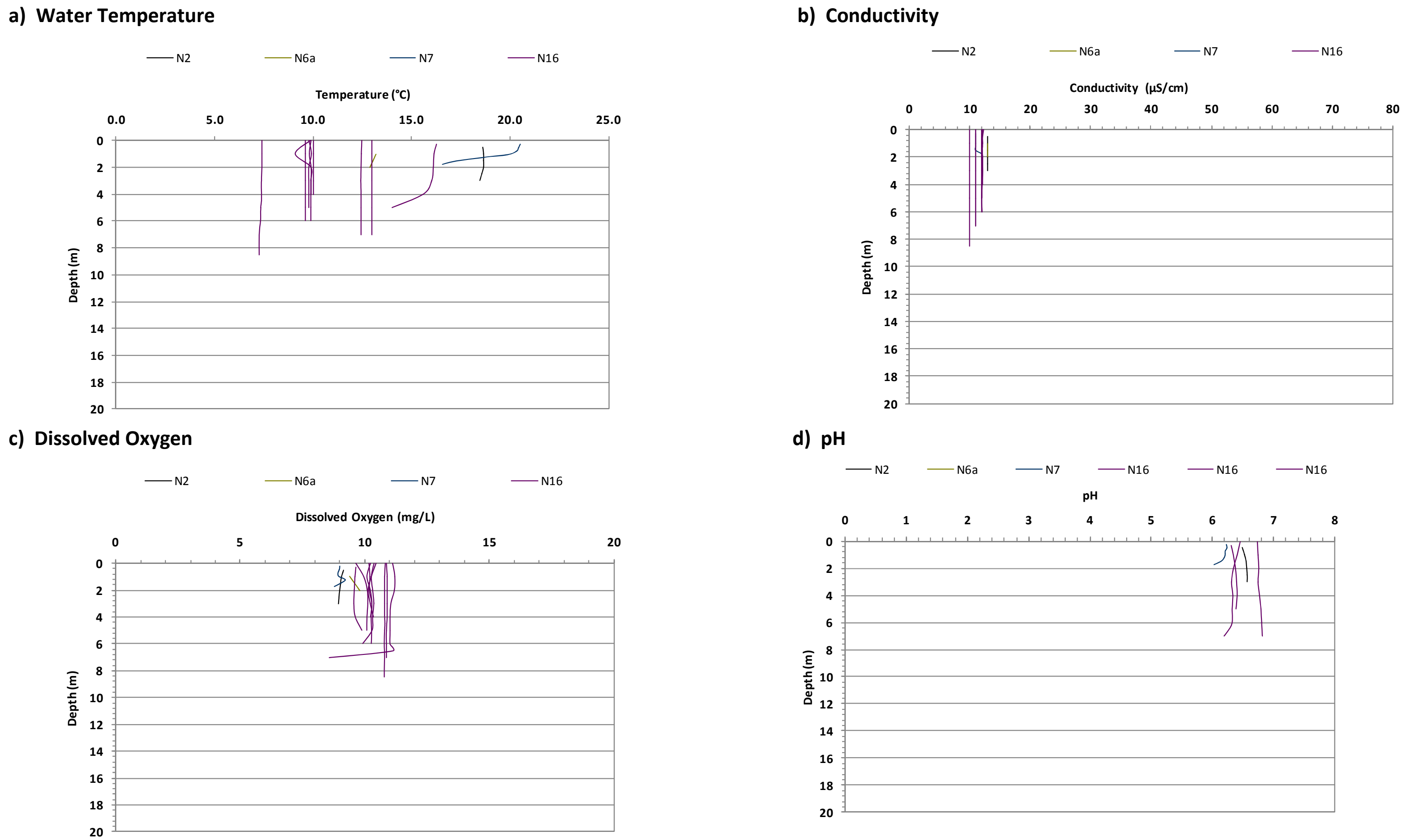
Vertical temperature profiles from Lake N16 indicated that the lake was well-mixed, with near surface temperatures that ranged from approximately 7 to 16°C. Near surface temperatures measured in other lakes in the N watershed varied between 19 and 21°C at the time of measurement. Seasonal thermoclines (steep temperature gradients) were measured in Lake N16 and Lake N7 in July 2010, just below the water surface (Figure 9.3-7a). The temperature gradients were between 2 and 4°C per metre.

Measured conductivity during open water conditions was very low, ranging between 10 and 12 µS/cm (Figure 9.3-7b). There was very little variability throughout the water column indicating that total dissolved solids (TDS) were equally distributed and that the lake was well mixed during open water conditions.

Dissolved oxygen concentrations were generally homogenous throughout the water column of Lake N16, concentrations ranging from 9 and 11 mg/L (Figure 9.3-7c). The DO concentrations in the surface waters of other lakes in the N watershed varied between 9 and 9.5 mg/L. The DO concentrations measured during most sampling events were above the CWQG for DO concentrations applicable to the protection of early life stages (9.5 mg/L) and other life stages (6.5 mg/L) of cold water aquatic life.

Vertical profiles of pH in Lake N16 showed only small variability throughout the water column. The values for Lake N16 were below the acceptable CWQG and CDWQG range, as were some in-situ measurements collected from other lakes in the watershed, which ranged between 6.0 and 6.8 pH units. Some of the lakes were slightly more acidic than Kennady Lake.

Figure 9.3-7 Physico-chemical Field Data for Lakes in the N Watershed during Open Water Conditions (1998 to 2010)



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 lakes within the N lakes watershed contribute to the loading of substances from the N watershed to Lake 410. The water quality data from samples collected from each of the N lakes surveyed are discussed for all surveyed lakes grouped together. The available data for the sample lakes in the N lakes watershed are presented in Table 9.3-21.

Baseline water quality information for lakes in the N lakes watershed was limited to samples collected during open water conditions. Lakes included in baseline surveys between 1995 and 2010 were Lakes N2, N6a, N7, N9, N11, N13, N14, and N16 (Figure 9.3-3).

The water in the N lakes is soft, having a median hardness of 4 mg/L during open water conditions (Table 9.3-21). The median total alkalinity during open water ice conditions is also 4 mg/L, indicating a low buffering capacity of water in these lakes.

The concentrations of TDS were low, but variable among the lakes during open water (5 to 52 mg/L), with a median concentration of 16 mg/L (Table 9.3-21). Bicarbonate was the dominant anion in most lakes and the major contributor to TDS. Sulphate and chloride were observed within the range recorded for the Kennady Lake watershed. Calcium and sodium were the major cations.

Concentrations of TSS were generally measured below detection limits in the N lakes during open water conditions (Table 9.3-21). Approximately 61% of open water samples were measured below detection. The highest measurement of TSS was 10 mg/L.

Low levels of nutrients were measured in samples collected from the N lakes (Table 9.3-21). Most concentrations of nitrate+nitrite were measured at, or below, detection during open water conditions (i.e., 9 of 10 samples below the detection limit of 0.003 mg/L). Ammonia concentrations were more variable, ranging from below detection to 0.22 mg N/L, with 71% of the samples measured below detection. Two of the five total Kjeldahl nitrogen (TKN) samples were above the detection limit of 0.2 mg N/L during open water conditions (i.e., values above detection were 0.3 and 0.4 mg N/L).

Table 9.3-21 Water Quality Data Summary for Lakes in the N Watershed, 1998 to 2010

Parameter Name	Unit	Method Detection Limit			Lakes in the N Watershed, 1998-2010									
					n	Minimum	Median	Maximum	Count Below Detection	% Below Detection	Guidelines			
											Aquatic Life-Chronic [(a)]		Human Health-Chronic [(b)]	
		Minimum	Maximum	Number of Method Detection Limits							Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Field measured														
pH	pH units	-	-	0	103	**6.4**[(c)]	**6.0**[(c)]	7.1	0	0	6.5-8.5	62	5.0-9.0	0
Temperature	°C	-	-	0	118	1.3	15	21	0	0	-	0	-	0
Specific Conductance	µS/cm	-	-	0	118	7	11	17	0	0	-	0	-	0
Dissolved Oxygen	mg/L	-	-	0	118	**0.06**[(c)]	9.6	13	0	0	6.5	5	-	0
Conventional Parameters														
Colour	TCU	1	1	1	12	0.5	10	30	3	25	-	0	-	0
Specific Conductance	µS/cm	-	-	0	31	8	12	24	0	0	-	0	-	0
Dissolved Organic Carbon	mg/L	-	-	0	22	2.8	4.8	9	0	0	-	0	-	0
Hardness	mg/L	6	6	1	21	3.9	4	5.3	12	57.1	-	0	-	0
pH	pH units	-	-	0	31	**5.5**[(c)]	**6.4**[(c)]	6.8	0	0	6.5-8.5	20	5.0-9.0	0
Total Alkalinity	mg/L	-	-	0	31	2	4	34	0	0	-	0	-	0
Total Dissolved Solids	mg/L	10	10	1	31	5	16	52	7	22.6	-	0	-	0
Total Organic Carbon	mg/L	-	-	0	28	2	4	8	0	0	-	0	-	0
Total Suspended Solids	mg/L	1	3	3	31	1	2	10	19	61.3	-	0	-	0
Major Ions														
Bicarbonate	mg/L	-	-	0	22	2.5	9	42	0	0	-	0	-	0
Calcium	mg/L	-	-	0	31	0.66	0.97	1.5	0	0	-	0	-	0
Carbonate	mg/L	0.5	1	2	22	<0.5	-	<1	22	100	-	0	-	0
Chloride	mg/L	0.1	1	3	31	0.1	0.4	1	17	54.8	230	0	-	0
Magnesium	mg/L	0.5	0.5	1	31	0.25	0.38	0.55	6	19.4	-	0	-	0
Potassium	mg/L	0.5	0.5	1	31	0.24	0.36	0.45	6	19.4	-	0	-	0
Sodium	mg/L	0.5	0.5	1	31	0.25	0.5	2.7	1	3.2	-	0	-	0
Sulphate	mg/L	0.5	1	2	31	0.6	1	1.6	18	58.1	-	0	-	0
Sulphide	µg/L	2	2	1	10	2	3	**4**[(c)]	5	50	2.3	3	-	0
Nutrients														
Nitrate + Nitrite	mg-N/L	0.003	0.003	1	10	<0.003	-	0.006	9	90	2.93	0	10	0
Nitrogen-Ammonia	mg-N/L	0.005	0.1	3	31	<0.005	-	0.22	22	71	23	0	-	0
Nitrogen-Kjeldahl	mg-N/L	0.2	0.2	1	5	0.3	-	0.4	3	60	-	0	-	0
Phosphorus, total	µg/L	5	300	3	31	5	6.5	118	19	61.3	-	2	-	0
Phosphorus, dissolved	mg/L	0.005	0.3	2	31	<0.005	-	0.007	21	67.7	-	0	-	0
General Organics														
Total Phenolics	µg/L	2	2	1	10	<2	-	3	9	90	5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	22	<0.1	-	24	18	81.8	-	0	-	0
Total Metals[(e)]														
Aluminum	µg/L	20	20	1	31	6	10	**482**[(c, H)]	6	19.4	100	1	100	1
Antimony	µg/L	0.02	0.1	3	31	<0.02	-	0.02	29	93.5	-	0	5.5	0
Arsenic	µg/L	0.1	0.4	2	31	0.09	0.13	0.4	20	64.5	5	0	10	1
Barium	µg/L	5	5	1	31	1.6	2.2	7	11	35.5	-	0	1000	0
Beryllium	µg/L	0.01	0.5	2	31	<0.01	-	<0.5	31	100	-	0	4	0
Boron	µg/L	10	20	2	31	<10	-	2	22	71	-	0	5000	0
Cadmium	µg/L	0.002	0.2	4	32	<0.002	-	**0.011**[(c)]	24	75	0.0021	7	5	0
Calcium	µg/L	1000	1000	1	31	380	940	3730	4	12.9	-	0	-	0

Table 9.3-21 Water Quality Summary for Lakes in the N Watershed, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lakes in the N Watershed, 1998-2010									
											Guidelines			
											Aquatic Life-Chronic (a)		Human Health-Chronic (b)	
		Minimum	Maximum	Number of Method Detection Limits	n	Minimum	Median	Maximum	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Chromium	µg/L	0.1	0.9	3	31	<0.1	-	**1.2**[c]	29	93.5	1	1	50	0
Cobalt	µg/L	0.1	0.1	1	31	0.019	0.037	0.3	17	54.8	-	0	-	0
Copper	µg/L	1	5	2	31	0.4	0.5	**7**[c]	9	29	2	2	1300	0
Iron	µg/L	10	50	3	31	18	67	250	11	35.5	300	0	300	0
Lead	µg/L	0.05	0.1	2	31	0.008	0.04	1	15	48.4	1	0	10	0
Lithium	µg/L	1	1	1	19	0.5	0.9	0.9	9	47.4	-	0	-	0
Magnesium	µg/L	500	500	1	31	310	391	620	11	35.5	-	0	-	0
Manganese	µg/L	3	3	1	31	1	3.6	26	1	3.2	-	0	50	0
Mercury	µg/L	0.0006	500	5	32	<0.0006	-	0.01	23	71.9	0.026	0	1	0
Molybdenum	µg/L	0.05	0.5	2	31	<0.05	-	0.06	30	96.8	73	0	-	0
Nickel	µg/L	0.6	0.6	1	31	0.15	0.3	1.3	8	25.8	25	0	340	0
Potassium	µg/L	500	500	1	31	300	370	460	12	38.7	-	0	-	0
Selenium	µg/L	0.04	10	4	31	<0.04	-	<10	31	100	1	0	10	0
Silver	µg/L	0.005	0.2	2	32	0.0005	0.0095	0.01	13	40.6	0.1	0	-	0
Sodium	µg/L	500	2000	2	31	360	420	620	12	38.7	-	0	-	0
Strontium	µg/L	-	-	0	19	4.3	6.1	8.2	0	0	-	0	-	0
Sulphur	µg/L	10000	10000	1	10	<10000	-	<10000	10	100	-	0	-	0
Thallium	µg/L	0.002	0.05	2	31	<0.002	-	0.05	22	71	0.8	0	0.13	0
Titanium	µg/L	0.5	0.5	1	19	10	10	10	10	52.6	-	0	-	0
Uranium	µg/L	0.05	0.05	1	31	0.003	0.01	0.08	11	35.5	-	0	-	0
Vanadium	µg/L	0.1	1	3	31	<0.1	-	1.4	24	77.4	-	0	-	0
Zinc	µg/L	1	2	2	31	0.6	2	14	11	35.5	30	0	5100	0
Dissolved Metals[e]														
Aluminum	µg/L	10	10	1	31	2.9	9.5	57	1	3.2	-	0	-	0
Antimony	µg/L	0.02	0.1	3	31	<0.02	-	0.09	22	71	-	0	-	0
Arsenic	µg/L	0.1	0.1	1	31	0.07	0.1	0.3	15	48.4	-	0	-	0
Barium	µg/L	3	3	1	31	1.5	2.1	3.7	12	38.7	-	0	-	0
Beryllium	µg/L	0.01	0.5	3	31	<0.01	-	0.1	28	90.3	-	0	-	0
Boron	µg/L	4	20	2	31	<4	-	2	22	71	-	0	-	0
Cadmium	µg/L	0.005	0.05	2	31	<0.005	-	0.13	29	93.5	-	0	-	0
Chromium	µg/L	0.1	0.4	2	31	<0.1	-	0.5	22	71	-	0	-	0
Cobalt	µg/L	0.05	0.1	2	31	0.025	0.1	1.6	9	29	-	0	-	0
Copper	µg/L	1	2	2	31	0.36	0.6	0.97	12	38.7	-	0	-	0
Iron	µg/L	1	30	3	31	0.5	20	1080	9	29	-	0	-	0
Lead	µg/L	0.005	0.05	2	31	<0.005	-	0.08	21	67.7	-	0	-	0
Lithium	µg/L	1	1	1	19	0.8	0.9	1.3	9	47.4	-	0	-	0
Manganese	µg/L	0.5	2	3	31	0.22	1.7	22	3	9.7	-	0	-	0
Mercury	µg/L	0.01	1	3	31	<0.01	-	0.009	21	67.7	-	0	-	0
Molybdenum	µg/L	0.05	0.3	2	31	<0.05	-	0.06	30	96.8	-	0	-	0
Nickel	µg/L	-	-	0	31	0.17	0.29	1.1	0	0	-	0	-	0
Selenium	µg/L	0.04	2	4	31	<0.04	-	<2	31	100	-	0	-	0
Silver	µg/L	0.005	0.05	3	31	<0.005	-	<0.05	31	100	-	0	-	0
Strontium	µg/L	-	-	0	19	4.1	6.1	8	0	0	-	0	-	0

Table 9.3-21 Water Quality Summary for Lakes in the N Watershed, 1995 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lakes in the N Watershed, 1998-2010									
											Guidelines			
											Aquatic Life-Chronic (a)		Human Health-Chronic (b)	
		Minimum	Maximum	Number of Method Detection Limits	n	Minimum	Median	Maximum	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count
Sulphur	µg/L	10000	10000	1	10	<10000	-	<10000	10	100	-	0	-	0
Thallium	µg/L	0.002	0.05	3	31	<0.002	-	0.003	28	90.3	-	0	-	0
Titanium	µg/L	0.5	10	2	19	<0.5	-	<10	19	100	-	0	-	0
Uranium	µg/L	0.01	0.05	2	31	0.004	0.01	0.025	18	58.1	-	0	-	0
Vanadium	µg/L	0.2	1	3	31	<0.2	-	<1	31	100	-	0	-	0
Zinc	µg/L	2	2	1	30	0.8	2	11	2	6.7	-	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 1999a, 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.
(H) 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, mg-N/L = milligrams nitrogen per litre, µg/L = micrograms per litre; TCU = True colour units; % = percent, n = number of samples, < = less than.

Total phosphorus concentrations were variable, with 61% measured below the detection limit. The median concentration was 0.0065 mg/L (6.5 μg/L). Dissolved phosphorus concentrations were near, or below, detection. The measured concentrations of nitrogen and phosphorus nutrients indicated that the lakes in the N watershed, like lakes in the Kennady Lake watershed, were typically oligotrophic.

Levels of TOC and DOC (<10 mg/L) were low during open water conditions (Table 9.3-21). Colour was measured at levels up to twice the CDWQG of 15 TCU (Table 9.3-21). Phenol and petroleum hydrocarbons were detected on few occasions (Table 9.3-21).

The concentrations of total and dissolved metals were typically low during open water conditions, with a range of metals near or below detection limits (e.g., cadmium, molybdenum, selenium and thallium) (Table 9.3-21). Exceedances of applicable guidelines were observed for total aluminum, cadmium, chromium, and copper. The median concentrations of many of the dissolved metals were similar to the total fraction.

Sediment Quality

Sediments collected from lakes within the N lakes watershed for sediment quality analyses were mainly composed of sand, with some silt and clay (Table 9.3-22). The total carbon (TC) content ranged from 0.4 to 18% of the sediment composition, with TOC comprising the majority of the sediment carbon (i.e., 0.4% to 17%). Inorganic carbon constituted less than 1.7%.

Total phosphorus was the dominant nutrient bound to the sediment, although the observed concentrations were variable (ranging from 458 to 997 μg/g dry weight) (Table 9.3-22). In comparison, available phosphorus concentrations ranged from 9 to 27 μg/g dry weight. Nitrate concentrations were low (maximum of 0.9 μg/g dry weight).

The TPH content in sediment from the N lakes was variable, ranging from 63 to 117 μg/g dry weight, with two values reporting below a higher detection limit (i.e., <600 μg/g) (Table 9.3-22). Hydrocarbons found in the sediment may be from natural sources, such as by-products associated with the decomposition of organic matter.

The predominant metals in the sediment included aluminum and iron (Table 9.3-22). Concentrations of metals in the sediment were generally within the applicable aquatic life guidelines; however, chromium, copper, and zinc concentrations were measured above the ISQG; the median copper concentrations was above the ISQG.

Table 9.3-22 Sediment Quality Data Summary for Lakes in the N Watershed

Parameter	Unit	Method Detection Limit		N Watershed							Guideline
		Min	Max	n	Min	Med	Max	Number Below Detection	% Below Detection	No. of Times a Guideline is Exceeded	ISQG
Texture and Carbon Content											
Sand	%	1	2	4	71	76.5	93	0	0	0	-
Silt	%	1	2	4	6	20	24	0	0	0	-
Clay	%	1	2	4	<1	3.5	5	1	25	0	-
Calcium Carbonate	%	0.005	0.005	2	0.114	0.14	0.167	0	0	0	-
Inorganic Carbon, Total	%	0.01	0.02	5	<0.01	0.94	1.69	1	20	0	-
Organic Carbon, Total	%	0.01	0.2	6	0.39	4.23	17	0	0	0	-
Carbon, Total	%	0.01	0.2	6	0.39	3.49	18	0	0	0	-
Nutrients and Organics											
Nitrate, Available	µg/g	0.5	0.5	2	<0.5	0.9	0.9	1	50	0	-
Phosphorus, Available	µg/g	1	1	4	9	17	27	0	0	0	-
Phosphorus, Total	µg/g	5	5	2	458	728	997	0	0	0	-
Total Petroleum Hydrocarbons	µg/g	8	600	4	63	90	<600	2	50	0	-
Total Metals											
Aluminum	µg/g	5	5	2	10900	11050	11200	0	0	0	-
Arsenic	µg/g	0.5	1	5	<0.5	2	3.2	1	20	0	5.9
Barium	µg/g	1	10	5	18	68	74	0	0	0	-
Cadmium	µg/g	0.1	0.2	5	0.3	0.3	0.4	2	40	0	0.6
Chromium	µg/g	0.5	1	5	7	27.2	**82**	0	0	2	37.3
Cobalt	µg/g	0.5	1	5	3	8	9.4	0	0	0	-
Copper	µg/g	0.1	5	5	7	**40**	**53.2**	0	0	3	35.7
Iron	µg/g	5	5	2	18100	21000	23900	0	0	0	-
Lead	µg/g	0.5	1	5	2	2.5	6	0	0	0	35
Manganese	µg/g	0.5	0.5	2	174	196	217	0	0	0	-
Mercury	µg/g	0.05	0.5	5	<0.05	-	<0.5	5	100	0	0.17
Molybdenum	µg/g	0.4	0.5	5	<0.4	2	3.1	1	20	0	-
Nickel	µg/g	0.5	1	5	7	32.8	50	0	0	0	-
Selenium	µg/g	0.5	0.5	5	<0.5	-	0.7	4	80	0	-
Sodium	µg/g	1	1	2	113	120	127	0	0	0	-
Thallium	µg/g	0.3	0.5	5	<0.3	-	<0.5	5	100	0	-
Vanadium	µg/g	0.2	1	5	7	23	31	0	0	0	-
Zinc	µg/g	0.5	10	5	11	61	**167**	0	0	1	123

Source: Canadian Environmental Quality Guidelines (CCME 1999b [with updates to 2002). Winnipeg, MB.
Note: **Bolded** numbers indicate where a guideline is exceeded.
ISQG = Interim Sediment Quality Guidelines (CCME 1999b); 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; min = minimum; med = medium; max = maximum

9.3.3.2.3 Lake 410 and Kirk Lake

Physical Limnology and Vertical Structure

Under-ice Conditions

A single vertical profile was measured during under-ice conditions for Lake 410 in May 2004, beginning at a depth of 3 m and ranging down to 6 m (Figure 9.3-8a). The profile had an inverse thermal gradient, with temperatures increasing from near 0°C near the ice-water interface to 3°C near the bottom of the lake.

The measured conductivity profile indicated low TDS concentrations, ranging between 15 and 17 µS/cm (Figure 9.3-8b).

The vertical DO profile had a concentration of 11 mg/L at the ice-water interface, which rapidly declined with increasing depth to anoxia near the bottom of the lake (i.e., 6 m) (Figure 9.3-8c). The DO concentrations near the water surface were greater than the upper range of acceptable concentrations for cold-water aquatic life in the CWQG (9.5 mg/L), whereas concentrations below 4 m were below the lowest acceptable concentration (6.5 mg/L). This profile pattern is commonly observed during under-ice conditions due to the ice cover and lack of wind-generated mixing in the waterbody.

Measurements of pH were not collected during under-ice conditions from Lake 410.

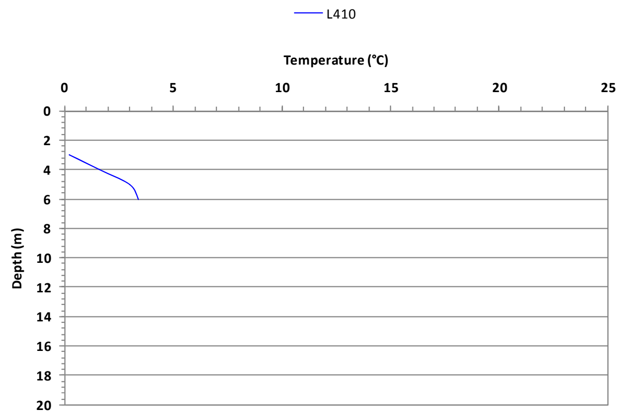
Open Water Conditions

Vertical physico-chemical data profiles were measured in Lake 410 and Kirk Lake in early August 2005, September 2007, and July 2010. Temperature profiles were variable (ranging from 6°C to 19°C) over the open-water period, but typically isothermal (Figure 9.3-9a). Water column temperatures measured in Lake 410 and Kirk Lake in August 2005 were similar in both lakes, ranging between 13°C and 14°C. The mid-September temperature profile measured in Lake 410 indicated the lake was well mixed and at a temperature of about 6°C. July 2010 profiles were warmer than the other water column measurements, ranging in temperature from 17°C to 19°C.

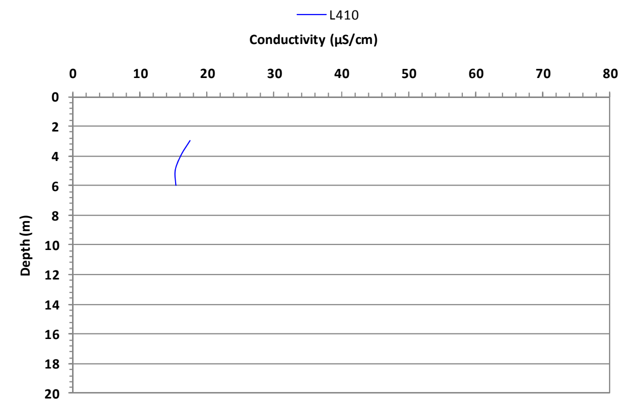
Measured conductivity profiles in Lake 410 and Kirk Lake during open water conditions ranged between 5 and 12 µS/cm (Figure 9.3-9b). There was very little variability in conductivity throughout the water column, indicating that the low TDS concentrations were equally distributed throughout the lakes, and that the lakes were well mixed during open water conditions.

Figure 9.3-8 Physico-chemical Field Data for Lake 410 during Under-ice Conditions (May 2004)

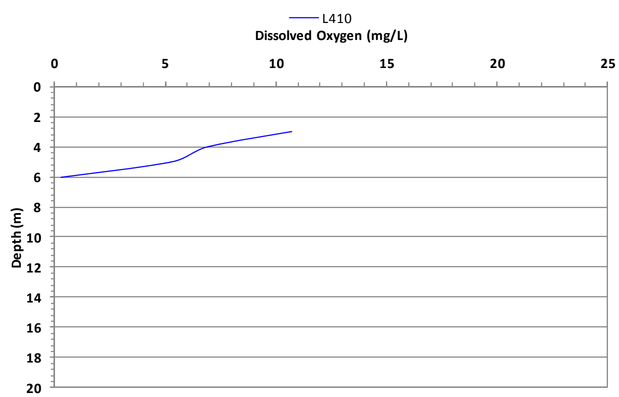
a) Water Temperature



b) Conductivity



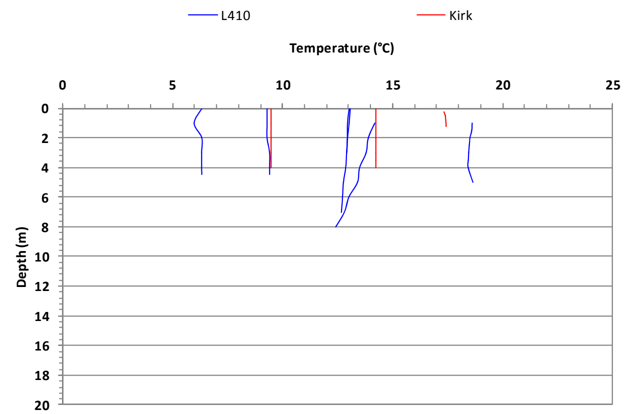
c) Dissolved Oxygen



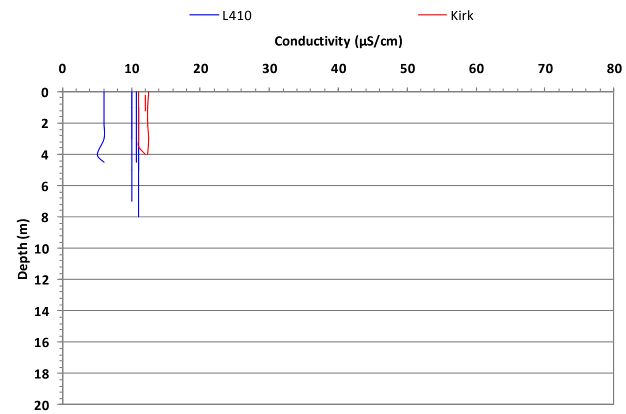
m = metre; °C = degrees Celsius; µS/cm = micro Siemens per centimetre; mg/L = milligrams per litre.
Individual field results not presented in field profile figures.

Figure 9.3-9 Physico-chemical Field Data for Lake 410 and Kirk Lake during Open Water Conditions (2005 to 2010)

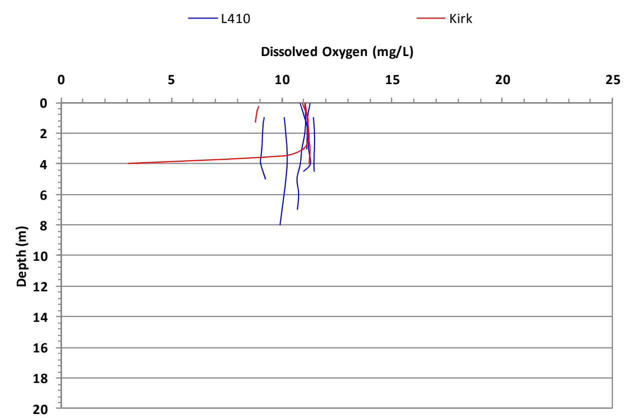
a) Water Temperature



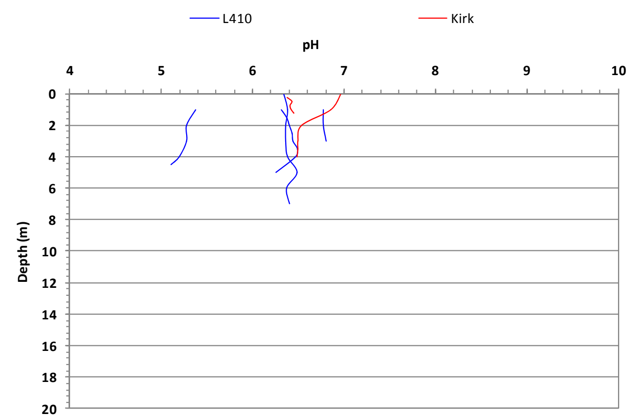
b) Conductivity



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.

Vertical DO concentrations in Lake 410 and Kirk Lake had only slight variability between the surface and the near bottom of these lakes, indicating that the lakes were typically well mixed during open water conditions. With the exception of one sampling event, dissolved oxygen concentrations ranged between 9 and 11 mg/L, and were generally greater than the upper range of acceptable concentrations for cold-water aquatic life in the CWQG (9.5 mg/L). A distinct oxycline (Figure 9.3-9c) was evident in Kirk Lake on August 2, 2005, below which the DO concentration dropped to 3.0 mg/L near the lake bottom.

Vertical profiles of pH (Figure 9.3-9d) in Lake 410 and Kirk Lake were slightly acidic to neutral, with little variance observed through the water column profile. The pH profile measurements were typically within the acceptable CWQG and CDWQG ranges; however, pH measured in Lake 410 in September 2004 were below the lower range of acceptable pH (i.e., pH 6.5).

Water Quality

Hardness and alkalinity were low in Lake 410 and Kirk Lake (Table 9.3-24), with several hardness measurements below the detection limit. 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.

The concentrations of TDS were low in the downstream lakes, ranging from <10 to 26 mg/L, indicating a very small amount of dissolved substances in the water (Table 9.3-24). For both lakes, bicarbonate was the dominant ion measured, with calcium being the next highest. Other ions were measured just above, at, or below, detection.

Both lakes were clear and contained very little suspended particulate matter, with most TSS concentrations measured at detection limits (Table 9.3-24). The highest concentration of TSS (3 mg/L) was measured in Lake 410.

Low levels of nutrients were measured in samples collected from Lake 410 and Kirk Lake (Table 9.3-24). Concentrations of nitrate+nitrite, ammonia and Kjeldahl nitrogen were measured below detection in all samples. Total phosphorus concentrations were variable, with 50% measured below the detection limit in Lake 410; however, the maximum concentration measured in Lake 410 was 0.071 mg/L, and in Kirk Lake it was 0.052 mg/L. Dissolved phosphorus concentrations were at, or below, detection. Based on the summary data for measured concentrations of nitrogen and phosphorus nutrients, the trophic status of Lake 410 and Kirk Lake is oligotrophic; however, the data are subject to poor detection limits and anomalously high values to provide a confident baseline concentration.

Levels of TOC and DOC in Lake 410 and Kirk Lake were low (3 to 6 mg/L) (Table 9.3-24). Colour was measured in Lake 410 at levels up to 20 TCU, which is above the CDWQG of 15 TCU (Table 9.3-24). Phenol was not detected, (Table 9.3-24). Total Recoverable Hydrocarbons were detected at levels up to 0.3 mg/L, although most (87.7%) were below detection limits.

The concentrations of total and dissolved metals were typically very low, with a range of metals near or below detection limits (e.g., beryllium, boron, chromium, molybdenum, selenium and thallium) (Table 9.3-21). No exceedances of applicable guidelines were observed for total metals measured in Lake 410 or Kirk Lake. The median concentrations of dissolved metals were similar to the total fraction.

Sediment Quality

Baseline sediment data for Kirk Lake consisted of two samples collected in 1999 and 2005. Two samples were collected from Lake 410 in 2004 and 2010. As sediment quality data were very limited from these lakes, the sediment data from both lakes were combined for the summary assessment.

Sediment samples collected from Lake 410 and Kirk Lake for sediment quality analyses were mainly composed of sand, with some silt and clay (Table 9.3-25). The total carbon (TC) content ranged from 4 to 19.5% of the sediment composition, with TOC comprising the majority of the sediment carbon (i.e., 0.7% to 18%) in most of the samples. Inorganic carbon constituted less than 3%.

Total phosphorus concentrations in the sediment ranged from 642 to 839 µg/g dry weight. In comparison, available phosphorus concentrations ranged from 23 to 60.7 µg/g dry weight (Table 9.3-25). Nitrate concentrations were below the detection limit of 0.5 µg/g dry weight.

The TPH content in the lake sediments was variable, ranging from below detection (i.e., <8 µg/g) to 3,030 µg/g dry weight (Table 9.3-25).

The predominant metals in the sediment included aluminum and iron (Table 9.3-25). Concentrations of metals in the sediment were generally within the applicable aquatic life guidelines; however, chromium and copper were measured above the ISQG in all samples.

Table 9.3-24 Water Quality Data Summary for Lake 410 and Kirk Lake (2004 to 2010)

Parameter Name	Unit	Method Detection Limit			Lake 410 Summary (2004-2010)						Guidelines				Kirk Lake Results (2005 and 2010)			Guidelines			
											Aquatic Life-Chronic[a]		Human Health-Chronic[b]		Kirk Lake	Kirk Lake	Kirk Lake Inlet	Aquatic Life-Chronic		Human Health-Chronic	
		Min	Max	No. of MDL	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	02-Aug-05	18-Jul-10	02-Aug-05	Value	No. of Times Guideline is Exceeded	Value	No. of Times Guideline is Exceeded
Field measured																					
pH	pH units	-	-	0	34	**5.2**[c]	**6.4**[c]	8	0	0	6.5-8.5	25	5.0-9.0	0	**6.49**[C]	**6.41**[C]	**6.44**[C]	6.5-8.5	3	5.0-9.0	0
Temperature	°C	-	-	0	46	0.2	13	19	0	0	-	0	-	0	14.26	17.42	10.86	-	0	-	0
Specific Conductance	µS/cm	-	-	0	46	8	11	17	0	0	-	0	-	0	11	12	10	-	0	-	0
Dissolved Oxygen	mg/L	-	-	0	41	**0.27**[c]	11	16	0	0	6.5	3	-	0	11.02	8.87	11.58	6.5	0	-	0
Conventional Parameters																					
Colour	TCU	1	1	1	10	0.5	5	20	2	20	-	0	-	0	5	-	5	-	0	-	0
Specific Conductance	µS/cm	-	-	0	14	11	13	18	0	0	-	0	-	0	14	12	12	-	0	-	0
Dissolved Organic Carbon	mg/L	-	-	0	14	3	4	6	0	0	-	0	-	0	5	3.8	6	-	0	-	0
Hardness	mg/L	6	6	1	13	<6	-	1.2	10	76.9	-	0	-	0	<6	-	<6	-	0	-	0
pH	pH units	-	-	0	15	**5.4**[c]	6.6	6.8	0	0	6.5-8.5	7	5.0-9.0	0	**5.62**[C]	**6.46**[C]	**5.41**[C]	6.5-8.5	3	5.0-9.0	0
Total Alkalinity	mg/L	-	-	0	14	1.9	10	27	0	0	-	0	-	0	14	3.9	17	-	0	-	0
Total Dissolved Solids	mg/L	10	10	1	14	10	12	26	5	35.7	-	0	-	0	<10	<10	<10	-	0	-	0
Total Organic Carbon	mg/L	-	-	0	14	3	4	6	0	0	-	0	-	0	5	4	4	-	0	-	0
Total Suspended Solids	mg/L	2	2	1	14	1	1	3	9	64.3	-	0	-	0	<2	1	<2	-	0	-	0
Major Ions																					
Bicarbonate	mg/L	-	-	0	14	2.3	12	32	0	0	-	0	-	0	17	4.8	21	-	0	-	0
Calcium	mg/L	-	-	0	14	0.77	0.9	1.3	0	0	-	0	-	0	0.9	0.8	0.9	-	0	-	0
Carbonate	mg/L	0.5	1	2	14	<0.5	-	<1	14	100	-	0	-	0	<1	<0.5	<1	-	0	-	0
Chloride	mg/L	1	1	1	14	0.3	0.45	1	3	21.4	230	0	-	0	0.4	1	0.3	230	0	-	0
Magnesium	mg/L	0.5	0.5	1	14	0.36	0.48	0.62	5	35.7	-	0	-	0	<0.5	0.5	<0.5	-	0	-	0
Potassium	mg/L	0.5	0.5	1	14	0.33	0.37	0.41	5	35.7	-	0	-	0	<0.5	0.4	<0.5	-	0	-	0
Sodium	mg/L	0.5	0.5	1	14	0.25	0.6	2.2	1	7.1	-	0	-	0	0.7	0.6	0.6	-	0	-	0
Sulphate	mg/L	1	1	1	14	0.5	0.7	1.5	4	28.6	-	0	-	0	0.9	<1	<0.5	-	0	-	0
Sulphide	µg/L	2	2	1	4	2	-	**3**[c]	2	50	2.3	1	-	0	-	**3**[C]	-	2.3	1	-	0
Nutrients																					
Nitrate + Nitrite	mg-N/L	0.003	0.003	1	4	<0.003	-	<0.003	4	100	2.93	0	10	0		<0.003		2.93	0	10	0
Nitrogen-Ammonia	mg-N/L	0.05	0.1	2	14	<0.05	-	<0.1	14	100	26	0	-	0	<0.1	<0.05	<0.1	22	0	-	0
Nitrogen-Kjeldahl	mg-N/L	0.2	0.2	1	5	<0.2	-	<0.2	5	100	-	0	-	0	-	-	-	-	0	-	0
Phosphorus, total	µg/L	20	50	2	14	4	7	71	7	50	50	3	-	0	<50	3	52	-	0	-	0
Phosphorus, dissolved	mg/L	0.005	0.005	1	14	<0.005	-	0.005	10	71.4	-	0	-	0	<0.005	0.002	<0.005	-	0	-	0
General Organics																					
Total Phenolics	µg/L	0.002	2	2	4	<2	-	<2	4	100	5	0	-	0	-	<0.002	-	5	0	-	0
Total Recoverable Hydrocarbons	mg/L	0.1	2	2	14	<0.1	-	0.3	12	85.7	-	0	-	0	<0.1	<2	<0.1	-	0	-	0
Total Metals[e]																					
Aluminum	µg/L	20	20	1	14	6	13	55	2	14.3	100	0	100	0	23	16.6	23	100	0	100	0
Antimony	µg/L	0.02	0.1	2	14	<0.02	-	0.5	12	85.7	-	0	5.5	0	0.6	<0.02	<0.1	-	0	5.5	0
Arsenic	µg/L	0.4	0.4	1	14	<0.4	-	0.12	10	71.4	5	0	10	0	0.8	0.11	<0.4	5	0	10	0
Barium	µg/L	5	5	1	14	<5	-	2	10	71.4	-	0	1000	0	<5	2.01	<5	-	0	1000	0
Beryllium	µg/L	0.01	0.5	2	14	<0.01	-	<0.5	14	100	-	0	4	0	<0.5	<0.01	<0.5	-	0	4	0
Boron	µg/L	10	20	2	14	<10	-	<20	14	100	-	0	5000	0	<10	<20	<10	-	0	5000	0
Cadmium	µg/L	0.002	0.2	2	14	<0.002	-	0.0033	13	92.9	0.054	0	5	0	<0.2	0.008	<0.2	0.054	0	5	0
Chromium	µg/L	0.1	0.9	2	14	<0.1	-	<0.9	14	100	1	0	50	0	0.9	<0.1	<0.9	1	0	50	0
Cobalt	µg/L	0.1	0.1	1	14	0.026	0.038	0.1	9	64.3	-	0	-	0	<0.1	0.037	<0.1	-	0	-	0
Copper	µg/L	1	5	2	14	0.45	0.56	1.8	9	64.3	2	0	1300	0	1.5	0.78	<1	3	0	1300	0
Iron	µg/L	10	50	2	14	30	50	186	6	42.9	300	0	300	0	<10	61	70	300	0	300	0
Lead	µg/L	0.1	0.1	1	14	0.006	0.018	0.7	8	57.1	1	0	10	0	0.4	0.034	<0.1	4	0	10	0
Lithium	µg/L	-	-	0	4	0.8	0.95	1.1	0	0	-	0	-	0	-	1.2	-	-	0	-	0
Manganese	µg/L	1	1	1	14	0.5	3	8.6	4	28.6	-	0	50	0	<1	3.41	3	-	0	50	0
Mercury	µg/L	0.0006	500	4	14	<0.0006	-	0.006	11	78.6	0.026	0	1	0	<0.1	0.007	<0.1	0.026	0	1	0
Molybdenum	µg/L	0.05	0.5	2	14	<0.05	-	<0.5	14	100	73	0	-	0	<0.5	<0.05	<0.5	73	0	-	0
Nickel	µg/L	0.6	0.6	1	14	0.17	0.44	2	7	50	25	0	340	0	2.5	0.5	<0.6	110	0	340	0
Selenium	µg/L	0.04	10	3	14	<0.04	-	<10	14	100	1	0	10	0	<0.8	<0.04	<0.8	1	0	10	0
Silver	µg/L	0.2	0.2	1	14	<0.2	-	0.0056	10	71.4	0.1	0	-	0	<0.2	0.005	<0.2	0.1	0	-	0

Table 9.3-24 Water Quality Summary for Lake 410, 2004 to 2010 (continued)

Parameter Name	Unit	Method Detection Limit			Lake 410 Summary (2004-2010)										Kirk Lake Results (2005 and 2010)						
											Guidelines							Guidelines			
											Aquatic Life-Chronic [a]		Human Health-Chronic [b]		Kirk Lake	Kirk Lake	Kirk Lake Inlet	Aquatic Life-Chronic		Human Health-Chronic	
		Min	Max	No. of MDL	n	Min	Med	Max	Count Below Detection	% Below Detection	Value	Guideline Exceedance Count	Value	Guideline Exceedance Count	02-Aug-05	18-Jul-10	02-Aug-05	Value	No. of Times Guideline is Exceeded	Value	No. of Times Guideline is Exceeded
Strontium	µg/L	-	-	0	4	5.2	5.4	6	0	0	-	0	-	0	0	5.53	0	-	0	-	0
Sulphur	µg/L	10,000	10,000	1	4	<10,000	-	<10,000	4	100	-	0	-	0	0	<10,000	0	-	0	-	0
Thallium	µg/L	0.002	0.05	2	14	<0.002	-	<0.05	14	100	0.8	0	0.13	0	<0.05	0.002	<0.05	0.8	0	0.13	0
Titanium	µg/L	0.5	0.5	1	4	<0.5	-	<0.5	4	100	-	0	-	0	0	<0.5	0	-	0	-	0
Uranium	µg/L	0.05	0.05	1	14	<0.05	-	0.013	10	71.4	-	0	-	0	<0.05	0.015	<0.05	-	0	-	0
Vanadium	µg/L	0.1	0.2	2	14	0.1	0.2	0.3	6	42.9	-	0	-	0	0.3	<0.2	0.3	-	0	-	0
Zinc	µg/L	2	2	1	14	0.5	0.8	24	7	50	30	0	5100	0	17	1.3	<2	30	0	5100	0
Dissolved Metals[e]																					
Aluminum	µg/L	10	10	1	14	5	10	16	2	14.3	-	0	-	0	14	12	18	-	0	-	0
Antimony	µg/L	0.1	0.1	1	14	<0.1	-	0.09	10	71.4	-	0	-	0	<0.1	0.1	<0.1	-	0	-	0
Arsenic	µg/L	0.1	0.1	1	14	0.07	0.1	0.2	7	50	-	0	-	0	0.1	1.5	<0.1	-	0	-	0
Barium	µg/L	3	3	1	14	<3	-	2	10	71.4	-	0	-	0	<3	1.9	<3	-	0	-	0
Beryllium	µg/L	0.01	0.1	2	14	0.1	0.1	0.1	9	64.3	-	0	-	0	<0.1	<0.05	0.1	-	0	-	0
Boron	µg/L	4	300	3	14	<4	-	<20	14	100	-	0	-	0	<4	<300	<4	-	0	-	0
Cadmium	µg/L	0.005	0.05	2	14	0.11	0.11	0.12	9	64.3	-	0	-	0	<0.05	<0.03	0.12	-	0	-	0
Chromium	µg/L	0.1	0.5	3	14	<0.1	-	<0.4	14	100	-	0	-	0	<0.4	<0.5	<0.4	-	0	-	0
Cobalt	µg/L	0.05	0.05	1	14	0.09	0.1	0.84	5	35.7	-	0	-	0	<0.05	3.68	0.11	-	0	-	0
Copper	µg/L	1	2	2	14	0.46	0.52	1.4	9	64.3	-	0	-	0	1.4	0.8	<1	-	0	-	0
Iron	µg/L	20	20	1	14	9	26	80	4	28.6	-	0	-	0	50	21	140	-	0	-	0
Lead	µg/L	0.05	0.05	1	14	<0.05	-	0.05	10	71.4	-	0	-	0	<0.05	0.03	<0.05	-	0	-	0
Lithium	µg/L	3	3	1	4	0.7	0.85	1	0	0	-	0	-	0	0	<3	0	-	0	-	0
Manganese	µg/L	2	2	1	14	0.9	2	16	3	21.4	-	0	-	0	<2	7.6	4	-	0	-	0
Mercury	µg/L	0.1	1	2	14	<0.1	-	0.007	10	71.4	-	0	-	0	<0.1	<0.002	<0.1	-	0	-	0
Molybdenum	µg/L	0.05	0.3	2	14	<0.05	-	<0.3	14	100	-	0	-	0	<0.3	<0.3	<0.3	-	0	-	0
Nickel	µg/L	-	-	0	14	0.1	0.3	1.2	0	0	-	0	-	0	2.1	0.9	0.4	-	0	-	0
Selenium	µg/L	0.04	2	3	14	<0.04	-	<2	14	100	-	0	-	0	<0.4	<0.2	<0.4	-	0	-	0
Silver	µg/L	0.005	0.05	2	14	<0.005	-	<0.05	14	100	-	0	-	0	<0.05	<0.03	<0.05	-	0	-	0
Strontium	µg/L	-	-	0	4	5.3	5.5	6.1	0	0	-	0	-	0	0	5.7	0	-	0	-	0
Sulphur	µg/L	10,000	10,000	1	4	<10,000	-	<10,000	4	100	-	0	-	0	0	1,860,000	0	-	0	-	0
Thallium	µg/L	0.002	0.02	2	14	<0.002	-	<0.02	14	100	-	0	-	0	0.03	<0.01	<0.02	-	0	-	0
Titanium	µg/L	0.5	0.5	1	4	<0.5	-	<0.5	4	100	-	0	-	0	0	<3	0	-	0	-	0
Uranium	µg/L	0.05	0.05	1	14	<0.05	-	0.012	10	71.4	-	0	-	0	<0.05	0.01	<0.05	-	0	-	0
Vanadium	µg/L	0.2	0.5	2	14	<0.2	-	<0.5	14	100	-	0	-	0	<0.5	<1	<0.5	-	0	-	0
Zinc	µg/L	2	2	1	14	0.6	2	3	5	35.7	-	0	-	0	20	1.3	<2	-	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 1999a, 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.
(H) 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, 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.

Table 9.3-25 Sediment Quality Data Summary for Lake 410 and Kirk Lake (1999, 2004, 2005, and 2010)

Parameter	Unit	Method Detection Limit		Lake 410 and Kirk Lake							Guideline
		Min	Max	n	Min	Med	Max	No. Below Detection	% Below Detection	No. of Times a Guideline is Exceeded	ISQG
Texture and Carbon Content											
Sand	%	1	2	2	61	67	73	0	0	0	-
Silt	%	1	2	2	24	29.5	35	0	0	0	-
Clay	%	1	2	2	3	3.5	4	0	0	0	-
Calcium Carbonate	%	0.005	0.005	2	0.2	0.28	0.37	0	0	0	-
Inorganic Carbon, Total	%	0.01	0.02	3	1.6	2.3	3	0	0	0	-
Organic Carbon, Total	%	0.01	0.2	4	0.7	15.1	18	0	0	0	-
Carbon, Total	%	0.01	0.2	3	4	19.5	20	0	0	0	-
Nutrients and Organics											
Nitrate, Available	µg/g	0.5	0.5	1	<0.5	-	<0.5	1	100	0	-
Phosphorus, Available	µg/g	1	1	2	23	41.9	60.7	0	0	0	-
Phosphorus, Total	µg/g	5	5	2	642	741	839	0	0	0	-
Total Petroleum Hydrocarbons	µg/g	8	800	3	<8	583	3030	1	33	0	-
Total Metals											
Aluminum	µg/g	5	5	3	10,300	10,500	15,000	0	0	0	-
Arsenic	µg/g	0.5	1	4	1.4	2.5	4.2	0	0	0	5.9
Barium	µg/g	1	10	4	63	76	101	0	0	0	-
Cadmium	µg/g	0.1	0.2	4	<0.1	0.25	0.3	1	25	0	0.6
Chromium	µg/g	0.5	1	4	22.3	35.7	**79**	0	0	1	37.3
Cobalt	µg/g	0.5	1	4	7	8.75	17.4	0	0	0	-
Copper	µg/g	0.1	5	4	29.3	35.5	**59.4**	0	0	2	35.7
Iron	µg/g	5	5	3	15,400	16,400	26,300	0	0	0	-
Lead	µg/g	0.5	1	4	2	3.95	18.3	0	0	0	35
Manganese	µg/g	0.5	0.5	3	167	171	209	0	0	0	-
Mercury	µg/g	0.05	0.5	4	<0.05	-	<0.5	4	100	0	0.17
Molybdenum	µg/g	0.4	0.5	4	0.9	1.2	3.2	0	0	0	-
Nickel	µg/g	0.5	1	4	27	35.1	50	0	0	0	-
Selenium	µg/g	0.5	0.5	4	<0.5	0.65	20	1	25	0	-
Thallium	µg/g	0.3	0.5	4	<0.3	-	<0.5	4	100	0	-
Vanadium	µg/g	0.2	1	4	23	28.8	34.4	0	0	0	-
Zinc	µg/g	0.5	10	4	50	69.5	76.5	0	0	0	123

Source: Canadian Environmental Quality Guidelines (CCME 1999b [with updates to 2002]). Winnipeg, MB.

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

ISQG = Interim Sediment Quality Guidelines (CCME 1999b); 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.

9.3.4 Lower Trophic Levels

The following section describes baseline limnology and lower trophic information collected downstream of the Kennady Lake watershed.

For additional information regarding limnology and lower trophic levels, the reader is referred to the limnology and lower trophic level sections of EIS Annex J (Fisheries and Aquatic Resources Baseline) and Addendum JJ (Additional Fisheries and Aquatic Resources Information).

9.3.4.1 Methods

Studies of limnology and lower trophic communities in the Kennady Lake area were initiated in 1996, and continued through 2007. Data collected for lower trophic levels include the following:

- Phytoplankton and zooplankton communities were sampled in Lake N16, Lake 410, and Kirk Lake.
- Benthic invertebrate communities sampled in Lake N16, Lake 410, Kirk Lake, and small streams downstream of Kennady Lake.
- Invertebrate drift was measured in two streams downstream of Kennady Lake.
- Sediment samples were collected from Lake N16, Lake 410, and Kirk Lake for toxicity analysis.

9.3.4.2 Results

9.3.4.2.1 Plankton Communities

Phytoplankton communities in Lake N16, Lake 410, and Kirk 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). This phytoplankton taxonomic composition is consistent with the observed communities in Kennady Lake.

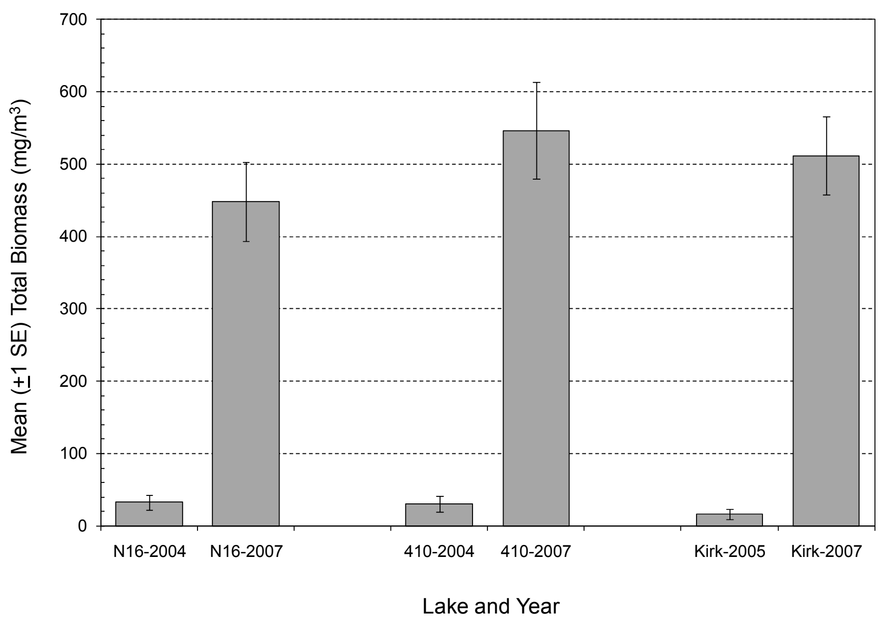
Total phytoplankton biomass varied little among the three lakes within studies, but was considerably lower in 2004 and 2005 than in 2007 (Figure 9.3-10).

Cyanobacteria were consistently the most abundant taxonomic group in all lakes in 2004 and 2005, whereas Chrysophyta were dominant in 2007 (Figure 9.3-11). Relative abundances of other groups were similar between years.

Cyanobacteria accounted for only a small proportion of the total phytoplankton biomass in 2004 and 2005, and for about a third of the total biomass in 2007 (Figure 9.3-12). Chrysophyta typically dominated the phytoplankton biomass in 2004 and 2005; co-dominance by two groups (Chrysophyta and cyanobacteria) or three groups (Chrysophyta, cyanobacteria, and Chlorophyta) was observed in 2007 (Figure 9.3-12). The observed dominance pattern is indicative of oligotrophic to oligo-mesotrophic conditions.

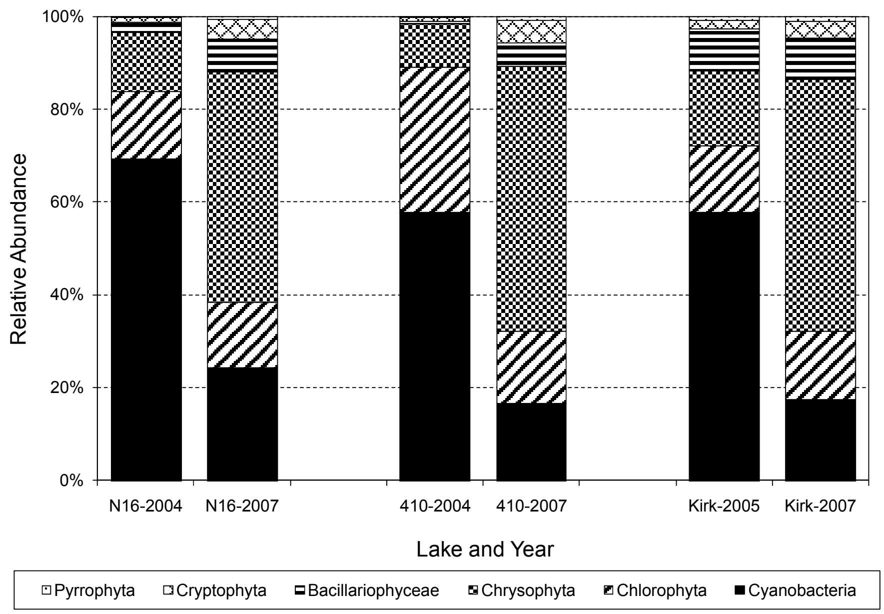
There was little variation in chlorophyll *a* concentration among the three lakes. Concentrations (about 1.0 micrograms per litre [µg/L]) were within a range characteristic of oligotrophic lakes and were consistent with lakes of similar trophic status in the Slave Geological Province, lakes between southern Yukon Territory and the Tuktoyaktuk Peninsula, Northwest Territories (NWT), and lakes between Yellowknife and Contwoyto Lake, NWT (Pienitz et al. 1997a, b).

Figure 9.3-10 Total Phytoplankton Biomass in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



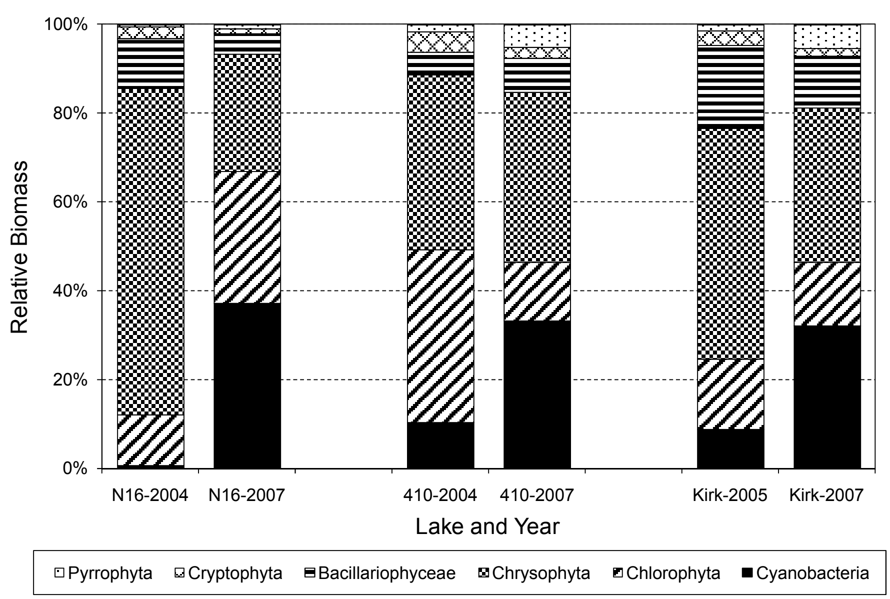
Note: + = plus or minus; SE = standard error; mg/m^3 = milligrams per cubic metre.

Figure 9.3-11 Relative Abundances of Major Phytoplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



Note: % = percent.

Figure 9.3-12 Relative Biomass of Major Phytoplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



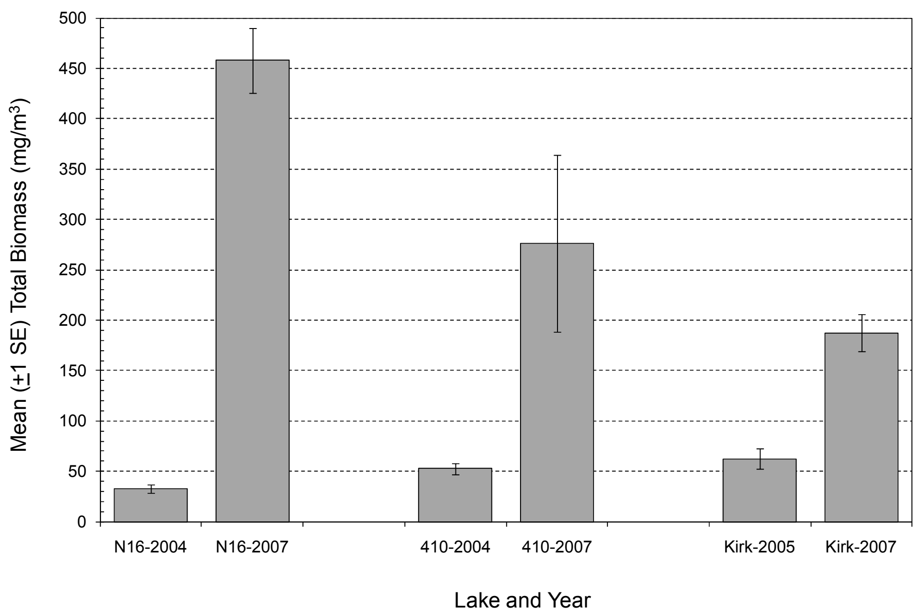
Note: % = percent.

The zooplankton communities of Lake N16, Lake 410, and Kirk Lake consisted of representatives of four major taxonomic groups: Rotifera, Cladocera, Calanoida (calanoid copepods), and Cyclopoida (cyclopoid copepods).

Total zooplankton biomass increased in a downstream direction from Lake N16 to Kirk Lake in 2004/2005, and showed the opposite spatial trend in 2007 (Figure 9.3-13). Total zooplankton biomass was considerably lower in 2004 and 2005 than in 2007. Total abundance of Rotifera was determined, but biomass was not measured in 2004 and 2005. Rotifer biomass contributed very little to total biomass in 2007.

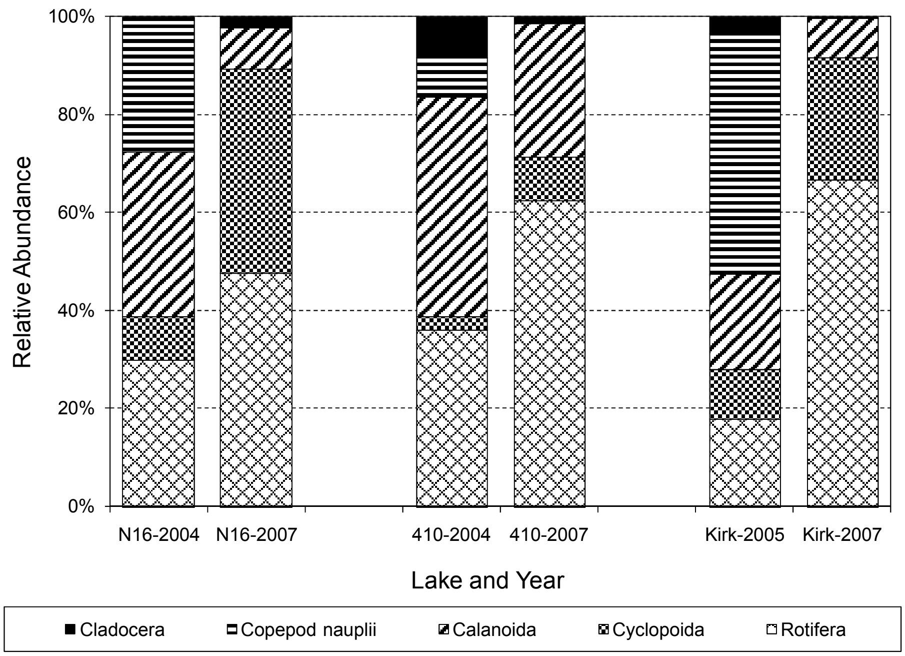
The relative abundances of major taxonomic groups were variable among lakes, with one of rotifers, cyclopoid copepods, calanoid copepods, or copepod nauplii dominating the community (Figure 9.3-14). The relative abundance of Cladocera was consistently low in all three lakes, in both years. Relative biomass (Figure 9.3-15) was more similar among lakes and years than density. Calanoid copepods generally dominated the zooplankton communities in all three lakes, in both years. Despite their low abundance, cladocerans accounted for about 10 to 50% of total biomass.

Figure 9.3-13 Total Zooplankton Biomass in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



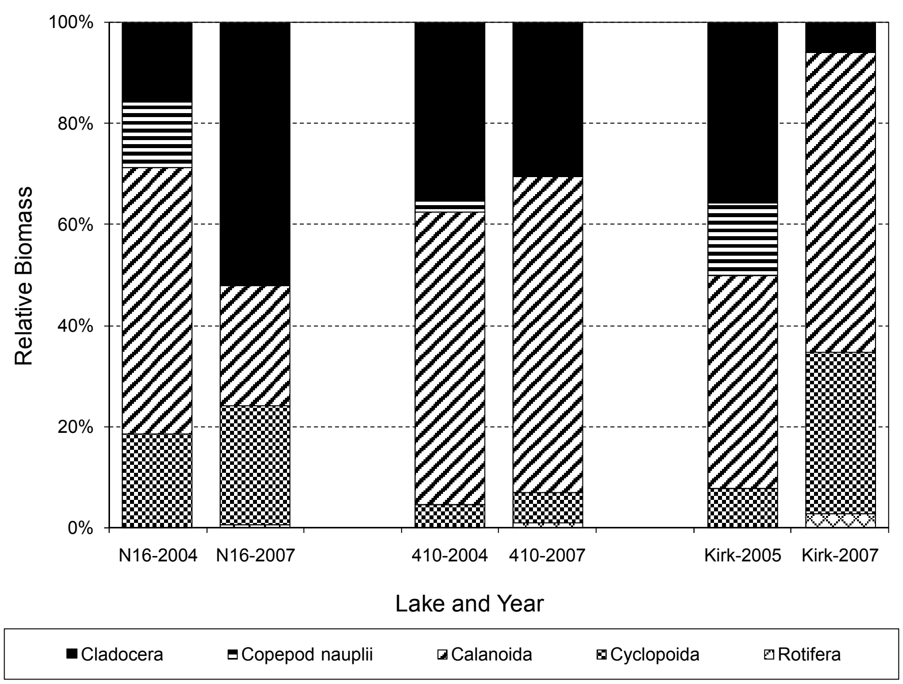
Note: + = plus or minus; SE = standard error; mg/m^3 = milligrams per cubic metre.

Figure 9.3-14 Relative Abundance of Major Zooplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005, and 2007



Note: % = percent.

Figure 9.3-15 Relative Biomass of Major Zooplankton Taxa in Lakes Downstream of Kennady Lake, 2004, 2005 and 2007



Note: % = percent.

9.3.4.2.2 Benthic Invertebrate Community

Lakes

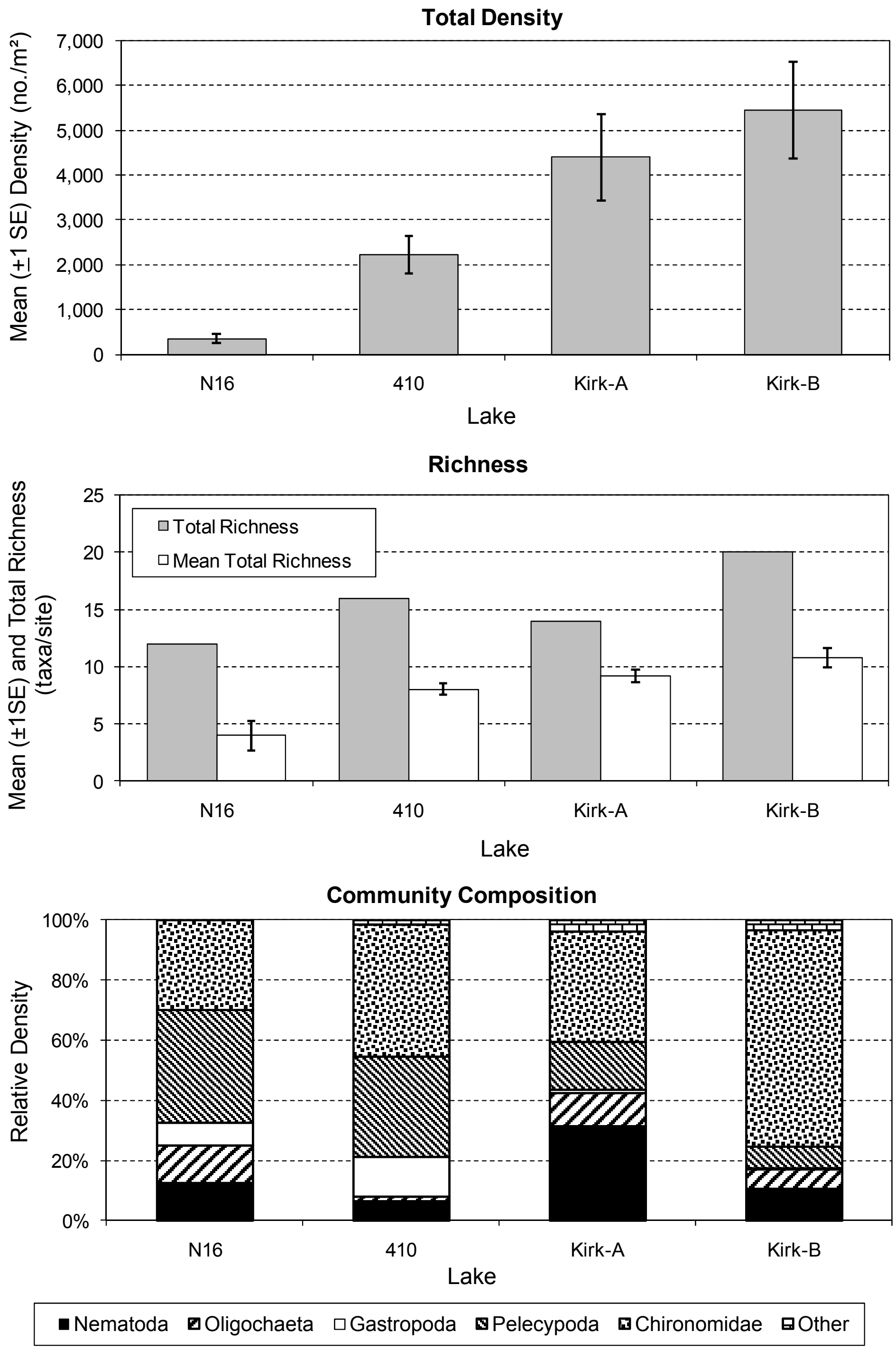
The benthic invertebrate community of Lake N16 in August (deep site) and September (shallow site) 2004 was characterized by low density (less than 1,000 organisms/m^2) and total richness of about 10 taxa (Figures 9.3-16 and 9.3-17). The 2007 data collected at four shallow sites revealed a greater degree of variability in both total density and richness (Figure 9.3-18). Midges (Chironomidae) were the dominant invertebrate group at the shallow sites in September 2004 and 2007, whereas fingernail clams (Pelecypoda: Sphaeriidae) were dominant at the deep site sampled in August 2004. Other common groups in Lake N16 included roundworms (Nematoda), aquatic worms (Oligochaeta), and snails (Gastropoda).

The benthic invertebrate community of Lake 410 at shallow sites sampled in August and September 2004 was more abundant and diverse than those at deeper sites in Lake N16 (Figure 9.3-16 and 9.3-17). This result was expected, because shallow sites usually support more abundant and diverse benthic communities. Midges and fingernail clams were co-dominant in this lake. Other common taxa included roundworms, aquatic worms, and snails.

Benthic communities of the two shallow sites (A and B) sampled in Kirk Lake in August 2005 had higher densities and similar richness compared to shallow sites sampled in Lake 410 in August 2004 (Figure 9.3-16). The benthic community of Kirk Lake was dominated by midges; roundworms, fingernail clams, and aquatic worms were also common.

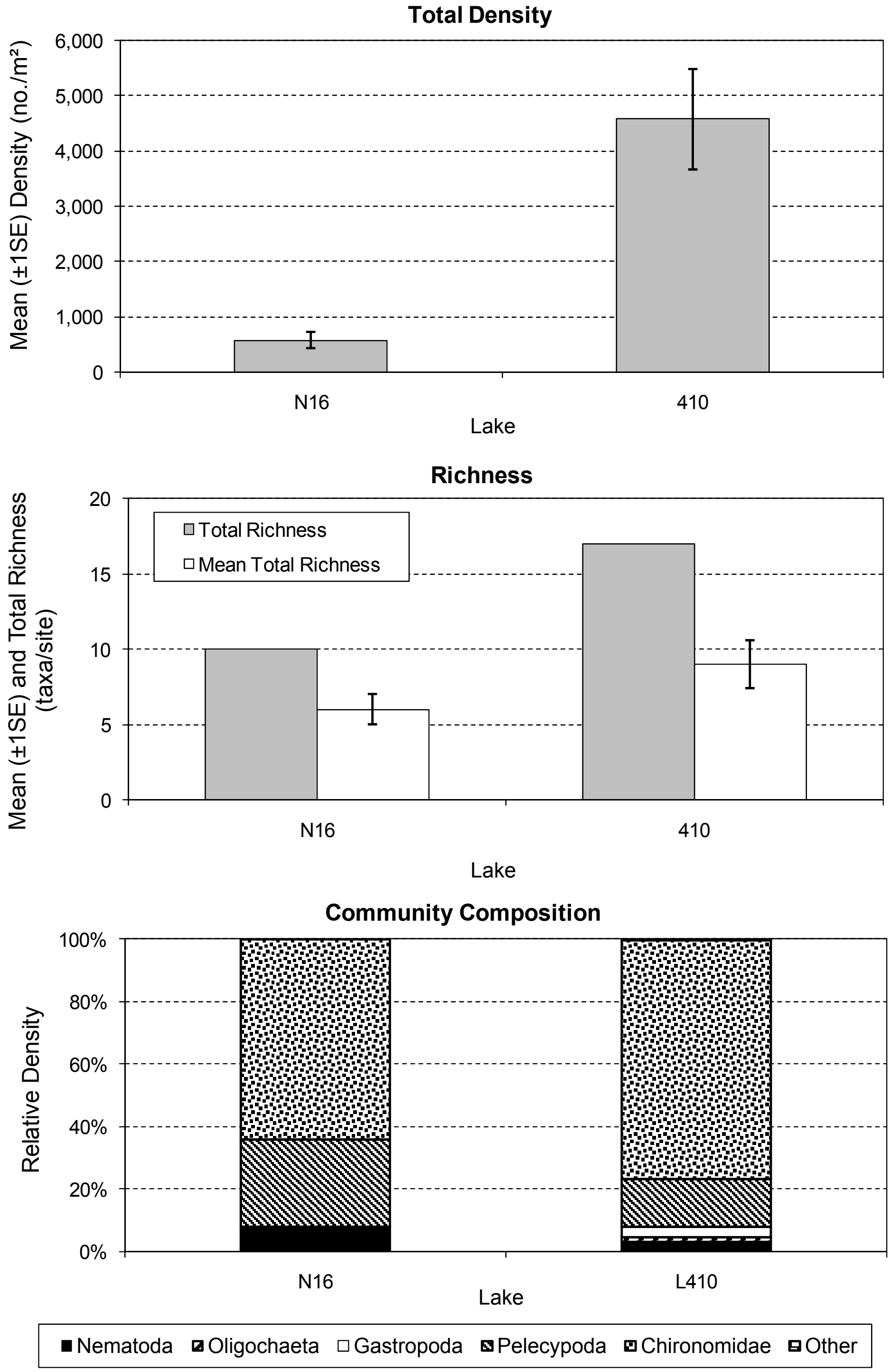
In summary, the benthic invertebrate communities of lakes downstream of Kennady Lake were characterized by low to moderate density and richness. The dominant taxa were similar among lakes and sites within lakes, and consisted of midges or fingernail clams. Roundworms, aquatic worms, and snails were also common in these lakes.

Figure 9.3-16 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Lakes Downstream of Kennady Lake, August 2004 and 2005



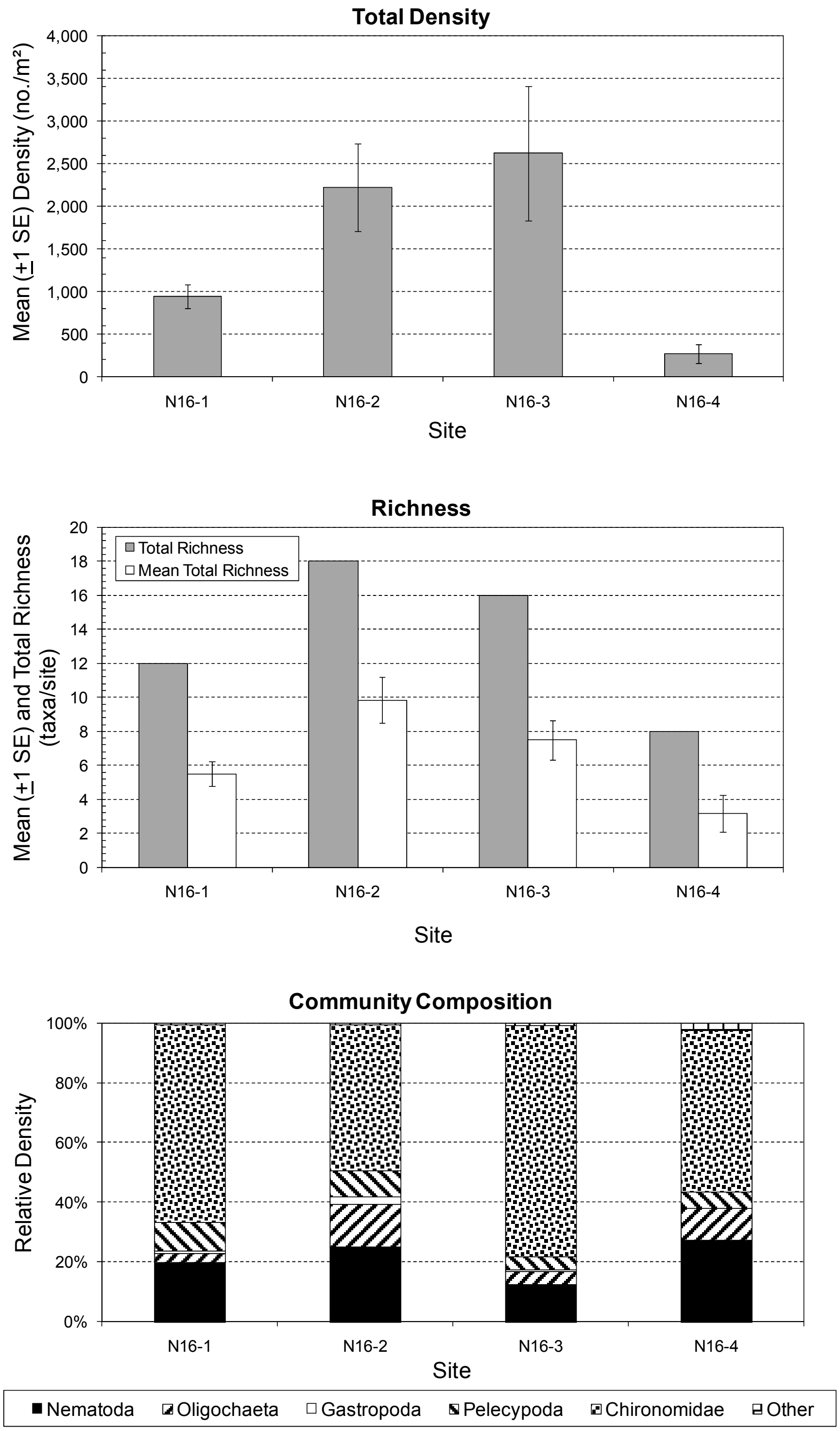
Note: Lakes N16 and 410 were sampled in August 2004, and Kirk Lake was sampled in August 2005; n=5.
± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Figure 9.3-17 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Lakes Downstream of Kennady Lake, September 2004



Note: n=5; ± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Figure 9.3-18 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Lake N16, Fall 2007



Note: n = 5; ± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Streams

Stream benthic communities sampled in summer 2005 in the N watershed and downstream of Kennady Lake were characterized by low to moderate density and richness (Table 9.3-27). Common benthic invertebrates in these streams included hydras (Hydrozoa), mites, and larvae of midges (Chironomidae) and blackflies. Stream sites sampled downstream of Kennady Lake in fall 2007 were characterized by low density and moderate richness (Figure 9.3-19). In 2007, the stream benthic community was dominated by midges. Caddisflies (Trichoptera) were also common. The “other taxa” group, which included hydras, snails, true bugs (Hemiptera), beetles (Coleoptera), and other true flies (other Diptera), accounted for up to about 20% of the benthic invertebrate community at various stream sites in 2007.

The benthic component of stream drift samples collected in summer 2005 in streams N3 and L3 was dominated by hydras (Hydrozoa); mites (Acari) and midges were occasionally common (Figure 9.3-20). Mean drift density was low (i.e., less than 50 organisms/100 m^3) near the water surface in both streams. Near-bottom drift density was slightly higher in Stream L3 and substantially higher in Stream N3, where it was about 1,000 organisms/100 m^3. Richness of drifting invertebrates showed a similar pattern as drift density, with a maximum value in Stream N3 near the bottom. Invertebrate drift also included a planktonic component, dominated by water fleas, which originated from lakes drained by the sampled streams.

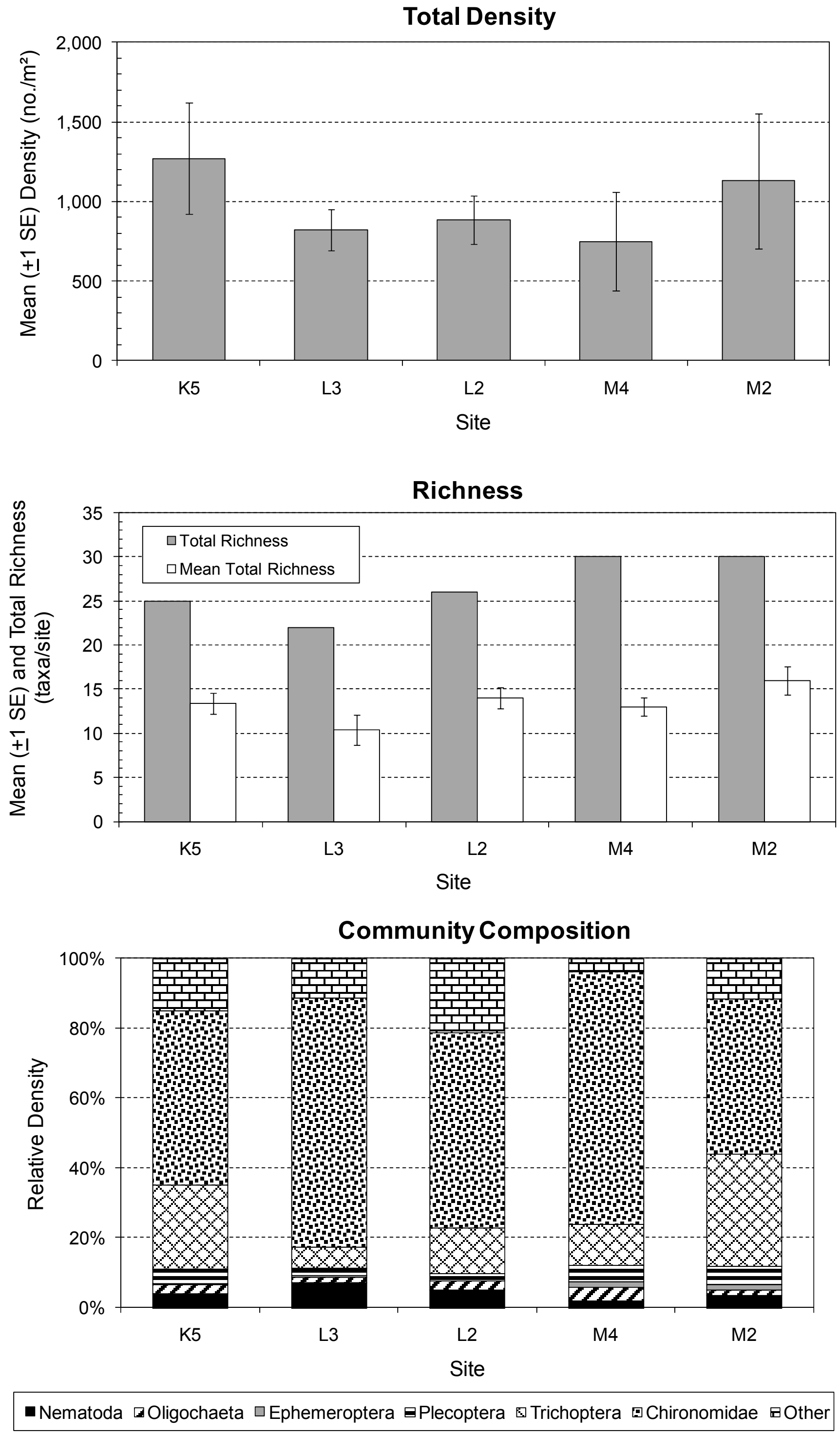
Table 9.3-27 Summary of Stream Benthic Invertebrate Data Collected in 2005

Stream	Total Density (number/m^2)	Richness (no. taxa)
N6	433	14
N5	467	7
N4	6,299	19
N3	578	7
N2	1,589	14
L3	8,710	11
L2	1,989	9
L1b	3,366	13
L1a	8,655	12
P4	1,222	11
K5 (Kennady Lake outlet stream)	2,122	11
KO (Kirk Lake outlet stream)	3,055	9
Mean ±1 SE	**3,207 ± 874**	**11 ± 1**

Note: Total density and richness values are presented for individual samples, because a single sample was collected in each stream.

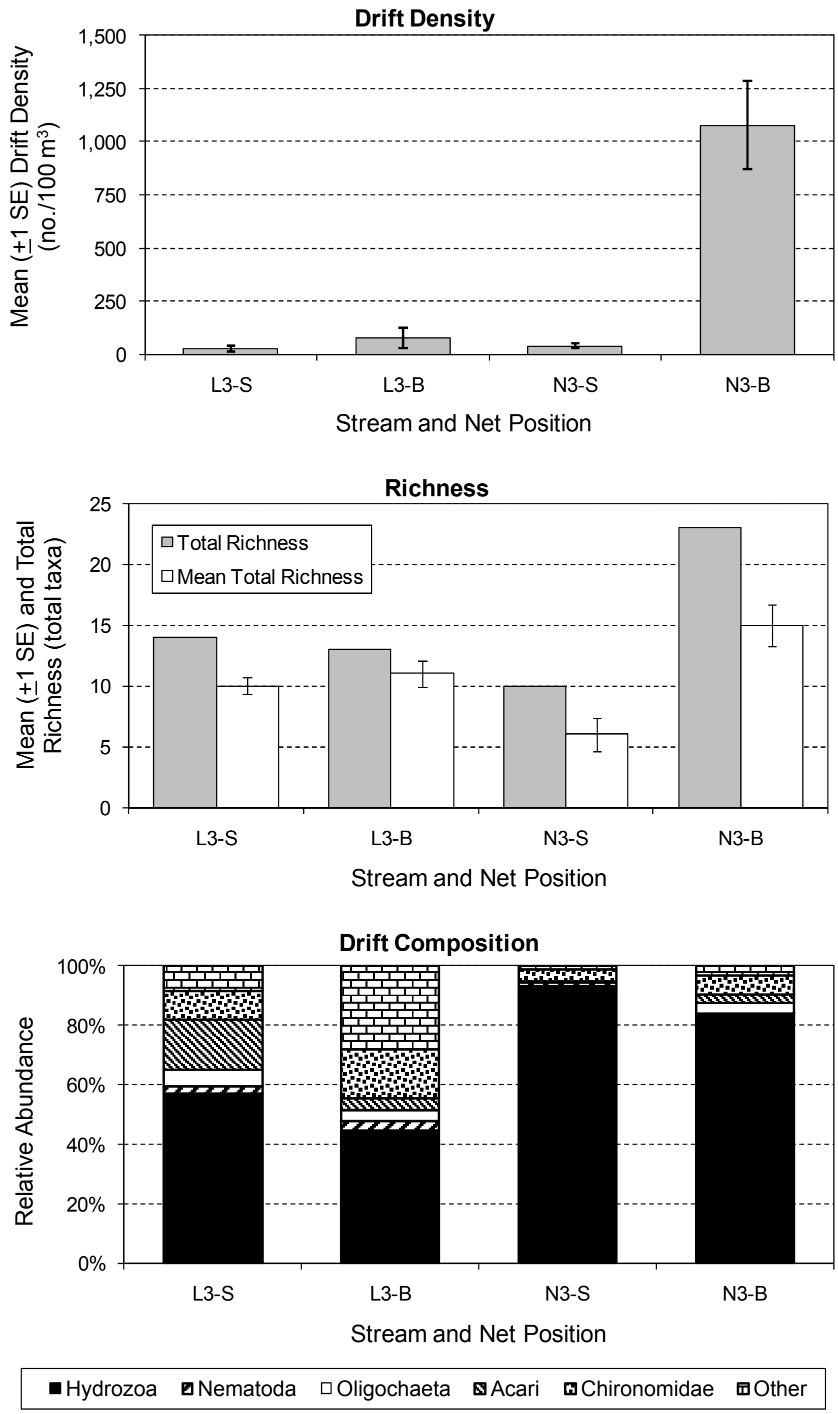
number/m^2 = number per square metre; no. taxa = number of taxa; SE = standard error.

Figure 9.3-19 Total Abundance, Richness, and Community Composition of Benthic Invertebrates in Streams Downstream of Kennady Lake, Fall 2007



Note: n = 5; ± = plus or minus; SE = standard error; no/m² = number of organisms per square metre; % = percent.

Figure 9.3-20 Density, Richness, and Community Composition of Drifting Benthic Invertebrates in Streams L3 and N3, Summer 2005



Note: Net position: S = immediately below water surface; B = near the bottom; n=4.

± = plus or minus; SE = standard error; no./100 m^3 = number of organisms per 100 cubic metres; % = percent.

9.3.4.2.3 Sediment Toxicity

In 2005, *Hyalella azteca* survival and growth, and *Chironomus tentans* survival in sediments collected from Kirk Lake and Lake N16 were not significantly different from the laboratory controls. *Chironomus tentans* growth in the Kirk Lake sample was also not significantly different from the laboratory control; however, growth in Lake N16 sample was significantly lower than in the laboratory control but not significantly different than in the Kirk Lake sample.

These results indicate that bottom sediments in Lake 410, Lake N16 and Kirk Lake are generally non-toxic to aquatic life. Of the eight survival and growth tests run in 2004 and 2005 combined, results were found to be significantly different from the laboratory controls for only one *Chironomus* test (growth) in 2005.

9.3.5 Fish

The following section describes the fish and fish habitat baseline information collected downstream of the Kennady Lake watershed and the adjacent 'N' watershed from 1996 to 2010. For additional information regarding fish and fish habitat, the reader is referred to Annex J and Addendum JJ.

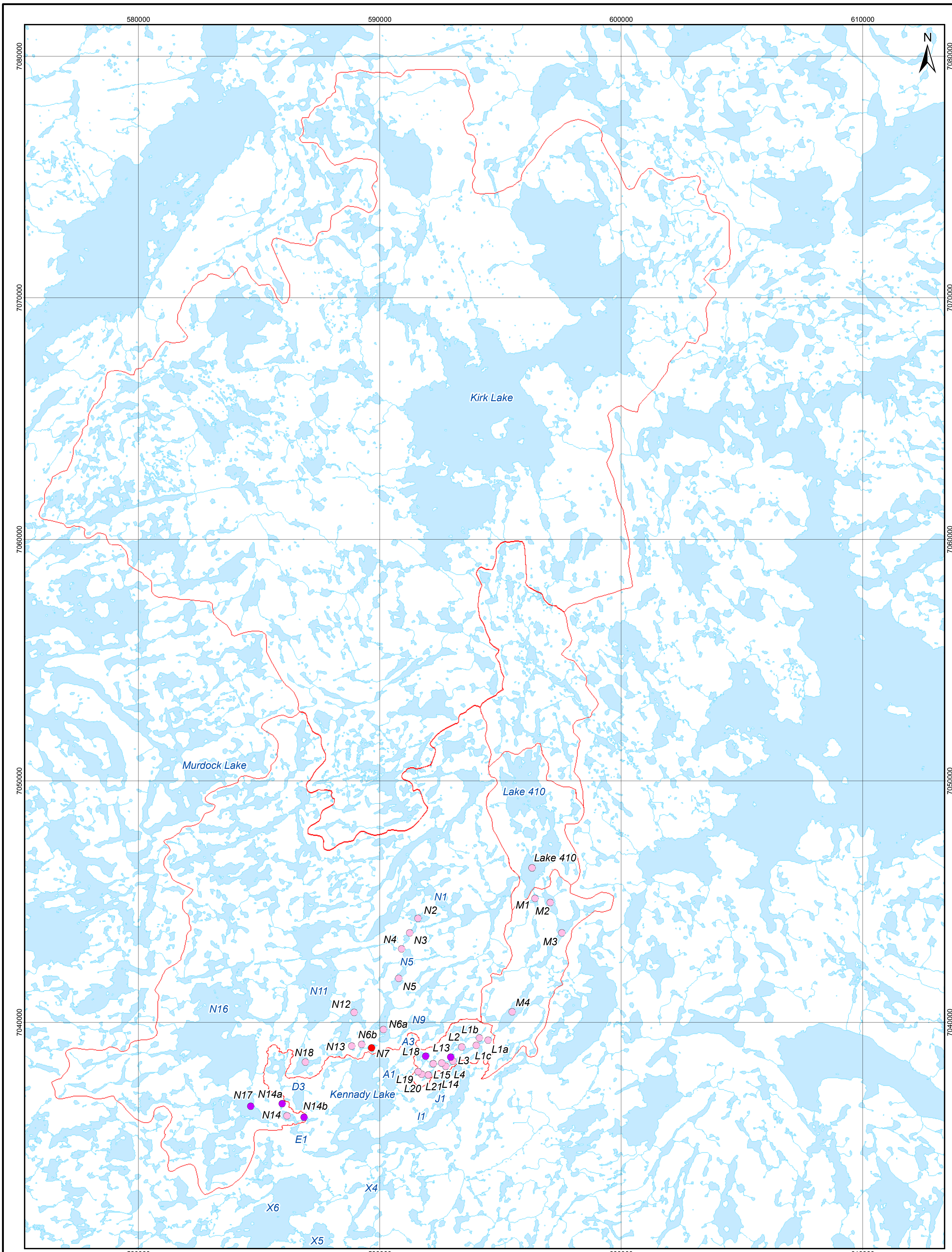
9.3.5.1 Methods

Aquatics studies in the Kennady Lake area were initiated in 1996, and continued through 2010.

The following data were collected from fisheries studies conducted between 1996 and 2010:

- Habitat information was collected for 32 small lakes. These included 18 lakes downstream of the Kennady Lake watershed, and 15 lakes in the N watershed. Small lake habitat sampling locations are shown in Figure 9.3-21.
- Limnological surveys were conducted in selected lakes in the N watershed and downstream of Kennady Lake. Limnology sampling locations are shown in Figure 9.3-22a.
- Stream habitat assessments were conducted in 21 streams in the N watershed and 26 streams downstream of the Kennady Lake watershed. Stream habitat sampling locations are shown in Figure 9.3-23.

- Aquatic habitat along the existing Winter Access Road route was assessed by helicopter.
- Gill-netting surveys were conducted to characterize the large-bodied fish community in Lake N16, Lake 410, and Kirk Lake
- Minnow traps and/or shoreline electrofishing were used to characterize the littoral fish community in Lake N16, Lake 410, and Kirk Lake
- Fish counting fences were installed to assess spring spawning migrations in five streams downstream of the Kennady Lake watershed and four streams in the N watershed.
- Lake habitat assessments were conducted in 17 small lakes downstream of the Kennady Lake watershed and 14 small lakes in the N watershed, as well as in Lake 410.
- Fish sampling was conducted to assess the fish-bearing status of 16 small lakes downstream of the Kennady Lake watershed and 13 small lakes in the N watershed. Small lake fish sampling locations are shown in Figure 9.3-24.
- Stream utilization surveys were conducted in 18 streams downstream of the Kennady Lake watershed and in 14 streams in the N watershed. Stream fish sampling locations are shown in Figure 9.3-25.
- Radio telemetry was used to monitor movements of fish within Kennady Lake and between Kennady Lake and downstream lakes.
- Fish tissue burdens were assessed by collecting muscle and liver samples for metals analysis from lake trout in Lake N16, Lake 410, and Kirk Lake.



LEGEND

- Watercourse
- Waterbody
- *A1* Lake Identifier

Sampling Year

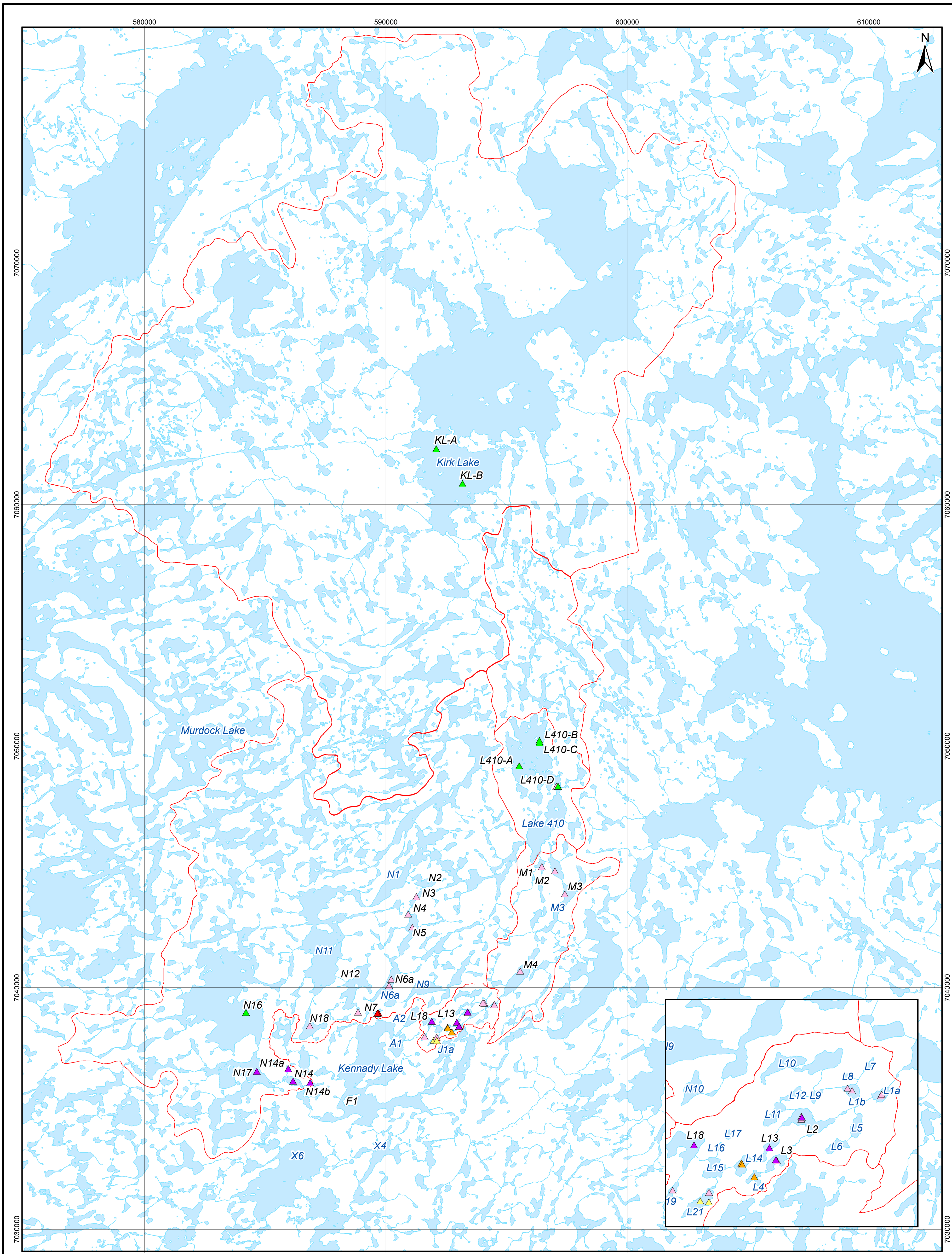
- 2010
- 2005
- 2004
- Watershed Boundary

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

GAHCHO KUÉ PROJECT

Fish Habitat Sampling Locations in Small Lakes in the N Watershed and Downstream of Kennady Lake, 2005 to 2010

PROJECTION: UTM Zone 12		DATUM: NAD83	DE BEERS CANADA
Scale: 1:150,000 (2 1 0 2 Kilometres)			
FILE No: E-Fish-131-GIS			DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 1		Figure 9.3-21
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	



LEGEND

Watercourse

Waterbody

A1 Lake Identifier

Sampling Year

2010

2007

2005 (Limnology)

2004 (Limnology)

2003 (Limnology, Zooplankton)

2002 (Limnology, Zooplankton)

Watershed Boundary

NOTES

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

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GAHCHO KUÉ PROJECT

Limnological Sampling Locations in the N Watershed and Downstream of Kennady Lake, 2002 to 2010

PROJECTION: UTM Zone 12	DATUM: NAD83

Scale: 1:150,000

2 1 0 2

Kilometres

DE BEERS CANADA

FILE No: E-Fish-133-GIS			DATE: December 17, 2010
JOB NO: 09-1365-1004	REVISION NO: 1		
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	**Figure 9.3-22**