GAHCHO KUÉ PROJECT

ENVIRONMENTAL IMPACT STATEMENT
CONFORMITY RESPONSE, ITEM 1

SECTION 8

KEY LINE OF INQUIRY: WATER QUALITY AND FISH IN KENNADY LAKE

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8 KEY LINE OF INQUIRY: WATER QUALITY AND FISH IN KENNADY LAKE

8.1 INTRODUCTION

8.1.1 Context

This section of the environmental impact statement (EIS) for the Gahcho Kué Project (Project) consists solely of the Key Line of Inquiry: Water Quality and Fish in Kennady Lake. 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) included this topic as a key line of inquiry because of the following concern:

> *"Lowering the water level of the majority of the lake and exposing the lake bottom for 15 or more years is of great concern to relevant government departments and Aboriginal communities."*

This assessment is based on an updated mine plan compared to the plan on which the Terms of Reference was based. The concern listed above is still generally applicable to the Project but the Water Management Plan will be slightly different and the duration lower due to a shorter mine life. The water level in Kennady Lake will be lowered, but the dewatering process will be staged through areas of the lake based on pit development through the mine operation. At the end of the mine operation, the lake will be refilled.

The potential impacts of the proposed Project on the aquatic environment are spread between three key lines of inquiry presented in Sections 8, 9, and 10 of the EIS. 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, operation, and closure and reclamation 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. 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: Water Quality and Fish in Kennady Lake includes the specific effects of changes caused by the Project within Kennady Lake and the Kennady Lake watershed. An analysis of the stability of deposited mine rock and processed kimberlite in excavated pits is included in this key line of inquiry, as well as in the following key line of inquiry and subjects of note:

- Long-term Biophysical Effects, Closure and Reclamation (Section 10);
- Mine Rock and Processed Kimberlite (Section 11.5);
- Permafrost, Groundwater, and Hydrogeology (Section 11.6); and
- Climate Change Impacts (Section 11.13).

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. The most comprehensive analysis with greatest detail will be provided once in the most appropriate location, but summaries will be provided in all other key lines of inquiry and subjects of note as required by the final Terms of Reference. For example, downstream effects will be addressed in detail in the Key Line of Inquiry: Downstream Water Effects. However, a similar requirement for downstream effects is included in the Terms of Reference for the Kennady Lake key line of inquiry. This will be addressed by a summary and a reference to the location of the in-depth analysis.

The Key Line of Inquiry: Water Quality and Fish in Kennady Lake will contain the primary substantive analysis of the effect of the Project on the water quality and fish in Kennady Lake; however, the primary substantive analysis of two closely related topics will be presented in the following subjects of note:

- Mine Rock and Processed Kimberlite; and
- Permafrost, Groundwater, and Hydrogeology.

Substantial summaries will be provided in this key line of inquiry because of their importance to the water quality and fish in Kennady Lake.

8.1.2 Purpose and Scope

The purpose of the Key Line of Inquiry: Water Quality and Fish in Kennady Lake is to meet the Terms of Reference for the EIS issued by the Gahcho Kué Panel. The table for concordance for the Terms of Reference for this key line of inquiry is shown in Table 8.1-1. The entire Terms of Reference document is included in Appendix 1.I of Section 1, Introduction of this EIS. The complete table of concordance for the entire Terms of Reference is provided in Section 1, Appendix 1.II.

Table 8.1-1 Terms of Reference Pertaining to Water Quality and Fish in Kennady Lake

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	Description	
3.1.3 Existing Environment: Water Quality and Quantity	Describe all water bodies, watercourses, and major drainage areas and watersheds potentially affected by the proposed development	8.3.1
	Describe Kennady Lake, including:	
	- lake-bed bathymetry and composition	8.3.8.2.1
	- lake volumes and seasonal variations	8.3.8.2.1
	- freeze/thaw timing	8.3.5.2.1
	- permafrost conditions beneath or around lake	8.3.3.2, 11.6.2.1, Annex D
	- flow patterns	8.3.5.2.3
	Describe existing water quality for each water body identified for use in the proposed development, and those immediately downstream	8.3.6.2.1, 8.3.6.2.2
	Describe existing groundwater resources in the Project area, including quality and quantity, flow patterns, recharge and discharge areas, and interactions with surface water	8.3.4.2.1, 8.3.4.2.2, 8.3.4.2.3, 8.3.4.3
	identify relevant federal, provincial, or territorial guidelines, criteria, or legislation	8.3.6.1
3.1.3 Existing Environment: Fish and Aquatic Life Forms	describe fish-bearing waterbodies and watercourses that may be affected by the proposed development	8.3.8.2.1
	describe potentially affected fish species and local populations, and for each describe:	
	- seasonal and life cycle movements	8.3.8.2
	- habitat requirements for each life stage	8.3.8.2.
	- local and regional abundance, distribution, use of habitat	8.3.8.2
	- known sensitive habitat areas, species or life stage/activity (e.g., spawning, hatching, feeding)	8.3.8.2
	describe key species used for traditional harvesting activities and any ecotourism activities	8.5.2.2
	describe the micro-organism community present in Kennady Lake, including plankton, algae, and benthic invertebrates	8.3.7.2.1, 8.3.7.2.2
	describe any known issues currently affecting fish and aquatic life forms in the proposed development (e.g., contamination of food sources, parasites, disease)	8.3.8.2.10

Table 8.1-1 Terms of Reference Pertaining to Water Quality and Fish in Kennady Lake (continued)

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
4.1.2 Key Lines of Inquiry: Water Quality and Fish in Kennady Lake	general requirements pertaining to water quality and fish in Kennady Lake include:	
	- the EIS must provide a detailed analysis of all impacts on fish abundance, health, and fitness for consumption including a comprehensive analysis of potential impacts on water quality of Kennady Lake as a result of possible contamination. Particular emphasis must be placed on the ability of the lake ecosystem, particularly fish and fish habitat, to recover from prolonged exposure of the lake-bed and on the viability of the proposed disposal methods for waste rock and kimberlite	8.8, 8.9, 8.10, 8.11, 11.5
	specific requirements pertaining to fish in Kennady Lake include:	
	- describe any impacts associated with the fish-out, fish salvage, and restocking	8.6.2.1, 8.10.3
	- describe habitat destruction and creation, including potential for interrupting fish migration, alterations to natural drainage, and addition of deep water habitat	8.6.2
	- describe possible fish contamination, and wildlife and human health effects from contaminated fish consumption, including pathways and long- and short-term exposure levels and health effects of toxic exposure levels on wildlife and humans.	8.6.2, 8.7.3, 8.9.8.12
	- describe possible changes to fish behaviour including interruption of migration and spawning patterns and associated effects and changes in the behaviour of wildlife species dependent on fish populations	8.6.2, 8.10, 8.11,8.12,
	specific requirements pertaining to water quality in Kennady Lake include:	
	- describe the water balance for Kennady Lake and analysis of related uncertainties	8.4.5, 8.15
	- describe expected changes in turbidity in Kennady Lake with adaptive management options for unexpected turbidity levels (this analysis may use simulation models)	8.8
	- describe the hydrogeological dynamics of the lake bottom under freezing conditions, in particular the potential for highly concentrated deep ground water to be expelled into the remaining ponds during freeze up, as well as an assessment of changes in the thermal regime of the lake bottom and the extent of freezing	11.6
	- provide a description of maintenance procedures for long-term frozen conditions of potentially reactive waste rock and barren kimberlite, including the incorporation of frozen conditions under climate change parameters	8.6, 11.6, 11.13
	- provide a long-term monitoring plan of thermal conditions of frozen waste rock and PK piles	8.11, 11.5
	- describe any interactions between ground water and submerged processed kimberlite and waste rock, including the possibility of the pits being a long-term contamination source	8.6.2.3, 11.6, 11.5

Table 8.1-1 Terms of Reference Pertaining to Water Quality and Fish in Kennady Lake (continued)

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
4.1.2 (continued)	- describe potential contamination sources including: mill effluent, lake-bed sediments, backfilled pits, use of explosives, spills (including additive effects of minor spills over time), waste rock and processed kimberlite, and deep ground water, including adequate information to evaluate the potential for dust generation from the exposed lake-bed (e.g., substrate characteristics, particle size, sediment chemistry) as well as bench testing of drying behaviour	8.4.6, 11.4, 11.6
	- describe all potential sources for water contamination, particularly hydrocarbon or ammonium nitrate contamination including accidents and malfunctions; this must also include an evaluation of the potential for explosive charges, exploded or unexploded, to contribute to pollution	8.4.6, 8.6
	- provide a detailed Water Management Plan with information on treatment surfactants and reagents with enough detail to assess the capability of the treatment system to protect water quality, including back up options for adaptive management	8.4.3
	- describe any proposed collection system for runoff from processed kimberlite and waste rock storage facilities, including expected contaminant levels and contingency plans	8.4.3
	- describe any proposed monitoring activities, including monitoring of untreated runoff from roads or other structures. (the principles addressed in section 3.2.7 on compliance inspection, monitoring, and follow-up apply)	8.16
	- describe the spatial extent of downstream effects and how these effects may change through time (seasonally and annually)	9
	- describe water balance calculations during present conditions and over time as the Project proceeds is required to compare baseline conditions with future downstream effects	8.4.5
	- describe impacts on riparian vegetation in Kennady Lake, water fowl, semi-aquatic furbearers, terrestrial mammals, and channel stability from downstream effects of water discharges during construction, fluctuating water levels during operation, and reduced water levels while the lake is refilling	8.12, 8.12.2.1.2, 11.12
	- describe impacts on wildlife resulting from a possible change in freeze-up and thaw conditions associated with the de-watering of Kennady Lake	8.12, 8.12.2.1.2, 11.12
	- describe the reversibility of impacts associated with water level changes and the ability of affected ecosystems to recover	8.6, 8.7.4, 8.11
	- describe the effects of lake dewatering and excavation of pits on ground water flow and quality in the Kennady Lake area in the short- and in the long-term as well as details on how groundwater flows will be managed (including simulations)	8.6.2.3, 8.7.3.2, 8.7.3.3, 11.6

Table 8.1-1 Terms of Reference Pertaining to Water Quality and Fish in Kennady Lake (continued)

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
4.1.2 (continued)	- describe the potential interaction between ground water and the open pits, as well as between ground water and submerged waste rock or kimberlite, including the possibility of the pits being a long-term contamination source	8.6.2.3, 11.6, 11.5
	- describe the relationship between taliks (i.e., unfrozen sections of soil beneath water bodies) and ground water flows in the Project area, particularly potential for taliks acting as a pathway for contaminants, including the distribution of taliks in the Project area and any connection or interactions between taliks of different lakes	8.3.4.2.1, 8.3.4.2.2, 8.3.4.2.3, 11.6
	- describe the chemical stability of co-disposed waste rock and processed kimberlite	Appendix 8.I
	- describe the confidence in predictions from long-term modelling has been conducted for permafrost issues, particularly effects of the pits on the thermal regime, and a verification that robust monitoring program will be in place	8.15
7 (Table 7-2) Fish Issues	remaining fish issues pertaining to watershed impacts include:	
	- fish health	8.9
	- fish behaviour (increase and decrease in flow)	8.10
	- migration interruption	8.10
	- water chemistry alterations from deep ground water	8.6, 8.8.4
	- chemistry changes in sediment and water	8.6, 8.8.3, 8.8.4
	- impacts of backfilling on aquatic biota	8.6, 8.10.4
	- fluctuation of water flows	8.7
	remaining fish issues pertaining to road effects include:	
	- ice road construction	8.6
	- erosion	8.7
	- water withdrawal	8.7
	- increased ice thickness	8.7
	- watercourse crossings	8.6, 8.10
	- spills	8.4, Appendix 3.I, Attachment 3.I.1
	remaining fish issues pertaining to operations and construction include:	
	- fish out	8.6, 8.10.3
	- contaminant levels	8.8

Table 8.1-1 Terms of Reference Pertaining to Water Quality and Fish in Kennady Lake (continued)

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
7 (Table 7-2) Fish Issues (continued)	- freshwater lake impacts	8.7, 8.8.1, 8.10.3, 8.11, 8.13
	- habitat destruction and creation	8.6, 8.10
	- noise and vibration on fish behaviour	8.6.2.2
	remaining fish issues pertaining to data collection include:	
	- baseline data	8.3
	- monitoring	8.16
	remaining fish issues pertaining to long-term effects include:	
	- feasibility of recovery	8.11
	- physical changes to lake	8.6
	- addition of deep water habitat post-mine and impacts on the rest of the lake	8.6, 8.8, 8.10
	remaining fish issues pertaining to reclamation methods include:	
	- alternative water sources	8.6
	- habitat creation	8.6, 10
	- restocking of fish	8.6, 8.11
7 (Table 7-3) Water Issues	remaining water issues pertaining to water quality include:	
	- end of pipe contamination	8.8.3
	- pits as long-term contamination sources	8.6, 8.8.4, 11.6, 11.5
	- turbidity during dewatering and rewatering lake	8.8.4
	- contamination runoff from PKC and waste rock	8.6
	- dust as water contamination	8.8.3
	- hydrocarbon contamination	8.6, Appendix 3.I, Attachment 3.I.1
	- length and adequacy of long-term water quality monitoring	8.16
	remaining Kennady Lake water issues related to public concern include:	
	- implications of water quality on human health	8.12
	remaining Kennady Lake water issues related to surface water and watershed include:	
	- ice quality on Kennady Lake and surrounding lakes	8.3.5.2.1
	remaining Kennady Lake water issues pertaining to water use and management include:	
	- alterations to natural drainage	8.7

Table 8.1-1 Terms of Reference Pertaining to Water Quality and Fish in Kennady Lake (continued)

Final Terms of Reference Requirements		Applicable EIS Sub-section
Section	**Description**	
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.	8.16
	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.	8.3.4.2.3, 8.3.4.3.2, 8.3.7.2.1, 8.4.6.3.1, 8.6.2.3, 8.8.3.1.1, 8.10.2.4, 8.10.3.2, 8.10.3.3, 8.15
	The EIS must include a proposal of how monitoring activities at the Gahcho Kué diamond mine can be coordinated with monitoring programs at all other diamond mines in the Slave Geological Province to facilitate cumulative impact monitoring and management. This proposal must also consider reporting mechanisms that could inform future environmental assessments or impact reviews. The developer is not expected to design and set up an entire regional monitoring system, but is expected to describe its views on a potential system. The developer must also state its views on the separation between developer and government responsibilities.	8.11, 8.16

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

EIS = environmental impact statement.

This key line of inquiry includes a detailed assessment of direct impacts to Kennady Lake, including inlets, outlets, and riparian zones. Impacts are included for the construction (i.e., drawdown), operation, and closure and reclamation phases. A comprehensive analysis of impacts on water quality of Kennady Lake resulting from potential Project-related contamination is incorporated. The potential for subsequent effects of contamination on fish, wildlife, and human health is considered. This assessment also includes impacts on fish abundance, health, and fitness for consumption. More detailed information on the requirements for this key line of inquiry can be found in Table 8.1-1.

8.1.3 Study Area

8.1.3.1 General Location

The Project is situated north of the north-eastern 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 8.1-1).

The Project is located in the watershed of Kennady Lake, a small headwater lake within the Lockhart River system. Kennady Lake discharges to the north, via a series of small lakes, into Kirk Lake and thence into Aylmer Lake located on the main stem of the Lockhart River. The Lockhart River system drains into the north-eastern arm of Great Slave Lake. .

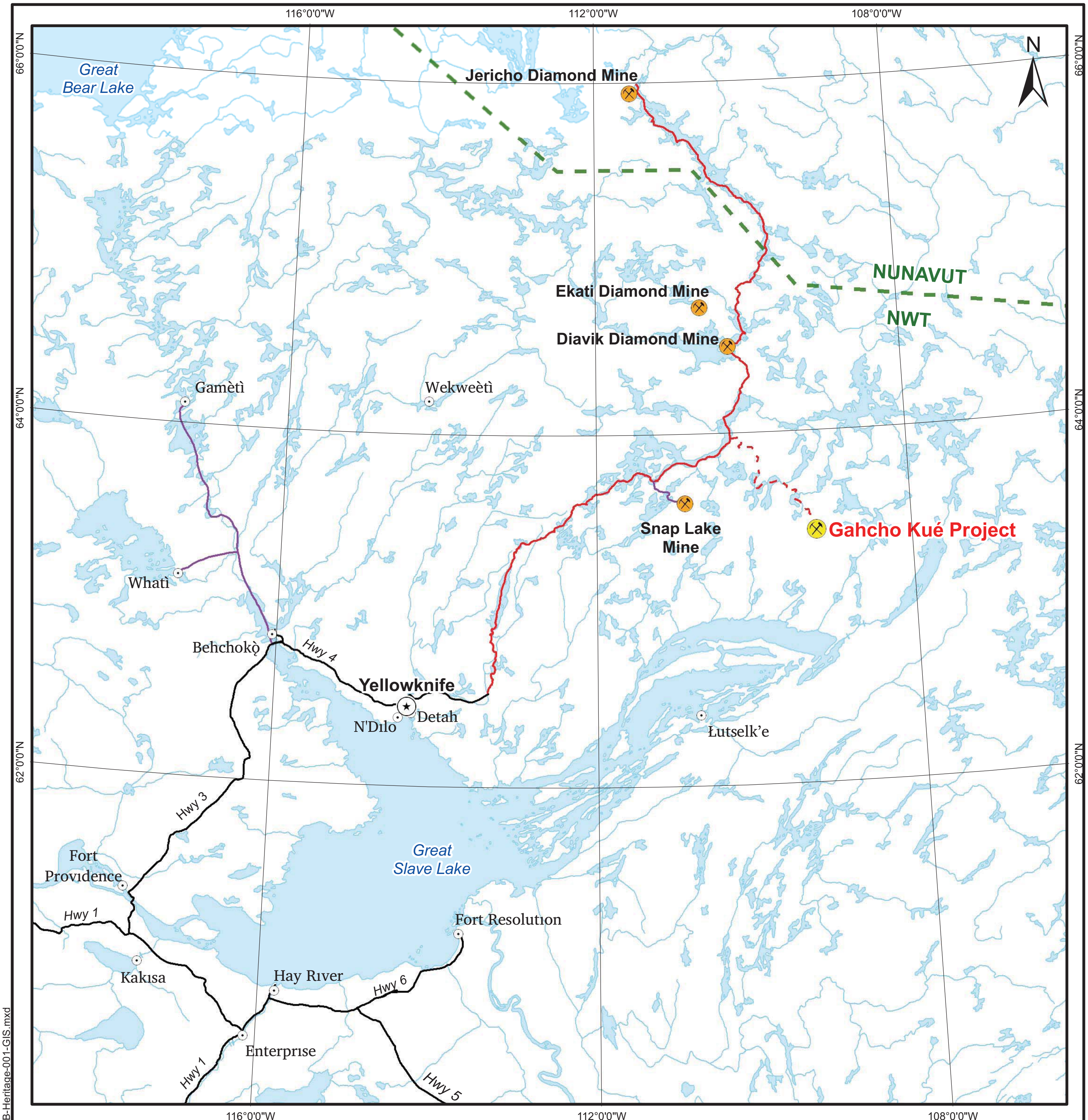
8.1.3.2 Study Area Selection

To assess the potential effects of the Project on the water quality and fish in Kennady Lake, 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 geographic scope for the analysis of this Key Line of Inquiry includes Kennady Lake itself, along with its inlets, outlets, and riparian zones.”

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.



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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:	DATUM:
Canadian Lambert Conf. Conic	NAD83

Scale: 1:3,500,000

50 25 0 50

Kilometres

DE BEERS CANADA

FILE No:			DATE:
B-Heritage-001-GIS			September 20, 2010
JOB NO:	REVISION NO:		
09-1365-1004	8		
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Figure 8.1-1

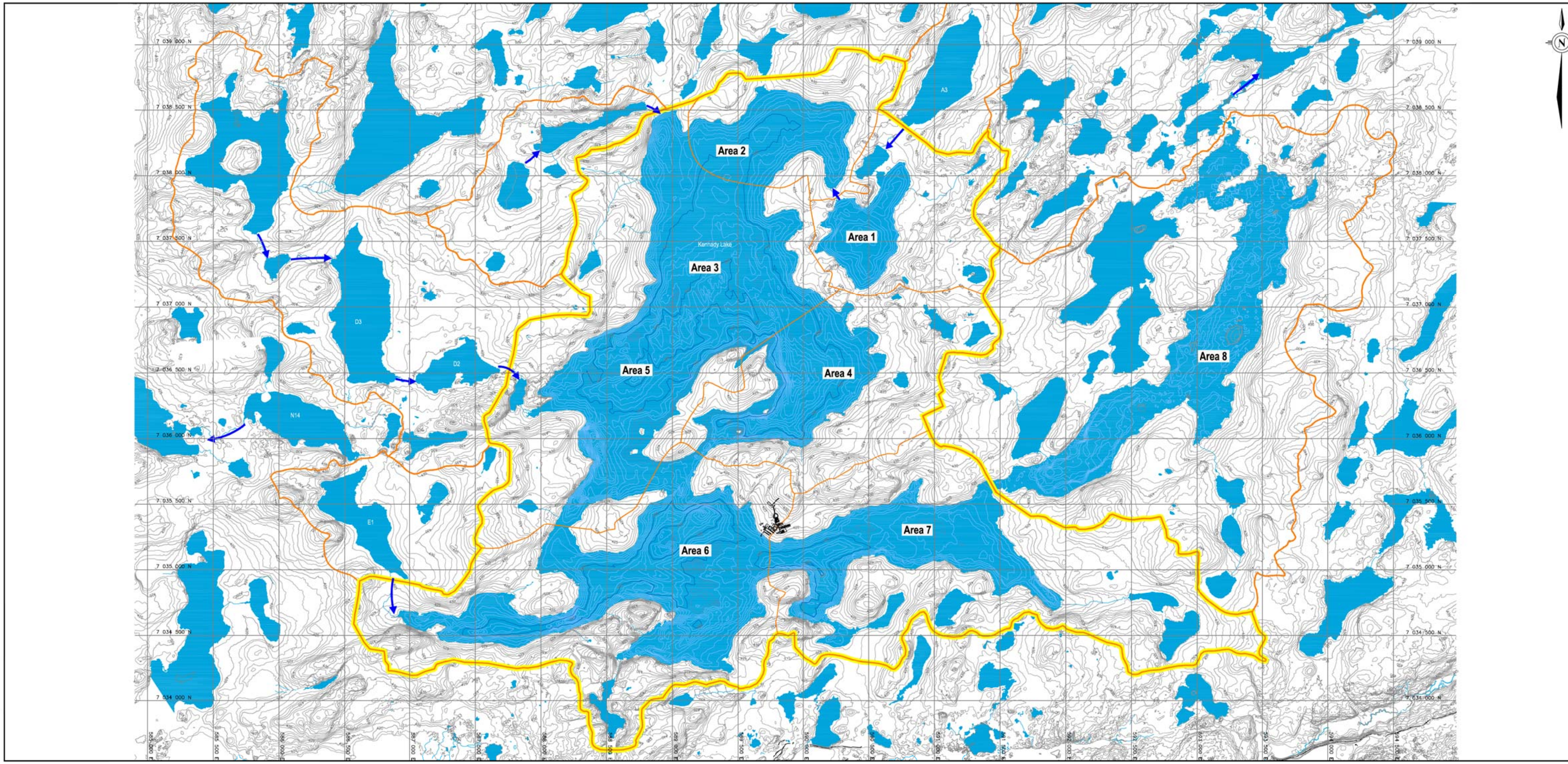
The boundaries were set so that all the expected direct and indirect effects of the Project would lie within the boundaries. The Local Study Area (LSA) in the baseline studies extended from Kennady Lake watershed to the outlet of Kirk Lake and included all the watersheds that could potentially be affected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

The study area identified by the Gahcho Kué Panel (2007) for this key line of inquiry forms the upper headwater region of the baseline LSA. Therefore a new study area, the Kennady Lake Study Area, has been defined that is specific to the Key Line of Inquiry: Water Quality and Fish in Kennady Lake (Figure 8.1-2). The baseline studies were sufficient to address the Terms of Reference requirements for the new study area within this key line of enquiry.

8.1.3.3 Kennady Lake Study Area

The Kennady Lake Study Area includes the eight areas of Kennady Lake (Areas 1, 2, 3, 4, 5, 6, 7, and 8, and the Kennady Lake watershed. The structure of the study area has been altered from that presented in the water quality baseline program (Annex I) where Kennady Lake was delineated by Basins (i.e., K1, K2, K3, K4, and K5). A comparison of the lake area and basin segregation is provided in Section 8.3. The Kennady Lake watershed is 32.5 square kilometres (km^2). The downstream limit of the study area is the Kennady Lake outflow in Area 8 (i.e., Stream K5). As required by the Terms of Reference (Gahcho Kué Panel 2007), the study area includes Kennady Lake itself, along with its inlets, outlets, and riparian zones (located in the Kennady Lake watershed). All waterbodies (and associated riparian areas) downstream of Kennady Lake up to Great Slave Lake will be addressed in the next key line of inquiry on downstream water effects (Section 9).

Kennady Lake watershed represents an appropriate study area for the surface water disciplines, including hydrology, water quality, riparian vegetation, lower trophic levels in the lake (e.g., benthic invertebrates, plankton), and fish. However, the boundaries for deep groundwater are different. Kennady Lake and the proposed Project footprint are located in the central part of the hydrogeology baseline LSA, which covers an area of some 222 square kilometres (km^2) (see also Figure 11.6-1). Major local lakes act as the controlling features of the deep groundwater flow. Therefore, the hydrogeology analysis will draw on information beyond the Kennady Lake Study Area to address the effects of the Project on Kennady Lake.



LEGEND

Existing Ground Contours
5m Index - 1m Intermediate

Bathymetry Contours
5m Index - 1m Intermediate

Controlled Area Boundary

Marsh Area

Scrub

Sub-watershed Boundary

Drainage Flow Direction

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

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GAHCHO KUÉ PROJECT

Kennady Lake Study Area

PROJECTION: UTM Zone 12	DATUM: NAD83	DE BEERS CANADA
SCALE 500 0 500 METRES		
FILE No: E-SWQ-004-CAD		DATE: November 22, 2010
JOB No: 09-1365-1004	REVISION No: X	Figure 8.1-2
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8.1.3.4 Content

This introduction is followed by details of the impact analysis and assessment related to water quality and fish in Kennady Lake. The headings of these sections 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, beginning with the general environmental setting in which the Project occurs, followed by a summary of baseline methods and results for specific components, including climate, permafrost, groundwater, surface water quantity, surface water and sediment quality, aquatic habitat, lower trophic levels, and fish (Section 8.3).
- **Water Management Plan Summary** presents a conceptual Water Management Plan and water balance during Project construction, operations, and closure, including a description of potential substance sources, and accidents and malfunctions relevant to water management (Section 8.4).
- **Assessment Approach** provides details on specific aspects of the assessment approach (described in Section 6 of the EIS) that are particularly relevant to the assessment of effects to water quality and fish in Kennady Lake (Section 8.5).
- **Pathway Analysis** identifies all potential pathways by which the Project could affect water quality and fish in Kennady Lake, and provides a screening level assessment of each pathway after applying environmental design features and mitigation that reduce or eliminate Project-related effects (Section 8.6).
- **Effects to Water Quantity** explains the scientific methods that were used to predict the changes to water levels, flows, and bank stability in the Kennady Lake watershed, and presents the results of the analysis of effects to water quantity during the construction, operations, and closure phases of the Project (Section 8.7).
- **Effects to Water Quality** explains the scientific methods, including modelling, that were used to simulate the changes to Kennady Lake's water quality during the construction, operations, and closure phases. It then presents the results of the analysis of effects to water quality as a result of the Project (Section 8.8).
- **Effects to Aquatic Health** explains the scientific methods that were used to predict the potential effects related to changes to water quality

and to acidifying emissions, and presents the results of the analysis of effects to aquatic health as a result of the Project (Section 8.9).

- **Effects to Fish and Fish Habitat** explains the methods that were used to predict the changes to Kennady Lake's aquatic habitat, lower trophic levels, and fish, and presents the results of the analysis of effects to fish resulting from the Project (Section 8.10).
- **Recovery of Kennady Lake and its Watersheds** explains the methods used, including a literature review, and the results related to the rate of recovery of Kennady Lake and the nature of the final ecosystem (Section 8.11).
- **Related Effects to Wildlife and Human Use** presents a summary of the results of the analysis of related effects to wildlife and human health that flow from any of the other effects to Kennady Lake, identified in other EIS sections, which are predicted to occur as a result of the Project (Section 8.12).
- **Residual Effects Summary** summarizes the effects to Kennady Lake that are predicted to remain after all measures (e.g., environmental design features) to eliminate or reduce negative effects have been incorporated into the Project design (Section 8.13).
- **Residual Impact Classification** describes methods used to classify residual effects, and summarizes the classification results (Section 8.14).
- **Uncertainty** discusses sources of uncertainty surrounding the predictions of impacts to Kennady Lake's water quality and fish and how this uncertainty is addressed by the Project (Section 8.15).
- **Monitoring and Follow-up** describes proposed monitoring programs, contingency plans, and/or adaptive management strategies related to Kennady Lake (Section 8.16).
- **References** list all documents and other material used in the preparation of this section (Section 8.17).
- **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 8.18).

8.2 SUMMARY

Background

The proposed Gahcho Kué Project (Project) is a diamond mine located in the watershed of Kennady Lake, a headwater lake within the Lockhart River system, located about 280 kilometres (km) northeast of Yellowknife, Northwest Territories (NWT). The Lockhart River drains into the East Arm of Great Slave Lake. Water quality and fish in Kennady Lake were identified in the *Terms of Reference for the Gahcho Kué Environmental Impact Statement* as a key line of inquiry because of concerns from several government departments and Aboriginal communities related to its proposed dewatering, and subsequent refilling.

The Key Line of Inquiry: Water Quality and Fish in Kennady Lake includes the specific effects of changes caused by the Project within Kennady Lake and the Kennady Lake watershed. Impacts are included for the construction (i.e., Kennady Lake dewatering), operation, and closure (i.e., refilling and recovery of Kennedy Lake) phases. The study area includes Kennady Lake itself, along with its inlets, outlets, and riparian zones, to the Kennady Lake outflow in Area 8 (Figure 8.1-2). The area downstream of Kennady Lake to Great Slave Lake is included in the Key Line of Inquiry: Downstream Water Effects (Section 9).

Existing Environment

Components of the existing environment that are relevant to this key line of inquiry include climate, permafrost, hydrogeology, surface water quantity, surface water quality, lower trophic levels, and fish and fish habitat. Where available, historical baseline data for Kennady Lake and streams and lakes in its watershed 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. The primary purpose of this plan is to reduce the effect of the Project on the aquatic ecosystem of Kennady Lake and downstream environments during construction, operations, and closure phases.

A large portion of Kennady Lake (Areas 2 to 7 in Figure 8.1-2) will be dewatered to allow access to the lake bed and underlying kimberlite pipes. Natural drainage from the upper portion of the Kennady Lake watershed will be diverted to an adjacent watershed (N watershed). The most downstream basin of the lake (Area 8) will be separated from the rest of Kennady Lake by the construction of a water retaining dyke (Dyke A).

During operations, Project activities will be designed to minimize the discharge of site water to downstream waterbodies, and to recycle process water to the greatest extent possible. After mining has been completed, the natural drainage system in the Kennady Lake watershed, which has not been modified by the Project, will be restored and refilling of the dewatered lake beds will begin.

Assessment Approach

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. Water quality and select fish species were identified as VCs and the following assessment endpoints were selected:

- 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.

Effects to Water Quantity

During construction and operation, the dewatering process is not expected to result in effects to natural channel or bank stability; however, the exposed lake bed within the dewatered Kennady Lake may be subject to erosion, depending on the bed substrate. The construction of earth-filled diversion dykes will increase water levels and surface areas in a number of the diversion lakes, block the existing outlet of another lake (Lake B1) with no change in water levels, and cause the cessation of flows downstream of the dykes for most of the year. However, as mean annual water level variation in the upper watershed lakes is expected to be similar or reduced from pre-diversion conditions, erosion potential and sediment sourcing will be minimized. The flow paths and constructed diversion channels that link the diverted lakes to the adjacent watershed, if required, will be designed to prevent erosion and maintain stability.

Runoff from Project surface infrastructure in watersheds that drain to Areas 2 to 7 will be conveyed to the Water Management Pond (WMP) in Areas 3 and 5 by the site water management system. Runoff from watersheds that drain directly to Area 8 will be free-draining. Project surface infrastructure, including the two mine rock piles, the Coarse Processed Kimberlite (PK) Pile, and the Fine Processed Kimberlite Containment (PKC) Facility, will be located almost entirely within the controlled area boundary and all drainage will be managed. No effects on natural channel or bank stability are anticipated.

During dewatering, water from Area 7 will be directed to Area 8. The resultant flows downstream of Area 8 will be generally increased from baseline conditions; however, flows will be limited so that discharge will not exceed the 1:2 year flood discharge volume. During operations, flows through Area 8 will be decreased from baseline conditions because there is no flow from the watershed upstream of Dyke A. The alterations in water levels in Area 8 will correspond with the flow changes; no adverse effects to channels or bank stability are anticipated.

During construction and operation phases, dewatering and WMP discharge from Areas 3 and 5 will be directed to Lake N11. Pumping to Lake N11 will commence on June 1 of each year, at a pumping rate that limits discharge at the Lake N11 outlet to not exceed 500,000 m^3/d.

At closure, the diverted watersheds, with the exception of the A watershed, will be restored, and pumping from Lake N11 will occur to supplement the refilling of Kennady Lake. No effects on channel or bank stability are expected during refilling, and erosion will be prevented at discharge points by armouring of outfalls and use of diffusers. No water from the refilled areas will be released to Area 8 until the water level is at the naturally armoured shoreline elevation, and water quality meets specific criteria. During the refilling of Kennady Lake, flows at the Area 8 outlet (Stream K5) will continue to be reduced similar to operations.

Beyond closure, the water balance will change for the Kennady Lake watershed resulting in the increase of mean annual water yield by 8.9 percent (%). The reduction in the surface area of Kennady Lake of 14.1% means that flood peak discharges will increase post-closure due to less storage in the lake.

Effects to Water Quality

Potential influences to water quality in the main areas of Kennady Lake (Areas 2 to 7) and Area 8 include the following:

- air emissions from the Project (e.g., fugitive dust, vehicle emissions);
- isolation of Areas 2 and 7 from Area 8;

- drainage in the controlled area that comes into contact with the Fine PKC Facility, mine rock piles, and the Coarse PK Pile; and
- the open Hearne and Tuzo pits.

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 in 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.

The effects of dust and associated metal deposition on water quality from Project air emissions were evaluated for a subset of lakes within the Kennady Lake watershed; changes to total suspended solids (TSS) and trace metals (e.g., aluminum, cadmium, chromium, copper, iron, mercury, and silver) concentrations resulting from deposition will potentially exceed average baseline concentrations in two or more lakes adjacent to the Project area during construction and operations by greater than 100%. The effects on TSS and metal concentrations are expected to be localized in the immediate vicinity of the Project and restricted to the period during and after freshet. Based on the evaluation of acidifying emissions during construction and operations, Project-related deposition of sulphate and nitrate in the Kennady Lake watershed is not predicted to result in lake acidification.

To estimate the water quality in Kennady Lake (i.e., Areas 2 to 7 and Area 8) through the closure phase (i.e., the refill period), and post-closure once Kennady Lake is refilled and Dyke A is breached, a dynamic, mass-balance water quality model was developed in GoldSim™. Water quality in Area 8 will remain similar to background conditions during operations and closure, before the removal of Dyke A, because this area will remain isolated from the main areas of Kennady Lake. Water quality in Area 8 during post-closure will be driven by the water flowing from Kennady Lake after Dyke A is breached, with additional dilution from the Area 8 sub-watershed.

Concentrations of total dissolved solids (TDS) and major ions in the main areas of Kennady Lake are projected to increase during the operations phase due to the management of water within the controlled area (e.g., runoff, groundwater inflows, process water) and decrease during the closure phase when the lake is refilled. Concentrations of TDS and major ions in Area 8 are predicted to increase when Dyke A is breached; concentrations are predicted to peak within five years of Dyke A being removed, as water in Area 8 is replaced with water from the refilled Kennady Lake. Over time, concentrations of TDS and major ions are generally predicted to decline, but for some parameters (e.g., potassium), concentrations are predicted to increase during the post-closure period and reach a long-term steady state concentration within a few decades. TDS and all major ions are predicted to remain above background conditions, but below levels that would affect aquatic health.

Nutrient levels are predicted to increase in Areas 2 through 7 during operations, with nitrogen projected to decrease during the closure phase as nitrogen residue in the stored PK and mine rock from blasting deplete. By the time Dyke A is removed, modelled nitrate and ammonia concentrations are expected to be at, or below, water quality guidelines and decline thereafter to near background levels. In Area 8, all forms of nitrogen are expected to peak in concentration in Area 8 within five years of breaching Dyke A, then return to near-background concentrations. Concentrations of phosphorus are projected to increase in Areas 3 to 7 of Kennady Lake during operations due to loading to the WMP, but to decrease during the closure phase due to the refilling of Kennady Lake. Phosphorus concentrations are projected to gradually increase to steady state concentrations during post-closure due to seepage from materials located in the mine rock piles, Coarse PK Pile and the Fine PKC Facility. The Fine PKC Facility is the largest contributing source of phosphorus. Using a combination of mitigation strategies, De Beers is committed to incorporating additional mitigation to achieve a long-term maximum steady-state total phosphorus concentration of 0.018 mg/L in Kennady Lake. Although the phosphorus concentrations will be reduced by the additional mitigation, they will remain higher than the baseline concentration range of <0.001 to 0.010 mg/L. As a result of the increase in phosphorus levels, changes in lake trophic status from oligotrophic (low productivity) to mesotrophic (moderately productive) are expected in the refilled Kennady Lake, including Area 8.

An increase in productivity (e.g., growth of phytoplankton and algae) will result in increased organic carbon remaining in the lake after senescence in the fall. An increased under-ice oxygen demand in Kennady Lake is anticipated as a result of the increased productivity. The winter oxygen depletion rates for surface (under ice to 6 m), middle (7 to 12 m) and deeper (>12 m) depth zones in Kennady Lake and a dissolved oxygen balance for Kennady Lake at the end of winter was estimated. The results indicate that the surface zone of the water column are expected to remain oxygenated over the winter, but the mid-depth and bottom depth zones will likely be subject to lower oxygen levels. The deeper epilimnetic zones of the open Tuzo and Hearne pits are not expected to be subject to the same winter oxygen demand as other shallower areas of Kennady Lake and are expected to remain well oxygenated.

Of the 23 trace metals that were modelled for the assessment, three patterns are predicted in modelled concentrations of the main areas of Kennady Lake over operations and closure:

- Some metals are predicted to increase in concentration during the operations phase, then steadily decline in concentration as the lake is flushed during post-closure. These include chromium, cobalt, iron, lead, manganese, mercury, selenium, silver, thallium, uranium, and zinc, in which chromium and iron are projected to exceed water quality guidelines in post-closure.
- Some metals are predicted to increase in concentration relatively steadily throughout the operations phase, rise or fall during closure, and then remain fairly constant throughout post-closure. These metals include aluminum, antimony, arsenic, cadmium, copper, nickel, and vanadium, in which cadmium and copper are projected to exceed water quality guidelines in post-closure.
- Some metals are predicted to increase after closure, reach steady state conditions in Kennady Lake within about 40 years. These metals include barium, beryllium, boron, molybdenum and strontium; none of these five metals are projected to exceed water quality guidelines in post-closure.

As groundwater and geochemical sources are the primary contributors of these metals**,** the dissolved fraction of these metals is predicted to comprise the majority of the total concentrations.

Concentrations of trace metals in Area 8 are predicted to remain similar to background concentrations until Dyke A is breached, after which it will take approximately five years for metals concentrations to peak and then follow the general trends described for Kennady Lake in post-closure. Of the 23 modelled trace metals, cadmium, chromium, and copper are projected to exceed water quality guidelines during post-closure in Area 8.

A long-term analysis evaluated the stability of the stratification (meromictic conditions) in the Tuzo Pit following the refilling of Kennady Lake, and concluded that the saline bottom layer will remain stable and will not overturn. The water quality in Kennady Lake above Tuzo Pit will, therefore, be primarily determined by the upper 20 metres (m) of fresh water, which will be subject to temperature and wind-driven summer seasonal stratification.

Effects to Aquatic Health

Potential effects to aquatic health were assessed based on the changes to water quality from Project emissions, and Project activities. During construction and operation, predicted maximum concentrations of suspended solids and some metals from Project air emissions are predicted to increase concentrations in some lakes close to the Project boundary above water quality guidelines; some of these lakes are fish-bearing. Given the conservatism in the predicted concentrations, and the short length of the exposure to elevated concentrations, the potential for adverse effects from dust and metals deposition is considered to be low. At the end of operations, the Project is no longer a notable source of dust and metal deposition and, therefore, a return to existing conditions is anticipated.

As a result of Project activities, changes to water quality in Kennady Lake during closure and post-closure are expected. For direct waterborne exposure, predicted maximum concentrations for most substances of potential concern (SOPCs) were lower than the corresponding chronic effects benchmark (CEB), with the exception of total copper, iron, and strontium. Despite the predicted exceedances of the CEB, the potential for copper, iron, and strontium to cause adverse effects to aquatic life in Kennady Lake was considered to be low. Follow-up monitoring will be undertaken to confirm this evaluation. For the indirect exposure pathway, predicted fish tissue concentrations will be below toxicological benchmarks for all substances considered in the assessment except silver. Given the modest predicted increase, and that both baseline and predicted tissue concentrations only marginally exceed the available no-effect concentration, the potential for predicted silver concentrations to cause effects to fish is concluded to be low. Based on the above results, changes to concentrations of all substances considered in this assessment are predicted to result in negligible effects to aquatic health in Kennady Lake.

Effects to Fish and Fish Habitat

Changes to fish habitat will occur from the footprint of the Project (e.g., excavation of the mine pits, placement of mine rock, placement of PK, dykes, and other construction activities). The affected habitat areas include the following:

- portions of Kennady Lake and adjacent lakes within the Kennady Lake watershed that will be permanently lost (194.56 hectares [ha] of lake area and 0.51 ha of watercourse area in tributaries to Kennady Lake);
- portions that will be physically altered after dewatering and later submerged in the refilled Kennady Lake (83.32 ha of lake area); and

- portions that will be dewatered (or partially dewatered) but not otherwise physically altered before being submerged in the refilled Kennady Lake (435.90 ha of lake area and 0.23 ha of watercourse area in tributaries to Kennady Lake).

The affected habitat areas were quantified in the Conceptual Compensation Plan, which also describes the various options considered for providing compensation, and presents a proposed plan to achieve no net loss of fish habitat. The options for compensation include: construction of impounding dykes to raise lake levels; construction of finger reefs in Kennady Lake; construction of habitat structures on the decommissioned mine pits/dykes; and widening the top bench of pits to create shelf areas where they extend onto land. The compensation ratio provided by the proposed compensation plan (gains:losses calculated based on total area of permanently lost habitat and physically altered and re-submerged habitat) is 0.65 for operations and 1.37 for closure.

To minimize the waste of fish caused by dewatering activities, fish salvage will be conducted to remove fish from Areas 2 to 7 before and during dewatering. A combination of gear types would be used to maximize capture efficiency. Dewatering will result in the temporary loss of fish habitat within Areas 2 to 7 of Kennady Lake; however, it is expected that a self-sustaining fish population will be present in Kennady Lake post-closure.

In the diversion watersheds, fish habitat downstream of the dykes will be dewatered and lost to fish residing in upstream lakes; the loss of habitat resulting from the placement of the dykes and the dewatering of downstream stream segments and lakes is included in the Conceptual Compensation Plan. Raising water levels in Lakes A3, D2, D3, and E1 within the Kennady Lake watershed will result in increased lake habitat area, which is likely to benefit fish residing in these lakes. Negligible effects on fish and fish habitat would be expected from shoreline erosion. Although the dykes will isolate fish populations within the B, D, and E watersheds for the duration of mine operations (and permanently in Lake A3), it is expected that the diversion watersheds will support self-sustaining populations of fish species, such as Arctic grayling (*Thymallus arcticus*), northern pike (*Esox lucius*), burbot (*Lota lota*), slimy sculpin (*Cottus cognatus*), and ninespine stickleback (*Pungitius pungitius*).

Isolation of Area 8 from the remainder of Kennady Lake during operations and closure is predicted to result in a small increase in nutrient concentrations, which is expected to result in a slight increase in productivity of plankton and benthic invertebrate communities. The residual fish community in Area 8 of Kennady Lake is anticipated to consist of small-bodied fish species (i.e., lake chub [*Couesius plumbeus*], ninespine stickleback, and slimy sculpin), as well as Arctic grayling, northern pike, and burbot. As a result of the existing overwintering limitations in Area 8 and the elimination of alternative overwintering refugia in Areas 2 through 7, lake trout (*Salvelinus namaycush*) and round whitefish (*Prosopium cylindraceum*) may not continue to persist in Area 8 throughout the operational period, as they are less tolerant of low dissolved oxygen concentrations.

Effects of TSS from dust and particulate deposition from windborne dust from Project facilities and exposed lake bed sediments on fish and fish habitat are expected to be localized in the immediate vicinity of the Project and temporally restricted to the period during and after freshet. The potential for adverse effects to aquatic health from dust and metals deposition was considered in the aquatic health assessment to be low and, therefore, no effects to fish populations or communities are expected to occur from changes in aquatic health.

At closure, the water levels in the raised lakes will return to baseline levels and the fish and lower trophic communities will adjust to the new lake levels. Habitat conditions for spawning, rearing, and overwintering will be similar to pre-Project conditions.

During post-closure, concentrations of nutrients are predicted to reach a long-term steady-state concentration of 0.018 mg/L, which is higher than the pre-development concentration range of <0.001 to 0.010 mg/L. The predicted change in the trophic status is expected to result in increased primary and secondary productivity in Kennady Lake, resulting in a change in trophic status from oligotrophic to mesotrophic. Due to the increases in the food base for fish (zooplankton and benthic invertebrates), and likely in the small-bodied forage fish community, there may also be increased growth and production in the large-bodied fish species of Kennady Lake. It is expected that due to the change in trophic status, overwintering habitat in Kennady Lake at post-closure would become more limited for cold-water fish species than under baseline conditions. The surface waters of Kennady Lake (i.e., under ice to 6 m depth) would be expected to retain sufficient levels of dissolved oxygen during winter to support fish; however, there may be reduced suitability and availability of overwintering habitat for cold-water fish species, such as lake trout.

The Project is expected to have low or negligible effects on aquatic health in Kennady Lake from changes in the chemical constituents of water quality; therefore, no effects to fish populations or communities are expected to occur from changes in aquatic health.

Recovery of Kennady Lake

An aquatic ecosystem will develop within Kennady Lake after refilling and reconnection of its basins. The physical and chemical environment in Kennady Lake is expected to be in a state that will allow re-establishment of an aquatic ecosystem, although projected nutrient concentrations indicate the re-established communities may differ from pre-development communities.

The expected time frame for recovery of the phytoplankton community is estimated to be approximately five years after refilling is complete, taking into account that the community will begin to develop during the refilling period. Zooplankton community development is predicted to follow recovery of the phytoplankton community (i.e., likely within five to ten years of Kennady Lake being completely refilled). The increased nutrient levels in the refilled Kennady Lake will facilitate community re-establishment and result in a more productive plankton community. Recovery of the benthic invertebrate community in Kennady Lake is expected to be slower than that of the plankton communities, with an estimated time for recovery of about ten years after refilling is complete. The benthic invertebrate community is expected to be different from the community that currently exists in Kennady Lake and in surrounding lakes; the community will be of higher abundance and biomass, reflecting the more productive nature of the lake, and will likely be dominated by midges and aquatic worms.

Re-establishment of the fish community within Kennady Lake, and the speed at which it will occur, will depend on the ability of fish to re-colonize the refilled lake, the habitat conditions within the lake, and how succession takes place within the refilled system after it has been fully connected to the surrounding environment. It is expected that a fish community will become re-established in Kennady Lake; however, due to changes in trophic status and associated habitat conditions, the fish community structure may be different than exists currently.

The B, D, and E watersheds are likely to be the primary source of initial migrants into the refilled lake. As conditions improve, and water depths increase, the early migrants will become permanently established. The increase in primary productivity may also result in increased growth and production of these small-bodied forage fish species. During refilling, exclusion measures will be used to limit the initial migration of large-bodied fish into the lake. Following the removal of Dyke A, fish will also enter from Area 8. The final fish community of Kennady Lake will likely continue to be characterized by low species richness (less than 10 species) consisting of a small-bodied forage fish community (e.g., lake chub, slimy sculpin, ninespine stickleback) and large-bodied species, (e.g., Arctic grayling, northern pike, burbot, round whitefish, lake trout, and possibly longnose sucker). Total lake standing stock and annual production may be increased over what currently exists in the lake. It is expected that the fish species assemblage (i.e., fish species present) within Kennady Lake will be similar to pre-Project conditions, but that due to biotic and abiotic factors, the community structure (i.e., relative abundances of the species) may differ. Mesotrophic conditions are likely to be more favourable to northern pike, burbot and Arctic grayling, than cold-water species, such as lake trout and round whitefish. As such, the relative abundances of the large-bodied fish species are likely to change from baseline conditions.

Overall, it is the life history attributes of the large-bodied fish species that will ultimately determine the duration of the complete recovery of the Kennady Lake aquatic ecosystem. Northern pike is expected to re-establish a stable, self-sustaining population in Kennady Lake later than Arctic grayling or burbot (i.e., approximately 50 to 60 years following the complete refilling of Kennady Lake). Lake trout would also require a long time to re-establish a stable, self-sustaining population (i.e., approximately 60 to 75 years following the complete refilling of Kennady Lake).

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 within the Kennady Lake watershed 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 in Kennady Lake. Phosphorus is projected to increase to a level that would shift the trophic status of Kennady Lake from oligotrophic to mesotrophic conditions. The projected increase in long-term phosphorus levels will not pose a health risk to a viable and self-sustaining aquatic ecosystem, though the increased productivity will likely cause it to be different from the pre-development 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. Arctic grayling, lake trout, and northern pike will be affected by the loss of habitat in Kennady Lake during the life of the mine; however, it is expected that self-sustaining populations will become established in the refilled lake.

8.3 EXISTING ENVIRONMENT

The following section provides a brief description of the existing environment in Kennady Lake and the Kennady Lake watershed that is directly relevant to the Key Line of Inquiry: Water Quality and Fish in Kennady Lake. Components of the existing conditions discussed herein include climate, permafrost, hydrogeology, surface water quantity, surface water quality, physical aquatic habitat, lower trophic levels, fish, and wildlife. The focus of the descriptions below is on baseline results for each component. For more details on methods or results, supplementary information regarding the existing environment of Kennady Lake and the Kennady Lake watershed is provided in the following annexes:

- Annex D (Bedrock Geology, Terrain, Soil, and Permafrost Baseline);
- Annex F (Wildlife Baseline);
- Annex G (Hydrogeology Baseline);
- Annex H (Climate and Hydrology Baseline);
- Annex I (Water Quality Baseline); and
- Annex J (Fisheries and Aquatic Resources Baseline).

8.3.1 General Setting

The Gahcho Kué Project (Project) is located within the Kennady Lake watershed at Kennady Lake, a headwater lake of the Lockhart River watershed in the Northwest Territories. Kennady Lake is 84 kilometres (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, about 127 km and 158 km northeast of Kennady Lake, respectively. The Project site is located at an elevation of approximately 420 metres above sea level (masl).

Kennady Lake is located in the sub-Arctic tundra, north of the treeline, and near the southern limit of continuous permafrost. Topography around Kennady Lake is characterized by low relief with occasional rocky ridges. Muskeg is the dominant vegetation, but willow shrubs (i.e., *Salix* spp.) exist in riparian areas and black spruce (i.e., *Picea* spp.) is found in valley depressions where wind exposure is reduced.

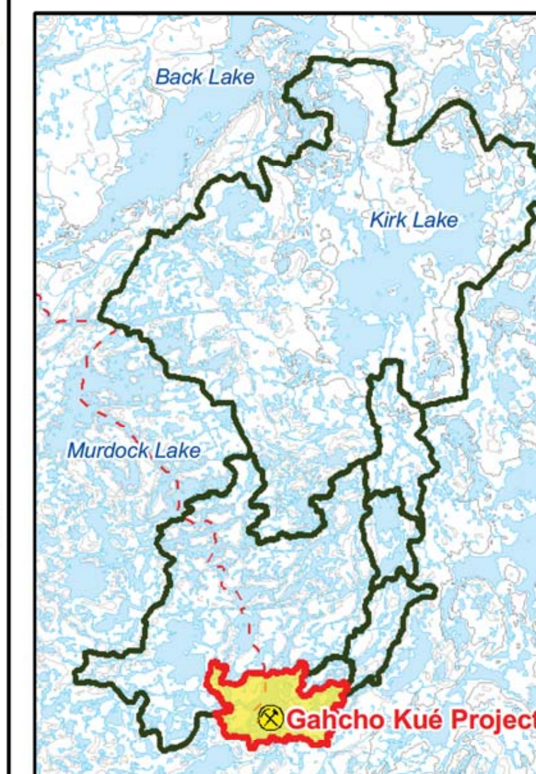
Kennady Lake is a small (815 hectares [ha]), oligotrophic, tundra lake that can be roughly divided into five main basins (Figure 8.3-1) based on key morphometric features. Four of these basins, referred to as Basins K1, K2, K3, and K4, have relatively deep zones, and are connected by deep-water (more than 5 metres [m]) channels. They represent approximately 82 percent (%) of the total surface area of Kennady Lake. The fifth basin (referred to as Basin K5) located at the outlet of Kennady Lake is shallow (average depth is less than 4 m), long (about 4 km), and narrow (less than 500 m wide) compared to the other basins. Kennady Lake has a mean depth of 5 m and a maximum depth of 18 m.

For this EIS, modifications have been made to the delineation of Kennady Lake from basins to areas (Figure 8.3-2). Eight areas, which include a portion of the A watershed, replace the five basins. These areas have an alignment to the basin delineation, with the exception of the Areas 1 and 2, which are linked to portions of the A watershed and the northeast corner of Kennady Lake that will become the Fine Processed Kimberlite Containment (PKC) Facility.

Area 1 includes Lakes A1 and A2. Area 2 constitutes a small portion of the northeast embayment of Kennady Lake, which was formerly the northern part of Basin K1. Areas 3 and 5 comprise the remaining part of Basin K1. Area 4 is equivalent to Area 6 is equivalent to Basin K3, and Area 7 is equivalent to Basin K4. Area 8 replaces Basin K5, which contains the lake outlet draining Kennady Lake to the north (Stream K5). The key morphological characteristics of the lake areas compared to the basins are detailed in Table 8.3-1.

There are also numerous small (less than 20 ha), shallow (less than 3 m) lakes within the Kennady Lake watershed. Most of these lakes are non-fish-bearing and are connected to Kennady Lake only during the spring freshet.

Kennady Lake drains northeast to north for about 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 is 37 square kilometres (km^2) and comprises 0.14% of the 27,500 km^2 Lockhart River watershed.



LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Contour (10m interval)
- Drainage Direction
- Brush
- Fen
- Tree
- Kennady Lake Watershed Boundary
- Interior Watershed Boundary
- Watershed Boundary
- K5 Lake Identifier
- Ke Watershed Identifier

NOTES

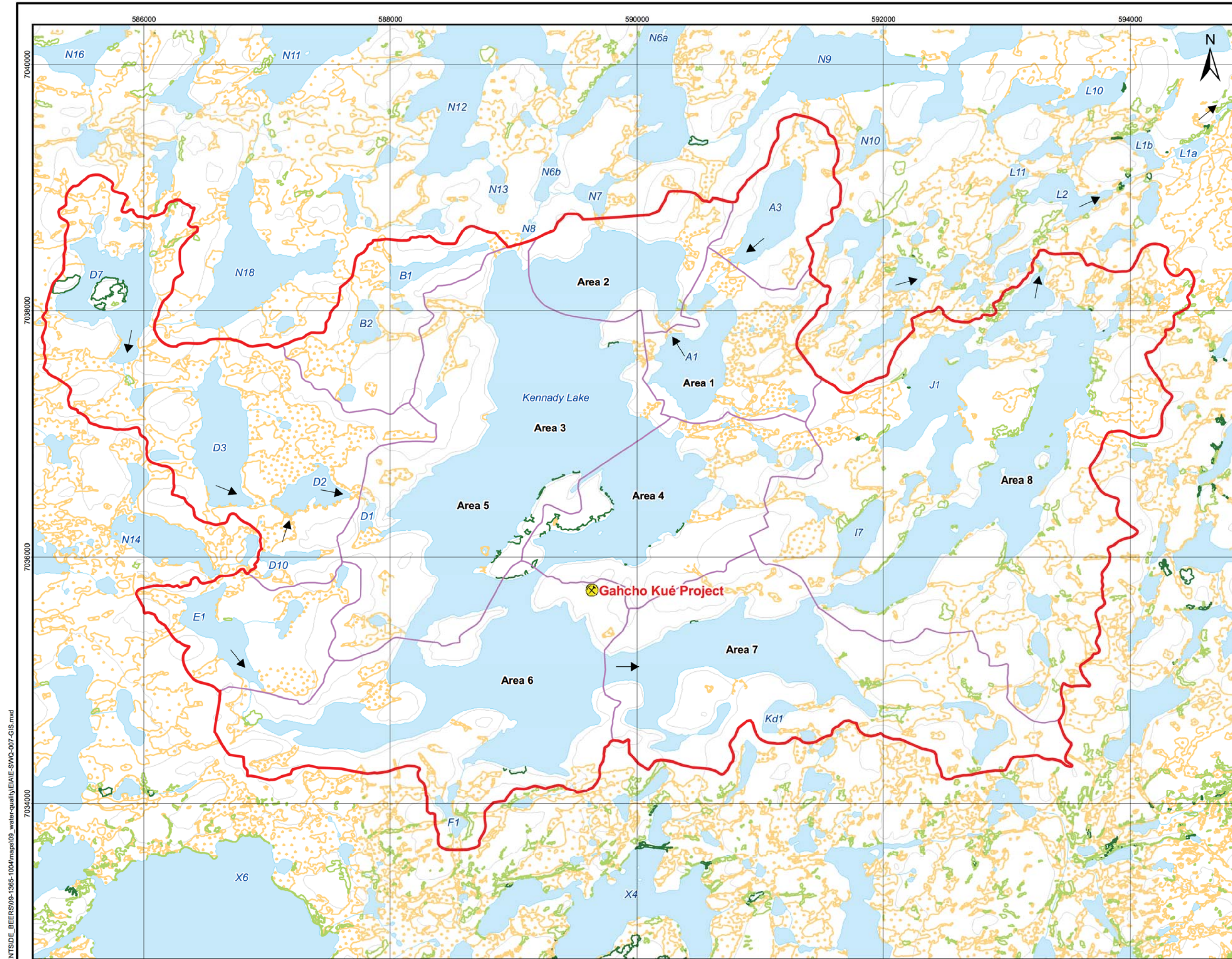
Base data source: National Topographic Base Data (NTDB) 1:50,000

GAHCHO KUÉ PROJECT

Kennady Lake Study Area Basin Delineation of Kennady Lake (prior to 2010)

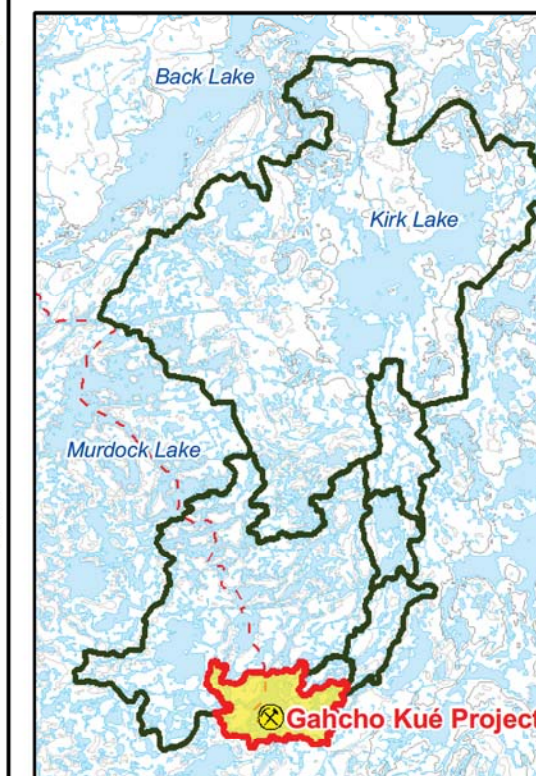
PROJECTION: UTM Zone 12	DATUM: NAD83		
Scale: 1:30,000			
500 250 0 500 Metres			
FILE No: E-SWQ-006-GIS		DATE: December 16, 2010	
JOB NO: 09-1365-1004	REVISION NO: 1		
OFFICE: GOLD-CAL	DRAWN: SK	CHECK: JF	Figure 8.3-1

DE BEERS CANADA



LEGEND

- Gahcho Kué Project
- Watercourse
- Waterbody
- Contour (10m interval)
- Drainage Direction
- Brush
- Fen
- Tree
- Kennady Lake Watershed Boundary
- Kennady Lake Area Boundary
- K5 Lake Identifier



NOTES

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

GAHCHO KUÉ PROJECT

Kennady Lake Study Area Area Delineation of Kennady Lake (2010)

PROJECTION: UTM Zone 12	DATUM: NAD83
Scale: 1:30,000 (500 250 0 500 Metres)	DE BEERS CANADA
FILE No: E-SWQ-007-GIS	DATE: December 16, 2010
JOB NO: 09-1365-1004	REVISION NO: 1
OFFICE: GOLD-CAL	DRAWN: SK CHECK: JF

Figure 8.3-2

Table 8.3-1 Summary of Kennady Lake Morphometry

Sub Basin	Lake Area (km^2)	Lake Area	Lake Area (km^2)	Lake Volume (Mm^3)	Lake Volume (%)	Maximum Lake Depth (m)	Local Watershed Drainage Area (km^2)
-	-	Area 1[(a)]	-	-	-	-	-
Basin K1	3.19	Area 2	0.61[(b)]	18.3	48	14	13.78
		Areas 3 and 5	2.56[(c)]				
Basin K2	0.76	Area 4	0.76	4.4	11.5	14	2.14
Basin K3	1.78	Area 6	1.78	8.6	22.6	18	5.17
Basin K4	0.99	Area 7	0.99	3.3	8.7	12	3.82
Basin K5	1.43	Area 8	1.43	3.5	9.2	9	7.56
Total	**8.15**		**8.15**	**38.1**	**100**	**-**	**32.47**

(a) Area 1 lies within the A watershed, upstream of Kennady Lake.

(b) The volume of Area 2 is 2.3 Mm^3.

(c) The volume of Area 2 is 16.0 Mm^3.

km^2 = square kilometre; Mm^3 = million cubic metre; m = metre; % = percent; - = not applicable.

The Project is accessed in the winter by a 120 km Winter Access Road that 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, and several smaller lakes and streams. The Winter Access Road typically operates for less than 70 days each year between November and March (De Beers 2002). The Project will also be accessed by air.

8.3.2 Climate

The following section provides a description of the climate conditions for Kennady Lake and the Kennady Lake watershed. For additional information regarding climate, the reader is referred to Annex H (Climate and Hydrology Baseline).

8.3.2.1 Methods

The description of climate at Kennady Lake focuses on the following parameters that are important in the hydrological cycle:

- air temperature;
- precipitation, including rainfall and snowfall;
- lake evaporation;
- evapotranspiration;

- relative humidity; and
- solar radiation and net radiation.

Long-term mean values and variability of air temperature, precipitation, and lake evaporation are based on climate data collected at the Project site (2004 to 2005) and long-term (1959 to 2005) regional data (combined data from the Lupin Airport and Contwoyto Lake stations). Relative humidity, soil temperature and heat flux, solar radiation, and net radiation results are based on short-term data (2004 to 2005) collected at the Project site. Evapotranspiration is calculated using the calibrated long-term mean water balance.

8.3.2.2 Results

8.3.2.2.1 General Climate

The Project is located in a sub-Arctic climate, characterized by long, cold winters and short, cool summers. Temperatures typically fall to below freezing by early October and remain so until mid- to late May. Monthly mean temperatures persist below -20 degrees Celsius (°C) from December through March, with daily means occasionally reaching below -40°C. The warmest month is July, with a mean temperature of about 12°C. Measured mean annual precipitation in the region is approximately 270 millimetres (mm) with about half falling as snow during the October to May winter period.

8.3.2.2.2 Air Temperature

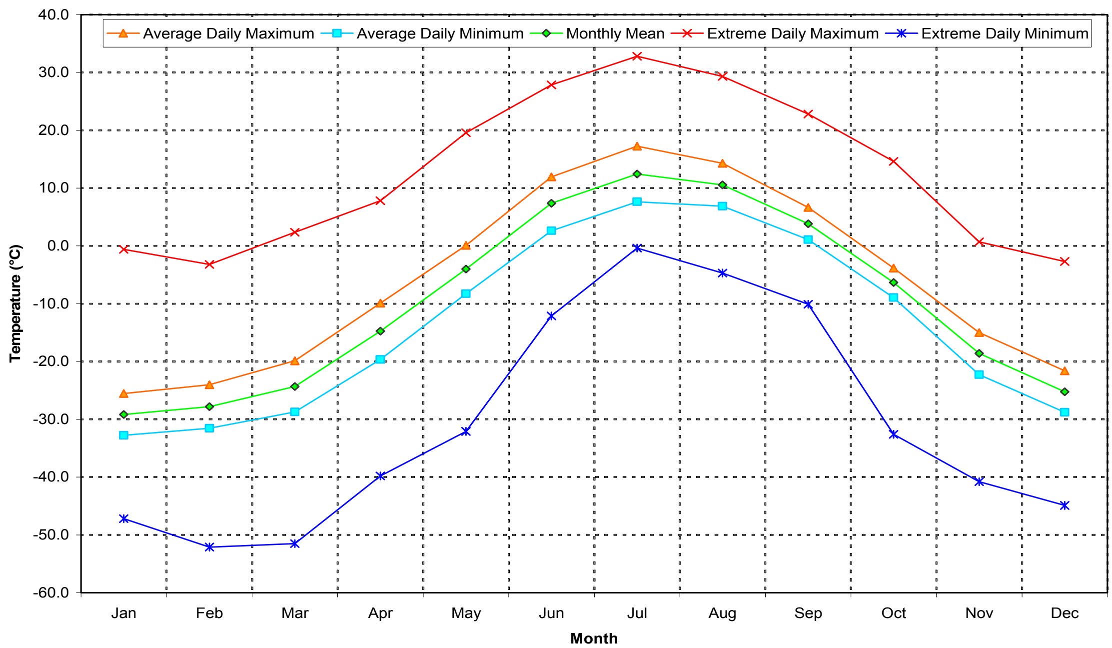
Monthly mean air temperatures at Lupin Combined (Lupin Airport and Contwoyto Lake stations) were used to derive long-term air temperature characteristics, as presented in Table 8.3-2. This shows that mean monthly temperatures are above freezing only for the four months of June through September. Mean temperatures are below -20°C from December through March. On average, January is the coldest month, but the most extreme low temperatures tend to occur in February. The annual mean temperature is estimated at -9.7°C. The data in Table 8.3-2 are shown graphically in Figure 8.3-3.

Table 8.3-2 Estimated Long-term Air Temperature Characteristics (°C), 1959 to 2005

Month	Extreme		Monthly Mean		Mean Monthly
	Maximum	Minimum	Maximum	Minimum	
January	-0.6	-47.2	-25.5	-32.8	-29.2
February	-3.2	-52.1	-24.0	-31.6	-27.8
March	2.4	-51.5	-19.9	-28.7	-24.3
April	7.8	-39.8	-9.9	-19.6	-14.7
May	19.6	-32.1	0.1	-8.3	-4.0
June	27.9	-12.1	11.9	2.6	7.3
July	32.8	-0.4	17.3	7.6	12.4
August	29.3	-4.7	14.3	6.9	10.5
September	22.8	-10.1	6.7	1.1	3.8
October	14.6	-32.6	-3.9	-9.0	-6.3
November	0.7	-40.8	-15.0	-22.3	-18.6
December	-2.7	-44.9	-21.6	-28.8	-25.2
Annual	32.8	-52.1	17.3	-32.8	-9.7

Source: Based in part on Environment Canada (2005) data from Lupin Airport and Contwoyto Lake stations.
°C = degrees Celsius.

Figure 8.3-3 Estimated Long-term Air Temperature Characteristics, 1959 to 2005



°C = degrees Celsius.

8.3.2.2.3 Precipitation

Precipitation at the Project site, including rainfall, snowfall, and total precipitation, was characterized by applying regional adjustments to the Lupin Combined data set for the period 1959 to 2005. Undercatch adjustments were also applied to account for trace and other rainfall and snowfall events not measured by instruments. The mean values of monthly rainfall, snowfall, and precipitation are summarized in Table 8.3-3.

Frequency analysis of annual rainfall, snowfall, and total precipitation (undercatch adjusted values) for Kennady Lake was conducted to describe the natural variability of these parameters. The frequency analysis results for rainfall, snowfall, and total precipitation are shown in Tables 8.3-4, 8.3-5, and 8.3-6, respectively. These analyses are based on a hydrological year, rather than a calendar year, to consider the amount of precipitation available for runoff in an open-water season.

Table 8.3-3 Estimated Long-term Precipitation Characteristics (Undercatch Adjusted Values), 1959 to 2005

Month	Rainfall (mm)	Snowfall (cm)	Precipitation (mm)
January	0.0	11.1	11.2
February	0.0	11.7	11.7
March	0.0	15.0	15.1
April	0.4	16.1	16.6
May	7.0	16.0	23.0
June	28.1	5.0	33.0
July	45.0	0.3	45.4
August	57.4	2.6	60.0
September	27.8	18.6	46.4
October	2.6	35.2	37.9
November	0.1	21.4	21.5
December	0.0	16.4	16.5
Annual	168.5	169.6	338.1

Source: Modified from Lupin Airport and Contwoyto Lake station s data (Environment Canada 2005).

Note: Total precipitation values are slightly different due to rounding.

mm = millimetres; cm = centimetres.

Table 8.3-4 Undercatch Adjusted, Annual Rainfall Depth and Frequency

Condition	Return Period (years)	Annual Rainfall Depth (mm)
Wet	100	319
	50	293
	25	266
	10	231
	5	203
Median	2	161
Dry	5	129
	10	116
	25	103
	50	96.0
	100	89.9

mm = millimetres.

Table 8.3-5 Undercatch Adjusted, Annual Snowfall Depth and Frequency

Condition	Return Period (years)	Annual Snowfall Depth (cm)
Wet	100	232
	50	227
	25	222
	10	211
	5	199
Median	2	171
Dry	5	140
	10	123
	25	105
	50	92.8
	100	82.0

cm = centimetres.

Table 8.3-6 Undercatch Adjusted, Annual Total Precipitation Depth and Frequency

Condition	Return Period (years)	Annual Precipitation Depth (mm)
Wet	100	553
	50	516
	25	478
	10	428
	5	388
Median	2	328
Dry	5	284
	10	265
	25	247
	50	237
	100	228

mm = millimetres.

The values in Tables 8.3-4 and 8.3-5 for annual rainfall extremes and annual snowfall extremes cannot simply be added together to obtain annual total precipitation extremes. Annual total precipitation extremes must be derived from the annual total precipitation series, as was done for the values reported in Table 8.3-6.

Snow water equivalent (SWE) values available for spring snowmelt were estimated by assuming that no runoff occurred over the October through May winter period, and that 30% of the accumulated precipitation was lost to sublimation (e.g., the process whereby ice changes directly into water vapour without melting), based on field data collected in 2004 and 2005. The results of a frequency analysis of estimated spring SWE values are listed in Table 8.3-7.

Table 8.3-7 Derived Spring Snowpack Snow Water Equivalent and Frequency

Condition	Return Period (years)	Snowpack Snow Water Equivalent (mm)
Wet	100	162.1
	50	159.1
	25	155.2
	10	147.7
	5	139.2
Median	2	119.8
Dry	5	98.1
	10	86.2
	25	73.4
	50	65.0
	100	57.4

mm = millimetres.

A frequency analysis of short-duration (n-day) rainfall data was conducted using daily rainfall data for the Lupin Combined Station. No adjustments were made for undercatch, because undercatch is generally not substantial for extreme rainfall events at a daily time scale. No regional adjustment factor was applied, as the derived factor applies only to annual and monthly values. The results are summarized in Table 8.3-8.

Table 8.3-8 N-day Extreme Rainfall (mm)

Return Period (years)	Duration (days)				
	1	3	5	10	30
2	22.7	28.0	31.3	39.5	66.4
10	37.6	45.1	49.5	64.0	104.3
50	50.6	60.1	65.3	85.5	137.4
100	56.1	66.4	72.0	94.6	151.5
200[(a)]	61.0	–	–	–	–
500[(a)]	68.0	–	–	–	–
Point PMR	208.0	245.5	262.5	353.3	551.7

Source: Derived from Lupin Airport and Contwoyto Lake station data (Environment Canada 2005).

(a) Values shown for 200- and 500-year periods are derived by graphical extrapolation.

PMR = Probable Maximum Rainfall; mm = millimetres; - = not available.

Short-duration (up to 24 hour) rainfall intensity data are not available for the Lupin Combined Station. The closest station with available data is Yellowknife Airport, and these were obtained from Environment Canada, based on tipping bucket data analysis for the period 1963 to 1990. The values presented in Table 8.3-9 are considered to be conservatively large. The higher rainfall intensities may be due to the Yellowknife station's proximity to Great Slave Lake, as well as its warmer summer temperatures.

Table 8.3-9 Short Duration Rainfall Intensities (mm/h) at Yellowknife Airport

Return Period (years)	Duration					
	10 minute	30 minute	1 hour	6 hours	12 hours	24 hours
2	31.2	15.8	9.6	3.1	1.9	1.1
5	48.4	24.2	14.5	4.8	2.9	1.8
10	59.8	29.8	17.7	5.9	3.6	2.2
25	74.1	36.8	21.8	7.3	4.4	2.7
50	84.8	42.0	24.8	8.3	5.0	3.1
100	95.3	47.2	27.8	9.3	5.6	3.5

Source: Yellowknife data, 1963 to 1990 (Environment Canada 2005).

mm/h = millimetres per hour.

8.3.2.2.4 Lake Evaporation

Lake evaporation was characterized by evaluating local and regional data to derive mean annual and monthly mean values for typical lakes near the Project site. Recommended values are presented in Table 8.3-10 and are plotted in Figure 8.3-4, where values derived by others for the Mackenzie River basin are presented for comparison. Inter-annual variability of lake evaporation is expected to be low relative to precipitation and primarily related to the length of the open water season.

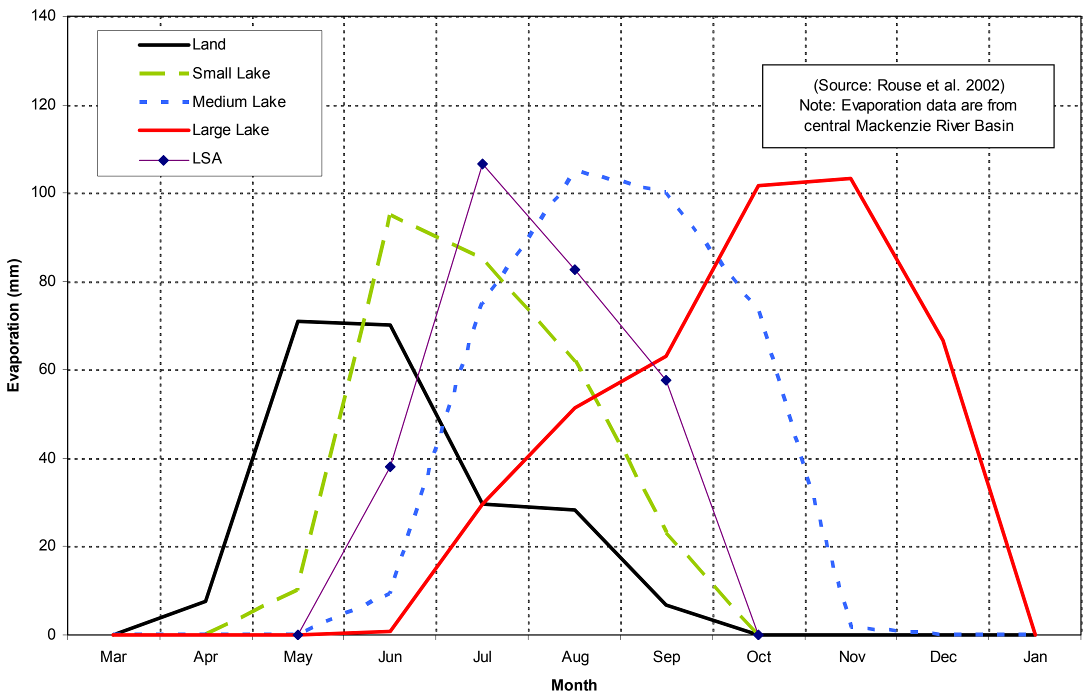
Table 8.3-10 Estimated Long-term Mean Small Lake Evaporation in the Local Study Area

Month	Lake Evaporation (mm)	Fraction of Annual
June	38.1	0.13
July	106.7	0.37
August	82.7	0.29
September	57.5	0.20
Annual	285.0	1.00

Source: Derived in part from Rouse et al. (2002).

mm = millimetres.

Figure 8.3-4 Seasonal Mean Monthly Lake Evaporation for Different Sized Lakes in the McKenzie Basin



Note: The Small Lakes within the Local Study Area (shown in Table 8.3-9) are represented by the LSA line in the graph.
mm = millimetre; LSA = Local Study Area.

8.3.2.2.5 Evapotranspiration

Evapotranspiration (ET) was derived using a water balance method and examination of the value using theoretical relationships. The value of annual ET derived by using the water balance method was equal to 66.8 mm. This value appears low, and may be due to overestimated sublimation losses from the winter snowpack.