PHASE 2

DRAFT ENVIRONMENTAL IMPACT STATEMENT

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Glossary and Abbreviations

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

AEMP	Aquatic Effects Monitoring Program
ANFO	Ammonium nitrate-Fuel Oil
AWR	All-weather road
CCME	Canadian Council of Ministers of Environment
DO	Dissolved oxygen
EA	Environmental assessment
EAA	Existing and Approved Authorization
EIS	Environmental Impact Statement
LSA	Local Study Area
NIRB	Nunavut Impact Review Board
NKTP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
PDA	Project development area
QA/QC	Quality assurance/quality control
RSA	Regional Study Area
TIA	Tailings impoundment area
TDS	Total dissolved solids
TK	Traditional knowledge
TMA	Tailings management area
tpd	tonnes per day
TSS	Total suspended solids
WRR	Winter road route
VEC	Valued Ecosystem Component

4. Freshwater Water Quality

Freshwater water quality is a critical component of the biological and physical environment. It constitutes the physical, chemical, biological, and aesthetic characteristics of water which are, in turn, determined by a variety of regional and local factors including rock weathering, surface transport, biological activity, and anthropogenic influences. An understanding of the freshwater quality, as well as its interactions with a project, is critical to support an environmental effects assessment as well as to contribute to engineering analysis and the design of water management features.

This section examines the potential effects of the proposed Phase 2 Project (the Project) on freshwater water quality. Monitoring studies of pre-development (i.e., baseline) freshwater water quality conditions were conducted to allow for the prediction, assessment, mitigation, and management of potential Project-related effects and were incorporated into mine, mine waste, and water management planning.

Alteration of freshwater water quality could potentially affect other Valued Ecological Components (VECs), and effects on these VECs are assessed in the following effects assessment sections:

- Volume 4, Section 9- Terrestrial Wildlife and Wildlife Habitat;
- Volume 5, Section 5, Freshwater Sediment Quality;
- Volume 5, Section 6 , Freshwater Fish;
- Volume 5, Section 8, Marine Water Quality;
- Volume 5, Section 10, Marine Fish;
- Volume 5, Section 11, Marine Wildlife; and
- Volume 6, Section 5, Human Health.

This section follows the effects assessment methodology described in Volume 2, Section 4 of the Environmental Impact Statement (EIS).

4.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

4.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

Available information from the *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project* (NTKP) report (Banci and Spicker 2016) was reviewed for existing environment and baseline information on freshwater water quality.

According to the information provided in the NTKP report, Inuit have seen changes in surface water quality over the past few decades. Inuit attribute recent shallower lakes and lower water flows in rivers as affecting the water quality. In general, changes to water quality in coastal areas is greater than changes in inland areas. While no specific causes for contaminants have been identified, potential sources have been identified such as dust, mineral exploration and mine development, melting of permafrost, long distance transport of pollutants, too many tourists, and an overpopulation of geese.

4.1.2 Incorporation of Traditional Knowledge for VEC Selection

The NTKP report was reviewed to refine the potential VEC list for freshwater water quality. Rivers and lakes are identified in the NTKP report as Inuit's source of water and important fish habitat. Traditional knowledge is combined with data from public consultation and baseline surveys to determine which valued components would potentially interact with the proposed Project, and should therefore be evaluated for inclusion in the candidate VEC list.

As a result of this process, and in consideration of the EIS guidelines (NIRB 2012a), freshwater water quality is selected as a candidate VEC for the EIS (Volume 2, Section 4; Effects Assessment Methodology).

4.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The results of the NTKP report are considered when developing the spatial and temporal boundaries for the Phase 2 Project. The NTKP report showed that specific and general fishing locations extend along both shores of Melville Sound, but are concentrated along the southern shore extending both east and west of Roberts Bay. General fishing areas also extend inland along the entire length of the Hope Bay Greenstone Belt. Water quality is an important component in determining the environmental quality for fish. Therefore, the entire Project area is included within the spatial boundaries of the assessment of freshwater water quality.

4.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

The results of the NTKP report were considered when developing the effects assessment for freshwater water quality. No specific references relevant to the effects assessment for water quality were included in the NTKP report. No specific drinking water sources were identified, but the potential for water use exists throughout the Project area.

4.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

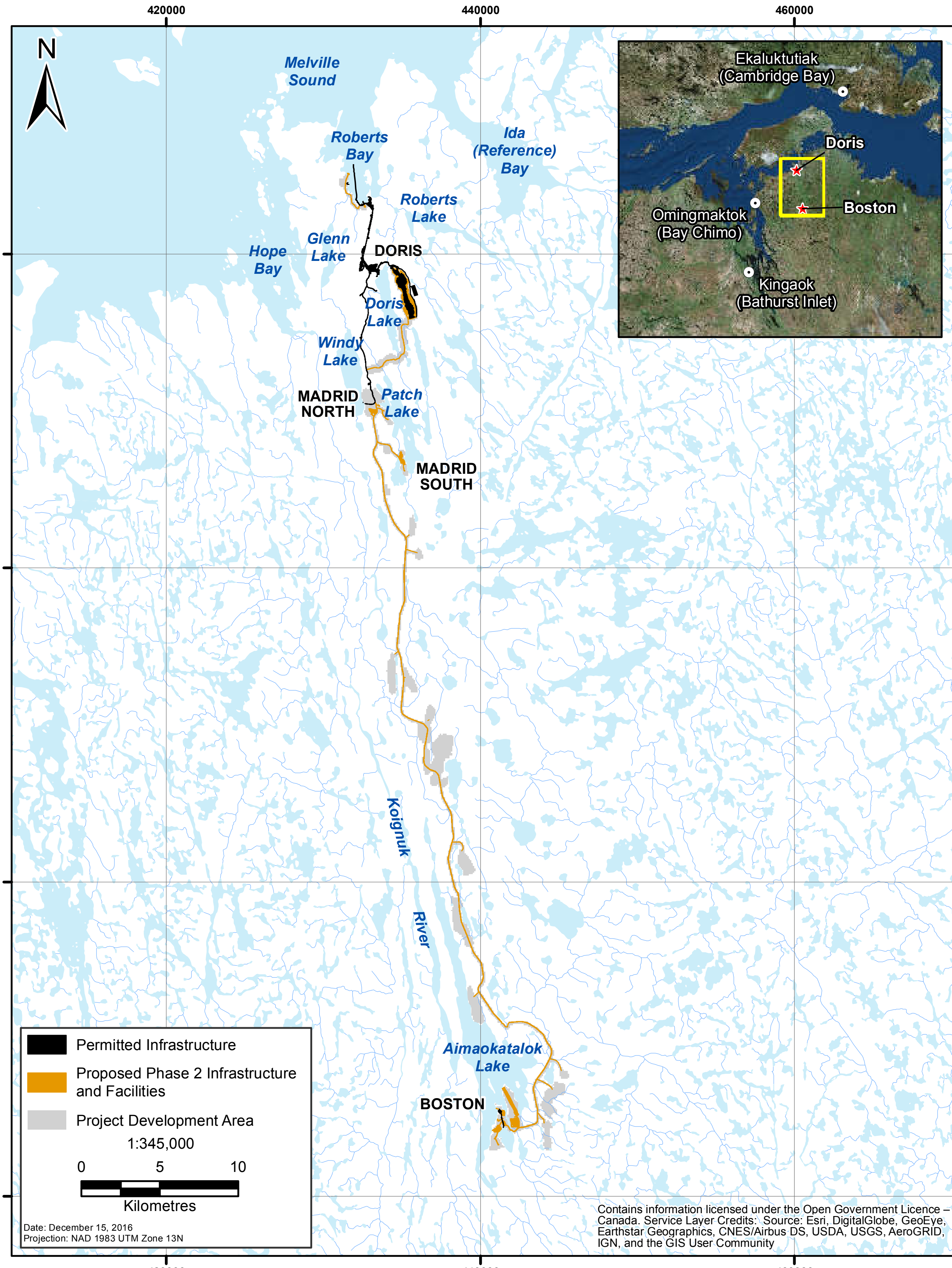
The NTKP report was considered when developing mitigation and adaptive management plans for freshwater water quality.

4.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

Phase 2 of the Hope Bay Project is situated within the Queen Maud Gulf Lowlands, approximately 153 km southwest of Cambridge Bay on the southern shore of Melville Sound in the West Kitikmeot region of Nunavut (Figure 4.2-1). The property contains a greenstone belt running 80 km in a north-south direction that varies in width between 7 km and 20 km. The Hope Bay Project consists of three developments, with Doris being the northernmost, followed by Madrid in the north-central area, and Boston at the southern end (Figure 4.2-1).

Baseline freshwater water quality data have been collected within the greenstone belt since the early 1990s. The proposed Phase 2 infrastructure in each mining district lies within a single defined Local Study Area (LSA) that is bounded by a larger Regional Study Area (RSA; see Section 4.4; Figure 4.2-2). Regionally, the Phase 2 Project lies entirely within the Southern Arctic Ecozone and is situated in an area of continuous permafrost. Generally, Doris has more variable relief, with exposed igneous extrusions to 160 m, and a greater marine influence than the Madrid or Boston areas, which are characterized by flat rolling bedrock covered by thin layers of moraine, lacustrine, and fluvial deposits.

Figure 4.2-1
Project Location



Winter is characterized by extreme cold, with mean monthly temperatures ranging from -33.4ºC to -3.1ºC, and the coldest temperatures in January and February. There is a short snow-free season (mid-June through September) with mean monthly temperatures ranging from -2.5ºC to 13.9ºC, and the warmest temperatures typically recorded in July (Volume 4, Section 1). The Doris meteorological station reports total summer rainfall (June to September) ranging from 47.8 mm (2012) to 97.8 mm (2011) (Volume 4, Section 1). The region's vegetation is characterized by shrub tundra vegetation such as dwarf birch (*Betula nana*), willow (*Salix* sp.), Labrador tea (*Ledum decumbens*), avens (*Dryas* sp.), and blueberries (*Vaccinium* sp.; Appendix V4-8A).

The freshwater LSA includes the Doris, Windy, and Koignuk-Aimaokatalok sub-watersheds in the north, and the Aimaokatalok and East watersheds in the south (Figure 4.2-2). Water from the northern Doris and central Madrid watersheds flows northward into Roberts Bay via Little Roberts Outflow and Glenn Outflow, while water from the southern Boston watersheds flows into Hope Bay via the large Koignuk River system. The largest lakes in the north and central belt include Doris, Windy, Patch, Glenn, and Ogama lakes, with Aimaokatalok Lake being the largest lake in the southern belt. The hydrology in the Phase 2 area is dominated by snowmelt, with peak flows occurring in June in most watersheds. The lakes are typically frozen from October to June with ice thicknesses ranging between 1.5 to 2.0 m (Appendices V5-3I and V5-3J). Winter flow is largely absent because of negligible groundwater reserves outside of the permafrost and the lack of unfrozen surface water. Due to the influences of climate and permafrost, there is one major flood period (freshet) in June that quickly recedes into summer, with the hydrograph being punctuated with occasional high–flow events from storms during the open-water season.

This section provides a summary of the methods and results from the freshwater water quality sampling carried out in the Phase 2 area and surrounding region.

4.2.1 Regulatory Framework

There are several acts, regulations, and guidelines relevant to the management and preservation of freshwater water quality. Table 4.2-1 lists and provides a brief description of the key acts and regulations pertaining to freshwater water quality.

In addition to these acts and regulations, the protection of freshwater water quality is also guided by the *Canadian Environmental Quality Guidelines* (CCME 2001b) which include the *Water Quality Guidelines for the Protection of Aquatic Life* (CCME 2016a) published by the Canadian Council of Ministers of the Environment (CCME). These water quality guidelines define concentrations of water quality parameters that should present a negligible risk to aquatic organisms.

Figure 4.2-2
Freshwater Water Quality Local and Regional Study Areas

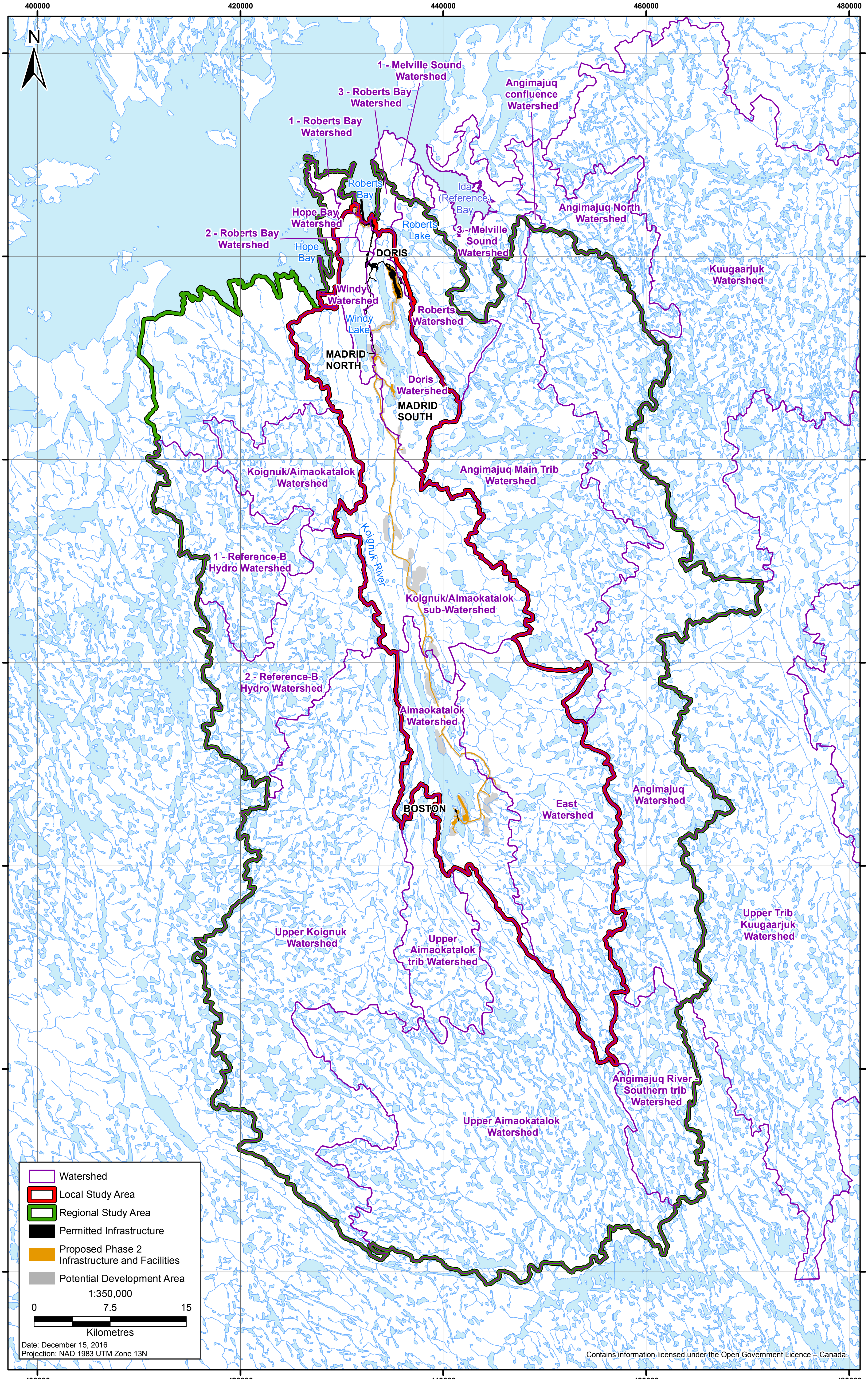


Table 4.2-1. Federal and Territorial Acts and Regulations Relevant to Freshwater Water Quality

Name of Act	Year (Year of Most Recent Amendment)	Administered by:	Relevant Regulations under the Act	Description/Purpose
Arctic Waters Pollution Prevention Act	1985 (2014)	Indigenous and Northern Affairs Canada	Arctic Waters Pollution Prevention Regulations (C.R.C., c. 354)	• Prohibits the deposit of waste in Arctic waters unless authorized under the *Canada Water Act*, and describes limits of liability.
Canada Water Act	1985 (2014)	Environment and Climate Change Canada		• Provides a framework for the management of water resources in Canada, including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources. • Establishes federal-provincial arrangement for the management of water resources.
Fisheries Act	1985 (2016)	Fisheries and Oceans Canada; Environment and Climate Change Canada	Metal Mining Effluent Regulations (SOR/2002-222)	• Protects fish habitat by prohibiting any harmful alteration, disruption, or destruction of fish habitat. • Prohibits the deposition of deleterious substances into waters frequented by fish, unless authorization is granted.
Canadian Environmental Protection Act	1999 (2016)	Environment and Climate Change Canada		• Deals with the prevention of pollution and the protection of the environment and human health from toxic substances, with the goal of contributing to sustainable development. • Regulates many substances that have a deleterious effect on the environment.
Nunavut Waters and Nunavut Surface Rights Tribunal Act	2002 (2016)	Indigenous and Northern Affairs Canada; Nunavut Water Board	Nunavut Waters Regulations (SOR/2013-69)	• Established the Nunavut Water Board • Nunavut Waters Regulations: Establishes licensing criteria for use of waters and for deposit of waste for mining undertaking.
Environmental Protection Act	1988 (1999)	Government of Nunavut, Department of Environment		• Prohibits the discharge of contaminants into the environment without authorization.
Environmental Rights Act	1988 (2011)	Government of Nunavut, Department of Environment		• Grants all residents the ability to launch an investigation into the release of a contaminant into the environment.

4.2.2 Data Sources

The primary sources of water quality data used to describe the existing environment in lakes, streams, and rivers are from the baseline studies conducted annually from 2007 to 2010, and the Aquatic Effects Monitoring Program (AEMP) for the Doris Project conducted from 2010 to 2015. Although water quality data have been collected historically (1992-2000 and 2003-2006) at some sites, only data collected from 2007 to 2015 are discussed in detail. Several activities associated with the permitted Doris Project began in 2007. Although the Doris AEMP has shown that there have been no effects of the Doris Project on the freshwater environment, data collected in the years prior to 2007 are considered representative of baseline conditions, while data collected from 2007 onward are considered representative of existing conditions. Full details of the baseline programs used to collect information are described in the following reports:

- Boston Property N.W.T.: Environmental Data Report (Rescan 1993; Appendix V5-3B);
- Boston Property N.W.T.: Environmental Data Report (Rescan 1994; Appendix V5-3C);
- Doris Lake Project, Northwest Territories: 1995 Environment Study (Klohn-Crippen Consultants Ltd. 1995; Appendix V5-4A)
- Boston Property N.W.T.: Environmental Data Report 1995 (Rescan 1995; Appendix V5-4B);
- Hope Bay Belt Project: Environmental Baseline Studies Report 1996 (Rescan 1997; Appendix V5-4C);
- Hope Bay Belt Project: 1997 Environmental Data Report (Rescan 1998; Appendix V5-4D);
- Hope Bay Belt Project: 1998 Environmental Data Report (Rescan 1999a; Appendix V5-4E);
- Hope Bay Belt Site Assessment 1999 (Rescan 1999b; Appendix V5-4F)
- Hope Bay Belt Project: 2000 Supplemental Environmental Baseline Data Report (Rescan 2001; Appendix V5-3D)
- Doris North Project Aquatic Studies 2003 (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003; Appendix V5-3F)
- Doris North Project Aquatic Studies 2004 (Golder Associates Ltd. 2005; Appendix V5-4G);
- Doris North Project Aquatic Studies 2005 (Golder Associates Ltd. 2006; Appendix V5-4H)
- Doris North Project Aquatic Studies 2006 (Golder Associates Ltd. 2007; Appendix V5-4I)
- Boston and Madrid Project Areas 2006 – 2007 Aquatic Studies (Golder Associates Ltd. 2008a; Appendix V5-3H)
- Doris North Project Aquatic Studies 2007 (Golder Associates Ltd. 2008b; Appendix V5-4J)
- Hope Bay Project Aquatic Studies 2008 (Golder Associates Ltd. 2009; Appendix V5-3I)
- 2009 Freshwater Baseline Report, Hope Bay Belt Project (Rescan 2010; Appendix V5-3J);
- Hope Bay Belt Project: 2010 Freshwater Baseline Report (Rescan 2011b; Appendix V5-3K);
- Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report (Rescan 2011a);
- Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report (Rescan 2012);
- Doris North Gold Mine Project: 2012 Aquatic Effects Monitoring Program Report (Rescan 2013);
- Doris North Project: 2013 Aquatic Effects Monitoring Program Report (ERM Rescan 2014);
- Doris North Project: 2014 Aquatic Effects Monitoring Program (ERM 2015); and
- Doris North Project: 2015 Aquatic Effects Monitoring Program Report (ERM 2016).

The Doris North Project Aquatic Effects Monitoring Program reports are available on the Nunavut Water Board (NWB) FTP site (ftp://ftp.nwb-oen.ca).

4.2.3 Methods

4.2.3.1 Lakes

Water quality samples and dissolved oxygen profiles were collected from 12 lakes in the LSA (nine in the North Belt and three in the South Belt) and eight lakes throughout the RSA from 2007 to 2015. A summary of the sampling programs, including sampling locations and replication, is shown in Table 4.2-2 and Figures 4.2-3 and 4.2-4. Sampled lakes in the LSA were close to existing or proposed infrastructure, while sampled lakes in the RSA were either reference sites or far field (upstream or downstream) sites. Water quality samples were typically collected near the surface (at 1 m) and at one to two metres above the sediment-water interface; in shallow lakes, only surface or mid-column samples were collected. Dissolved oxygen profiles were collected throughout the water column. Profiles were typically collected over the deepest area of the lake or in a spatially significant location (e.g., within mine footprint, or near future tailings or waste rock piles). Multiple sites were sampled at the largest lakes including Doris, Patch, and Aimaokatalok within the LSA.

Table 4.2-2. Lake Water Quality Sampling Programs in the LSA and RSA from 2007 to 2015

Year	2007	2008	2009	2010	2011 and 2012	2013 to 2015
Month Sampled	May July August September	May July August September	April/May August	April July August September	April July August September	April July August September
Sampling Equipment	Kemmerer Sampler, Horiba U-22 multi-parameter probe	Kemmerer Sampler, Horiba U-22 multi-parameter probe, Hach HQ40-D probe	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter	Niskin/GO-FLO, YSI meter
Water Quality Parameters	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total metals	Physical parameters, anions, nutrients, total metals
Lakes Sampled (LSA)	<u>North Belt</u> Doris Ogama Patch Wolverine P.O. Windy Glenn <u>South Belt</u> Aimaokatalok Stickleback Trout	<u>North Belt</u> Doris Ogama Patch Wolverine P.O. Windy Glenn <u>South Belt</u> Aimaokatalok Stickleback Trout	<u>North Belt</u> Doris Ogama Patch Wolverine P.O. Nakhaktok Imniagut Windy Glenn	<u>North Belt</u> Doris Windy <u>South Belt</u> Aimaokatalok Stickleback Trout	<u>North Belt</u> Doris	<u>North Belt</u> Doris

Year	2007	2008	2009	2010	2011 and 2012	2013 to 2015
Lakes Sampled (RSA)	Boston Reference	Boston Reference	Little Roberts	Little Roberts	Roberts	Little Roberts
	Little Roberts	Little Roberts	Naiqunnguut	Reference B	Little Roberts	Reference B
	Roberts	Roberts	Reference A	Reference D	Reference B	Reference D
	Pelvic	Pelvic	Reference B		Reference D	
Site Replication	Duplicate samples collected at Stickleback and Doris lakes	Duplicate samples collected at Stickleback and Doris lakes	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 20% replication	n = 1 @ shallow and deep depths + 20% replication

In 2007 and 2008, water quality samples were collected using a Trace Metal Acrylic Kemmerer water sampler. From 2009 to 2015, under-ice water quality samples (April, May, or June) were collected using a Niskin bottle and open-water season samples (July to September) were collected using a GO-FLO bottle. Subsamples for the various water quality parameters (e.g., nutrients, metals) were drawn from the sampling device. Lake water samples were collected from each site using clean techniques. After collection and preservation in the field, samples were transported on ice to either Maxxam Analytics Inc. (Burnaby, BC), Alberta Research Council (Vegreville, AB), or ALS Environmental (Burnaby or Vancouver, BC) for analysis of physical parameters, anions, nutrients, cyanides, and metals content. Full methodologies can be found in the historical baseline and AEMP reports listed in Section 4.2.2.

Under-ice dissolved oxygen profiles were collected during late winter (April, May or June). Open water dissolved oxygen profiles were typically collected during July, August, and September. At shallower lake stations (<10 m), dissolved oxygen values were typically recorded at 0.5 m intervals, while at deeper lake stations (>10 m), values were recorded at 1 m intervals. The profiles typically ended at approximately 0.5 to 1 m above the sediment surface to minimize the disturbance of bottom sediments.

4.2.3.2 Streams and Rivers

Water quality samples were collected from 20 streams and rivers in the LSA (10 in the North Belt and 10 in the South Belt) and nine streams and rivers throughout the RSA from 2007 to 2015. A summary of the sampling programs, including sampling locations and replication, is shown in Table 4.2-3 and Figures 4.2-3 and 4.2-4. Sampled streams and rivers in the LSA were close to existing or proposed infrastructure, while sampled streams and rivers in the RSA were either reference sites or far field (upstream or downstream) sites. The Koignuk River was sampled in multiple locations both within the South Belt LSA and the North Belt LSA.

Stream water samples were collected from each site using clean techniques. Samples were collected from stream banks or rocks to prevent contamination from sediments, or where sufficiently high flow was present, samples were collected while the sampler stood in the stream. In these instances, the bottles were held upstream of the sampler and care was taken to avoid disturbing bottom sediments. Samples were collected as grab samples, avoiding water from stream surface. After collection and preservation in the field, samples were transported on ice to either Maxxam Analytics Inc. (Burnaby, BC), Alberta Research Council (Vegreville, AB), or ALS Environmental (Burnaby or Vancouver, BC) for analysis as was done for lake samples.

Figure 4.2-3
Historical Freshwater Sampling Locations in the North Belt LSA and RSA, 1995 to 2015

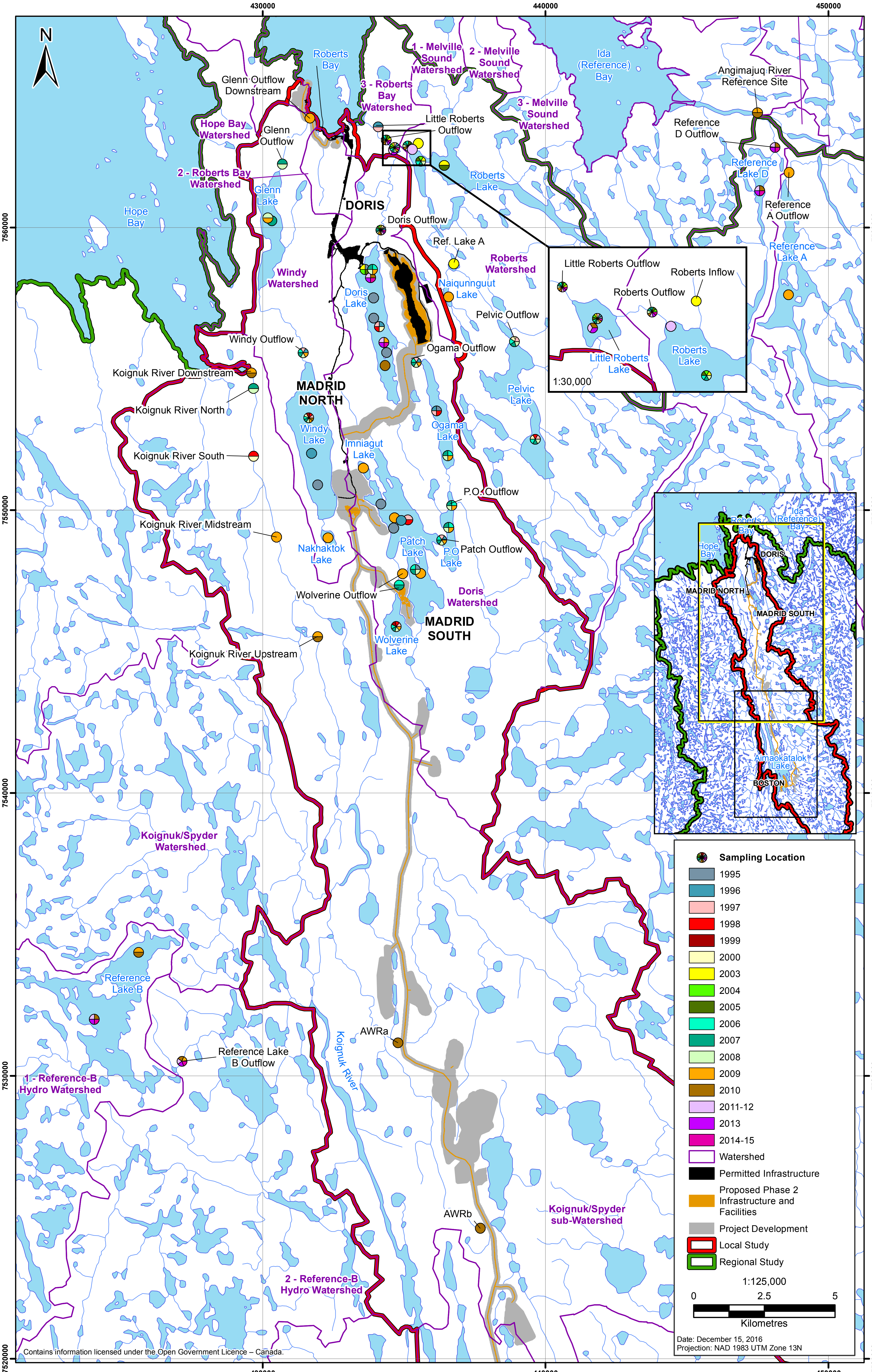


Figure 4.2-4
Historical Freshwater Sampling Locations in the South Belt LSA and RSA, 1992 to 2015

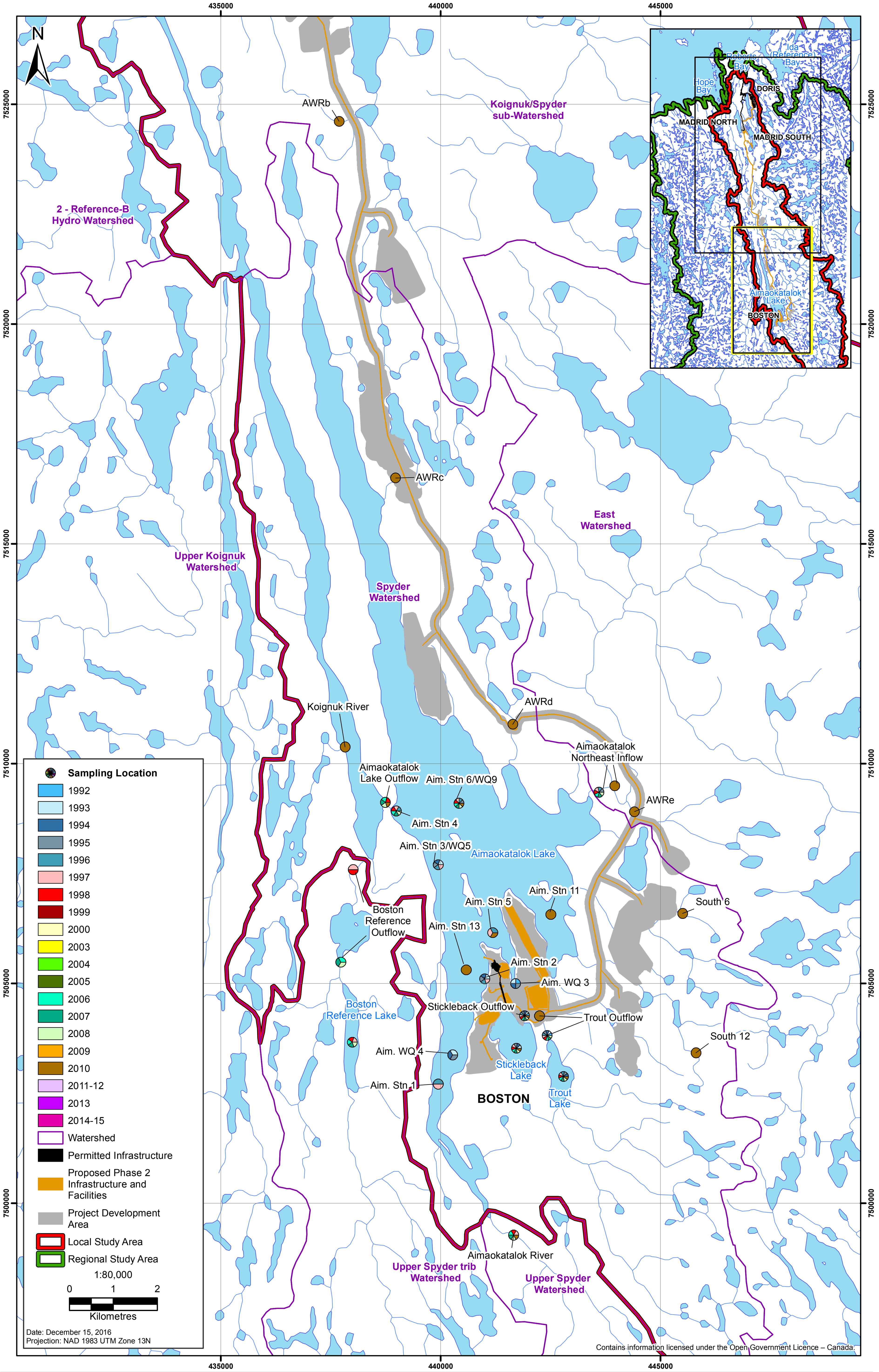


Table 4.2-3. Stream and River Water Quality Sampling Programs in the LSA and RSA from 2007 to 2015

Year	2007	2008	2009	2010	2011 to 2015
Month Sampled	June July August September	June July August September	May June August September	June July August September	June July August September
Water Quality Parameters	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total and dissolved metals	Physical parameters, anions, nutrients, total metals
Sites Sampled (LSA)	North Belt Doris OF Ogama OF Patch OF P.O. OF Windy OF Glenn OF Koignuk River South Belt Stickleback OF Trout OF Aimaokatalok NE IF Aimaokatalok OF	North Belt Doris OF Ogama OF Patch OF P.O. OF Windy OF Glenn OF Koignuk River South Belt Stickleback OF Trout OF Aimaokatalok NE IF Aimaokatalok OF	North Belt Doris OF Ogama OF Patch OF Wolverine OF P.O. OF Windy OF Glenn OF Koignuk River	North Belt Doris OF AWRa AWRb Koignuk River South Belt Stickleback OF Trout OF Koignuk River Aimaokatalok NE IF Aimaokatalok OF S6 S12 AWRc AWRd AWRe	North Belt Doris OF
Sites Sampled (RSA)	Little Roberts OF Roberts OF Pelvic OF Boston Reference OF Aimaokatalok River	Little Roberts OF Roberts OF Pelvic OF Boston Reference OF Aimaokatalok River	Little Roberts OF Reference A OF Reference B OF Aimaokatalok River Angimajug River	Little Roberts OF Roberts OF Reference B OF Reference D OF Aimaokatalok River Angimajug River	Little Roberts OF Roberts OF Reference B OF Reference D OF
Site Replication	n = 2 at one stream (Windy, Pelvic or Ogama OF) per sampling month	n = 2 at Windy OF only	n = 2	n = 2	n = 2

4.2.3.3 Calculation of Summary Statistics

Summary statistics were calculated for water quality parameters within the LSA (North and South belts) and the RSA. The North Belt LSA contains the Doris, Windy, and Koignuk-Aimaokatalok sub-watersheds and the South Belt LSA contains the Aimaokatalok and East watersheds (Figure 4.2-2).

For the calculation of minimum, maximum, mean, median, and the 75th and 95th percentile values for water quality parameters, one half of the value of the detection limit was substituted for sample concentrations that were below analytical detection limits. The minimum value represents the lowest value reported for any replicate after substituting one half of the detection limit for values that were below detection limits. The maximum value represents the highest detectable concentration in any replicate and excludes values reported as being below analytical detection limits (except when all values were below detection limits, in which case the maximum represents the highest detection limit). Water quality data collected from the same site and depth and on the same date (replicates) were averaged prior to the calculation of the mean, median, and the 75th and 95th percentiles to give equal weighting to samples regardless of the degree of replication. Whenever the value of the minimum, maximum, mean, median, or percentile was a censored value (i.e., sample concentration below the analytical detection limit), this value was reverted back from one half of the detection limit to its raw form (i.e., reported as being less than '<' the given detection limit) in order to clearly distinguish censored values.

4.2.3.4 Quality Assurance and Quality Control

Field and equipment blanks as well as duplicate samples were collected during each lake, stream, or river survey as part of the quality assurance and quality control (QA/QC) program. All water quality samples were recorded on chain of custody forms before being sent to the analytical laboratory.

4.2.4 Characterization of Existing Conditions

A summary of water quality data collected between 2007 and 2015 from the lake, stream, and river sampling program in the LSA (North and South Belt) and RSA is presented in this section.

The Canadian Council of Ministers of the Environment has established guidelines for water quality parameters to protect aquatic life. The CCME guidelines are conservative empirical thresholds that are meant to be protective of all forms of aquatic life and all aspects of aquatic cycles, including the most sensitive species over the long term (CCME 2007). The water quality data are discussed within the framework of CCME guidelines where applicable.

4.2.4.1 Lakes

Lakes are important parts of the freshwater system as they are habitats for aquatic organisms, serve as water sources for many terrestrial organisms, and are significant sources of water for human uses. Water quality is defined as a suite of chemical and physical parameters that describe the characteristics of water in terms of meeting the needs of aquatic and terrestrial organisms, ecosystem functions, human uses, and aesthetics. All water quality parameters are naturally variable due to heterogeneity in the landscape, biogeochemical cycling, weather, and climate. The baseline sampling program served to measure this natural variation such that future potential Project effects on water quality can be assessed.

<u>General Parameters</u>

General chemical characteristics of freshwater include: pH, alkalinity, hardness, conductivity, total dissolved solids, and major ions. pH is an important indicator that describes the acid-base balance of water and influences many chemical reactions that can, in turn, shape biological communities. Alkalinity describes the buffering capacity of water, while hardness and total dissolved solids are measures related to the quantity of dissolved ions and other materials in the water. The toxicity of some metals and compounds may depend on the pH or hardness of the water. Chloride and fluoride are also discussed among the general water quality parameters as these ions are naturally occurring in freshwater but can become toxic to aquatic organisms at high concentrations.

Between 2007 and 2015, pH levels ranged from 6.0 to 8.5 in LSA lakes and 6.1 to 8.2 in RSA lakes (Table 4.2-4). pH levels occasionally dropped below the lower limit of the CCME pH guideline range of 6.5 to 9.0 (CCME 2016b).

Table 4.2-4. Lake Water Chemistry at LSA and RSA Sites, 2007 to 2015

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples Outside of CCME Guidelines[d]
pH									
LSA - North Belt	218	195	6.1	7.3	7.6	7.8	8.1	8.5	2.6
LSA - South Belt	56	53	6.0	6.8	7.1	7.4	7.8	8.0	13
RSA	197	145	6.1	7.2	7.3	7.6	8.0	8.2	2.1
Hardness (mg $CaCO_3$/L)									
LSA - North Belt	247	217	30.9	60.0	53.5	66.0	93.2	181	-
LSA - South Belt	71	62	9.63	30.5	14.6	24.9	101	202	-
RSA	211	157	10.7	34.4	23.4	44.1	92.7	192	-
Total Alkalinity (mg $CaCO_3$/L)									
LSA - North Belt	237	215	19.1	37.4	32.3	46.0	59.1	117	-
LSA - South Belt	65	62	7.7	19.5	10.3	20.2	77.4	106	-
RSA	208	156	8.4	20.9	16.9	25.0	52.5	105	-
Total Dissolved Solids (mg/L)									
LSA - North Belt	197	175	87.8	191	174	212	297	560	-
LSA - South Belt	71	62	19.9	61.2	35.5	44.0	199	425	-
RSA	143	110	17.8	110	100	144	286	613	-
Total Organic Carbon (mg/L)									
LSA - North Belt	169	155	1.23	5.25	5.32	6.59	9.22	13.4	-
LSA - South Belt	65	62	3.90	6.07	5.15	5.75	10.3	22.4	-
RSA	106	88	2.49	5.70	5.19	6.80	10.2	18.9	-
Dissolved Organic Carbon (mg/L)									
LSA - North Belt	113	106	1.20	4.70	4.75	5.99	7.30	10.4	-
LSA - South Belt	54	48	3.60	5.38	4.68	5.11	9.80	19.7	-
RSA	71	61	1.87	5.44	5.10	6.10	8.76	16.8	-
Chloride (mg/L)									
LSA - North Belt	173	156	33.1	85.0	77.6	95.9	135	275	9.6
LSA - South Belt	49	40	<0.3	19.2	9.01	18.7	49.8	131	2.5
RSA	102	85	3.5	50.8	55.6	62.7	144	306	7.1
Fluoride (mg/L)									
LSA - North Belt	173	156	0.034	0.069	0.060	0.080	0.12	0.25	5.1
LSA - South Belt	70	61	<0.01	0.055	0.030	0.040	0.21	0.38	9.8
RSA	106	89	<0.01	0.045	0.040	0.050	0.11	0.24	4.5

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples Outside of CCME Guidelines[d]
Sulphate (mg/L)									
LSA - North Belt	247	217	<0.5	3.92	2.75	4.00	10.6	15.0	-
LSA - South Belt	71	62	0.82	3.08	1.50	3.00	6.90	48.0	-
RSA	209	157	1.35	3.44	2.67	4.21	8.52	14.0	-

Notes:
'<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).

Lake water hardness varied widely among lakes in the LSA and RSA (9.63 to 202 mg $CaCO_3$/L in the LSA and 10.7 to 192 mg $CaCO_3$/L in the RSA; Table 4.2-4). Within the LSA, Aimaokatalok Lake had particularly soft water, with an average hardness of 13.5 mg $CaCO_3$/L. The other lakes in the LSA would generally be considered soft (< 60 mg $CaCO_3$/L) to moderately hard (60 to 120 mg $CaCO_3$/L).

Alkalinity ranged from 7.7 to 117 mg $CaCO_3$/L in the LSA and 8.4 to 105 mg $CaCO_3$/L in the RSA (Table 4.2-4). Aimaokatalok Lake in the South Belt LSA was particularly acid-sensitive, with a mean alkalinity of only 9.9 mg $CaCO_3$/L. Aimaokatalok Lake was the only LSA lake with a mean alkalinity below 20 mg $CaCO_3$/L.

Similar to the trends seen for alkalinity and hardness, total dissolved solid (TDS) concentrations were higher in the North Belt LSA than in the RSA (Table 4.2-4). In the South Belt LSA, TDS concentrations in Aimaokatalok Lake were markedly lower than in other LSA lakes, and were comparable to several of the reference lakes in the RSA.

Chloride concentrations in both LSA and RSA lakes were occasionally greater than the CCME long-term concentration guideline of 120 mg/L (CCME 2016b; Table 4.2-4). Within the LSA, baseline concentrations were greater than the chloride CCME guideline in some samples from Patch, Wolverine, Nakhaktok, Ogama, and Stickleback lakes. Within the RSA, chloride concentrations were sometimes higher than the CCME guideline in Little Roberts and Naiqunnguut lakes, which are both near the edge of the LSA. All chloride concentrations were consistently below the CCME short-term concentration guideline of 640 mg/L.

Fluoride concentrations within each study area were occasionally higher than the CCME interim guideline of 0.12 mg/L (CCME 2016b; Table 4.2-4). Baseline fluoride concentrations were greater than the CCME guideline in some samples from Doris, Ogama, P.O., Patch, Windy, Wolverine, Aimaokatalok, Stickleback, and Trout lakes in the LSA. Within the RSA, fluoride concentrations were sometimes higher than the CCME guideline in Boston Reference, Little Roberts, and Pelvic lakes.

Total Suspended Solids and Turbidity

The concentration of total suspended solids (TSS) and turbidity are related measures describing the quantity of particulate material, primarily sediment, suspended in the water. These parameters are also related to water clarity as high concentrations of TSS and high turbidity levels are associated with reduced water clarity. Natural variation in TSS concentrations and turbidity result from spatial differences in terrestrial runoff, surrounding cover, bathymetry, and mixing due to temporal changes from season and weather.

Lakes in the LSA and RSA had variable TSS and turbidity levels. TSS concentrations ranged from below the analytical detection limit (< 1.0 mg/L) to 19.0 mg/L in the LSA lakes, and < 1.0 mg/L to 15.3 mg/L in the RSA lakes (Table 4.2-5). Turbidity ranged from 0.25 to 18.9 NTU in the LSA lakes, and 0.18 to 7.99 NTU in RSA lakes (Table 4.2-5). TSS and turbidity levels were sporadically elevated and highly variable over time and across lakes.

Table 4.2-5. Lake Total Suspended Solids and Turbidity at LSA and RSA Sites, 2007 to 2015

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
TSS (mg/L)								
LSA - North Belt	247	217	<1.0	3.47	3.50	5.00	6.76	19.0
LSA - South Belt	71	62	<1.0	1.05	<1.0	<3.0	2.00	4.0
RSA	209	157	<1.0	2.51	<3.0	3.10	9.20	15.3
Turbidity (NTU)								
LSA - North Belt	150	127	0.25	5.20	5.05	6.21	11.2	18.9
LSA - South Belt	17	14	0.29	1.11	1.09	1.43	1.94	2.38
RSA	164	112	0.18	1.80	1.14	2.96	4.66	7.99

Notes:
'<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.

Lake Dissolved Oxygen

Dissolved oxygen (DO) concentration is an important environmental parameter that has major effects on the chemistry and aquatic life of freshwater ecosystems. Redox chemistry can affect the solubility and availability of nutrients and metals, which can be released from or precipitated into the sediments under low DO conditions. Low DO concentrations can also inhibit growth and reproduction in zooplankton, benthic invertebrates, and fish, and may lead to mortalities if low DO impedes respiration. The CCME guideline for DO concentrations for cold-water organisms is 9.5 mg/L for early life stages and 6.5 mg/L for other life stages (CCME 2016b).

Lakes in the LSA and RSA were typically ice-covered from October into June, with ice thicknesses of around 2 m in late winter. Between 2007 and 2015, the winter DO profiles were typical of ice-covered Arctic lakes, with concentrations being highest near the water-ice interface (maximum of 18 mg/L at Doris Lake in 2012 and Little Roberts Lake in 2012 and 2015) and gradually declining with depth, particularly in deeper lakes. The amount of oxygen depletion at depth varied among lakes and across years. Bottom waters in some lakes (i.e., Ogama, Wolverine, Stickleback, and Trout lakes in the LSA, and Reference Lake B, Little Roberts and Pelvic lakes in the RSA) were nearly anoxic (DO ≤ 1 mg/L) on some winter sampling occasions, indicating that there was oxygen-consuming decomposition occurring in bottom waters or sediments and limited vertical mixing to replenish the oxygen supply.

Winter DO concentrations in the upper portion of the water column of most lakes were above the CCME guideline for the protection of cold-water aquatic life of 9.5 mg/L for early life stages and 6.5 mg/L for other life stages (CCME 2016b). However, bottom water DO concentrations were often below one or both guideline levels (e.g., Doris, Windy, and Nakhaktok lakes in the North Belt LSA; Aimaokatalok Lake in the South Belt LSA; and Reference Lake A, Reference Lake B, and Pelvic Lake in the RSA). DO concentrations were lower than 6.5 mg/L throughout the water column at some shallow lakes of all three study areas (e.g., Ogama, Wolverine, Stickleback, Trout, Little Roberts lakes and Reference Lake D). However, DO concentrations varied widely among years in some lakes such as Ogama, Little Roberts Lake, and Reference Lake D, and DO concentrations were not below guideline levels during all years. The oxygen depletion observed in the deep waters of the sampled lakes is a common phenomenon in Arctic lakes, and is a result of respiration and a lack of exchange with atmospheric oxygen.

Open-water season DO concentrations were also typical of Arctic lakes. Summer DO concentrations changed little throughout the water columns of all lakes, and temperature profiles generally showed that lakes were well mixed during the summer. Overall, lakes were well oxygenated, with surface water column oxygen concentrations ranging from 8.5 mg/L to 14.7 mg/L. Most lakes had DO concentrations above CCME guidelines of 6.5 mg/L and 9.5 mg/L throughout the water column. Some oxygen depletion occasionally occurred near the lake bottom at Aimaokatalok, Doris, Imniagut, Ogama, Patch, Pelvic, and Nakhaktok lakes, likely due to respiratory oxygen consumption. DO concentrations fell below the 9.5 mg/L guideline in all lakes in 2011. Trout, Stickleback, and some shallow stations in Aimaokatalok Lake had DO concentrations above the 6.5 mg/L guideline but below the 9.5 mg/L guideline throughout the water column in 2010. Summer bottom water concentrations in Doris, Ogama, and Pelvic lakes occasionally dropped below the 6.5 mg/L guideline.. Conversely, a few lakes exhibited a slight increase in oxygen with depth. These increases were typically inversely related to water temperature, and likely reflected the increased oxygen carrying capacity of colder water.

Nutrients

Nutrients are the chemicals required by photosynthetic organisms for growth and productivity and ultimately serve as building blocks for organic matter flowing through aquatic food webs. Variation in nutrient concentrations can be caused by periodic mixing, terrestrial runoff events, changes in allochthonous inputs from the surrounding terrestrial environment, and variations in nutrient uptake and remineralization by primary producers and microbes, respectively.

Ammonia and nitrate concentrations in LSA and RSA lakes were often below analytical detection limits and were usually lowest during the open-water season, likely due to uptake by primary producers. Mean nitrate concentrations were highest in the South Belt LSA (0.039 mg nitrate-N/L) and lowest in the North Belt LSA (0.015 mg nitrate-N/L; Table 4.2-6). Mean ammonia concentrations were lowest in the North Belt LSA (0.0083 mg ammonia-N/L) and similar in the South Belt LSA and the RSA (0.018 and 0.019 mg ammonia-N/L, respectively). Nitrate concentrations in all surveyed lakes were always well below the CCME guideline of 3.0 mg nitrate-N/L, and ammonia concentrations were always below the pH- and temperature-dependent CCME guideline for total ammonia (CCME 2016b). Nitrite concentrations in LSA and RSA lakes were typically below analytical detection limits (< 0.001 mg nitrite-N/L) and reached a maximum concentration of 0.02 mg nitrite-N/L in Trout Lake in 2007 (Table 4.2-6). All nitrite concentrations in study area lakes were below the CCME guideline of 0.06 mg nitrite-N/L (CCME 2016b).

Table 4.2-6. Lake Nutrient Concentrations at LSA and RSA Sites, 2007 to 2015

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples Outside of CCME Guidelines[d]
Nitrate (mg N/L)									
LSA - North Belt	243	216	<0.005	0.0152	<0.005	0.0060	0.0698	0.791	0
LSA - South Belt	71	62	<0.001	0.0389	<0.005	0.0180	0.132	1.06	0
RSA	208	156	<0.001	0.0169	<0.005	0.0121	0.0754	0.257	0
Nitrite (mg N/L)									
LSA - North Belt	247	217	<0.001	0.00068	<0.001	<0.001	0.0016	0.0077	0
LSA - South Belt	71	62	<0.001	0.00172	0.00075	<0.005	<0.005	0.0200	0
RSA	209	157	<0.001	0.00079	<0.001	<0.001	0.0020	0.0160	0
Ammonia (mg N/L)									
LSA - North Belt	247	217	0.002	0.0083	0.0055	0.0090	0.0258	0.133	0
LSA - South Belt	71	62	<0.005	0.0184	0.0090	0.0139	0.0471	0.260	0
RSA	211	157	<0.005	0.0191	0.0050	0.0110	0.0412	0.520	0
Total Phosphorus (mg P/L)									
LSA - North Belt	247	217	0.0021	0.0214	0.0221	0.0277	0.0355	0.188	-
LSA - South Belt	71	62	0.0060	0.0143	0.0120	0.0164	0.0270	0.0390	-
RSA	209	157	0.0021	0.0169	0.0110	0.0200	0.0450	0.162	-

Notes: '<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).

Total phosphorus concentrations varied seasonally and across lakes, but tended to be highest in North Belt LSA lakes (Table 4.2-6). All lakes in the LSA were assigned a trophic status based on the CCME trigger ranges for total phosphorus concentrations in freshwater systems (CCME 2004); Table 4.2-7 provides a listing of all study lakes by trophic status. Lakes were often assigned more than one trophic status because of the seasonal variability of total phosphorus concentrations. Within the North Belt LSA, lake trophic status covered the entire spectrum from ultra-oligotrophic to hyper-eutrophic. Windy Lake had the lowest total phosphorus concentrations and varied from ultra-oligotrophic to mesotrophic. P.O. was the only lake with total phosphorus concentrations that reached the hyper-eutrophic range. In the South Belt LSA, Aimaokatalok and Stickleback lakes were classified as oligotrophic to meso-eutrophic, while Trout Lake was considered mesotrophic to eutrophic. In the RSA, Reference lakes A, B, and D were classified as ultra-oligotrophic during some sampling periods, but reached oligotrophic (Reference A), mesotrophic (Reference B), or eutrophic (Reference D) status depending on the year or season. Boston Reference and Pelvic lakes were the only RSA lakes that seasonally reached hyper-eutrophic status.

Table 4.2-7. Trophic Status of Lakes by Total Phosphorus Trigger Ranges, 2007 to 2015

Trophic Status	Total Phosphorus Concentration (mg/L)	LSA - North Belt	LSA - South Belt	RSA
Ultra-Oligotrophic	<0.004	Windy	-	Reference A, Reference B, Reference D
Oligotrophic	0.004-0.01	Doris, Glenn, Imniagut, Patch, P.O., Windy	Aimaokatalok, Stickleback	Naiqunnguut, Reference A, Reference B, Reference D, Roberts
Mesotrophic	0.01-0.02	Doris, Glenn, Ogama, Patch, P.O., Windy, Wolverine	Aimaokatalok, Stickleback, Trout	Boston Reference, Little Roberts, Reference B, Reference D, Roberts
Meso-eutrophic	0.02-0.035	Doris, Glenn, Ogama, P.O.	Aimaokatalok, Stickleback, Trout	Boston Reference, Little Roberts, Pelvic, Reference D, Roberts
Eutrophic	0.035-0.1	Doris, Nakhaktok, Ogama, Patch, Wolverine	Trout	Little Roberts, Pelvic, Reference D
Hyper-eutrophic	<0.1	P.O.	-	Boston Reference, Pelvic

Notes:
Total phosphorus concentrations may vary between years and seasons; as a result, lakes may be listed under multiple trigger ranges.
Trigger ranges from Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems (CCME 2004).

Metals

Many metals are biologically significant chemical constituents of water because they are required nutritional co-factors for organisms. However, some metals may become toxic to aquatic organisms at elevated concentrations, particularly in acidic, soft-water environments. Understanding the natural variability in metal concentrations is an important component of the baseline water quality sampling program. Table 4.2-8 presents the summary statistics for stream and river metal concentrations in each study area, and the percentage of sample metal concentrations that were above CCME guidelines.

Table 4.2-8. Lake Metal Concentrations at LSA and RSA Sites, 2007 to 2015

	Total Metal Concentrations (mg/L)						% of Samples with Concentrations Greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	
LSA - North Belt	**n = 247**	**n = 217**	**n = 217**	**n = 217**	**n = 217**	**n = 247**	**n = 217**
Aluminum	0.0040	0.126	0.059	0.104	0.519	1.05	25
Arsenic	<0.0004	0.00044	0.00038	0.00057	0.00081	0.00182	0
Boron	0.0142	0.0324	0.0299	0.0385	0.0543	0.0742	0
Cadmium	<0.000002	0.0000050	<0.000005	<0.00001	0.0000120	0.000193	0.5
Chromium	0.00010	0.00042	<0.0005	0.00048	0.00112	0.00182	6.0% (Cr (VI)); 0% (Cr (III))[e]
Copper	0.000306	0.00159	0.00145	0.00167	0.00304	0.00424	15
Iron	<0.002	0.144	0.103	0.179	0.400	0.821	11
Lead	<0.000001	0.000154	0.000059	0.000147	0.000605	0.00223	1.4
Mercury	<0.0000005	0.0000019	0.0000008	<0.00001	<0.00001	0.000012	0
Molybdenum	0.000055	0.000282	0.000195	0.000241	0.000743	0.00115	0
Nickel	0.000005	0.00064	0.00054	0.00069	0.00119	0.00701	0
Selenium	<0.0001	0.00061	<0.0005	0.0010	0.0019	0.0044	25
Silver	<0.0000005	0.0000035	<0.000005	<0.00001	0.0000090	0.0000681	0
Thallium	<0.0000003	0.0000112	<0.000005	0.0000062	<0.0001	0.000018	0
Uranium	0.0000205	0.000077	0.000039	0.000062	0.000278	0.000335	0
Zinc	<0.0001	0.00424	<0.003	0.00167	0.00453	0.372	1.4
LSA - South Belt	**n = 71**	**n = 62**	**n = 62**	**n = 62**	**n = 62**	**n = 71**	**n = 62**
Aluminum	<0.007	0.0515	0.0477	0.0677	0.126	0.155	25
Arsenic	0.00003	0.00024	0.00019	0.00024	0.00050	0.00121	0
Boron	0.0020	0.0086	0.0059	0.0108	0.0204	0.0376	0
Cadmium	<0.000002	0.0000033	0.0000015	0.0000048	0.0000114	0.0000240	0
Chromium	0.0000387	0.00036	0.00026	0.00039	0.00100	0.00180	4.8% (Cr (VI)); 0% (Cr (III))[e]
Copper	0.000233	0.00113	0.00100	0.00125	0.00228	0.00529	6.5
Iron	0.013	0.168	0.092	0.129	0.400	2.81	13
Lead	<0.000001	0.00013	0.00004	0.00008	0.00061	0.00209	1.6
Mercury	<0.0000006	0.0000020	0.0000012	0.0000033	<0.00001	0.0000080	0
Molybdenum	0.0000106	0.0000461	0.0000420	0.0000542	0.0000829	0.000162	0
Nickel	<0.000005	0.00056	0.00043	0.00059	0.00116	0.00302	0
Selenium	<0.0001	0.00039	0.00026	0.00047	0.00063	0.00436	3.2
Silver	<0.0000005	0.0000041	0.0000031	<0.00001	0.0000130	0.0000200	0
Thallium	<0.0000003	0.0000127	0.0000024	0.0000051	<0.0001	0.0000071	0
Uranium	0.000008	0.000026	0.000023	0.000027	0.000044	0.000117	0
Zinc	<0.0001	0.00240	0.00140	0.00227	0.00788	0.0208	0
RSA	**n = 211**	**n = 156**	**n = 156**	**n = 156**	**n = 156**	**n = 211**	**n = 156**
Aluminum	<0.003	0.075	0.056	0.113	0.224	0.644	28
Arsenic	<0.0001	0.00032	0.00023	0.00044	0.00100	0.00231	0
Boron	0.0031	0.0204	0.0175	0.0258	0.0460	0.0980	0
Cadmium	<0.000002	0.0000042	<0.000005	<0.000005	0.0000147	0.0000551	0
Chromium	<0.0001	0.00036	0.00025	0.00037	0.00092	0.00330	4.5% (Cr (VI)); 0% (Cr (III))[e]
Copper	<0.001	0.00147	0.00135	0.00168	0.00266	0.00726	9.6

	Total Metal Concentrations (mg/L)						% of Samples with Concentrations Greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	
Iron	<0.01	0.216	0.112	0.220	0.856	2.76	15
Lead	<0.000001	0.00027	0.00007	0.00012	0.00104	0.0138	5.7
Mercury	<0.0000005	0.0000018	0.0000007	0.0000022	<0.00001	0.000034	0.6
Molybdenum	<0.00005	0.000110	0.000077	0.000186	0.000247	0.000383	0
Nickel	<0.0002	0.00051	0.00046	0.00063	0.00119	0.00207	0
Selenium	<0.0001	0.00035	<0.0002	0.00047	0.00109	0.00657	6.4
Silver	<0.0000005	0.0000026	<0.000005	<0.000005	<0.00001	0.0000142	0
Thallium	<0.0000003	0.0000057	0.0000018	0.0000030	<0.0001	0.0000080	0
Uranium	0.0000194	0.000042	0.000041	0.000047	0.000066	0.000086	0
Zinc	<0.0001	0.0028	<0.003	<0.003	0.0038	0.166	0.6

Notes: '<' indicates that metal concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).
[e] The CCME guideline for chromium is dependent on its speciation (Cr(VI) or Cr(III)). Routine metal analysis does not distinguish between chromium species, so total chromium results were used to compare with CCME guidelines to be conservative.

Metal concentrations were sometimes greater during the ice-covered season due to solute extrusion during ice formation, changes in redox chemistry, increased remineralization, and/or decreased biological uptake. Between 2007 and 2015, concentrations of metals such as cadmium, selenium, silver, and thallium were frequently near or less than analytical detection limits (Table 4.2-8). Some metals such as aluminum, chromium, copper, iron, lead, and selenium were occasionally naturally elevated in LSA and RSA lakes. These naturally-elevated metal concentrations were greater than CCME guideline levels in some lake samples collected from all study areas (North Belt LSA, South Belt LSA, and RSA; Table 4.2-8). There were also some metal concentrations that were sporadically higher than CCME guidelines, including cadmium, mercury, and zinc. Cadmium concentrations were higher than the hardness-dependent, long-term CCME guideline in one sample collected from Doris Lake (North Belt LSA; Table 4.2-8). The mercury concentration in a single sample collected from Reference Lake B (RSA) was higher than the CCME guideline of 0.000026 mg/L (Table 4.2-8). Zinc concentrations in three samples collected from Doris Lake and one sample from Reference Lake B were higher than the CCME guideline concentration of 0.03 mg/L (Table 4.2-8).

Cyanide

Cyanide is a naturally-occurring organic nitrogen compound produced by micro-organisms and plants. Free cyanide concentrations were occasionally measured in lakes for comparison with the CCME guideline for the protection of aquatic life of 0.005 mg/L (CCME 2016b). Free cyanide concentrations in North Belt LSA and RSA lakes were usually below the analytical detection limit (<0.001 or <0.005 mg/L; Table 4.2-9). Maximum concentrations of 0.0020 and 0.0034 mg/L were measured in the North Belt LSA and RSA, respectively (Table 4.2-9). Concentrations of free cyanide always remained below the CCME guideline of 0.005 mg/L (CCME 2016b). Free cyanide concentrations were not measured in South Belt LSA lakes.

Table 4.2-9. Lake Free Cyanide Concentrations at LSA and RSA Sites, 2011 to 2015

	n (min, max)	n (mean)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples Outside of CCME Guideline[d]
Free Cyanide (mg/L)									
LSA - North Belt	86	73	<0.001	0.0006	<0.001	<0.001	0.0016	0.0020	0
RSA	125	80	<0.001	0.0006	<0.001	<0.001	<0.005	0.0034	0

Notes:
'<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
Free cyanide concentrations were not measured in samples collected from the South Belt of the LSA.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detection limit since all concentrations of free cyanide were below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).

4.2.4.2 Streams and Rivers

Streams and rivers are the other significant component of freshwater environments in the Phase 2 area. Streams and rivers are hosts to many aquatic organisms, serve as water sources for many terrestrial organisms, and are valuable sources of water for human uses. Streams in the Phase 2 Project area are seasonal and usually flow between June and September. Like lakes, all water quality indicators in streams and rivers are naturally variable due to heterogeneity in the landscape, biogeochemical cycling, weather, and climate. The baseline sampling program served to measure this natural variation to identify any future Phase 2 effects on water quality.

<u>General Parameters</u>

Streams and rivers in the LSA and RSA had slightly acidic to slightly alkaline pH levels between 2007 and 2015, ranging from 5.6 to 8.4 in the LSA and 6.0 to 8.7 in the RSA (Table 4.2-10). Some pH levels in all study areas fell below the lower limit of the CCME pH guideline range of 6.5 to 9.0 (CCME 2016b).

Table 4.2-10. Stream and River Water Chemistry at LSA and RSA Sites, 2007 to 2015

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples Outside of CCME Guidelines[d]
pH									
LSA - North Belt	187	115	5.6	6.9	7.5	7.7	8.0	8.3	5.2
LSA - South Belt	98	65	6.0	6.7	7.2	7.4	7.7	8.4	20
RSA	263	152	6.0	7.1	7.3	7.6	7.8	8.7	4.6
Hardness (mg $CaCO_3$/L)									
LSA - North Belt	189	117	12.1	45.4	47.3	55.1	71.0	81.9	-
LSA - South Belt	99	66	2.2	26.2	19.8	29.3	71.1	75.2	-
RSA	263	152	7.3	27.8	23.8	39.7	48.3	60.3	-

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples Outside of CCME Guidelines[d]
Total Alkalinity (mg $CaCO_3$/L)									
LSA - North Belt	189	117	9.0	28.4	28.7	33.0	48.5	56.4	-
LSA - South Belt	99	66	<2.0	17.5	13.8	21.2	35.5	54.0	-
RSA	263	152	5.2	17.0	15.3	22.3	26.9	29.8	-
Total Dissolved Solids (mg/L)									
LSA - North Belt	165	105	28	133	143	166	214	278	-
LSA - South Belt	99	66	<10	58	44	66	125	187	-
RSA	171	106	16	84	73	128	154	180	-
Total Organic Carbon (mg/L)									
LSA - North Belt	189	117	1.58	6.36	5.80	6.62	10.4	46.3	-
LSA - South Belt	99	66	0.90	7.02	6.25	8.08	12.1	18.4	-
RSA	263	152	2.43	5.19	5.12	6.01	7.75	14.0	-
Dissolved Organic Carbon (mg/L)									
LSA - North Belt	85	73	1.50	5.59	5.09	6.00	9.32	44.7	-
LSA - South Belt	32	32	1.70	6.18	5.45	7.90	10.9	11.5	-
RSA	136	88	2.27	5.05	5.13	5.80	7.30	7.90	-
Chloride (mg/L)									
LSA - North Belt	189	117	4.39	56.4	61.4	72.8	95.2	112	0
LSA - South Belt	83	50	1.39	15.6	10.4	17.9	50.8	52.1	0
RSA	255	144	3.30	35.7	43.7	57.7	64.3	70.9	0
Fluoride (mg/L)									
LSA - North Belt	189	117	<0.02	0.086	0.056	0.070	0.130	1.65	6.8
LSA - South Belt	98	65	<0.01	0.042	0.033	0.040	0.088	0.38	3.1
RSA	263	152	<0.02	0.041	0.038	0.048	0.084	0.33	1.3
Sulphate (mg/L)									
LSA - North Belt	189	117	0.68	3.8	2.7	4.0	10	18	-
LSA - South Belt	99	66	<0.5	2.1	<3.0	1.8	6.0	12.0	-
RSA	262	151	0.95	2.8	2.4	4.0	5.0	7.61	-

Notes:
'<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).
Total Suspended Solids and Turbidity

Water in the streams and rivers of the LSA and RSA can generally be characterized as soft (hardness of less than 60 mg $CaCO_3$/L), though hardness sometimes increased seasonally to levels that would be considered moderately hard (maximum of 81.9 mg $CaCO_3$/L in the North Belt LSA, 75.2 mg $CaCO_3$/L in the South Belt LSA, and 60.3 mg $CaCO_3$/L in the RSA; Table 4.2-10).

The acid-sensitivity of streams and rivers in the LSA and RSA was generally high. Alkalinity levels of less than 20 mg $CaCO_3$/L (indicating sensitivity to acid because of poor buffering capacity) occurred seasonally in nearly all streams of the LSA and RSA. The only streams of the LSA in which alkalinity remained higher than 20 mg $CaCO_3$/L during all sampling periods were Ogama and Windy outflows in the North Belt LSA.

Stream and river TDS concentrations were higher in the North Belt LSA than in the South Belt LSA or the RSA (Table 4.2-10). Mean concentrations of total and dissolved organic carbon were highest in the South Belt LSA (Table 4.2-10).

Chloride concentrations in streams of the LSA and RSA were always below the CCME guidelines for the protection of freshwater aquatic life (Table 4.2-10). Fluoride concentrations in stream and river samples collected in 2007 from all of the study areas were occasionally higher than the CCME interim guideline of 0.12 mg/L; however, all fluoride concentrations in samples collected from 2008 to 2015 were below this guideline (CCME 2016b; Table 4.2-10).

Streams and rivers in the LSA and RSA had highly variable TSS and turbidity levels. TSS concentrations ranged widely from below the analytical detection limit (< 1.0 mg/L) to 198 mg/L in LSA streams, and < 1.0 mg/L to 20 mg/L in RSA streams. Turbidity ranged from 0.25 to 218 NTU in LSA streams, and 0.28 to 19 NTU in RSA streams. Mean and maximum TSS and turbidity levels were highest in the North Belt LSA (Table 4.2-11).

Table 4.2-11. Stream and River Total Suspended Solids and Turbidity at LSA and RSA Sites, 2007 to 2015

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
TSS (mg/L)								
LSA - North Belt	189	117	<1.0	6.8	3.6	5.4	21.0	198
LSA - South Belt	99	66	<1.0	3.0	1.5	3.1	11.3	23.0
RSA	263	152	<1.0	3.2	2.3	3.9	9.4	20.0
Turbidity (NTU)								
LSA - North Belt	128	56	0.36	13.1	5.6	9.8	44.2	218
LSA - South Belt	67	34	0.25	2.7	1.6	2.8	10.0	12.1
RSA	223	112	0.28	3.3	2.4	4.5	10.3	19.0

Notes:
'<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
One half of the value of the analytical detection limit was substituted for values that were below detection limits for the calculation of summary statistics.
[a] *Minimum represents the lowest concentration in any replicate sample.*
[b] *Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.*
[c] *Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.*

Nutrients

Nitrate concentrations in streams and rivers ranged from below the analytical detection limit (< 0.001 mg/L) to 0.56 mg/L in the LSA and from < 0.001 mg/L to 0.27 mg/L in the RSA (Table 4.2-12). All concentrations remained well below the CCME guideline of 3.0 mg nitrate-N/L (CCME 2016b). Nitrite concentrations throughout the LSA and RSA were near or below the analytical detection limit (<0.001 mg/L; Table 4.2-12) and well below the CCME guideline of 0.06 mg nitrite-N/L (CCME 2016b). Ammonia concentrations were similar in the LSA and RSA, ranging from below the detection limit (<0.005 mg/L) to 0.24 mg/L in both the LSA and RSA streams (Table 4.2-12). Concentrations always remained below the pH- and temperature-dependent CCME guideline for total ammonia (CCME 2016b).

Table 4.2-12. Stream and River Nutrient Concentrations at LSA and RSA Sites, 2007 to 2015

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples Outside of CCME Guidelines[d]
Nitrate (mg N/L)									
LSA - North Belt	189	117	<0.005	0.0139	<0.005	<0.005	0.0147	0.556	0
LSA - South Belt	99	66	<0.001	0.0085	<0.005	0.0060	0.0284	0.181	0
RSA	263	152	<0.001	0.0072	<0.005	0.0059	0.0201	0.268	0
Nitrite (mg N/L)									
LSA - North Belt	189	117	<0.001	0.0007	<0.001	<0.001	0.0020	0.0030	0
LSA - South Belt	99	66	<0.001	0.0010	<0.001	0.0010	0.0025	0.0030	0
RSA	263	152	<0.001	0.0006	<0.001	<0.001	0.0020	0.0020	0
Total Ammonia (mg N/L)									
LSA - North Belt	189	117	<0.005	0.0083	0.0070	0.0106	0.0200	0.044	0
LSA - South Belt	99	66	<0.005	0.0145	0.0120	0.0154	0.0305	0.238	0
RSA	263	152	<0.005	0.0080	0.0050	0.0083	0.0178	0.239	0
Total Phosphorus (mg P/L)									
LSA - North Belt	189	117	<0.002	0.0209	0.0198	0.0279	0.0392	0.0650	-
LSA - South Belt	99	66	0.0029	0.0169	0.0143	0.0200	0.0338	0.0990	-
RSA	263	152	0.0023	0.0158	0.0149	0.0210	0.0329	0.0670	-

Notes:
'<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).

Mean and maximum total phosphorus concentrations were highest in the North Belt LSA (mean: 0.021 mg/L, maximum: 0.065 mg/L; Table 4.2-12). Total phosphorus concentrations were highly variable among streams but also within streams over time. Table 4.2-13 provides a listing of all study streams and rivers by trophic status. Within the North Belt LSA, some streams and rivers such as P.O. Outflow, Patch Outflow, and the Koignuk River ranged widely in trophic status from oligotrophic to eutrophic based on total phosphorus concentrations (Table 4.2-13). Streams that were eutrophic during at least one sampling event also included AWRa, Doris Outflow, Glenn Outflow, and Ogama Outflow. At the lower end the total phosphorus range, Wolverine Outflow was classified as ultra-oligotrophic, and Windy Outflow ranged from ultra-oligotrophic to mesotrophic. In the South Belt LSA, stream S6 was classified as ultra-oligotrophic, while most streams and rivers in the area were oligotrophic to mesotrophic. Aimaokatalok NE Inflow ranged from meso-eutrophic to eutrophic, and Trout Outflow ranged from mesotrophic to eutrophic. In the RSA, Reference B Outflow was at the low end of the total phosphorus range and was classified as ultra-oligotrophic to oligotrophic. Most streams and rivers in the RSA ranged from oligotrophic to meso-eutrophic. Only Little Roberts Outflow and Pelvic Outflow fell into the eutrophic category during at least one sampling session.

Table 4.2-13. Trophic Status of Streams and Rivers by Total Phosphorus Trigger Ranges, 2007 to 2015

Trophic Status	Total Phosphorus Concentration (mg/L)	LSA - North Belt	LSA - South Belt	RSA
Ultra-Oligotrophic	<0.004	Windy OF, Wolverine OF	S6	Reference B OF
Oligotrophic	0.004-0.01	Koignuk River, P.O. OF, Patch OF, Windy OF	Aimaokatalok OF, AWRc, AWRe, Koignuk River, S12, Stickleback OF	Aimaokatalok River, Angimajuq River, Boston Reference OF, Reference A OF, Reference B OF, Reference D OF
Mesotrophic	0.01-0.02	AWRb, Doris OF, Glenn OF, Koignuk River, P.O. OF, Patch OF, Windy OF	Aimaokatalok OF, AWRc, AWRd, AWRe, Koignuk River, Stickleback OF, Trout OF	Aimaokatalok River, Angimajuq River, Boston Reference OF, Little Roberts OF, Reference D OF, Roberts OF
Meso-eutrophic	0.02-0.035	AWRa, AWRb, Doris OF, Glenn OF, Koignuk River, Ogama OF, P.O. OF	Aimaokatalok NE IF, AWRd, Stickleback OF, Trout OF	Aimaokatalok River, Boston Reference OF, Little Roberts OF, Pelvic OF, Roberts OF
Eutrophic	0.035-0.1	AWRa, Doris OF, Glenn OF, Koignuk River, Ogama OF, P.O. OF, Patch OF	Aimaokatalok NE IF, Trout OF	Little Roberts OF, Pelvic OF
Hyper-eutrophic	<0.1	-	-	-

Notes:
OF = Outflow, IF = Inflow.
Total phosphorus concentrations may vary between years and seasons; as a result, streams may be listed under multiple trigger ranges.
Trigger ranges from Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems (CCME 2004).

Metals

Table 4.2-14 presents the summary statistics for stream and river metal concentrations in each study area, and the percentage of sample metal concentrations that were above CCME guidelines. Concentrations of many metals in stream and river samples were near or less than analytical detection limits (e.g., silver, and thallium; Table 4.2-14). As observed in lakes, some metals such as aluminum, chromium, copper, iron, and selenium were naturally elevated in LSA and RSA streams and rivers. With the exception of selenium, these metal concentrations were greater than CCME guideline levels in some stream and river samples collected from all study areas (North Belt LSA, South Belt LSA, and RSA; Table 4.2-14). Selenium concentrations were greater than the CCME guideline of 0.001 mg/L in 21% of samples collected from the North Belt LSA and 5.9% of samples collected from the RSA (Table 4.2-14); most of elevated concentrations occurred in 2007 and 2008. In the South Belt LSA, all concentrations of selenium in streams and rivers were below the CCME guideline (Table 4.2-14). There were also some metal concentrations that were sporadically higher than CCME guidelines, including arsenic, cadmium, lead, and mercury. The arsenic concentration in one sample from Roberts Outflow in the RSA was slightly greater than the CCME guideline of 0.005 mg/L (Table 4.2-14). Cadmium concentrations were higher than the hardness-dependent, long-term CCME guideline in one sample collected from the Koignuk River (North Belt LSA) and one sample collected from Reference B Outflow (RSA; Table 4.2-14). Lead concentrations were greater than the hardness-dependent CCME guideline in samples collected from Glenn Outflow and the Koignuk River in the North Belt LSA and in a sample collected from the Aimaokatalok River in the RSA (Table 4.2-14). The mercury concentration in one sample collected from Roberts Outflow was higher than the CCME guideline for inorganic mercury of 0.000026 mg/L (Table 4.2-14).

Table 4.2-14. Stream and River Metal Concentrations at LSA and RSA Sites, 2007 to 2015

	Total Metal Concentrations (mg/L)						% of Samples with Concentrations Greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	
LSA - North Belt	**n = 189**	**n = 117**	**n = 117**	**n = 117**	**n = 117**	**n = 189**	**n = 117**
Aluminum	0.0218	0.325	0.189	0.353	1.08	3.90	64
Arsenic	<0.0001	0.00041	0.00037	0.00050	0.00066	0.00372	0
Boron	0.0043	0.0239	0.0232	0.0285	0.0462	0.0526	0
Cadmium	<0.000002	0.0000061	0.0000033	<0.00001	0.0000135	0.000165	0.9
Chromium	<0.0001	0.00078	0.00045	0.00090	0.00226	0.00739	22% (Cr (VI)); 0% (Cr (III))[e]
Copper	0.00057	0.00181	0.00150	0.00192	0.00354	0.00948	25
Iron	0.015	0.365	0.199	0.440	1.15	3.97	38
Lead	0.000008	0.000177	0.000081	0.000189	0.000456	0.00528	1.7
Mercury	<0.0000006	0.0000022	0.0000013	<0.00001	<0.00001	0.0000039	0
Molybdenum	<0.00005	0.000230	0.000172	0.000229	0.000658	0.000720	0
Nickel	0.000005	0.00093	0.00067	0.00104	0.00232	0.00529	0
Selenium	<0.0001	0.00059	<0.001	0.00084	0.00137	0.00216	21
Silver	<0.000005	0.0000050	<0.000005	<0.00001	0.0000148	0.000117	0
Thallium	<0.0000003	0.0000166	0.0000045	<0.00001	<0.00001	0.0000172	0
Uranium	0.000013	0.000082	0.000050	0.000085	0.000277	0.000447	0
Zinc	<0.0001	0.0022	0.0015	0.0026	0.0051	0.0180	0
LSA - South Belt	**n = 99**	**n = 66**	**n = 66**	**n = 66**	**n = 66**	**n = 99**	**n = 66**
Aluminum	0.011	0.121	0.069	0.125	0.409	0.836	45
Arsenic	<0.00005	0.00027	0.00020	0.00037	0.00070	0.00097	0
Boron	0.00209	0.00997	0.0103	0.0133	0.0177	0.0265	0

	Total Metal Concentrations (mg/L)						% of Samples with Concentrations Greater than CCME Guidelines[d]
	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]	
Cadmium	<0.000002	0.0000047	<0.00001	<0.00001	0.0000089	0.0000255	0
Chromium	<0.00003	0.00047	0.00037	0.00064	0.00110	0.00135	11% (Cr (VI)); 0% (Cr (III))[e]
Copper	0.000093	0.00124	0.00108	0.00151	0.00221	0.0156	6.1
Iron	0.026	0.421	0.285	0.508	1.174	3.46	48
Lead	0.0000071	0.000065	0.000029	0.000084	0.000203	0.000860	0
Mercury	<0.0000006	0.0000030	<0.00001	<0.00001	<0.00001	0.0000029	0
Molybdenum	0.0000022	0.0000683	0.0000612	0.0000788	0.000154	0.000482	0
Nickel	<0.0001	0.00073	0.00065	0.00101	0.00144	0.00226	0
Selenium	<0.0001	0.00029	<0.0005	<0.001	0.00059	0.000754	0
Silver	<0.0000005	0.0000045	<0.00001	<0.00001	0.0000094	0.0000230	0
Thallium	<0.0000003	0.0000272	<0.00001	<0.00001	<0.00001	0.0000125	0
Uranium	<0.00001	0.000049	0.000024	0.000045	0.000085	0.00112	0
Zinc	<0.0001	0.0019	0.0015	0.0021	0.0043	0.0175	0
RSA	**n = 263**	**n = 152**	**n = 152**	**n = 152**	**n = 152**	**n = 263**	**n = 152**
Aluminum	0.0044	0.126	0.085	0.156	0.445	0.717	47
Arsenic	<0.00005	0.00036	0.00022	0.00031	0.00057	0.00517	0.7
Boron	0.0012	0.0181	0.0182	0.0249	0.0343	0.0542	0
Cadmium	<0.000002	0.0000042	<0.000005	0.0000028	0.0000071	0.000213	0.7
Chromium	<0.0001	0.00037	<0.0005	0.00039	0.00090	0.00258	3.3% (Cr (VI)); 0% (Cr (III))[e]
Copper	<0.0005	0.00133	0.00135	0.00153	0.00189	0.00396	2.6
Iron	<0.03	0.220	0.166	0.273	0.617	1.09	21
Lead	0.000022	0.000063	0.000031	0.000070	0.000180	0.00136	0.7
Mercury	<0.0000005	0.0000027	0.0000011	0.0000024	<0.00001	0.000106	0.7
Molybdenum	0.000019	0.000112	0.000091	0.000180	0.000209	0.000270	0
Nickel	<0.0002	0.00052	0.00052	0.00064	0.00093	0.00219	0
Selenium	<0.0001	0.00026	<0.0002	0.00024	0.00102	0.00142	5.9
Silver	<0.000005	0.0000035	<0.000005	0.0000028	0.0000067	0.000104	0
Thallium	<0.0000003	0.0000078	0.0000025	0.0000046	<0.0001	0.0000079	0
Uranium	0.000019	0.000046	0.000043	0.000052	0.000073	0.000176	0
Zinc	<0.0001	0.0016	<0.003	<0.003	0.0031	0.0102	0

Notes:
'<' indicates that metal concentration was less than the analytical detection limit shown.
n = number of observations.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detectable concentration in any replicate sample and excludes values reported as being below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).
[e] The CCME guideline for chromium is dependent on its speciation (Cr(VI) or Cr(III)). Routine metal analysis does not distinguish between chromium species, so total chromium results were used to compare with CCME guidelines to be conservative.

Cyanide

Stream and river free cyanide concentrations were occasionally measured for comparison with the CCME guideline for the protection of aquatic life of 0.005 mg/L (CCME 2016b). All free cyanide concentrations measured in North Belt LSA and RSA streams and rivers were below analytical detection limits (Table 4.2-15) and below the CCME guideline for free cyanide. Cyanide concentrations were not measured in South Belt LSA streams and rivers.

Table 4.2-15. Stream and River Free Cyanide Concentrations at LSA and RSA Sites, 2011 to 2015

	n (min, max)	n (mean, median, percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Samples with Concentrations Greater than CCME Guideline[d]
Free Cyanide (mg/L)									
LSA - North Belt	40	20	<0.001	all concentrations below detection limit				<0.005	0
RSA	160	80	<0.001	all concentrations below detection limit				<0.005	0

Notes:
'<' indicates that value was less than the analytical detection limit shown.
n = number of observations.
Free cyanide concentrations were not measured in samples collected from the South Belt of the LSA.
[a] Minimum represents the lowest concentration in any replicate sample.
[b] Replicate samples collected at the same site, date, and depth were averaged for the calculation of mean, median, and the 75th and 95th percentiles.
[c] Maximum represents the highest detection limit since all concentrations of free cyanide were below analytical detection limits.
[d] CCME guidelines for the protection of freshwater aquatic life, Canadian Council of Ministers of the Environment (accessed October 2016).

4.3 VALUED COMPONENTS

4.3.1 Potential Valued Components and Scoping

Valued Ecological Components (VECs) are those components of the biophysical environment considered to be of scientific, ecological, economic, social, cultural, or heritage importance (Volume 2, Section 4). The selection and scoping of VECs considers biophysical conditions and trends that may interact with the proposed Project, variability in biophysical conditions over time, and data availability as well as the ability to measure biophysical conditions that may interact with the Project. For an interaction to occur there must be spatial and temporal overlap between a VEC and Project component and/or activities. The selection and scoping of VECs also considers their importance to the communities potentially impacted by the Project.

4.3.1.1 The Scoping Process and Identification of VECs

The scoping of VECs follows the process outlined in the Assessment Methodology (Volume 2, Section 4). The selection of VECs began with those proposed in the EIS guidelines and was further informed through consultation with communities, regulatory agencies, available TK, professional expertise, and the NIRB's final scoping report (Appendix B of the EIS Guidelines). The EIS guidelines (NIRB 2012a) propose that freshwater water quality be considered for inclusion in the effects assessment. The selection of freshwater water quality as a VEC was also informed by:

- the potential for Phase 2 activities and components to interact with the local and regional freshwater environment;

- Review of recently completed Nunavut EAs (e.g., Back River, Meliadine);
- Consultation and engagement with local and regional Inuit groups (e.g., the KIA);
- The Environmental Impact Statement (EIS) guidelines and appendices (NIRB 2012a);
- the existence of federal or territorial acts, regulations, and guidelines that directly or indirectly identify water quality as an important freshwater component (e.g., CCME water quality guidelines, MMER under the *Fisheries Act* (1985c); and
- The public, during public consultation and open house meetings held in the Kitikmeot communities in May 2016 (see Volume 2, Section 2, Public Consultation).

4.3.1.2 NIRB Scoping Sessions

Scoping sessions hosted by NIRB (NIRB 2012b) with key stakeholders and local community members (i.e., the public) focused on identifying the components that are important to local residents, as related to the Project. Comments made during these sessions were compiled and analysed as part of VEC scoping. Concerns regarding the effects of dust during spring runoff on freshwater water quality and post-closure effects to water quality (i.e., "water should be left as clean as when the mine first started").

4.3.1.3 TMAC Consultation and Engagement Informing VEC or VSEC Selection

Community meetings for the Phase 2 Project were conducted in each of the five Kitikmeot communities as described in Section 3 of Volume 2. The meetings are a central component of engagement with the public and an opportunity to share information and seek public feedback. Overall, the community meetings were well attended. Public feedback (questions, comments, and concerns) about the proposed Project was obtained through open dialogue during Project presentations, through discussions that arose during the presentation of Project materials and comments provided in feedback forms. No specific feedback was provided about freshwater water quality.

4.3.2 Valued Components Included in the Assessment

The scoping analysis identified the freshwater water quality VEC for inclusion in the assessment. The freshwater water quality VEC was selected as a component of the assessment of the potential effects of the Phase 2 Project on freshwater environment because of the following:

- the potential to interact with the activities and components of the Project;
- the importance of water quality in community consultations and TK;
- identification as important by government regulators and the NIRB;
- inclusion in recently completed Nunavut EAs (e.g., Back River, Mary River); and
- informed by professional judgement.

Table 4.3-1 summarizes the freshwater water quality *VEC* included in this assessment.

Table 4.3-1. Valued Ecosystem Component(s) Included in the Assessment

VEC	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Government	
Freshwater Water Quality	×	×	×	Moderate to significant comments expressed by regulatory agencies and potentially significant regulatory considerations.

4.4 SPATIAL AND TEMPORAL BOUNDARIES

The spatial boundaries selected to shape this assessment are determined by Phase 2's potential effects on the freshwater environment. The freshwater water quality VEC spatial and temporal boundaries were defined as the maximum limits within which the assessment was conducted. The boundaries were determined by the criteria specified in the EIS guidelines (NIRB 2012a), and outlined in the Effects Assessment Methodology (Volume 2, Section 4).

Temporal boundaries are selected that consider the different phases of Phase 2 and their durations. The Project's temporal boundaries reflect those periods during which planned activities will occur and have potential to affect the freshwater environment.

The determination of spatial and temporal boundaries also takes into account the development of the entire Hope Bay Greenstone Belt. The assessment considers both the incremental potential effects of Phase 2 as well as the total potential effects of the additional Phase 2 activities in combination with the existing and approved Projects including the Doris Project and advanced exploration activities at Madrid and Boston.

4.4.1 Project Overview

Through a staged approach, the Hope Bay Project is scheduled to achieve mine operations in the Hope Bay Greenstone Belt through mining at Doris, a bulk sample followed by commercial mining at Madrid North and South, and mining of the Boston deposit. To structure the assessment, the Hope Bay Project is broadly divided into: 1) the Approved Projects (Doris and exploration), and 2) the Phase 2 Project (this application).

4.4.1.1 The Approved Projects

The Approved Projects include:

1. the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
2. the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
3. the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1217); and
4. the Madrid Advanced Exploration Project (NWB Type B Water Licence under Review).

<u>The Doris Project</u>

Following acquisition of the Hope Bay Project by TMAC in March 2013, planning and permitting, advanced exploration and construction activities have focused on bringing Doris into gold production in early 2017. In 2016, the Nunavut Impact Review Board and Nunavut Water Board (NWB) granted an amendment to the Doris Project Certificate and Doris Type A Water Licence respectively, to expand mine operations to six years and mine the full Doris deposit. Mining and milling rates were increased to a nominal 1,000 tpd to 2,000 tpd.

The Doris Project includes the following:

- The Roberts Bay offloading facility: marine jetty, barge landing area, beach and pad laydown areas, fuel tank farm/transfer station, and quarries;
- The Doris Site: 280 person camp, laydown area, service complex (e.g., workshop, wash bay), quarries, fuel tank farm/transfer station, potable water treatment, waste water treatment, incinerators, explosives storage, and diesel power plant;
- Doris Mine works and processing: underground portal, temporary waste rock pile, ore stockpile, and processing plant;
- Water use for domestic, drilling and industrial uses, and groundwater inflows to underground development;
- Tailings Impoundment Area (TIA): Schedule 2 designation of Tail Lake with two dams (North and South dams), roads, pump house, and quarry;
- all-weather roads and airstrip, winter airstrip, and helicopter pads; and
- water discharge from the TIA will be directed to the outfall in Roberts Bay.

Water is managed at the Doris Project through:

- Freshwater input from Doris Lake for drinking, fire suppression and makeup process water for the mill;
- Process water input primarily from Tail Lake;
- Saline water from mining, porewater from waste rock and ore discharged to Tail Lake;
- Sewage and greywater treated in a waste water treatment plant and discharged to Tail Lake; and
- Water from Tail Lake treated and discharged to Roberts Creek (although note that this discharge changed in the amendment to the Doris Project).

<u>Hope Bay Regional Exploration Project</u>

The Hope Bay Regional Exploration Project has been ongoing since the 1990s. Much of the previous work for the program was based out of the Windy Lake (closed in 2008) and Boston sites (put into care and maintenance in 2011). All exploration activities are currently based from the Doris Site with plans for some future exploration at the Boston Site. Components and activities for the Hope Bay Regional Exploration Project include:

- staging of drilling activities out of Doris or Boston sites; and
- operation of exploration drills in the Hope Bay Belt area, which are supported by helicopter.

<u>Boston Advanced Exploration</u>

The Boston Advanced Exploration Project, which operates under a Type B Water Licence, includes:

- the Boston exploration camp, sewage and greywater treatment plant, fuel storage and transfer station, landfarm, and a heli-pad;

- mine works consisting of underground development for exploration drilling and bulk sampling, temporary waste rock pile, and ore stockpile;
- potable water and industrial water taken from Aimaokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

Since the construction of Boston will require the reconfiguration of the entire site, construction and operation of all aspects of the Boston Site will be considered as part of the Phase 2 Project for the purposes of the assessment.

Madrid Advanced Exploration

In 2014, TMAC applied for an advanced exploration permit to conduct a bulk sample at the Madrid North and Madrid South sites, which are approximately 4 km south of the Doris Site. The program includes extraction of a 50,000 tonne bulk sample, which will be trucked to the mill at the Doris Site for processing and placement of tailings in the TIA. All personnel will be housed at the Doris Site.

The Water Licence application is currently before the NWB. Madrid advanced exploration includes constructing and operating of the following at each of the sites:

- Madrid North and Madrid South: workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station, contact water pond, and quarry;
- Madrid North and Madrid South mine works: underground portal and works, waste rock pad, ore stockpile, compressor building, brine mixing facility, saline storage tank, air heating facility, and vent raises; and
- a road from the Doris Site to Madrid with branches to Madrid North, Madrid North vent raise, and the Madrid South portal.

4.4.1.2 The Phase 2 Project

The Phase 2 Project includes the construction and operation of commercial mining at the Madrid (North and South) and Boston sites, the continued operation of Roberts Bay and the Doris Site to support mining at Madrid and Boston, and the Reclamation and Closure and Post-Closure phases of all sites. Excluded from the Phase 2 Project, for the purposes of the assessment, are the reclamation and closure and post-closure of unaltered components of the Doris Project as currently permitted and approved.

Construction

Phase 2 construction will use the infrastructure associated with Approved Projects.

Additional infrastructure to be constructed for the proposed Phase 2 Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, and development of a west road to facilitate access);
- construction of an off-loading cargo dock at Roberts Bay (including a fuel pipeline, expansion of the fuel tank farm and laydown area);
- construction of infrastructure at Madrid North and Madrid South to accommodate mining;
- complete development of the Madrid North and Madrid South mine workings;
- construction of a process plant, fuel storage, power plant, and laydown at Madrid North;

- all weather access road (AWR) and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston with associated quarries;
- all infrastructure necessary to support mining activities at Boston including construction of a new 200-person camp at Boston and associated support facilities, additional fuel storage, laydown area, ore pad, waste rock pad, process plant, airstrip, diesel power plant, and dry-stack tailings management area (TMA) at Boston; and
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston.

Operation

Phase 2 Project represents the staged development of the Hope Bay Belt beyond the Doris Project (Phase 1). Phase 2 operations includes:

- mining of the Madrid North, Madrid South, and Boston deposits;
- transportation of ore from Madrid North, Madrid South and Boston to Doris for processing, and transportation of concentrate from process plants at Madrid North and Boston to Doris for final gold refining once the process plants at Madrid North and Boston are constructed;
- use of Roberts Bay and Doris facilities, including processing at Doris and maintaining and operating the Robert's Bay outfall for discharge of water from the TIA;
- operation of a process plant at Madrid North to concentrate ore, and disposal of tailings at the Doris TIA;
- operation of a process plant at Boston to concentrate ore, and disposal of tailings to the Boston TMA; and
- ongoing use and maintenance of transportation infrastructure (cargo dock, jetty, roads, and quarries).

Reclamation and Closure

At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Section 5.5):

- Camps and associated infrastructure, laydown areas and quarries, buildings and physical structures will be decommissioned. All foundations will be re-graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re-established.
- Using non-hazardous landfill, facilities will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- Mine waste rock will be used as structural mine backfill.
- The Doris TIA surface will be covered rock. Once the water quality in the reclaim pond has reached the required discharge criteria, the North Dam will be breached and the flow returned to Doris Creek.
- The Madrid to Boston All-Weather Road and Boston Airstrip will remain in place after Reclamation and Closure. Peripheral equipment will be removed. Where rock drains, culverts, or bridges have been installed, the roadway or airstrip will be breached and the element removed. The breached opening will be sloped and armoured with rock to ensure that natural drainage can pass without the need for long-term maintenance.

- A low-permeability cover, including a geomembrane, will be placed over the Boston TMA. The contact water containment berms will be breached. The balance of the berms will be left in place to prevent localised permafrost degradation.

4.4.2 Spatial Boundaries

Spatial boundaries are determined based on the anticipated magnitude and spatial extent of the potential Phase 2 effects. Spatial boundaries are determined by the location and distribution of VECs and are here defined as the anticipated zone of influence between Project component/activities and freshwater water quality.

There are three zones of influence related to freshwater water quality: the Project Development Area (PDA), the Local Study Area (LSA), and the Regional Study Area (RSA).

4.4.2.1 Project Development Area

The Project Development Area (PDA) is shown in Figure 4.2-2 and is defined as the area which has the potential for infrastructure to be developed as part of the Phase 2 Project. The PDA includes engineering buffers around the footprints of structures. These buffers allow for refinement in the final placement of a structure through detailed design and necessary in-filed modifications during construction phase. Areas with buildings and other infrastructure in close proximity are defined as pads with buffers whereas roads are defined as linear corridors with buffers. The buffers for pads varied depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m on either side.

Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of these features. In all cases, the PDA does not include the Phase 2 design buffers applied to potentially environmentally sensitive features. These are detailed in Volume 3, Section 2 (Project Design Considerations).

4.4.2.2 Local Study Area

The local study area (LSA) is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on the freshwater environment due to an interaction with a Project component(s) or physical activity. The LSA includes the watersheds for key waterbodies, such as the Aimaokatalok Lake and Doris Lake, and is the same used for the surface hydrology, sediment quality, and fish and fish habitat VECs (Figure 4.2-2).

4.4.2.3 Regional Study Area

The Regional Study Area (RSA) is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur (Figure 4.2-2). The freshwater RSA includes the PDA, the LSA, and additional areas within which there is the potential for indirect or cumulative effects. The RSA for the freshwater water quality VEC includes portions of the Angimajuq watershed and the Koignuk River watershed located to the west of the PDA, and is the same used for the surface hydrology, sediment quality, and fish and fish habitat VECs.

4.4.3 Temporal Boundaries

The Project represents a significant development in the mining of the Hope Bay Greenstone Belt. Even though this Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, Phase 2 is a continuation of development currently underway. Phase 2 has four separate operational sites: Roberts Bay, Doris, Madrid (North and South), and Boston and three mine sites: Madrid North, Madrid South and Boston. Development, operation and closure of the Phase 2 Project will overlap mining and post-mining activities at the existing Doris mine. As such, the temporal boundaries of this Project overlap with a number of Existing and Approved Authorizations (EAAs) for the Hope Bay Project and the extension of activities during Phase 2.

For the purposes of the EIS, distinct phases of the Project are defined (Table 4.4-1). It is understood that construction, operation and closure activities will, in fact, overlap among sites; this is outlined in Table 4.4-1 and further described in Volume 3, Section 2 (Project Design Considerations).

Table 4.4-1. Temporal Boundaries for the Effects Assessment for Freshwater Water Quality

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Construction	1 to 5	2019 to 2023	5	• **Doris**: expansion of the Doris TIA and accommodations (Year 1); • **Madrid North:** construction of process plant and road to Doris TIA (Year 1); • **All-weather Road**: construction (Year 1 to 3); • **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 to 5).
Operation	1 to 14	2019 to 2032	14	• **Doris**: milling and infrastructure use (Year 1 to 14); • **Madrid North:** mining, ore transport to Doris mill, ore processing and concentrate transport to Doris mill (Year 2 to 13); • **Madrid South:** mining, ore transport to Doris mill (Year 11 to 14); • **All-weather Road**: operational (Year 4 to 16); • **Boston**: winter access road operating (Year 1 to 3); mining (Year 4 to 14); ore transport to Doris mill (Year 4 to 5); processing ore (Year 6 to 14); and concentrate transport to Doris mill (Year 6 to 13).
Reclamation and Closure	14 to 17	2032 to 2035	4	• **Doris**: accommodations and facilities will be operational during closure; mining, milling, and TIA decommissioning (Year 15 to 17); • **Madrid North:** all components decommissioned (Year 14 to 15); • **Madrid South:** all components decommissioned (Year 15 to 16); • **All-weather Road**: road will be operational (Year 15 to 16); decommissioning (Year 17); • **Boston**: all components decommissioned (Year 15 to Year 16).
Post-Closure	16 to 19	2034 to 2037	4	• **All Sites:** Post-closure monitoring.
Temporary Closure	NA	NA	NA	• **All Sites:** Care and maintenance activities, generally consisting of closing down operations, securing infrastructure, removing surplus equipment and supplies, and implementing on-going monitoring and site maintenance activities.

The assessment also considers a Temporary Closure phase should there be a suspension of Project activities during periods when Phase 2 becomes uneconomical due to market conditions. During this phase, Phase 2 would be under care and maintenance. This could occur in any year of Construction or Operation with an indeterminate length (one to two year duration would be typical).

4.5 PROJECT-RELATED EFFECTS ASSESSMENT

4.5.1 Methodology Overview

To provide a comprehensive understanding of the potential effects for the Project, the Phase 2 components and activities are assessed on their own as well as in the context of the Approved Projects (Doris and exploration) within the Hope Bay Greenstone Belt. The effects assessment process is summarized as follows:

1. Identify potential interactions between the Phase 2 Project and the VECs or VSECs;
2. Identify the resulting potential effects of those interactions;
3. Identify mitigation or management measures to eliminate or reduce the potential effects;
4. Identify residual effects (potential effects that would remain after mitigation and management measures have been applied) for Phase 2 in isolation;
5. Identify residual effects of Phase 2 in combination with the residual effects of Approved Projects; and
6. Determine the significance of combined residual effects.

After the identification of potential effects (Step 1, Section 4.5.2), the mitigation and management measures were considered (Step 2, Section 4.5.3). If the application of these measurements were considered to effectively mitigate the effect, the Phase 2 Project-related effects to freshwater water quality were characterized as *negligible* and not identified as incremental residual effects. In parallel, the mitigation of potential effects of Phase 2 in combination with the Existing and Approved Projects were considered, and considered negligible if the mitigation and management measures were considered effective (Steps 3 and 4, Section 4.5.4).

All remaining potential effects were then considered residual effects, and characterized (Step 5, Section 4.5.5) using the following attributes:

- Direction (positive, neutral, or negative);
- Magnitude (negligible, low, moderate, or high);
- Duration (short, medium, long);
- Frequency (infrequent, intermittent, continuous);
- Geographic (spatial) extent (PDA, LSA, RSA, beyond regional); and
- Reversibility (reversible, reversible with effort, irreversible).

The rating criteria for the assessment of residual effects to freshwater water quality are described in the Effects Assessment Methodology section (Volume 2, Section 4) and are further defined for freshwater water quality in Table 4.5-20. The observed and modelled baseline conditions are used, along with water quality guidelines (CCME 2016a), as assessment thresholds for the determination of magnitude. The significance of each residual effects (Step 6, Section 4.5.5.2) was determined by considering the characterization of each residual effect with an assessment of the probability of effects and the confidence in the baseline data and predictions of the effects of the Phase 2 Project and the Hope Bay Development on the freshwater environment.

4.5.1.1 Water Quality Indicators

Water quality is an aggregate definition that encompasses a complex suite of parameters and indicators that describe the aquatic environment and its ability to sustain ecological and biogeochemical functions. The assessment of the potential effects of the Phase 2 Project on freshwater water quality was based on seven indicators that described the most probable and significant interactions between the Phase 2 Project and the freshwater environment (Table 4.5-1). These indicators were chosen because they have the following characteristics:

- specific empirical definitions;
- established analytical measurement methodologies;
- existing baseline information;
- quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life; and
- responsive to the potential effects of industrial and mining activities in the Arctic.

Table 4.5-1. Freshwater Water Quality Indicators for the Assessment of Effects

Indicator	Description	Interaction with Project
pH	Acid-base balance of water	Project activities may increase pH outside of natural range through runoff, deposition, and discharge
TSS	Solid material (i.e., not dissolved) material suspended in water	Project activities may disturb in-water sediments, increase runoff of deposited sediment, or discharge suspended material
Nutrients	Chemical compounds that may contribute to aquatic plant and algal growth, alter trophic interactions, and/or change primary producer community structure	Project activities may contribute nutrients to waterbodies
Metals	Metals particulate-associated or dissolved in water	Project activities may contribute metals to the aquatic environment in runoff, discharge, or deposition
Hydrocarbons	Petroleum hydrocarbon compounds	Project activities may contribute hydrocarbon compounds in runoff, discharge, or aerial deposition
BOD	Organic compounds that may enhance aquatic respiration	Project activities may contribute organic compounds to waterbodies by discharge
Other constituents	Chemical compounds from natural or human sources	Underground water may have high concentrations of base cations and anions (i.e., chloride, sulphate, sodium), cyanide is a process chemical

For the effects assessment, assessment thresholds are applied to the water quality indicators (Table 4.5-2). As detailed in Section 4.5.4.2, the observed and modelled baseline conditions are used as assessment thresholds for the determination of magnitude of potential residual effects. Furthermore, the potential residual effects are screened against CCME water quality guidelines for the protection of aquatic life, when applicable. If water quality guidelines are not available, the thresholds may be defined based on existing conditions defined by the baseline sampling program.

Table 4.5-2. Guidelines Used As Assessment Thresholds for Freshwater Water Quality Indicators

Indicator	Parameter	Guideline
pH		6.5 – 9.0[a]
TSS		Narrative
Nutrients	Ammonia N (total)	pH- and temperature-dependent[b]
	Nitrate N	124 mg/L (short term); 3 mg/L (long term)
	Nitrite N	0.06 mg/L
	Total P	Guidance framework[c]
Metals	Aluminum	0.005 mg/L (if pH < 6.5); 0.1 mg/L (if pH ≥ 6.5)
	Antimony	0.006 mg/L (HC)
	Arsenic	0.005 mg/L
	Barium	1 mg/L (HC)
	Beryllium	0.1 mg/L (Agriculture)
	Boron	640 mg/L (short term); 1.5 mg/L (long term)
	Cadmium	hardness dependent[d]
	Calcium	1,000 mg/L (Agriculutre)
	Chromium	0.001 mg/L (hexavalent); 0.0089 mg/L (trivalent)
	Cobalt	0.05 (Agriculture)
	Copper	0.002 mg/L[e]
	Iron	0.3 mg/L
	Lead	0.001 mg/L[f]
	Lithium	2.5 mg/L (Agriculture)
	Mercury	0.000026 mg/L
	Molybdenum	0.073 mg/L
	Nickel	0.025 mg/L[g]
	Selenium	0.001 mg/L
	Silver	0.0001 mg/L
	Sodium	200 mg/L (HC)
	Thallium	0.0008 mg/L
	Uranium	0.033 mg/L (short term); 0.015 mg/L (long term)
	Vanadium	0.1 mg/L (Agriculture)
	Zinc	0.03 mg/L

Indicator	Parameter	Guideline
Other indicators	Dissolved Oxygen	9.5 mg/L (early life stages); 6.5 mg/L (other life stages)
	Petroleum hydrocarbons	*range of guidelines for petroleum hydrocarbon compounds*
	Sulphate	500 mg/L (HC)
	Chloride	640 mg/L (short term) 120 mg/L (long term)
	Cyanide	0.005 mg/L (as free cyanide); 0.2 mg/L (total cyanide)
	BOD	*no established CCME guideline*

Notes:
The most conservative guideline available from the CCME and the Health Canada Drinking Water guidelines are used for the assessment. Health Canada Drinking Water guidelines are noted with "HC", whereas CCME guidelines for the protection of agriculture (irrigation or livestock) are noted with "Agriculture".
[a] *pH values in pH units.*
[b] *The CCME guideline for total ammonia depends on pH and temperature. For circum-neutral freshwater (pH 6.5 - 7.5) at conservative temperatures (15°C), the guideline for total ammonia is 2.22 to 22.0 mg/L.*
[c] *See nutrient subsections in Sections 5.2.4.1 and 5.2.4.2.*
[d] *The CCME guideline for total cadmium is hardness-dependent.*
[e] *The CCME guideline for copper is hardness-dependent, but hardness values in the Project area were generally less than the lower hardness limit (~80 mg/L $CaCO_3$) and, therefore, the minimum guideline value was 0.002 mg/L.*
[f] *The CCME guideline for lead is hardness-dependent. However, average hardness were less than lower hardness limit, and therefore the minimum guideline value of 0.001 mg/L would apply.*
[g] *The CCME guideline for nickel is hardness-dependent. However, average hardness values were less than threshold for the minimum guideline value of 0.025 mg/L.*

4.5.2 Identification of Potential Effects

The Phase 2 Project has the potential to interact with the freshwater environment through a number of activities, pathways, and mechanisms. Project activities have been grouped into broad components as described in Section 4.3.4.1 of the Effects Assessment Methodology (Volume 2, Section 4). The interactions between the Phase 2 Project and freshwater water quality were further refined by an *interaction group*. Interaction groups are interaction pathways that share similar modes of interaction with the Project, specific mitigation and management measures, assessment thresholds, and key indicators. For example, 'fuel storage and handling' and 'TMA roads use and maintenance' in the Boston area during the Operation phase were both assigned to the *Fuels, Oils, and Polycyclic Aromatic Hydrocarbons* (PAH) interaction group because both project components may interact with freshwater water quality through activities related to the storage and use of fuel. The defined interaction groups for the assessment of effects to freshwater water quality are the following:

- *Site Preparation, Construction, and Decommissioning* - activities that include the clearing of overburden, earthworks, and construction activities for pads and infrastructure.
- *Site and Mine Contact Water* - water that contacts infrastructure, mine surfaces and operations, including runoff from waste rock storage areas and ore storage areas, water management, drilling water, and underground mine water. The site and mine contact water interaction group includes the operation of the water treatment plant at the Boston site.
- *Water Use* - Project activities requiring the withdrawal of water from waterbodies.
- *Quarries and Borrow Pits* - activities related to the operation of quarries and borrow pits.
- *Explosives* - Project activities related to the transport, manufacture, storage, and use of explosives.

- *Fuels, Oils, and PAH* - activities related to the storage of fuels, fueling and maintenance operations, and the combustion of waste.
- *Treated Sewage Discharge* - discharge of effluent from domestic water treatment facilities.
- *Dust Deposition* - activities that generate dust, including vehicle traffic, airstrip activity, and quarry and borrow pit activities that can then be deposited in freshwater receiving environment.

The potential interactions between the Project and the freshwater environment are presented in Table 4.5-3. These components were judged to have probable or likely interactions with the freshwater environment. These potential interactions may be direct or indirect, and this screening step did not consider application of mitigation and management measures.

Table 4.5-3. Project Interaction with the Freshwater Water Quality VEC

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Water Use	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
Roberts Bay	**Construction - proposed Phase 2 infrastructure**								
	Dock access road	×							×
	Fuel pipeline and tank farm	×					×		
	Construction and Operation - use of existing approved and permitted infrastructure								
	Fuel tank farm						×		
	Laydown areas		×			×	×		×
	Roberts Bay-Doris road use and maintenance						×		×
	Site roads use and maintenance						×		×
	Water Management System		×						
	Operation - proposed Phase 2 infrastructure								
	Use of dock access road						×		×
	Fuel pipeline and tank farm						×		
	Quarry				×				
	Reclamation and Closure - proposed Phase 2 infrastructure								
	Site surface infrastructure	×					×		×
	Dock access road	×					×		×
	Quarry				×				
	Temporary Closure								
	Care and maintenance		×				×		

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Water Use	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
Doris	**Construction - proposed Phase 2 infrastructure**								
	Expansion of Project Development Area	×							
	Expansion of accommodations (280 person capacity, expanded to 400 person capacity)	×						×	
	Quarry				×				
	Raising the TIA South Dam	×							
	TIA perimeter road extensions	×							
	TIA West Dam	×							
	Road to TIA South Dam	×							×
	Operation - use of existing approved and permitted infrastructure								
	Airstrip, winter ice strip and helicopter pad						×		×
	Site facilities (sewage treatment facilities, domestic water treatment, fire suppression)			×				×	
	Chemical and hazardous material management facilities						×		
	Fuel storage and handling						×		
	Incinerator						×		
	Ore stockpile		×						×
	Site roads use and maintenance						×		×
	Storage and handling of explosives					×	×		
	Surface infrastructure (maintenance facilities, warehouses, laydown areas, waste management facilities)		×				×		×
	Water discharge to the receiving environment		×						
	Water management system		×						
	Water use from Doris Lake			×					
	Water use from Windy Lake			×					
	Operation - proposed Phase 2 infrastructure								
	Accommodations (expanded)		×					×	
	Quarry				×				
	TIA road use and maintenance		×						×
	TIA storage		×						

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Water Use	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Reclamation and Closure – proposed Phase 2 infrastructure								
	Accommodations (expanded)	×						×	×
	Quarry	×			×				×
	TIA roads (perimeter and South Dam)	×					×		×
	TIA	×	×						
	Temporary Closure								
	Care and maintenance		×				×		
Madrid North	**Construction – use of existing approved and permitted infrastructure**								
	Fuel storage and handling						×		
	Ore stockpile		×						×
	Quarry				×				×
	Site roads								×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)								×
	Underground mine (drilling, blasting, excavation, ventilation)		×			×			×
	Waste rock pile		×						×
	Water management system		×						
	Construction – proposed Phase 2 infrastructure								
	Expansion of site pad (waste rock stockpile)	×	×						×
	Process plant (concentrator)	×							
	Power plant	×							
	Water discharge to the receiving environment								
	Water management system (including expanded CWP)	×	×						
	Operation – use of existing approved and permitted infrastructure								
	Doris - Madrid road use and maintenance		×				×		×
	Fuel storage and handling						×		
	Madrid North access road use and maintenance		×				×		×
	Ore stockpile		×						×
	Quarry				×				
	Site roads use and maintenance						×		×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)		×				×		×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Water Use	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Underground mine (drilling, blasting, excavation, ventilation)		×			×			×
	Waste rock pile		×						×
	Water management system		×						
	Operation – proposed Phase 2 infrastructure								
	Water discharge to the receiving environment		×						
	Water management system (including CWP)		×						
	Reclamation and Closure – proposed Phase 2 infrastructure								
	Inter-site roads	×					×		×
	Site surface and mining infrastructure	×	×				×		×
Madrid South	**Construction – use of existing approved and permitted infrastructure**								
	Fuel storage and handling						×		
	Ore stockpile		×						×
	Quarry				×				
	Site roads								×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)								×
	Underground mine (drilling, blasting, excavation, ventilation)		×			×			×
	Waste rock pile		×						×
	Water management system		×						
	Construction – proposed Phase 2 infrastructure								
	Expansion of Project Development Area	×							
	Expansion of site pad (waste rock stockpile)	×	×						×
	Water discharge to the receiving environment		×						
	Water management system (including expanded CWP)	×	×						
	Operation – use of existing approved and permitted infrastructure								
	Doris - Madrid road use and maintenance						×		×
	Fuel storage and handling						×		
	Ore stockpile		×						×
	Quarry				×				

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Water Use	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Site roads use and maintenance						×		×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)						×		×
	Underground mine (drilling, blasting, excavation, ventilation)		×			×			×
	Waste rock pile		×						×
	Water management system – Type B licence		×						
	Operation – proposed Phase 2 infrastructure								
	Water discharge to the receiving environment		×						
	Water management system (including CWP)		×						
	Reclamation and Closure – proposed Phase 2 infrastructure								
	Inter-site roads	×					×		×
	Site surface and mining infrastructure	×					×		×
Madrid-Boston All-Weather Road	**Construction – use of existing approved and permitted infrastructure**								
	Madrid-Boston winter road						×		×
	Construction – proposed Phase 2 infrastructure								
	All weather road (grading, backfill, excavation, drainage)	×							×
	Construction accommodations	×						×	×
	Quarries	×			×				×
	Water crossings	×							×
	Operation – use of existing approved and permitted infrastructure								
	Madrid-Boston winter road						×		×
	Operation – proposed Phase 2 infrastructure								
	All weather road use and maintenance						×		×
	Quarries				×				×
	Water crossings	x	×						
	Reclamation and Closure – proposed Phase 2 infrastructure								
	All-weather road, quarries and associated infrastructure	×							×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Water Use	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
Boston	**Construction – proposed Phase 2 infrastructure**								
	Site facilities (sewage treatment facilities, domestic water treatment, fire suppression)	×						×	×
	Fuel storage and handling	×					×		
	Heliport and heliport shack	×							×
	Incinerator	×							
	Landfarm	×							×
	Ore stockpile	×	×						×
	Overburden pile	×							×
	Quarry				×				
	Second mine portal	×							×
	Site roads	×							×
	Surface infrastructure (exploration office, core storage facility, laydown area, office, emergency shelter, office, warehouse, reagent storage, workshop, waste management facility)	×							×
	Underground mine (drilling, blasting, excavation, ventilation)	×	×			×			×
	Waste rock pad and pile	×	×						×
	Water discharge to the environment		×						
	Water management system	×	×						
	Water use from Aimaokatalok Lake			×					
	Process plant (concentrator)	×							
	Dry-stack TMA	×	×						×
	TMA roads	×							×
	TMA water management system	×	×						
	Operation – proposed Phase 2 infrastructure								
	Site facilities (sewage treatment facilities, domestic water treatment, fire suppression)							×	×
	Fuel storage and handling						×		
	Incinerator						×		×
	Landfarm								×
	Ore stockpile		×						×
	Overburden pile		×						×
	Quarry				×				

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Water Use	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Treated Sewage Discharge	Dust Deposition
	Site roads and maintenance						×		×
	Surface infrastructure (exploration office, core storage facility, laydown area, office, emergency shelter, office, warehouse, reagent storage, workshop, waste management facility)		×				×		×
	Underground mine (drilling, blasting, excavation, ventilation)		×			×			×
	Waste rock pile		×						×
	Water discharge to the environment		×						
	Water use from Aimaokatalok Lake			×					
	Water management system		×						
	Process plant (concentrator)		×						
	Dry-stack TMA		×						×
	TMA roads use and maintenance						×		×
	TMA water management system		×						
	Reclamation and Closure - proposed Phase 2 infrastructure								
	Site surface and mining infrastructure	×	×				×	×	×
	TMA and associated infrastructure	×	×						×
Boston Airstrip	**Construction - proposed Phase 2 infrastructure**								
	Access road	×							×
	Airstrip and lighting	×							×
	Project Development Area	×							×
	Quarry				×				
	Operation - proposed Phase 2 infrastructure								
	Access road use and maintenance						×		×
	Airstrip and lighting						×		×
	Quarry				×				×
	Reclamation and Closure - proposed Phase 2 infrastructure								
	Site surface infrastructure	×							×

Activities and infrastructure interact with the environment through discrete pathways. These pathways describe specific mechanisms of interactions that are useful for specifying the physical relationship between a Phase 2 component and the freshwater environment, for identifying applicable mitigation measures, and for characterizing the residual effects. For the effects assessment on the freshwater water quality VEC, the following pathways were defined:

- *runoff*, which describes the transport of material or compounds from the terrestrial environment into the freshwater environment by precipitation or snowmelt;
- *discharge*, which is the directed input of water into the freshwater environment;
- *water withdrawal*, which describes the influence that changes in volume and flow may have on freshwater waterbodies;
- *seepage*, which describes the flow of water through the active layer and taliks;
- *physical*, which is the direct physical interaction between Project activities and the freshwater environment; and
- *aerial deposition*, which is the direct input of material and chemical compounds from the air into the freshwater environment.

The pathways applicable to each Phase 2 interaction group are summarized in Table 4.5-4. These pathways were then used through the effects assessment to describe the potential effects, identify mitigation and management measures, and characterize the residual effects from Phase 2 activities.

Table 4.5-4. Pathways of Interactions with the Freshwater Environment for the Freshwater Water Quality Effects Assessment

Project Activity	Pathway	Indicators	Project Phases
Site preparation, construction, and decommissioning activities	Runoff and physical	pH, TSS, nutrients, metals, hydrocarbons	Construction, Reclamation and Closure
Site and mine contact water	Runoff, discharge, seepage	pH, TSS, nutrients, metals, hydrocarbons, other constituents (anions, cations, cyanide)	Construction, Operation, Reclamation and Closure, Post-closure, Temporary Closure
Water use	Water withdrawal	pH, TSS, nutrients, metals	Construction, Operation, Reclamation and Closure
Quarries	Runoff	pH, TSS, metals,	Construction and Operation
Explosives	Runoff and aerial deposition	Nutrients, hydrocarbons	Construction and Operation
Fuels, oils, PAH	Runoff and aerial deposition	Hydrocarbons	Construction, Operation, and Reclamation and Closure
Treated Sewage Discharges	Discharge	TSS, nutrients, metals, BOD	Construction, Operation, and Reclamation and Closure
Dust deposition	Aerial deposition	TSS and metals	Construction, Operation, and Reclamation and Closure

The potential effects of each of the Project activities identified in Table 4.5-3 are characterized below in the Sections 4.5.2.1 to 4.5.2.8. The potential effects analysis considered the proposed Project activities (Volume 2) and the pathway(s) linking the Project activities to the freshwater environment. These potential effects are identified prior to the application of mitigation or management measures. The subsequent characterization of the potential effects considers mitigation and management measures, and may show that the potential effects are negligible.

4.5.2.1 Site Preparation, Construction, and Decommissioning Activities

Ground preparation will be required in the Construction phase throughout the PDA to construct necessary Phase 2 infrastructure, including buildings, roads, and mine works. As outlined in Table 4.5-3, the Phase 2 Project includes expansion of the TIA, which will require additional construction activities that were not authorized by the 2AM-DOH1323 Water Licence. Site preparation and construction activities will involve vegetation clearing, the removal and relocation of surficial materials, and the construction of pad areas from surficial material, borrow material, and quarried rock. The activities would also include the construction of water management structures, such as ditches, diversion structures, and berms to mitigate runoff, and earthworks for the TIA (Doris area) and the TMA (Boston area). The decommissioning and reclamation of Phase 2 infrastructure will similarly require surface contact and the transportation and relocation of surficial materials.

Landscape disturbance (ground works) has the potential for effects on freshwater water quality. The primary pathway for these potential effects would be runoff (i.e., the transport of material in overland flow). This would occur primarily during snowmelt and freshet in the spring, during precipitation events in the summer and fall, and would be absent in the winter. Some in-water or near-water activities, such as the installation or decommissioning of stream-crossing infrastructure for the AWRs, also have the potential for effects on water quality. Effects that may occur via dust deposition are considered separately (Section 4.5.2.8).

Runoff from prepared and decommissioned areas has the potential to effect freshwater water quality by contributing TSS (erosion), metals (TSS), nutrients (vegetation removal and blasting residue), and hydrocarbons (use of fuel, oil, and grease from vehicles and machinery) into the freshwater environment.

The potential effects from site preparation, construction, and decommissioning activities may occur during the Construction and Reclamation and Closure phases.

4.5.2.2 Site and Mine Contact Water

Site contact water was defined as the runoff from snowmelt and precipitation events that interacts with constructed site surfaces including roads and laydown areas. A comprehensive geochemical characterization program was conducted to assess the metal leaching and acid rock drainage (ML/ARD) potential (see Section 5, Geochemistry); only rock from quarries defined as suitable for use based on a low risk of ARD and low risk of metal leaching under neutral pH conditions, will be used as construction material. Flowing surface water in runoff can contact these surfaces, and subsequently could transport acid equivalents, suspended material, metals, nutrients, and petroleum hydrocarbon compounds into the freshwater environment. The potential for effects from site contact water could occur during all phases of the Phase 2 Project.

The use of the Doris-Boston WRR is considered as part of the *Site and Mine Contact Water* interaction group. The WRR will be used during the Construction phase prior to the completion of the AWR. Use of the WRR is authorized by the existing Type “B” water licence for the Boston Exploration Site. The construction of winter ice roads may affect vegetation cover along the shores of waterbodies, which could increase runoff and erosion. This may influence mixing processes that could re-suspend sediments, metals, nutrients, and dissolved oxygen concentrations in affected waterbodies.

Mine contact water was defined as the underground water removed from mine works; water that interacts with waste rock storage areas, ore stockpiles, and water management structures (e.g., Contact Water Ponds); mill process water; and water in the TIA. Exploration activities related to the Phase 2 Project will occur throughout the Project life. Included in the site and mine contact water interaction group is drilling fluid from exploration activities, which has the potential to contact the freshwater receiving environment prior to the application of mitigation and management measures. Operation of the water treatment plant at the Boston site is included in the *site and mine contact water* interaction group. The contact water discharge via the Roberts Bay Discharge System at the Doris site is not included in the freshwater water quality assessment because the effluent is not contacting the freshwater environment. Potential effects to marine water quality from the Roberts Bay Discharge System are assessment in the marine water quality section (Volume 5, Section 8).

The pathways of interaction between mine contact water and the freshwater environment are runoff, discharge, and seepage. Mine contact water, including water interacting with overburden, waste rock, and tailings, could affect the freshwater water quality by changing pH (interaction with geological material), and contributing TSS (erosion), metals (TSS), nutrients (contact with blasting residues), and other water quality indicators such as chloride (e.g., saline groundwater) into the freshwater environment.

The potential effects from site and mine contact water may occur during any Project phase.

4.5.2.3 Water Use

Water for domestic and process use will be drawn from Doris, Windy, and Aimaokatalok lakes and will occur during all phases of Phase 2. Water withdrawals could potentially affect the freshwater water quality VEC by reducing water volume and depth in the source waterbody. This may influence the concentrations of sediments, metals, and nutrients.

The potential effects from water use may occur during the Construction, Operation, and Reclamation and Closure phases.

4.5.2.4 Quarries and Borrow Pits

Quarries and borrow sources will be developed to meet the requirements for construction and maintenance. The pathway of interaction between quarries and the freshwater environment is through runoff, and this may occur during the Construction and Operation phases. Contact water in quarries and borrow pits may transport acid equivalents, metals, and suspended sediments into the freshwater environment. Runoff from quarries and borrow pits could affect the freshwater water quality VEC by changing pH (interaction with surficial material), and contributing TSS (erosion), metals, nutrients (contact with blasting residues - covered in the *Explosives* interaction pathway), and hydrocarbons (mechanical use of fuel, oil, and grease) into the freshwater environment.

The potential effects from quarries and borrow pits may occur during the Construction and Operation phases.

4.5.2.5 Explosives

Ammonium nitrate-fuel oil (ANFO) explosives will be used as the explosive for quarries and mine development and production. Components of the explosives have the potential for effects on freshwater water quality because of the presence of ammonium nitrate and petroleum hydrocarbons. The pathways of interaction between explosives and the freshwater environment are runoff and aerial deposition, and the potential effects may occur during Construction and Operations phases. Runoff and deposition of explosives (or blasting residues) into the freshwater environment can affect water quality by increasing the concentrations of ammonia and nitrate. The petroleum hydrocarbons component, either as dissolved constituents or particle-attached compounds, is a minor fraction of the explosives by weight (e.g., hydrophobic hydrocarbon residues). The petroleum hydrocarbons components of the explosives are not considered further as a potential effect because of their small relative proportion in the ANFO explosives and the proposed mitigation and management measures.

The potential effects from explosives may occur during the Construction and Operation phases.

4.5.2.6 Fuels, Oils, and PAH

The *Fuels* Project interaction group includes the storage and transport of fuels and petroleum hydrocarbons, fueling and maintenance operations, and the incineration of waste that may create PAH by incomplete combustion. The primary pathways of interactions between these sources of hydrocarbons and the freshwater environment are runoff and aerial deposition. Activities at facilities, laydown areas, fuel storage areas, and waste management areas can deposit hydrocarbon compounds, such as oil or grease, onto surfaces that can subsequently be transported into freshwater environments in runoff. Combustible waste, including the solids from sewage treatment, will be combusted using an incinerator. Incomplete combustion can create airborne hydrocarbons that can be deposited into freshwater environment via deposition or runoff. The potential effects from spills, including fuel spills, are not assessed as part of the normal operating conditions, and are considered in the Accidents and Malfunctions section of the EIS (Volume 7, Section 1).

The potential effects from fuels and other hydrocarbons may occur during the Construction, Operations, and Closure phases.

4.5.2.7 Treated Sewage Discharge

Treated sewage from domestic water treatment facilities at Boston will be discharged to Aimaokatalok Lake during the Construction, Operations, and Closure phases. Domestic sewage from Madrid North, Madrid South, and Doris will be treated and discharged to the TIA, which is subsequently discharged to the freshwater environment. Discharge of sewage effluent may affect freshwater water quality by increasing nutrient concentrations and by altering oxygen dynamics by the introduction of organic material. The potential effects from treated sewage discharge may occur during the Construction, Operations, and Closure phases.

4.5.2.8 Dust Deposition

Dust can be generated by a variety of Project activities, including vehicle traffic, blasting activities, quarry operations, and rock processing. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. The aerial deposition of the Project-generated dust is the primary pathway of interaction. Dust deposition into the freshwater environment may affect the freshwater water quality VEC by introducing suspended material and associated metals and nutrients into surrounding waterbodies. The potential effects from dust deposition may occur during all phases of the Project.

4.5.3 Mitigation and Adaptive Management

4.5.3.1 Mitigation by Project Design

The following measures were included in the design of the project to minimize or eliminate potential effects on the freshwater environment:

- Utilization of existing infrastructure associated with the Doris Project.
- Inclusion of climate change projections for key climatic and hydrologic design details.
- Construction of roads and pipelines as far as is practical from stream channel crossings and wet, boggy areas where fish habitat may be disturbed.

- Planned set-backs and buffer zones from aquatic and riparian environments.
- Avoidance, as required and feasible, of sensitive features, including riparian ecosystems and floodplains, esker complexes, fragile or rare wetlands, shallow open water, ponds, marshes, beaches, intertidal areas, and marine backshores.
- Only geochemically suitable rock quarries and borrow sources will be used to construct roads, pads, and structures.
- Infrastructure will be located, whenever feasible, on competent bedrock or appropriate base material that will limit permeability and transport of potentially poor quality water into the active layer, and ultimately to the marine environment.
- Fuel storage tanks will be within lined facilities to provide secondary containment, should leaks occur.
- Erosion potential will be reduced by working during periods of low runoff (e.g., winter) as much as possible.
- Water will be recycled / reused where possible.

The design of the Phase 2 Project also included adherence to regulatory requirements relevant to the mitigation of potential effects on the freshwater environment. These regulatory requirements included the following:

- The operation of incinerators will comply with Nunavut standards (Government of Nunavut Department of Environment 2012), *Canada-Wide Standards for Dioxins and Furans* (CCME 2001a) and *Canada-Wide Standards for Mercury Emissions* (CCME 2000).
- Treated effluent from Boston activities will be discharged to Aimaokatalok Lake in compliance with Type A Water Licence and Metal Mining Effluent Regulation (MMER; SOR/2002-222) requirements in a manner that will facilitate mixing and dispersion and consequently result in dilution to concentrations protective of aquatic life within 250 m of the discharge point.
- Blasting restrictions outlined in DFO's *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters* (Wright and Hopky 1998) will be implemented for blasting occurring near water.
- Culvert maintenance will be conducted following the guidance provided in *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016), which adheres to the *Fisheries Act* (1985c).
- In-water work will be conducted during approved timing windows presented in *Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat* (DFO 2013).
- Water withdrawal for exploration drilling will follow the conditions outlined in *Water Withdrawal under Ice Guidelines* (DFO 2010).
- Water withdrawal will follow Type A Water Licence conditions.

4.5.3.2 Best Management Practices

Reducing potential effects to freshwater water by avoidance is the most effective mitigation measure to reduce the potential for serious damage or harm. The design of the Project included a number of features to avoid potential effects. Further management and mitigation measures are described in relevant management plans provided as annexes to Volume 8, including the following:

- Oil Pollution Prevention Plan / Oil Pollution Emergency Plan (Annex 3);

- Hope Bay Project Spill Contingency Plan (Annex 4);
- Doris Project Domestic Wastewater Treatment Management Plan (Annex 5);
- Hope Bay Project Groundwater Management Plan (Annex 6);
- Water Management Plan: Madrid Advanced Exploration Program, North and South Bulk Samples (Annex 7);
- Water Management Plan, Hope Bay Project (Annex 8);
- Overview of Madrid North and Madrid South Bulk Sample ML/ARD Characterization Programs and Conceptual Waste Rock Management Plans (Annex 9);
- Sewage Treatment Plan Operation and Maintenance Plan (Annex 10);
- Hope Bay Project Doris Tailings Impoundment Area Operations, Maintenance, and Surveillance Manual (Annex 11);
- Waste Rock and Ore Management Plan (Annex 12);
- Hope Bay Project Interim Non-hazardous Waste Management Plan (Annex 13);
- Doris North Landfarm Management and Monitoring Plan (Annex 14);
- Hope Bay Project Hazardous Waste Management Plan (Annex 15);
- Incinerator Management Plan (Annex 16);
- Hope Bay Project Quarry Management and Monitoring Plan (Annex 17);
- Quarry Blasting Operations Management Plan (Annex 18);
- Air Quality Management Plan (Annex 19);
- Hope Bay Project Phase 2 Aquatic Effects Monitoring Plan (Annex 21); and
- Hope Bay Project, Phase 2 Conceptual Closure and Reclamation Plan (Annex 27).

Specific mitigation and management measures relevant to the assessment of effects on freshwater water quality include the following:

- Implementation of sediment control measures for works in or near waterbodies and watercourses, such as use of silt fences at drainage points and the minimization of vegetation clearing.
- Implementation of erosion control measures where necessary, such as capping of soils exposed during construction activities with rock.
- Regular inspections will be conducted to ensure erosion and sediment control measures are functioning properly; all necessary repairs and adjustments will be conducted in a timely manner. Efforts shall be made to minimize the duration of any in-water works and minimize disturbance of riparian vegetation.
- Activities will be planned and executed to minimize the release of sediment or sediment laden water into water frequented by fish.
- Facilities are designed with consideration of footprint minimization and will be located, where possible, in areas of reduced runoff.
- Pads are constructed of non-mineralized rock and are designed to direct contact water to contact water ponds.

- Seepage and runoff from waste rock and ore stockpiles will be directed to contact water ponds.
- Clean water and snow will be managed such that they do not contribute to potentially poor quality water and be diverted to maintain natural drainage networks as much as possible.
- Non-contact water will be diverted around infrastructure, as much as feasible, and directed to the existing drainage networks.
- Contact water pond storage capacity, freshet flows and expected storm event volumes will be determined based on site specific conditions. The sizing and design of these facilities is such that they can hold water during unusual storm events and contain freshet flows for prescribed periods.
- Water collected in the contact water ponds at Madrid North and Madrid South will be routinely discharged to the TIA or tundra (where permitted and in compliance with discharge requirements), to retain maximum pond holding capacity and reduce the possibility of unintentional releases. Ponds will be routinely monitored and inspected and water is pumped out of them once the volume they contain is large enough for one continuous hour of pumping.
- Groundwater from Madrid North and Madrid South will be collected in mine sumps and may be stored temporarily in the mine site, and either transferred to the Marine Outfall Mixing Box located in the Doris mill building and discharged to Roberts Bay or transferred to the TIA. Discharge to Roberts Bay or the TIA may occur year around.
- Where possible, groundwater will be utilized during underground drilling to reduce freshwater and salt consumption, and to minimize groundwater discharge volumes.
- The TIA has been designed with substantial additional capacity to store both natural and Project-related inputs in excess of routinely expected volumes. Water will routinely be discharged from the TIA to Roberts Bay, and compliant groundwater preferentially be sent directly to Roberts Bay.
- Waters intended for discharge directly from either the water control ponds and the TIA to the environment will be sampled for, and meet, applicable requirements under the MMER, water licences and/or surface leases administered pursuant to the *Territorial Lands Act*.
- Exploration drilling water will be recycled to minimize the quantity of freshwater used, and to reduce salt use. Excess brine remaining following drill completion will be disposed of with salt-containing drill cuttings. Drill cuttings will be moved to a cuttings management containment system that allows the cuttings to settle and separate from the drill water. The clarified water will be re-circulated through the system. If cuttings are brine free (where not generated while added salt was used), cuttings sludge may be deposited into a natural depression near the drill hole, or transported by helicopter to a central cuttings management area where direct flow into a water body is not possible and no additional effects created. If the cuttings are contaminated with brine, they will be transported to a containment facility where runoff will be captured for treatment or transferred to an appropriate wastewater disposal facility (e.g., Doris TIA, or Boston TMA).
- Appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water.
- Spills will be contained according to the Spill Contingency Plan (Annex 4) including the prioritization of the protection of sensitive areas.
- Soil, snow and water contaminated with diesel fuel, aviation gasoline, jet fuels and/or gasoline will report to the landfarm. Treated water from the snow or clean water pond will only be removed for discharge to the tundra only once sample analysis has confirmed the quality is

suitable for release to the environment. If water does not meet discharge criteria following treatment, the water will be transferred to the TIA for disposal. Soil collected from the landfarm will either be disposed of underground or at the TIA.

- Hazardous waste will be minimized to the extent possible. Hazardous wastes will be shipped off site.
- Quarries will be developed to the extent possible to ensure that water entering the quarry from precipitation and snowmelt is retained within the quarry boundary. If required a quarry sump will be used to collect water, sump water will be sampled and discharged to the environment only if discharge requirements are met. Non-compliant water that needs to be discharged will be transported to contact water ponds for management and/or transported directly to the TIA for disposal.
- High quality ammonium nitrate and fuel oil (ANFO) explosives have been selected for blasting operations. The explosive product may be in the form of prills, emulsion or be prepackaged. Different forms of the product may be used depending on the particular circumstances of use. Industry best practices will be employed to maximize source control and blast efficiency so as to minimize the potential for blasting product or blasting residues to occur in downstream waters.
- Dust suppression as appropriate will be applied to roadways to minimize dust from ore and waste rock haulage, site road traffic, and road maintenance (grading) when ambient air temperatures permit.
- Sewage and greywater will be treated and treated effluent may be discharged to the tundra only if water quality discharge criteria are met. Sewage sludge will be incinerated or disposed of in the TIA.
- Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to *Measures to Avoid Causing Harm to Fish and Fish Habitat* (DFO 2016).
- The bulk fuel storage facilities and all transfer-related equipment will be routinely inspected repairs (if required) carried out promptly.
- During temporary closure the following will take place to protect freshwater water quality:
  - physical, chemical and biological monitoring and treatments will continue in accordance with the Project licences and permits.
  - Fuel, hazardous wastes and explosives will be properly stored or removed from site.
  - Waste rock and ore piles and tailings facilities as well as dams, roads and pipelines will be inspected and maintained.
  - Surface water management and sediment and erosion control will continue as needed.
- During closure, the TIA North Dam will be breached in a manner that minimizes harm to the freshwater receiving environment. To minimize environmental risk, the TIA North Dam will not be breached until the tailings have been covered as outlined in the approved closure plan and water quality in the TIA is confirmed suitable for discharge back into the Doris Lake system.
- During closure, a low infiltration cover will be placed over the tailings in the Boston TMA. Once the cover is in place, the contract water pond berm will be breached to restore natural drainage. The remainder of the berms will stay in place in order to preserve the permafrost. The closure plan for the Boston TMA will be refined through the operations period through monitoring of water quality in the contact water ponds and updating water quality predictions.

4.5.3.3 Proposed Monitoring Plans and Adaptive Management

An Aquatic Effects Monitoring Plan (Annex 21) will be in place that outlines the Aquatic Effects Monitoring Program (AEMP) that will be carried out during all phases of the Project. The AEMP will include the following:

- monitoring the freshwater environment at locations potentially affected by the Project and at reference areas well away from Project activities;
- monitoring freshwater water quality, sediment quality, and aquatic biology.

Regular inspections of water management facilities will be conducted by on-site Environmental Personnel.

There will be a Surveillance Monitoring Program that will be outlined in the future Type A Water License. This monitoring program will cover all of the site compliance monitoring required for the management and release of water from all Project infrastructure.

Adaptive management and corrective actions will be determined on a case-by-case basis. The actions may include modifications to existing mitigation and management measures or installation of additional control measures. Indications of the need for corrective actions and additional control measures may include:

- non-compliant observations or trends from the Surveillance Monitoring Program; or
- the observations of negative effects to the freshwater environment in the AEMP.

4.5.4 Characterization of Potential Effects to Freshwater Water Quality VEC

Potential effects of the Project on freshwater water quality are characterized in this section. Specific mitigation and management measures are considered for each potential effect, and if the implementation of mitigation measures eliminates a potential effect, the effect is eliminated from further analyses. Project residual effects are the effects that remain or persist after mitigation and management measures are taken into consideration. If the proposed implementation controls and mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and a significance determination.

Residual effects of Phase 2 can occur directly or indirectly. Direct effects result from specific Project/environment interactions between Project activities and components, and the freshwater water quality VEC. Indirect effects are the result of direct effects on the environment that lead to secondary or collateral effects on the freshwater water quality VEC.

The potential for residual effects of the Project on the freshwater water quality VEC identified in Section 4.5.2 were assessed using both quantitative water quality modelling as well as qualitative methods, including a combination of best available data and professional judgment/experience. The characterization of potential effects considers both the incremental effects of Phase 2 developments and activities as well as the overall effects from all components of the Hope Bay Development.

4.5.4.1 Site, Preparation, Construction, and Decommissioning Activities

The disturbance of the landscape through the construction of infrastructure, such as roads and pads creates the potential for runoff that can influence the freshwater environment, and would be indicated primarily by changes to TSS (Table 4.5-4). The primary goal of sedimentation mitigation strategies is to prevent soil, sediments, and particulate matter from entering the receiving environment. The existing Doris Project has demonstrated that erosion and sedimentation control measures are effective (as evaluated in the Doris AEMP), including the implementation of additional control measures on a case-by-case basis. Although identified mitigation and best management strategies (Section 4.5.3) are effective in minimizing erosion, sedimentation, and potential siltation in the receiving environment, these strategies may not fully prevent all surface runoff and sediment entry. Thus, a potential residual effect from construction and decommissioning activities on freshwater water quality may occur. Changes to water quality during construction and decommissioning activities will be monitored to ensure drainage and erosion controls are effective.

Characterization of Phase 2 Potential Effect

The Phase 2 construction and decommissioning activities include the development of additional pads, laydown areas, ore stockpiles, and waste rock storage areas in the Madrid South and Boston areas, as well as the construction of the AWR. The in-water construction of the Boston discharge outfall in Aimaokatalok Lake is also included as a potential activities in this interaction group. The installation of cement pipeline anchors and associated infrastructure could temporarily re-suspend sediments into the water column.

Although the mitigation and management measures are known to be effective, a potential residual effect from construction and decommissioning activities on freshwater water quality may occur. These residual effects to water quality are associated with the transport of suspended material (TSS), which may create localized increases in the concentrations of suspended sediments and sediment-associated metals. These residual effects are anticipated to occur during or immediately after the construction or decommissioning activities when surface materials are more likely to be disturbed, and have the greatest potential to occur during periods of significant overland flow, such as freshet and rainfall events. Although sediment from runoff has the potential to increase TSS and turbidity in the receiving environment, the known effectiveness of the mitigation and management measures are predicted to mitigate the potential effects and the changes in suspended sediment concentrations are not expected to be greater than CCME guidelines for the protection of aquatic life.

The potential effects from the in-water construction of the Boston discharge pipeline and outfall are expected to be highly localized to the footprint of the cement ballast that anchors the pipeline and will be short-lived as the re-suspended sediment resettles following deployment. Once installed on the lake bottom, no further disturbance of the sediments would be expected.

Characterization of Hope Bay Development Potential Effect

Construction of a substantial portion of the infrastructure at Roberts Bay and Doris has already been completed, and therefore does not present a potential effect from construction activities. Similarly, construction at Madrid North under the Type “B” licence will be completed as authorized. These past residual effects were negligible, because no construction-related effects were observed in Doris as evaluated under the Doris AEMP. As a result, any localized, short-term changes in water quality from the construction of existing and permitted infrastructure will not coincide with the proposed Phase 2 activities, and there is minimal potential for a cumulative effect across the Hope Bay Development. Therefore, the residual effects from site preparation and construction activities for the Hope Bay Development are anticipated to be the same as the Phase 2 residual effects.

However, decommissioning activities will occur through the Project areas, and include the decommissioning of infrastructure at Roberts Bay and Doris. The effective mitigation and management measures will be applied, but a potential for residual effects from decommissioning activities remains.

As discussed in the section for the Phase 2 potential effects, runoff during periods of decommissioning activities may transport suspended material into the freshwater environment.

4.5.4.2 Site and Mine Contact Water

The potential residual effects from site contact water and mine contact water are characterized together because of the quantitative predictions from the Water and Load Balance model (Appendix V3-2D). The model considered the contributions of both site and mining activities for predicting the effects of the Project on the aquatic environment. For example, runoff from pad areas is combined in the model with runoff from ore stockpiles.

The potential for residual effects from site contact water are predicted to be reduced by the application of the mitigation and management measures outlined in Section 4.5.3. Once the water management systems are constructed, the majority of site contact water will be intercepted and prevented from contacting the freshwater receiving environment (Water Management Plan, Volume 8, Annex 8). Intercepted site contact water will be stored in contact water ponds (CWP) and discharged to the marine environment via the TIA (Doris, Madrid North, and Madrid South areas) or treated and discharged to Aimaokatalok Lake (Boston area). These water management and treatment measures are included in the water balance model, which improves the realism and accuracy of the model (Appendix V3-2D). During construction and decommissioning of Project infrastructure, some site contact water may flow to the freshwater receiving environment when the water management system is not operational. Furthermore, runoff from some pads and laydown areas will not be diverted to the TIA or Boston water treatment plant; site contact water from these locations will be collected in sumps and discharged if the contact water meets permit conditions for water quality. Site contact water will not be released to the receiving environment unless it meets the water quality criteria outlined in applicable water licences.

Throughout all areas of Phase 2, the release of site contact water has the potential to transport suspended sediments into the receiving environment. The application of the mitigation and management measures associated with suspended sediments, outlined in Section 4.5.3, are predicted to be effective and reduce the quantities of transported suspended material. However, the potential for alteration of suspended sediment concentrations in the receiving may occur prior to the completion of the water management infrastructure and during normal, permitted releases of contact water from sumps. Adherence to the water licence criteria and application of the proven mitigation and management measures are expected to maintain suspended sediment concentrations below CCME water quality guidelines for the protection of aquatic life (i.e., increases of 25 mg/L short-term and 5 mg/L long-term for the TSS indicator), but may be associated with localized, temporary increases above baseline conditions.

The potential effects on freshwater water quality from exploration drilling fluids are considered fully mitigated by the measures outlined in Sections 4.8.2 and 4.8.3 of the Project Description (Volume 3, Section 4). Drilling fluid is not expected to contact the freshwater environment, and therefore is not anticipated to have any effects to freshwater water quality.

Residual effects from mine contact water, which is defined as the runoff from waste rock and ore stockpiles, underground water, and water from ore processing mills, are also expected to be reduced by mitigation and management, including water treatment. The interception of mine contact water prior to contact with the freshwater environment is a fundamental measure in the design of the Phase 2 Project. In the Boston area, mine contact water will be treated and discharged to Aimaokatalok Lake. This discharge is modelled in the water balance model, and assessed as a potential residual effect. After decommissioning and reclamation of Project infrastructure, runoff from the TIA (Doris area) and

TMA (Boston area) will be directed to the freshwater environment. Therefore, there is a potential residual effect in the Post-closure phase from mine contact water.

The water balance model considers the entirety of the Hope Bay Development, including the constructed infrastructure and planned mining in the Doris area authorized under the Type “A” Licence 2AM-DOH1323 and the development of the Madrid infrastructure under the submitted Type “B” Licence. The Phase 2 potential effects and the Hope Bay Development potential effects are necessarily confounded in the water balance model in some cases. For example, tailings from the Doris underground mine, authorized by Licence 2AM-DOH1323, will be deposited in the TIA and effectively mixed with tailings from Madrid North. The mine contact water from these mixed tailings in the TIA are effectively a mixture of Phase 2 and Hope Bay Development effects, and the water balance model does not separate these two potential mine contact water sources. For the freshwater water quality effects assessment, therefore, the characterization of Phase 2 potential effects considers the quantitative predictions of the water balance model. The characterization of the Hope Bay Development potential effects is necessarily more qualitative, and considers the contributions of authorization existing and planned infrastructure and activities.

Characterization of Phase 2 Potential Effect

The potential effects to the freshwater water quality VEC from contact water are assessed using the quantitative water balance model (Appendix V3-2D). The water balance model describes the flow of water and chemical constituents within and between the Hope Bay Development and the environment. The model includes terms for precipitation, evaporation, neutral load, runoff (from both disturbed and undisturbed areas), discharge, groundwater flow, and climate change. The modelled chemical constituents include base cations and anions (e.g., sulphate, chloride, and calcium), inorganic nitrogen species (i.e., ammonia, nitrite, and nitrate), cyanide, and metals (e.g., arsenic, copper, mercury, and iron). The timing of specific infrastructure and activities (such as the commissioning of waste rock storage areas) is explicitly included in the model.

For the characterization of the potential residual effects to freshwater water quality, the predictions of the water balance model are screened against the modelled baseline conditions, the range of observed baseline conditions, and the assessment thresholds (Table 4.5-2). The assessment against modelled baseline was included because of the inclusion of climate change in the model, as well as providing an efficient conceptual screen between the effects of Projects activities (predicted case) and the environment without the Project (baseline case). The screening compared the predicted value of the indicators to these three screening criteria at each timestep of the model (one month), and then summarizes the results by Project phase (i.e., Construction, Operation, Reclamation and Closure, and Post-Closure). In the first screening step, predicted and background concentrations of parameters were compared to assess if parameters were predicted to change relative to existing conditions due to Project activities. Background concentration plus 10% was used in screening based on professional experience to allow for the variability that can occur due to analytical uncertainty. For the purposes of the assessment, it defines these parameters as measurably different from existing/baseline concentrations and indicates an effect to freshwater water quality. This comparison provides a good indicator of the potential for incremental change due to Project-related activities and screens out parameters with background concentrations at or above guidelines, but which were not predicted to increase due to the Project; existing guideline exceedances are not a Project-related effect. If the predicted concentrations represented a greater than 10% increase over baseline concentrations, the parameter was retained for the second screening step. For the second screening criterion, the magnitude of the effect was assessed by comparison with indicator thresholds (Table 4.5-2).

The characterization results are assessed for each Project area because the timing of each phase depends on the sequence of activities throughout Phase 2. Furthermore, the specific interactions between Project activities and infrastructure depend on the Project area, and therefore characterization of the residual effects is most efficient at this granular scale.

Boston Area

The screening of the water balance model predictions in the Boston area identified residual effects to freshwater water quality in Stickleback, Aimaokatalok Lake, and downstream in the Koignuk River (Tables 4.5-5 to 4.5-10).

Stickleback Lake is close to infrastructure in the Boston area and receives runoff during the Construction, Operation, Closure, and Post-closure phases from some parts of the Boston infrastructure. This includes runoff from the reclaimed CWP during the Post-closure phase. Screening of the water balance model predictions (Table 4.5-5) identified residual effects to water quality in Stickleback Lake for the following indicators:

- aluminum;
- antimony;
- arsenic;
- barium;
- chromium;
- copper;
- iron;
- manganese;
- molybdenum;
- nickel;
- selenium;
- zinc;
- ammonia;
- nitrite;
- nitrate;
- calcium;
- chloride;
- fluoride;
- sodium; and
- sulphate.

These predicted increases in concentrations were greater than modelled and observed baseline conditions. Predicted concentrations of aluminum, chromium, copper, iron, selenium, chloride, and fluoride were also greater than guideline thresholds (Table 4.5-5); however, these were restricted to under-ice conditions between October and May, and were specifically due to the model assumptions regarding cryo-concentration. The water balance model was constructed using Goldsim™ – a dynamic and probabilistic simulation software (Appendix V3-2D). Goldsim™ models biogeochemical reactions that are expected to occur *in situ* to generate more accurate predictions that better reflect natural conditions. The inclusion of a cryo-concentration function in the Goldsim™ model helps to predict the effects of the natural processes of solute extrusion that occurs during winter. However, the cryo-concentration function in the model may be overly conservative because other coincident and potentially ameliorating biogeochemical processes likely to occur under ice have been excluded. For example, at the physicochemical conditions (eH/pH) anticipated to occur under ice, concentrations of copper, iron, aluminum, and to lesser extent chromium and selenium, would also be governed by solubility constraints and sorption and assimilation reactions that would reduce concentrations for these parameters in Stickleback Lake. Similarly, comparable studies in the Canadian Arctic have found that leaching rates and subsequent cyro-concentration of trace metals systematically to not adhere to a general thermal relationship, and instead found trace metal concentrations to be controlled by formation of secondary mineral phases (Golder 2011).

Table 4.5-5. Summary of Screening for Effects to Water Quality in Stickleback Lake

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Aluminum	Construction	0.1	0.0099	0.013	-	0.066	0.239	0.0389	0.138	Feb
	Operation				Feb, Mar, Apr	0.065	0.238	0.0457	0.183	Jan, Feb, Mar
	Closure				Feb, Mar, Apr	0.064	0.230	0.0522	0.188	Jan, Feb, Mar
	Post-closure				Feb, Mar, Apr, May	0.058	0.228	0.0558	0.211	Jan, Feb, Mar
Antimony	Construction	0.006	0.000020	0.000050	Feb	0.000015	0.000055	0.000015	0.000053	-
	Operation				Feb	0.000016	0.000061	0.000017	0.000068	-
	Closure				Feb	0.000017	0.000061	0.000019	0.000069	-
	Post-closure				Jan, Feb, Mar	0.000016	0.000062	0.000025	0.00010	-
Arsenic	Construction	0.005	0.00042	0.00048	Jan, Feb, Mar	0.00023	0.00084	0.00028	0.0010	-
	Operation				Jan, Feb, Mar	0.00023	0.00084	0.00028	0.0010	-
	Closure				Jan, Feb, Mar	0.00022	0.00081	0.00028	0.0010	-
	Post-closure				Jan, Feb, Mar, Apr, Dec	0.00020	0.00080	0.00035	0.0014	-
Barium	Construction	1	0.0054	0.0060	Jan, Feb, Mar, Dec	0.0031	0.011	0.0042	0.015	-
	Operation				Jan, Feb, Mar, Dec	0.0030	0.011	0.0038	0.015	-
	Closure				Jan, Feb, Mar	0.0029	0.011	0.0035	0.013	-
	Post-closure				Jan, Feb, Mar	0.0027	0.011	0.0032	0.013	-
Chromium	Construction	0.001	0.00018	0.00050	Feb, Mar	0.00034	0.0012	0.00028	0.0010	Feb
	Operation				Feb, Mar	0.00033	0.0012	0.00030	0.0011	Feb
	Closure				Feb, Mar	0.00033	0.0012	0.00031	0.0011	Feb
	Post-closure				Feb, Mar	0.00031	0.0012	0.00031	0.0012	Feb
Copper	Construction	0.002	0.0015	0.0017	Feb, Mar	0.0013	0.0049	0.0009	0.0034	Feb
	Operation				Feb, Mar, Apr, May	0.0013	0.0048	0.0012	0.0049	Jan, Feb, Mar, Dec
	Closure				Feb, Mar, Apr, May, Jun	0.0013	0.0046	0.0014	0.0050	Jan, Feb, Mar, Dec
	Post-closure				all months	0.0012	0.0046	0.0022	0.0088	Jan, Feb, Mar, Apr, May, Oct, Nov, Dec

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Iron	Construction	0.3	0.075	0.096	Feb, Mar, Apr	0.16	0.57	0.13	0.45	Feb
	Operation				Feb, Mar, Apr, May	0.15	0.56	0.13	0.48	Feb
	Closure				Feb, Mar, Apr, May	0.15	0.53	0.13	0.48	Feb
	Post-closure				Feb, Mar, Apr, May	0.13	0.52	0.13	0.49	Feb
Manganese	Construction	0.05	0.0086	0.012	all months	0.022	0.081	0.048	0.18	Jan, Feb, Mar, Apr, Nov, Dec
	Operation				all months	0.021	0.080	0.040	0.17	Jan, Feb, Mar, Apr, Nov, Dec
	Closure				Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec	0.021	0.075	0.033	0.12	Feb, Mar
	Post-closure				Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov	0.018	0.074	0.026	0.12	Feb, Mar
Molybdenum	Construction	0.073	0.000050	0.00032	-	0.000068	0.00025	0.000056	0.00020	-
	Operation				-	0.000066	0.00024	0.000069	0.00028	-
	Closure				-	0.000064	0.00023	0.000080	0.00029	-
	Post-closure				Jan, Feb, Mar	0.000058	0.00023	0.00014	0.00055	-
Nickel	Construction	0.025	0.00031	0.00050	-	0.00060	0.0022	0.00037	0.0013	-
	Operation				Feb, Mar, Apr	0.00058	0.0022	0.00044	0.0018	-
	Closure				Feb, Mar, Apr	0.00057	0.0021	0.00051	0.0019	-
	Post-closure				Feb, Mar, Apr, May, Jun, Jul, Aug, Sep	0.00051	0.0020	0.00063	0.0025	-
Selenium	Construction	0.001	0.00050	0.00059	Feb, Mar	0.00028	0.0010	0.00036	0.0013	Feb
	Operation				Feb, Mar	0.00027	0.0010	0.00033	0.0013	Feb
	Closure				Feb, Mar	0.00027	0.00097	0.00031	0.0011	Feb
	Post-closure				Feb, Mar	0.00025	0.00097	0.00026	0.0011	Feb
Uranium	Construction	0.015	0.000010	0.000012	Feb, Mar	0.000030	0.00011	0.000022	0.000078	-
	Operation				Feb, Mar, Apr, May	0.000029	0.00011	0.000027	0.00011	-
	Closure				Feb, Mar, Apr, May, Jun, Jul, Aug	0.000029	0.00010	0.000032	0.00012	-
	Post-closure				all months	0.000026	0.00010	0.000050	0.00020	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Zinc	Construction	0.03	0.0019	0.0025	Feb, Mar, Apr, May, Jun, Jul, Aug	0.0032	0.012	0.0036	0.013	-
	Operation				Feb, Mar, Apr, May, Jun	0.0031	0.011	0.0034	0.013	-
	Closure				Feb, Mar, Apr, May	0.0030	0.011	0.0032	0.012	-
	Post-closure				Feb, Mar, Apr, May	0.0026	0.011	0.0029	0.012	-
Ammonia	Construction	1.83	0.013	0.020	Feb, Mar, Apr, May	0.018	0.064	0.022	0.083	-
	Operation				Feb, Mar, Apr	0.017	0.063	0.020	0.079	-
	Closure				Feb, Mar, Apr	0.016	0.059	0.018	0.066	-
	Post-closure				Feb, Mar, Apr	0.014	0.058	0.014	0.064	-
Nitrite	Construction	0.06	0.0005	0.0017	-	0.019	0.069	0.012	0.041	-
	Operation				Feb, Mar, Apr	0.018	0.068	0.013	0.049	-
	Closure				Feb, Mar, Apr	0.017	0.062	0.014	0.050	-
	Post-closure				Feb, Mar, Apr, May	0.015	0.061	0.013	0.050	-
Nitrate	Construction	3	0.0025	0.0031	Feb	0.0014	0.0052	0.0014	0.0052	-
	Operation				Feb	0.0014	0.0051	0.0014	0.0051	-
	Closure				Feb	0.0014	0.0050	0.0013	0.0049	-
	Post-closure				Feb	0.0012	0.0049	0.0012	0.0049	-
Calcium	Construction	1,000	17.0	17.6	Feb	3.7	13.6	7.0	25.9	-
	Operation				Feb	3.6	13.5	6.2	24.7	-
	Closure				Feb	3.6	12.9	5.6	20.6	-
	Post-closure				Feb	3.2	12.8	6.0	23.1	-
Chloride	Construction	120	44	51	Jan, Feb, Mar	11.9	43	32	122	Feb
	Operation				Jan, Feb, Mar	11.6	43	25	112	-
	Closure				Feb	11.4	41	20	75	-
	Post-closure				Feb	10.3	41	11.9	70	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Fluoride	Construction	0.12	0.045	0.075	Feb, Mar	0.042	0.15	0.049	0.18	Feb
	Operation				Feb, Mar	0.041	0.15	0.046	0.18	Feb
	Closure				Feb, Mar	0.040	0.14	0.043	0.16	Feb
	Post-closure				Feb, Mar	0.036	0.14	0.039	0.16	Feb
Sodium	Construction	200	14.8	15.9	Feb, Mar	6.8	25	7.5	27	-
	Operation				Feb	6.6	25	7.0	27	-
	Closure				Feb	6.5	24	6.7	24	-
	Post-closure				Feb	5.9	23	5.6	24	-
Sulphate	Construction	500	1.5	1.5	Feb, Mar, Apr, May	4	15.5	4	15.9	-
	Operation				Feb, Mar, Apr, May, Jun, Jul, Aug	4	15.4	5	16.9	-
	Closure				Feb, Mar, Apr, May, Jun, Jul, Aug	4	14.9	5	17	-
	Post-closure				Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec	4	14.8	6	22.1	-

Notes:

[a] *Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.*

[b] *Site-specific guidelines (i.e., for aluminum, ammonia, copper, and nickel) calculated using observed baseline conditions. To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.*

The conservative estimation of the effects of cryo-concentration resulting in an overestimation of concentrations of water quality indicators under ice is apparent in the modelled baseline estimates (Table 4.5-6). In the model, cryo-concentration resulted in under-ice concentrations that were 5- and 6-fold greater than open-water conditions in Stickleback and Wolverine lakes in the model validation year (calendar year 2018). The observed ratios in small lakes in the Project area (i.e., Stickleback, Wolverine, P.O., and Little Roberts lakes) were much smaller, and ranged from 0.5 to 3.5 between under-ice and open-water seasons. Natural variation in the under-ice/open-water ratios, likely the result of differing biogeochemical processes, were observed between different water quality parameters. Iron, which interacts with a number of biotic and abiotic geochemical processes, was more seasonally variable than copper (ratios of 3.5 and 1.5, Table 4.5-6).

The increased under-ice concentrations predicted by the water balance model are conservative, based on the observed variation and the known biogeochemical activities of many of water quality indicators. The predicted exceedances of guidelines for aluminum, chromium, copper, iron, selenium, chloride, and fluoride are likely the result of an over-estimation by the cryo-concentration function in the model. In addition, the predicted exceedances occurred in both the baseline and predicted cases for aluminum, chromium, copper, iron, and fluoride, which indicates that the predicted changes in the concentrations of these parameters in Stickleback Lake are not the result of Project activities and infrastructure.

The outflow of Stickleback Lake enters Aimaokatalok Lake in its eastern arm. The proposed Boston TMA is also proximate to the eastern arm of Aimaokatalok Lake (Figure 4.2-4). This portion of Aimaokatalok Lake is modelled as a distinct basin because of the inflow of water from Stickleback Lake and, in the Post-Closure phase, runoff from the TMA into Aimaokatalok Lake. The water balance model predicts concentrations greater than baseline conditions for the following indicators (Table 4.5-7):

- antimony;
- arsenic;
- copper;
- manganese;
- nickel;
- uranium;
- calcium; and
- sulphate.

The largest predicted increases in concentrations were for antimony and arsenic, and these predicted increases were 2-fold or less for these indicators. No predicted concentrations were greater than applicable guideline thresholds (i.e., CCME water quality guidelines), except for copper during under-ice conditions. These predicted concentrations of copper greater than water quality guidelines are likely the result of overestimation by the cryo-concentration function. Furthermore, the predicted increases in copper concentrations during those under-ice months are only modestly (25% or less) greater than the modelled baseline concentrations. Therefore, the copper concentrations in the eastern arm of Aimaokatalok Lake are not expected to be greater than the water quality guideline.

Site and mine contact water will be intercepted during the Construction and Operation phases at the Boston area and treated prior to discharge to Aimaokatalok Lake. The discharge in the southwestern arm of the Lake (Figure 4.2-4) will be equipped with a diffuser to facilitate mixing in the receiving environment. Near-field mixing modelling shows that the effluent will be rapidly mixed under a range of conditions, including under-ice, freshet, and open-water conditions (Appendix V5-4K). The most conservative scenario is the discharge of effluent under-ice during low current conditions, which results in a 40-fold dilution only 3 m from the outfall.

Table 4.5-6. Comparison of Observed and Modelled Variation between Open-Water and Under-Ice Seasons in Selected Water Quality Parameters in Small Lakes in the Project Area

Parameter	Stickleback Lake		Wolverine Lake		P.O. Lake		Under-Ice (Observed)			Open-Water (Observed)			Ratio of Median Observed Under-Ice to Open-Water
	Under-Ice 2018 Modelled Baseline (February; mg/L)	Open-Water 2018 Modelled Baseline (July; mg/L)	Under-Ice 2018 Modelled Baseline (February; mg/L)	Open-Water 2018 Modelled Baseline (July; mg/L)	Under-Ice 2018 Modelled Baseline (February; mg/L)	Open-Water 2018 Modelled Baseline (July; mg/L)	Median Observed Baseline (mg/L)	75th Quantile Observed Baseline (mg/L)	N	Median Observed Baseline (mg/L)	75th Quantile Observed Baseline (mg/L)	N	
Arsenic	0.0010	0.00020	0.0017	0.00028	0.00058	0.00028	0.00075	0.0012	13	0.00039	0.0005	47	1.9
Cadmium	0.000024	0.0000047	0.000031	0.0000050	0.000010	0.000005	0.0000046	0.00001	13	0.0000025	0.0000042	47	1.8
Chromium	0.00098	0.00019	0.0031	0.00050	0.0010	0.00050	0.0005	0.00067	13	0.00025	0.00038	47	2.0
Cobalt	0.00042	0.000080	0.00031	0.000050	0.00010	0.00005	0.000089	0.00020	13	0.00005	0.000069	47	1.8
Copper	0.0029	0.00059	0.0082	0.0013	0.0028	0.0013	0.0022	0.0024	13	0.0014	0.0016	47	1.5
Iron	0.44	0.086	0.97	0.16	0.33	0.16	0.52	0.57	13	0.15	0.20	47	3.5
Selenium	0.0014	0.00026	0.0012	0.00020	0.00041	0.00020	0.00025	0.00088	13	0.0005	0.00097	47	0.5
Chloride	133	25	232	63	130	63	159	207	9	62	74	35	2.6
Sulphate	16	3.1	16	2.7	5.5	2.7	8.5	9.9	13	3.1	3.9	47	2.7

Note: Under-ice to open-water ratios in the modelled baseline were approximately 5, 6, and 2 in Stickleback, Wolverine, and P.O. lakes, respectively.

Table 4.5-7. Summary of Screening for Effects to Water Quality in Eastern Arm of Aimaokatalok Lake

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Antimony	Construction	0.006	0.000050	0.000050	-	0.000031	0.000036	0.000032	0.000039	-
	Operation				-	0.000031	0.000037	0.000033	0.000040	-
	Closure				-	0.000031	0.000037	0.000034	0.000040	-
	Post-closure				Jan, Feb, Mar, Apr, May, Oct, Nov, Dec	0.000028	0.000037	0.000050	0.000081	-
Arsenic	Construction	0.005	0.00020	0.00050	-	0.00028	0.00033	0.00031	0.00038	-
	Operation				-	0.00028	0.00033	0.00033	0.00039	-
	Closure				-	0.00028	0.00033	0.00034	0.00039	-
	Post-closure				Jan, Feb, Mar, Apr, May, Oct, Nov, Dec	0.00026	0.00033	0.00048	0.00076	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Copper	Construction	0.002	0.00096	0.0012	Jan, Feb, Mar, Apr, May, Oct, Nov, Dec	0.0016	0.0019	0.0018	0.0022	Jan, Feb, Mar, Apr, Nov, Dec
	Operation				Jan, Feb, Mar, Apr, May, Oct, Nov, Dec	0.0016	0.0019	0.0019	0.0023	Jan, Feb, Mar, Apr, Nov, Dec
	Closure				Jan, Feb, Mar, Apr, May, Oct, Nov, Dec	0.0016	0.0019	0.0020	0.0023	Jan, Feb, Mar, Apr, Nov, Dec
	Post-closure				all months	0.0014	0.0019	0.0019	0.0026	Jan, Feb, Mar, Apr, Nov, Dec
Manganese	Construction	0.05	0.0051	0.0089	Sep	0.022	0.026	0.023	0.028	-
	Operation				Jan, Feb, Mar, Apr, May, Jun, Aug, Sep, Oct, Nov, Dec	0.022	0.026	0.024	0.029	-
	Closure				Jan, Feb, Mar, Apr, May, Sep, Oct, Nov, Dec	0.022	0.026	0.024	0.029	-
	Post-closure				all months	0.019	0.026	0.022	0.030	-
Nickel	Construction	0.025	0.00050	0.00068	-	0.00069	0.00081	0.00072	0.00087	-
	Operation				-	0.00069	0.00081	0.00074	0.00088	-
	Closure				-	0.00068	0.00081	0.00075	0.00088	-
	Post-closure				Jan, Feb, Mar, Apr, Nov, Dec	0.00063	0.00081	0.00072	0.00094	-
Uranium	Construction	0.015	0.000021	0.000025	Jan, Feb, Mar, Apr, May, Jul, Aug, Sep, Oct, Nov, Dec	0.000036	0.000042	0.000040	0.000051	-
	Operation				all months	0.000036	0.000042	0.000044	0.000053	-
	Closure				all months	0.000036	0.000042	0.000045	0.000053	-
	Post-closure				all months	0.000033	0.000042	0.000045	0.000059	-
Calcium	Construction	1,000	2.2	2.6	Jun, Jul, Aug, Sep, Oct, Nov, Dec	4.3	5.1	4.8	6.0	-
	Operation				all months	4.3	5.1	5.2	6.2	-
	Closure				all months	4.3	5.1	5.2	6.2	-
	Post-closure				all months	3.9	5.1	5.1	6.8	-
Sulphate	Construction	500	1.5	1.5	Jul, Aug, Sep, Oct, Nov, Dec	5.19	6.12	5.52	6.82	-
	Operation				all months	5.18	6.12	5.84	6.98	-
	Closure				all months	5.17	6.1	5.9	6.96	-
	Post-closure				all months	4.73	6.1	5.81	7.68	-

Notes:
[a] Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.
[b] Site-specific guidelines (i.e., for copper and nickel) calculated using observed baseline conditions. To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.

To assess the near-field effects to water quality in Aimaokatalok Lake, the predicted effluent quality is analyzed in the context of this rapid near-field mixing. This analysis is used to predict the maximal near-field water quality conditions in the immediate vicinity of the outfall to understand the most conservative case. The maximum predicted effluent quality concentrations are multiplied by the modelled mixing ratio achieved 3 m from the outfall (Table 4.5-8). Only indicators with predicted effluent concentrations greater than guideline thresholds (i.e., guidelines) are analyzed; twenty indicators are selected for analysis based on this criteria.

The near-field mixing model combined with the water and load balance predicts that no indicators will be greater than assessment thresholds (Table 4.5-8). The predicted concentrations of indicators, after the predicted rapid mixing, are at least 5-fold lower than thresholds for all parameters, except for the following indicators:

- chromium (60% of threshold);
- chloride (42% of threshold); and
- fluoride (34% of threshold).

The water balance model further predicts concentrations in Aimaokatalok Lake as a whole. This whole-lake modelling node integrates the multiple sources potentially influencing Aimaokatalok Lake, including runoff from undisturbed areas, water withdrawals, discharge from the sewage and water treatment plants, and runoff from the TIA in the Post-closure phase. The Aimaokatalok Lake modelling node is therefore screened against baseline conditions and guidelines to predicted the lake-scale effects to water quality (Table 4.5-9). The integrated Project influences in the model results in predicted concentrations for the following indicators greater than baseline conditions:

- antimony;
- ammonia;
- nitrite;
- nitrate;
- calcium;
- chloride; and
- Sulphate

For all parameters, the predicted increases in concentrations are modest and substantially lower than guidelines.

The far-field effects of Project activities and infrastructure in the Boston area were modelled in the Koignuk River. These potential far-field effects are assessed against baseline conditions and guideline thresholds (Table 4.5-10). The water balance model predicted increases in the following parameters relative to baseline:

- aluminum;
- antimony;
- copper;
- iron;
- manganese;
- nickel;
- uranium;
- ammonia;
- nitrite;
- nitrate;
- calcium;
- chloride;
- fluoride;
- sodium; and
- sulphate.

The majority of these parameters are predicted to be greater than baseline conditions only during under-ice periods between November and April, and may be the result of cryo-concentrations as well as modelling assumptions regarding under-ice flow in the Koignuk River. All predicted changes in concentrations are modest and substantially lower than guidelines.

Table 4.5-8. Predicted Effluent and Receiving Environment Concentrations from the Boston Water Treatment Plant for Selected Parameters

Indicator	Under-Ice Maximum Predicted Effluent Concentration (mg/L)	Freshet (June) Maximum Predicted Effluent Concentration (mg/L)	Open-water Maximum Predicted Effluent Concentration (mg/L)	Receiving Environment Concentration (mg/L)◊				Assessment Threshold (mg/L)
				Under-Ice (low current scenario)	Under-Ice (high current scenario)	Under-Ice (freshet scenario)	Open-water	
Aluminum	0.27	0.27	0.27	0.0072	0.00080	0.0015	0.00024	0.1
Antimony	0.013	0.032	0.032	0.00035	0.000039	0.00019	0.000029	0.006
Arsenic	0.015	0.015	0.015	0.00040	0.000045	0.000087	0.000014	0.005
Boron	0.78	4.0	3.8	0.021	0.0023	0.023	0.0035	1.2
Cadmium	0.00010	0.00010	0.00010	0.0000028	0.00000031	0.00000060	0.00000009	0.00004
Chromium	0.022	0.017	0.021	0.00060	0.000067	0.000099	0.000019	0.001
Iron	1.4	1.4	1.4	0.038	0.0042	0.0082	0.0013	0.3
Lead	0.0031	0.0022	0.0029	0.000084	0.0000093	0.000013	0.0000026	0.001
Manganese	0.15	0.44	0.40	0.0041	0.00046	0.0026	0.00037	0.05
Mercury	0.00016	0.000085	0.00014	0.0000044	0.00000048	0.00000050	0.00000013	0.000026
Molybdenum	0.010	0.010	0.010	0.00027	0.000030	0.000058	0.0000092	0.01
Selenium	0.0020	0.0020	0.0020	0.000054	0.0000061	0.000012	0.0000019	0.001
Silver	0.00074	0.00043	0.00065	0.000020	0.0000022	0.0000025	0.00000060	0.00025
Thallium	0.0013	0.00082	0.0011	0.000034	0.0000038	0.0000048	0.0000010	0.0008
Vanadium	0.11	0.052	0.091	0.0028	0.00032	0.00030	0.000084	0.1
Chloride	1875	1356	1697	51	5.6	7.9	1.6	120
Fluoride	1.5	0.82	1.3	0.041	0.0046	0.0048	0.0012	0.12
Sodium	222	87	189	6.0	0.67	0.51	0.17	200
Sulphate	502	414	498	13.6	1.5	2.4	0.46	500
Nitrite	0.27	0.11	0.23	0.0073	0.00081	0.00061	0.00021	0.06

Notes:
Only indicators with effluent concentrations greater than assessment thresholds (i.e., CCME and Health Canada guidelines, Section 4.5.1.1). Site-specific guidelines were calculated using observed baseline information. To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.
◊ *Receiving environment concentrations calculated based on near-field mixing model (Appendix V5-4K). For comparison purposes, the calculations are based on the centreline mixing predictions 3 m away from the diffusers in all four scenarios, which are conservative estimates of mixing within the immediate vicinity of the outfall.*

Table 4.5-9. Summary of Screening for Effects to Water Quality in Aimaokatalok Lake

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Antimony	Construction	0.006	0.000050	0.000050	-	0.000020	0.000034	0.000021	0.000034	-
	Operation				Jan, Feb, Mar, Apr, May, Dec	0.000020	0.000034	0.000045	0.000083	-
	Closure				Jen, Feb, Mar	0.000020	0.000034	0.000039	0.000065	-
	Post-closure				Jan, Feb, Mar	0.000019	0.000034	0.000020	0.000066	-
Ammonia	Construction	1.83	0.010	0.015	Jan, Feb, Mar, Apr, May, Nov, Dec	0.012	0.020	0.016	0.029	-
	Operation				Jan, Feb, Mar, Apr, May, Jun, Oct, Nov, Dec	0.012	0.020	0.020	0.039	-
	Closure				Jan, Feb, Mar, Apr, May, Nov, Dec	0.012	0.020	0.017	0.030	-
	Post-closure				Jan, Feb, Mar, Apr, May	0.012	0.020	0.012	0.027	-
Nitrite	Construction	0.06	0.0005	0.0010	-	0.013	0.020	0.013	0.020	-
	Operation				May	0.013	0.020	0.013	0.021	-
	Closure				-	0.013	0.019	0.013	0.020	-
	Post-closure				-	0.012	0.019	0.012	0.020	-
Nitrate	Construction	3	0.0025	0.0140	Jan, Feb, Mar, Apr, May, Dec	0.0012	0.0020	0.0091	0.029	-
	Operation				Jan, Feb, Mar, Apr, May, Dec	0.0012	0.0020	0.013	0.030	-
	Closure				Jan, Feb, Mar, Apr, May, Dec	0.0012	0.0020	0.013	0.029	-
	Post-closure				Jan, Feb, Mar, Apr	0.0012	0.0020	0.0012	0.023	-
Calcium	Construction	1,000	2.2	2.6	-	3.0	5.0	3.2	5.2	-
	Operation				all months	3.0	5.0	3.9	6.6	-
	Closure				all months	3.0	5.0	3.3	5.7	-
	Post-closure				Jan, Feb, Mar, Apr	2.9	5.0	3.1	5.6	-
Chloride	Construction	120	7	9	-	9.8	16.5	9.9	16.5	-
	Operation				Jan, Feb, Mar, Apr, May, Jun, Aug, Sep, Oct, Nov, Dec	9.8	16.5	12.1	21.2	-
	Closure				-	9.8	16.4	10.0	17.2	-
	Post-closure				-	9.6	16.4	9.6	16.4	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Sulphate	Construction	500	1.5	1.5	-	3.6	6.0	3.6	6.1	-
	Operation				all months	3.6	6.0	4.4	7.5	-
	Closure				-	3.6	6.0	3.8	6.5	-
	Post-closure				-	3.5	6.0	3.6	6.3	-

Notes:

[a] *Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.*

[b] *Site-specific ammonia guideline calculated using observed baseline conditions. To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.*

Table 4.5-10. Summary of Screening for Effects to Water Quality in Koignuk River

Parameter	Phase	Guideline (mg/L)[c]	Observed Baseline[a]			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[b]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Aluminum	Construction	0.1	0.040	0.057	-	0.055	0.055	0.055	0.056	-
	Operation				Jan, Feb, Mar, Apr, Nov, Dec	0.055	0.055	0.057	0.096	-
	Closure				-	0.055	0.055	0.056	0.071	-
	Post-closure				-	0.055	0.062	0.055	0.080	-
Antimony	Construction	0.006	0.000050	0.000050	-	0.000017	0.000029	0.000016	0.000030	-
	Operation				Jan, Feb, Mar, Apr, May, Dec	0.000017	0.000029	0.000044	0.000083	-
	Closure				-	0.000017	0.000029	0.000031	0.000047	-
	Post-closure				-	0.000017	0.000029	0.000018	0.000054	-
Copper	Construction	0.002	0.00096	0.0012	-	0.0010	0.0010	0.0010	0.0010	-
	Operation				Jan, Feb, Mar, Apr, Dec	0.0010	0.0010	0.0011	0.0019	-
	Closure				-	0.0010	0.0010	0.0010	0.0014	-
	Post-closure				-	0.0010	0.0011	0.0010	0.0015	-

Parameter	Phase	Guideline (mg/L)[c]	Observed Baseline[a]			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[b]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Iron	Construction	0.3	0.083	0.120	-	0.10	0.11	0.10	0.11	-
	Operation				Jan, Feb, Mar, Apr, Nov, Dec	0.10	0.11	0.11	0.19	-
	Closure				-	0.10	0.11	0.10	0.14	-
	Post-closure				-	0.10	0.11	0.10	0.16	-
Manganese	Construction	0.05	0.0051	0.0089	-	0.013	0.015	0.013	0.015	-
	Operation				Jan, Feb, Mar, Apr, Nov, Dec	0.013	0.015	0.016	0.026	-
	Closure				-	0.013	0.015	0.013	0.019	-
	Post-closure				-	0.013	0.016	0.013	0.021	-
Nickel	Construction	0.025	0.00050	0.00068	-	0.00045	0.00045	0.00044	0.00045	-
	Operation				Jan, Feb, Mar	0.00045	0.00045	0.00049	0.00082	-
	Closure				-	0.00044	0.00045	0.00045	0.00060	-
	Post-closure				-	0.00044	0.00050	0.00045	0.00067	-
Uranium	Construction	0.015	0.000021	0.000025	-	0.000023	0.000023	0.000023	0.000023	-
	Operation				Jan, Feb, Mar, Apr, Nov, Dec	0.000023	0.000023	0.000026	0.000044	-
	Closure				-	0.000023	0.000023	0.000024	0.000032	-
	Post-closure				-	0.000023	0.000026	0.000023	0.000036	-
Ammonia	Construction	1.83	0.010	0.015	-	0.010	0.012	0.012	0.015	-
	Operation				Jan, Feb, Mar, Apr, May, Jun, Oct, Nov, Dec	0.010	0.012	0.019	0.039	-
	Closure				-	0.010	0.012	0.012	0.021	-
	Post-closure				-	0.011	0.012	0.011	0.022	-
Nitrite	Construction	0.06	0.0005	0.0010	-	0.010	0.013	0.010	0.013	-
	Operation				Jan, Feb, Mar, Apr, May, Nov, Dec	0.010	0.013	0.013	0.021	-
	Closure				-	0.010	0.013	0.010	0.015	-
	Post-closure				-	0.010	0.013	0.010	0.017	-
Nitrate	Construction	3	0.0025	0.014	-	0.0011	0.0011	0.0053	0.013	-
	Operation				Jan, Feb, Mar, Apr, May, Dec	0.0011	0.0011	0.013	0.029	-
	Closure				-	0.0011	0.0011	0.0064	0.017	-
	Post-closure				-	0.0011	0.0012	0.0011	0.019	-

Parameter	Phase	Guideline (mg/L)[c]	Observed Baseline[a]			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[b]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Calcium	Construction	1,000	2.2	2.6	-	2.8	2.8	2.8	3.0	-
	Operation				all months	2.8	2.8	3.9	6.6	-
	Closure				-	2.8	2.8	3.0	4.2	-
	Post-closure				-	2.8	3.1	2.8	4.6	-
Chloride	Construction	120	7	9	-	9.1	9.1	9.0	9.2	-
	Operation				Jan, Feb, Mar, Apr, May, Sep, Oct, Nov, Dec	9.1	9.1	12.1	21.1	-
	Closure				-	9.1	9.1	9.0	12.7	-
	Post-closure				-	9.0	10.1	9.0	13.6	-
Fluoride	Construction	0.12	0.030	0.040	-	0.030	0.031	0.030	0.030	-
	Operation				Jan, Feb, Mar, Apr, Dec	0.030	0.031	0.034	0.059	-
	Closure				-	0.030	0.030	0.030	0.041	-
	Post-closure				-	0.030	0.033	0.030	0.046	-
Sodium	Construction	200	3.9	4.7	-	5.14	5.15	5.11	5.13	-
	Operation				Jan, Feb, Mar, Apr, Nov, Dec	5.14	5.15	5.69	9.76	-
	Closure				-	5.14	5.14	5.1	6.94	-
	Post-closure				-	5.12	5.72	5.12	7.69	-
Sulphate	Construction	500	1.5	1.5	-	3.3	3.3	3.3	3.4	-
	Operation				Jan, Feb, Mar, Apr, May, June, Sep, Oct, Nov, Dec	3.3	3.3	4.3	7.4	-
	Closure				-	3.3	3.3	3.4	4.8	-
	Post-closure				-	3.3	3.7	3.3	5.2	-

Notes:
[a] Aimaokatalok Lake observed baseline data were used for screening purposes because the Lake serves as the source for the Koignuk River and has a robust baseline dataset.
[b] Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline. Aimaokatalok Lake baseline values used for screening as source waterbody for Koignuk River. The water balance model assumed no flow in the Koignuk River between November and April, and only had predicted flow during the Operation Phase due to discharge into Aimaokatalok Lake and treatment of the lake as a reservoir.
[c] Site-specific guidelines (i.e., for aluminum, copper, nickel, and ammonia) calculated using observed baseline hardness values. To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.

Madrid Area

The screening for potential residual effects to water quality in the Madrid area identifies effects in Windy, Wolverine, and Patch lakes, which are proximate to the Madrid North and Madrid South mines and may be influenced by groundwater flow through taliks. Furthermore, the screening identifies effects downstream of Patch Lake in P.O. and Ogama lakes.

Windy Lake is near the Madrid North site, and will interact with the Project through water withdraws for industrial use at Madrid North, drinking water for the Doris site, runoff from the decommissioned CWP at the Madrid North, and drawdown through the talik into the Doris mine. The water balance model predicts increases greater than modelled and observed baselines for the following indicators (Table 4.5-11):

- arsenic;
- cobalt;
- copper;
- manganese;
- nickel; and
- zinc.

The maximum predicted increases are substantially less than applicable water quality guidelines. All increases were predicted to occur during the Post-closure phase when groundwater seeps from the closed Madrid North mine into Windy Lake. The predicted movement of water from the closed Madrid North mine into Windy is slow (less than 0.1 m^3/d), which is consistent with the predicted changes in concentration (Section 5.3.2, Appendix V3-4B).

Wolverine Lake is proximate to the Madrid South site, and will interact with the Project through runoff from the Madrid South site, including runoff in Post-Closure from decommissioned pad and stockpile areas. The water balance model predicts increases greater than modelled and observed baselines for the following indicators (Table 4.5-12):

- antimony;
- arsenic;
- cadmium;
- cobalt;
- copper;
- molybdenum;
- nickel;
- uranium;
- vanadium;
- sulphate; and
- calcium.

All predicted concentrations are less than applicable guideline concentrations and greater than baseline except for copper concentrations during the under-ice periods in the Post-closure phase. Wolverine Lake has a relatively small catchment area relative to the size of the lake, and is relatively shallow (i.e., the mean depth is less than 3 m). As a result, the runoff from the reclaimed infrastructure areas at the Madrid South site is predicted to increase copper concentrations. However, as discussed in the characterization of potential effects to Stickleback Lake, the water balance model cryo-concentration predictions are overly conservative, and are over-estimating under-ice concentrations. Therefore, the predicted copper concentrations that are greater than guidelines are likely the result of the overly conservative cryo-concentration assumptions.

Table 4.5-11. Summary of Screening for Effects to Water Quality in Windy Lake.

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Arsenic	Operation	0.005	0.00054	0.00070	-	0.00030	0.00035	0.00030	0.00035	-
	Closure				-	0.00030	0.00035	0.00031	0.00036	-
	Post-closure				all months	0.00029	0.00035	0.0013	0.0020	-
Cobalt	Operation	0.05	0.000036	0.00005	-	0.000054	0.000063	0.000054	0.000063	-
	Closure				Dec	0.000053	0.000062	0.000054	0.000063	-
	Post-closure				all months	0.000051	0.000062	0.00018	0.00029	-
Copper	Operation	0.002	0.00094	0.0011	-	0.0014	0.0017	0.0014	0.0017	-
	Closure				-	0.0014	0.0017	0.0014	0.0017	-
	Post-closure				all months	0.0014	0.0017	0.0015	0.0018	-
Manganese	Operation	0.05	0.0020	0.0025	-	0.023	0.027	0.023	0.027	-
	Closure				-	0.023	0.026	0.023	0.026	-
	Post-closure				all months	0.022	0.026	0.025	0.030	-
Nickel	Operation	0.072	0.0002	0.00033	-	0.00055	0.00064	0.00055	0.00064	-
	Closure				-	0.00054	0.00063	0.00055	0.00063	-
	Post-closure				all months	0.00052	0.00063	0.00100	0.0014	-
Zinc	Operation	0.03	0.0013	0.0026	-	0.0032	0.0038	0.0032	0.0038	-
	Closure				-	0.0032	0.0037	0.0032	0.0037	-
	Post-closure				all months	0.0031	0.0037	0.0032	0.0038	-

Notes:
[a] *Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.*
[b] *Hardness-dependent guidelines (i.e., for copper, nickel, and zinc) calculated using observed baseline hardness values. To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.*

Table 4.5-12. Summary of Screening for Effects to Water Quality in Wolverine Lake

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Antimony	Operation	-	0.000016	0.00005	-	0.000032	0.00013	0.000033	0.00013	-
	Closure				-	0.000032	0.00013	0.000033	0.00013	-
	Post-closure				Jan, Feb, Mar, Dec	0.000029	0.00013	0.000034	0.00014	-
Arsenic	Operation	0.005	0.00056	0.00076	-	0.00042	0.0017	0.00043	0.0017	-
	Closure				-	0.00042	0.0017	0.00043	0.0018	-
	Post-closure				Jan, Feb, Mar, Dec	0.00038	0.0017	0.00046	0.0020	-
Cadmium	Operation	0.0009	0.0000045	0.000021	-	0.0000075	0.000031	0.0000075	0.000031	-
	Closure				-	0.0000073	0.000030	0.0000074	0.000030	-
	Post-closure				Feb	0.0000066	0.000029	0.0000071	0.000031	-
Cobalt	Operation	0.05	0.00005	0.00013	-	0.000075	0.00031	0.000075	0.00031	-
	Closure				-	0.000073	0.00030	0.000075	0.00030	-
	Post-closure				Jan, Feb, Mar, Dec	0.000066	0.00029	0.000074	0.00032	-
Copper	Operation	0.002	0.00066	0.0011	-	0.0020	0.0082	0.0021	0.0084	-
	Closure				-	0.0020	0.0079	0.0021	0.0084	-
	Post-closure				all months	0.0018	0.0079	0.0023	0.010	Jan, Feb, Mar, Apr, May, Oct, Nov, Dec
Molybdenum	Operation	0.073	0.000083	0.00011	-	0.00026	0.0011	0.00027	0.0011	-
	Closure				-	0.00026	0.0010	0.00026	0.0011	-
	Post-closure				all months	0.00023	0.0010	0.00027	0.0012	-
Nickel	Operation	0.025	0.00042	0.00059	-	0.00076	0.0031	0.00077	0.0031	-
	Closure				-	0.00074	0.0030	0.00076	0.0030	-
	Post-closure				all months	0.00067	0.0030	0.00075	0.0032	-
Uranium	Operation	0.015	0.000029	0.000034	-	0.000050	0.00020	0.000051	0.00021	-
	Closure				-	0.000049	0.00020	0.000052	0.00021	-
	Post-closure				all months	0.000044	0.00020	0.000056	0.00025	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Vanadium	Operation	0.1	N/A	N/A	-	0.00023	0.00096	0.00024	0.00096	-
	Closure				-	0.00023	0.00093	0.00024	0.00096	-
	Post-closure				all months	0.00021	0.00093	0.00025	0.0011	-
Sulphate	Operation	500	1.5	1.5	-	4.0	16	4.1	17	-
	Closure				-	3.9	16	4.2	17	-
	Post-closure				all months	3.5	16	4.5	20	-
Calcium	Operation	1,000	8.4	10	-	13	54	13	54	-
	Closure				-	13	52	13	52	-
	Post-closure				Jan, Feb, Mar, Apr, May, Oct, Nov, Dec	12	52	13	54	-

Notes:

[a] *Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.*

[b] *Hardness-dependent guidelines (i.e., for copper and nickel) calculated using observed baseline hardness values. To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.*

Patch, P.O., and Ogama lakes are downstream of permitted and proposed Phase 2 activities at both the Madrid North and Madrid South sites. Potential Project effects on water quality are primarily upstream effects from runoff and groundwater seepage to decommissioned underground mines. The decommissioning of water management infrastructure, such as contact water ponds at Madrid North and Madrid South, and the cessation of mine contact water management during Closure, resulted in the prediction of residual effects to water quality in Patch, P.O., and Ogama lakes during the Post-closure phase. In Patch and P.O. lakes, the concentrations of arsenic and cobalt are predicted to be greater than baseline conditions in the Post-closure phase (Tables 4.5-13 and 4.5-14). Further downstream in Ogama Lake, arsenic concentrations are predicted to be greater than baseline conditions (Table 4.5-15). However, all predicted increases in concentrations relative to baseline conditions in Patch, P.O., and Ogama lakes are lower than applicable guidelines.

Doris Area

The potential for residual effects to freshwater water quality in the Doris area are identified in the screening of the predictions of the water balance model. Site and mine contact water have the potential to interact with Doris Lake through indirect flow from the Madrid North and Madrid South sites via Ogama Lake, runoff from infrastructure at the Doris site, runoff from the TIA in the Post-closure phase, and groundwater interactions with the Doris mine. These interactions are quantitatively considered in the water balance model.

The water quality screening is conducted on the most sensitive area of Doris Lake and downstream in Little Roberts Lake. The DC node in the water balance model corresponds to the northern outflow from Doris Lake, and integrates water quality in Doris Lake with the runoff from the TIA during the Post-closure Phase. The water balance model predicts increases, relative to modelled and observed baseline conditions, for the following indicators (Table 4.5-16):

- antimony;
- arsenic;
- barium;
- beryllium;
- boron;
- cadmium;
- cobalt;
- copper;
- manganese;
- molybdenum;
- nickel;
- selenium;
- silver;
- thallium;
- uranium;
- zinc;
- calcium; and
- sulphate.

All predicted concentrations are less than their guideline thresholds. Predicted concentrations are highest in the Post-closure phase when the runoff from the TIA joins the natural flows in the Doris catchment. Downstream of the outflow from Doris Lake is Little Roberts Lake. The water balance model predicts increases relative to baseline in Little Roberts Lake for the following indicators (Table 4.5-17):

- antimony;
- arsenic;
- chromium;
- cobalt;
- manganese;
- nickel;
- silver;
- zinc;
- nitrite;
- calcium; and
- sulphate.

Table 4.5-13. Summary of Screening for Effects to Water Quality in Patch Lake

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Arsenic	Operation	0.005	0.00055	0.00072	-	0.00034	0.00058	0.00034	0.00059	-
	Closure				-	0.00034	0.00058	0.00036	0.00058	-
	Post-closure				all months	0.00033	0.00057	0.00081	0.0015	-
Cobalt	Operation	0.05	0.000050	0.000065	-	0.000061	0.00010	0.000060	0.00010	-
	Closure				-	0.000060	0.00010	0.000059	0.000099	-
	Post-closure				Jan, Feb, Mar, Apr, Nov, Dec	0.000058	0.00010	0.000064	0.00011	-

Notes:
[a] Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.
[b] To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.

Table 4.5-14. Summary of Screening for Effects to Water Quality in P.O. Lake

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Arsenic	Operation	0.005	0.00059	0.00060	-	0.00037	0.00058	0.00037	0.00058	-
	Closure				-	0.00037	0.00057	0.00037	0.00057	-
	Post-closure				all months	0.00036	0.00057	0.00077	0.0013	-
Cobalt	Operation	0.05	0.000071	0.00010	-	0.000065	0.00010	0.000064	0.00010	-
	Closure				-	0.000064	0.00010	0.000063	0.000099	-
	Post-closure				Jan, Feb, Mar	0.000061	0.00010	0.000067	0.00011	-

Notes:
[a] Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.
[b] To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.

Table 4.5-15. Summary of Screening for Effects to Water Quality in Ogama Lake

Parameter	Phase	Guideline (mg/L)b	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baselinea	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Arsenic	Operation	0.005	0.00054	0.00069	-	0.00037	0.00059	0.00037	0.00059	-
	Closure				-	0.00037	0.00058	0.00037	0.00058	-
	Post-closure				Jan, Feb, Mar, Apr, Dec	0.00036	0.00058	0.00054	0.00093	-

Notes:
[a] *Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.*
[b] *To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.*

Table 4.5-16. Summary of Screening for Effects to Water Quality in Doris Lake Outflow

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Antimony	Operation	0.006	0.000021	0.000033	-	0.000023	0.000025	0.000023	0.000023	-
	Closure				-	0.000023	0.000025	0.000024	0.000031	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.000023	0.000025	0.000058	0.00010	-
Arsenic	Operation	0.005	0.00033	0.00047	-	0.00031	0.00033	0.00031	0.00031	-
	Closure				-	0.00031	0.00033	0.00032	0.00037	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.00031	0.00033	0.0016	0.0044	-
Barium	Operation	1	0.0033	0.0036	-	0.0037	0.0040	0.0035	0.0036	-
	Closure				-	0.0037	0.0039	0.0035	0.0039	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.0036	0.0039	0.0045	0.0066	-
Beryllium	Operation	0.1	0.0000025	0.0000040	May, Jun, Jul, Aug, Sep, Oct	0.0000055	0.0000058	0.0000058	0.0000059	-
	Closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.0000054	0.0000058	0.0000059	0.0000067	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.0000053	0.0000057	0.0000077	0.0000092	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Boron	Operation	1.2	0.028	0.032	-	0.036	0.039	0.034	0.035	-
	Closure				-	0.036	0.038	0.034	0.038	-
	Post-closure				May, Jun, Sep	0.035	0.038	0.038	0.039	-
Cadmium	Operation	0.00009	0.0000025	0.0000064	-	0.0000055	0.0000058	0.0000052	0.0000054	-
	Closure				-	0.0000054	0.0000058	0.0000053	0.0000062	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.0000053	0.0000057	0.0000075	0.0000079	-
Cobalt	Operation	0.05	0.000028	0.000051	-	0.000055	0.000058	0.000053	0.000054	-
	Closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.000054	0.000058	0.000056	0.000275	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.000053	0.000057	0.00090	0.0010	-
Copper	Operation	0.002	0.0015	0.0017	-	0.0015	0.0016	0.0015	0.0015	-
	Closure				-	0.0015	0.0015	0.0015	0.0016	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.0014	0.0015	0.0017	0.0019	-
Manganese	Operation	0.05	0.015	0.025	-	0.024	0.025	0.023	0.023	-
	Closure				Oct, Nov	0.024	0.025	0.024	0.029	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.023	0.025	0.040	0.044	-
Molybdenum	Operation	0.073	0.00017	0.00021	-	0.00019	0.00021	0.00019	0.00019	-
	Closure				-	0.00019	0.00020	0.00019	0.00021	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.00019	0.00020	0.00023	0.00029	-
Nickel	Operation	0.025	0.00050	0.00062	-	0.00055	0.00060	0.00054	0.00055	-
	Closure				Jun, Jul, Aug, Sep, Oct, Nov	0.00055	0.00059	0.00057	0.0014	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.00054	0.00058	0.0037	0.0043	-
Selenium	Operation	0.001	0.00010	0.00054	-	0.00022	0.00023	0.00021	0.00021	-
	Closure				-	0.00022	0.00023	0.00022	0.00031	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.00021	0.00023	0.00054	0.00061	-
Silver	Operation	0.00025	0.0000025	0.0000025	-	0.0000055	0.0000058	0.0000052	0.0000053	-
	Closure				-	0.0000054	0.0000058	0.0000052	0.0000057	-
	Post-closure				May, Jun, Sep	0.0000053	0.0000057	0.0000056	0.0000059	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Thallium	Operation	0.0008	0.0000010	0.0000048	-	0.0000022	0.0000023	0.0000021	0.0000022	-
	Closure				-	0.0000022	0.0000023	0.0000022	0.0000029	-
	Post-closure				Jan, Feb, Mar, Apr, May	0.0000021	0.0000023	0.0000045	0.0000049	-
Uranium	Operation	0.015	0.000034	0.000037	-	0.000036	0.000039	0.000036	0.000037	-
	Closure				-	0.000036	0.000038	0.000036	0.000041	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.000035	0.000038	0.000044	0.000047	-
Zinc	Operation	0.03	0.0015	0.0025	-	0.0033	0.0035	0.0031	0.0032	-
	Closure				-	0.0032	0.0035	0.0031	0.0035	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	0.0032	0.0035	0.0035	0.0037	-
Calcium	Operation	1,000	7.3	8.1	-	9.6	10.3	9.3	9.5	-
	Closure				-	9.5	10.2	9.3	11.0	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	9.3	10.1	13.2	14.0	-
Sulphate	Operation	500	3	3	-	2.9	3.1	2.9	3.0	-
	Closure				May, Jun, Jul, Aug, Sep, Oct, Nov	2.9	3.1	3.1	6.1	-
	Post-closure				May, Jun, Jul, Aug, Sep, Oct, Nov	2.8	3.1	14.4	16.3	-

Notes:
Flow in Doris Lake outflow was assumed to occur between May and Nov. Screening was only conducted on predicted concentrations during those months throughout all Project phases.
[a] *Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.*
[b] *To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.*

Table 4.5-17. Summary of Screening for Effects to Water Quality in Little Roberts Lake

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline Median (mg/L)	Observed Baseline 75th Quantile (mg/L)	Observed Baseline Months with Exceedances of Baseline[a]	Modelled Baseline Median (mg/L)	Modelled Baseline Maximum (mg/L)	Predicted Values Median (mg/L)	Predicted Values Maximum (mg/L)	Predicted Values Months with Exceedances of Guideline
Antimony	Operation	0.006	0.000021	0.000041	-	0.000015	0.000018	0.000017	0.000022	-
	Closure				-	0.000015	0.000018	0.000016	0.000021	-
	Post-closure				May	0.000015	0.000018	0.000033	0.000042	-
Arsenic	Operation	0.005	0.00039	0.00051	-	0.00020	0.00024	0.00022	0.00029	-
	Closure				-	0.00020	0.00023	0.00021	0.00028	-
	Post-closure				all months	0.00020	0.00023	0.00056	0.0018	-
Chromium	Operation	0.001	0.00025	0.00045	Jan, Feb, Mar, Nov, Dec	0.00035	0.00041	0.00038	0.00048	-
	Closure				Jan, Feb	0.00035	0.00041	0.00035	0.00047	-
	Post-closure				-	0.00034	0.00041	0.00035	0.00040	-
Cobalt	Operation	0.05	0.000060	0.000083	-	0.000035	0.000041	0.000038	0.000049	-
	Closure				Sep, Oct, Nov, Dec	0.000035	0.000041	0.000044	0.00017	-
	Post-closure				all months	0.000034	0.000041	0.00043	0.00067	-
Manganese	Operation	0.05	0.011	0.015	Jan, Feb, Mar, Apr, May, Nov, Dec	0.015	0.018	0.017	0.022	-
	Closure				Jan, Feb, Mar, Apr, May, Oct, Nov, Dec	0.015	0.018	0.016	0.021	-
	Post-closure				all months	0.015	0.018	0.023	0.030	-
Nickel	Operation	0.025	0.00065	0.00077	-	0.00036	0.00042	0.00039	0.00050	-
	Closure				Nov, Dec	0.00036	0.00041	0.00043	0.00089	-
	Post-closure				all months	0.00035	0.00041	0.0019	0.0028	-
Silver	Operation	0.00025	0.0000025	0.0000025	Jan, Feb, Mar, Apr, May, Nov, Dec	0.0000035	0.0000041	0.0000038	0.0000049	-
	Closure				Jan, Feb, Mar, Apr, May	0.0000035	0.0000041	0.0000035	0.0000047	-
	Post-closure				-	0.0000034	0.0000041	0.0000035	0.0000042	-
Zinc	Operation	0.03	0.0015	0.0025	Jan, Feb, Mar, Nov, Dec	0.0021	0.0025	0.0023	0.0029	-
	Closure				Jan, Feb, Mar	0.0021	0.0024	0.0021	0.0028	-
	Post-closure				-	0.0020	0.0024	0.0022	0.0026	-

Parameter	Phase	Guideline (mg/L)[b]	Observed Baseline			Modelled Baseline		Predicted Values		
			Median (mg/L)	75th Quantile (mg/L)	Months with Exceedances of Baseline[a]	Median (mg/L)	Maximum (mg/L)	Median (mg/L)	Maximum (mg/L)	Months with Exceedances of Guideline
Nitrite	Operation	0.06	0.0005	0.001	Jan, Feb, Mar, Apr, May, Nov, Dec	0.0035	0.0041	0.0038	0.0048	-
	Closure				Jan, Feb, Mar, Apr, May	0.0035	0.0041	0.0035	0.0046	-
	Post-closure				-	0.0034	0.0041	0.0033	0.0039	-
Calcium	Operation	1,000	7.3	8.1	Jan, Feb, Mar, Nov, Dec	6.2	7.3	6.8	8.6	-
	Closure				Jan, Feb	6.2	7.2	6.4	8.4	-
	Post-closure				Jan, Feb, Mar, Oct, Nov, Dec	6.0	7.1	7.7	9.6	-
Sulphate	Operation	500	4	5	-	1.9	2.2	2.1	2.7	-
	Closure				-	1.9	2.2	2.3	4.0	-
	Post-closure				all months	1.8	2.2	7.3	10.7	-

Notes:

[a] *Predicted values greater than modelled baseline + 10% and greater than 75th quantile of observed baseline.*

[b] *To be conservative, the lowest guideline value is shown between the CCME guidelines for the protection of aquatic life, CCME guidelines for the protection of agriculture (irrigation), CCME guidelines for the protection of agriculture (livestock), and Health Canada drinking water guidelines.*

The predicted increases in concentrations in Little Roberts Lake are the result of two processes—flow from Doris Lake and cryo-concentration within Little Roberts Lake during the ice-covered season. However, no concentrations are predicted to be greater than their applicable assessment thresholds (i.e., water quality guidelines).

The water balance model also includes total suspended solids as a parameter. However, the model is not optimized to predict the transport of suspended material in runoff and relies on simple assumptions for the total suspended solid content of discharges. Site and mine contact water, including the discharge from the Boston water treatment plant, has the potential to transport suspended material in the receiving environment, which may create localized increases in the concentrations of suspended sediments and sediment-associated metals. These residual effects are anticipated to have the greatest potential to occur during periods of significant overland flow, such as freshet and rainfall events. Although sediment from runoff has the potential to increase TSS and turbidity in the receiving environment, the known effectiveness of the mitigation and management measures are predicted to mitigate the potential effects and the changes in suspended sediment concentrations are not expected to be greater than CCME guidelines for the protection of aquatic life.

<u>Characterization of Hope Bay Development Potential Effect</u>

Potential effects from the Hope Bay development are included in the water balance model, as discussed at the beginning of the section. Mining operations at Doris will continue until 2021 under the current mine plan. These potential effects include components of the site and mine water contact interaction groups, including the following effects during the Operation, Closure, and Post-closure phases:

- runoff from pads and infrastructure at the Doris site;
- tailings from the Doris mine deposited in the TIA; and
- mine water from the Doris mine.

Therefore, the potential residual effects from the Doris development have already been assessed within the Phase 2 assessment for the Operation, Closure, and Post-closure phases. Site contact water during the construction of Doris infrastructure may have had the potential for residual effects to freshwater water quality. These potential residual effects would have included the runoff of metals, acid-equivalents, and hydrocarbons from disturbed areas of the landscape, pads areas, and laydown areas. However, the current Hope Bay water monitoring program, which includes surveillance monitoring of contact water and AEMP monitoring in the receiving environment, has not identified any Project-related effects in Doris Lake or downstream in Doris Creek and Little Roberts Lake. As a result, no incremental residual effects from the Hope Bay Development from site and mine contact water are identified, beyond the effects already described in the water balance model.

4.5.4.3 Water Use

<u>Characterization of Phase 2 Potential Effect</u>

Water use describes the withdrawal of water from Aimaokatalok, Windy, and Doris lakes for industrial and domestic uses. Water use is incorporated into water balance model with withdrawal volumes included in the water and load balance for the affected lakes and downstream flow networks. Although the effects on predicted water quality from water use are integrated with other effects, such as runoff and groundwater flows, the predicted changes in overall lake volumes were relatively small (Hydrology assessment, Volume 5, Section 1). Lake surface elevations were predicted to have maximum changes around 1%, which would be expected to associated with effects of similar magnitude to water quality.

Therefore, no potential residual effects from water use are identified for Phase 2, beyond the effects already integrated and identified in Section 4.5.4.2.

Characterization of Hope Bay Development Potential Effect

No major water uses are identified for the Hope Bay development that are not already assessed in the water balance model. For example, the water balance model considers water withdrawals associated with milling Doris ore. Not included in the water balance model is the withdrawal of domestic water for the Doris site from Windy Lake, but the volumes of water is negligible relative to the lake volume. Therefore, no potential residual effects from water use are identified for the Hope Bay Development.

4.5.4.4 Quarries and Borrow Pits

Characterization of Phase 2 Potential Effect

Runoff is the primary pathway for interaction between quarries and the freshwater environment. As a result, minimizing the transport of material in runoff and reducing the quantity of runoff will be the primary goal of mitigation and management measures (Section 4.5.3). The potential effects from quarries and borrow pits will be minimized by the following specific measures:

- only geochemically suitable material will be used for quarries and borrow pits;
- equipment will be maintained and repaired to avoid potential leaks of fuels and petroleum hydrocarbons;
- local drainage patterns will be maintained and the flow of water into the quarry minimized by the diversion of non-contact water around quarries; and
- quarries and borrow pits will have water collection and control infrastructure (Hope Bay Quarry Management and Monitoring Plan; Volume 8, Annex 17).

If the runoff is turbid but chemically-unaltered, it will be allowed to infiltrate into the ground if it meets permit discharge criteria. By minimizing the volume of water within quarries and collecting water within the quarries, suspended sediments and sediment-associated metals can be settled in sump and will not contact the freshwater environment. Due to the mitigation and management measures, including monitoring and adaptive management of quarry runoff, no residual effects from quarries and borrow pits were predicted for freshwater water quality for the Phase 2 development.

Characterization of Hope Bay Development Potential Effect

Existing quarries and borrow pits for the Doris site have been operating with no detected effects to water quality in the freshwater environment. The mitigation and management measures applied to quarries and borrow pits have been shown to be effective. Therefore, no residual effects from the overall Hope Bay development are predicted.

4.5.4.5 Explosives

Characterization of Phase 2 Potential Effect

Potential residual effects from explosives may occur from the transport, storage, and use of ANFO explosives for mining and construction. The potential effects from transport and storage were considered fully mitigated by the following measures:

- Storage and transport in accordance with the *Explosives Act* (1985b);

- the handling and manufacture of explosives by licensed operators;
- interception and collection of runoff from explosive storage and manufacture facilities prior to contact with the freshwater environment; and
- the application of BMP for blasting and the handling of explosives to minimize residues and spillage.

Blasting residues on mine workings, waste rock, tailings, and run-of-quarry material may affect water quality through runoff and seepage. The water balance model includes blasting residues, and provides quantitative predictions of nitrogenous residues (ammonia, nitrite, and nitrate) in the freshwater environment (Appendix V3-2D). The predicted concentrations of all nitrogenous species are less than assessment thresholds throughout the Project area. The water balance model predicted increases relative to baseline conditions in Stickleback and Aimaokatalok lakes for nitrogenous compounds associated with blasting residues (Tables 4.5-5 and 4.5-9). These predicted increases were, at least partially, attributable to blasting residues in site and mine contact water. The effects from blasting residues on water quality through the aerial deposition pathway is predicted to be negligible. Although the predicted increases in nitrogen compound concentrations are greater than modelled and observed baseline concentrations, the final predicted concentrations are less than 0.1 mg/L (total).

The majority of explosives use will occur underground. Surface blasting for quarrying and construction will be designed to minimize the generation of dust.

<u>Characterization of Hope Bay Development Potential Effect</u>

Construction and mining activities throughout the Hope Bay development require the use of explosives. Mitigation and management measures have been effective for the existing Doris development, and no explosives-related changes in the concentration of nitrogen compounds have been observed in the current Doris AEMP. To be conservative, however, the potential for localized increased in nitrogen compounds from the development of the Madrid North infrastructure and on-going activities at the Doris site was considered to exist and may result in localized, small changes in nitrogen compound concentrations. These potential changes in nitrogen compound concentrations resulting from the use of explosives in the overall Hope Bay Development were predicted to be relatively small, based on the observed performance of the mitigation and management measures and the small magnitude of predicted effects in the water balance model.

4.5.4.6 Fuels, Oils, and PAH

The fuels, oils, and PAH Project interaction group activities will interact with the freshwater environment through runoff and aerial deposition (for PAH, Section 5.5.3.7). The potential effects to freshwater water quality from the use of fuels, including refueling and maintenance, are considered fully mitigated by the application of best management practices and the mitigation and management measures related to the use and potential spills of fuels and petroleum products are detailed in the Hope Bay Project Spill Contingency Plan (Volume 8, Annex 4). These measures include, secondary containment for fuel storage, the use of oil-water separators at maintenance facilities, and established spill response plans. The majority of runoff from site pads, laydown areas, and waste management areas will be directed to the water management infrastructure and not discharged to the freshwater environment. This intercepted water will be diverted to the TIA or the Boston Water Treatment Plant (WTP). Otherwise, runoff will be collected in sumps and discharged only if it meets water quality standards under applicable water licences.

For the aerial deposition of PAH, the primary mitigation measure will be the efficient operation of the incinerator (Incineration Management Plan; Volume 8, Annex 16). The operation of the incinerator will comply with Nunavut guidelines (Government of Nunavut Department of Environment 2012), *Canada-Wide Standards for Dioxins and Furans* (CCME 2001a) and *Canada-Wide Standards for Mercury Emissions* (CCME 2000). The operation of the incinerator includes the following management measures:

- waste segregation (i.e., materials that are unsuitable for incineration, e.g., chlorinated plastics, will be diverted to alternate waste disposal facilities);
- properly trained personnel for incinerator operations; and
- periodic stack testing and adaptive management to ensure compliance with standards.

Project activities related to fuels and other petroleum hydrocarbons are anticipated to have negligible effects on freshwater water quality. The mitigation and management measures are considered to be effective at minimizing the potential for effects on the freshwater environment during normal operations. No hydrocarbon compounds or sediments from Project activities at the sites, laydown areas, fuel areas, or waste storage areas are expected to reach the freshwater environment because of the BMP for machinery operation, maintenance, and fueling, and the direction of runoff carrying potential compounds to the water management facilities. The incinerator will be operated according to guidelines and standards, and therefore negligible aerial deposition of PAH into the freshwater environment is expected. Therefore, no residual effects from fuels, oils, and PAHs are anticipated on freshwater water quality. This prediction is applicable to both the incremental effects of the Phase 2 Project as well as the overall Hope Bay Development.

4.5.4.7 Treated Sewage Discharges

Treated domestic sewage has the potential to interact with the freshwater environment through the discharge pathway. As described in Section 4.4.1, treated sewage from Doris, Madrid North, and Madrid South areas will be discharged to the TIA, and subsequently to the marine environment. Treated domestic sewage in the Boston area may be discharged to the tundra prior to the commissioning of the Boston WTP and to Aimaokatalok Lake with combined effluent from the Boston WTP when operational.

<u>Characterization of Phase 2 Potential Effect</u>

The Phase 2 potential effect from treated sewage discharge is restricted to the Boston area. Domestic sewage from other Project areas will be discharged to the marine environment via the TIA, and therefore no potential exists during normal operations for contact between treated sewage and the freshwater environment.

The Boston domestic treated sewage may be discharged to the tundra during Construction and Closure phases, and is therefore not considered to interact with the freshwater environment. Therefore, only the discharge of treated sewage into Aimaokatalok Lake during Operations has the potential for residual effects to freshwater water quality. The water balance model includes discharge from the sewage treatment plant. The effluent concentrations of nitrite, nitrate, and chromium are predicted to be greater than water quality guidelines (Table 4.5-18).

The treated sewage will be discharged into Aimaokatalok Lake via a combined outfall with the WTP, and will be effectively mixed in the receiving environment using a diffuser (Appendix V5-4K). The near-field mixing model predicts rapid mixing within 3 m of the outfall, and the predicted receiving environment concentrations of nitrite, nitrate, and chromium are less than their applicable assessment thresholds (i.e., water quality guidelines; Table 4.5-18). Beyond the near-field mixing environment, the potential effects on water quality from discharge of treated sewage are predicted by the water balance model. The water balance model predictions for Aimaokatalok Lake water quality integrate the contributions of the sewage discharge with other Project and natural influences on water quality

(Table 4.5-9). Therefore, no potential residual effects from sewage discharge are identified for Phase 2, beyond the effects already integrated and identified in Section 4.5.4.2.

Table 4.5-18. Predicted Effluent and Receiving Environment Concentrations from the Boston Sewage Treatment Plant

Indicator	Predicted Effluent Concentration (mg/L)	Receiving Environment Concentration (mg/L)◊				Assessment Threshold (mg/L)
		Under-Ice (low current scenario)	Under-Ice (high current scenario)	Under-Ice (freshet scenario)	Open-water	
Chromium	0.0025	0.000068	0.0000075	0.000015	0.0000023	0.001†
Nitrate	30	0.81	0.09	0.18	0.03	3‡
Nitrite	1	0.027	0.0030	0.0058	0.00092	0.06

◊ *Receiving environment concentrations calculated based on near-field mixing model (Appendix V5-4).*
† *Chr(III) used as conservative assessment threshold (see Section 4.5.1.1).*
‡ *CCME long-term guideline for the protection of aquatic life (see Section 4.5.1.1).*

<u>Characterization of Hope Bay Development Potential Effect</u>

The discharge of domestic sewage to the marine environment via the TIA from the Doris, Madrid North, and Madrid South areas removed the potential for effects on the freshwater environment beyond the effects discussed above for the Boston area. Therefore, no Hope Bay Development residual effect from sewage discharge is identified.

4.5.4.8 Dust Deposition

<u>Characterization of Phase 2 Potential Effect</u>

Quantitative air quality monitoring included the prediction of dust deposition rates across the Project area (Volume 4, Section 2). This dust deposition modelling included operation of the TIA and vehicle traffic as potential dust sources. The results of the quantitative dust deposition modelling are used to estimate average dust deposition rates in Project area lakes. Interpolated dust deposition rates from the gridded air quality modelling field are calculated for each of the lakes summaries in Table 4.5-19.

Table 4.5-19. Summary of Predicted Dust Deposition Rates in Project Area Lakes

Lake	Mean Depth (m)	Construction Mean Annual Maximum Deposition Rate (g/m^2/year)	Operation Mean Annual Maximum Deposition Rate (g/m^2/year)	Construction Daily Load (mg/L/d)	Operation Daily Load (mg/L/d)
Doris	7.3	11	11	0.004	0.004
Ogama	2.6	9	9	0.009	0.009
Patch	4.1	11	12	0.007	0.008
P.O.	2.1	9	9	0.01	0.01
Windy	9.9	10	11	0.003	0.003
Aimaokatalok	6.4	9	9	0.004	0.004
Trout	2.3	9	10	0.01	0.01
Stickleback	2.5	18	17	0.02	0.02

Note: Daily loads calculated by integrating the annual load throughout the water column of the lake. Mean water depths are described in the Limnology and Bathymetry chapter (Volume 5, Chapter 3).

The average daily loads calculated from the air quality modelling are predicted to contribute from 0.003 to 0.02 mg/L/d of dust into Aimaokatalok Lake (normalized to lake volume). These daily loads are 100-fold lower than observed total suspended solids concentrations (Section 4.2.4.1). Dust particles deposited into the freshwater environment will sink and aggregate, and therefore have a limited residence time in the water column. Even if dust particles reside in the water column for days to a week, the relative increase in total suspended sediment concentrations, and particle-associated metals, is negligible compared to observed water quality conditions. Therefore, the potential effects from dust deposition are not considered further.

Characterization of Hope Bay Development Potential Effect

The air quality model includes the contributions of the activities at the Doris site during the period of overlap between the Doris mine and Phase 2. The Construction phase therefore represents the period of maximal potential dust influences of the freshwater environment from existing . No effects from dust deposition effects from the construction of the Doris site have been observed in the Doris AEMP monitoring program (e.g., ERM 2016). On the basis of the results of the quantitative air quality modelling and the absence of any evidence of dust-related effects, the potential effects from dust deposition for the Hope Bay development on freshwater water quality is concluded to be negligible, and not considered further.

4.5.5 Characterization of Residual Effects

4.5.5.1 Definitions for Characterization of Residual Effects

To determine the significance of a Project residual effect, each potential negative residual effect is characterized by a number of attributes consistent with those defined in of the EIS guidelines (Section 7.14, Significance Determination for the Hope Bay Project; (NIRB 2012a)). A definition for each attribute and the contribution that it has on significance determination is provided in Table 4.5-20. These attributes consider the baseline information presented in Section 4.3 and are focused on the indicators and thresholds described in Tables 4.5-1 and 4.5-2.

Table 4.5-20. Attributes to Evaluate Significance of Potential Residual Effects

Attribute	Definition and Rationale	Impact on Significance Determination
Direction (positive, neutral, or negative)	The ultimate long-term trend of a potential residual effect - positive, neutral, or negative.	Positive, neutral, and negative potential effects on the freshwater water quality VEC are assessed, but only negative residual effects are characterized and assessed for significance.
Magnitude (negligible, low, moderate, or high)	The degree of change in a measurable parameter or variable relative to existing conditions. This attribute may also consider complexity - the number of interactions (Project phases and activities) contributing to a specific effect.	The higher the magnitude, the higher the potential significance.
Duration (short, medium, long)	The length of time over which the residual effect occurs.	The longer the length of time of an interaction, the higher the potential significance.
Frequency (infrequent, intermittent, continuous)	The number of times during the Project or a Project phase that an interaction or environmental/ socio-economic effect can be expected to occur.	Greater the number times of occurrence (higher the frequency), the higher the potential significance.

Attribute	Definition and Rationale	Impact on Significance Determination
Geographic Extent (PDA, LSA, RSA, beyond regional)	The geographic area over which the interaction will occur.	The larger the geographical area, the higher the potential significance.
Reversibility (reversible, reversible with effort, irreversible)	The likelihood an effect will be reversed once the Project activity or component is ceased or has been removed. This includes active management for recovery or restoration.	The lower the likelihood a residual effect will be reversed, the higher the potential significance.

For the determination of significance, each attribute is characterized. The characterizations and criteria for the characterizations are provided in Table 4.5-21. Each of the criteria contributes to the determination of significance.

Table 4.5-21. Criteria for Residual Effects for Environmental Attributes

Attribute	Characterization	Criteria
Direction	Positive	Beneficial
	Variable	Both beneficial and undesirable
	Negative	Undesirable
Magnitude	Negligible	No change on the indicator or overall freshwater water quality
	Low	Differing from the modelled or observed baseline values to a small degree (more than 10%), but within the range of natural variation (defined as 75th quantile of observed baseline) and below a guideline or threshold value
	Moderate	Differing from the modelled or observed baseline values (more than 10%) and greater than the range of natural variation (defined as 75th quantile of observed baseline) but below or equal to a guideline or threshold value
	High	Differing from the existing environment and exceeding guideline or threshold values
Duration	Short	Up to 5 years (Construction phase)
	Medium	Greater than 5 years and up to 17 years (5 years Construction phase, 14 years Operation phase, 3 years Reclamation and Closure phase – not consecutive)
	Long	Beyond the life of the Project
Frequency	Infrequent	Occurring only occasionally
	Intermittent	Occurring during specific points or under specific conditions during the Project
	Continuous	Continuously occurring throughout the Project life
Geographic Extent	Project Development Area (PDA)	Confined to the PDA
	Local Study Area (LSA)	Beyond the PDA and within the LSA
	Regional Study Area (RSA)	Beyond the LSA and within the RSA
	Beyond Regional	Beyond the RSA
Reversibility	Reversible	Effect reverses within an acceptable time frame with no intervention
	Reversible with effort	Active intervention (effort) is required to bring the effect to an acceptable level
	Irreversible	Effect will not be reversed

4.5.5.2 Determining the Significance of Residual Effects

Section 7.4 of the EIS guidelines provided guidance, attributes, and criteria for the determination of significance for residual effects (NIRB 2012a). Also, the Canadian Environmental Assessment Agency's *Determining Whether a Project is Likely to Cause Significant Adverse Environmental Effects* (CEAA 1992) also guided the evaluation of significance for identified residual effects. The significance of residual effects is based on comparing the predicted state of the environment with and without the Project, including a judgment as to the importance of the changes identified.

Probability of Occurrence or Certainty

Prior to the determination of the significance for negative residual effects, the probability of the occurrence or certainty of the effect is evaluated. For each negative residual effect, the probability of occurrence is categorized as unlikely, moderate or likely. Table 4.5-22 presents the definitions applied to these categories.

Table 4.5-22. Definition of Probability of Occurrence and Confidence for Assessment of Residual Effects

Attribute	Characterization	Criteria
Probability of occurrence or certainty	Unlikely	Some potential exists for the effect to occur; however, current conditions and knowledge of environmental trends indicate the effect is unlikely to occur.
	Moderate	Current conditions and environmental trends indicate there is a moderate probability for the effect to occur.
	Likely	Current conditions and environmental trends indicate the effect is likely to occur.
Confidence	High	Baseline data are comprehensive; predictions are based on quantitative predictive model; effect relationship is well understood.
	Medium	Baseline data are comprehensive; predictions are based on qualitative logic models; effect relationship is generally understood, however, there are assumptions based on other similar systems to fill knowledge gaps.
	Low	Baseline data are limited; predictions are based on qualitative data; effect relationship is poorly understood.

Determination of Significance

Significance of a residual effect depends on the magnitude of the effect and conditions under which the residual effect interacts with the freshwater environment. The magnitude of a **significant** residual effect must be *high*, because *moderate* or *low* magnitude residual effects are necessarily less than environmental quality criteria (e.g., CCME guidelines for the protection of aquatic life) or within the range of natural variation. Furthermore, a **significant** residual effect will also have a greater spatial and temporal extent, such as a *regional*-scale effect and *long*-term duration. **Significant** residual effects will also be *irreversible* or *reversible-with-effort* because the reversibility of the residual effect describes, in part, the resilience of the ecosystem component to change.

Confidence

The knowledge or analysis that supports the prediction of a potential residual effect—in particular with respect to limitations in overall understanding of the environment and/or the ability to foresee future events or conditions—determines the confidence in the determination of significance. In general, the lower the confidence, the more conservative the approach to prediction of significance must be. The level of confidence in the prediction of a significant or non-significant potential residual effect qualifies the determination, based on the quality of the data and analysis and their extrapolation to the predicted residual effects. *Low* is assigned where there is a low degree of confidence in the inputs, *medium* when there is moderate confidence and *high* when there is a high degree of confidence in the inputs. Where rigorous baseline data were collected and scientific analysis performed, the degree of confidence will generally be *high*. Predictive water quality modelling is employed using industry standard modelling software to support the assessment process, including the investigation of multiple sensitivities. The goals are to remove as much subjectivity from the assessment process as possible, and to increase certainty in the predictions of changes to freshwater water quality indicators, residual effects, and significance determination to produce a robust, transparent, and defensible approach to the assessment of freshwater water quality effects. Therefore, there is *high* confidence in the results of this residual effects assessment for predicted water quality effects on the freshwater environment in the Phase 2 area. Water quality monitoring will be ongoing in Construction, Operations, and Reclamation and Closure phases and will serve to validate water quality predictions. Table 4.5-22 provides descriptions of the confidence criteria.

Residual effects identified in the Project-related effects assessment are carried forward to assess the potential for cumulative interactions with the residual effects of other projects or human activities and to assess the potential for transboundary impacts should the effects linked directly to the activities of the Project inside the Nunavut Settlement Area (NSA), which occurs across provincial, territorial, international boundaries or may occur outside of the NSA.

4.5.5.3 Characterization of Residual Effect for Freshwater Water Quality VEC

The potential residual effects brought forward in the assessment from Section 4.5.4 are analyzed as described in sections 4.5.5.1 and 4.5.5.2. The characterization of residual effects is detailed below in Section 4.5.5.3 and summarized in Tables 4.5-23 and 4.5-24.

<u>Site Preparation, Construction and Decommissioning Activities</u>

Phase 2 Potential Effect

Residual effects from construction and decommissioning activities are anticipated during the Construction phase when water management features are in the process of being constructed and commissioned. Only small amounts of runoff are expected to reach the surrounding waterbodies while the water management features are being constructed. The extensive mitigation and management measures, which incorporate design, BMPs, and adaptive management, are predicted to minimize the transport of sediments through runoff into the freshwater environment. However, the potential for changes in water quality beyond the range of baseline conditions remain. The effectiveness of mitigation and management measures are expected to limit any changes in water quality to less than applicable water quality guidelines. Therefore, the predicted magnitude of the residual effect from all construction and decommissioning activities is *moderate*.

The effects are expected to be footprint (within the PDA) or *local* (restricted to the LSA), *short-term* in duration, and *intermittent* as runoff would only occur during snowmelt and large precipitation events. The freshwater environment has the capacity to recover and the effects are expected to be fully *reversible*. The probability of occurrence is estimated to be *moderate* due to the uncertainties related to precipitation, and confidence was *high* because of the quantitative input from the baseline environmental data, the predictable nature of this potential effect, and the confidence in the mitigation and management strategies.

The residual effect of construction and decommissioning activities for Phase 2, which describes the disturbance of the landscape due to the construction and reclamation of Project infrastructure, is concluded to be **Not Significant** on freshwater water quality.

Table 4.5-23. Summary of Residual Effects and Overall Significance Rating for Freshwater Water Quality - Phase 2

Residual Effect	Attribute Characteristic						Overall Significance Rating		
	Direction (*positive*, *variable*, *negative*)	**Magnitude** (negligible, *low*, *moderate*, *high*)	**Duration** (*short*, *medium*, *long*)	**Frequency** (*infrequent*, *intermittent*, *continuous*)	**Geographic Extent** (PDA, *LSA*, *RSA*, *beyond regional*)	**Reversibility** (*reversible*, *reversible with effort*, *irreversible*)	**Probability** (*unlikely*, *moderate*, *likely*)	**Significance** *(not significant*, *significant)*	**Confidence** (*low*, *medium*, *high*)
Construction and Decommissioning Activities	Negative	Moderate	Short	Intermittent	LSA	Reversible	Moderate	Not significant	High
Site and Mine Contact Water	Negative	Moderate	Medium to Long	Intermittent to Continuous	LSA	Irreversible	Likely	Not significant	High
Explosives	Negative	Moderate	Medium	Intermittent to Continuous	LSA	Reversible	Moderate	Not significant	High

Table 4.5-24. Summary of Residual Effects and Overall Significance Rating for Freshwater Water Quality - Hope Bay Development

Residual Effect	Attribute Characteristic						Overall Significance Rating		
	Direction (*positive*, *variable*, *negative*)	**Magnitude** (negligible, *low*, *moderate*, *high*)	**Duration** (*short*, *medium*, *long*)	**Frequency** (*infrequent*, *intermittent*, *continuous*)	**Geographic Extent** (PDA, *LSA*, *RSA*, *beyond regional*)	**Reversibility** (*reversible*, *reversible with effort*, *irreversible*)	**Probability** (*unlikely*, *moderate*, *likely*)	**Significance** *(not significant*, *significant)*	**Confidence** (*low*, *medium*, *high*)
Construction and Decommissioning Activities	Negative	Moderate	Short	Intermittent	LSA	Reversible	Moderate	Not significant	High
Site and Mine Contact Water	Negative	Moderate	Medium to Long	Intermittent to Continuous	LSA	Irreversible	Likely	Not significant	High
Explosives	Negative	Moderate	Medium	Intermittent to Continuous	LSA	Reversible	Moderate	Not significant	High

Hope Bay Development Potential Effect

The effects from the Hope Bay Development from construction and decommissioning activities are expected to be similar to the residual effects from the Phase 2 development. Closure and reclamation of infrastructure at the Doris site had the potential for *local*, *short*-term changes in water quality after the application of mitigation and management measures. However, these effects are expected to be less than applicable water quality guidelines, and therefore *moderate* in magnitude. Similarly, the probability of occurrence is concluded to be *moderate* due to uncertainties related to precipitation and runoff, and the confidence was *high*.

The residual effect of construction and decommissioning activities for the Hope Bay Development are concluded to be **Not Significant**.

<u>Site and Mine Contact Water</u>

Phase 2 Potential Effect

Residual effects from site and mine contact water are predicted based on the quantitative water balance modelling and extensive baseline data. The analysis, outlined in Section 4.5.4.2, predicts increases in metal, anion, cation, and nitrogen species resulting from the discharge, runoff, and seepage of site and mine contact water. The magnitude of the residual effect is concluded to be *moderate*. Many of the predicted changes in water quality are predicted to remain throughout the Post-closure phase, and are therefore concluded to be *long*-term in duration. However, the geographic extent of the residual effects from site and mine contact water were concluded to be restricted to the *LSA*.

The residual effects from site and contact water are concluded to be *irreversible*. The long-term effects associated with runoff from the TIA, TMA, and reclaimed Project infrastructure are predicted to continue through-out the Post-closure phase. As discussed in the Water and Load Balance Model report (Appendix V3-2D), interactions between decommissioned Project infrastructure may continue for hundreds of years as equilibria are reached in groundwater interactions between closed mine works and nearby lakes.

The residual effects were concluded to be *likely* with a *high* degree of confidence. The quantitative water balance model included a range of source water and mass loadings, and included algorithms for modelling *in situ* biogeochemical reactions. Furthermore, sensitivities analyses carried out on the water balance model (Appendix V3-2D) supported the overall conclusions and predictions of the model.

The residual effect to freshwater water quality from site and mine contact water is concluded to be **Not Significant** because the predicted effects were *moderate* in magnitude and localized to the *LSA*.

Hope Bay Development Potential Effect

No additional incremental effects from site and mine contact water beyond the effects assessment under the Phase 2 development are identified (Section 4.5.4.2). The water balance model includes the majority of potential residual effects, and these effects are analyzed as part of the Phase 2 development.

Therefore, the residual effect to freshwater water quality from site and mine contact water for the Hope Bay development is concluded to be **Not Significant**, following the same criteria as for the Phase 2 analysis.

Explosives

Phase 2 Potential Effect

The residual effect from explosives for the Phase 2 development is concluded to be *moderate* in magnitude based on the predictions from the water balance model and the known effectiveness of mitigation and management measures. The effects are predicted to be *medium*-term in duration and restricted to the LSA. The frequency of the residual effect was concluded to be *intermittent* to *continuous* because some effects from explosives residues would be associated with runoff events, which are necessarily intermittent, whereas other effects, such as the discharge of explosive residues in contact water from the TMA may be closer to continuous in frequency during some periods of the Project. The effects from explosives are concluded to be *reversible* because the primary components are readily degraded in the freshwater environment as part of the nitrogen and carbon cycles.

Therefore, the residual effect to freshwater water quality from explosives for the Phase 2 development is concluded to be **Not Significant**.

Hope Bay Development Potential Effect

Additional, incremental residual effects from explosives are identified for the Hope Bay Development. To be conservative, the magnitude of this residual effect is concluded to be *moderate* because of the possibility of changes in water quality beyond the range of baseline conditions. However, like the residual effect for the Phase 2 development, the residual effect for the Hope Bay development is predicted to the *local* in scale and *medium*-term in duration. Similarly, the effect was predicted to be fully *reversible*.

The residual effect to freshwater water quality from explosives for the Hope Bay development is concluded to be **Not Significant**.

4.6 CUMULATIVE EFFECTS ASSESSMENT

The potential for cumulative effects arises when the potential residual effects of the Project affect (i.e., overlap and interact with) the same freshwater water quality VEC that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities.

4.6.1 Methodology Overview

4.6.1.1 Approach to Cumulative Effects Assessment

The general methodology for cumulative effects assessment (CEA) is described in Volume 2, Section 4, and focuses on the following activities:

1. Identify the potential for Project-related (Phase 2 and the complete Hope Bay Development) residual effects to interact with residual effects from other human activities and projects within specified assessment boundaries. Key potential residual effects associated with past, existing, and reasonably foreseeable future projects were identified using publicly available information or, where data was unavailable, professional judgment was used (based on previous experience in similar geographical locations) to approximate expected environmental conditions.
2. Identify and predict potential cumulative effects that may occur and implement additional mitigation measures to minimize the potential for cumulative effects.

3. Identify cumulative residual effects after the implementation of mitigation measures.
4. Determine the significance of any cumulative residual effects.

4.6.1.2 Assessment Boundaries

The CEA considers the spatial and temporal extent of Project-related residual effects on the freshwater water quality VEC combined with the anticipated residual effects from other projects and activities to assist with analyzing the potential for a cumulative effect to occur.

Spatial Boundaries

The spatial boundary for the CEA was the assessment Regional Study Area (RSA; Figure 4.2-2). This study area contains the LSA and was determined to cover the extent of direct and indirect effects of the Project on the freshwater environment.

Temporal Boundaries

The temporal boundaries of the CEA were defined by the timelines for Past, Existing, and Reasonably Foreseeable Projects as described in the CEA methodology (Volume 2, Section 4). These timelines were compared to the Project timeline (Section 4.4.3).

4.6.2 Potential Interactions of Residual Effects with Other Projects

The mining industry is the main source of industrial activity in Nunavut, which is being explored for uranium, diamonds, gold and precious metals, base metals, iron, coal, and gemstones. In addition to major mining development projects, other land use activities are also present in the territory and, as required under Section 7.11 of the Project EIS guidelines, were considered for potential interactions with the Project (see Volume 2, Section 4 for more detail).

No past, present, or foreseeable projects that could potentially interact with the residual effects of the Hope Bay Project lie within the freshwater assessment RSA. Given that the Project residual effects were confined to the LSA, no cumulative effects to the freshwater water quality VEC were predicted.

4.7 TRANSBOUNDARY EFFECTS

The Project EIS guidelines define transboundary effects as those effects linked directly to the activities of the Project inside the NSA, which occur across provincial, territorial, international boundaries or may occur outside of the NSA (NIRB 2012a). Transboundary effects of the Project have the potential to act cumulatively with other projects and activities outside the NSA.

The non-significant Project effects to the freshwater water quality VEC were predicted to be restricted to the LSA. The LSA lies entirely within Nunavut, and therefore no potential for transboundary effects was identified.

4.8 IMPACT STATEMENT

The assessment of effects from the Project to the freshwater water quality VEC considers potential effects grouped into interaction groups. These interaction groups considered Project effects that are related by timing and mitigation and management measures. The following interaction groups re considered as potential effects:

- construction and decommissioning activities;
- site contact water;
- mine contact water;
- water use;
- quarries and borrow pits;
- explosives; fuels, oils, and PAH;
- treated sewage discharge; and
- dust deposition.

Potential effects are characterized using key indicators and quantitative thresholds as well as experience from the Hope Bay Development. The assessment considers mitigation and management measures already applied in the Hope Bay Development, drawn from guidance documents, and applied in other mining projects in Nunavut and the Northwest Territories.

A quantitative water balance model is used to predict the effects of Phase 2 on freshwater water quality. Residual effects are identified based on the predictions of the water balance model and the application of mitigation and management measures. Three residual effects are identified: construction and decommissioning activities; site and mine contact water; and explosives.

Using the thresholds identified for the key indicators, each of these residual effects are concluded to be moderate in magnitude. All residual effects to freshwater water quality are predicted to be restricted to the LSA. As a result, the residual effects are rated as Not Significant. No cumulative effects are predicted to occur because the Project freshwater water quality residual effects are not predicted to overlap spatially with any other past, existing, or reasonably foreseeable project. Similarly, no transboundary effects are identified because the Project residual effects are predicted to extend only within the LSA that is entirely within Nunavut.

4.9 REFERENCES

1985a. *Canada Water Act*, RSC, 1985, c C-11.

1985b. *Explosives Act*, RSC, 1985, c E-17.

1985c. *Fisheries Act*, RSC, 1985, c F-14.

Arctic Waters Pollution Prevention Regulations, C.R.C., c. 354.

Metal Mining Effluent Regulations, SOR/2002-222.

Nunavut Waters Regulations, SOR/2013-69.

Areva. 2015. *Thank you for submitting your comments*. http://kiggavik.ca/2015/01/20/thank-you-for-submitting-your-comments/ (accessed February 2015).

Banci, V. and R. Spicker, (Compilers, Editors & GIS). 2016. *Inuit Traditional Knowledge for TMAC Resources Inc. Proposed Hope Bay Project, Naonaiyaotit Traditional Knowledge Project (NTKP)*. Prepared for TMAC Resources Inc. Kitikmeot Inuit Association: Kugluktuk, NU.

CCME. 2000. *Canada-Wide Standards for Mercury Emissions*. Canadian Council of Ministers of the Environment: Quebec City, QC.

CCME. 2001a. *Canada-Wide Standards for Dioxins and Furans*. Canadian Council of Ministers of the Environment: Winnipeg, MB.

CCME. 2001b. *Introduction. Updated. In: Canadian environmental quality guidelines*. Canadian Council of Ministers of the Environment: Winnipeg, MB.

CCME. 2004. *Canadian water quality guidelines for the protection of aquatic life: Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems*. Canadian Council of Ministers of the Environment: Winnipeg, MB.

CCME. 2007. *Protocol for the derivation of water quality guidelines for the protection of aquatic life 2007. In: Canadian environmental quality guidelines, 1999*. EPC-98E. Canadian Council of Ministers of the Environment: Winnepeg, MB.

CCME. 2016a. *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Summary Table*. Canadian Council of Ministers of the Environment. http://st-ts.ccme.ca/en/index.html (accessed November 2016).

CCME. 2016b. *Canadian Water Quality Guidelines for the Protection of Aquatic Life: Summary Table*. Canadian Council of Ministers of the Environment. http://st-ts.ccme.ca/en/index.html (accessed November 2016).

CEAA. 1992. *Reference Guide: Determining Whether A Project is Likely to Cause Significant Adverse Environmental Effects*. http://www.CEAa-acee.gc.ca/default.asp?lang=En&n=D213D286-1&offset=&toc=hide (accessed May 2016).

DFO. 2010. *Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut. Department of Fisheries and Oceans, Ottawa, Ontario*. http://www.mvlwb.ca/Boards/WLWB/Registry/2010/W2010C0005/W2010C0005%20%20Novus%20Gold%20%20LUP%20Application%20%20DFO%20Water%20Withdrawal%20Protocol%20%20Aug%2025_10.pdf (accessed December 2016).

DFO. 2013. *Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat*. http://www.dfo-mpo.gc.ca/pnw-ppe/timing-periodes/nu-eng.html (accessed December 1, 2016).

DFO. 2016. *Measures to Avoid Causing Harm to Fish and Fish Habitat*. http://www.dfo-mpo.gc.ca/pnw-ppe/measures-mesures/measures-mesures-eng.html (accessed December 1, 2016).

ERM. 2015. *Doris North Project: 2014 Aquatic Effects Monitoring Program*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd. : Yellowknife, NT.

ERM. 2016. *Doris North Project: 2015 Aquatic Effects Monitoring Program Report*. Prepared for TMAC Resources Inc. by ERM Consultants Canada Ltd.: Yellowknife, NT.

ERM Rescan. 2014. *Doris North Project: 2013 Aquatic Effects Monitoring Program Report*. Prepared for TMAC Resources Inc. by ERM Rescan: Yellowknife, NT.

Golder. 2011. *Snap Lake Mine Site Water Quality*. Prepared for De Beers Canada Inc. by Golder Associates, Ltd.

Golder Associates Ltd. 2005. *Doris North Project Aquatic Studies 2004*. Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 04-1373-009:

Golder Associates Ltd. 2006. *Doris North Project Aquatic Studies 2005*. Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 05-1373-014-F:

Golder Associates Ltd. 2007. *Doris North Project Aquatic Studies 2006*. Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 06-1373-026:

Golder Associates Ltd. 2008a. *Boston and Madrid Project Areas: 2006-2007 Aquatic Studies*. Prepared for Hope Bay Mining Ltd. by Golder Associates Ltd.: Edmonton, AB.

Golder Associates Ltd. 2008b. *Doris North Project Aquatic Studies 2007*. Prepared for Miramar Hope Bay Ltd. by Golder Associates Ltd. Report No. 07-1373-0018D:

Golder Associates Ltd. 2009. *Hope Bay Project: Aquatic Studies 2008*. Prepared for Hope Bay Mining Ltd. by Golder Associates Ltd.: Edmonton, AB.

Government of Nunavut Department of Environment. 2012. *Guidline: Burning and Incineration of Solid Waste*. Goverment of Nunavut Department of Environment: Iqaluit, NU.

Klohn-Crippen Consultants Ltd. 1995. *Doris Lake Project, Northwest Territories: 1995 Environmental Study*. Prepared for BHP Minerals Canada Ltd. by Klohn-Crippen Consultants Ltd.:

Natural Resources Canada. 2015. *Exploration plus deposit appraisal expenditures, by province and territory, 2009-2014.*

NIRB. 2012a. *Guidelines for the Preparation of an Environmental Impact Statement for Hope Bay Mining Ltd.'s Phase 2 Hope Bay Belt Project* (NIRB File No. 12MN001). Nunavut Impact Review Board: Cambridge Bay, NU.

NIRB. 2012b. *Public Scoping Meetings Summary Report for the NIRB's Review of Hope Bay Mining's Ltd.'s "Phase 2 Hope Bay Belt Project* NIRB File No.: 12MN001. Nunavut Impact Review Board: Cambridge Bay, NU.

Nunatsiaq. 2013. *Owner puts Nunavut's Lupin Mine project back into limbo.*

Rescan. 1993. *Boston Property N.W.T.: Environmental Data Report*. Prepared for BHP Minerals Canada Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 1994. *Boston Property N.W.T.: Environmental Data Report*. Prepared for BHP Minerals Canada Ltd. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 1995. *Boston Property N.W.T.: Environmental Data Report 1995*. Prepared for BHP World Minerals by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 1997. *Environmental Baseline Studies Report 1996*. Prepared for BHP World Minerals by Rescan Environmental Services Ltd.:

Rescan. 1998. *Hope Bay Belt Project: 1997 Environmental Data Report*. Prepared for BHP World Minerals by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 1999a. *Hope Bay Belt Project: 1998 Environmental Data Report*. Prepared for BHP Diamonds Inc. by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 1999b. *Hope Bay Belt Site Assessment 1999*. Prepared for BHP Diamonds Inc. by Rescan Environmental Services Ltd.: Yellowknife, NT.

Rescan. 2001. *2000 Supplemental Environmental Baseline Data Report Hope Bay Belt Project*. Prepared for Hope Bay Joint Venture by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2010. *2009 Marine Baseline Report, Hope Bay Belt Project*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2011a. *Doris North Gold Mine Project: 2010 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Limited: Vancouver, BC.

Rescan. 2011b. *Doris North Gold Mine Project: Wildlife Mitigation and Monitoring Program, 2010*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Limited. January 2011.:

Rescan. 2012. *Doris North Gold Mine Project: 2011 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

Rescan. 2013. *Doris North Gold Mine Project: 2012 Aquatic Effects Monitoring Program Report*. Prepared for Hope Bay Mining Limited by Rescan Environmental Services Ltd.: Vancouver, BC.

RL&L Environmental Services Ltd./Golder Associates Ltd. 2003. *Doris North Project: Aquatic Studies 2003*. Prepared for Miramar Hope Bay Ltd. by RL&L Environmental Services Ltd./Golder Associates Ltd. Report No. 03-1370-007: Edmonton, AB.

Sabina Gold & Silver Corp. 2015. *Sabina Gold & Silver reports on important Back River permitting milestone*. http://www.sabinagoldsilver.com/s/news.asp?ReportID=690639 (accessed February 2015).

Wright, D. G. and G. E. Hopky. 1998. *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters*. Canadian Technical Report of Fisheries and Aquatic Sciences 2107