MADRID-BOSTON PROJECT
FINAL 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
ARD	Acid rock drainage
AWR	All-weather road
CCME	Canadian Council of Ministers of the Environment
CEA	Cumulative effects assessment
CEAA	Canadian Environmental Assessment Agency
CWP	Contact water pond
DFO	Fisheries and Oceans Canada
ECCC	Environment and Climate Change Canada
EIS	Environmental Impact Statement
GN DOE	Government of Nunavut, Department of Environment
HDPE	High-density polyethylene
INAC	Indigenous and Northern Affairs Canada
ISQG	Interim Sediment Quality Guidelines
KIA	Kitikmeot Inuit Association
LSA	Local Study Area
ML	Metal leaching
MMER	Metal Mining Effluent Regulations
MOMB	Marine outfall mixing box
NIRB	Nunavut Impact Review Board
NSA	Nunavut Settlement Area
NTKP	Naonaiyaotit Traditional Knowledge Project
NWB	Nunavut Water Board
PAH	Polycyclic aromatic hydrocarbons

PDA	Project Development Area
PEL	Probable Effects Level
Project	The Madrid-Boston Project
QA/QC	Quality assurance and quality control
RSA	Regional Study Area
STP	Sewage treatment plant
TIA	Tailings impoundment area
TK	Traditional knowledge
TMA	Tailings management area
TMAC	TMAC Resources Inc.
TOC	Total organic carbon
tpd	Tonnes per day
TSS	Total suspended solids
VEC	Valued Ecosystem Component
WRR	Winter road route
WTP	Water treatment plant

5. Freshwater Sediment Quality

Freshwater sediment quality has been identified as a Valued Ecosystem Component (VEC) for the Madrid-Boston Project (the Project) because Project activities have the potential to interact with the freshwater environment through infrastructure development, runoff, dust deposition, and the discharge of water. Freshwater sediments are important because they serve as a habitat for benthic organisms, which are key components of aquatic food webs and play an important role in nutrient and metal biogeochemical cycling. Sediment quality is an aggregate term that encompasses a complex suite of parameters and indicators that describe the sediment environment and its ability to sustain ecological and biogeochemical functions.

Project activities may introduce chemical constituents that affect sediment quality by increasing the concentrations of metals, nutrients, organic matter, and pollutants in sediments. The potential effects of the Project on freshwater sediment quality include physical disturbances to sediments from site preparation, construction, and decommissioning activities; inputs of nutrients and pollutants from the use of explosives, fuels, and oils; inputs of metals, nutrients, and pollutants from dust deposition; and exposure to discharges of treated sewage or wastewater containing site or mine contact water. The Project will minimize or eliminate potential adverse changes to sediments through mitigation and management efforts such as erosion and runoff control measures and adherence to effective management practices.

This chapter presents the existing conditions of the freshwater sediment quality as it relates to the proposed Project and identifies and evaluates the potential Project-related effects and cumulative effects within a local and regional context.

5.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

5.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

The *Inuit Traditional Knowledge for TMAC Resources Inc. Proposed Hope Bay Project, Naonaiyaotit Traditional Knowledge Project* (NTKP) report (Banci and Spicker 2016) was reviewed for information related to freshwater sediment quality. There were no direct references relevant to the existing freshwater sediment quality in the NTKP report.

5.1.2 Incorporation of Traditional Knowledge for Valued Ecosystem Component Selection

The NTKP report made no direct reference to freshwater sediment quality (Banci and Spicker 2016). Inuit value the integrity of the environment, and noted the general importance of water quality, benthic invertebrates, fish communities, and fish habitat, all of which are directly affected by or dependent upon sediment quality. Therefore, the importance of freshwater sediment quality as a facet of environmental quality was considered in the selection of freshwater sediment quality as a VEC.

5.1.3 Incorporation of Traditional Knowledge for Spatial and Temporal Boundaries

The results of the NTKP report were considered when developing the spatial and temporal boundaries for the Madrid-Boston 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. Sediment quality is an important component in determining the quality of fish habitat. Therefore, the entire Hope Bay Development area was included within the spatial boundaries of the assessment of freshwater sediment quality.

5.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

The results of the NTKP report were considered when developing the effects assessment for freshwater sediment quality. No specific references relevant to the effects assessment for sediment quality were included in the NTKP report.

5.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

The NTKP report was considered when developing mitigation and adaptive management plans for freshwater sediment quality. No specific references to mitigation and adaptive management measures relevant to sediment quality were included in the NTKP report.

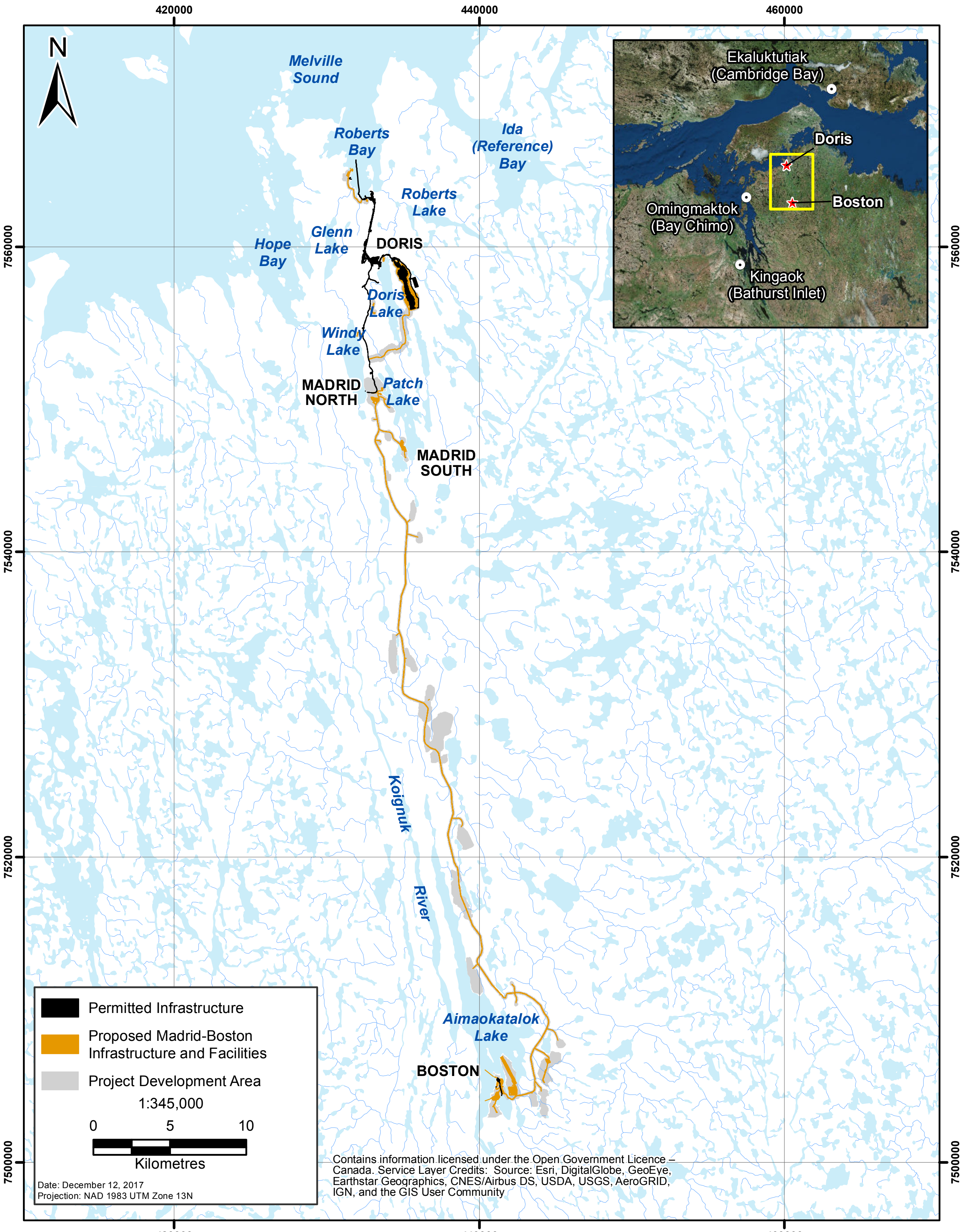
5.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

The Madrid-Boston Project (a component 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 5.2-1). 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 5.2-1). The proposed Project 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 5.4; Figure 5.2-2).

Regionally, the Project lies entirely within the Southern Arctic Ecozone and is situated in an area of continuous permafrost with flat rolling bedrock covered by thin layers of moraine, lacustrine, and fluvial deposits. Winter in the Project area is characterized by extreme cold, with mean monthly temperatures ranging from -33.4ºC to -3.1ºC, and the coldest temperatures occurring 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 occurring in July (see Volume 4, Chapter 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, Chapter 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.; Volume 4, Chapter 8).

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 5.2-2). 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 Madrid-Boston 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 thickness ranging between 1.5 to 2.0 m (Rescan 2010a, 2011b). 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.

Figure 5.2-1
Project Location



Baseline freshwater information has been collected within the greenstone belt since the early 1990s. The following sections provide a summary of the methods and results from the freshwater sediment quality sampling carried out in the Project area and surrounding region. Neither monitoring for sedimentation rates nor the modelling of sediment dispersion has been conducted for the Project as these have been deemed unnecessary based on potential Project activities in or near freshwater environments. Project activities are expected to interact minimally with freshwater sediments, because of the application of mitigation and management measures, as detailed in the relevant management plans provided in Section 5.5.3.2.

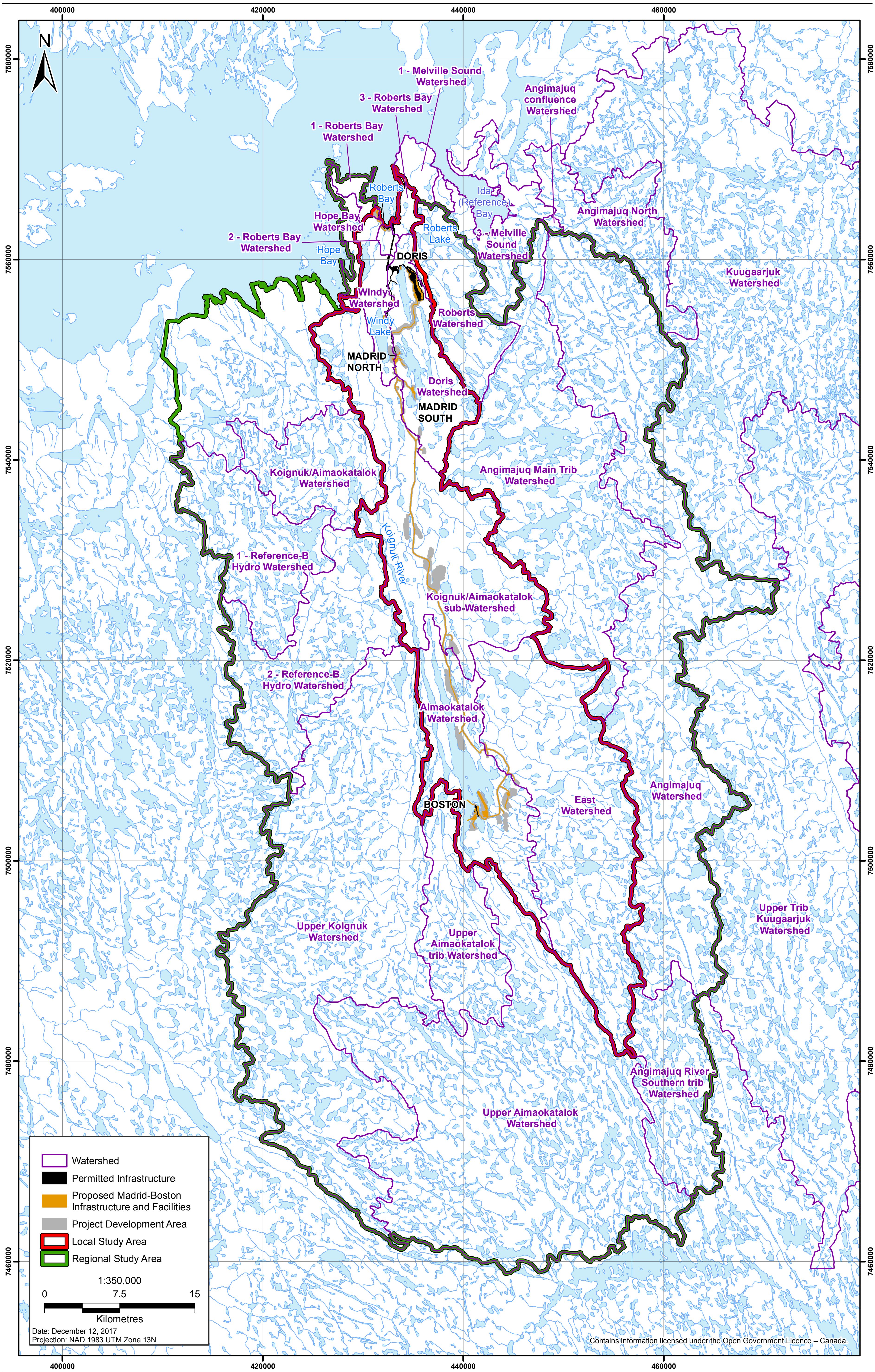
5.2.1 Regulatory Framework

There are several acts, regulations, and guidelines relevant to the management and preservation of freshwater sediment quality. Table 5.2-1 lists and provides a brief description of the key acts and regulations pertaining to freshwater sediment quality.

Table 5.2-1. Federal and Territorial Acts and Regulations Relevant to Freshwater Sediment 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 (INAC)	Arctic Waters Pollution Prevention Regulations	• Prohibits the deposit of waste in Arctic waters unless authorized under the Canada *Water Act*, and describes limits of liability.
Fisheries Act	1985 (2016)	Fisheries and Oceans Canada (DFO) Environment and Climate Change Canada (ECCC)	Metal Mining Effluent Regulations	• 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 (2017)	ECCC	-	• 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)	INAC; NWB	Nunavut Waters Regulations	• Established the Nunavut Water Board (NWB). • 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 (GN-DOE)	-	• Prohibits the discharge of contaminants into the environment without authorization.
Environmental Rights Act	1988 (2011)	GN-DOE	-	• Grants all residents the ability to launch an investigation into the release of a contaminant into the environment.

Figure 5.2-2
Freshwater Sediment Quality Local and Regional Study Areas



In addition to these acts and regulations, the protection of freshwater sediment quality is also guided by the *Canadian Environmental Quality Guidelines* (CCME 2001b), which include the *Sediment Quality Guidelines for the Protection of Aquatic Life* (CCME 2017) published by the Canadian Council of Ministers of the Environment (CCME). These sediment quality guidelines define concentrations of sediment quality parameters that should present a negligible risk to aquatic organisms.

5.2.2 Data Sources

The primary sources of sediment quality data used to describe the existing environment in lakes, streams, and rivers of the LSA and RSA are the baseline studies conducted in 2007, 2009, 2010, and 2017, and the Aquatic Effects Monitoring Program (AEMP) for the Doris Project conducted annually from 2010 to 2017. Although sediment quality data have been collected historically (1993 to 2006) at some sites, only data collected from 2007 to 2017 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 (e.g., ERM 2017a), 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 sediment quality baseline programs conducted in the greenstone belt are described in the following reports:

- Boston Property N.W.T.: Environmental Data Report (Rescan 1994; Appendix V5-3C);
- Hope Bay Belt Project: Environmental Baseline Studies Report 1996 (Rescan 1997; Appendix V5-3F);
- Hope Bay Belt Project: 1997 Environmental Data Report (Rescan 1998; Appendix V5-3G);
- Doris North Project Aquatic Studies 2002 (RL&L / Golder 2003; Appendix V5-5A);
- Boston and Madrid Project Areas 2006 – 2007 Aquatic Studies (Golder 2008; Appendix V5-3P);
- 2009 Freshwater Baseline Report, Hope Bay Belt Project (Rescan 2010b; Appendix V5-3S);
- Hope Bay Belt Project: 2010 Freshwater Baseline Report (Rescan 2011b; Appendix V5-3T);
- 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); and
- Doris North Project: 2014 Aquatic Effects Monitoring Program (ERM 2015a);
- Doris North Project: 2015 Aquatic Effects Monitoring Program Report (ERM 2016);
- Doris Project: 2016 Aquatic Effects Monitoring Program Report (ERM 2017a);
- Doris Project: 2017 Aquatic Effects Monitoring Program Report (ERM In preparation); and
- Hope Bay Project: 2017 Madrid-Boston Freshwater Baseline Report (ERM 2017b; Appendix V5-3U).

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

5.2.3 Methods

5.2.3.1 Lakes

Between 1993 and 2017, sediment quality samples were collected from 13 lakes in the LSA: 10 in the North Belt (Figure 5.2-3) and 3 in the South Belt (Figure 5.2-4). Seven lakes were also sampled for sediment quality throughout the RSA (Figures 5.2-3 and 5.2-4). Sampling efforts focussed on lakes near existing and proposed infrastructure within the LSA, and at reference sites or far-field (downstream) sites in the RSA. Multiple sites and/or depths were often sampled at many of the largest lakes including Doris, Patch, Windy, Glenn, and Aimaokatalok within the LSA; and Reference Lake A and Reference Lake B in the RSA (Figures 5.2-3 and 5.2-4). A summary of the lake sediment quality sampling programs undertaken between 2007 and 2017, including sampling locations and replication, is shown in Table 5.2-2.

Table 5.2-2. Summary of Lake Sediment Sampling Conducted in the LSA and RSA, 2007 to 2017

Year	2007	2009	2010	2011 and 2012	2013 to 2016	2017
Month Sampled	August	August	August	August	August	August
Sampling Equipment	gravity corer Ekman	Ekman	Ekman	Ekman	Ekman	Ekman
Sediment Quality Parameters	Particle size, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, TOC, metals
LSA	North Belt	North Belt	North Belt	North Belt	North Belt	North Belt
	Glenn	Doris	Doris	Doris	Doris	Doris
	Ogama	Glenn	Little Roberts	Little Roberts	Little Roberts	Patch
	P.O.	Imniagut	Patch	-	-	Windy
	Patch	Little Roberts	Windy	-	-	Wolverine
	Windy	Nakhaktok	Wolverine	-	-	-
	Wolverine	Ogama		-	-	-
	-	P.O.		-	-	-
	South Belt	Patch	South Belt	-	-	South Belt
	Aimaokatalok	Windy	Aimaokatalok	-	-	Aimaokatalok
	Stickleback	Wolverine	Stickleback	-	-	Stickleback
	Trout	-	Trout	-	-	-
RSA	Pelvic	Naiqunnguut	Reference B	Reference B	Reference B	Reference B
	Boston Reference	Reference A	Reference D	Reference D	Reference D	-
		Reference B		Roberts		-
Site Replication	n = 5 (gravity corer)	n = 3	n = 3	n = 3	n = 3	n = 3
	n = 1 (Ekman)	-	-	-	-	-

Figure 5.2-3
Historical Freshwater Sediment Sampling Locations in the North Belt LSA and RSA, 1996 to 2017

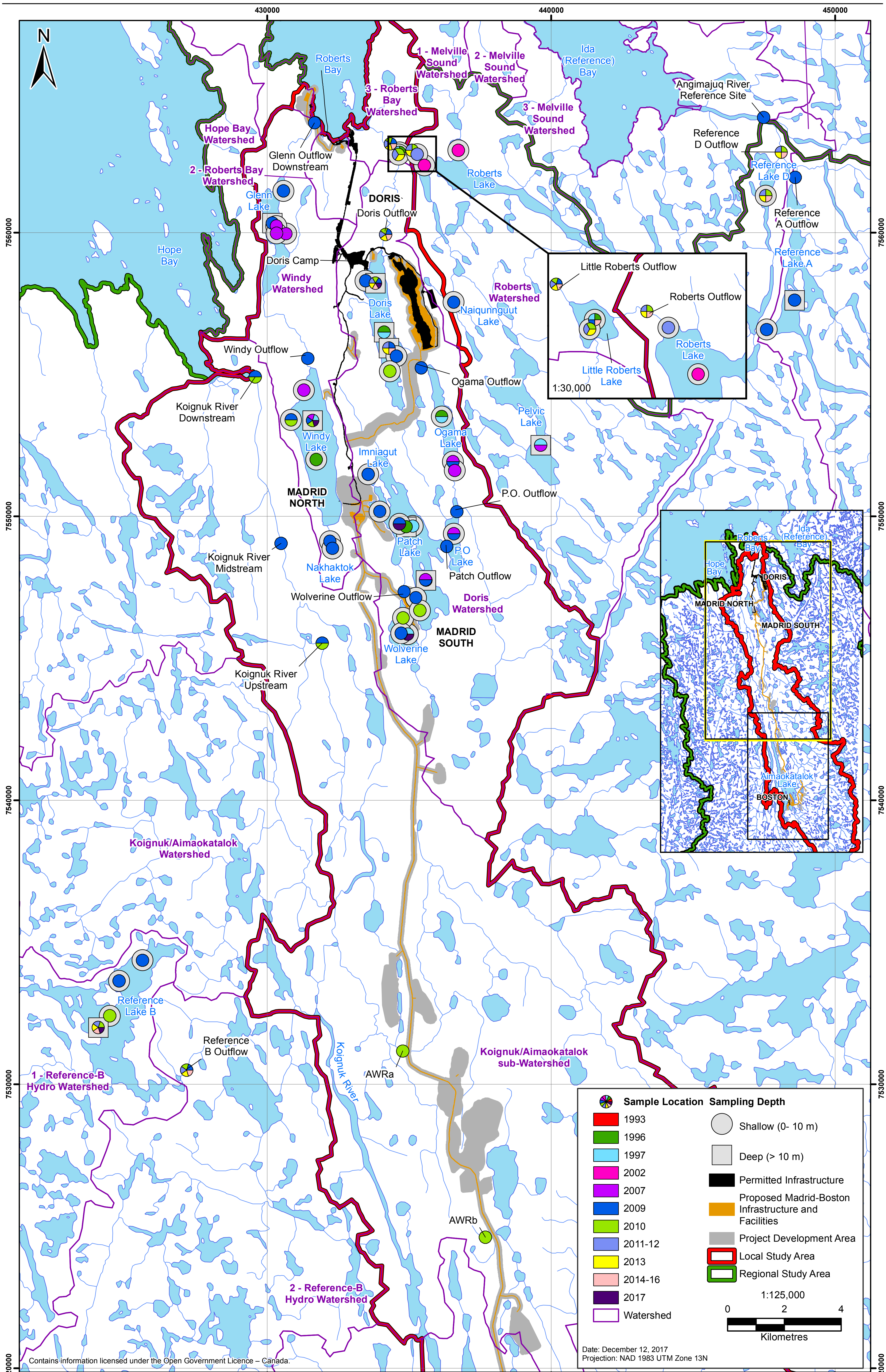
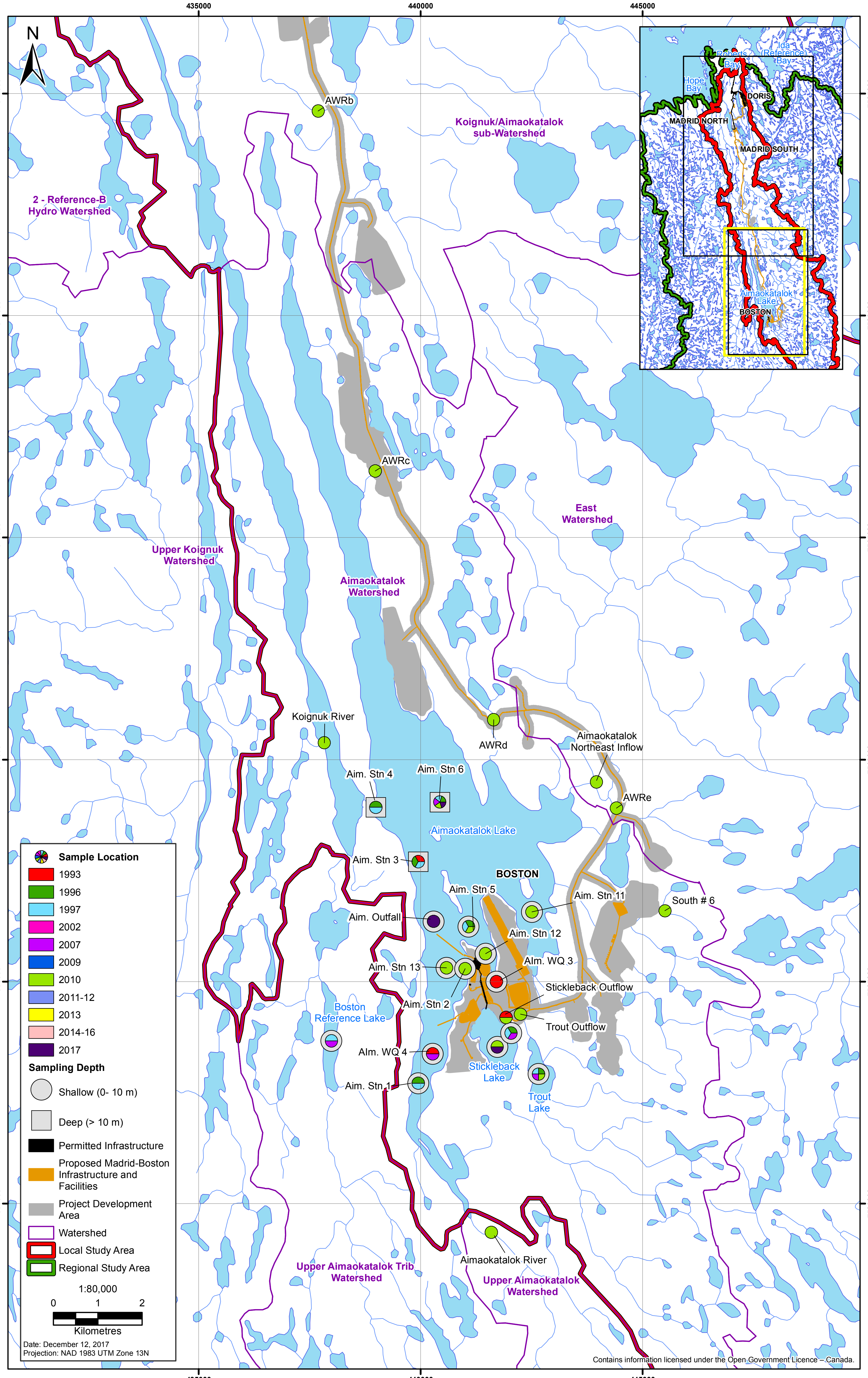


Figure 5.2-4
Historical Freshwater Sediment Sampling Locations in the South Belt LSA and RSA, 1993 to 2017



Lake sediment quality samples were collected using an Ekman dredge (2007 to 2017) or a Wildco gravity corer (2007 only), with one to five replicate samples collected at each site. The top few centimetres of each sediment sample were subsampled and stored in clean plastic bags, and sent to Maxxam Analytics Inc. (Burnaby, BC; 2007) or ALS Environmental (Vancouver or Burnaby, BC; 2009 to 2017) for analysis of physical and chemical properties. Full methodologies can be found in the historical baseline and AEMP reports listed in Section 5.2.2.

For the characterization of existing conditions, data were grouped by depth strata since sediments in shallow, near-shore areas tend to be coarser than deeper, calmer areas where finer materials settle, and fine-grain sediments tend to be associated with higher metal and organic carbon concentrations. Sample depths of 0 to 10 m were considered ‘shallow’ sites, and sample depths greater than 10 m were considered ‘deep’ sites.

5.2.3.2 Streams and Rivers

Sediment quality samples were collected from 16 streams and rivers in the LSA and 7 streams and rivers throughout the RSA from 1993 to 2017 (Figures 5.2-3 and 5.2-4). Sampling efforts focussed on streams and rivers near existing and proposed infrastructure within the LSA, and at reference sites or far-field (downstream) sites in the RSA. The Koignuk River was sampled upstream in the South Belt LSA and downstream in the North Belt LSA (Figures 5.2-3 and 5.2-4). A summary of the sampling programs undertaken between 2009 and 2016 (there were no stream or river sediment samples collected in 2007, 2008, or 2017), including sampling locations and replication, is shown in Table 5.2-3.

Table 5.2-3. Summary of Stream and River Sediment Sampling Conducted in the LSA and RSA, 2009 to 2016

Year	2009	2010	2011 to 2016
Month Sampled	August	August	August
Sampling Equipment	Grab samples	Grab samples	Grab samples
Sediment Quality Parameters	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals	Particle size, nutrients, TOC, metals
LSA	North Belt	North Belt	North Belt
	Doris OF	AWRa	Doris OF
	Glenn OF	AWRb	Little Roberts OF
	Koignuk River	Doris OF	-
	Little Roberts OF	Koignuk River	-
	Ogama OF	Little Roberts OF	-
	P.O. OF	-	-
	Patch OF	South Belt	-
	Windy OF	Aimaokatalok NE IF	-
	-	AWRc	-
	-	AWRd	-
	-	AWRe	-
	-	Koignuk River	-
	-	S6	-
	-	Stickleback OF	-
	-	Trout OF	-

Year	2009	2010	2011 to 2016
RSA	Angimajug River Reference A OF Reference B OF -	Aimaokatalok River Reference B OF Reference D OF Roberts OF	Reference B OF Reference D OF Roberts OF -
Site Replication	n = 3	n = 3	n = 3

Note: OF = Outflow, IF = Inflow, NE = Northeast

From 2009 to 2016, stream and river sediment quality samples were typically collected using a plastic spoon and bowl. Three replicate samples were collected at each site, with each replicate consisting of several spoonfuls of sediments, with replicates collected three times the channel width apart whenever possible. The sediments were carefully drained of excess water, homogenized, and transferred into Whirl-Pak bags. An Ekman dredge was used occasionally (as described for lake sediment sampling) if the site consisted of fine-grained material or was too deep or fast flowing to sample using the spoon method. The samples were kept cool until shipment to ALS Environmental (Vancouver or Burnaby, BC) where the sediments were analyzed for particle size, nutrients, total organic carbon (TOC), and metals content. Full methodologies can be found in the historical baseline and AEMP reports listed in Section 5.2.2.

5.2.3.3 Quality Assurance and Quality Control

The lake, stream, and river sediment sampling quality assurance and quality control (QA/QC) program included the use of chain of custody forms and the collection of replicate sediment samples to account for within-site variability.

5.2.3.4 Calculation of Summary Statistics

Summary statistics were calculated for sediment quality parameters within the LSA (North Belt and South Belt) and the RSA. The North Belt LSA includes the Doris, Windy, and Koignuk-Aimaokatalok sub-watersheds and the South Belt LSA includes the Aimaokatalok and East watersheds (Figure 5.2-2).

For the calculation of minimum, maximum, mean, median, and the 75th and 95th percentile values for sediment 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 sample 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 sample 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). Whenever the value of the minimum or maximum was a censored value (i.e., the sample concentration was 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) to clearly distinguish censored values.

Sediment quality data collected from the same site and on the same date (replicates) were averaged prior to the calculation of the mean, median, and the 75th and 95th percentiles, and for comparisons against sediment quality guidelines to give equal weighting to samples regardless of the degree of replication.

5.2.4 Characterization of Existing Conditions

Many aquatic organisms live in or on the sediments (benthic organisms or benthos), and these organisms are potential prey items for higher trophic level consumers. The CCME has established interim guidelines for sediment quality parameters to monitor and protect freshwater life from acute and chronic toxicity (CCME 2017). 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 1995).

Summaries of particle size and sediment quality results from the lake, stream, and river sampling programs conducted from 2007 to 2017 are provided below. These data are discussed within the framework of CCME sediment quality guidelines where applicable (CCME 2017).

5.2.4.1 Lakes

Lake sediment quality data were grouped by project area (North Belt LSA, South Belt LSA, and RSA) to highlight general regional trends. These data are presented in Tables 5.2-4 to 5.2-6. Lake-specific data for LSA lakes are presented in Table 5.2-7.

<u>Sediment Composition</u>

The particle size composition of sediments is important for determining the type and variety of benthic organisms, and estimating the metal adsorption potential and organic carbon content of the sediments. Finer sediments composed of silt and clay tend to have greater concentrations of organic carbon and metals and may host different types of benthic organisms compared to coarser sediments.

Lake sediments collected from the LSA and RSA were mainly comprised of fine material, with mean silt and clay contents ranging from 78 to 85% in shallow sampling sites (0 to 10 m depth) and from 87 to 99% in deep sites (> 10 m depth; Table 5.2-4). Shallower areas typically contained more sand and less clay than deeper areas. The mean gravel content was low in all study areas (≤ 2%; Table 5.2-4).

Table 5.2-4. Lake Sediment Composition in the LSA and RSA, 2007 to 2017

Parameter	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
LSA - North Belt						
Shallow Sites	**n = 81**	**n = 27**	**n = 27**	**n = 27**	**n = 27**	**n = 81**
Gravel > 2 mm (%)	< 0.1	0.5	0.5	0.5	1.3	4.0
Sand 2.0 mm - 0.063 mm (%)	< 0.5	18	8.3	19	81	91
Silt 0.063 mm - 4 µm (%)	5.0	54	58	66	77	81
Clay < 4 µm (%)	2.0	27	26	35	53	64
Deep Sites	**n = 63**	**n = 21**	**n = 21**	**n = 21**	**n = 21**	**n = 63**
Gravel > 2 mm (%)	< 0.1	0.3	0.05	0.5	0.5	4.0
Sand 2.0 mm - 0.063 mm (%)	0.2	1.0	0.8	1.3	1.7	3.3
Silt 0.063 mm - 4 µm (%)	24	54	50	60	75	91
Clay < 4 µm (%)	8.0	45	48	50	62	76
LSA - South Belt						
Shallow Sites	**n = 27**	**n = 9**	**n = 9**	**n = 9**	**n = 9**	**n = 27**
Gravel > 2 mm (%)	< 0.1	0.9	0.1	0.5	3.9	17
Sand 2.0 mm - 0.063 mm (%)	< 1	22	8.4	41	51	70

Parameter	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
Silt 0.063 mm - 4 µm (%)	26	59	58	66	86	94
Clay < 4 µm (%)	0.3	18	18	28	40	49
Deep Sites	**n = 6**	**n = 2**	**n = 2**	**n = 2**	**n = 2**	**n = 6**
Gravel > 2 mm (%)	< 1.0	All concentrations below detection limits				< 1.0
Sand 2.0 mm - 0.063 mm (%)	7.4	9.9	9.9	10	11	12
Silt 0.063 mm - 4 µm (%)	43	49	49	51	53	60
Clay < 4 µm (%)	30	41	41	44	47	49
RSA						
Shallow Sites	**n = 42**	**n = 14**	**n = 14**	**n = 14**	**n = 14**	**n = 42**
Gravel > 2 mm (%)	< 0.1	0.3	0.1	0.4	1.0	4.0
Sand 2.0 mm - 0.063 mm (%)	0.2	15	6.0	27	47	74
Silt 0.063 mm - 4 µm (%)	21	65	66	79	89	95
Clay < 4 µm (%)	2.5	20	19	21	46	64
Deep Sites	**n = 27**	**n = 9**	**n = 9**	**n = 9**	**n = 9**	**n = 27**
Gravel > 2 mm (%)	< 0.1	2.1	0.6	0.9	7.6	24
Sand 2.0 mm - 0.063 mm (%)	1.0	11	11	13	18	24
Silt 0.063 mm - 4 µm (%)	42	56	58	59	62	67
Clay < 4 µm (%)	9.5	31	31	35	43	53

Notes:
n = number observations.
'<' indicates that concentration was less than the analytical detection limit shown.
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 sample.
[b] Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).

Among the LSA lakes, nearly all lake sediments were dominated by silt, except Glenn and P.O. lakes that had sediments consisting mostly of clay (Table 5.2-7).

Total Organic Carbon and Nutrients

The mean TOC content of sediments ranged from 2.0 to 3.6% in the shallow sites of the LSA and RSA, and from 0.8 to 2.2% in the deep sites (Table 5.2-5). The pooled data from all samples indicated that TOC content was positively correlated with silt content ($r = 0.61$, $p < 0.001$, $n = 249$; Pearson's correlations of logit transformed percentage data) and negatively correlated with sand content ($r = -0.57$, $p < 0.001$, $n = 249$).

Within the LSA, the mean TOC content of sediments was highest at Stickleback Lake (10.3%), followed by Imniagut Lake (7.8%). Sediments from Windy Lake (0.58%) and Ogama Lake (0.57%) contained the least TOC (Table 5.2-7).

Concentrations of plant available nitrate and nitrite were generally near or below detection limits in lakes of the LSA and RSA. Available ammonium concentrations were highest in the South Belt LSA sediments, and available phosphate concentrations were variable among sites and sampling depths (Table 5.2-5).

Table 5.2-5. Lake Sediment Total Organic Carbon and Nutrient Concentrations in the LSA and RSA, 2007 to 2017

Parameter	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
LSA - North Belt						
Shallow Sites	**n = 114**	**n = 40**	**n = 40**	**n = 40**	**n = 40**	**n = 114**
Total Organic Carbon (%)	0.05	2.0	1.7	2.6	7.3	8.9
	n = 75	**n = 25**	**n = 25**	**n = 25**	**n = 25**	**n = 75**
Available Ammonium (as N) (mg/kg)	1.2	20	15	23	64	117
Available Nitrate (as N) (mg/kg)	< 2	2.4	1.6	2.6	3.9	30
Available Nitrite (as N) (mg/kg)	< 0.4	All concentrations below detection limits				< 1.7
Available Phosphate (as P) (mg/kg)	< 2	5.3	4.3	5.3	11	52
Deep Sites	**n = 75**	**n = 24**	**n = 24**	**n = 24**	**n = 24**	**n = 75**
Total Organic Carbon (%)	0.07	2.2	2.8	3.0	3.1	3.3
	n = 60	**n = 20**	**n = 20**	**n = 20**	**n = 20**	**n = 60**
Available Ammonium (as N) (mg/kg)	1.74	25	29	31	40	75
Available Nitrate (as N) (mg/kg)	< 2	1.7	2.0	2.0	2.1	2.9
Available Nitrite (as N) (mg/kg)	< 0.4	All concentrations below detection limits				< 1
Available Phosphate (as P) (mg/kg)	< 2	3.7	2.6	3.5	11	21
LSA - South Belt						
Shallow Sites	**n = 40**	**n = 14**	**n = 14**	**n = 14**	**n = 14**	**n = 40**
Total Organic Carbon (%)	0.04	3.6	0.9	1.9	19	23
	n = 21	**n = 7**	**n = 7**	**n = 7**	**n = 7**	**n = 21**
Available Ammonium (as N) (mg/kg)	< 0.8	8.6	6.9	10	23	34
Available Nitrate (as N) (mg/kg)	< 2	All concentrations below detection limits				< 5
Available Nitrite (as N) (mg/kg)	< 0.4	All concentrations below detection limits				< 1
Available Phosphate (as P) (mg/kg)	< 2	4.4	3.9	4.4	8.2	12
Deep Sites	**n = 12**	**n = 4**	**n = 4**	**n = 4**	**n = 4**	**n = 12**
Total Organic Carbon (%)	0.08	0.8	0.7	1.5	1.7	1.9
	n = 3	**n = 1**	**n = 1**	**n = 1**	**n = 1**	**n = 3**
Available Ammonium (as N) (mg/kg)	5.8	7.2	7.2	7.2	7.2	8.7
Available Nitrate (as N) (mg/kg)	< 5	All concentrations below detection limits				< 6
Available Nitrite (as N) (mg/kg)	< 1	All concentrations below detection limits				< 1.2
Available Phosphate (as P) (mg/kg)	9.4	11	11	11	11	15
RSA						
Shallow Sites	**n = 49**	**n = 17**	**n = 17**	**n = 17**	**n = 17**	**n = 49**
Total Organic Carbon (%)	0.1	3.4	3.4	4.4	8.8	11
	n = 42	**n = 14**	**n = 14**	**n = 14**	**n = 14**	**n = 42**
Available Ammonium (as N) (mg/kg)	2.3	22	23	30	43	80
Available Nitrate (as N) (mg/kg)	< 2	2.1	2.0	2.5	4.4	6.5
Available Nitrite (as N) (mg/kg)	< 0.4	All concentrations below detection limits				< 4
Available Phosphate (as P) (mg/kg)	< 2	7.9	6.0	7.2	21	41

Parameter	Min[a]	Mean[b]	Median[b]	75th percentile[b]	95th percentile[b]	Max[c]
Deep Sites	**n = 33**	**n = 11**	**n = 11**	**n = 11**	**n = 11**	**n = 33**
Total Organic Carbon (%)	0.14	1.1	0.6	1.5	3.1	5.3
	n = 27	**n = 9**	**n = 9**	**n = 9**	**n = 9**	**n = 27**
Available Ammonium (as N) (mg/kg)	< 1.6	5.5	5.2	5.8	9.6	13
Available Nitrate (as N) (mg/kg)	< 2	All concentrations below detection limits				< 6
Available Nitrite (as N) (mg/kg)	< 0.4	All concentrations below detection limits				< 1.2
Available Phosphate (as P) (mg/kg)	< 2	17	3.3	11	63	124

Notes:
n = number observations.
'<' indicates that concentration was less than the analytical detection limit shown.
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 sample.
[b] Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).

Metals

Metal concentrations in lake sediments were examined within the framework of CCME guidelines (CCME 2017). The Interim Sediment Quality Guidelines (ISQG) are conservative empirical thresholds below which no effects on freshwater benthic organisms are predicted to occur. The CCME Probable Effects Level (PEL) thresholds describe the sediment concentration at which biological effects are likely to occur. The concentrations of lake sediment metals of interest in the LSA and RSA as well as the CCME guidelines for these sediment metal concentrations are summarized in Table 5.2-6. Lake-specific sediment metal concentrations are summarized in Table 5.2-7.

With the exception of copper and mercury concentrations in RSA sediments and arsenic concentrations in South Belt LSA sediments, mean concentrations of sediment metals were typically greater at deep depths in the LSA and RSA lakes compared to shallow depths. This corresponds to the higher proportions of silt and clay particles in the sediments collected at deep depths compared to shallow depth. Within each depth class, mean metal concentrations tended to highest in the North Belt LSA compared to the other study areas (Table 5.2-6).

Several metal concentrations were naturally low in the LSA and RSA lake sediments: cadmium, lead, mercury, and zinc concentrations were consistently below CCME ISQG and PEL guideline levels. In contrast, some metals such as chromium were naturally elevated in the LSA and RSA lake sediments. Mean concentrations of chromium in LSA and RSA sediments were consistently above the ISQG of 37.3 mg/kg in the deep-water samples, and were frequently greater than the ISQG in the shallow waters (Table 5.2-6). Mean arsenic and copper concentrations were also frequently greater than the ISQGs of 5.9 mg/kg for arsenic and 35.7 mg/kg for copper in sediments of the LSA and RSA lakes (Table 5.2-6). Arsenic concentrations in sediments collected from the North Belt LSA (specifically, Doris Lake) were also occasionally greater than the PEL of 17 mg/kg (Tables 5.2-6 and 5.2-7).

Within the LSA, Doris Lake sediments contained the highest mean arsenic concentration (11.6 mg/kg), and Imniagut Lake sediments contained the highest mean chromium (74.5 mg/kg) and copper (58.5 mg/kg) concentrations (Table 5.2-7).

Table 5.2-6. Lake Sediment Metal Concentrations in the LSA and RSA, 2007 to 2017

Parameter	CCME Guidelines for the Protection of Aquatic Life (mg/kg)[a]		Total Metal Concentration (mg/kg)						% of Sample Concentrations Greater than ISQG[e]	% of Sample Concentrations Greater than PEL[e]
	ISQG[b]	PEL[c]	Min[d]	Mean[e]	Median[e]	75th Percentile[e]	95th Percentile[e]	Max[f]		
LSA - North Belt										
Shallow Sites			**n = 114**	**n = 40**	**n = 40**	**n = 40**	**n = 40**	**n = 114**	**n = 40**	**n = 40**
Arsenic	5.9	17	0.98	4.7	3.6	5.1	11.7	18.4	20	0
Cadmium	0.6	3.5	< 0.05	0.085	0.082	0.108	0.145	0.190	0	0
Chromium	37.3	90	14.5	57.0	59.5	70.0	77.8	84.8	88	0
Copper	35.7	197	6.4	30.9	29.8	37.4	53.7	60.8	30	0
Lead	35	91.3	2.2	8.1	8.2	9.9	12.6	13.9	0	0
Mercury	0.17	0.49	< 0.005	0.0229	0.0250	0.0250	0.0343	0.0676	0	0
Zinc	123	315	15.0	69.6	71.7	80.2	97.1	105	0	0
Deep Sites			**n = 75**	**n = 24**	**n = 24**	**n = 24**	**n = 24**	**n = 75**	**n = 24**	**n = 24**
Arsenic	5.9	17	3.27	12.0	11.6	15.2	22.4	30.1	75	21
Cadmium	0.6	3.5	0.080	0.121	0.118	0.133	0.160	0.180	0	0
Chromium	37.3	90	63.9	74.2	74.7	77.4	81.0	91.0	100	0
Copper	35.7	197	30.9	40.2	39.8	42.2	48.5	51.1	88	0
Lead	35	91.3	9.4	11.2	10.8	11.5	13.5	15.1	0	0
Mercury	0.17	0.49	0.0168	0.0469	0.0527	0.0594	0.0669	0.0807	0	0
Zinc	123	315	80.9	95.8	96.0	102	106	110	0	0
LSA - South Belt										
Shallow Sites			**n = 40**	**n = 14**	**n = 14**	**n = 14**	**n = 14**	**n = 40**	**n = 14**	**n = 14**
Arsenic	5.9	17	0.558	4.28	3.58	4.69	9.84	15.6	21	0
Cadmium	0.6	3.5	< 0.05	0.095	0.087	0.138	0.174	0.330	0	0
Chromium	37.3	90	7.6	34.4	37.1	43.0	57.0	64.5	50	0
Copper	35.7	197	2.0	22.1	20.9	33.5	47.0	50.2	29	0
Lead	35	91.3	< 2.0	5.53	5.80	6.62	9.72	10.7	0	0
Mercury	0.17	0.49	< 0.005	0.0244	0.0250	0.0250	0.0551	0.0671	0	0
Zinc	123	315	9.0	51.1	59.9	64.0	78.9	94.2	0	0

Parameter	CCME Guidelines for the Protection of Aquatic Life (mg/kg)[a]		Total Metal Concentration (mg/kg)						% of Sample Concentrations Greater than ISQG[e]	% of Sample Concentrations Greater than PEL[e]
	ISQG[b]	PEL[c]	Min[d]	Mean[e]	Median[e]	75th Percentile[e]	95th Percentile[e]	Max[f]		
Deep Sites			**n = 12**	**n = 4**	**n = 4**	**n = 4**	**n = 4**	**n = 12**	**n = 4**	**n = 4**
Arsenic	5.9	17	2.40	3.75	3.54	3.80	4.38	4.58	0	0
Cadmium	0.6	3.5	< 0.1	0.142	0.157	0.164	0.179	0.260	0	0
Chromium	37.3	90	52.0	60.8	59.4	64.8	68.5	77.7	100	0
Copper	35.7	197	20.4	22.3	22.3	23.1	23.2	25.4	0	0
Lead	35	91.3	7.7	9.2	8.9	9.8	10.6	12.8	0	0
Mercury	0.17	0.49	0.0249	0.0339	0.0308	0.0397	0.0471	0.0517	0	0
Zinc	123	315	81.0	95.0	95.8	96.6	97.9	111	0	0
RSA										
Shallow Sites			**n = 49**	**n = 17**	**n = 17**	**n = 17**	**n = 17**	**n = 49**	**n = 17**	**n = 17**
Arsenic	5.9	17	0.6	3.05	2.63	3.14	7.62	10.6	12	0
Cadmium	0.6	3.5	< 0.05	0.121	0.089	0.119	0.296	0.380	0	0
Chromium	37.3	90	14.1	44.4	44.5	51.7	61.7	77.5	76	0
Copper	35.7	197	10.2	30.6	22.8	36.9	64.5	85.3	29	0
Lead	35	91.3	2.60	6.48	6.80	7.43	8.13	10.5	0	0
Mercury	0.17	0.49	0.005	0.0256	0.0242	0.0301	0.0430	0.0598	0	0
Zinc	123	315	28.9	68.6	69.3	82.2	107	115	0	0
Deep Sites			**n = 33**	**n = 11**	**n = 11**	**n = 11**	**n = 11**	**n = 33**	**n = 11**	**n = 11**
Arsenic	5.9	17	1.46	4.35	4.57	5.33	5.72	7.10	0	0
Cadmium	0.6	3.5	0.060	0.231	0.240	0.283	0.397	0.774	0	0
Chromium	37.3	90	37.3	50.6	46.7	58.1	67.3	68.0	100	0
Copper	35.7	197	16.8	27.9	21.9	31.5	50.9	73.6	9	0
Lead	35	91.3	5.56	7.32	7.17	8.00	9.65	10.5	0	0
Mercury	0.17	0.49	0.0055	0.0178	0.0103	0.0226	0.0441	0.0646	0	0
Zinc	123	315	46.7	71.9	76.2	82.6	90.1	129	0	0

Table 5.2-6 notes:
n = number observations.
'<' indicates that concentration was less than the analytical detection limit shown.
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] Canadian sediment quality guidelines for the protection freshwater aquatic life, Canadian Council Ministers the Environment (CCME 2017).
[b] ISQG = Interim Sediment Quality Guideline.
[c] PEL = Probable Effects Level.
[d] Minimum represents the lowest concentration in any sample.
[e] Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.
[f] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).

Table 5.2-7. Lake-specific Sediment Quality Summary, 2007 to 2017

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Aimaokatalok	Gravel > 2 mm (%)	24	8	< 0.1	1.0	0.35	0.50	4.2	17	-	-
	Sand 2.0 mm - 0.063 mm (%)	24	8	3.5	27	25	42	52	70	-	-
	Silt 0.063 mm - 4 µm (%)	24	8	26	50	49	57	63	88	-	-
	Clay <4 µm (%)	24	8	0.33	23	23	37	46	49	-	-
	Total Organic Carbon (%)	31	11	0.04	0.76	0.42	1.15	1.98	2.21	-	-
	Available Ammonium (as N)	18	6	< 0.8	5.0	4.6	7.1	10.0	26.1	-	-
	Available Nitrate (as N)	18	6	< 2	All concentrations below detection limits				< 6	-	-
	Available Nitrite (as N)	18	6	< 0.4	All concentrations below detection limits				< 1.2	-	-
	Available Phosphate (as P)	18	6	< 2	4.8	3.9	4.6	9.8	15.4	-	-
	Total Arsenic	31	11	0.56	4.12	3.52	4.16	10.1	15.6	18%	0%
	Total Cadmium	31	11	< 0.05	0.096	0.070	0.149	0.171	0.260	0%	0%
	Total Chromium	31	11	7.6	40.4	54.9	58.4	66.4	77.7	55%	0%
	Total Copper	31	11	2.0	15.3	21.5	23.0	23.3	25.4	0%	0%
	Total Lead	31	11	< 2	6.5	8.3	9.4	10.5	12.8	0%	0%
	Total Mercury	31	11	< 0.005	0.0233	0.0250	0.0308	0.0506	0.0544	0%	0%
	Total Zinc	31	11	9.0	60.1	76.1	92.9	97.1	111.0	0%	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Doris	Gravel > 2 mm (%)	57	19	< 0.1	0.34	0.05	0.28	1.8	4.0	-	-
	Sand 2.0 mm - 0.063 mm (%)	57	19	0.26	7.2	1.0	1.6	37	86	-	-
	Silt 0.063 mm - 4 µm (%)	57	19	9.0	54	50	60	77	91	-	-
	Clay <4 µm (%)	57	19	3.0	38	44	49	55	60	-	-
	Total Organic Carbon (%)	57	19	0.38	2.66	2.84	3.02	3.09	3.32	-	-
	Available Ammonium (as N)	57	19	2.3	25.9	29.3	31.5	40.5	74.5	-	-
	Available Nitrate (as N)	57	19	< 2	All concentrations below detection limits				< 4	-	-
	Available Nitrite (as N)	57	19	< 0.4	All concentrations below detection limits				< 0.8	-	-
	Available Phosphate (as P)	57	19	< 2	2.6	2.3	3.1	4.4	10.5	-	-
	Total Arsenic	57	19	2.20	11.6	11.7	15.3	21.0	27.2	74%	21%
	Total Cadmium	57	19	< 0.1	0.118	0.118	0.135	0.165	0.180	0%	0%
	Total Chromium	57	19	21.3	68.8	70.9	77.1	79.8	83.1	95%	0%
	Total Copper	57	19	7.3	37.1	38.9	41.4	45.6	47.7	79%	0%
	Total Lead	57	19	2.2	10.4	10.7	11.4	12.7	15.1	0%	0%
	Total Mercury	57	19	0.0051	0.0530	0.0558	0.0618	0.0676	0.0807	0%	0%
	Total Zinc	57	19	19.5	91.7	96.2	103	106	110	0%	0%
Glenn	Gravel > 2 mm (%)	6	2	< 1	All concentrations below detection limits				< 1	-	-
	Sand 2.0 mm - 0.063 mm (%)	6	2	< 1	2.6	2.6	3.6	4.5	6.0	-	-
	Silt 0.063 mm - 4 µm (%)	6	2	24	30	30	32	34	36	-	-
	Clay <4 µm (%)	6	2	58	68	68	71	74	76	-	-
	Total Organic Carbon (%)	13	5	0.046	0.297	0.066	0.600	0.691	0.740	-	-
	Available Ammonium (as N)	6	2	1.7	1.9	1.9	1.9	2.0	2.4	-	-
	Available Nitrate (as N)	6	2	< 2	2.4	2.4	2.6	2.7	2.9	-	-
	Available Nitrite (as N)	6	2	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	6	2	1.30	2.80	2.80	3.35	3.79	4.10	-	-
	Total Arsenic	13	5	2.30	2.95	2.70	3.33	3.59	4.07	0%	0%
	Total Cadmium	13	5	0.050	0.089	0.084	0.117	0.117	0.120	0%	0%
	Total Chromium	13	5	49.0	72.0	75.4	75.7	84.7	91.0	100%	0%
	Total Copper	13	5	30.0	39.8	37.9	45.3	48.0	51.1	80%	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Glenn	Total Lead	13	5	6.7	10.5	9.9	12.6	13.4	14.0	0%	0%
	Total Mercury	13	5	0.0115	0.0211	0.0250	0.0250	0.0250	0.0190	0%	0%
	Total Zinc	13	5	64.0	91.7	97.2	100	105	110	0%	0%
Imniagut	Gravel > 2 mm (%)	3	1	< 1	All concentrations below detection limits				< 1	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	2.0	5.3	5.3	5.3	5.3	11.0	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	52	56	56	56	56	59	-	-
	Clay <4 µm (%)	3	1	37	39	39	39	39	41	-	-
	Total Organic Carbon (%)	3	1	6.95	7.82	7.82	7.82	7.82	8.58	-	-
	Available Ammonium (as N)	3	1	60.6	66.2	66.2	66.2	66.2	73.2	-	-
	Available Nitrate (as N)	3	1	< 2	1.7	1.7	1.7	1.7	2.2	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	4.90	25.5	25.5	25.5	25.5	51.8	-	-
	Total Arsenic	3	1	4.25	5.04	5.04	5.04	5.04	6.60	0%	0%
	Total Cadmium	3	1	0.160	0.173	0.173	0.173	0.173	0.190	0%	0%
	Total Chromium	3	1	73.1	74.9	74.9	74.9	74.9	76.2	100%	0%
	Total Copper	3	1	56.5	58.5	58.5	58.5	58.5	60.8	100%	0%
	Total Lead	3	1	11.0	11.3	11.3	11.3	11.3	11.6	0%	0%
	Total Mercury	3	1	0.0555	0.0626	0.0626	0.0626	0.0626	0.0676	0%	0%
	Total Zinc	3	1	95.7	97.1	97.1	97.1	97.1	98.6	0%	0%
Little Roberts	Gravel > 2 mm (%)	24	8	< 0.1	0.14	0.05	0.11	0.42	0.74	-	-
	Sand 2.0 mm - 0.063 mm (%)	24	8	0.51	11	9.4	14	19	32	-	-
	Silt 0.063 mm - 4 µm (%)	24	8	52	70	70	76	79	81	-	-
	Clay <4 µm (%)	24	8	12	20	21	23	27	33	-	-
	Total Organic Carbon (%)	24	8	0.96	2.50	2.29	3.09	3.46	4.83	-	-
	Available Ammonium (as N)	24	8	8.4	21.3	19.6	24.9	35.0	43.8	-	-
	Available Nitrate (as N)	24	8	< 2	3.8	1.8	3.0	12.4	30.3	-	-
	Available Nitrite (as N)	24	8	< 0.4	All concentrations below detection limits				< 1.2	-	-
	Available Phosphate (as P)	24	8	< 2	4.6	4.1	4.8	9.0	24.5	-	-
	Total Arsenic	24	8	2.11	3.48	3.50	3.78	4.31	4.74	0%	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Little Roberts	Total Cadmium	24	8	< 0.05	0.094	0.089	0.109	0.128	0.140	0%	0%
	Total Chromium	24	8	32.6	49.7	49.7	53.6	56.0	60.8	100%	0%
	Total Copper	24	8	15.9	25.6	24.7	28.1	32.1	34.2	0%	0%
	Total Lead	24	8	4.2	6.4	6.2	7.3	7.7	8.9	0%	0%
	Total Mercury	24	8	0.0070	0.0221	0.0205	0.0236	0.0316	0.0390	0%	0%
	Total Zinc	24	8	37.8	67.1	67.9	70.6	77.9	88.0	0%	0%
Nakhaktok	Gravel > 2 mm (%)	6	2	< 1	All concentrations below detection limits				< 1	-	-
	Sand 2.0 mm - 0.063 mm (%)	6	2	2.0	7.0	7.0	8.3	9.4	14	-	-
	Silt 0.063 mm - 4 µm (%)	6	2	55	59	59	60	60	62	-	-
	Clay <4 µm (%)	6	2	28	34	34	36	37	40	-	-
	Total Organic Carbon (%)	6	2	2.80	4.01	4.01	4.36	4.64	5.05	-	-
	Available Ammonium (as N)	6	2	8.5	32.6	32.6	44.1	53.3	66.8	-	-
	Available Nitrate (as N)	6	2	< 2	2.0	2.0	2.3	2.6	3.9	-	-
	Available Nitrite (as N)	6	2	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	6	2	2.7	5.2	5.2	5.9	6.5	7.3	-	-
	Total Arsenic	6	2	2.24	9.98	9.98	10.8	11.5	18.4	100%	0%
	Total Cadmium	6	2	< 0.1	0.100	0.100	0.113	0.124	0.130	0%	0%
	Total Chromium	6	2	58.8	63.1	63.1	64.4	65.4	67.5	100%	0%
	Total Copper	6	2	36.9	46.0	46.0	49.6	52.5	55.9	100%	0%
	Total Lead	6	2	9.5	10.5	10.5	10.8	11.0	11.5	0%	0%
	Total Mercury	6	2	0.0212	0.0283	0.0283	0.0313	0.0337	0.0363	0%	0%
	Total Zinc	6	2	68.8	75.2	75.2	77.2	78.8	82.6	0%	0%
Ogama	Gravel > 2 mm (%)	3	1	< 1	0.67	0.67	0.67	0.67	1.0	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	6	18	18	18	18	39	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	41	56	56	56	56	65	-	-
	Clay <4 µm (%)	3	1	20	26	26	26	26	33	-	-
	Total Organic Carbon (%)	10	4	0.05	0.57	0.25	0.64	1.51	2.21	-	-
	Available Ammonium (as N)	3	1	6.5	14.7	14.7	14.7	14.7	19.1	-	-
	Available Nitrate (as N)	3	1	< 2	All concentrations below detection limits				< 2	-	-

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Ogama	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	2.3	2.6	2.6	2.6	2.6	3.1	-	-
	Total Arsenic	10	4	1.90	3.49	2.62	3.84	6.22	12.7	25%	0%
	Total Cadmium	10	4	< 0.05	0.053	0.055	0.065	0.075	0.080	0%	0%
	Total Chromium	10	4	39.9	53.7	55.5	60.0	60.0	61.0	100%	0%
	Total Copper	10	4	16.7	23.2	23.7	25.7	26.1	27.0	0%	0%
	Total Lead	10	4	5.9	7.5	8.0	8.1	8.2	10.2	0%	0%
	Total Mercury	10	4	0.0143	0.0246	0.0250	0.0250	0.0250	0.0366	0%	0%
	Total Zinc	10	4	49.1	66.6	68.5	75.7	77.2	79.0	0%	0%
P.O.	Gravel > 2 mm (%)	3	1	< 1	All concentrations below detection limits				< 1	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	1	1	1	1	1	2	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	41	42	42	42	42	44	-	-
	Clay <4 µm (%)	3	1	54	56	56	56	56	58	-	-
	Total Organic Carbon (%)	9	3	0.13	0.95	0.21	1.35	2.26	2.71	-	-
	Available Ammonium (as N)	3	1	25.7	35.2	35.2	35.2	35.2	44.2	-	-
	Available Nitrate (as N)	3	1	< 2	All concentrations below detection limits				< 2	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	4.7	5.3	5.3	5.3	5.3	6.2	-	-
	Total Arsenic	9	3	3.80	5.95	5.16	6.68	7.90	8.20	33%	0%
	Total Cadmium	9	3	0.070	0.108	0.090	0.117	0.138	0.150	0%	0%
	Total Chromium	9	3	63.0	72.5	71.0	77.2	82.1	84.8	100%	0%
	Total Copper	9	3	29.3	36.2	32.5	38.7	43.7	46.4	33%	0%
	Total Lead	9	3	8.5	10.3	9.6	11.2	12.4	13.9	0%	0%
	Total Mercury	9	3	0.0243	0.0249	0.0250	0.0250	0.0250	0.0248	0%	0%
	Total Zinc	9	3	78.0	87.6	87.8	92.5	96.2	99.3	0%	0%
Patch	Gravel > 2 mm (%)	18	5	< 0.1	0.7	0.5	0.8	1.2	3.0	-	-
	Sand 2.0 mm - 0.063 mm (%)	18	5	1.0	17	6	32	42	91	-	-
	Silt 0.063 mm - 4 µm (%)	18	5	5.0	48	48	55	60	64	-	-
	Clay <4 µm (%)	18	5	2.0	35	33	44	49	52	-	-

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Patch	Total Organic Carbon (%)	30	9	0.15	1.17	1.04	1.81	2.55	3.39	-	-
	Available Ammonium (as N)	15	4	1.2	11.2	11.5	16.9	17.4	21.8	-	-
	Available Nitrate (as N)	15	4	< 2	All concentrations below detection limits				< 8.6	-	-
	Available Nitrite (as N)	15	4	< 0.4	All concentrations below detection limits				< 1.7	-	-
	Available Phosphate (as P)	15	4	2.4	4.3	4.5	4.9	5.2	9.7	-	-
	Total Arsenic	30	9	0.98	6.13	4.32	5.60	14.3	16.9	22%	0%
	Total Cadmium	30	9	< 0.1	0.092	0.084	0.103	0.154	0.180	0%	0%
	Total Chromium	30	9	14.5	65.0	68.0	73.7	80.3	83.7	100%	0%
	Total Copper	30	9	6.4	35.6	32.6	37.3	56.4	58.3	33%	0%
	Total Lead	30	9	2.5	9.3	9.5	10.1	11.3	13.5	0%	0%
	Total Mercury	30	9	< 0.005	0.0216	0.0250	0.0250	0.0255	0.0269	0%	0%
	Total Zinc	30	9	15.0	75.8	83.6	87.0	92.2	98.0	0%	0%
Stickleback	Gravel > 2 mm (%)	6	2	< 0.1	All concentrations below detection limits				< 1	-	-
	Sand 2.0 mm - 0.063 mm (%)	6	2	< 1	0.8	0.8	0.9	1.0	1.3	-	-
	Silt 0.063 mm - 4 µm (%)	6	2	69	84	84	88	92	94	-	-
	Clay <4 µm (%)	6	2	6.2	16	16	20	24	30	-	-
	Total Organic Carbon (%)	12	4	0.92	10.3	8.88	18.1	21.5	22.5	-	-
	Available Ammonium (as N)	3	1	17.7	27.9	27.9	27.9	27.9	33.6	-	-
	Available Nitrate (as N)	3	1	< 3.8	All concentrations below detection limits				< 5	-	-
	Available Nitrite (as N)	3	1	< 0.75	All concentrations below detection limits				< 1	-	-
	Available Phosphate (as P)	3	1	7.4	9.6	9.6	9.6	9.6	11.7	-	-
	Total Arsenic	12	4	4.20	5.45	4.66	5.52	7.42	9.50	25%	0%
	Total Cadmium	12	4	0.120	0.155	0.156	0.174	0.176	0.330	0%	0%
	Total Chromium	12	4	33.8	37.7	37.1	39.1	41.7	43.8	50%	0%
	Total Copper	12	4	34.6	42.5	42.9	46.9	47.3	50.2	100%	0%
	Total Lead	12	4	5.20	6.04	6.04	6.47	6.65	6.80	0%	0%
	Total Mercury	12	4	< 0.05	0.0371	0.0315	0.0436	0.0570	0.0671	0%	0%
	Total Zinc	12	4	57.0	60.3	60.7	61.0	61.1	65.0	0%	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Trout	Gravel > 2 mm (%)	3	1	< 0.1	All concentrations below detection limits				< 0.1	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	0.8	1.2	1.2	1.2	1.2	2.1	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	60	64	64	64	64	66	-	-
	Clay <4 µm (%)	3	1	32	35	35	35	35	40	-	-
	Total Organic Carbon (%)	9	3	0.24	1.25	0.33	1.72	2.82	3.85	-	-
	Available Ammonium (as N)	3	1	7.5	9.2	9.2	9.2	9.2	10.2	-	-
	Available Nitrate (as N)	3	1	< 2	All concentrations below detection limits				< 3	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.6	-	-
	Available Phosphate (as P)	3	1	3.5	3.9	3.9	3.9	3.9	4.3	-	-
	Total Arsenic	9	3	2.11	2.59	2.22	2.79	3.25	3.90	0%	0%
	Total Cadmium	9	3	< 0.1	0.075	0.080	0.087	0.093	0.110	0%	0%
	Total Chromium	9	3	39.0	43.3	43.2	45.4	47.2	55.0	100%	0%
	Total Copper	9	3	16.1	20.1	18.8	21.0	22.7	26.9	0%	0%
	Total Lead	9	3	5.80	6.37	6.17	6.60	6.95	8.00	0%	0%
	Total Mercury	9	3	0.0206	0.0242	0.0250	0.0250	0.0250	0.0240	0%	0%
	Total Zinc	9	3	54.1	64.6	65.0	67.3	69.1	77.0	0%	0%
Windy	Gravel > 2 mm (%)	15	5	< 0.1	0.5	0.5	0.5	0.7	2.1	-	-
	Sand 2.0 mm - 0.063 mm (%)	15	5	0.2	22	0.5	32	66	77	-	-
	Silt 0.063 mm - 4 µm (%)	15	5	17	45	47	55	63	72	-	-
	Clay <4 µm (%)	15	5	4.1	33	35	45	59	63	-	-
	Total Organic Carbon (%)	22	8	0.07	0.58	0.49	1.06	1.23	1.36	-	-
	Available Ammonium (as N)	12	4	1.3	3.6	3.4	5.2	6.0	6.8	-	-
	Available Nitrate (as N)	12	4	< 2	1.9	2.1	2.4	2.4	3.1	-	-
	Available Nitrite (as N)	12	4	< 0.4	All concentrations below detection limits				< 1	-	-
	Available Phosphate (as P)	12	4	< 2	8.4	7.9	12.1	16.0	20.6	-	-
	Total Arsenic	22	8	2.60	8.62	6.06	7.26	21.8	30.1	63%	0%
	Total Cadmium	22	8	< 0.05	0.083	0.089	0.110	0.131	0.140	0%	0%
	Total Chromium	22	8	24.0	59.6	74.0	76.8	78.5	81.5	63%	0%
	Total Copper	22	8	10.3	34.0	39.9	42.7	47.0	50.2	63%	0%

Lake	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75[th] Percentile[b]	95[th] Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Windy	Total Lead	22	8	3.1	8.9	10.7	10.9	12.4	13.2	0%	0%
	Total Mercury	22	8	< 0.005	0.0193	0.0237	0.0250	0.0250	0.0246	0%	0%
	Total Zinc	22	8	20.7	68.6	86.8	90.4	92.1	96.0	0%	0%
Wolverine	Gravel > 2 mm (%)	9	3	< 0.1	All concentrations below detection limits				< 1	-	-
	Sand 2.0 mm - 0.063 mm (%)	9	3	< 1	2.0	1.2	2.8	4.0	6.0	-	-
	Silt 0.063 mm - 4 µm (%)	9	3	52	63	66	69	70	73	-	-
	Clay <4 µm (%)	9	3	26	35	32	37	41	46	-	-
	Total Organic Carbon (%)	15	5	0.35	4.25	5.39	7.24	7.71	8.93	-	-
	Available Ammonium (as N)	6	2	8.6	44.2	44.2	58.8	70.4	117	-	-
	Available Nitrate (as N)	6	2	< 2	2.3	2.3	2.6	2.8	3.1	-	-
	Available Nitrite (as N)	6	2	< 0.4	All concentrations below detection limits				< 1.3	-	-
	Available Phosphate (as P)	6	2	< 2	6.7	6.7	7.7	8.6	11.7	-	-
	Total Arsenic	15	5	3.10	6.74	4.75	9.09	12.3	15.9	40%	0%
	Total Cadmium	15	5	0.070	0.095	0.093	0.110	0.113	0.120	0%	0%
	Total Chromium	15	5	59.0	65.3	66.2	69.8	70.4	75.4	100%	0%
	Total Copper	15	5	28.0	33.6	33.2	37.8	37.9	39.7	40%	0%
	Total Lead	15	5	8.9	9.7	9.5	10.0	10.6	11.4	0%	0%
	Total Mercury	15	5	0.0119	0.0245	0.0250	0.0256	0.0292	0.0317	0%	0%
	Total Zinc	15	5	68.2	74.7	74.4	78.8	79.5	86.6	0%	0%

Notes:
Units are in mg/kg unless otherwise indicated.
n = number observations.
'<' indicates that concentration was less than the analytical detection limit shown.
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] *Canadian sediment quality guidelines for the protection freshwater aquatic life, Canadian Council Ministers the Environment (CCME 2017).*
[b] *ISQG = Interim Sediment Quality Guideline.*
[c] *PEL = Probable Effects Level.*
[d] *Minimum represents the lowest concentration in any sample.*
[e] *Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.*
[f] *Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).*

5.2.4.2 Streams and Rivers

Stream and river sediment quality data were grouped by project area (North Belt LSA, South Belt LSA, and RSA) to highlight general regional trends. These data are presented in Tables 5.2-8 to 5.2-10. Stream- and river-specific data are presented in Table 5.2-11.

<u>Sediment Composition</u>

Stream and river sediments in the LSA and RSA were mainly comprised of sand (mean range = 46% to 55%), with lesser proportions of silt (mean range = 11% to 35%), clay (mean range = 4.5% to 19%), and gravel (mean range = 0.9% to 29%; Table 5.2-8). Streams and rivers in the South Belt LSA tended to have finer sediments, on average, than streams and rivers in the North Belt LSA or RSA (Table 5.2-8).

Table 5.2-8. Stream and River Sediment Composition in the LSA and RSA, 2009 to 2016

Parameter	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
LSA - North Belt	**n = 84**	**n = 28**	**n = 28**	**n = 28**	**n = 28**	**n = 84**
Gravel > 2 mm (%)	< 0.1	21	18	31	48	78
Sand 2.0 mm - 0.063 mm (%)	9.0	54	53	65	76	97
Silt 0.063 mm - 4 µm (%)	< 0.1	17	10	31	43	60
Clay <4 µm (%)	0.21	8.2	4.8	12	20	52
LSA - South Belt	**n = 21**	**n = 8**	**n = 8**	**n = 8**	**n = 8**	**n = 21**
Gravel > 2 mm (%)	< 0.1	0.9	0.1	1.2	3.3	8.0
Sand 2.0 mm - 0.063 mm (%)	3.2	46	54	70	82	93
Silt 0.063 mm - 4 µm (%)	2.7	35	33	53	58	72
Clay < 4 µm (%)	0.61	19	15	31	40	44
RSA	**n = 75**	**n = 25**	**n = 25**	**n = 25**	**n = 25**	**n = 75**
Gravel > 2 mm (%)	< 0.1	29	31	40	52	81
Sand 2.0 mm - 0.063 mm (%)	5.2	55	52	63	76	99
Silt 0.063 mm - 4 µm (%)	< 0.1	11	8.2	13	25	49
Clay <4 µm (%)	< 0.1	4.5	1.8	4.4	21	47

Notes:
n = number observations.
'<' indicates that concentration was less than the analytical detection limit shown.
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 sample.*
[b] *Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.*
[c] *Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).*

<u>Total Organic Carbon and Nutrients</u>

Fine sediments composed of silt and clay often contain greater concentrations of organic carbon and metals than coarse sediments. This was observed in the South Belt LSA streams and rivers, where the mean sediment TOC content (11%) was substantially greater than in the North Belt LSA (1.0%) or RSA (0.76%) sediments (Table 5.2-9), corresponding to the greater proportions of fine sediments in this study area (Table 5.2-8).

Table 5.2-9. Stream and River Sediment Total Organic Carbon and Nutrient Concentrations in the LSA and RSA, 2009 to 2016

Parameter	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]
LSA - North Belt	**n = 84**	**n = 28**	**n = 28**	**n = 28**	**n = 28**	**n = 84**
Total Organic Carbon (%)	< 0.1	1.0	0.37	1.5	2.6	6.9
Available Ammonium (as N) (mg/kg)	< 0.8	4.5	2.7	5.3	15	34
Available Nitrate (as N) (mg/kg)	< 1	1.4	1.0	1.4	2.7	7.0
Available Nitrite (as N) (mg/kg)	< 0.4	all concentrations below detection limits				< 1.2
Available Phosphate (as P) (mg/kg)	< 1	3.1	3.0	4.2	4.7	7.7
LSA - South Belt	**n = 24**	**n = 8**	**n = 8**	**n = 8**	**n = 8**	**n = 24**
Total Organic Carbon (%)	0.25	11	9.1	13	29	35
Available Ammonium (as N) (mg/kg)	2.87	20	13	20	57	74
Available Nitrate (as N) (mg/kg)	< 1	all concentrations below detection limits				< 30
Available Nitrite (as N) (mg/kg)	< 0.4	all concentrations below detection limits				< 6
Available Phosphate (as P) (mg/kg)	< 2	3.7	3.9	4.6	6.4	8.1
RSA	**n = 75**	**n = 25**	**n = 25**	**n = 25**	**n = 25**	**n = 75**
Total Organic Carbon (%)	< 0.1	0.76	0.42	1.0	2.7	6.3
Available Ammonium (as N) (mg/kg)	< 0.8	3.7	3.0	3.6	9.2	20
Available Nitrate (as N) (mg/kg)	< 1	1.3	1.0	1.9	2.1	2.7
Available Nitrite (as N) (mg/kg)	< 0.4	all concentrations below detection limits				< 1.5
Available Phosphate (as P) (mg/kg)	< 2	3.2	3.3	3.8	5.2	9.3

Notes:
n = number observations.
'<' indicates that concentration was less than the analytical detection limit shown.
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 sample.
[b] Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.
[c] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).

Pooled data from all sites indicated that there was a strong positive correlation between TOC content and the silt fraction of sediments ($r = 0.76$, $p < 0.001$, $n = 180$; Pearson's correlations of logit transformed percentage data), a positive correlation between TOC and clay content ($r = 0.64$, $p < 0.001$, $n = 180$), and a negative correlation between TOC and sand content ($r = -0.41$, $p < 0.001$, $n = 180$).

Mean sediment TOC content was notably high at sites AWRd (21.5%), AWRe (10.8%), S6 (33.5%), and Trout Outflow (10.6%) in the South Belt LSA; these sites also tended to have high silt and clay content relative to other sites (Table 5.2-11).

Concentrations of plant available nitrate and nitrite were generally near or below detection limits in streams of the LSA and RSA. Available ammonium concentrations were highest in the South Belt LSA sediments, and available phosphate concentrations were similar across study areas (Table 5.2-9).

Table 5.2-10. Stream and River Sediment Metal Concentrations in the LSA and RSA, 2009 to 2016

Parameter	CCME Guidelines for the Protection of Aquatic Life[a]		Total Metal Concentration (mg/kg)						% of Sample Concentrations Greater than ISQG[e]	% of Sample Concentrations Greater than PEL[e]
	ISQG[b]	PEL[c]	Min[d]	Mean[e]	Median[e]	75th percentile[e]	95th percentile[e]	Max[f]		
LSA - North Belt			**n = 84**	**n = 28**	**n = 28**	**n = 28**	**n = 28**	**n = 84**	**n = 28**	**n = 28**
Arsenic	5.9	17	0.54	1.99	1.86	2.54	3.54	9.97	0	0
Cadmium	0.6	3.5	< 0.05	0.041	0.050	0.050	0.050	0.079	0	0
Chromium	37.3	90	10.3	31.7	28.6	39.4	60.3	193	29	4
Copper	35.7	197	3.8	13.2	12.4	15.9	24.7	37.7	0	0
Lead	35	91.3	0.83	3.33	3.05	4.56	6.49	9.50	0	0
Mercury	0.17	0.49	< 0.005	0.0053	0.0031	0.0058	0.0125	0.0252	0	0
Zinc	123	315	15.6	33.4	31.4	40.7	56.6	80.6	0	0
LSA - South Belt			**n = 24**	**n = 8**	**n = 8**	**n = 8**	**n = 8**	**n = 24**	**n = 8**	**n = 8**
Arsenic	5.9	17	0.06	2.99	2.03	2.79	8.59	17.8	13	0
Cadmium	0.6	3.5	< 0.1	0.104	0.050	0.119	0.262	0.370	0	0
Chromium	37.3	90	7.4	22.3	19.3	21.6	39.7	52.4	13	0
Copper	35.7	197	4.3	17.1	15.0	23.9	34.4	58.4	13	0
Lead	35	91.3	< 2.0	3.82	3.58	4.02	6.04	7.60	0	0
Mercury	0.17	0.49	< 0.005	0.0368	0.0302	0.0432	0.0950	0.134	0	0
Zinc	123	315	13.4	43.2	40.1	55.8	74.9	87.1	0	0
RSA			**n = 75**	**n = 25**	**n = 25**	**n = 25**	**n = 25**	**n = 75**	**n = 25**	**n = 25**
Arsenic	5.9	17	0.074	1.26	1.08	1.31	2.69	7.23	0	0
Cadmium	0.6	3.5	< 0.05	0.036	0.025	0.050	0.054	0.118	0	0
Chromium	37.3	90	6.48	20.3	19.7	24.4	42.2	63.6	12	0
Copper	35.7	197	2.5	14.7	12.1	17.3	25.5	105	4	0
Lead	35	91.3	0.87	2.32	1.66	2.60	5.32	7.53	0	0
Mercury	0.17	0.49	< 0.005	0.0047	0.0034	0.0056	0.0114	0.0199	0	0
Zinc	123	315	14.3	28.2	25.1	30.9	50.9	68.8	0	0

Table 5.2-10 notes:
n = number observations.
'<' indicates that concentration was less than the analytical detection limit shown.
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] Canadian sediment quality guidelines for the protection freshwater aquatic life, Canadian Council Ministers the Environment (CCME 2017).
[b] ISQG = Interim Sediment Quality Guideline.
[c] PEL = Probable Effects Level.
[d] Minimum represents the lowest concentration in any sample.
[e] Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.
[f] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).

Table 5.2-11. Stream- and River-specific Sediment Quality Summary, 2009 to 2016

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Aimaokatalok NE IF	Gravel > 2 mm (%)	3	1	< 0.1	0.077	0.077	0.077	0.077	0.130	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	71.3	76.1	76.1	76.1	76.1	84.0	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	14.8	22.1	22.1	22.1	22.1	27.6	-	-
	Clay < 4 µm (%)	3	1	1.04	1.67	1.67	1.67	1.67	2.90	-	-
	Total Organic Carbon (%)	3	1	1.17	1.53	1.53	1.53	1.53	2.05	-	-
	Available Ammonium (as N)	3	1	6.8	13.2	13.2	13.2	13.2	21.0	-	-
	Available Nitrate (as N)	3	1	< 3.3	All concentrations below detection limits				< 5	-	-
	Available Nitrite (as N)	3	1	< 0.67	All concentrations below detection limits				< 1	-	-
	Available Phosphate (as P)	3	1	6.70	7.23	7.23	7.23	7.23	8.10	-	-
	Total Arsenic	3	1	0.730	0.791	0.791	0.791	0.791	0.857	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	16.6	17.8	17.8	17.8	17.8	19.7	0%	0%
	Total Copper	3	1	5.40	5.70	5.70	5.70	5.70	6.00	0%	0%
	Total Lead	3	1	3.10	3.37	3.37	3.37	3.37	3.70	0%	0%
	Total Mercury	3	1	0.00730	0.00777	0.00777	0.00777	0.00777	0.00800	0%	0%
	Total Zinc	3	1	24.9	26.7	26.7	26.7	26.7	28.3	0%	0%

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
AWRa	Gravel > 2 mm (%)	3	1	< 0.1	0.60	0.60	0.60	0.60	1.50	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	53.1	66.4	66.4	66.4	66.4	77.0	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	15.7	21.3	21.3	21.3	21.3	26.5	-	-
	Clay < 4 µm (%)	3	1	5.8	11.7	11.7	11.7	11.7	20.2	-	-
	Total Organic Carbon (%)	3	1	0.57	1.45	1.45	1.45	1.45	2.77	-	-
	Available Ammonium (as N)	3	1	9.3	11.1	11.1	11.1	11.1	13.0	-	-
	Available Nitrate (as N)	3	1	< 2	All concentrations below detection limits				< 3.3	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.67	-	-
	Available Phosphate (as P)	3	1	< 2	1.43	1.43	1.43	1.43	2.30	-	-
	Total Arsenic	3	1	1.30	1.87	1.87	1.87	1.87	2.26	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	14.4	21.9	21.9	21.9	21.9	33.8	0%	0%
	Total Copper	3	1	3.80	7.00	7.00	7.00	7.00	11.7	0%	0%
	Total Lead	3	1	2.20	3.53	3.53	3.53	3.53	5.20	0%	0%
	Total Mercury	3	1	< 0.005	0.00400	0.00400	0.00400	0.00400	0.00700	0%	0%
	Total Zinc	3	1	15.6	24.2	24.2	24.2	24.2	37.2	0%	0%
AWRb	Gravel > 2 mm (%)	3	1	1.22	1.66	1.66	1.66	1.66	2.39	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	16.4	32.5	32.5	32.5	32.5	63.2	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	26.7	46.0	46.0	46.0	46.0	59.7	-	-
	Clay < 4 µm (%)	3	1	7.8	19.9	19.9	19.9	19.9	29.4	-	-
	Total Organic Carbon (%)	3	1	2.79	5.38	5.38	5.38	5.38	6.85	-	-
	Available Ammonium (as N)	3	1	4.1	18.3	18.3	18.3	18.3	34.2	-	-
	Available Nitrate (as N)	3	1	< 5	All concentrations below detection limits				< 6	-	-
	Available Nitrite (as N)	3	1	< 1	All concentrations below detection limits				< 1.2	-	-
	Available Phosphate (as P)	3	1	< 2	All concentrations below detection limits				< 2	-	-
	Total Arsenic	3	1	2.15	2.85	2.85	2.85	2.85	3.54	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	30.9	42.5	42.5	42.5	42.5	56.7	100%	0%
	Total Copper	3	1	9.60	13.1	13.1	13.1	13.1	16.8	0%	0%

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
AWRb	Total Lead	3	1	5.10	6.33	6.33	6.33	6.33	7.80	0%	0%
	Total Mercury	3	1	0.0183	0.0217	0.0217	0.0217	0.0217	0.0252	0%	0%
	Total Zinc	3	1	46.5	61.9	61.9	61.9	61.9	80.6	0%	0%
AWRc	Gravel > 2 mm (%)	3	1	< 0.1	0.60	0.60	0.60	0.60	1.36	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	44	55	55	55	55	64	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	30	38	38	38	38	47	-	-
	Clay < 4 µm (%)	3	1	5.3	7.0	7.0	7.0	7.0	8.0	-	-
	Total Organic Carbon (%)	3	1	3.45	4.58	4.58	4.58	4.58	6.51	-	-
	Available Ammonium (as N)	3	1	3.6	5.4	5.4	5.4	5.4	7.4	-	-
	Available Nitrate (as N)	3	1	< 5	All concentrations below detection limits				< 7.5	-	-
	Available Nitrite (as N)	3	1	< 1	All concentrations below detection limits				< 1.5	-	-
	Available Phosphate (as P)	3	1	< 2	1.4	1.4	1.4	1.4	2.3	-	-
	Total Arsenic	3	1	0.33	0.83	0.83	0.83	0.83	1.12	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	14.5	19.9	19.9	19.9	19.9	24.7	0%	0%
	Total Copper	3	1	5.50	7.37	7.37	7.37	7.37	8.9	0%	0%
	Total Lead	3	1	2.60	3.80	3.80	3.80	3.80	5.40	0%	0%
	Total Mercury	3	1	0.0055	0.0113	0.0113	0.0113	0.0113	0.0176	0%	0%
	Total Zinc	3	1	16.9	23.0	23.0	23.0	23.0	32.7	0%	0%
AWRd	Gravel > 2 mm (%)	2	1	< 0.1	All concentrations below detection limits				< 0.1	-	-
	Sand 2.0 mm - 0.063 mm (%)	2	1	12	15	15	15	15	18	-	-
	Silt 0.063 mm - 4 µm (%)	2	1	48	53	53	53	53	58	-	-
	Clay < 4 µm (%)	2	1	30.0	32	32	32	32	34	-	-
	Total Organic Carbon (%)	3	1	17.5	21.5	21.5	21.5	21.5	27.6	-	-
	Available Ammonium (as N)	3	1	18.0	29.0	29.0	29.0	29.0	40.0	-	-
	Available Nitrate (as N)	3	1	< 20	All concentrations below detection limits				< 30	-	-
	Available Nitrite (as N)	3	1	< 4	All concentrations below detection limits				< 6	-	-
	Available Phosphate (as P)	3	1	< 5.7	All concentrations below detection limits				< 11	-	-
	Total Arsenic	3	1	3.88	11.7	11.7	11.7	11.7	17.8	100%	0%

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
AWRd	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	13.0	20.6	20.6	20.6	20.6	30.6	0%	0%
	Total Copper	3	1	13.80	20.5	20.5	20.5	20.5	26.3	0%	0%
	Total Lead	3	1	4.30	4.57	4.57	4.57	4.57	5.00	0%	0%
	Total Mercury	3	1	0.0415	0.0585	0.0585	0.0585	0.0585	0.0812	0%	0%
	Total Zinc	3	1	36.2	39.1	39.1	39.1	39.1	41.2	0%	0%
AWRe	Gravel > 2 mm (%)	3	1	< 0.1	All concentrations below detection limits				< 0.1	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	44	53	53	53	53	63	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	25	29	29	29	29	31	-	-
	Clay < 4 µm (%)	3	1	11.9	18	18	18	18	27	-	-
	Total Organic Carbon (%)	3	1	6.1	10.8	10.8	10.8	10.8	19.9	-	-
	Available Ammonium (as N)	3	1	4.7	10.1	10.1	10.1	10.1	19.6	-	-
	Available Nitrate (as N)	3	1	< 6	All concentrations below detection limits				< 20	-	-
	Available Nitrite (as N)	3	1	< 1.2	All concentrations below detection limits				< 4	-	-
	Available Phosphate (as P)	3	1	< 4	2.5	2.5	2.5	2.5	2.9	-	-
	Total Arsenic	3	1	1.36	2.0	2.0	2.0	2.0	3.3	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	22.7	24.7	24.7	24.7	24.7	27.7	0%	0%
	Total Copper	3	1	7.50	9.4	9.4	9.4	9.4	11.9	0%	0%
	Total Lead	3	1	3.30	3.37	3.37	3.37	3.37	3.50	0%	0%
	Total Mercury	3	1	0.0246	0.0317	0.0317	0.0317	0.0317	0.0428	0%	0%
	Total Zinc	3	1	44.3	65.6	65.6	65.6	65.6	87.1	0%	0%
Doris OF	Gravel > 2 mm (%)	24	8	< 0.1	33	24	42	60	78	-	-
	Sand 2.0 mm - 0.063 mm (%)	24	8	22	57	59	71	75	84	-	-
	Silt 0.063 mm - 4 µm (%)	24	8	< 1	7.7	4.1	5.9	21	55	-	-
	Clay < 4 µm (%)	24	8	0.2	2.9	1.2	3.4	8.9	20	-	-
	Total Organic Carbon (%)	24	8	< 0.1	0.61	0.33	0.69	1.70	5.45	-	-
	Available Ammonium (as N)	24	8	< 1	3.1	2.7	3.4	5.3	8.1	-	-
	Available Nitrate (as N)	24	8	< 1	1.2	1.1	1.3	1.8	4.0	-	-

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Doris OF	Available Nitrite (as N)	24	8	< 0.4	All concentrations below detection limits				< 0.8	-	-
	Available Phosphate (as P)	24	8	2.0	3.9	4.1	4.5	4.7	7.7	-	-
	Total Arsenic	24	8	0.54	1.52	1.07	1.67	3.28	9.97	0%	0%
	Total Cadmium	24	8	< 0.05	0.0356	0.0250	0.0500	0.0563	0.0790	0%	0%
	Total Chromium	24	8	10.3	26.6	18.7	31.1	55.9	97.6	25%	0%
	Total Copper	24	8	4.4	11.4	9.7	13.5	21.7	37.7	0%	0%
	Total Lead	24	8	0.85	1.99	1.32	2.36	4.24	8.27	0%	0%
	Total Mercury	24	8	< 0.005	0.0043	0.0025	0.0047	0.0094	0.0237	0%	0%
	Total Zinc	24	8	18.2	30.3	25.2	35.1	48.0	78.5	0%	0%
Glenn OF	Gravel > 2 mm (%)	3	1	2.0	4.7	4.7	4.7	4.7	9.0	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	38	59	59	59	59	75	-	-
	Silt 0.063 mm - 4 μm (%)	3	1	15	25	25	25	25	37	-	-
	Clay < 4 μm (%)	3	1	8.0	11	11	11	11	16	-	-
	Total Organic Carbon (%)	3	1	0.34	0.40	0.40	0.40	0.40	0.48	-	-
	Available Ammonium (as N)	3	1	1.7	2.5	2.5	2.5	2.5	3.2	-	-
	Available Nitrate (as N)	3	1	< 2	All concentrations below detection limits				< 2	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	1.6	2.6	2.6	2.6	2.6	3.3	-	-
	Total Arsenic	3	1	0.58	2.08	2.08	2.08	2.08	2.89	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	34.4	35.9	35.9	35.9	35.9	37.6	0%	0%
	Total Copper	3	1	13.4	19.2	19.2	19.2	19.2	22.8	0%	0%
	Total Lead	3	1	3.80	3.90	3.90	3.90	3.90	4.10	0%	0%
	Total Mercury	3	1	< 0.005	All concentrations below detection limits				< 0.005	0%	0%
	Total Zinc	3	1	26.6	32.4	32.4	32.4	32.4	36.0	0%	0%
Koignuk River (North Belt)	Gravel > 2 mm (%)	15	5	0.2	7.6	12	13	13	36	-	-
	Sand 2.0 mm - 0.063 mm (%)	15	5	15	48	39	46	77	97	-	-
	Silt 0.063 mm - 4 μm (%)	15	5	< 0.1	30	32	42	43	50	-	-
	Clay < 4 μm (%)	15	5	0.8	14	17	20	22	37	-	-

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Koignuk River (North Belt)	Total Organic Carbon (%)	15	5	< 0.1	0.86	0.83	1.15	1.41	1.78	-	-
	Available Ammonium (as N)	15	5	< 1.2	3.7	4.2	5.6	6.0	11.6	-	-
	Available Nitrate (as N)	15	5	< 2	1.1	1.0	1.2	1.3	2.0	-	-
	Available Nitrite (as N)	15	5	< 0.4	All concentrations below detection limits				< 0.6	-	-
	Available Phosphate (as P)	15	5	< 2	3.1	3.3	4.1	4.3	6.0	-	-
	Total Arsenic	15	5	1.96	3.17	2.86	3.26	4.33	5.56	0%	0%
	Total Cadmium	15	5	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	15	5	22.7	37.3	37.0	40.8	50.5	65.9	50%	0%
	Total Copper	15	5	8.2	18.9	21.7	22.3	26.6	33.4	0%	0%
	Total Lead	15	5	< 2	5.30	6.00	6.57	7.58	8.70	0%	0%
	Total Mercury	15	5	< 0.005	0.0050	0.0048	0.0054	0.0073	0.0112	0%	0%
	Total Zinc	15	5	24.3	38.9	35.1	41.5	55.6	69.6	0%	0%
Koignuk River (South Belt)	Gravel > 2 mm (%)	3	1	0.2	3.4	3.4	3.4	3.4	8.0	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	51	68	68	68	68	82	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	16	17	17	17	17	18	-	-
	Clay < 4 µm (%)	3	1	0.6	11	11	11	11	24	-	-
	Total Organic Carbon (%)	3	1	1.09	7.67	7.67	7.67	7.67	18.2	-	-
	Available Ammonium (as N)	3	1	5.5	11.9	11.9	11.9	11.9	17.9	-	-
	Available Nitrate (as N)	3	1	< 2	All concentrations below detection limits				< 10	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 2	-	-
	Available Phosphate (as P)	3	1	< 2	All concentrations below detection limits				< 4	-	-
	Total Arsenic	3	1	0.06	2.78	2.78	2.78	2.78	5.76	0%	0%
	Total Cadmium	3	1	< 0.1	0.1	0.1	0.1	0.1	0.310	0%	0%
	Total Chromium	3	1	14.8	18.7	18.7	18.7	18.7	20.7	0%	0%
	Total Copper	3	1	9.9	27.9	27.9	27.9	27.9	58.4	0%	0%
	Total Lead	3	1	< 2	3.03	3.03	3.03	3.03	5.10	0%	0%
	Total Mercury	3	1	< 0.005	0.0286	0.0286	0.0286	0.0286	0.0711	0%	0%
	Total Zinc	3	1	19.1	41.1	41.1	41.1	41.1	64.8	0%	0%

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Little Roberts OF	Gravel > 2 mm (%)	24	8	< 0.1	24.6	28.3	35.8	44.9	55.1	-	-
	Sand 2.0 mm - 0.063 mm (%)	24	8	37.2	58.0	56.5	61.5	71.5	77.7	-	-
	Silt 0.063 mm - 4 µm (%)	24	8	0.75	13.0	7.3	14.3	34.3	44.7	-	-
	Clay < 4 µm (%)	24	8	0.38	4.52	2.14	4.5	12.9	15.0	-	-
	Total Organic Carbon (%)	24	8	< 0.1	0.64	0.28	0.69	1.92	2.75	-	-
	Available Ammonium (as N)	24	8	< 1	2.98	2.40	3.28	5.61	6.47	-	-
	Available Nitrate (as N)	24	8	< 1	1.29	1.00	1.33	2.43	3.30	-	-
	Available Nitrite (as N)	24	8	< 0.4	All concentrations below detection limits				< 1	-	-
	Available Phosphate (as P)	24	8	< 1	2.79	2.53	2.96	4.51	5.80	-	-
	Total Arsenic	24	8	0.82	1.70	1.64	1.92	2.25	2.97	0%	0%
	Total Cadmium	24	8	< 0.05	0.0341	0.0293	0.0418	0.0500	0.0670	0%	0%
	Total Chromium	24	8	11.5	29.9	18.9	29.9	74.8	193	13%	13%
	Total Copper	24	8	6.0	10.6	9.8	11.0	15.7	19.3	0%	0%
	Total Lead	24	8	0.83	2.24	1.62	2.76	4.27	5.00	0%	0%
	Total Mercury	24	8	< 0.005	0.0049	0.0025	0.0053	0.0122	0.0170	0%	0%
	Total Zinc	24	8	17.1	28.0	25.8	31.7	42.1	52.6	0%	0%
Ogama OF	Gravel > 2 mm (%)	3	1	36	48	48	48	48	58	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	36	39	39	39	39	42	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	3.0	7.0	7.0	7.0	7.0	14	-	-
	Clay < 4 µm (%)	3	1	1.0	6.0	6.0	6.0	6.0	14	-	-
	Total Organic Carbon (%)	3	1	0.21	0.26	0.26	0.26	0.26	0.35	-	-
	Available Ammonium (as N)	3	1	1.1	3.4	3.4	3.4	3.4	6.3	-	-
	Available Nitrate (as N)	3	1	< 2	1.9	1.9	1.9	1.9	2.5	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	3.6	4.3	4.3	4.3	4.3	5.3	-	-
	Total Arsenic	3	1	1.01	1.22	1.22	1.22	1.22	1.55	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	32.5	39.1	39.1	39.1	39.1	48.3	100%	0%
	Total Copper	3	1	9.8	14.5	14.5	14.5	14.5	19.8	0%	0%

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Ogama OF	Total Lead	3	1	< 2	3.37	3.37	3.37	3.37	6.40	0%	0%
	Total Mercury	3	1	< 0.005	All concentrations below detection limits				< 0.005	0%	0%
	Total Zinc	3	1	31.6	39.1	39.1	39.1	39.1	53.6	0%	0%
P.O. OF	Gravel > 2 mm (%)	3	1	< 1	2	2	2	2	3	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	22	43	43	43	43	58	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	25	35	35	35	35	50	-	-
	Clay < 4 µm (%)	3	1	14	20	20	20	20	28	-	-
	Total Organic Carbon (%)	3	1	1.63	2.93	2.93	2.93	2.93	4.72	-	-
	Available Ammonium (as N)	3	1	6.4	17.7	17.7	17.7	17.7	28.6	-	-
	Available Nitrate (as N)	3	1	2.1	3.8	3.8	3.8	3.8	7.0	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	1.2	2.7	2.7	2.7	2.7	3.6	-	-
	Total Arsenic	3	1	1.44	1.88	1.88	1.88	1.88	2.42	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	26.6	34.3	34.3	34.3	34.3	46.0	0%	0%
	Total Copper	3	1	13.7	15.6	15.6	15.6	15.6	19.1	0%	0%
	Total Lead	3	1	5.20	5.67	5.67	5.67	5.67	5.90	0%	0%
	Total Mercury	3	1	0.0081	0.0101	0.0101	0.0101	0.0101	0.0137	0%	0%
	Total Zinc	3	1	31.5	42.4	42.4	42.4	42.4	55.8	0%	0%
Patch OF	Gravel > 2 mm (%)	3	1	3	12	12	12	12	17	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	40	55	55	55	55	64	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	13	23	23	23	23	38	-	-
	Clay < 4 µm (%)	3	1	7	11	11	11	11	19	-	-
	Total Organic Carbon (%)	3	1	0.96	1.78	1.78	1.78	1.78	2.89	-	-
	Available Ammonium (as N)	3	1	1.4	3.6	3.6	3.6	3.6	6.9	-	-
	Available Nitrate (as N)	3	1	< 2	All concentrations below detection limits				< 2	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	3.3	3.6	3.6	3.6	3.6	4.0	-	-
	Total Arsenic	3	1	1.33	1.57	1.57	1.57	1.57	1.73	0%	0%

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Patch OF	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	26.4	28.2	28.2	28.2	28.2	30.2	0%	0%
	Total Copper	3	1	8.1	12.2	12.2	12.2	12.2	18.4	0%	0%
	Total Lead	3	1	3.50	3.93	3.93	3.93	3.93	4.60	0%	0%
	Total Mercury	3	1	< 0.005	0.0053	0.0053	0.0053	0.0053	0.0109	0%	0%
	Total Zinc	3	1	25.7	30.5	30.5	30.5	30.5	37.0	0%	0%
S6	Gravel > 2 mm (%)	1	1	< 0.1	All concentrations below detection limits				< 0.1	-	-
	Sand 2.0 mm - 0.063 mm (%)	1	1	3.2	3.2	3.2	3.2	3.2	3.2	-	-
	Silt 0.063 mm - 4 µm (%)	1	1	53	53	53	53	53	53	-	-
	Clay < 4 µm (%)	1	1	44	44	44	44	44	44	-	-
	Total Organic Carbon (%)	3	1	31.7	33.5	33.5	33.5	33.5	35.2	-	-
	Available Ammonium (as N)	3	1	68.1	71.8	71.8	71.8	71.8	74.0	-	-
	Available Nitrate (as N)	3	1	< 20	All concentrations below detection limits				< 30	-	-
	Available Nitrite (as N)	3	1	< 4	All concentrations below detection limits				< 6	-	-
	Available Phosphate (as P)	3	1	< 8	All concentrations below detection limits				< 8	-	-
	Total Arsenic	3	1	1.32	2.03	2.03	2.03	2.03	2.43	0%	0%
	Total Cadmium	3	1	0.260	0.3	0.3	0.3	0.3	0.370	0%	0%
	Total Chromium	3	1	9.0	15.8	15.8	15.8	15.8	24.2	0%	0%
	Total Copper	3	1	31.9	37.9	37.9	37.9	37.9	46.6	100%	0%
	Total Lead	3	1	2.20	3.83	3.83	3.83	3.83	5.10	0%	0%
	Total Mercury	3	1	0.102	0.115	0.115	0.115	0.115	0.134	0%	0%
	Total Zinc	3	1	38.0	52.5	52.5	52.5	52.5	70.0	0%	0%
Stickleback OF	Gravel > 2 mm (%)	3	1	< 0.1	3	3	3	3	6	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	78	85	85	85	85	93	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	3	8	8	8	8	13	-	-
	Clay < 4 µm (%)	3	1	1	4	4	4	4	9	-	-
	Total Organic Carbon (%)	3	1	0.25	0.87	0.87	0.87	0.87	1.78	-	-
	Available Ammonium (as N)	3	1	2.9	3.3	3.3	3.3	3.3	4.2	-	-
	Available Nitrate (as N)	3	1	< 2.3	All concentrations below detection limits				< 3.8	-	-

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Stickleback OF	Available Nitrite (as N)	3	1	< 0.46	All concentrations below detection limits				< 0.75	-	-
	Available Phosphate (as P)	3	1	2.2	3.7	3.7	3.7	3.7	5.4	-	-
	Total Arsenic	3	1	0.59	0.92	0.92	0.92	0.92	1.34	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	7.4	13.0	13.0	13.0	13.0	20.0	0%	0%
	Total Copper	3	1	4.30	5.60	5.60	5.60	5.60	7.90	0%	0%
	Total Lead	3	1	< 2	1.73	1.73	1.73	1.73	3.20	0%	0%
	Total Mercury	3	1	< 0.005	0.0036	0.0036	0.0036	0.0036	0.0058	0%	0%
	Total Zinc	3	1	13.4	17.8	17.8	17.8	17.8	25.6	0%	0%
Trout OF	Gravel > 2 mm (%)	3	1	< 0.1	Al concentrations below detection limits				< 0.1	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	5	9	9	9	9	15	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	42	60	60	60	60	72	-	-
	Clay < 4 µm (%)	3	1	23	31	31	31	31	44	-	-
	Total Organic Carbon (%)	3	1	8.07	10.6	10.6	10.6	10.6	12.0	-	-
	Available Ammonium (as N)	3	1	8.9	16.6	16.6	16.6	16.6	21.0	-	-
	Available Nitrate (as N)	3	1	< 20	All concentrations below detection limits				< 30	-	-
	Available Nitrite (as N)	3	1	< 4	All concentrations below detection limits				< 6	-	-
	Available Phosphate (as P)	3	1	< 8	All concentrations below detection limits				< 13	-	-
	Total Arsenic	3	1	2.60	2.83	2.83	2.83	2.83	3.25	0%	0%
	Total Cadmium	3	1	0.100	0.113	0.113	0.113	0.113	0.140	0%	0%
	Total Chromium	3	1	43.1	47.7	47.7	47.7	47.7	52.4	100%	0%
	Total Copper	3	1	19.6	22.6	22.6	22.6	22.6	27.6	0%	0%
	Total Lead	3	1	6.30	6.83	6.83	6.83	6.83	7.60	0%	0%
	Total Mercury	3	1	0.0335	0.0381	0.0381	0.0381	0.0381	0.0432	0%	0%
	Total Zinc	3	1	70.9	80.0	80.0	80.0	80.0	86.0	0%	0%
Windy OF	Gravel > 2 mm (%)	3	1	1	18	18	18	18	51	-	-
	Sand 2.0 mm - 0.063 mm (%)	3	1	9	48	48	48	48	91	-	-
	Silt 0.063 mm - 4 µm (%)	3	1	4	15	15	15	15	38	-	-
	Clay < 4 µm (%)	3	1	1	19	19	19	19	52	-	-

Stream/River	Parameter	n (Min, Max)	n (Mean, Median, Percentiles)	Min[a]	Mean[b]	Median[b]	75th Percentile[b]	95th Percentile[b]	Max[c]	% of Sample Concentrations greater than ISQG[e]	% of Sample Concentrations greater than PEL[e]
Windy OF	Total Organic Carbon (%)	3	1	0.15	0.27	0.27	0.27	0.27	0.43	-	-
	Available Ammonium (as N)	3	1	< 0.8	1.0	1.0	1.0	1.0	1.5	-	-
	Available Nitrate (as N)	3	1	< 2	1.6	1.6	1.6	1.6	2.8	-	-
	Available Nitrite (as N)	3	1	< 0.4	All concentrations below detection limits				< 0.4	-	-
	Available Phosphate (as P)	3	1	1.0	1.5	1.5	1.5	1.5	2.3	-	-
	Total Arsenic	3	1	1.40	2.61	2.61	2.61	2.61	4.83	0%	0%
	Total Cadmium	3	1	< 0.1	All concentrations below detection limits				< 0.1	0%	0%
	Total Chromium	3	1	27.4	45.9	45.9	45.9	45.9	69.3	100%	0%
	Total Copper	3	1	6.0	16.5	16.5	16.5	16.5	37.0	0%	0%
	Total Lead	3	1	3.20	6.20	6.20	6.20	6.20	9.50	0%	0%
	Total Mercury	3	1	< 0.005	All concentrations below detection limits				< 0.005	0%	0%
	Total Zinc	3	1	26.1	43.0	43.0	43.0	43.0	75.3	0%	0%

Notes:
Units are in mg/kg unless otherwise indicated.
n = number observations, OF = Outflow, IF = Inflow.
'<' indicates that concentration was less than the analytical detection limit shown.
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] Canadian sediment quality guidelines for the protection freshwater aquatic life, Canadian Council Ministers the Environment (CCME 2017).
[b] ISQG = Interim Sediment Quality Guideline.
[c] PEL = Probable Effects Level.
[d] Minimum represents the lowest concentration in any sample.
[e] Replicate samples collected at the same site and date were averaged for the calculation mean, median, and the 75th and 95th percentiles, and CCME guidelines.
[f] Maximum represents the highest detectable concentration in any sample and excludes values reported as being below analytical detection limits (unless all concentrations are below detection limit, in which case the maximum represents the highest detection limit).

Table 5.3-1 summarizes the scoping considerations and rationale for including freshwater sediment quality as a VEC in this assessment.

Table 5.3-1. Valued Ecosystem Component(s) Included in the Assessment

VEC	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Government	
Freshwater Sediment Quality	-	x	x	Moderate to significant comments expressed by regulatory agencies and potentially significant regulatory considerations

5.2.5 TMAC Consultation and Engagement Informing VEC Selection

Community meetings for the Madrid-Boston Project were conducted in each of the five Kitikmeot communities as described in Volume 2, Chapter 3. 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. There were no direct comments received relating to freshwater sediment quality.

5.3 SPATIAL AND TEMPORAL BOUNDARIES

The freshwater sediment quality spatial and temporal boundaries define the maximum spatial and temporal extent within which the potential effects assessment is conducted. The spatial boundaries selected to shape this assessment are determined by the Project's potential effects on the freshwater environment. The boundaries are determined by the criteria specified in the EIS guidelines (NIRB 2012), and outlined in the Effects Assessment Methodology (Volume 2, Chapter 4). Temporal boundaries consider the different phases of the Project 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 Madrid-Boston Project as well as the total potential effects of the additional Madrid-Boston activities in combination with the existing and approved projects including the Doris Project and advanced exploration activities at Madrid and Boston.

5.3.1 Project Overview

The Madrid-Boston Project consists of proposed mine operations at the Madrid North, Madrid South and Boston deposits. The Madrid-Boston Project is part of a staged approach to continuous development of the Hope Bay Project, comprised of existing operations at Doris and bulk samples followed by commercial mining at Madrid North, Madrid South, and Boston deposits. The Madrid-Boston Project would use and expand upon the existing Doris Project infrastructure.

The Madrid-Boston Project is the focus of this application. Because the infrastructure of existing and approved projects will be utilized by the Madrid-Boston Project, and because the existing and approved projects have the potential to interact cumulatively with the Madrid-Boston Project, existing and approved project are described below.

5.3.1.1 Existing and Approved Projects

Existing and approved projects include:

- the Doris Project (NIRB Project Certificate 003, NWB Type A Water Licence 2AM-DOH1323);
- the Hope Bay Regional Exploration Project (NWB Type B Water Licence 2BE-HOP1222);
- the Madrid Advanced Exploration Program (NWB Type B Water Licence 2BB-MAE1727); and
- the Boston Advanced Exploration Project (NWB Type B Water Licence 2BB-BOS1727).

The Doris Project

The Doris Project was approved by NIRB in 2006 (NIRB Project Certificate 003) and licenced by NWB in 2007 (Type A Water Licence 2AM-DOH0713). The Type A Water Licence was amended in 2010, 2011 and 2012 and received modifications in 2009, 2010, and 2011.

Construction of the Doris Project began in early 2010. In early 2012, the Doris Project was placed into care and maintenance, suspending further Project-related construction and exploration activity along the Hope Bay Greenstone Belt. Following TMAC's acquisition of the Hope Bay Project in March 2013, NWB renewed the Doris Project Type A Water Licence (Type A Water Licence 2AM-DOH1323), and TMAC advanced planning, permitting, exploration, and construction activities. In 2016, NIRB approved an amendment to Project Certificate 003 and NWB granted Amendment No. 1 to Type A Water Licence 2AM-DOH1323, extending operations from two to six years through mining two additional mineralized zones (Doris Connector and Doris Central zones) to be accessed via the existing Doris North portal. Amendment No. 1 to Type A Water Licence 2AM-DOH1323 authorizes a mining rate of approximately 2,000 tonnes per day of ore and a milling throughput of approximately 2,000 tonnes per day of ore. The Doris Project began production early in 2017.

The Doris Project includes the following components and facilities:

- The Roberts Bay offloading facility: marine jetty, barge landing area, beach laydown area, access roads, weather havens, fuel tank farm/transfer station, waste storage facilities and incinerator, and quarry;
- The Doris site: 280 person camp, laydown areas, service complex (e.g., workshop, wash bay, administration buildings, mine dry), two quarries (mill site platform and solid waste landfill), core storage areas, batch plant, brine mixing facilities, vent raise (3), air heating units, reagent storage, fuel tank farm/transfer station, potable water treatment, waste water treatment, incinerator, landfarm and handling/temporary hazardous waste storage, explosives magazine, and diesel power plant;
- Doris Mine works and processing: underground portal, overburden stockpile, temporary waste rock pile, ore stockpile, and ore processing plant (mill);
- Tailings Impoundment Area (TIA): Schedule 2 designation for Tail Lake with two dams (North and South dams), sub-aerial deposition of flotation tailings, emergency tailings dump catch basins, pump house, and quarry;
- All-season main road with transport trucks: Roberts Bay to Doris site (4.8 km, 150 to 200 tractor and 300 fuel tanker trucks/year);
- Access roads from Doris site used predominantly by light-duty trucks to: the TIA, the explosives magazine, Doris Lake float plane dock (previously in use), solid waste disposal site, and to the

tailings decant pipe, from the Roberts Bay offloading facility to the location where the discharge pipe enters the ocean; and

- All-weather airstrip (914 m), winter airstrip (1,524 m), helicopter landing site and building, and Doris Lake float plane and boat dock.

Water is managed at the Doris Project through:

- freshwater input from Doris Lake for mining, milling, and associated activities and domestic purposes;
- freshwater input from Windy Lake for domestic purposes;
- process water input primarily from the TIA reclaim pond;
- surface mine contact water discharged to the TIA;
- underground mine contact water directed to the TIA or to Roberts Bay via the marine outfall mixing box (MOMB);
- treated waste water discharged to the TIA; and
- water from the TIA treated and discharged to Roberts Bay via a discharge pipeline, with use of a MOMB.

Hope Bay Regional Exploration Project

The Hope Bay Regional Exploration Project has been renewed several times since 1995. The current extension expires in June 2022. Much of the previous work for the program was based out of Windy Lake and Boston camps. These camps were closed in October 2008 with infrastructure either decommissioned or moved to the Doris site. All exploration activities are now based from the Doris site. Components and activities for the Hope Bay Regional Exploration Project include:

- operation of helicopters from Doris; and
- the use of exploration drills, which are periodically moved by roads and by helicopter as required.

Madrid Advanced Exploration

In 2017, the NWB issued a Type B Water Licence (2BB-MAE1727) for the Madrid Advanced Exploration Program to support continued exploration and a bulk sample program at the Madrid North and Madrid South sites, located approximately 4 km south of the Doris site. The program includes extraction of a bulk sample totaling 50 tonnes from each of the Madrid North and South locations, which will be trucked to the mill at the Doris site for processing and placement of tailings in the tailings impoundment area (TIA). All personnel will be housed in the Doris camp.

The Madrid Advanced Exploration Program includes the following components and activities.

- Use of existing infrastructure associated with the Doris Project:
    - camp facilities to support up to 70 personnel as required to undertake the advanced exploration activities;
    - mill to process ore;
    - TIA;
    - landfill and hazardous waste areas, particularly if closure and remediation becomes required for the Madrid Advanced Exploration Program infrastructure;

- fuel tank farms; and
- Doris airstrip and Roberts Bay facility for transport of personnel and supplies.

- Use of existing infrastructure at the Madrid and Boston areas:
  - borrow and rock quarry facilities: existing Quarries A, B, and D along the Doris-Windy all-weather road (AWR);
  - AWR between Doris and Windy Lake for transportation of personnel, ore, waste, fuel, and supplies; and
  - future mobilization of existing exploration site infrastructure, should it become necessary.
- Construction of additional facilities at Madrid North and South:
  - access portals and ramps for underground operations at Madrid North and at Madrid South;
  - 4.7 km extension of the existing AWR originating from the Doris to the Windy exploration area (Madrid North) to the Madrid South deposit, with branches to Madrid North, Madrid North vent raise, and the Madrid South portal;
  - development of a winter road route (WRR) from Madrid North to access Madrid South until AWR has been constructed;
  - borrow and rock quarry facilities; two quarries referenced as Quarries G and H;
  - waste rock and ore stockpiles;
  - water and waste management structures; and
  - additional site infrastructure, including compressor building, brine mixing facility, saline storage tank, air heating facility, four vent raises, workshop and office, laydown area, diesel generator, emergency shelter, fuel storage facility/transfer station.
- Undertaking of advanced exploration access to aforementioned deposits through:
  - continue field mapping and sampling, as well as airborne/ground/downhole geophysics;
  - diamond drilling from the surface and underground; and
  - bulk sampling through underground mining methods and mine development.

<u>Boston Advanced Exploration</u>

The Boston Advanced Exploration Project Type B Water Licence No. 2BB-BOS1217 was renewed as Water Licence No. 2BB-BOS1727 in July 2017 and includes:

- the Boston camp (65 person), maintenance shops, workshops, laydown areas, water pumphouse, vent raise, warehouse, site service roads, sewage and greywater treatment plant, fuel storage and transfer station, landfarm, solid waste landfill and a heli-pad;
- mine works, consisting of underground development for exploration drilling and bulk sampling, waste rock and ore stockpiles;
- potable water and industrial water from Aimaokatalok Lake; and
- treated sewage and greywater discharged to the tundra.

5.3.1.2 The Madrid-Boston Project

The Madrid-Boston Project includes: the Construction and Operation of commercial mining at the Madrid North, Madrid 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 Madrid-Boston Project for the purposes of the assessment are the Reclamation and Closure and Post-closure components of the Doris Project as currently permitted and approved.

Construction

Madrid-Boston construction will use the infrastructure associated with Existing and Approved Projects. This may include:

- an all-weather airstrip at the Boston exploration area and helicopter pad;
- seasonal construction and/or operation of a winter ice strip on Aimaokatalok Lake;
- Boston camp with expected capacity for approximately 65 people during construction
- Quarry D Camp with capacity for up to 180 people;
- seasonal construction/operation of Doris to Boston WRR;
- three existing quarry sites along the Doris to Windy AWR;
- Doris camp with capacity for up to 280 people;
- Doris airstrip, winter ice strip, and helicopter pad;
- Roberts Bay offloading facility and road to Doris; and
- Madrid North and Madrid South sites and access roads.

Additional infrastructure to be constructed for the proposed Madrid-Boston Project includes:

- expansion of the Doris TIA (raising of the South Dam, construction of West Dam, development of a west road to facilitate access, and quarrying, crushing, and screening of aggregate for the construction);
- construction of a cargo dock at Roberts Bay (including a fuel pipeline, mooring points, beach landing and gravel pad, shore manifold);
- construction of an additional tank farm at Roberts Bay (consisting of two 10 ML tanks);
- expansion of Doris accommodation facility (from 280 to 400 person), mine dry and administrative building, water treatment at Doris site;
- expansion of the Doris mill to accommodate concentrate handling on the south end of the building facility and rearrangement of indoor crushing and processing within the mill building;
- complete development of the Madrid North and Madrid South mine workings;
- incremental expansion of infrastructure at Madrid North and Madrid South to accommodate production mining, including vent raise, access road, process plant buildings;
- construction of a 1,200 tpd concentrator, fuel storage, power plant, mill maintenance shop, warehouse/reagent storage at Madrid North;
- all weather access road and tailings line from Madrid North to the south end of the TIA;
- AWR linking Madrid to Boston (approximately 53 km long, nine quarries for permitting purposes, four of which will likely be used);
- all-weather airstrip, airstrip building, helipad and heliport building at Boston;
- construction of a 2,400 tpd process plant at Boston;

- all infrastructure necessary to support mining and processing activities at Boston including construction of a new 300-person accommodation facility, mine office and dry and administration buildings, additional fuel storage, laydown area, ore pad, waste rock pad, diesel power plant and dry-stack tailings management area (TMA);
- infrastructure necessary to support ongoing exploration activities at both Madrid and Boston; and
- wind turbines near the Doris (2), Madrid (2), and Boston (2) sites.

<u>Operation</u>

The Madrid-Boston Project Operation phase includes:

- mining of the Madrid North, Madrid South, and Boston deposits;
- operation of a concentrator at Madrid North;
- transportation of ore from Madrid North, Madrid South, and Boston to the Doris process plant, and transporting the concentrate from the Madrid North concentrator to the Doris process plant;
- extending the operation at Roberts Bay and Doris;
- processing the ore and/or concentrate from Madrid North, Madrid South, and Boston at the Doris process plant with disposal of the detoxified tailings underground at Madrid North, flotation tailings from the Doris process plant pumped to the expanded Doris TIA, and discharge of the TIA effluent to the marine environment;
- operation of a concentrator at Madrid North and disposal of tailings at the Doris TIA;
- operation of a process plant and wastewater treatment plant at Boston with disposal of flotation tailings to the Boston TMA and a portion placed underground and the detoxified leached tailings placed in the underground mine at Boston;
- operation of two wind turbines for power generation; and
- on-going maintenance of transportation infrastructure at all sites (cargo dock, jetty, roads, and quarries).

<u>Reclamation and Closure</u>

Areas which are no longer needed to carry out Madrid-Boston Project activities may be reclaimed during Construction and Operation.

At Reclamation and Closure, all sites will be deactivated and reclaimed in the following manner (see Volume 3, Chapter 2, Section 5.5):

- Camps and associated infrastructure will be disassembled and/or disposed of in approved non-hazardous site landfills.
- Non-hazardous landfills will be progressively covered with quarry rock, as cells are completed. At final closure, the facility will receive a final quarry rock cover which will ensure physical and geotechnical stability.
- Rockfill pads occupied by construction camps and associated infrastructure and laydown areas will be re-graded to ensure physical and geotechnical stability and promote free-drainage, and any obstructed drainage patterns will be re-established.
- Quarries no longer required will be made physically and geotechnically stable by scaling high walls and constructing barrier berms upstream of the high walls.

- Landfarms will be closed by removing and disposing of the liner, and re-grading the berms to ensure the area is physically and geotechnically stable.
- Mine waste rock will be used as structural mine backfill.
- The Doris TIA surface will be covered waste 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 AWR 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 and the liner will be cut to prevent collecting any water. The balance of the berms will be left in place to prevent localized permafrost degradation.

5.3.2 Spatial Boundaries

The spatial boundaries selected to shape this assessment are determined by the Project's potential effects on the freshwater environment. Spatial boundaries are determined based on the anticipated zone of influence between Project components/activities and freshwater sediment quality.

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

5.3.2.1 Project Development Area

The PDA is shown in Figure 5.2-2 and is defined as the area that has the potential for infrastructure to be developed as part of the Madrid-Boston 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-field modifications during the 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 vary 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 the Doris infrastructure.

5.3.2.2 Local Study Area

The LSA for the assessment of freshwater sediment quality 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 Aimaokatalok, Windy, Patch, and Doris lakes, and is consistent with the LSA used for the surface hydrology, water quality, and fish and fish habitat VECs (Figure 5.2-2).

5.3.2.3 Regional Study Area

The RSA for the assessment of freshwater sediment quality is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur. 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 sediment quality VEC includes portions of the Angimajuq Watershed and the Koignuk River Watershed located to the west of the PDA, and is consistent with the RSA used for the surface hydrology, water quality, and fish and fish habitat VECs (Figure 5.2-2).

5.3.3 Temporal Boundaries

The Project represents an important 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, the Madrid-Boston Project is a continuation of development currently underway. The Project has four separate operational sites: Roberts Bay, Doris, Madrid (North and South), and Boston. The development of these sites is planned to be sequential. As such, the temporal boundaries of this Project overlap with a number of existing and approved authorizations for the Hope Bay Project and the extension of activities.

For the purposes of the EIS, distinct phases of the Project are defined (Table 5.4-1). It is understood that Construction, Operation and Closure activities will, in fact, overlap among sites; this is outlined in Table 5.4-1 and further described in Volume 3, Chapter 2 (Project Description).

The assessment also considers a Temporary Closure phase should there be a suspension of Project activities during periods when the Project becomes uneconomical due to market conditions. During this phase, the Project 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).

Table 5.4-1. Temporal Boundaries for the Effects Assessment for Freshwater Sediment Quality

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Construction	1 - 4	2019 - 2022	4	• **Roberts Bay:** construction of access road (Year 1), marine dock and additional fuel facilities (Year 2 – Year 3) • **Doris**: expansion of the Doris TIA and accommodation facility (Year 1) • **Madrid North:** construction of concentrator and road to Doris TIA (Year 1 – Year 2) • **All-weather Road**: construction (Year 1 – Year 3) • **Boston**: site preparation and installation of all infrastructures including process plant (Year 2 – Year 5)
Operation	5 - 14	2023 - 2032	10	• **Roberts Bay**: sealift and fuel supply (Year 1 – Year 14) • **Doris**: processing and infrastructure use (Year 1 – Year 14) • **Madrid North:** mining (Year 1 – 13); ore transport to Doris process plant (Year 1 -13); ore processing and concentrate transport to Doris process plant (Year 2 – Year 13) • **Madrid South:** mining (Year 11 – Year 14); ore transport to Doris process plant (Year 11 – Year 14) • **All-weather Road**: operational (Year 4 – Year 14) • **Boston**: winter access road operating (Year 1 – Year 3); mining (Year 4 – Year 11); ore transport to Doris process plant (Year 4 – Year 6); and processing ore (Year 5 – Year 11)

Phase	Project Year	Calendar Year	Length of Phase (Years)	Description of Activities
Reclamation and Closure	15 - 17	2033 - 2035	3	• **Roberts Bay**: facilities will be operational during closure (Year 15 – Year 17) • **Doris**: camp and facilities will be operational during closure (Year 15 – Year 17); mine, process plant, and TIA decommissioning (Year 15 – Year 17) • **Madrid North:** all components decommissioned (Year 15 – Year 17) • **Madrid South:** all components decommissioned (Year 15 – Year 17) • **All-weather Road**: road will be operational (Year 15 – Year 16); decommissioning (Year 17) • **Boston**: all components decommissioned (Year 15 – Year 17)
Post-Closure	18 - 22	2036 - 2040	5	• **All Sites:** Post-closure monitoring
Temporary Closure	Not Applicable	Not Applicable	Not Applicable	• **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

5.4 PROJECT-RELATED EFFECTS ASSESSMENT

5.4.1 Methodology Overview

This assessment is informed by a methodology used to identify and assess the potential environmental effects of the Madrid-Boston Project and is consistent with the requirements of Section 12.5.2 of the Nunavut Agreement and the EIS guidelines (NIRB 2012). The effects assessment evaluates the potential direct and indirect effects of the Project on the freshwater environment and follows the general methodology provided in Volume 2, Chapter 4 (Effects Assessment Methodology). It comprises a number of steps that collectively assess the manner in which the Madrid-Boston Project will interact with the freshwater sediment quality VEC defined for the assessment (Section 5.3).

To provide a comprehensive understanding of the potential effects of the Project, the components and activities of the Madrid-Boston Project are assessed on their own as well as in the context of the existing and 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 Madrid-Boston Project and freshwater sediment quality;
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 the Madrid-Boston Project in isolation;
5. Identify residual effects of the Madrid-Boston Project in combination with the residual effects of existing and approved projects; and
6. Determine the significance of residual effects.

After the identification of potential interactions between the Madrid-Boston Project and freshwater sediment quality (Step 1, Section 5.5.2), the potential effects of these interactions are identified (Step 2, Section 5.5.2). Mitigation and management measures are then considered (Step 3, Section 5.5.3). If the application of these measures is expected to effectively mitigate the effects from the Madrid-Boston Project, the Madrid-Boston Project-related effects to freshwater sediment quality are characterized as *negligible* and not carried forward as residual effects (Step 4, Section 5.5.4). In parallel, the potential effects of the Madrid-Boston Project in combination with the existing and approved projects are assessed, and characterized as *negligible* if the mitigation and management measures are considered effective (Step 5, Section 5.5.4).

All remaining potential effects are then considered residual effects, and characterized (Step 6, Section 5.5.5) using the following attributes:

- direction;
- magnitude;
- duration;
- frequency;
- geographical extent; and
- reversibility.

The rating criteria for the assessment of residual effects are described in the Effects Assessment Methodology chapter (Volume 2, Chapter 4). The significance of each residual effect (Step 6, Section 5.5.5) is determined by considering the characterization of each residual effect, the probability of occurrence, and the confidence in the predictions of the effects.

5.4.1.1 Sediment Quality Indicators

Sediment quality is an aggregate term that encompasses a complex suite of parameters and indicators that describe the sediment environment and its ability to sustain ecological and biogeochemical functions. These parameters and indicators range from physical descriptions of the composition of the sediments (e.g., the relative abundance of coarse and fine particles) to the presence and concentration of specific chemical constituents. The assessment of the potential effects of the Madrid-Boston Project on freshwater sediment quality is based on indicators that described the most probable and significant interactions between the Madrid-Boston Project and the freshwater sediment environment (Table 5.5-1). These indicators are 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 5.5-1. Freshwater Sediment Quality Indicators for the Assessment of Effects

Indicator	Description	Interaction with Project
Particle Size	The relative proportion of silt-, clay-, sand-, and gravel-sized particles	Project activities may disturb sediments, increase runoff of deposited sediment, or discharge suspended material
Nutrients and Organic Carbon	Nutrients adsorbed to sediment particles or dissolved in sediment interstitial water and organic material in sediments	Project activities may contribute organic material to waterbodies directly through discharge, runoff, or deposition, or indirectly through nutrient addition (eutrophication)
Metals	Metals adsorbed to sediment particles or dissolved in sediment interstitial water	Contribute metals (dissolved or particulate) through runoff, discharge, and deposition
Hydrocarbons	Petroleum hydrocarbon compounds	Contribute petroleum hydrocarbons through runoff, discharge, and deposition

For the effects assessment, thresholds are applied to the sediment quality indicators (Table 5.5-2). These thresholds are based on CCME sediment quality guidelines for the protection of aquatic life, when applicable. In some cases, baseline concentrations of sediment metals (e.g., arsenic, chromium, and copper) are naturally higher than CCME guidelines (see Sections 5.2.4.1 and 5.2.4.2); for these naturally enriched metals, baseline concentrations are also considered in the determination of acceptable threshold concentrations. If sediment quality guidelines are not available, the thresholds may be defined based on existing conditions described in the baseline sampling program. Some residual effects may be assessed qualitatively, which do not necessarily permit the application of specific, quantitative thresholds.

Table 5.5-2. Assessment Thresholds for Freshwater Sediment Quality Indicators

		CCME Guideline Concentration (mg/kg)	
Indicator	Parameter	ISQG†	PEL†
Particle size	Particle size	*No regulatory threshold value; threshold set to 75th percentile of baseline values*	
Nutrients and Organic Carbon	Nutrients and TOC	*No regulatory threshold value; threshold set to 75th percentile of baseline values*	
Metals	Arsenic*	5.9	17
	Cadmium	0.6	3.5
	Chromium*	37.3	90
	Copper*	35.7	197
	Lead	35.0	91.3
	Mercury	0.170	0.486
	Zinc	123	315
Hydrocarbons	Petroleum hydrocarbons	*Range of guidelines for petroleum hydrocarbon compounds (CCME 2017)*	

† CCME freshwater sediment ISQG and PEL for the protection of aquatic life (CCME 2017).
** Baseline concentrations of these metals were naturally higher than CCME ISQGs in several freshwater sediment samples, particularly from lake sediments (Tables 5.2-6 and 5.2-7). When the 75th percentile of baseline concentrations of a metal is higher than the ISQG for that metal, the threshold is set at the 75th percentile of baseline concentrations.*

5.4.2 Identification of Potential Effects

The Madrid-Boston Project has the potential to interact with the freshwater environment through a number of activities, pathways, and mechanisms. Project activities are grouped into broad components as described in Section 4.3.4.1 of the Effects Assessment Methodology (Volume 2, Chapter 4). The interactions between the Madrid-Boston Project and freshwater sediment quality are 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 sediment quality through activities related to the storage and use of fuel. The defined interaction groups for the assessment of effects to freshwater sediment 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 site surface infrastructure, mine surfaces (e.g., waste rock piles, ore storage areas, crown pillar recovery trenches) and operations (e.g., water management, drilling water, underground mine water). The site and mine contact water interaction group also includes the operation of the water treatment plant (WTP) and sewage treatment plant (STP) at the Boston site, where the two water sources will be treated, combined, and then discharged into Aimaokatalok Lake through a single pipeline-diffuser system.
- *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.
- *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 5.5-3. These components are expected to have probable or likely interactions with the freshwater environment. These potential interactions may be direct or indirect, and this screening step does not consider application of mitigation and management measures.

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 Project component and the freshwater environment, for identifying applicable mitigation measures, and for characterizing the residual effects. For the freshwater sediment quality effects assessment, the following pathways are 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;
- *seepage*, which describes the flow of water through the active layer and taliks;
- *physical*, which is the direct physical effects of Project activities in the freshwater environment; and
- *aerial deposition*, which is the direct input of material and chemical compounds from the air into the freshwater environment.

Table 5.5-3. Project Interaction with the Freshwater Sediment Quality VEC

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Roberts Bay	**Construction - proposed Madrid-Boston infrastructure**						
	Dock access road	×	×				×
	Fuel pipeline and tank farm	×	×			×	
	Quarry	×	×	×	×		×
	Equipment and vehicle emissions					×	×
	Construction and Operation - use of existing approved and permitted infrastructure						
	Fuel tank farm	×	×			×	
	Laydown areas	×	×			×	×
	Equipment and vehicle emissions					×	×
	Roberts Bay-Doris road use and maintenance	×	×			×	×
	Site roads use and maintenance	×	×			×	×
	Water Management System	×	×				
	Operation - proposed Madrid-Boston infrastructure						
	Use of dock access road		×			×	×
	Fuel pipeline and tank farm		×			×	
	Quarry		×	×	×		×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure - use of existing approved and permitted infrastructure						
	Site surface infrastructure	×	×			×	
	Equipment and vehicle emissions					×	×
	Roberts Bay-Doris road	×	×			×	×
	Reclamation and Closure - proposed Madrid-Boston infrastructure						
	Site surface infrastructure	×	×			×	
	Equipment and vehicle emissions					×	×
	Dock access road	×	×			×	×
	Quarry	×	×				×
	Post Closure - proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Doris	**Construction - proposed Madrid-Boston infrastructure**						
	Expansion of the PDA	×	×				×
	Expansion of accommodations	×	×				×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Doris	Equipment and vehicle emissions					×	×
	Quarries	×	×	×	×		×
	Raising the TIA South Dam	×	×				×
	TIA perimeter road extensions	×	×				×
	TIA West Dam	×	×				×
	Road to TIA South Dam	×	×				×
	Windy Lake north freshwater intake	×					
	Expansion to mine dry and administration building	×	×				×
	Expansion to water treatment plant	×	×				×
	Operation – use of existing approved and permitted infrastructure						
	Airstrip, winter ice strip and helicopter pad		×			×	×
	Accommodation facilities (sewage treatment facilities, domestic water treatment, fire suppression)		×				
	Chemical and hazardous material management facilities		×			×	
	Diesel power plant		×			×	×
	Fuel storage and handling		×			×	
	Incinerator		×			×	×
	Equipment and vehicle emissions					×	×
	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		×				
	Operation – proposed Madrid-Boston infrastructure						
	Expanded PDA		×				
	Quarry		×	×	×		×
	TIA road use and maintenance		×			×	×
	TIA storage		×				
	Equipment and vehicle emissions					×	×
	Reclamation and Closure – use of existing approved and permitted infrastructure						
	Equipment and vehicle emissions					×	×
	Site surface and mining infrastructure	×	×				×
	Airstrip	×	×			×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Doris	**Reclamation and Closure – proposed Madrid-Boston infrastructure**						
	Equipment and vehicle emissions					×	×
	Accommodations (expanded)	×					
	Quarry	×	×				×
	TIA roads (perimeter and South Dam)	×	×			×	×
	TIA	×	×				
	Windy Lake north freshwater intake	×					
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Madrid North	**Construction – use of existing approved and permitted infrastructure**						
	Air heating facility	×					×
	Brine mixing facility	×					×
	Diesel power plant	×				×	×
	Fuel storage and handling	×	×			×	
	Equipment and vehicle emissions					×	×
	Ore stockpile	×	×				×
	Quarry	×	×	×	×		×
	Site roads	×	×			×	×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)	×	×				×
	Underground mine (drilling, blasting, excavation, ventilation)	×	×		×		×
	Wasterock pile	×	×				×
	Water management system	×	×				
	Construction – proposed Madrid-Boston infrastructure						
	Expansion of the PDA	×	×				×
	Expansion of site pad (waste rock stockpile)	×	×				×
	Process plant (concentrator)	×					×
	Power plant	×				×	×
	Water discharge to the receiving environment		×				
	Water management system (including expanded CWP)	×	×				
	Expansion to fuel storage	×	×			×	×
	Expansion to power generation	×	×			×	×
	Expansion to ore and waste-rock stockpile	×	×				×
	Vent raise and access road	×	×				×
	Tailings pipeline and service road to Doris TIA	×	×				×
	Equipment and vehicle emissions					×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Madrid North	**Operation - use of existing approved and permitted infrastructure**						
	Diesel power plant		×			×	×
	Doris - Madrid road use and maintenance		×			×	×
	Fuel storage and handling		×			×	
	Equipment and vehicle emissions		×			×	×
	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)		×			×	×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×		×
	Wasterock pile		×				×
	Water management system		×				
	Operation - proposed Madrid-Boston infrastructure						
	Expansion of PDA		×				
	Power plant					×	×
	Water discharge to the receiving environment		×				
	Water management system (including CWP)		×				
	Domestic water trucked from existing water intake location						×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure - proposed Madrid-Boston infrastructure						
	Inter-site roads	×	×			×	×
	Machine and vehicle emissions					×	×
	Site surface and mining infrastructure	×	×			×	×
	Post Closure - proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Madrid South	**Construction - use of existing approved and permitted infrastructure**						
	Air heating facility	×					×
	Brine mixing facility	×					×
	Diesel power plant	×				×	×
	Fuel storage and handling	×	×			×	
	Equipment and vehicle emissions					×	×
	Ore stockpile	×	×				×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Madrid South	Quarry	×	×	×	×		×
	Site roads	×	×			×	×
	Surface infrastructure (shop, compressor building, laydown area, office, emergency shelter)	×	×				×
	Underground mine (drilling, blasting, excavation, ventilation)	×	×		×		×
	Wasterock pile	×	×				×
	Water management system	×	×				
	Construction – proposed Madrid-Boston infrastructure						
	Expansion of PDA	×	×				×
	Expansion of site pad (waste rock stockpile)	×	×				×
	Water discharge to the receiving environment		×				
	Water management system (including expanded CWP)	×	×				
	Expansion of ore and waste-rock stockpile	×	×				×
	Vent raise and access road	×	×				×
	Equipment and vehicle emissions					×	×
	Operation – use of existing approved and permitted infrastructure						
	Diesel power plant		×			×	×
	Doris - Madrid road use and maintenance		×			×	×
	Fuel storage and handling		×			×	
	Equipment and vehicle emissions					×	×
	Ore stockpile		×				×
	Quarry		×	×	×		×
	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 Madrid-Boston infrastructure						
	Expansion of the PDA		×				
	Water discharge to the receiving environment		×				
	Water management system (including CWP)		×				
	Domestic water trucked from existing water intake location						×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Inter-site roads	×				×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Madrid South	Equipment and vehicle emissions					×	×
	Site surface and mining infrastructure	×	×			×	×
	Post Closure - proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Madrid-Boston All-Weather Road	**Construction - use of existing approved and permitted infrastructure**						
	Quarries	×	×	×	×		×
	Construction - proposed Madrid-Boston infrastructure						
	All weather road (grading, backfill, excavation, drainage)	×	×			×	×
	Animal crossings	×	×				
	Construction accommodations	×					×
	Equipment and vehicle emissions					×	×
	Quarries	×	×	×	×		×
	Water crossings	×	×				
	Operation - use of existing approved and permitted infrastructure						
	Equipment and vehicle emissions					×	×
	Operation - proposed Madrid-Boston infrastructure						
	All weather road use and maintenance		×			×	×
	Animal crossings		×				
	Equipment and vehicle emissions					×	×
	Quarries		×	×	×		×
	Water crossings		×				
	Reclamation and Closure - use of existing approved and permitted infrastructure						
	Madrid-Boston winter road	×	×			×	×
	Construction accommodation	×	×				×
	Equipment and vehicle emissions					×	×
	Reclamation and Closure - proposed Madrid-Boston infrastructure						
	All-weather road, quarries and associated infrastructure	×	×				×
	Equipment and vehicle emissions					×	×
	Post Closure - proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Boston	**Construction – use of existing approved and permitted infrastructure**						
	Airstrip and helicopter pad	×	×				×
	Winter ice strip on Aimaokatalok Lake	×	×				
	Accommodations	×	×				×
	Equipment and vehicle emissions					×	×
	Construction – proposed Madrid-Boston infrastructure						
	Accommodations (sewage treatment facilities, potable water treatment, fire suppression)	×	×				×
	Diesel power plant	×	×			×	×
	Expansion of PDA	×	×				×
	Fuel storage and handling	×	×			×	
	Heliport and heliport shack	×	×				×
	Incinerator	×	×			×	×
	Landfarm	×	×				×
	Equipment and vehicle emissions					×	×
	Ore stockpile	×	×				×
	Overburden pile	×	×				×
	Quarries	×	×	×	×		×
	Second mine portal	×	×				×
	Site roads	×	×			×	×
	Surface infrastructure (exploration office, core storage facility, laydown area, emergency shelter, office, warehouse, reagent storage, workshop, waste management facility, brine mixing facility, vent raise)	×	×			×	×
	Underground mine (drilling, blasting, excavation, ventilation)	×	×		×		×
	Waste rock pad and pile	×	×				×
	Water discharge to the environment		×				
	Water management system	×	×				
	Process plant (concentrator)	×	×				×
	Dry-stack TMA	×	×				×
	TMA roads	×	×			×	×
	TMA water management system	×	×				
	Explosives facility	×	×		×		×
	Operation – proposed Madrid-Boston infrastructure						
	Camp (sewage treatment facilities, potable water treatment, fire suppression)		×				×
	Diesel power plant		×			×	×
	Expanded PDA		×				

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Boston	Fuel storage and handling		×			×	
	Heliport and heliport shack		×				×
	Incinerator		×			×	×
	Landfarm		×				×
	Equipment and vehicle emissions					×	×
	Ore stockpile		×				×
	Overburden pile		×				×
	Quarries		×	×	×		×
	Site roads and maintenance		×			×	×
	Surface infrastructure (exploration office, core storage facility, laydown area, office, emergency shelter, warehouse, reagent storage, workshop, waste management facility)		×			×	×
	Underground mine (drilling, blasting, excavation, ventilation)		×		×		×
	Waste rock pile		×				×
	Water discharge to the environment		×				
	Water management system		×				
	Process plant (concentrator)		×				
	Dry-stack TMA		×				×
	TMA roads use and maintenance					×	×
	TMA water management system		×				
	Reclamation and Closure - proposed Madrid-Boston infrastructure						
	Site surface and mining infrastructure	×	×			×	×
	Equipment and vehicle emissions					×	×
	TMA and associated infrastructure	×	×				×
	Post Closure - proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	
Boston Airstrip	**Construction - proposed Madrid-Boston infrastructure**						
	Access road	×	×				×
	Airstrip and lighting	×	×				×
	PDA	×	×				×
	Equipment and vehicle emissions					×	×
	Quarry	×	×	×	×		×
	Operation - proposed Madrid-Boston infrastructure						
	Access road use and maintenance		×			×	×
	Airstrip and lighting		×			×	×

Location	Project Component/Activity	Site Preparation, Construction, and Decommissioning	Site and Mine Contact Water	Quarries and Borrow Pits	Explosives	Fuels, Oils, and PAH	Dust Deposition
Boston Airstrip	PDA		×				
	Equipment and vehicle emissions					×	×
	Quarry		×	×	×		×
	Reclamation and Closure – proposed Madrid-Boston infrastructure						
	Site surface infrastructure	×	×			×	×
	Equipment and vehicle emissions					×	×
	Post Closure – proposed Madrid-Boston infrastructure						
	Post closure monitoring		×				
	Temporary Closure						
	Care and maintenance		×			×	

The pathways applicable to each Project interaction group are summarized in Table 5.5-4. These pathways are used throughout the effects assessment to describe the potential effects, identify mitigation and management measures, and characterize the residual effects from Project activities.

The potential effects of each of the Project activities identified in Table 5.5-4 are characterized in Sections 5.5.2.1 to 5.5.2.6. The potential effects analysis considers the proposed Project activities and the pathway(s) linking the Project activities to the freshwater environment. The potential effects are identified prior to the application of mitigation or management measures. The subsequent characterization of the potential effects (Section 5.5.4) considers mitigation and management measures, and may show that the potential effects are negligible.

Table 5.5-4. Pathways of Interactions with the Freshwater Environment for the Freshwater Sediment Quality Effects Assessment

Project Activity	Pathway	Indicators	Project Phases
Site preparation, construction, and decommissioning activities	Runoff, physical, aerial deposition	Particle size, TOC, nutrients, metals, hydrocarbons	Construction, and Reclamation and Closure
Site and mine contact water	Runoff, discharge, seepage	Particle size, TOC, nutrients, metals, hydrocarbons	Construction, Operation, Reclamation and Closure, Post-closure, Temporary Closure
Quarries	Runoff, aerial deposition	Particle size, TOC, nutrients, metals, hydrocarbons	Construction, Operation, Reclamation and Closure
Explosives	Runoff, aerial deposition	TOC, nutrients, hydrocarbons	Construction and Operation
Fuels, oils, PAH	Runoff, aerial deposition	hydrocarbons	Construction, Operation, Reclamation and Closure, Temporary Closure
Dust deposition	Aerial deposition	Particle size, nutrients, metals, hydrocarbons	Construction, Operation, and Reclamation and Closure

5.4.2.1 Site Preparation, Construction and Decommissioning Activities

During the Construction phase, ground preparation will be required throughout the PDA to construct necessary Madrid-Boston infrastructure, including buildings, roads, and mine works. As outlined in Table 5.5-3, the Madrid-Boston Project includes the 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 Madrid-Boston 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 sediment 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. Runoff from areas undergoing site preparation or decommissioning could affect freshwater sediment quality by changing sediment particle size composition (sedimentation of eroded material) and by contributing metals, nutrients, organic matter, and hydrocarbons (from the use of fuels and oils) into the freshwater environment.

In-water or near-water activities, including the installation or decommissioning of stream-crossing infrastructure for the AWRs, the discharge pipeline in Aimaokatalok Lake, and freshwater intake pipelines in Aimaokatalok and Windy lakes, also have the potential to disturb and rework sediments. Four AWRs are proposed that will cross streams including the Roberts Bay Cargo Dock Access Road, Madrid North-TIA AWR, the Madrid South AWR, and the Boston-Madrid AWR. Culverts or bridges will be installed in or over streams that will be crossed by roads to allow for the flow of water and passage of fish.

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

Site Preparation, construction, and decommissioning activities that could generate dust (which could ultimately be deposited in the freshwater environment) are considered in Section 5.5.2.6.

5.4.2.2 Site and Mine Contact Water

Site contact water is 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 Volume 4, Chapter 5, Geochemistry); only rock from quarries defined as suitable for use on the basis of 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 transport suspended material, metals, nutrients, organic matter, and petroleum hydrocarbon compounds into the freshwater environment if not managed or mitigated. The potential for effects from site contact water could occur during all phases of the Madrid-Boston Project.

Mine contact water is defined as the underground water removed from mine works; water that interacts with waste rock storage areas, ore stockpiles, crown pillar recovery trenches, and water management structures that will be directed to contact water ponds (CWPs); mill process water; and water in the TIA. The pathways of interaction between mine contact water and the freshwater environment are runoff, seepage, and discharge. Discharge is included as an interaction pathway since the mine and site contact water at the Boston site will be collected, treated, and discharged to

Aimaokatalok Lake. Discharge from the Boston sewage treatment plant (STP) is also included in this interaction group as the Boston greywater and sewage will be treated and combined with the other Boston WTPs before being discharged to Aimaokatalok Lake. The site and mine water collected at the Doris and Madrid sites will be transferred to the TIA and discharged to Roberts Bay via the Roberts Bay Discharge System; therefore, this discharge stream is not included in the freshwater sediment quality assessment because the effluent is directed to the marine environment (see Volume 5, Chapter 9).

Site and mine contact water (including water interacting with overburden, waste rock, and tailings), including discharge from the Boston WTPs and STP, could affect the freshwater water quality by changing pH, and contributing TSS, metals, nutrients (contact with blasting residues, treated sewage), and other water quality indicators such as hydrocarbons into the freshwater environment. A change in freshwater water quality could secondarily affect sediment quality through changes in dissolved oxygen dynamics and redox conditions, changes in water-sediment exchange processes, or through the settling of particulate material onto the lake, stream, or river bed. Depending on the environmental conditions and the biogeochemical properties of the parameter in question, sediments can act as a net sink for introduced metals, nutrients, organic matter, or contaminants or as a net source if conditions favour the release of these elements or compounds from sediments into the water.

The potential effects from site and mine contact water may occur during the Construction, Operation, Reclamation and Closure, Post-closure, and Temporary Closure phases of the Madrid-Boston Project.

5.4.2.3 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. Contact water in quarries and borrow pits may transport metals, nutrients (from contact with blasting residues - considered in Section 5.5.2.4) and suspended sediments into the freshwater environment. Runoff from quarries and borrow pits could change the particle-size composition of sediments (because of the deposition of eroded sediments) and add metals, nutrients, organic material, and hydrocarbons (mechanical use of fuel, oil, and grease) into the freshwater environment, where they have the potential to interact with sediments.

The dust generated at quarries and borrow pits that could ultimately be deposited in the freshwater environment are considered in Section 5.5.2.6.

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

5.4.2.4 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 sediment 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. Runoff and deposition of explosives (or blasting residues) into the freshwater environment can affect sediment quality directly by increasing the concentrations of ammonia and nitrate, and indirectly as a nutrient source for primary producers that could affect sediment TOC concentrations. The petroleum hydrocarbon 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 to sediment quality because of their small relative proportion in the ANFO explosives.

Airborne explosives residues that could potentially be deposited in the freshwater environment are considered in Section 5.5.2.6.

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

5.4.2.5 Fuels, Oils, and PAH

The *Fuels, Oils, and PAH* 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 interaction 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, Chapter 1).

The potential for the deposition of airborne PAH generated by incomplete combustion into the freshwater environment is considered in Section 4.5.2.6.

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

5.4.2.6 Dust Deposition

Dust (i.e., airborne particulates) can be generated by a variety of Project activities, including construction activities, vehicle traffic, blasting, incinerator use, quarry operations, and rock processing. Areas cleared for infrastructure (i.e., laydown areas) can also be sources of dust. The aerial deposition of Project-generated dust is the primary pathway of interaction. Dust deposited into the freshwater environment can affect freshwater sediment quality by introducing airborne material into lake, stream, and river beds, which could change the particle-size composition of sediments and increase the concentrations of metals, nutrients, or organic material in sediments.

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

5.4.3 Mitigation and Adaptive Management

5.4.3.1 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:

- Use of existing infrastructure associated with the Doris Project;
- Inclusion of climate change projections for key climatic and hydrological design details (Package P5-2);
- 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 waterways;

- 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;
- Using 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
- Appropriate secondary containment systems will be used for petroleum product storage tanks to prevent spills and releases to water. Bulk fuel storage areas, hazardous materials storage areas, and explosives storage facilities will be bermed and lined with impermeable barriers to minimize leaks and spills.

The design of the Madrid-Boston Project also incorporated adherence to regulatory requirements relevant to the mitigation of potential effects on the freshwater environment. These regulatory requirements include 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), as well as TMAC's own Incinerator Management Plan (Package P4-16). Modern incineration equipment will be installed to minimize airborne contaminant loading of PAH;
- 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); and
- Water withdrawal will follow Type A Water Licence conditions.

5.4.3.2 Best Management Practices

Reducing potential effects to the freshwater environment by avoidance is the most effective mitigation measure to reduce the potential for serious damage or harm. The design of the Project includes a number of features to avoid or minimize direct or indirect potential effects to sediments. Management and mitigation measures relevant to the avoidance or minimization of potential effects to the freshwater environment are described in the following plans and manuals:

- Oil Pollution Prevention Plan (OPPP) / Oil Pollution Emergency Plan (OPEP; Volume 8, Annex 1);
- Air Quality Management Plan (Volume 8, Annex 2);

- Hope Bay Project Spill Contingency Plan (Package P4-3);
- Doris Project Domestic Wastewater Treatment Management Plan (Package P4-4);
- Hope Bay Project: Boston Sewage Treatment Operations and Maintenance Management Plan (Package P4-5);
- Hope Bay Project Groundwater Management Plan (Package P4-6);
- Hope Bay Project Doris-Madrid Water Management Plan (Package P4-7);
- Hope Bay Project Boston Water Management Plan (Package P4-8);
- Hope Bay Project Doris-Madrid Tailings Impoundment Area Operations, Maintenance, and Surveillance Manual (Package P4-9);
- Hope Bay Project Boston Tailings Management Area Operations, Maintenance, and Surveillance Manual (Package P4-10);
- Hope Bay Project Waste Rock and Ore Management Plan (Package P4-11);
- Hope Bay Project Water and Ore/Waste Rock Management Plan (Package P4-12);
- Hope Bay Project Non-hazardous Waste Management Plan (Package P4-13);
- Hope Bay Project Hydrocarbon Contaminated Material Management Plan (Package P4-14);
- Hope Bay Project Hazardous Waste Management Plan (Package P4-15);
- Hope Bay Project Incinerator Management Plan (Package P4-16);
- Hope Bay Quarry Management and Monitoring Plan (Package P4-17);
- Hope Bay Project Aquatic Effects Monitoring Plan (Package P4-18);
- Hope Bay Project Boston Conceptual Closure and Reclamation Plan, November 2017 (Package P4-19); and
- Hope Bay Project Doris-Madrid Interim Closure and Reclamation Plan, November 2017 (Package P4-21).

Specific mitigation and management measures relevant to the assessment of effects on freshwater sediment 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 CWPs;

- Seepage and runoff from waste rock and ore stockpiles and crown pillar recovery trenches will be directed to CWPs;
- 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;
- Crown pillar recovery trenches will be covered following use to restore natural runoff to the existing drainage networks;
- CWP 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 CWPs 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;
- 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 groundwater preferentially be sent directly to Roberts Bay;
- Waters intended for discharge directly from the CWPs 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);
- The flotation tails from the Boston ore will be dewatered using a filter press and deposited in the Boston TMA dry stack facility. Filter press water will be internally recycled in the Boston process plant. A bleed stream from the process plant will first be treated in a two-stage treatment plant for metals removal followed by a biological process for ammonia removal prior to discharge to Aimaokatalok Lake;
- Excess water from CWPs will be treated in a two-stage treatment plant prior to discharge to Aimaokatalok Lake;
- 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 (Package P4-3) 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 CWPs for management and/or transported directly to the TIA for disposal;
- High quality 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 and sediment 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 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 CWPs and updating water quality predictions.

5.4.3.3 Proposed Monitoring Plans and Adaptive Management

An Aquatic Effects Monitoring Plan (Package P4-18) 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; and
- 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.

5.4.4 Characterization of Potential Effects to Freshwater Sediment Quality

The potential for effects on freshwater sediment from the Project activities identified in Section 5.5.2 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 assessment. Project residual effects are the effects that remain after mitigation and management measures are taken into consideration. If the proposed mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and a significance determination (Section 5.5.5).

Residual effects of the Madrid-Boston Project can occur directly or indirectly. Direct effects result from direct interactions between Project activities and freshwater sediment quality. Indirect effects can occur when the primary effect is to another component of the environment (e.g., water quality), which can lead to secondary or indirect effects on freshwater sediment quality.

The characterization of potential effects considers both the incremental effects of Madrid-Boston developments and activities as well as the overall effects from all components of the Hope Bay Development.

5.4.4.1 Site Preparation, Construction, and Decommissioning

The disturbance of the landscape through site preparation and the construction of infrastructure such as roads and pads can affect freshwater sediment quality through physical contact and runoff. Physical contact with sediments could cause the mobilization and redistribution of sediments which could alter the particle size distribution, and consequently affect the concentrations of metals, organic material, and pollutants in sediments. Runoff can introduce metals, nutrients, hydrocarbons, and suspended sediments into the freshwater environment, and these can interact with sediments to cause a change from baseline conditions or a degradation of sediment quality. Potential effects of runoff on sediment quality are mainly indirect, resulting from runoff water interacting with water quality, which in turn could interact with sediment quality.

The primary goal of runoff and sedimentation control 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 5.5.3) are effective in minimizing erosion, sedimentation, and potential siltation in the receiving environment, these strategies may not fully prevent all surface runoff and sediment transport. Thus, a potential residual effect from construction and decommissioning activities on freshwater sediment quality may occur. Changes to water and sediment quality during construction and decommissioning activities will be monitored to ensure that erosion controls and sedimentation mitigation strategies are effective.

Characterization of Madrid-Boston Project Potential Effects

Infrastructure that will be constructed and potentially decommissioned as part of the Madrid-Boston Project includes additional pads, roads, laydown areas, ore stockpiles, waste rock storage areas, and site surface infrastructure (e.g., camps, offices, waste management facility). Site preparation, construction, and decommissioning activities will cause a disturbance to the landscape and could increase the potential for runoff into the freshwater environment.

Although the mitigation and management measures to control erosion, runoff, and sedimentation are known to be effective, the potential for residual effects from construction and decommissioning activities on freshwater water quality is identified (see Volume 5, Chapter 4). The residual effects to water quality are predicted to be localized, short-term in duration, and occurring intermittently during snowmelt and large precipitation events. The effects of runoff during site preparation, construction, and decommissioning on freshwater water quality are further characterized as reversible and ultimately rated as not significant (Volume 5, Chapter 4). Because runoff is expected to interact primarily with water quality (which in turn interacts with sediment quality) and the residual effect of runoff on water quality is rated as not significant, there is not anticipated to be any potential residual effect of runoff from site preparation, construction, and decommissioning on freshwater sediment quality.

The in-water works required for the installation and eventual decommissioning (the portion of pipe which is buried by rock fill will remain in place) of the discharge pipeline in Aimaokatalok Lake and the freshwater intake pipelines in Windy and Aimaokatalok lakes are also included in this interaction group, because the installation on the lakebed of infrastructure associated with the pipelines (e.g., cement pipeline anchors, rock berms, high-density polyethylene (HDPE) pipeline) could temporarily disturb and re-suspend sediments. The potential effects from the in-water construction and ultimate removal of the discharge and intake pipelines (the portions not covered in rock fill) are expected to be highly localized to the lakebed footprint of the infrastructure (i.e., 1,140 m^2 for the discharge pipeline, 1,603 m^2 for the Aimaokatalok Lake intake pipeline, and 88 m^2 for the Windy Lake intake pipeline, Packages P5-23 and P5-24), and will be short-lived as the re-suspended sediments will re-settle once the pipeline installation or removal is complete.

The installation of culverts or bridges where AWRs cross streams could also affect sediment quality by disturbing and mobilizing sediments and altering the particle size distribution and sedimentation patterns. Streams in which culverts or bridges could be installed include Glenn, Ogama, Wolverine, Trout, and Stickleback outflows, and Patch, Doris, and Aimaokatalok inflows, as well as Roberts Bay Inflow and Boulder Creek (see Table 6.5-4 in Volume 5, Chapter 6 for specific locations of these streams).

The potential effects of the site preparation, construction, and decommissioning activities associated with direct physical contact with sediments (e.g., culvert and pipeline installation) are considered to be potential residual effects and are further characterized in Section 5.5.5.

Characterization of Hope Bay Development Potential Effects

As is the case for the Madrid-Boston Project, the potential residual effects on water quality of runoff from site preparation, construction, and decommissioning activities associated with the Hope Bay Development are assessed in Volume 5, Chapter 4, and are concluded to be not significant. Given that runoff is expected to interact primarily with water quality (which in turn interacts with sediment quality) and the residual effect of runoff on water quality is rated as not significant, there are not anticipated to be any potential residual effects of runoff from site preparation, construction, and decommissioning on freshwater sediment quality for the entire Hope Bay Development.

Decommissioning activities will occur throughout the Hope Bay Development, and will include the decommissioning of infrastructure at Roberts Bay and Doris. Effective mitigation and management measures will be applied, but the potential for residual effects on sediment quality from physical contact with sediments during in-water or near-water decommissioning activities remains. These potential residual effects will be further characterized in Section 5.5.5

5.4.4.2 Site and Mine Contact Water

Water and sediment quality are closely related because metals, nutrients, and organic material are continuously exchanged between the water column and sediments depending on the specific environmental conditions and the properties of the constituents of water or sediments. The potential effects from site and mine contact water on sediment quality are mainly informed by the quantitative predictions from the site-wide Water and Load Balance model (Package P5-4) as well as near-field (Appendix 5-4B) and far-field hydrodynamic mixing modeling (Appendix 5-4E) in Aimaokatalok Lake. The potential residual effects from site contact water and mine contact water are characterized together because the quantitative models consider the combined contributions of site and mining activities for predicting the effects of the Project on water quality.

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 5.5.3. Once the water management systems are constructed, the majority of site contact water will be intercepted and prevented from contacting the freshwater receiving environment (Doris-Madrid Water Management Plan (Package P4-7) and Boston Water Management Plan (Package P4-8)). Intercepted site contact water will be stored in CWPs 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 and Load Balance model (Package P5-4). During the construction and decommissioning of Project infrastructure, some site contact water will report 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 WTP; 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 the Project, 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 (see Section 5.5.3) are predicted to be effective at reducing the quantities of transported suspended material. However, there is the potential for alteration of suspended sediment concentrations in the receiving environment 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 mitigation and management measures are predicted 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. These potential increases in suspended sediments are not expected to cause significant deposition of sediments onto lake or stream beds, and there are not anticipated to be residual effects to sediment particle size composition.

Residual effects from mine contact water, which is defined as the runoff from waste rock and ore stockpiles, crown pillar recovery trenches, 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 Madrid-Boston Project. In the Boston area, mine contact water during Operation will be treated, combined with treated water from the STP, and discharged to Aimaokatalok Lake. The incorporation of the combined discharge from both waste streams into the lake are modelled using probabilistic (Water and Load Balance model; Package P5-4), and near-field (Appendix V5-4B) and hydrodynamic mixing (Appendix V5-4E) simulations. The chemical constituents evaluated in the Water and Load Balance model include inorganic nitrogen species (e.g., ammonia, nitrite, and nitrate) and metals (e.g., arsenic, copper, mercury), while total phosphorus and chromium are evaluated within the hydrodynamic model. These constituents are indicators of sediment quality as well as water quality. The timing of specific infrastructure and activities (such as the commissioning of waste rock storage areas) and their inputs are incorporated in the models. 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.

Details of the predicted effects to freshwater water quality from site and mine contact water using the quantitative water balance model (Water and Load Balance, Package P5-4) and the near-field (Appendix V5-4B) and far-field hydrodynamic model (Appendix V5-4E) are provided in Volume 5, Chapter 4. Effects to sediment quality are not incorporated into the quantitative model, but are informed by the results of the quantitative water quality assessment.

<u>Characterization of Madrid-Boston Project Potential Effects</u>

Aimaokatalok Watershed

Wastewater from the WTP and STP will be combined and discharged into Aimaokatalok Lake through a single pipeline-diffuser system (Appendix V5-4B). Concentrations of several water quality parameters in the effluent are predicted to be greater than CCME guidelines (Volume 5, Chapter 4); however, near-field mixing modeling predicted sufficient mixing will occur in the receiving environment such that all water quality parameters will be lower than CCME water quality guidelines within 3 m of the outfall (Volume 5 Chapter 4; Appendix V5-4B). Additional hydrodynamic modeling confirmed that the combined WTP-STP discharge will be effectively mixed in Aimaokatalok Lake such that lake-wide concentrations will be near baseline, below CCME water quality guidelines, and the effluent will be effectively flushed from the lake (Appendix V5-4E).

The assessment of effects of site and mine contact water on freshwater water quality predicts that concentrations of some metals and nutrients will increase above baseline concentrations in the waters of Stickleback and Aimaokatalok lakes (Volume 5, Section 4). Some of these metals and nutrients are expected to increase during several different Project phases, while others are only elevated during specific phases (e.g., arsenic in the small, eastern arm of Aimaokatalok Lake (Post-closure)). Although some metal and nutrient concentrations are predicted to increase above baseline levels, only fluoride in Stickleback Lake is predicted to increase above the water quality assessment threshold identified in Table 4.5-2 of Volume 5, Chapter 4.

Lake, river, and stream sediments in the Boston area are naturally metal-rich, and baseline studies have shown that sediment metal concentrations occasionally exceed CCME sediment quality guidelines for arsenic, chromium, and copper (Section 5.2.4). Considering only those metals for which there are CCME sediment quality guidelines (i.e., arsenic, cadmium, chromium, copper, lead, mercury, and zinc), the Water and Load Balance model predicted a moderate increase in the concentration of arsenic (maximum 2.9-fold increase) in the eastern arm of Aimaokatalok Lake near the inflow from Stickleback Lake in Post-closure, and relatively minor increases (ranging from 1.2 to 1.7 times the baseline levels) in the concentrations of cadmium and copper in the eastern arm of Aimaokatalok Lake, and arsenic, copper, and mercury in Stickleback Lake (Volume 5, Chapter 4). The predicted increases remained below CCME water quality guidelines or water quality objectives. Modeling results for the main body of Aimaokatalok Lake did not predict any increases in the concentrations of these metals from baseline levels; therefore, the predicted increases in arsenic, cadmium, and copper relative to baseline concentrations are expected to be localized to the area near the inflow from Stickleback Lake, and will be diluted within Aimaokatalok Lake (Volume 5, Chapter 4).

Constituents such as metals and nutrients are continuously exchanged between sediments and overlying waters. Therefore, predicted increases in water quality parameters such as metals and nutrients may cause residual effects to sediment quality as well. Residual effects to sediment quality in the Boston area are further characterized in Section 5.5.5.

Windy Watershed

Windy Lake is near the Madrid North site, and will interact with the Project through water withdrawal for industrial use at Madrid North, drinking water for the Doris site, runoff from the decommissioned CWP at Madrid North, and drawdown through groundwater seepage into the Doris mine. The Water and Load Balance model predicted that there will be some increases in the concentrations of several metals and sulphate relative to baseline concentrations in Windy Lake in Post-closure (Package P5-4; Volume 5, Chapter 4). This is attributable to the return of the groundwater flow system to its original state, which is expected to affect Windy Lake (Package P5-4). Of all the parameters that are expected to increase above baseline concentrations in Windy Lake during Post-closure, none are predicted to exceed water quality thresholds or objectives (Volume 5, Chapter 4).

The water quality parameters that are most relevant to the assessment of potential effects to sediment quality are those metals for which there are sediment quality thresholds (i.e., CCME sediment guidelines). Windy Lake sediments are naturally enriched in arsenic, chromium, and copper (Section 5.2.4). The Water and Load Balance model predicted that concentrations of arsenic, copper, lead, and mercury would increase relative to baseline concentrations in Windy Lake. As was the case for the Boston area lakes, arsenic was associated with the largest predicted increase relative to baseline levels (4.2-fold increase during the open-water and under-ice seasons), while the other metals of interest were predicted to increase by a factor of only 1.2 to 2.2 times the baseline median (Volume 5, Chapter 4). The predicted concentrations of these metals (including arsenic) remained below CCME guidelines and water quality objectives (Volume 5, Chapter 4); however, because there are predicted increases in water quality parameters relative to baseline levels, there is the potential for residual effects to sediment quality in Windy Lake, and this is further characterized in Section 5.5.5.

Doris Watershed

The Water and Load Balance model predicts the effects of site and mine contact water on several lakes in the Doris area (Wolverine, Patch, P.O., Ogama, and Little Roberts lakes) and one stream (Doris Creek). The Doris TIA will discharge to Doris Creek under the terms set out in Water Licence 2AM-DOH1323, until the Roberts Bay discharge system and MOMB is operational, at which time the TIA discharge will be redirected to the marine environment. At closure, the TIA will be drained to the marine environment, and the North Dam will be breached to restore the natural flow through the Tail Lake catchment to Doris Lake and into Doris Creek (Package P5-4). As stated in the Water and Load Balance report, the model results are overly conservative in that they assume that the Tail Lake catchment bypasses Doris Lake and flows directly to Doris Creek; however, in reality, the Tail Lake catchment flow will be diluted by Doris Lake before reaching Doris Creek (Package P5-4).

The Doris, Madrid North, and Madrid South mines are all expected to intercept talik. At Post-closure, the groundwater flow system will return to the initial state, and recharge from taliks could affect Doris, Patch, Wolverine, and Windy lakes (the water quality modeling results for Windy are described in the previous section; Package P5-4).

Sources of metals to the freshwater environment during the Post-closure phase include tailings seepage and runoff from the covered Doris TIA (source of copper and arsenic), disturbed runoff from mine infrastructure, and re-flooded mine water, which could introduce arsenic into groundwater (Package P5-4).

Several water quality parameters were predicted to increase relative to baseline concentrations in Doris Watershed lakes (i.e., Wolverine, Patch, P.O., Ogama, and Little Roberts lakes) and Doris Creek, particularly during the Post-closure phase when the runoff from the TIA joins the natural flows in the Doris catchment. The greatest change from baseline levels was predicted for arsenic and mercury in Little Roberts Lake and Doris Creek; however, all parameter concentrations remained below assessment thresholds except for aluminum in Doris Creek (Volume 5, Chapter 4). The predicted increases in metal concentrations in Doris Creek and in downstream Little Roberts Lake are likely over-estimated by the conservative approach of the Water and Load Balance model of not considering the dilution effect of Doris Lake on Doris Creek parameter concentrations (Package P5-4).

As in other waterbodies in the region, freshwater sediments in the Doris Watershed are naturally metal-rich, and baseline data show that concentrations of arsenic, chromium, and copper in sediment samples are frequently been higher than CCME ISQG guidelines (Section 5.2.4). Metals are continuously exchanged between sediments and overlying waters; therefore, predicted increases in metal concentrations in the water column may cause residual effects to sediment quality as well. Residual effects to sediment quality in the Doris Watershed are further characterized in Section 5.5.5.

<u>Characterization of Hope Bay Project Potential Effects</u>

Potential effects from the Hope Bay development were incorporated in the water balance model. Mining operations at Doris will continue until Project Year 3 of Madrid-Boston 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 as part of the Madrid-Boston Project 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 sediment quality. These potential residual effects would have included the runoff of metals and hydrocarbons from disturbed areas of the landscape, pads areas, and laydown areas. However, the current Hope Bay water monitoring programs, including surveillance monitoring of contact water and AEMP monitoring in the receiving environment, have not identified any Project-related effects to the sediment quality of Doris Lake or downstream in Doris Creek and Little Roberts Lake (e.g., ERM 2017a). As a result, no incremental residual effects on sediment quality from the Hope Bay Development from site and mine contact water are identified beyond the effects already described for the Madrid-Boston Project.

5.4.4.3 Quarries and Borrow Pits

Characterization of Madrid-Boston Project Potential Effects

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 is the primary goal of mitigation and management efforts (Section 5.5.3). 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
- quarry runoff water collected in quarry sumps will be monitored, and water that does meet discharge criteria will be transported to CWPs (Hope Bay Quarry Management and Monitoring Plan (Package P4-17)).

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 the 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 are predicted for freshwater sediment quality for the Madrid-Boston development.

Characterization of Hope Bay Development Potential Effects

Existing quarries and borrow pits for the Doris site have been operating with no detected effects to sediment quality in the freshwater environment. The mitigation and management measures applied to quarries and borrow pits have been shown to be effective as evaluated by the Doris AEMP (e.g., ERM 2017a). Therefore, no residual effects from the overall Hope Bay Development are predicted.

5.4.4.4 Explosives

Characterization of Madrid-Boston Project Potential Effects

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 are 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 best management practices for blasting and the handling of explosives to minimize residues and spillage.

Runoff and seepage of blasting residues on mine workings, waste rock, tailings, and run-of-quarry material could affect water quality, which could in turn affect sediment quality. The Water and Load Balance model includes blasting residues, and provides quantitative predictions of nitrogenous residues (ammonia, nitrite, and nitrate) in the freshwater environment (Package P5-4). The model predicted that the concentrations of nitrogenous compounds may increase relative to baseline conditions in Stickleback and Aimaokatalok lakes and in Doris Creek and Little Roberts Lake (Volume 5, Chapter 4). However, the predicted concentrations are always below both threshold concentrations (i.e., CCME water quality guidelines) and the 95th percentile of observed baseline concentrations, suggesting that the elevated concentrations are within the range of natural variability. The predicted increases are, at least partially, attributable to blasting residues in site and mine contact water. Increases in nitrogenous compounds in the water could affect the concentrations of these nutrients in sediments as well as the concentration of TOC in sediments if introduced nutrients stimulate the productivity of freshwater systems.

Although explosives are considered a potential residual effect for the water quality analysis (Volume 5, Chapter 4), they are ultimately characterized as not significant. Given that explosives would be expected to interact directly with water quality, but indirectly with sediment quality (because sediment quality changes would only be expected to occur if changes to water quality were apparent), and the residual effect of explosives on water quality is rated as not significant, there is not expected to be a residual effect of explosives on sediment quality. Moreover, ammonia, nitrite, and nitrate are highly soluble, so these would likely remain in solution and would be expected to affect water quality more than sediment quality.

The effect from blasting residues on sediment quality through the aerial deposition pathway is predicted to be negligible (see Section 5.5.4.6). 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 Effects</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 (e.g., ERM 2017a). The results of the Water and Load Balance model predicted an increase in the concentrations of ammonia, nitrate, and nitrite in several waterbodies near the Boston site (which is associated with the Madrid-Boston Project). However, for the Madrid and Doris area, Doris Creek was the only waterbody in which increases relative to baseline concentrations were predicted for nitrogen species, and all predicted concentrations remained below threshold concentrations and within the range of observed baseline concentrations (Package P5-4). Therefore, approved projects are not expected to cause increases in nitrogen species in freshwater systems. The potential changes in nitrogen compound concentrations resulting from the use of explosives in the overall Hope Bay Development are 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. As is concluded for the Madrid-Boston Project, there is not expected to be a residual effect of explosives use on sediment quality in the Hope Bay Development.

5.4.4.5 Fuels, Oils, and PAH

The fuels, oils, and PAH Project interaction group will interact with the freshwater environment through runoff and aerial deposition (for PAH, see Section 5.5.4.6). 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, which are detailed in the Hope Bay Project Spill Contingency Plan (Package P4-3). 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 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. The operation of the incinerator 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), as well as TMAC's own Incinerator Management Plan (Package P4-16). 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 predicted to have negligible effects on freshwater sediment 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 adherence to best management practices 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, which should result in negligible aerial deposition of PAH into the freshwater environment. Therefore, no residual effects from fuels, oils, and PAH are anticipated on freshwater sediment quality. This prediction is applicable to both the incremental effects of the Madrid-Boston Project as well as the overall Hope Bay Development.

5.4.4.6 Dust Deposition

The Air Quality Management Plan (Volume 8, Annex 2) describes the specific mitigation measures that will be followed to ensure that the generation and transport of airborne particulates is minimized. Despite these mitigation measures, the results of air quality modelling work (Volume 4, Chapter 2) predicted that Madrid-Boston Project activities will generate dust that could potentially be deposited into the freshwater environment.

<u>Characterization of Madrid-Boston Project Potential Effects</u>

Quantitative air quality modelling predicted dust deposition rates across the Project area (Volume 4, Chapter 2). Potential dust sources such as construction activities, operation of the TIA, and vehicle traffic were incorporated into the model. The results of the quantitative dust deposition modelling are used to estimate average dust deposition rates in Project area lakes (Table 5.5-5). The predicted average annual dust deposition rates for lakes in the LSA lakes during the Construction and Operation phases range from 0.97 to 6.0 g/m^2/year (Table 5.5-5).

Table 5.5-5. Calculated Average Annual Dust Deposition Rates in LSA Lakes

Lake	Average Annual Deposition Rate (g/m^2/year)	
	Construction Phase	Operation Phase
North Belt LSA		
Doris	1.9	2.1
Imniagut	5.2	5.8
Little Roberts	0.98	0.97
Ogama	1.8	1.9
Patch	2.9	3.2
P.O.	1.4	1.5
Windy	2.8	3.0
Wolvering	2.5	2.3
South Belt LSA		
Aimaokatalok	1.4	1.5
Stickleback	5.2	6.0
Trout	1.9	2.1

Note: Predicted annual loads include background levels.

For the purposes of this assessment, it is assumed that all dust that is deposited on a lake surface would reach the lakebed. The particle sizes considered for the dust deposition model are generally smaller than 100 µm in diameter. In terms of sediment particle sizes, deposited dust would be classified as clay, silt, or fine sand, which are relatively small particles that could remain in suspension (size classes shown in Table 9.2-3). Therefore, the assumption that all deposited dust would reach the lakebed is conservative.

For the analysis of sediment quality (e.g., metals, TOC, nutrients), the uppermost 2 to 3 cm of the sediments are typically sampled (e.g., Rescan 2010a, 2011b). The density of lake sediments generally ranges from 1,000,000 to greater than 2,000,000 g/m^3 (Last and Smol 2006). Assuming a sediment density of 1,500,000 g/m^3, a 3 cm-thick layer of sediment occupying a 1 m^2 area of the lakebed would contain approximately 45,000 g of sediment. Considering the highest predicted deposition rate of 6.0 g/m^2/year for Stickleback Lake during Operation, the average annual deposition of 6 g onto 45,000 g of sediment in a 1 m^2 area would represent an annual increase of 0.01%. Over the 17-year timeline of the Madrid-Boston Project, this would amount to less than a 0.3% increase. This estimated increase is negligible and would be within the margin of error of sediment quality analyses. Therefore, dust deposition is not expected to cause a measurable change in sediment quality in the LSA lakes, and dust deposition is not further assessed as a residual effect.

Characterization of Hope Bay Project Potential Effects

The dust modelling results consider dust generated by the Madrid-Boston Project as well as from approved projects. The dust inputs specific to the Madrid-Boston Project were not considered in isolation of other activities within the Hope Bay Development; therefore, the discussion of Madrid-Boston potential effects applies equally to the Hope Bay Development. Dust deposition is not expected to affect freshwater sediment quality, and is not further assessed as a residual effect for the Hope Bay Development.

5.4.5 Characterization of Residual Effects on Freshwater Sediment Quality

5.4.5.1 Definitions for Characterization of Residual Effects

To determine the significance of 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 2012). A definition for each attribute and the contribution that it has on significance determination is provided in Table 5.5-6.

Table 5.5-6. 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 VECs 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 (once, infrequent, frequent, continuous)	The number of times during the Project or a Project phase that an interaction or environmental effect can be expected to occur.	Greater the number times of occurrence (higher the frequency), the higher the potential significance.
Geographical Extent (PDA, LSA, RSA, beyond regional)	The geographical 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 5.5-7. Each of the criteria contributes to the determination of significance.

5.4.5.2 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 2012). 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.

<u>Probability of Occurrence or Certainty</u>

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 5.5-8 presents the definitions applied to these categories.

Table 5.5-7. Criteria for Residual Effects for Environmental Attributes

Attribute	Characterization	Criteria
Direction	Positive	Beneficial
	Variable	Beneficial or undesirable
	Negative	Undesirable
Magnitude	Negligible	No change on the indicator/VEC
	Low	Differing from the average value for the existing environment to a small degree, but within the range of natural variation and well below a guideline or threshold value
	Moderate	Differing from the average value for the existing environment and approaching the limits of natural variation, but below or equal to a guideline or threshold value
	High	Differing from the existing environment and exceeding guideline or threshold values so that there will be a detectable change beyond the range of natural variation (i.e., change of state from the existing conditions)
Duration	Short	Up to 4 years (Construction phase)
	Medium	Greater than 4 years and up to 17 years (combined Construction, Operation, and Reclamation and Closure phases)
	Long	Beyond the life of the Project
Frequency	Once	Occurring only once
	Infrequent	Occurring more than once but less than 50% of the time over the life of the Project
	Frequent	Occurring more than 50% but less than 100% of the time over the life of the Project
	Continuous	Continuously occurring over the life of the Project
Geographical 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

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 is 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. Table 5.5-8 provides descriptions of the confidence criteria.

Table 5.5-8. 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

A description of how residual effects were designated as *not significant* or *significant* is provided in this section. Although general guidelines can be followed for the determination of significance, it is not practicable to outline all possible permutations of attribute criteria that would result in an effect being designated as *not significant* or *significant*. Rather, residual effects are assessed on a case-by-case basis using the criteria outlined below as well as professional judgement to ultimately assign a significance rating.

Not Significant: A residual effect rated as *not significant* may result in a slight to moderate decline in freshwater sediment quality within the zone of influence of the Project relative to reference conditions during the life of the Project, but sediment quality would generally be expected to return to baseline conditions after Project closure. Non-significant residual effects on sediment quality are not considered to have serious consequences (e.g., sediments metals increase slightly from baseline concentrations or sediment particle size composition changes during the life of the Project but all sediment indicators return to baseline conditions during Closure and Reclamation or Post Closure). The specific attribute criteria leading to a designation of an effect as not significant can be variable.

Significant Effect: A residual effect rated as *significant* is expected to result in the degradation of freshwater sediment quality within the LSA or extending into the RSA relative to reference conditions, and is irreversible or requires some effort to reverse. Significant residual effects on sediment quality are consequential (e.g., sediments are contaminated and can no longer support their ecosystem function). Regional management actions such as research, monitoring, and recovery initiatives may be required should changes to freshwater sediment quality exceed acceptable thresholds. Specific criteria of attributes such as duration, frequency, geographic extent, and reversibility that lead to a residual effect being considered significant can be variable.

5.4.5.3 Characterization of Residual Effect for Freshwater Sediment Quality

The potential residual effects carried forward from Section 5.5.4 are assessed in this section, according to the attributes and criteria described in Sections 5.5.5.1 and 5.5.5.2.

Site Preparation, Construction, and Decommissioning

Madrid-Boston Potential Effect

There exists the potential for residual effects to freshwater sediments from the in-water works required for the installation and decommissioning of the discharge pipeline in Aimaokatalok Lake, the intake pipelines in Aimaokatalok and Windy lakes, as well as the culverts in streams that will be crossed by AWRs. These activities may cause some temporary and localized disturbance and redistribution of sediments. A change in the particle size distribution of sediments and in sedimentation patterns could represent a deviation from baseline particle size composition and sediment metal concentrations.

A summary of the characterization and assessment of the residual effects of physical disturbances associated with site preparation, construction, and decommissioning is provided in Table 5.5-9. The residual effects from in-water works may result in a redistribution of sediments, but since there will be no net increase in potentially adverse sediment constituents such as metals or hydrocarbons because of the use of geochemically inert materials for construction, the direction of the residual effect is considered to be *variable*. Any residual effects are expected to be *low* in magnitude because the redistribution of existing loads of metals or pollutants is not expected to cause any change in sediment quality indicators beyond what is expected from the natural variation and heterogeneity of sediment quality within a waterbody. The duration of the potential residual effects is expected be *short*, because the potential physical disturbance will only occur during a relatively short window of time during the Construction or Closure phases, and the suspended sediments will resettle following the infrastructure installation or removal. The frequency of the potential effect is predicted to be *infrequent*, because potential sediment mobilization could occur periodically during the installation or decommissioning of in-water infrastructure. The potential residual effects are expected be confined to the LSA as only sediments within Aimaokatalok Lake, Windy Lake, or specific streams crossed by AWRs will be affected. Within Aimaokatalok and Windy lakes, the residual effect is expected to be highly localized to the footprint of pipeline infrastructure, and within the affected streams, the effect will be largely confined to the footprint of the culvert. Any residual effects are predicted to be *reversible* once in-water installation or decommissioning activities are completed, because in the absence of physical disturbances sediments will be re-worked by natural physical processes such wind-driven mixing or stream flow (Table 5.5-9).

The probability of occurrence of residual effects from in-water works is considered to be *likely*. The overall significance of the effects of physical disturbances associated with in-water works is **not significant** because of the variable direction and low magnitude of the residual effect, the confinement of the effect within a small fraction of the overall freshwater LSA, and the reversibility of the residual effect. The confidence of the overall rating is considered to be *high* (Table 5.5-9).

Hope Bay Project Potential Effect

The potential residual effects identified for freshwater sediments from site preparation, construction, and decommissioning activities are mainly associated with Madrid-Boston Project infrastructure. The installation of the discharge pipeline in Aimaokatalok Lake and the installation of culverts or bridges in streams associated with AWR crossings are being undertaken as part of the Madrid-Boston Project. Other than the potential effects from Madrid-Boston, the only known residual effects to freshwater sediments from in-water or near-water works related to site-preparation, construction, and decommissioning activities in the Hope Bay Development are those associated with the decommissioning of existing near or in-water infrastructure such as intake pipelines, culverts, and bridges. These activities are expected to incrementally add to the potential residual effects characterized for the Madrid-Boston activities. The overall characterization of effects for the entire Hope Bay Development (Table 5.5-10) is identical to the characterization provided for the Madrid-Boston Project in isolation (Table 5.5-9). The overall significance of the effects of site preparation, construction, and decommissioning activities on freshwater sediment quality in the Hope Bay Development is **not significant** (Table 5.5-10).

Table 5.5-9. Summary of Residual Effects and Overall Significance Rating for Freshwater Sediment Quality - Madrid-Boston Project

Residual Effect	Attribute Characteristic						Overall Significance Rating		
	Direction *(positive, variable, negative)*	**Magnitude** *(negligible, low, moderate, high)*	**Duration** *(short, medium, long)*	**Frequency** *(once, infrequent, frequent, 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)*
Site Preparation, Construction, and Decommissioning	Variable	Low	Short	Infrequent	LSA	Reversible	Likely	Not Significant	High
Site and Mine Contact Water	Negative	Moderate	Long	Frequent	LSA	Irreversible	Likely	Not Significant	Medium

Table 5.5-10. Summary of Residual Effects and Overall Significance Rating for Freshwater Sediment 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** *(once, infrequent, frequent, 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)*
Site Preparation, Construction, and Decommissioning	Variable	Low	Short	Infrequent	LSA	Reversible	Likely	Not Significant	High
Site and Mine Contact Water	Negative	Moderate	Long	Frequent	LSA	Irreversible	Likely	Not Significant	Medium

Site and Mine Contact Water

Madrid-Boston Potential Effect

Residual effects from site and mine contact water on freshwater sediment quality are informed by the analysis of effects to freshwater water quality (Volume 5, Chapter 4), which is based on the quantitative predictions from the site-wide Water and Load Balance model (Package P5-4) as well as near-field (Appendix 5-4B) and far-field hydrodynamic modeling (Appendix 5-4E) in Aimaokatalok Lake. Metals, nutrients, and organic material are continuously exchanged between the water column and sediments depending on the specific environmental conditions and the properties of the constituents of the water or sediments.

Lake, river, and stream sediments in the Hope Bay Greenstone Belt area are naturally metal-rich, and baseline studies have shown that sediment metal concentrations often exceed CCME sediment quality guidelines for arsenic, chromium, and copper (Section 5.2.4).The results of the Water and Load Balance model predicted that there would be increases in the concentrations of certain water quality indicators relative to baseline conditions in some of the waterbodies included in the model; however, most of the predicted increases remained below threshold concentrations and were always within the range of natural variability observed in the baseline dataset (Volume 5, Chapter 4).

The water quality parameters that are most relevant to the assessment of potential effects to sediment quality are those metals for which there are CCME sediment guidelines (i.e., arsenic, cadmium, chromium, copper, lead, mercury, and zinc). Among these metals, arsenic was generally associated with the highest predicted increases from baseline concentrations, and the elevated concentrations were typically predicted to occur during Post-closure (Package P5-4; Volume 5, Chapter 4). Arsenic-containing rocks and minerals are commonly associated with gold deposits (Nekrasov 1996). This explains why sediments in the region are naturally enriched in arsenic, with baseline concentrations often exceeding the CCME ISQG guideline (Section 5.2.4). In natural waters with near-neutral pH (such as lakes and streams in the Project area) and under both oxidizing and reducing conditions, arsenic tends to remain in solution and does not preferentially bind to sediments (Smedley and Kinniburgh 2002). Arsenic is therefore a common and persistent contaminant in groundwater (Smedley and Kinniburgh 2002).

The Water and Load Balance model predicts a slight to moderate increase in the concentration of arsenic relative to baseline levels in Aimaokatalok (eastern arm), Stickleback, Windy, Little Roberts, Ogama, Patch, and P.O. lakes, as well as in Doris Creek (Volume 5, Chapter 4). The predicted arsenic concentrations are always expected to remain below the CCME water quality guideline for arsenic of 0.005 mg/L in the Project lakes; however, in Doris Creek, arsenic concentrations are expected to reach concentrations above the CCME guideline but below the water quality threshold of 0.028 mg/L in Post-closure. As mentioned, the predicted arsenic concentrations in Doris Creek waters during Post-closure are over-estimated in the Water and Load Balance model (Package P5-4) because dilution of the Tail Lake catchment flow into Doris Lake prior to reaching Doris Creek is not considered. Also, the Doris Creek sediments are coarse, consisting mainly of gravel and sand (mean: 90%; Table 5.2-11) with very little clay (mean: 2.9%), which limits the adsorption potential onto the sediment mineral faces (Mohapatra et al. 2007), and baseline sediment arsenic concentrations in Doris Creek (mean: 1.52 mg/kg; Table 5.2-11) are well below the CCME ISQG of 5.9 mg/kg, indicating that there is the capacity to adsorb additional arsenic into the sediments while remaining protective of aquatic life (i.e., below the arsenic CCME ISQG).

Overall, the freshwater water quality assessment of effects concluded that there may be increases in the concentrations of some metals and nutrients above baseline levels in the waters of Stickleback, Aimaokatalok, Stickleback, Windy, Wolverine, Patch, P.O., Ogama, and Little Roberts lakes and in

Doris Creek resulting from the discharge, runoff, and seepage of site and mine contact water (Volume 5, Chapter 4). Increases in water column concentrations of metals due to mine and contact water would not necessarily result in increases to sediment quality concentrations of metals, as shown in 17 years of aquatic effects monitoring at the Ekati Diamond Mine in Canada's Northwest Territories, where arsenic, nickel, and selenium have increased in lake waters with no corresponding increase in the lake sediments (ERM 2015b). However, for the purposes of this assessment, the conservative approach of assuming that *moderate* increases to water quality parameter concentrations would result in *moderate* increases to sediment quality parameters is adopted.

The potential residual effect of site and mine contact water on sediment quality is characterized as *negative* in direction and *moderate* in magnitude. Many of the predicted increases are predicted to remain throughout the Post-closure phase, and are therefore concluded to be *long*-term in duration. The frequency of inputs of site and mine contact water is characterized as *frequent*. However, the geographical extent of the residual effects from site and mine contact water is concluded to be restricted to the *LSA* (Table 5.5-9).

The residual effects from site and contact water are characterized as *irreversible* (Table 5.5-9). The long-term effects associated with runoff from the TIA, TMA, and reclaimed Project infrastructure are predicted to continue throughout the Post-closure phase. As discussed in the Water and Load Balance Model report (Package P5-4), interactions between decommissioned Project infrastructure may continue beyond Post-closure as equilibria are reached in groundwater interactions between closed mine works and nearby lakes.

The residual effects are characterized as *likely* with a *medium* degree of confidence. The characterization of effects of site and mine water on sediment quality is informed by the water quality assessment of effects, which is based on quantitative models. Quantitative water balance and mixing modeling results provide a high level of confidence for the water quality assessment, but only a medium degree of confidence for the sediment quality assessment because sediment quality predictions are not incorporated into the model. There is some uncertainty associated with predicting the behaviour and fate of various metals and nutrients introduced into freshwater systems. The residual effect to freshwater sediment quality from site and mine contact water is concluded to be **not significant** because the predicted effects were *moderate* in magnitude, localized to the LSA, and assigned a *medium* degree of confidence (Table 5.5-9).

Hope Bay Development Potential Effect

All components of the Hope Bay development were incorporated in the water balance model. Therefore, following the same criteria as for the Madrid-Boston Project characterization of residual effects, the potential residual effects of site and mine contact water from the Hope Bay Development on freshwater sediment quality are concluded to be **not significant** (Table 5.5-10).

5.5 CUMULATIVE EFFECTS ASSESSMENT

The potential for cumulative effects arises when the potential residual effects of the Madrid-Boston Project add to or otherwise interact with the residual effects of other past, existing or reasonably foreseeable projects or activities. As defined by the EIS guidelines (NIRB 2012) and the *NIRB Technical Guide Series: Terminology and Definitions* (NIRB 2013), cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

5.5.1 Methodology Overview

5.5.1.1 Approach to Cumulative Effects Assessment

The general methodology for cumulative effects assessment (CEA) is described in Volume 2, Chapter 4, and follows these steps:

1. Identify the potential for Madrid-Boston Project-related residual effects to interact with residual effects from the Doris Project, the Hope Bay Regional Exploration Project, the Madrid Advanced Exploration Program, the Boston Advanced Exploration Project and 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. A key task in the CEA is to understand the contribution of Madrid-Boston Project to the overall cumulative effect on freshwater sediment quality (i.e., the amount of the cumulative effect can be apportioned to Madrid-Boston Project as compared to the Doris Project, the Hope Bay Regional Exploration Project, the Madrid Advanced Exploration Program, the Boston Advanced Exploration Project and other projects and activities).

5.5.1.2 Assessment Boundaries

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

<u>Spatial Boundaries</u>

The CEA considers past, existing, and reasonably foreseeable projects with potential residual effects that occur within the outer geographical limit of possible interaction with Madrid-Boston Project and the Hope Bay Project. The spatial boundary for the CEA for freshwater sediment quality was the assessment Regional Study Area (RSA; Figure 5.2-2). 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.

<u>Temporal Boundaries</u>

The temporal boundaries of the CEA were defined by the timelines for past, existing, and reasonably forseeable projects as described in the CEA methodology (Volume 2, Chapter 4). These timelines were compared to the Project timeline (Section 4.4.3).

5.5.2 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 were also considered for potential interactions with the Project, as required under Section 7.11 of the Project EIS guidelines (see Volume 2, Chapter 4 for more detail).

The potential residual effects identified for the Madrid Boston Project and the Hope Bay Development as a whole were confined to the LSA. Given that no past, present, or foreseeable projects that could potentially interact with the residual effects of the Hope Bay Project lie within the freshwater LSA, no cumulative effects to freshwater sediment quality are predicted.

5.6 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 2012). Transboundary effects of the Project have the potential to act cumulatively with other projects and activities outside the NSA.

The non-significant residual effects to freshwater sediment quality are predicted to be restricted to the LSA. The LSA lies entirely within Nunavut; therefore, there is no potential for transboundary effects.

5.7 IMPACT STATEMENT

The assessment of effects of the Project on freshwater sediment quality considers potential effects based on specified interaction groups. These interaction groups incorporate Madrid-Boston Project effects that are related by timing, infrastructure, and mitigation and management measures. The following interaction groups are considered as potential effects:

- site preparation, construction, and decommissioning activities;
- site and mine contact water;
- quarries and borrow pits;
- explosives;
- fuels, oils, and PAH; 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.

Quantitative and qualitative analyses are used to predict the effects of the Project on freshwater sediment quality. Residual effects are identified for two interaction groups: site preparation, construction and decommissioning activities from in-water works; and site and mine contact water.

Using the thresholds identified for the key indicators, the residual effects to freshwater sediment quality are concluded to be low to moderate in magnitude and are 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 sediment 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, which is entirely within Nunavut.

5.8 REFERENCES

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