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
CPUE	Catch per unit effort
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CRA	Commercial, Recreational, and Aboriginal fisheries
EIS	Environmental Impact Statement
DELT	Deformities, Erosion, Lesions, or Tumors
DFO	Fisheries and Oceans Canada
EEM	Environmental Effects Monitoring
ERM	Environmental Resource Management
DGPS	Differential Global Positioning System
GPS	Global Positioning System
FHAP	Fish Habitat Assessment Procedure
FOP	Fisheries Offsetting Plan
FPP	Fisheries Protection Program
HBML	Hope Bay Mining Ltd.
ICPMS	Inductively Coupled Plasma – Mass Spectroscopy
IIAB	Inuit Impacts and Benefits Agreement
LSA	Local Study Area
IPC	Instantaneous Pressure Change
KIA	Kitikmeot Inuit Association
MAD	Mean Annual Discharge
MDL	Method Detection Limit
MMER	Metal Mining Effluent Regulations
n	Sample size
NIRB	Nunavut Impact Review Board

NWB	Nunavut Water Board
PAD	Permanent alteration to, or destruction
PIT	Passive Integrated Transponder
PoP	Pathway of Effect
The Project	The Madrid-Boston Project
QA/QC	Quality Assurance and Quality Control
RPD	Relative Percent Difference
RIC	Resource Inventory Committee
RSA	Regional Study Area
SARA	*Species at Risk Act*
SE	Standard Error
SHIM	Sensitive Habitat Inventory Mapping
TIA	Tailings Impoundment Area
TK	Traditional Knowledge
TP	Total Phosphorus
NTKP	Naonaiyaotit Traditional Knowledge Project
US EPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VEC	Valued Ecosystem Component

6. Freshwater Fish

The Madrid-Boston Project (the Project) may interact with freshwater fish and fish habitat through the development of infrastructure such as roads, water intakes and discharge pipelines, and quarry sites, as well as through water use or groundwater loss to mine development. This chapter provides an overview of the available freshwater fish habitat and the freshwater fish communities in the areas surrounding the Project, and identifies and evaluates the potential Project-related effects and cumulative effects on freshwater fish habitat and fish communities in a local and regional context.

Fish habitat is defined in the federal *Fisheries Act* (1985) as "spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas, on which fish depend directly or indirectly in order to carry out their life processes." Fish habitat thereby includes lower trophic levels: primary and secondary producers (i.e., biological resources) and forage fish. Fish habitat within the Project area is provided by numerous lakes, rivers, streams, ponds, and marine areas.

The term "fish" in the *Fisheries Act* includes "parts of fish; shellfish, crustaceans, marine animals, and any parts of shellfish, crustaceans, or marine animals; and the eggs, sperm, larvae, spat, and juvenile stages of fish, shellfish, crustaceans, and marine animals". The freshwater fish communities within the Project area are representative of Arctic freshwater ecosystems. Many of these fish species serve an important role in the ecological, economic, and cultural health of the region.

6.1 INCORPORATION OF TRADITIONAL KNOWLEDGE

Traditional Knowledge (TK) information was gathered by the Kitikmeot Inuit Association (KIA) in a report titled *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project (NTKP)* report (Banci and Spicker 2016). This report provides recorded and georeferenced TK pertaining to the Project by means of interviews conducted between 1997 and 2000, regional and site-specific studies, the *Inuit Land Use Occupancy Study*, focused workshops in Kugluktuk and Cambridge Bay in 2013, and studies of anadromous Lake Trout from Roberts Lake by Dr. Heidi Swanson of the University of Waterloo.

6.1.1 Incorporation of Traditional Knowledge for Existing Environment and Baseline Information

The NTKP report was reviewed for existing environment and baseline information on freshwater fish and fish habitat. Fish were, and continue to be, an important component of the Inuit seasonal diet. They were essential during times of food shortage, particularly when caribou did not arrive because of a change in migration route or calving area. They were also important for feeding dog teams during winter trapping.

Inuit fishing places in the Project area were identified along the coastline of Roberts Bay and the southern coastline of Melville Sound, including Hope Bay and the Lower Koignuk River. A smaller number of fishing places were on the shores of lakes and rivers further inland. Areas of general fishing effort in the Project area included Roberts Lake and Roberts Creek, Windy and Patch lakes, and an elongated area encompassing Aimaokatalok Lake, the Upper Koignuk River, and surrounding lakes and ponds.

> *Inuit fished the rivers when fish were going down river and up river, when they needed food. We fished at Hakvatok, (south coast of Melville Sound), Naoyak and Etibliakyok, Kolgayok (Tingmeak River), Kunayok (Ellice River) … and all along the coast of Victoria Island. These areas have charr and trout … and cisco whitefish ...*

In general, Inuit fished wherever they were on the land, in conjunction with other harvesting activities. Fishing was not only a harvesting activity but included an element of recreation.

> *In the fall we used gill nets to catch a lot of fish for the dogs, and for dry fish too. All these places where we had our nets have inokhok or rock pile markers … On our traplines too we fished. We did a lot of fishing especially on the days that were stormy. We did a lot of fishing to pass the time …*

In the past, Inuit fished by jigging, spearing, trapping, and sometimes with nets. Fishing is now most commonly conducted using nets. Inuit fished primarily in the spring and fall. The spring fishing period coincided with migrations of spring spawners such as hulukpaugan (Arctic Grayling; *Thymallus arcticus*), from overwintering lake habitat to stream and river spawning habitat. The fall fishing period focused on migrations of fall-spawners such as ekalukpik (Arctic Char; *Salvelinus alpinus*) and ehok (Lake Trout; *Salvelinus namaycush*) from the sea to lake spawning habitat. TK of the dominant fish species of the Project area is summarized in the following sub-sections.

6.1.1.1 Ekalukpik (Arctic Char)

Anadromous Arctic Char (*Salvelinus alpinus*) was the main target species identified in the NTKP report because it is present in many of the coastal lakes and rivers and along the coastline, where Inuit focus most of their fishing effort, and because it is a prized food fish. This is particularly true of Arctic Char that are returning to their natal lakes in a fattened condition after spending a summer feeding in the ocean. The Inuit targeted ekalukpik at the mouths of rivers with weirs, fish traps, spears, and baskets. More recently, nets are also used.

> *Some lakes that have rivers to the ocean contain Arctic charr. There are many lakes with Arctic charr; so many that I can't name them all. Some of these lakes are further inland. In the spring the charr that have been in the lakes in the winter return back to the ocean while others are going to the lakes …*

> *When the fish went up the river (Arctic charr fall migration) at Hiukkittat, Havaktok (chain of lakes at coast) and Kangihoakyok (Daniel Moore Bay), Inuit speared them or scooped them up in baskets … The fish look (healthy) when going up the river (from the ocean to the lakes). At Ekalokakok and Kilanaktovik there are lots of cracks in the rocks. Some of these fish get stuck trying to go up or down the rivers, and the fish may become injured.*

> *These fish found inland are very good to eat, The Arctic charr where I lived long ago (Tahikyoak and Kiligiktokmik (Bathurst Inlet)) and from some of the areas around here (Killinik (Victoria Island)) are very good to eat, just before the fall migration.*

> *We fished for charr at Ekalolialok (lake on island of the same name) … They must be sea run. They migrate to the lake in the fall and return to the sea in the spring.*

6.1.1.2 Ehok (Lake Trout)

Lake Trout (*Salvelinus namaycush*) are also a common food fish because they are found in many lakes and ponds. They are also known to be anadromous with Inuit catching them in lakes and along the marine shoreline and close to the mouths of rivers.

> *You could wait around for lake trout. Anywhere there is an outlet on the lake, where the ice is thin … That's where people go fish. These areas you don't have to chop through two or three feet of ice. Most year-round these rivers, any outlet on a lake or inlet, you find fish, charr, year-round.*

Ehok, they go to the ocean but mostly they stay around the river mouth or stream. In the ocean they mostly stick around the river mouth.

… Some rivers, and even the ocean, have fish that are usually found in the lakes. They got caught in our nets. Inuit sometimes caught lake trout in the rivers and sometimes in the ocean. If there are fish around you can really catch a lot when you are using nets.

Any lake, any little pond there too, you wouldn't think there would be ehok there too, but depending how deep there are, there is always ehok in there. It could be a small little lake. You'd never think there are fish in there but ehok are common in those areas too.

6.1.1.3 Kapihillik (Arctic Cisco) and Anakheek (Broad Whitefish)

Arctic cisco (*Coregonus autumnalis*) and whitefish were harvested for food by Inuit. Arctic Cisco resides in large rivers and is anadromous, being caught along the marine shoreline. The NTKP report refers specifically to Arctic Cisco, although there are at least two other species of cisco in the Project area: Cisco (*Coregonus artedi*) and Least Cisco (*Coregonus sardinella*). Cisco and Least Cisco are largely lake-resident but some populations are anadromous.

Consultants did not have a different name for Lake Whitefish (*Coregonus clupeaformis*) and Broad Whitefish (*Coregonus nasus*), and called them all anakheek. Broad Whitefish are bottom-feeders and larger in body size than the ciscoes. Both Broad Whitefish and Lake Whitefish are mainly lake dwellers, although they have been caught in estuaries. The NTKP report states that Arctic Cisco and whitefish are not found in lakes with high copper content.

… There are different kinds of whitefish. Some are small and some are big. The broad whitefish are always really fat and the cisco whitefish are lean. Cisco whitefish only have white flesh. Towards fall, before spawning the cisco whitefish from around Kugluktuk get fat and then they are really tasty. The two whitefish taste different.

Anywhere, there are lots and lots (of Arctic cisco).

There will be whitefish here (Bathurst Inlet). In summertime, they will be at the coast. Then they will go back to the lakes and the river systems... (In the oceans) they mostly will stick around the coasts.

The cisco whitefish also have fat and eggs and are very tasty but not the broad whitefish. The broad whitefish does not have many eggs. These are different types of whitefish that are much bigger than the cisco whitefish.

Whitefish are found around the shorelines. They are seldom seen out in the ocean.

All these little streams and rivers that drain into the lakes have whitefish. There is more concentration in some parts of the lakes.

The larger lake whitefish, you can find them just about anywhere you find lake trout, in rivers, where there are fresh water rivers. Kogluk (meaning fast rapids) has lots and lots of anakheek (broad whitefish), especially at the mouth of the rivers. Every river has kogluks. So if you fish any river with rapids, you will likely catch anakheek and kapihillik (Arctic cisco)…

6.1.1.4 Hulukpaugan (Arctic Grayling)

Arctic Grayling (*Thymallus arcticus*) are fished to a lesser degree than Arctic Char, Lake Trout, and whitefish and fewer locations with Arctic Grayling were mapped in the NTKP report study area. Arctic Grayling are an exclusively freshwater species that reside in lakes or large rivers and spawn in rivers and tributary streams. They are largely insectivores that feed in the upper water layer. In the Project area they are present in the Aimaokatalok Watershed and the Koignuk River.

> *Grayling are found in the rivers further inland. Long ago when I was a young boy I caught grayling at the rivers leading to lakes. There were so many grayling in some lakes.*
>
> *It is the same for grayling. If there is copper content in those lakes, there will be no lake whitefish or grayling. There is none of those where there is lots of copper content in the water.*

6.1.1.5 Tiktalik (Burbot)

Burbot (*Lota lota*) are another freshwater species that was identified as a food fish in the NTKP report.

> *Burbot stay in freshwater systems.*
>
> *First time I caught it, a really big one, I was really young. I told my dad I caught a really, really ugly fish.*
>
> *First time my wife see tiktalik, she asked 'what kind of fish is this?" It's a really good fish but it looks funny. They're good, they're really good, that tiktalik.*
>
> *They are something like barracuda but they're small. They are silver.*

6.1.2 Incorporation of Traditional Knowledge for Freshwater Fish VEC Selection

The NTKP report was reviewed to refine the potential Valued Ecosystem Component (VEC) list for freshwater fish. The freshwater and anadromous fish species identified in the NTKP report and other commercial and recreational fish and their habitats were considered as potential VECs for the effects assessment. In addition, Inuit traditional fishing places and known fish distribution/locations identified in the NTKP report were considered as potential VECs for the effects assessment. Traditional knowledge was combined with data from public consultation and baseline surveys to determine which valued components would potentially interact with the Project, and should therefore be evaluated for inclusion in the candidate VEC list.

As a result of this process, and in consideration of the EIS guidelines (NIRB 2012a), Lake Trout, Arctic Grayling, Arctic Char, cisco (Cisco and Least Cisco), and whitefish (Lake Whitefish and Broad Whitefish) were selected as candidate VECs for the EIS (Volume 2, Chapter 4; Effects Assessment Methodology). While available TK information specifically identified Arctic Cisco as a fish species used by Inuit in the NTKP report study area, Arctic Cisco have not been confirmed to be present and high value freshwater habitats used by Arctic Cisco are very limited in the smaller, freshwater fish baseline study area boundaries (see Section 6.2.1) for the Project, based on baseline information collected since 1993. Thus, Arctic Cisco was not considered as part of the Cisco candidate VEC. Burbot was not considered as a candidate VEC because it is rare in the Project area, having been captured only in the Koignuk River and Trout Outflow of the Aimaokatalok Watershed.

6.1.3 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 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. Therefore, the entire Hope Bay Project area was included within the spatial boundaries of the assessment. The temporal boundaries of the assessment extend into the future, aligned with the Post-closure phase, as preservation of the productive capacity of the freshwater aquatic ecosystem, particularly the capacity to produce food fish and fishing opportunities, is a key value of Inuit culture.

6.1.4 Incorporation of Traditional Knowledge for Project Effects Assessment

Inuit value a suite of fish species as food fish and as key attributes of freshwater aquatic systems. The potential effects considered in the effects assessment focus on the habitat requirements of these fish species. The effects assessment considers the spatial and temporal overlap of the Project with these fish species, specifically considering high value habitats and life history periodicity. Four of the main food fish species – Lake Trout, Arctic Char, cisco and whitefish – are anadromous species thus their rearing lakes, outlet streams and rivers, and the estuarine and coastal habitat immediately adjacent to those stream and river mouths are equally essential for preservation of productive populations. Productive lake ecosystems in addition to continued access to the sea are key requirements for both species. Arctic Grayling require accesses to good quality rearing and spawning habitat in streams and overwintering habitat in lakes.

6.1.5 Incorporation of Traditional Knowledge for Mitigation and Adaptive Management

As summarized within Land Use (Volume 6, Chapter 4), focus group sessions revealed Inuit concerns about the potential for freshwater fish or fish habitat quality to be affected by the Madrid-Boston Project. The Project infrastructure has been designed, where possible to avoid the habitats of fish species identified as important in TK information and best management practices will be applied to avoid and/or mitigate the loss or alteration to fish habitats and harm to fish. Additional mitigation of Project effects on freshwater fish and fish habitat may be achieved through fisheries offsetting (as deemed necessary and approved by DFO). Ongoing consultation with Fisheries and Oceans Canada (DFO), and future engagement with local Inuit, regarding the further development of the FOP, including the development of additional or alternative options that could provide value to the local communities, is intended through the life of the Project.

6.2 EXISTING ENVIRONMENT AND BASELINE INFORMATION

6.2.1 Regional Overview and Past Activities

The Hope Bay Greenstone Belt has an area of 1,101 km^2 and comprises one contiguous property approximately 80 by 20 km. It is located 705 km northeast of Yellowknife, NT and 153 km southwest of Cambridge Bay, NU in Nunavut Territory, and is situated east of Bathurst Inlet. The centre of the Hope Bay Project lies approximately 143 km above the Arctic Circle at 67°50’ N latitude and 106°30’W longitude. The Hope Bay Project consists of the existing Doris Project as well as the proposed Madrid-Boston Project, which includes mining of three deposit areas: Madrid North, Madrid South, and Boston (Figure 6.2-1).

Baseline freshwater aquatic information has been collected within the Hope Bay Greenstone Belt since 1993. The proposed Madrid-Boston Project infrastructure lies within a single defined Local Study Area

(LSA) that is bounded by a larger Regional Study Area (RSA; see Section 6.4; Figure 6.2-1). Regionally, the Project lies entirely within the Southern Arctic Ecozone and is situated in an area of continuous permafrost. Generally, the northern portion of the belt (Doris area) has more variable relief, with exposed igneous extrusions to 160 m, and a greater marine influence than Madrid or Boston. Madrid and Boston are characterized by flat rolling bedrock covered by thin layers of moraine, lacustrine, and fluvial deposits.

Winter is characterized by extreme cold, with mean monthly temperatures ranging from -33.4ºC to -3.1ºC. The coldest temperatures occur in January and February. There is a short snow-free season from mid-June through September with mean monthly temperatures ranging from -2.5ºC to 13.9ºC. The warmest temperatures are typically recorded in July. The Doris meteorological station reports total summer rainfall (June to September) ranging from 47.8 mm in 2012 to 97.8 mm in 2011 (see 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.).

The freshwater LSA includes the Doris, Windy, and Koignuk sub-watersheds in the north, and the Aimaokatalok and East sub-watersheds in the south (Figure 6.2-1). The Doris and Windy Watersheds flow northward into Roberts Bay via Little Roberts Outflow and Glenn Outflow, respectively, while watersheds around Boston flow into Hope Bay exclusively via the large Koignuk River system. The largest lakes in the north belt include Doris, Windy, Patch, Glenn, and Ogama. Aimaokatalok Lake is the largest lake in the south belt.

The hydrology of the Project area is dominated by snowmelt, with peak flows in most watersheds occurring in June. The lakes are typically frozen from November to June with ice thickness ranging between 1.5 and 2.0 m (Appendices V5-3S and V5-3T). 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.

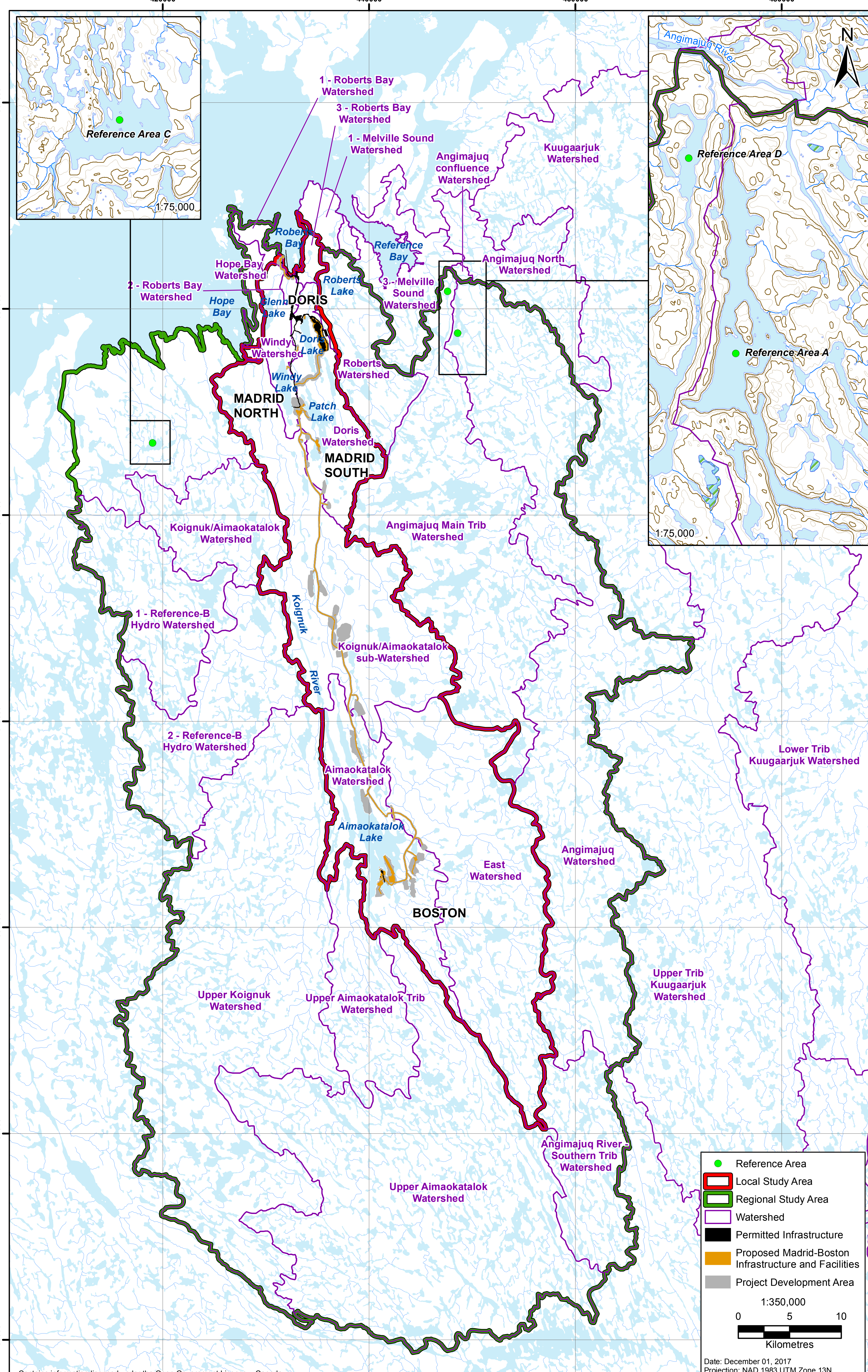
Past mining activities associated with the Project include the previously permitted Doris North Gold Mine (Doris; see Volume 3, Project Description and Alternatives). The Doris deposit is located in the northernmost portion of the Belt, approximately 5 km inland from the coast. Doris infrastructure includes a jetty and associated infrastructure in Roberts Bay, all weather roads connecting Roberts Bay to the Doris mine, the Tailings Impoundment Area (TIA), as well as an all-weather airstrip, waste management facilities, accommodations, and water withdrawal from Doris and Windy lakes. The Madrid North, Madrid South, and Boston deposits, the subject of this EIS, are located south of Doris but will make use of existing Doris infrastructure where possible.

6.2.2 Proximity to Designated Environmental Areas

There are currently no existing or proposed parks or conservation areas near the Project. The nearest conservation area is the Queen Maud Gulf Migratory Bird Sanctuary approximately 50 km east of the Project area by air and over 300 km by water (because Melville Sound is isolated from the Queen Maud Gulf by the Kent Peninsula).

The Draft Nunavut Land Use Plan (Nunavut Planning Commission 2016) has designated the Project area as having high mineral potential and being within an area of Arctic Char abundance. The proposed Hiukitak River Cultural Area on the eastern shore of northern Bathurst Inlet is approximately 100 km beyond the Project freshwater RSA boundary. Past, current, and potential future activities near the Project are outlined in the Effects Assessment Methodology (Volume 2, Chapter 4).

Figure 6.2-1
Local and Regional Study Areas for Freshwater Fish



6.2.3 Regulatory Framework

Several federal regulations guide development where it pertains to fish and fish habitat protection. These include:

- *Fisheries Act* (1985);
- Metal Mining Effluent Regulations (MMER; SOR/2002-222); and
- *Species at Risk Act* (2002).

The following sections describe these acts, regulations, and guidelines and how they apply to the protection of fish and fish habitat.

6.2.3.1 Fisheries Act

Fish and fish habitat are protected under the *Fisheries Act*. In 2012, the *Fisheries Act* was amended to focus efforts on protecting the productivity of commercial, recreational, and Aboriginal fisheries (i.e., CRA fisheries); to institute enhanced compliance and protection tools that are more easily enforceable; to provide clarity, certainty, and consistency of regulatory requirements; and to enable enhanced partnerships with stakeholders.

The *Fisheries Act* includes a prohibition against causing serious harm to fish that are part of or support a CRA fishery (Section 35), provisions for flow and passage (Sections 20 and 21), and a framework for regulatory decision-making (Sections 6 and 6.1). The fisheries protection provisions of the *Fisheries Act* aim to provide for the sustainability and ongoing productivity of CRA fisheries (DFO 2013a).

The four factors in Section 6 and 6.1 to be taken into account by the Minister in decision-making (e.g., issuing authorizations) or making regulations are:

- the contribution of the relevant fish to the ongoing productivity of commercial, recreational, or Aboriginal fisheries;
- fisheries management objectives;
- whether there are measures and standards to avoid, mitigate, or offset serious harm to fish that are part of a commercial, recreational, or Aboriginal fishery; and
- the public interest.

For the purposes of the *Fisheries Act* (1985), "serious harm to fish" includes the death of fish or any permanent alteration to, or destruction (PAD) of fish habitat. The *Fisheries Act* defines fish habitat as "spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas, on which fish depend directly or indirectly in order to carry out their life processes." The term "fish" includes parts of fish; shellfish, crustaceans, marine animals, and any parts of shellfish, crustaceans, or marine animals; and the eggs, sperm, larvae, spat, and juvenile stages of fish, shellfish, crustaceans, and marine animals. An alteration of fish habitat is considered a permanent alteration if it is "of a spatial scale, duration or intensity that limits or diminishes the ability of fish to use such habitats… in order to carry out one or more of their life processes". An alteration of fish habitat is considered the destruction of fish habitat if it is "of a spatial scale, duration, or intensity that fish can no longer rely upon such habitats…in order to carry out one or more of their life processes".

Any project or activity that causes a serious harm to fish that are part of, or support, a commercial, recreational, or Aboriginal fishery requires an authorization from DFO. Regulations have been developed to guide the application for this authorization: Applications for Authorization under

Paragraph 35(2)(b) of the *Fisheries Act* Regulations. DFO has issued additional guidance in *The Fisheries Protection Program Policy Statement* (DFO 2013c).

Under the *Fisheries Act* a factor that must be considered for the issuance of an authorization for a project is whether there are measures and standards to avoid, mitigate, or offset serious harm to fish. According to the Fisheries Protection Policy Statement (DFO 2013c), efforts should be made to first prevent (avoid) impacts, then, when avoidance is not possible, to minimize (mitigate) impacts. After avoidance and mitigation actions are applied, any remaining impacts would normally require an authorization and should then be addressed by offsetting. Offsetting measures are intended to produce tangible conservation outcomes for fish and fish habitat to counterbalance the loss of fish habitat and fisheries productivity resulting from project impacts. Examples of offsetting measures include localized improvements in fish habitat and measures that address limitations on fisheries productivity. When applying for an authorization, proponents are required to submit an offsetting plan that demonstrates avoidance, mitigation, and offsetting measures and demonstrates how offsetting measures will maintain or improve the productivity of fisheries (DFO 2013a).

The Fisheries Protection Policy Statement (DFO 2013c) was issued on November 1, 2013 and replaced the earlier Policy for the Management of Fish Habitat (DFO 1986). Although the new policy statement does not include the "no net loss" principle, as outlined in the earlier policy, application of this principle provides some useful guidance when considering "serious harm to fish". Additional information is also available through scientific guidance documents developed by DFO (Koops et al. 2013; Randall et al. 2013).

6.2.3.2 Metal Mining Effluent Regulations

In 1996, Environment Canada undertook an assessment of the aquatic effects of mining in Canada. This assessment provided recommendations regarding the review and amendments of the Metal Mining Liquid Effluent Regulations, currently titled the Metal Mining Effluent Regulations (MMER; SOR/2002-222), and the design of a national Environmental Effects Monitoring (EEM) program for metal mining. The MMER, under the *Fisheries Act*, instructs metal mines to conduct EEM as a condition governing the authority to deposit effluent (MMER, Part 2, section 7).

The MMER (SOR/2002-222) permit the deposition of mine effluent into water containing fish if the effluent pH is within a defined range, if the concentrations of the MMER deleterious substances in the effluent do not exceed authorized limits, and if the effluent is demonstrated to be not acutely lethal to fish. These discharge limits were established to be minimum national standards based on the best available technology that is economically achievable at the time that the MMER were promulgated. To assess the adequacy of the effluent regulations for protecting the aquatic environment, the MMER include EEM requirements to evaluate the potential effects of effluents on fish, fish habitat, and the use of fisheries resources.

Regulations Amending the MMER were published in the Canada Gazette, Part II, in October 2006 (Canada Gazette 2006). The purpose of these amendments was to clarify the regulatory requirements by addressing matters related to the interpretation and clarity of the regulatory text that had emerged from the implementation of the Regulations.

Additional amendments to the MMER were published in the Canada Gazette, Part II, in March 2012 (Canada Gazette 2012). The following changes were made to expand EEM provisions of the MMER:

- modifications to the definition of an "effect on fish tissue" in order to be consistent with the Health Canada fish consumption guidelines and to clarify that the concentration of total mercury in tissue of fish from the exposure area must be statistically different from and higher than its concentration in fish tissue from the reference area;

- addition of selenium and electrical conductivity to the list of parameters required for effluent characterization and water quality monitoring;
- exemption for mines, other than uranium mines, from monitoring radium 226 as part of the water quality monitoring, if 10 consecutive test results showed that radium 226 levels are less than 10% of the authorized monthly mean concentration (subsection 13(2) of the Regulations; SOR/2002-222);
- change to the time frame for the submission of interpretative reports for mines with effects on the fish population, fish tissue, and benthic invertebrate community from 24 to 36 months;
- change to the time frame for the submission of interpretative reports for magnitude and geographic extent of effects, and for investigation of cause of effects, from 24 to 36 months; and
- minor changes to the wording for consistency within Schedule 5.

6.2.3.3 Species at Risk Act

The federal *Species at Risk Act* (2002) is designed to prevent Canadian indigenous species, subspecies, and distinct populations from becoming extirpated or extinct. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses and identifies species at risk. COSEWIC is designated under SARA to assess species according to their level of conservation concern: *extinct*, *extirpated*, *endangered*, *threatened*, *special concern*, *not at risk* or *data deficient*. Only those species listed in Schedule 1 of the *Act* qualify for legal protection and recovery under SARA. The *Act* prohibits the killing, harming, harassing, capturing or taking of an individual of a species that is listed in Schedule 1 as *extirpated*, *endangered* or *threatened* by SARA (section 32(1)). SARA also protects the residence of species listed as *extirpated*, *endangered* or *threatened* from being damaged and destroyed as specified in Section 33. No fish species listed under SARA were captured in freshwater habitats in baseline studies.

6.2.4 Data Sources

From 1993 to 1998, freshwater aquatic studies were conducted throughout the entire Hope Bay Greenstone Belt for BHP Minerals Canada Ltd., focusing mainly on the Boston and Doris areas. Environmental studies continued under BHP Diamonds Inc. in 1998 and 1999, mainly focusing on the Boston area.

Miramar Hope Bay Ltd./Hope Bay Joint Venture (Miramar) acquired the property in 1999, and continued environmental studies in the belt, ultimately focusing on the Doris area. The Doris property went through the environmental permitting process, and was issued a Project Certificate by the Nunavut Impact Review Board (NIRB), a Type A water licence by the Nunavut Water Board (NWB), and a Schedule 2 amendment to the MMER for Tail Lake, now the Doris Tailings Impoundment Area (TIA). Other regulatory approvals such as a Fisheries Authorization and Fish Habitat Compensation Agreement for the Roberts Bay Jetty, a Navigable Waters Authorization, a Water Compensation Agreement with the KIA, and an Inuit Impacts and Benefits Agreement (IIBA) with the KIA, were also obtained. As a result of permitting the Doris Project, most of the freshwater aquatic studies between approximately 2002 and 2006 focused on the Doris area. However, some baseline work in the Boston and Madrid areas was initiated in 2006, and continued in 2007 and 2008.

Newmont Mining Corporation acquired the property in March 2008, formed Hope Bay Mining Ltd. (HBML) and continued exploration activities, and evaluated various options for long-term development of the belt. HBML also worked through the compliance commitments from the Doris Project, and determined how best to proceed given the objective of permitting additional deposits in the belt. That work included preparing a review of baseline studies and a data gap analysis (Rescan 2009) and undertaking subsequent additional baseline studies for the Madrid-Boston Project. In 2012, TMAC acquired the property and continued freshwater aquatic studies including baseline studies, annual compliance reports, and reports of the Doris Aquatic Effects Monitoring Program (AEMP).The Doris Project Certificate and Water Licence were amended in 2015 and fish and fish habitat studies were conducted to support the identification and mitigation of potential effects in the amendment application.

6.2.4.1 Freshwater Fish Habitat - Biological Resources

Freshwater biological resources are those communities of plants and animals that form the basis of aquatic food webs and which support fish: phytoplankton, periphyton, zooplankton, and benthic invertebrates. Forage fish – small-bodied fish species that are prey for larger fish – can be considered biological resources because of their positions in the food webs, but are described in the fish sections of this document.

Biological resources data were compiled from site-specific surveys in the LSA and RSA that were conducted from 1993 to 2017. The primary sources of biological resource information used in the EIS were the baseline studies conducted from 1993 to 2010 (Rescan 1993, 1994, 1995, 1997, 1998, 1999b, 2001; RL&L Environmental Services Ltd./Golder Associates Ltd. 2003b; Golder Associates Ltd. 2008, 2009; Rescan 2010c, 2011c) and the AEMP sampling for the Doris Project (Rescan 2011a, 2012a, 2013a; ERM Rescan 2014a; ERM 2015b, 2016b, 2017b). All reports can be found in associated appendices, except the Doris Project AEMP reports (Rescan 2011a, 2012a, 2013a; ERM Rescan 2014a; ERM 2015b, 2016b, 2017b), which are available on the Nunavut Water Board (NWB) FTP site (ftp://ftp.nwb-oen.ca). Titles and associated appendix numbers of the baseline studies are the following:

- Boston Property N.W.T.: Environmental Data Report (1993) (Rescan 1993; Appendix V5-3B);
- Boston Property N.W.T.: Environmental Data Report (1994) (Rescan 1994; Appendix V5-3C);
- Boston Property N.W.T.: Environmental Data Report 1995 (Rescan 1995; Appendix V5-3E);
- 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);
- Hope Bay Belt Project: 1998 Environmental Data Report (Rescan 1999b; Appendix V5-3H);
- 2000 Supplemental Environmental Baseline Data Report, Hope Bay Belt Project (Rescan 2001; Appendix V5-3I);
- Doris North Project: Aquatic Studies 2003 (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003b; Appendix V5-3K);
- Boston and Madrid Project Areas: 2006-2007 Aquatic Studies (Golder Associates Ltd. 2008; Appendix V5-3P);
- Hope Bay Project: Aquatic Studies 2008 (Golder Associates Ltd. 2009; Appendix V5-3R);
- 2009 Freshwater Baseline Report, Hope Bay Belt Project (Rescan 2010a; Appendix V5-3S);
- Hope Bay Belt Project: 2010 Freshwater Baseline Report (Rescan 2011c; Appendix V5-3T); and
- Hope Bay Project: 2017 Madrid-Boston Freshwater Baseline Report (ERM 2017e; Appendix V5-3U).

6.2.4.2 Freshwater Fish Habitat - Physical Characteristics and Fish Community

Surveys of fish and fish habitat in streams and lakes of the Hope Bay Belt began in 1993 and continued to 2017. Surveys were conducted in 24 of those 26 years; no surveys were conducted in the years 1999 and 2001. Sampling covered the North Belt (i.e., Doris area) and the South Belt (i.e., Madrid and Boston areas) of the LSA and selected lakes and streams within the RSA. Comprehensive baseline aquatic studies for the Madrid-Boston EIS were conducted in 2009 and 2010. Additional studies in support of the Doris AEMP and other environmental compliance programs were conducted from 2010 to 2017. Full details of the fish and fish habitat surveys from 1993 to 2017, including studies conducted in support of the Doris Project Certificate and Type A Water License amendments and Madrid-Boston EIS in are described in the reports listed in Section 6.2.3.1 and the following 32 additional reports (associated appendix numbers included):

- Doris Lake Project, Northwest Territories 1995 Environmental Study (Klohn-Crippen Consultants Ltd. 1995; Appendix V5-3D);
- Hope Bay Belt Project, Metal Concentrations in Fish Tissues from Five Lakes in the Hope Bay Belt, Nunavut (Rescan 1999a; Appendix V5-6A);
- Aquatic Baseline Studies: Doris Hinge Project Data Compilation Report 1995-2000 (RL&L/Golder 2002; Appendix V5-3J);
- Doris North Project Aquatic Studies 2002 (RL&L Environmental Services Ltd./Golder Associates Ltd. 2003a; Appendix V5-5A);
- Doris North Project Aquatic Studies 2004 (Golder 2005; Appendix V5-3L);
- Bathymetric Surveys: Hope Bay Project, Hope Bay, Nunavut (Golder 2006a; Appendix V5-3N);
- Doris North Project Aquatic Studies 2005 (Golder 2006b; Appendix V5-3M);
- Doris North Project Aquatic Studies 2006 (Golder 2007a; Appendix V5-3O);
- Doris North Project “No Net Loss” Plan (Golder 2007b; Appendix V5-6B);
- Doris North Project Aquatic Studies 2007 (Golder 2008b; Appendix V5-3Q);
- Aquatic Baseline Studies Boston Project Data Compilation Report 1992 – 2000 (Golder 2008a; Appendix V5-6C);
- 2009 Freshwater Fish and Fish Habitat Baseline Report, Hope Bay Belt Project (Rescan 2010b; Appendix V5-6D);
- Hope Bay Belt Project: 2010 Freshwater Fish and Fish Habitat Baseline Report (Rescan 2011d; Appendix V5-6E);
- Doris North Gold Mine Project: Doris Mine Site Fisheries Authorization Monitoring Report 2010 (Rescan 2011b; Appendix V5-6F);
- Doris North Gold Mine Project: Doris Mine Site Fisheries Authorization Monitoring Report 2011 (Rescan 2012c; Appendix V5-6G);
- Doris North Gold Mine Project: 2011 Tail Lake Fish-out Report (Rescan 2012b; Appendix V5-6H);
- Doris North Gold Mine Project: Windy Lake Shoal Monitoring, 2012 (Rescan 2012e; Appendix V5-6I);
- Doris North Gold Mine Project: Roberts Outflow and E09 Fish Habitat Enhancement Report (Rescan 2012d; Appendix V5-6J);
- Doris North Gold Mine Project: 2012 Roberts Lake and Outflow Fish Monitoring Report (Rescan 2013b; Appendix V5-6K);
- Doris North Project: 2013 Windy Lake Shoal Compliance Monitoring Report (ERM Rescan 2014c; Appendix V5-6L);
- Doris North Project: 2013 Roberts Lake and Outflow Fish Compliance Monitoring Program Report (ERM Rescan 2014b; Appendix V5-6M);
- Doris North Project: 2014 Windy Lake Shoal Compliance Monitoring Report (ERM 2014; Appendix V5-6N);

- o Doris North Project: 2014 Roberts Lake and Outflow Fish Compliance Monitoring Program Report (ERM 2015c; Appendix V5-6O);
- o Imniagut Lake Fisheries Assessment, Doris North Project, 2014 (ERM 2015d; Appendix V5-6P);
- o Proposed Access Road Fisheries Assessments, Doris North Project 2015 (ERM 2015e; Appendix V5-6Q);
- o Doris Creek and Little Roberts Outflow Fisheries Assessment – Hydraulic Modeling Results (ERM 2015a; Appendix V5-6R);
- o Doris Lake, Doris Creek, and Little Roberts Outflow Fisheries Assessment (ERM 2016a; Appendix V5-6S);
- o Doris North Project: 2015 Roberts Lake Fish Enhancement Monitoring Program (ERM 2016c; Appendix V5-6T);
- o Doris, Roberts, and Little Roberts Outflows Fisheries Assessments (ERM 2016d; Appendix V5-6U);
- o 2017 Patch Outflow, Ogama Inflow, and Ogama Outflow Fisheries Assessment – Hydraulic Modeling Results (ERM 2017a; Appendix V5-6V);
- o Hope Bay Project: 2017 Freshwater Fish and Fish Habitat Baseline Report (ERM 2017d; Appendix V5-6W); and
- o Fish Bearing Status of Four Ponds in Proximity to Boston, 2017 (ERM 2017c; Appendix V5-6X).

6.2.5 Methods

6.2.5.1 Freshwater Fish Habitat – Biological Resources

The methods used to collect biological resources data are described below.

<u>Phytoplankton and Periphyton</u>

Phytoplankton and periphyton are photosynthetic microorganisms that use inorganic nutrients and sunlight to produce organic matter. Phytoplankton are free-floating while periphyton are attached to submerged surfaces such as rocks. These primary producers play a key ecological role in freshwater systems as the basis of aquatic food webs. Phytoplankton are important primary producers in lentic (still water) ecosystems such as lakes, while periphyton are important primary producers in the littoral habitat lakes and in lotic (flowing water) ecosystems such as streams and rivers.

Phytoplankton samples were collected from 13 lakes within the LSA and 8 lakes within the RSA from 1993 to 2017, with periphyton samples being collected from 17 streams within the LSA and 8 streams within the RSA. Tables 6.2-1 and 6.2-2 provide an overview of the phytoplankton and periphyton biomass and taxonomy sampling sites in the LSA and RSA. Figures 6.2-2 and 6.2-3 show the baseline phytoplankton and periphyton sampling sites.

Periphyton samples were usually collected using Plexiglas artificial substrate samplers installed in streams for a set period of time. Upon retrieval, known surface areas of the plates were scraped and rinsed into a bottle for analysis of biomass as chlorophyll *a* and/or taxonomy. Periphyton samples collected as instantaneous rock scrapings were not included in this data compilation as this method is not comparable to periphyton collected using artificial substrate samplers.

Phytoplankton and periphyton biomass samples were filtered onto 0.45 μm filters that were wrapped in aluminum foil and stored frozen. Biomass samples were sent either to the University of British Columbia, the Alberta Research Council, or ALS Environmental (Burnaby or Vancouver, BC) for analysis of chlorophyll *a*.

Figure 6.2-2
Freshwater Phytoplankton and Periphyton Sampling Sites, North Belt, 1996-2017

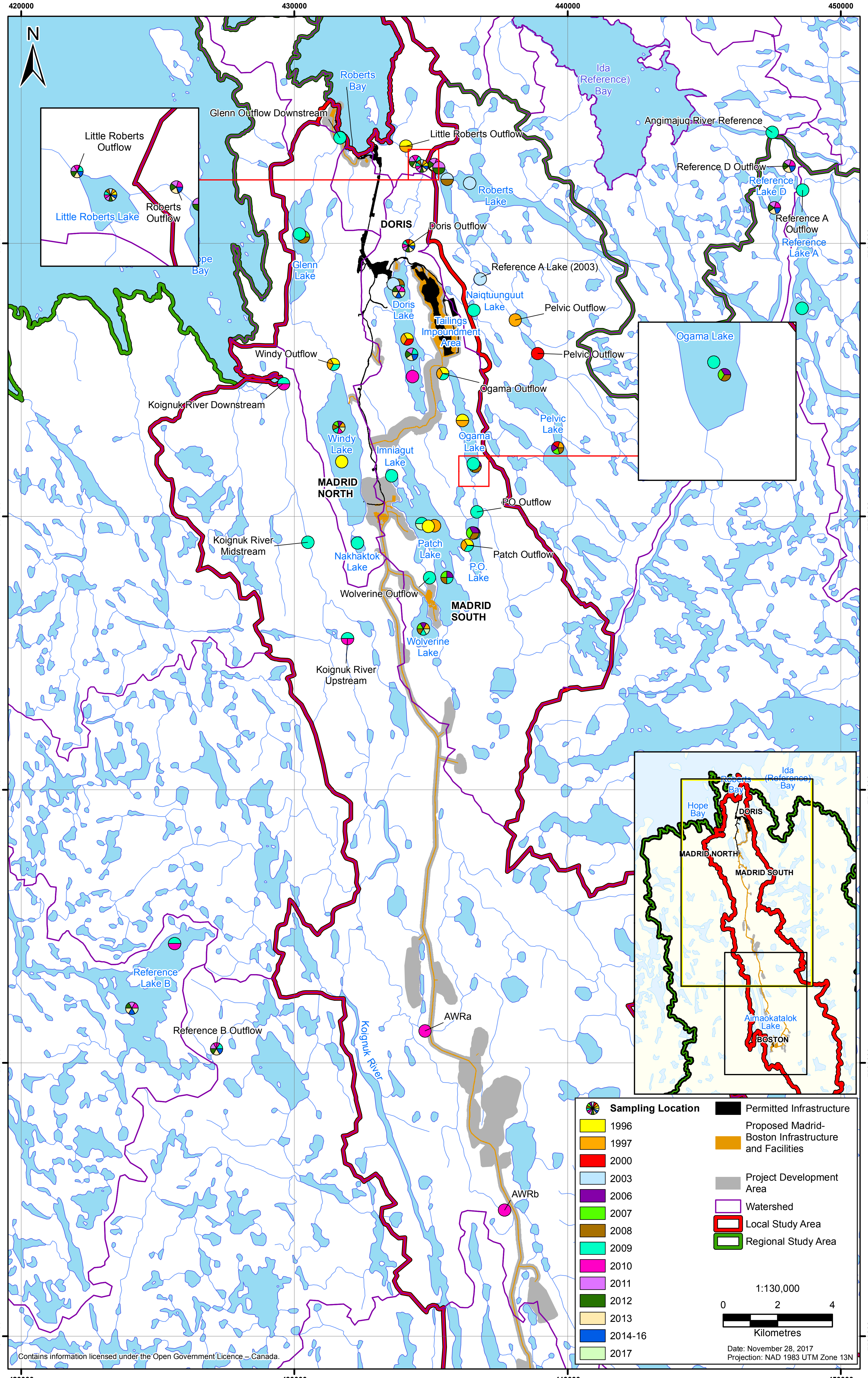


Figure 6.2-3
Freshwater Phytoplankton and Periphyton Sampling Sites, South Belt, 1993-2017

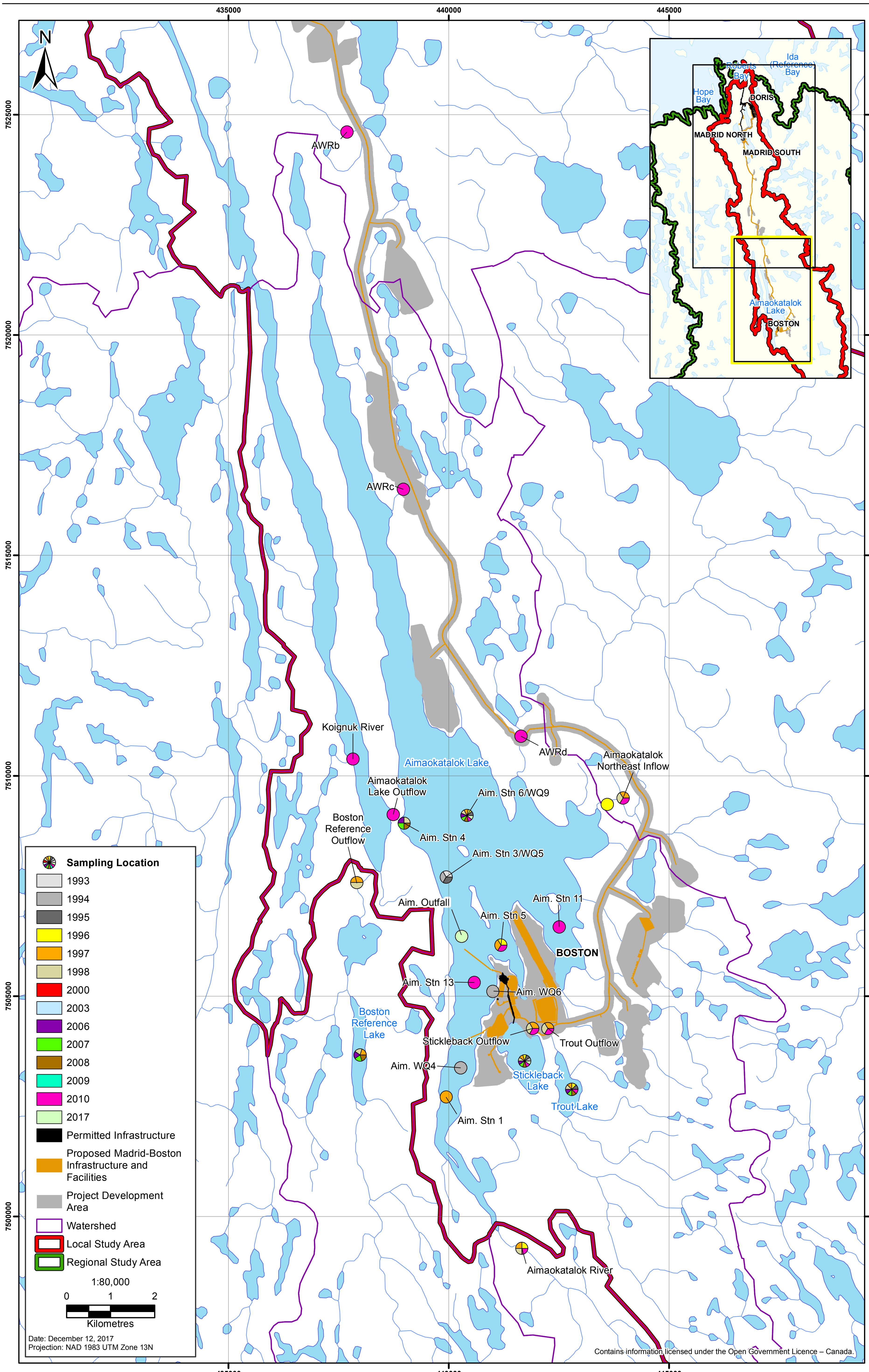


Table 6.2-1. Lake Phytoplankton Biomass (as Chlorophyll *a*) and Taxonomy Sampling Sites, 1993 to 2017

	1993	1994	1995	1996	1997	1998	2000	2003	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
LSA - North Belt																				
Doris Lake	-	-	-	T	BT	-	BT	B	-	-	B	BT	B	B	B	B	B	B	B	B
Glenn Lake	-	-	-	-	-	-	-	-	-	B	B	BT	-	-	-	-	-	-	-	-
Imniagut Lake	-	-	-	-	-	-	-	-	-	-	-	BT	-	-	-	-	-	-	-	-
Little Roberts Lake	-	-	-	T	BT	-	-	B	-	-	B	BT	B	B	B	B	B	B	B	-
Nakhaktok Lake	-	-	-	-	-	-	-	-	-	-	-	BT	-	-	-	-	-	-	-	-
Ogama Lake	-	-	-	T	BT	-	-	-	B	B	B	BT	-	-	-	-	-	-	-	-
P.O. Lake	-	-	-	-	-	-	-	-	B	B	B	BT	-	-	-	-	-	-	-	-
Patch Lake	-	-	-	T	BT	-	-	-	B	B	B	BT	-	-	-	-	-	-	-	B
Windy Lake	-	-	-	T	BT	-	-	-	B	B	B	BT	BT	-	-	-	-	-	-	B
Wolverine Lake	-	-	-	-	BT	-	-	-	B	B	B	BT	-	-	-	-	-	-	-	B
LSA - South Belt																				
Aimaokatalok Lake	T	BT	T	BT	BT	BT	-	-	B	B	B	-	BT	-	-	-	-	-	-	B
Stickleback Lake	-	BT	T	BT	BT	BT	-	-	B	B	B	-	BT	-	-	-	-	-	-	B
Trout Lake	-	-	T	BT	BT	BT	-	-	B	B	B	-	BT	-	-	-	-	-	-	-
RSA																				
Boston Reference Lake	-	-	-	-	BT	BT	-	-	B	B	B	-	-	-	-	-	-	-	-	-
Naiqunnguut Lake	-	-	-	-	-	-	-	-	-	-	-	BT	-	-	-	-	-	-	-	-
Pelvic Lake	-	-	-	-	BT	-	BT	-	B	B	B	-	-	-	-	-	-	-	-	-
Reference A Lake (2003)	-	-	-	-	-	-	-	B	-	-	-	-	-	-	-	-	-	-	-	-
Reference Lake A	-	-	-	-	-	-	-	-	-	-	-	BT	-	-	-	-	-	-	-	-
Reference Lake B	-	-	-	-	-	-	-	-	-	-	-	BT	BT	B	B	B	B	B	B	B
Reference Lake D	-	-	-	-	-	-	-	-	-	-	-	-	BT	B	B	B	B	B	B	-
Roberts Lake	-	-	-	-	-	-	-	B	-	-	B	-	-	B	B	-	-	-	-	-

Notes:
Dashes indicate no samples were collected.
"B" indicates that biomass samples were collected.
"T" indicates that taxonomy samples were collected.
"BT" indicates that both biomass and taxonomy samples were collected.

Table 6.2-2. Stream Periphyton Biomass (as Chlorophyll *a*) and Taxonomy Sampling Sites, 1997 to 2016

LSA - North Belt	1997	1998	2000	2009	2010	2011	2012	2013	2014	2015	2016
AWRa	-	-	-	-	BT	-	-	-	-	-	-
AWRb	-	-	-	-	BT	-	-	-	-	-	-
Doris Outflow	BT	-	BT	BT	B	B	B	B	B	B	B
Glenn Outflow Downstream	-	-	-	BT	-	-	-	-	-	-	-
Koignuk River (Upstream, Midstream, Downstream)	-	-	-	BT	BT	-	-	-	-	-	-

LSA - North Belt	1997	1998	2000	2009	2010	2011	2012	2013	2014	2015	2016
Little Roberts Outflow	BT	-	-	BT	B	B	B	B	B	B	B
Ogama Outflow	BT	-	-	BT	-	-	-	-	-	-	-
P.O. Outflow	-	-	-	BT	-	-	-	-	-	-	-
Patch Outflow	BT	-	-	BT	-	-	-	-	-	-	-
Windy Outflow	BT	-	-	BT	-	-	-	-	-	-	-
LSA - South Belt											
Aimaokatalok NE Inflow	BT	BT	-	-	BT	-	-	-	-	-	-
Aimaokatalok Outflow	-	-	-	-	BT	-	-	-	-	-	-
AWRc	-	-	-	-	BT	-	-	-	-	-	-
AWRd	-	-	-	-	BT	-	-	-	-	-	-
Koignuk River	-	-	-	-	BT	-	-	-	-	-	-
Stickleback Outflow	BT	BT	-	-	BT	-	-	-	-	-	-
Trout Outflow	BT	BT	-	-	BT	-	-	-	-	-	-
RSA											
Aimaokatalok River	BT	BT	-	-	BT	-	-	-	-	-	-
Angimajuq River Reference	-	-	-	BT	-	-	-	-	-	-	-
Boston Reference Outflow	BT	BT	-	-	-	-	-	-	-	-	-
Pelvic Outflow	BT	-	BT	-	-	-	-	-	-	-	-
Reference A Outflow	-	-	-	BT	-	-	-	-	-	-	-
Reference B Outflow	-	-	-	BT	BT	B	B	B	B	B	B
Reference D Outflow	-	-	-	-	BT	B	B	B	B	B	B
Roberts Outflow	-	-	-	-	B	B	B	B	B	B	B

Notes:
Dashes indicate no samples were collected.
"B" indicates that biomass samples were collected.
"T" indicates that taxonomy samples were collected.
"BT" indicates that both biomass and taxonomy samples were collected.
Phytoplankton biomass (as chlorophyll a*) and taxonomy samples were typically collected using Niskin sampling bottles during the ice-covered season (October to June) and GO-FLO or Kemmerer sampling bottles during the open-water season (July to September).*

Phytoplankton and periphyton taxonomy samples were preserved with Lugol's iodine solution and were sent to a qualified taxonomist for enumeration and identification. Phytoplankton taxonomy data from Golder (2008) were not included in this baseline data compilation because results were reported in units (e.g., biovolume or carbon biomass) that are not comparable to data from other years, i.e., numerical abundance per unit volume.

Primary producer communities were described using abundance (cells/mL for phytoplankton and cells/cm^2 for periphyton), genus richness (number of genera per sample), and genus diversity (Simpson's Diversity Index). The Simpson's Diversity Index (1-D) considers both evenness amongst and the number of genera. Values range from 0 to 1 with lower values indicating a lower diversity, i.e., a larger number of genera and/or evenness of abundance amongst genera.

Zooplankton

Zooplankton are small aquatic organisms that feed on bacteria, phytoplankton, other zooplankton, and particulate organic matter. They are prey for larger organisms including other zooplankton, benthic invertebrates, and fish.

Zooplankton samples were collected in lakes throughout the LSA and RSA between 1993 and 2010 (Figures 6.2-4 and 6.2-5). Samples were typically collected using vertical hauls conducted by lowering a net (118 μm mesh size) to within 1 to 2 m of the lake bottom and bringing it to the surface at a constant, slow speed (~ 0.5 m/s). Nets with different mesh sizes were used for some samples (64 μm mesh size used in 1993, 180 μm mesh size used in 2000), which could contribute to variability in the data. An internally mounted flowmeter was used to record the volume of water passing through the net during all hauls. Taxonomic samples were preserved with buffered formalin and sent to a qualified taxonomist for enumeration and identification.

Zooplankton communities were described using abundance (organisms/m^3), genus richness (number of genera per sample), and genus diversity (Simpson's Diversity Index). Zooplankton taxonomy data from Golder (2008) were not included in this baseline data compilation because results were reported as biomass per unit volume that were not comparable to taxonomy data from other years that were reported as numerical abundance per unit volume.

Benthic Invertebrates

Benthic invertebrates are a diverse group of organisms that live on or in the sediments, making up an important component of lake, stream, and river ecosystems. Crustaceans, insects, and molluscs compose the bulk of this community, at least by weight. These organisms feed on algae, bacteria, detritus, and other invertebrates and are an important pathway for energy and nutrients to move from primary producers into higher trophic levels, particularly fish.

Benthic invertebrate samples were collected in lakes, streams, and rivers throughout the LSA and RSA between 1993 and 2017 (Figures 6.2-6 and 6.2-7). Lake benthic invertebrate samples were collected using an Ekman grab sampler (surface area of 0.023 m^2) lowered to the lake bottom and triggered closed to collect sediments. Upon retrieval, sediments were sieved through a 500 μm sieve bucket to retain benthic macroinvertebrates. For some baseline studies, a 250 μm sieve bucket was used which would retain smaller organisms (meiofauna) than a 500 μm sieve bucket and contribute to some variability in the data. Lake benthic invertebrates were carefully collected and preserved in buffered formalin and send to a qualified taxonomist for enumeration and identification.

Stream and river benthic invertebrates were collected using a either a Hester-Dendy artificial substrate sampler that was installed in streams for approximately one month to allow for colonization by benthic invertebrates (1996 to 2000), or a Hess sampler with a sampling surface area of 0.096 m^2 and a net mesh size of 250 μm (1993, 1995) or 500 μm (2009-2016). Stream benthic invertebrates were carefully collected and preserved in buffered formalin and sent to a qualified taxonomist for enumeration and identification. A preliminary investigation of the pooled historical benthic invertebrate data showed that these two different sampling methods produced comparable results, so all benthic invertebrate data collected in LSA and RSA streams and rivers were included in this baseline data compilation.

Benthic invertebrate communities were described using abundance (organisms/m^2), genus richness (number of genera per sample), and genus diversity (Simpson's Diversity Index). There was some variability in the reporting of benthic invertebrate data in the historical dataset. Some studies included all counted organisms in the benthic invertebrate dataset, while others excluded some organisms for various reasons. For example, nematodes and harpacticoid copepods were sometimes excluded because these organisms are considered meiobenthic invertebrates and are not adequately sampled using mesh sizes of 250 to 500 µm which are typically used to collect macrobenthic organisms. Cladocerans, calanoid and cyclopoid copepods were also commonly excluded because these are largely pelagic organisms that do not typically live in benthic environments. These differences in data processing likely contribute to some of the variability in the pooled baseline data.

Quality Assurance and Quality Control

Although some quality assurance and quality control (QA/QC) measures differed among the aquatic resources baseline studies, common practices included the use of chain of custody forms to track all samples, and sample replication to account for within-site variability (between three and five replicates were usually collected for aquatic resources).

For most benthic invertebrate surveys, taxonomists determined the sorting efficiency of samples as an additional QA/QC measure. A re-sorting of randomly selected sample residues was conducted on a minimum of 10% of the benthos samples to determine the level of sorting efficiency. The criterion for an acceptable sorting was that more than 90% of the total number of organisms was recovered during the initial sort. The number of organisms initially recovered from the sample was expressed as a percentage of the total number after the re-sort (total of initial and re-sort count). Any sample not meeting the 90% removal criterion was re-sorted a third time. During this step of the QA/QC program, 90% minimum efficiency was attained for all benthos samples.

6.2.5.2 Freshwater Fish Habitat – Physical Characteristics

Fish habitat – the physical resources essential for fish to carry out life processes – was assessed in the Hope Bay Project area between 1993 and 2017. Multiple fish habitat survey methods were conducted in lakes, ponds and/or streams, as follows:

Lakes and Ponds

- Aerial surveys by helicopter;
- Reconnaissance surveys of the shorelines and littoral zones on foot or by small boat;
- Bathymetric surveys using hydroacoustic methods;
- Habitat assessment of littoral zones;
- Estimation of surface area and maximum depth of small headwater lakes of the Roberts Watershed;
- Snorkel surveys of littoral lake habitat of Windy Lake; and
- Hydroacoustic and underwater video surveys of deep-water lake substrate.

Streams

- Aerial surveys by helicopter;
- Reconnaissance surveys on foot;
- Habitat assessment;
- Fish Habitat Assessment Procedure (FHAP; Johnston and Slaney 1996); Sensitive Habitat Inventory Mapping (SHIM) of streams and wetlands; and
- Hydraulic modeling.

Figure 6.2-4
Freshwater Zooplankton Sampling Sites, North Belt, 1996-2010

TMAC RESOURCES

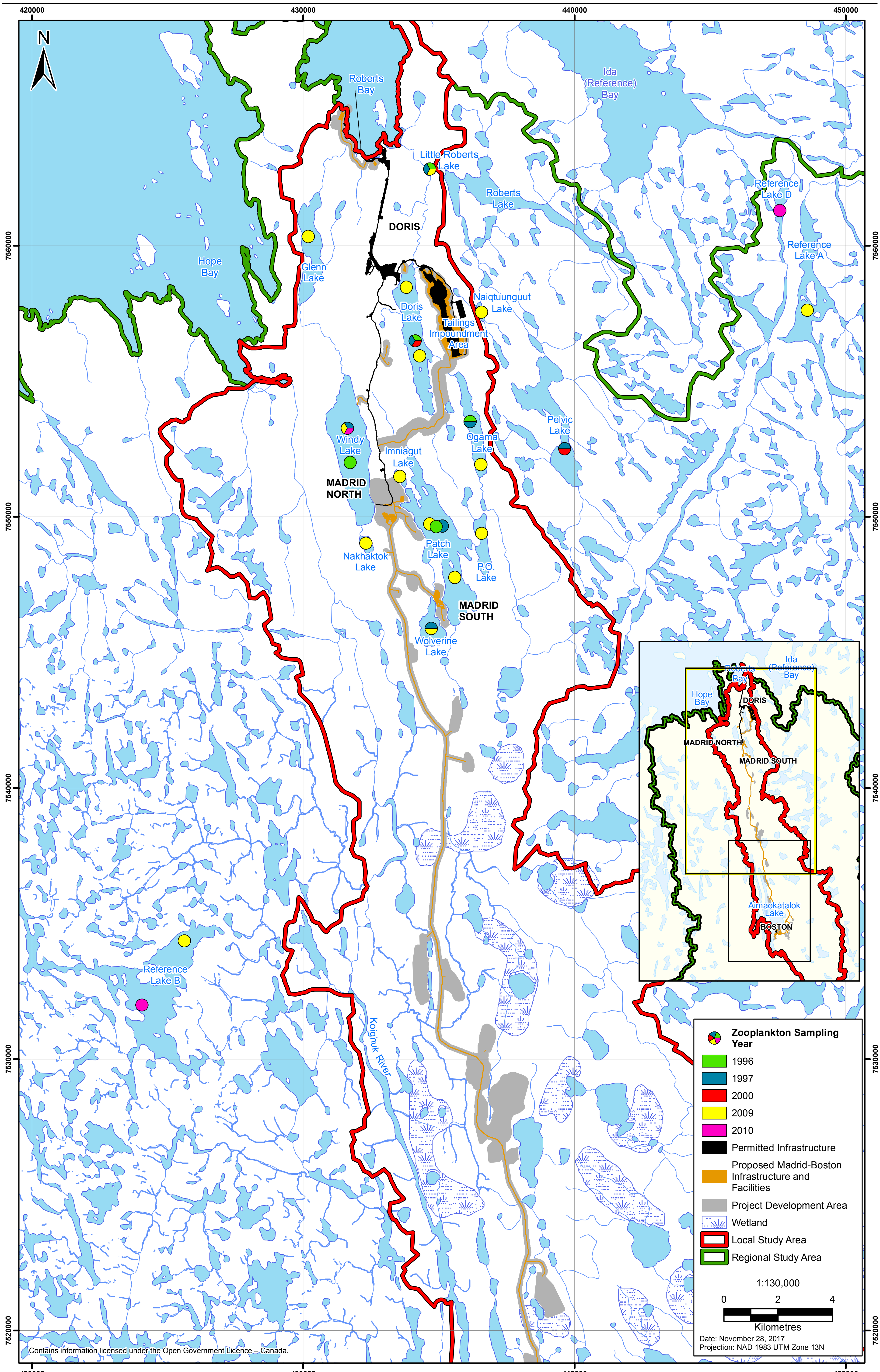


Figure 6.2-5
Freshwater Zooplankton Sampling Sites, South Belt, 1993-2010

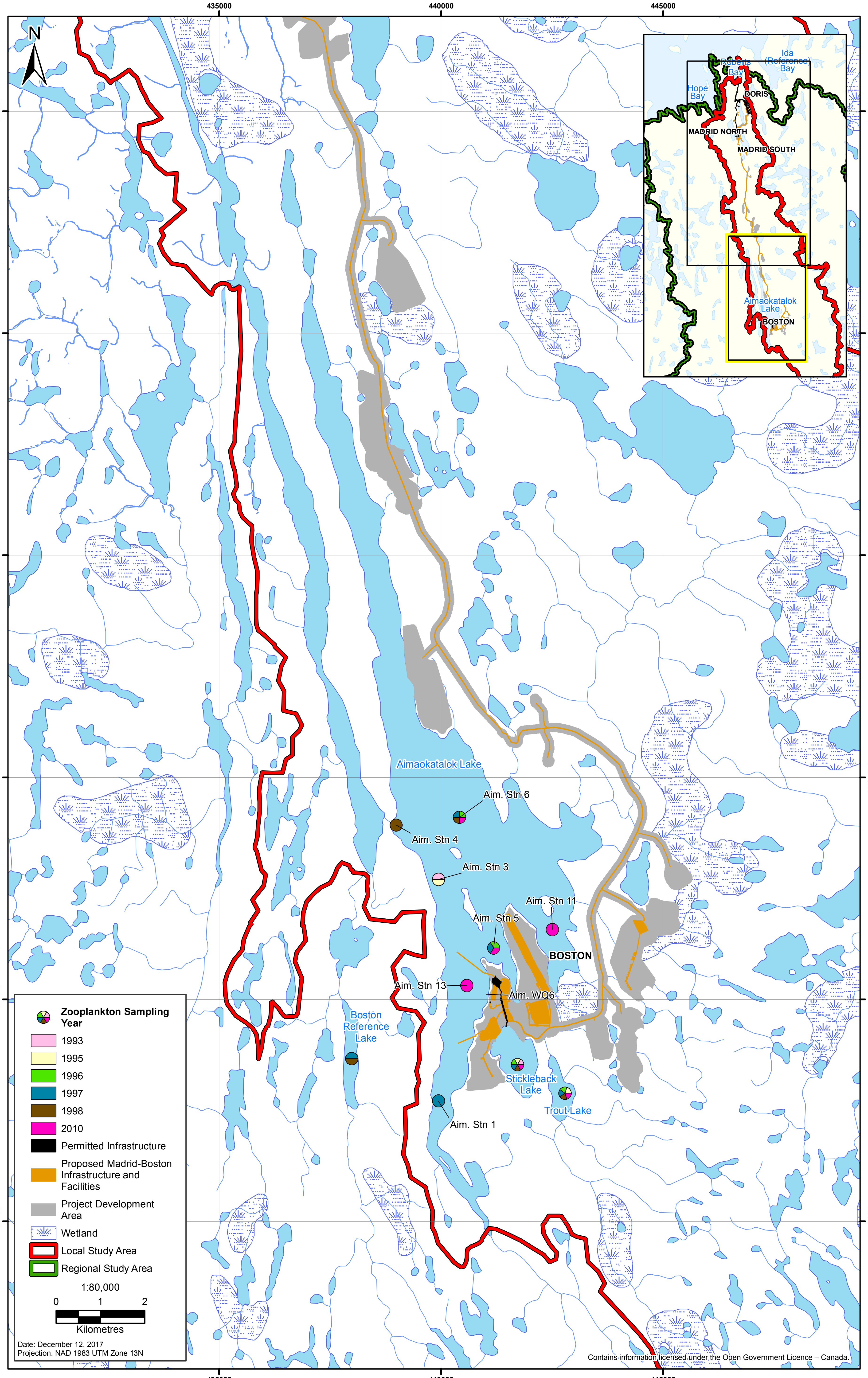


Figure 6.2-6
Freshwater Benthic Invertebrate Sampling Sites, North Belt, 1996-2017

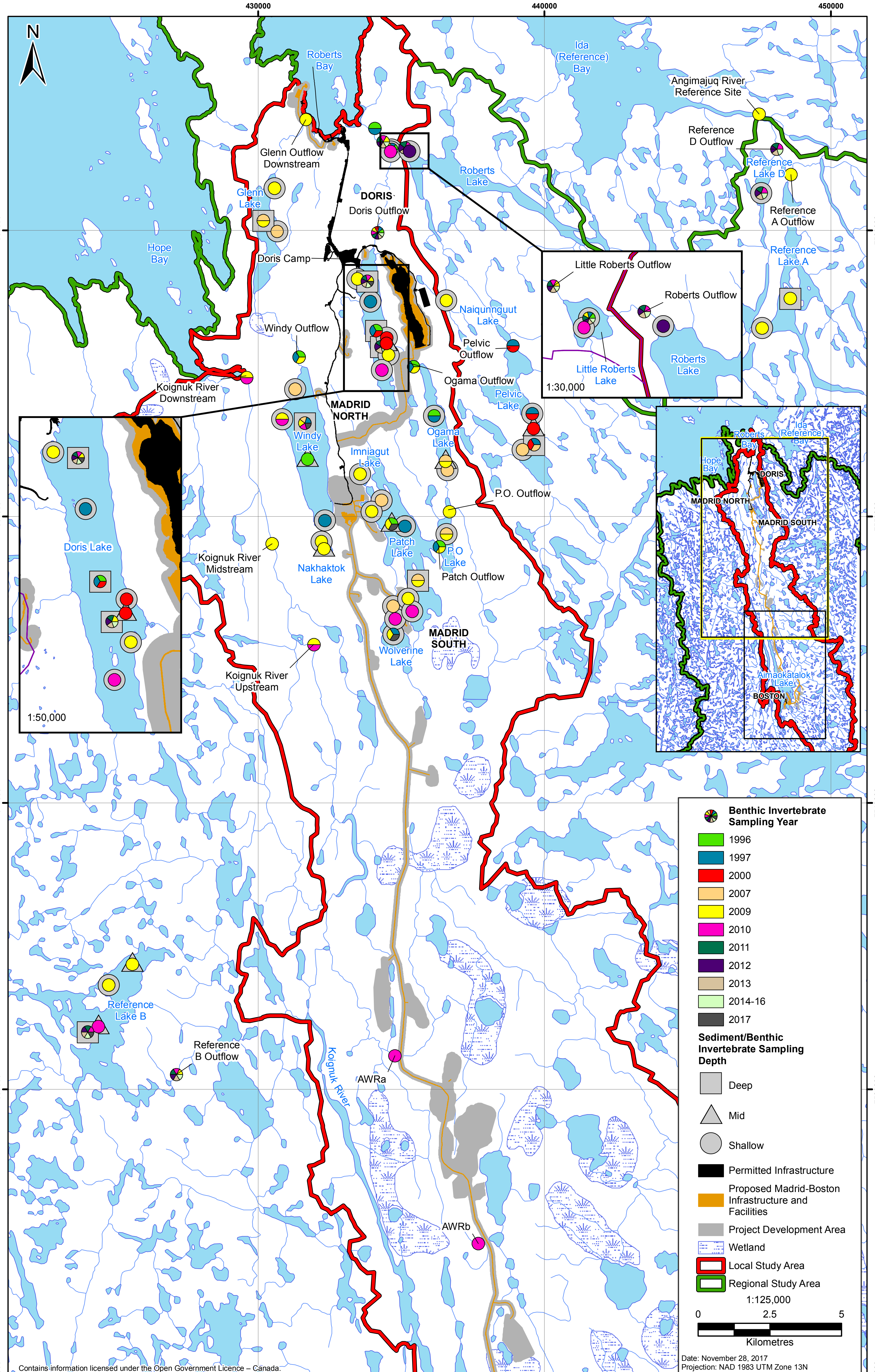


Figure 6.2-7
Freshwater Benthic Invertebrate Sampling Sites, South Belt, 1993-2017

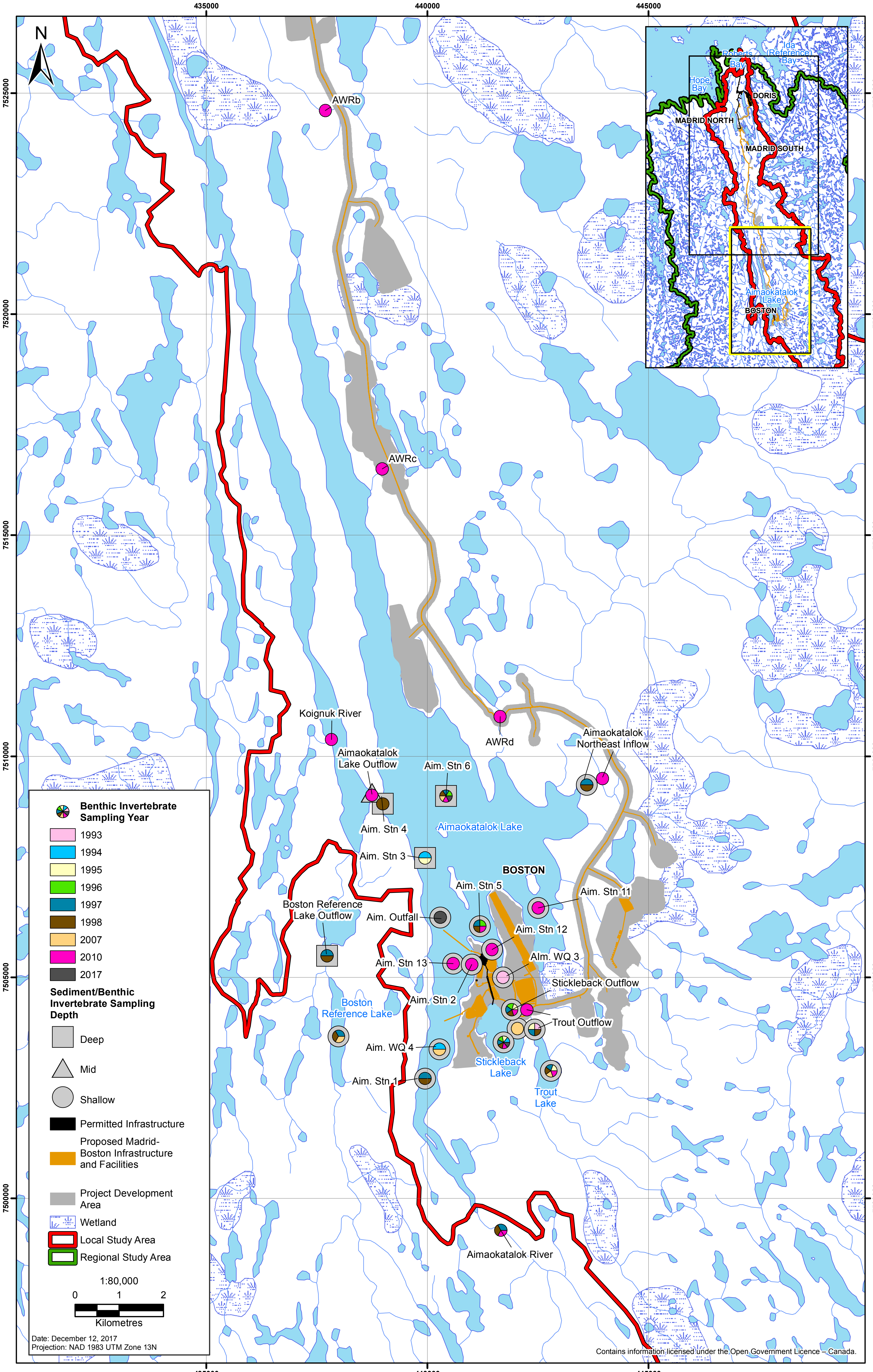


Table 6.2-3 presents a list of surveyed waterbodies by study area, watershed, type of waterbody (lake or pond), and survey method, and Table 6.2-4 presents a list of watercourses by study area, watershed, type of watercourse (stream or river), and survey method. Table 6.2-5 presents the number of surveyed waterbodies and watercourses by method, study area, and watershed. Figures 6.2-8 to 6.2-11 show the locations of all fish habitat surveys conducted from 1993 to 2017. Appendix V5-6Y lists each waterbody surveyed for fish habitat from 1993 to 2017 by sampling year including study area, waterbody name, survey method, and data source.

Tail Lake is not included in these tables and figures because it was reclassified as a tailings impoundment area under Schedule 2 of the MMER and was fished out and converted to the TIA in 2011. However, records for Tail Lake and Tail Outflow are retained in Appendix V5-6Y for historical completeness and to maximize the sample size of a regression of fish species richness on lake surface area (see Section 6.2.6.2).

The following sub-sections describe habitat survey methods in detail. Information collected by these methods was used to provide a general description of fish habitat in the Madrid-Boston Project LSA and RSA (Section 6.2.5.2). Detailed fish habitat data are not presented but are available for use as historical data to be compared with similar data that may be collected during construction, operations, and closure of the Madrid-Boston Project.

Aerial Surveys

Aerial surveys were used to describe general habitat features, confirm stream connectivity to upstream and/or downstream lakes and ponds, and to identify candidate streams for visual surveys and habitat assessments. A helicopter flew slow and low (about 100 m above the ground). GPS co-ordinates and photographs were taken, and notes were made on maps.

Aerial surveys of streams and lakes in the North and South LSA were conducted in six sampling years: 1995 (Klohn-Crippen Consultants Ltd. 1995; Rescan 1995), 1996 (Rescan 1997), 1997 (Rescan 1998), 2000 (Rescan 2001), 2006 (Golder 2007a; Golder Associates Ltd. 2008), and 2017 (ERM 2017d). The 1995 surveys covered the length of the Koignuk River. Those in 1996 surveyed inlet and outlet streams of Doris, Patch, Ogama, Windy, Aimaokatalok, Trout, and Stickleback lakes. These surveys were repeated in 1997. The surveys in 2000 covered Doris, Tail, and Little Roberts lakes, and the 2006 survey covered Little Roberts Lake. In 2017, aerial surveys were performed along the length of streams with proposed all-weather road crossing locations. A total of two lakes, 41 streams, and one river were surveyed by helicopter (Table 6.2-5).

Reconnaissance Surveys

Reconnaissance surveys were conducted by walking along a stream or slowly boating along the shoreline of a lake and taking notes on general features of the physical habitat such as stream width and depth, turbidity, dominant substrate types, and cover. Discrete habitat units were not delineated. Habitat quality was assigned based on professional judgement.

An early example of reconnaissance surveys is the descriptions of habitat of lakes and streams of the Doris Watershed and of the Koignuk River in 1996 by Klohn-Crippen Consultants Ltd. (1995). Later examples include the survey of 14 headwater lakes of the Roberts Watershed in 2006 (Golder 2007a) and a survey of habitat at six sites along the length of the lower Koignuk River in 2007 (Golder 2008b; Golder Associates Ltd. 2008). Reconnaissance surveys were conducted on a total of 26 lakes and seven streams (Table 6.2-5), with the majority of the surveyed lakes located in the RSA (21) compared to the LSA North (five) and the LSA South (zero).

Table 6.2-3. Lakes and Ponds Surveyed for Fish Habitat in the LSA and RSA, 1993 - 2017

Area	Waterbody	Watershed	Waterbody Type	Aerial Survey	Recon. Survey	Bathymetry	SLA	Habitat Assessment	Snorkel	Hydro-acoustics
LSA - North Belt	Doris Lake	Doris	Lake	X	X	X	-	X	-	X
LSA - North Belt	Imniagut Lake	Doris	Lake	-	-	X	-	X	-	-
LSA - North Belt	Ogama Lake	Doris	Lake	-	X	X	-	X	-	-
LSA - North Belt	P.O. Connector Lake	Doris	Lake	-	-	X	-	X	-	-
LSA - North Belt	P.O. Inflow Lake	Doris	Lake	-	-	-	-	X	-	-
LSA - North Belt	P.O. Lake	Doris	Lake	-	-	X	-	X	-	-
LSA - North Belt	Patch Lake	Doris	Lake	-	X	X	-	X	-	X
LSA - North Belt	Wolverine Lake	Doris	Lake	-	-	X	-	X	-	-
LSA - North Belt	Little Roberts Lake	Roberts	Lake	X	X	X	-	X	-	-
LSA - North Belt	Glenn Lake	Windy	Lake	-	-	-	-	X	-	-
LSA - North Belt	Nakhaktok Lake	Windy	Lake	-	-	-	-	X	-	-
LSA - North Belt	Windy Lake	Windy	Lake	-	X	X	-	X	X	-
LSA - North Belt	Pond 2	Roberts	Pond	-	-	-	-	X	-	-
LSA - North Belt	Ponds Q02, Q04	Doris	Pond	-	-	-	-	X	-	-
LSA - North Belt	Ponds Q20 to Q22	Doris	Pond	-	-	-	-	X	-	-
LSA - North Belt	Pond TAS 2	Doris	Pond	-	-	X	-	-	-	-
LSA - North Belt	Ponds Q05, Q06	Koignuk	Pond	-	-	-	-	X	-	-
LSA - North Belt	Ponds Q13 to Q16	Koignuk	Pond	-	-	-	-	X	-	-
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	-	-	X	-	X	-	X
LSA - South Belt	Stickleback Lake	Aimaokatalok	Lake	-	-	X	-	X	-	-
LSA - South Belt	Trout Lake	Aimaokatalok	Lake	-	-	X	-	X	-	-
LSA - South Belt	Boston Pond 1	Aimaokatalok	Pond	-	-	-	-	X	-	-
LSA - South Belt	Boston Pond 2	Aimaokatalok	Pond	-	-	-	-	X	-	-
LSA - South Belt	Boston Pond 3	Aimaokatalok	Pond	-	-	-	-	X	-	-
LSA - South Belt	Boston Pond 4	Aimaokatalok	Pond	-	-	-	-	X	-	-
LSA - South Belt	Ponds Q08, Q09	Aimaokatalok	Pond	-	-	-	-	X	-	-
LSA - South Belt	Pond Q10, Q11,Q23 to Q25	Aimaokatalok	Pond	-	-	-	-	X	-	-
RSA	Reference Lake A	Reference A	Lake	-	-	-	-	X	-	-
RSA	Reference Lake B	Reference B	Lake	-	-	X	-	X	-	-
RSA	Reference Lake D	Reference D	Lake	-	-	X	-	X	-	-

(continued)

Table 6.2-3. Lakes and Ponds Surveyed for Fish Habitat in the LSA and RSA, 1993 - 2017 (completed)

Area	Waterbody	Watershed	Waterbody Type	Aerial Survey	Recon. Survey	Bathymetry	SLA	Habitat Assessment	Snorkel	Hydro-acoustics
RSA	Lake 04	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 05	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 06	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 06a	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 06b	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 06c	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 06d	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 07	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 07a	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 09	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 10	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 12	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 13	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 14	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 31a	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 31b	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 32	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 32a	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 33	Roberts	Lake	-	X	-	X	-	-	-
RSA	Lake 35	Roberts	Lake	-	X	-	X	-	-	-
RSA	Pelvic Lake	Roberts	Lake	-	-	-	-	X	-	-
RSA	Roberts Lake	Roberts	Lake	-	X	X	-	X	-	X

SLA = Small Lake Area; estimation of surface area and maximum depth of small lakes

X = survey conducted; Dashes = no survey conducted

LSA = Local Study Area and RSA = Regional Study Area.

Table 6.2-4. Rivers and Streams Surveyed for Fish Habitat in the LSA and RSA, 1993 - 2017

Area	Watercourse	Watershed	Waterbody Type	Aerial Survey	Recon. Survey	Habitat Assessment	FHAP	Hydraulic Modelling	SHIM
LSA - North Belt	Koignuk River	Koignuk	River	X	X	X	X	-	-
LSA - North Belt	Stream AWR 10	Doris	Stream	-	-	X	-	-	-
LSA - North Belt	Doris Area N20 and N25	Doris	Stream	-	-	-	-	-	X
LSA - North Belt	Doris Inflow	Doris	Stream	X	X	-	X	-	-
LSA - North Belt	Doris Outflow	Doris	Stream	X	X	X	X	X	-
LSA - North Belt	Doris Stream N20	Doris	Stream	-	-	X	-	-	-
LSA - North Belt	Imniagut Outflow	Doris	Stream	X	-	-	X	-	-
LSA - North Belt	Ogama Inflow	Doris	Stream	X	X	X	X	X	-
LSA - North Belt	Ogama Outflow	Doris	Stream	X	X	X	X	X	-
LSA - North Belt	P.O. Inflows N15, N18, N24	Doris	Stream	X	-	-	X	-	X
LSA - North Belt	P.O. Outflow	Doris	Stream	-	-	-	X	-	-
LSA - North Belt	Patch Stream N10/N22	Doris	Stream	-	-	-	X	-	X
LSA - North Belt	Patch Inflow	Doris	Stream	X	-	-	X	-	-
LSA - North Belt	Patch North Inflows N21, N23	Doris	Stream	X	-	-	X	-	X
LSA - North Belt	Patch Outflow	Doris	Stream	X	-	-	X	X	-
LSA - North Belt	Doris Connector Vent Raise Road	Doris	Stream	-	-	-	X	-	-
LSA - North Belt	Wolverine Outflow	Doris	Stream	X	-	-	X	-	-
LSA - North Belt	Wolverine Outflow East	Doris	Stream	X	-	-	X	-	-
LSA - North Belt	All-weather Route Crossing 12	Koignuk	Stream	-	-	X	-	-	-
LSA - North Belt	Boulder Creek C01 (C-MBR-7)	Koignuk	Stream	X	-	X	X	-	-
LSA - North Belt	Boulder Creek PRC13 and PRC14	Koignuk	Stream	-	-	X	-	-	-
LSA - North Belt	Boulder Creek Tributary C02 (C-MBR-8)	Koignuk	Stream	X	-	X	X	-	-
LSA - North Belt	Boulder Creek Tributary PRC15	Koignuk	Stream	-	-	X	-	-	-
LSA - North Belt	Little Roberts Outflow	Roberts	Stream	X	-	X	X	X	-
LSA - North Belt	Streams AWR 2 and AWR 3	Roberts Bay	Stream	-	-	X	-	-	-
LSA - North Belt	Roberts Bay Inflow C-CDR-01	Roberts Bay	Stream	X	-	-	X	-	-
LSA - North Belt	Roberts Bay Inflow N01	Roberts Bay	Stream	-	-	-	X	-	-
LSA - North Belt	Roberts Bay Inflow N02	Roberts Bay	Stream	-	-	-	X	-	-
LSA - North Belt	Roberts Bay Discharge Access Road	Roberts Bay	Stream	-	-	-	X	-	-
LSA - North Belt	Glenn Inflow	Windy	Stream	-	-	-	X	-	-
LSA - North Belt	Glenn Outflow	Windy	Stream	X	-	X	X	-	-
LSA - North Belt	Windy Inflow	Windy	Stream	X	-	-	X	-	-
LSA - North Belt	Windy Outflow	Windy	Stream	X	-	X	X	-	-
LSA - South Belt	Aimaokatalok River	Aimaokatalok	River	X	-	X	X	-	-
LSA - South Belt	Aimaokatalok Inflow BP05/C-MBR-18	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflow BP07/C-MBR-10	Aimaokatalok	Stream	X	-	-	X	-	-

(continued)

Table 6.2-4. Rivers and Streams Surveyed for Fish Habitat in the LSA and RSA, 1993 - 2017 (completed)

Area	Watercourse	Watershed	Waterbody Type	Aerial Survey	Recon. Survey	Habitat Assessment	FHAP	Hydraulic Modelling	SHIM
LSA - South Belt	Aimaokatalok Inflow C03 (C-MBR-9)	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflow C-MBR-17	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflow S03 (C-MBR-11)	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflow S04/S05/C-MBR-12	Aimaokatalok	Stream	X	-	X	X	-	-
LSA - South Belt	Aimaokatalok Inflow S07 (C-MBR-13)	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflow S09 (C-MBR-14)	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflow S10/S11 (C-MBR-15)	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflow S16 (C-MBR-16)	Aimaokatalok	Stream	X	-	-	X	-	-
LSA - South Belt	Aimaokatalok Inflows BP08 to BP11	Aimaokatalok	Stream	X	-	-	-	-	-
LSA - South Belt	Aimaokatalok Outflow	Aimaokatalok	Stream	-	-	-	X	-	-
LSA - South Belt	Streams AWR 17, AWR 20, AWR 22	Aimaokatalok	Stream	-	-	X	-	-	-
LSA - South Belt	Boston Stream S33	Aimaokatalok	Stream	-	-	X	-	-	X
LSA - South Belt	Boston Streams S06, S12 to 15	Aimaokatalok	Stream	-	-	-	X	-	-
LSA - South Belt	Boston Streams S31, S32, S34, S35	Aimaokatalok	Stream	-	-	-	-	-	X
LSA - South Belt	Boston Streams S21, S23, S27	Aimaokatalok	Stream	-	-	-	X	-	X
LSA - South Belt	Boston Streams S22, S25,S26, S28, S30	Aimaokatalok	Stream	-	-	-	X	-	-
LSA - South Belt	Boston 1 Tailings Stream S22	Aimaokatalok	Stream	-	-	-	X	-	-
LSA - South Belt	Boston 1 East S24	Aimaokatalok	Stream	-	-	-	X	-	X
LSA - South Belt	Stickleback Inflows BP13 and BP14	Aimaokatalok	Stream	X	-	-	-	-	-
LSA - South Belt	Stickleback Outflow	Aimaokatalok	Stream	X	-	X	X	-	-
LSA - South Belt	Trout Inflow	Aimaokatalok	Stream	X	-	X	-	-	-
LSA - South Belt	Trout Outflow	Aimaokatalok	Stream	X	-	X	X	-	-
RSA	Angimajuq River Reference	Angimajuq	River	-	-	-	X	-	-
RSA	Reference A Outflow	Reference A	Stream	-	-	-	X	-	-
RSA	Reference B Outflow	Reference B	Stream	-	-	-	X	-	-
RSA	Reference D Outflow	Reference D	Stream	-	-	-	X	-	-
RSA	Roberts Inflow E06	Roberts	Stream	-	-	-	X	-	-
RSA	Roberts Inflow E09	Roberts	Stream	-	X	X	X	-	-
RSA	Roberts Inflow E13, E14, E31, E33, E36	Roberts	Stream			X	X		
RSA	Roberts Inflows E04, E07, E10, E11, E12, E15, E32, E36	Roberts	Stream	-	-	X	-	-	-
RSA	Roberts Outflow	Roberts	Stream	-	X	X	X	-	-

FHAP = Fish Habitat Assessment Procedure, SHIM = Sensitive Habitat Inventory Method

X = survey conducted; Dashes = no survey conducted

LSA = Local Study Area and RSA = Regional Study Area.

Table 6.2-5. Number of Waterbodies and Watercourses Surveyed for Fish Habitat in the LSA and RSA, 1993-2017

Survey Method	LSA - North Belt			LSA - South Belt			RSA			Total			Years
	Lake	Pond	Stream	Lake	Pond	Stream	Lake	Pond	Stream	Lake	Pond	Stream	
Aerial	2	0	22	0	0	20	0	0	0	2	0	42	1995-2017
Reconnaissance	5	0	5	0	0	0	21	0	2	26	0	7	1995-2014
Bathymetry	9	1	0	3	0	0	3	0	0	15	1	0	1993-2010
Small Lake Area	0	0	0	0	0	0	20	0	0	20	0	0	2006
Habitat Assessment	12	12	17	3	11	9	5	0	15	20	23	41	1995-2017
FHAP	0	0	29	0	0	29	0	0	12	0	0	70	2009-2017
Snorkel	1	0	0	0	0	0	0	0	0	1	0	0	2010-2014
Hydroacoustic	2	0	0	1	0	0	1	0	0	4	0	0	2009-2010
Hydraulic Modelling	0	0	5	0	0	0	0	0	0	0	0	5	2015-2017
SHIM	0	0	8	0	0	9	0	0	0	0	0	17	2010

FHAP = Fish Habitat Assessment Procedure and SHIM = Sensitive Habitat Inventory Mapping.

LSA = Local Study Area and RSA = Regional Study Area.

Figure 6.2-8
Freshwater Fish Habitat Surveys in Lakes and Ponds, North Belt, 1993-2017

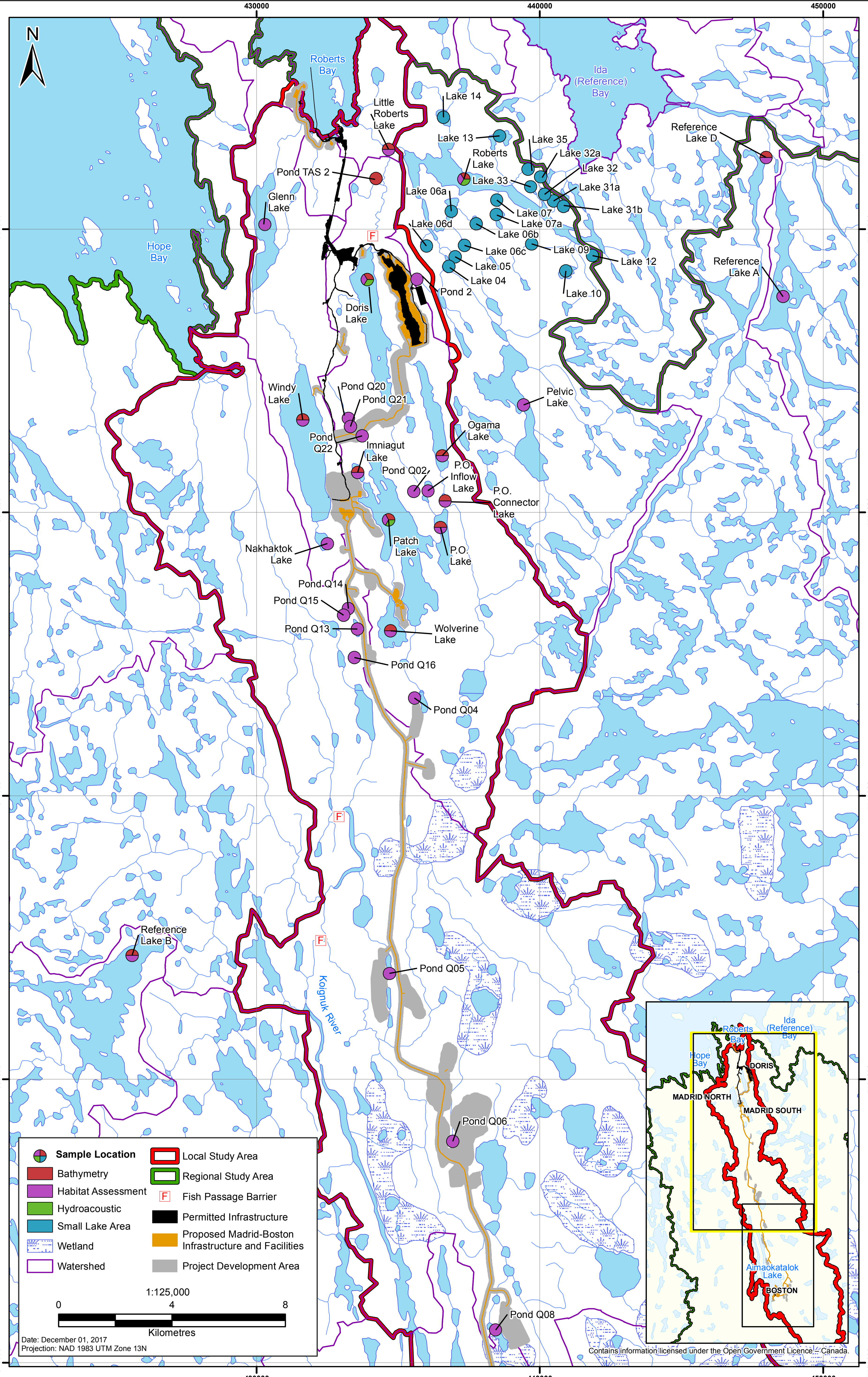


Figure 6.2-9
Freshwater Fish Habitat Surveys in Lakes and Ponds, South Belt, 1993-2017

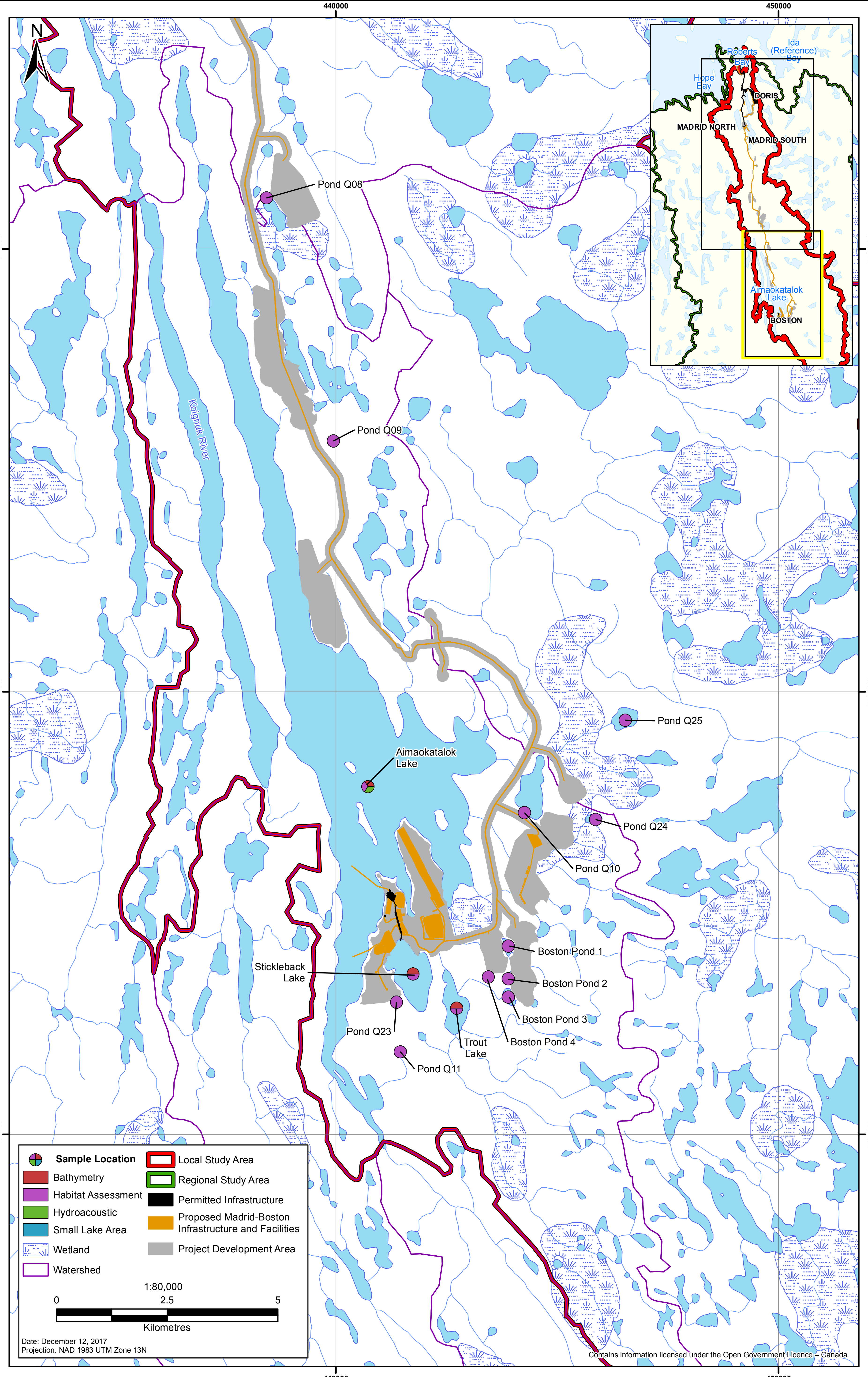


Figure 6.2-10
Freshwater Fish Habitats Surveys in Streams, North Belt, 1993-2017

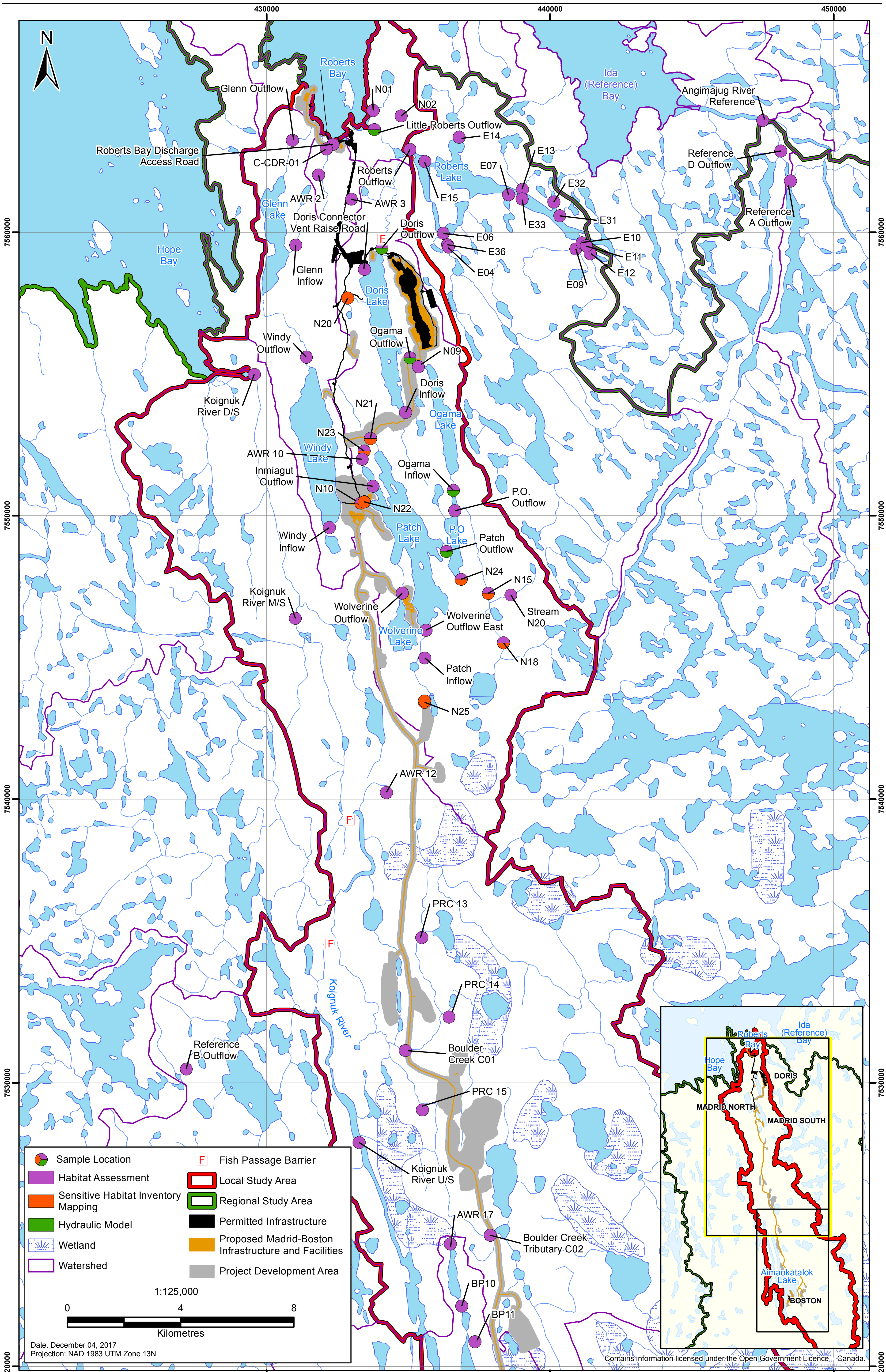
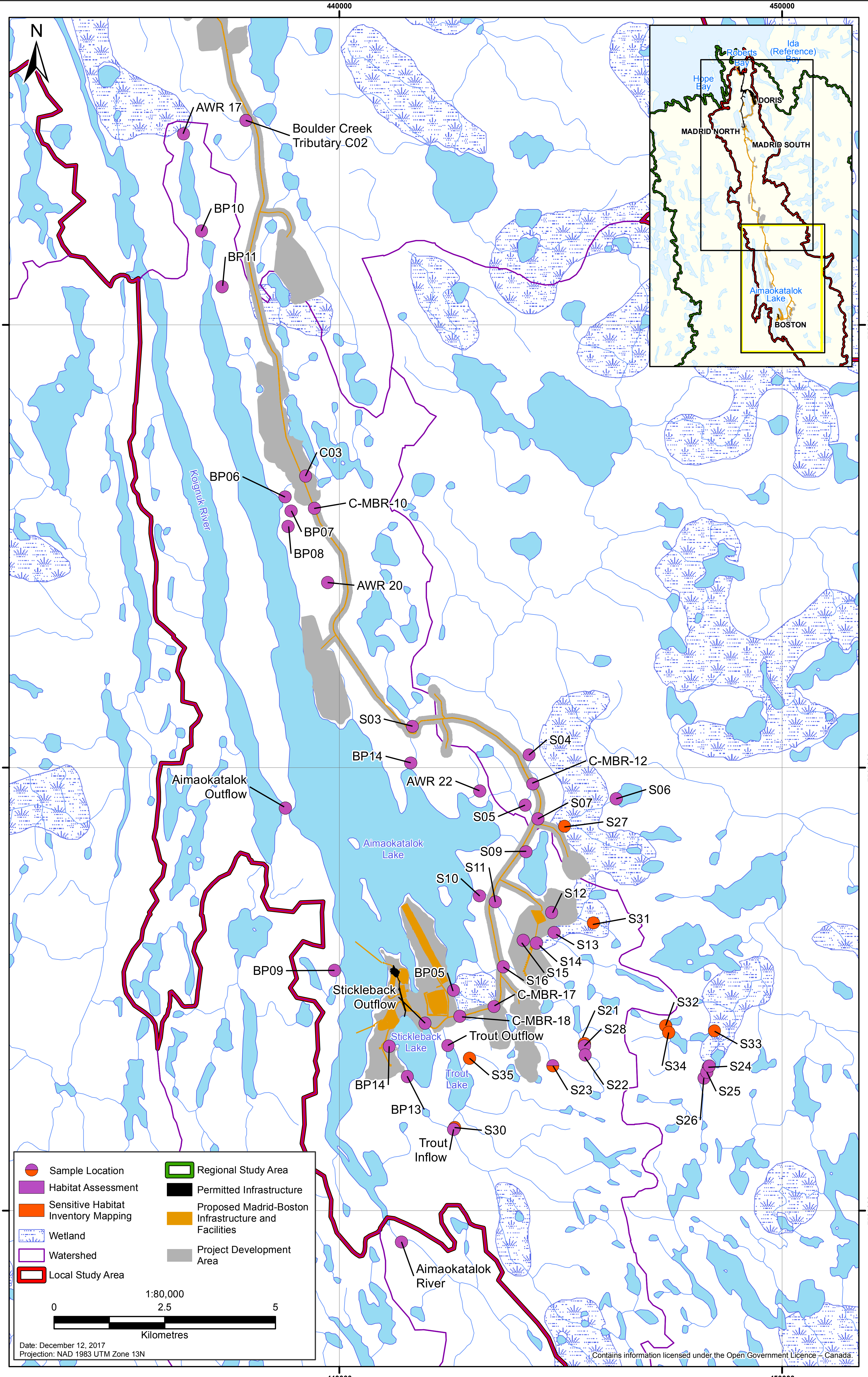


Figure 6.2-11
Freshwater Fish Habitat Surveys in Streams, South Belt, 1993-2017



Bathymetric Mapping

Bathymetric surveys were conducted in a total of 15 lakes and one pond (Table 6.2-5). Twelve lakes were surveyed in the LSA: nine in the North Belt (Little Roberts, Doris, Ogama, Patch, Wolverine, P.O., P.O. Connector, Imniagut, and Windy), three in the South Belt (Aimaokatalok, Trout, and Stickleback). Three lakes were surveyed in the RSA: Roberts, Reference B, and Reference D. The surveyed pond was located in the Doris watershed in the North Belt LSA. In some cases, surveys were completed a second time to increase accuracy or resolution of the survey using improved technology and techniques. Only results from the most recent surveys of each lake are presented in this EIS.

Volume 5, Chapter 3 (Limnology and Bathymetry) summarizes the methods and results of bathymetric mapping. Figures 3.2-3 and 3.2-4 show the locations of the surveyed lakes in the North LSA and RSA and the South LSA and RSA, respectively. Appendix V5-3A shows bathymetric maps for 14 of the surveyed lakes (does not include P.O. Connector Lake).

Estimation of Lake Surface Area and Maximum Depth

In 2006, surface areas were estimated from maps for 20 small headwater lakes of the Roberts Watershed (Golder 2007a; Table 6.2-5). Bathymetry was not directly measured; however, maximum depths of 18 of those lakes were estimated from spot depth measurements using hand-held lines.

Habitat Assessment of Streams and Shorelines of Lakes and Ponds

Habitat assessments were conducted by slowly boating along the shoreline of lakes and ponds or by walking along the length of a stream. Habitat units were delineated and their characteristics were described. Habitat unit characteristics were used to define habitat quality for fish as good, fair, poor, or none.

Habitat units of the littoral zones of lakes and ponds were delineated from the type of substrate. Substrates of both streams and lakes were classified as bedrock, boulder, cobble, gravel, and fines. Substrate size classes followed the modified Wentworth scale for particle size (< 2 mm = fines, 2 to 64 mm = gravel, 64 to 256 mm = cobble, > 256 mm = boulder). Substrate composition was recorded as a percent coverage (e.g., 70% cobble and 30% boulder) within delineated units. Patches of emergent and submergent vegetation were noted and recorded on a field map. Photographs were taken to illustrate various habitat types.

Habitat units of streams were identified based on habitat type (i.e., glide, pool, riffle and flat), gradient, width, water depth, substrate composition, and availability of cover. From 1995 to 2008, a classification and rating system was sometimes used to assign habitat quality to each unit (O'Neil and Hildebrand 1986; Golder 2008b). Photographs were taken to illustrate various habitat types. From 2009 to 2015, the Fish Habitat Assessment Procedure (FHAP) was used to survey instream habitat (Johnston and Slaney 1996). FHAP is the approved method for assessing stream fish habitat in British Columbia and is described in the following sub-section.

A total of 41 streams, 20 lakes, and 23 ponds were assessed for habitat quality from 1995 to 2017 (Table 6.2-5). Many waterbodies, particularly streams, were assessed multiple times because surveys were conducted at different sites within the waterbody.

Fish Habitat Assessment Procedure (FHAP)

FHAP was only applied to streams that have clearly defined channels. Survey lengths were divided into habitat units (pool, glide, riffle, and cascade) and assessed according to methods described by Johnston and Slaney (1996). FHAP was modified for use in Nunavut by excluding data specific to forested and montane areas. Within each habitat unit, the physical features (e.g., gradient, mean depth, mean width, substrate composition, water velocity, availability of cover for fish, potential barriers, bank stability, and bank height) were measured. Data were collected with a measuring tape, meter stick, clinometer (for gradient), and by visual inspection.

These data were used to evaluate the overall quality of fish habitat at sites within a stream. Fish habitat quality was evaluated for all fish life stages (e.g., spawning, rearing, adult feeding, migration, and overwintering) and categorized as none, poor, fair or good. These evaluations were used in combination with fish capture data to determine the fish-bearing status of a stream.

Some streams have no clearly defined channel, with water flowing among boulder gardens and terrestrial vegetation. In these circumstances, the stream was designated as a “non-classified drainage” and a description of the flow characteristics and potential fish habitat was provided. A detailed breakdown into different habitat types was not conducted. FHAP was used on a total of 70 streams: 29 in the LSA North, 29 in the LSA South and twelve in the RSA (Table 6.2-5).

Snorkel Surveys of Windy Lake Littoral Zone

Snorkel surveys were conducted at 18 sites along the littoral zone of Windy Lake in 2010, 2012, 2013 and 2014 (Rescan 2011b, 2012e; ERM 2014; ERM Rescan 2014c; Table 6.2-5). The purpose of the 2010 survey was a reconnaissance survey of substrate types. Six rock shoals were installed in April 2011 as compensation for the loss of fish habitat associated with the Doris Project in Tail Lake and Tail Lake Outflow, the site of the TIA. The shoals were intended to increase the quantity and quality of juvenile Lake Trout rearing habitat. The purpose of surveys in 2011, 2012, and 2013 was to monitor the use of compensatory shoal habitat by Lake Trout and compare it to Lake Trout use of reference sites.

Snorkel surveys were initiated by defining the two end points of a survey reach using a handheld GPS unit. A snorkel survey was only conducted when the horizontal visibility was greater than 3 m. Two snorkelers slowly swam in a zigzag pattern, adjacent to each other for 15 minutes. Snorkeler observations of habitat and fish were recorded on an underwater slate board and subsequently transcribed to a field notebook.

Hydroacoustic Assessment of Lake Littoral and Pelagic Substrate

Mobile hydroacoustic and underwater video equipment were used to identify and map the type of substrate in deep-water and littoral zones of Doris (2009), Patch (2009), and Aimaokatalok (2010) lakes (Table 6.2-5). This allowed a more accurate assessment of habitat quality and lake productive capacity than could be achieved by visual surveys of the littoral zone. Hydroacoustic methods were the only way to assess substrate type in Doris Lake because it is turbid compared to other lakes of the LSA North. Due to the large size of Aimaokatalok Lake, only two areas were surveyed using hydroacoustic methods: the Ore Deposit area, which is adjacent to the Boston deposit at the south end of the lake, and the Reference area, which is 2 km north of the Ore Deposit area. The Reference area was selected because it has a similar depth profile as the Ore Deposit area.

Hydraulic Modeling

In 2015 and 2017, hydraulic models were developed for five streams in the North Belt LSA (Doris Outflow, Little Roberts Outflow, Ogama Outflow, Ogama Inflow, and Patch Outflow; Table 6.2-5). To develop the models, streams were scouted in June of the survey year, during high freshet flows. Transect locations along the length of the channel were selected for water level surveys to contribute to calibration and validation of the hydraulic model. Water level surveys at the calibration transects were performed in June, July, and August. Stream discharge was measured on each water level survey date. In September, complete geometric surveys were performed along each stream using a total station. A Hydraulic Engineering Center, River Analysis System (HEC-RAS) hydraulic model was developed for each stream using the geometric survey data, then calibrated and verified using water level survey and discharge data. Complete model development methods and results are presented in Appendices V5-6R and V5-6V.

Sensitive Habitat Inventory Mapping (SHIM)

In 2010, all streams and wetlands located within areas that had been proposed as tailings, waste rock, and infrastructure footprints were ground-truthed and mapped and habitat was assessed using the Sensitive Habitat Inventory Mapping (SHIM) protocol described by (Mason and Knight 2001; Rescan 2011d). SHIM is used as a standard for watercourse and fish habitat mapping in British Columbia. These methods were adapted for streams found in Nunavut. SHIM is designed to ensure the collection and mapping of reliable, high quality, current, and spatially accurate information about fish habitats and watercourses.

The geographic coordinates of stream and wetland sampling sites were located with a DGPS unit. Moving in an upstream direction, streams were mapped, barriers were identified, and habitat assessments were conducted. The presence of falls greater than 2 m high, steep cascades, channel gradients greater than 30%, and locations where habitat becomes discontinuous or insufficient to support fish were identified as “end of fish use” points. The “end of fish use” for each stream was further confirmed with fish sampling.

Detailed fish habitat data was collected in the field at the same time as streams and wetlands were mapped. Spatial data was tied to fish habitat data collected in the field. Collection of habitat data followed a combination of the Reconnaissance (1:20,000) Fish and Fish Habitat Inventory: Standards and Procedures (RISC 2001) and the FHAP (Johnston and Slaney 1996). A total of 17 streams were surveyed using SHIM: eight in the LSA North and nine in the LSA South (Table 6.2-5).

6.2.5.3 Freshwater Fish Community

A total of 14 species of fish were captured in lakes and streams of the LSA and RSA from 1993 to 2017 (Table 6.2-6). Ten of the species captured reside in freshwater for all or part of their life history. Four additional species – Greenland Cod, Arctic Flounder, Starry Flounder, and Fourhorn Sculpin – live predominantly in marine or brackish waters and occasionally move up large rivers for short distances.

Table 6.2-6. Common and Scientific Names of Fish Species Captured in Freshwaters of the LSA and RSA, 1993-2017

Family	Common Name	Scientific Name	Code
Salmonidae	Arctic Char	*Salvelinus alpinus*	ARCH
	Lake Trout	*Salvelinus namaycush*	LKTR
	Lake Whitefish	*Coregonus clupeaformis*	LKWH
	Broad Whitefish	*Coregonus nasus*	BRWH
	Arctic Cisco	*Coregonus autumnalis*	ARCS
	Cisco[1]	*Coregonus artedi*	CISC
	Least Cisco	*Coregonus sardinella*	LSCS
	Arctic Grayling	*Thymallus arcticus*	ARGR
Gadidae	Greenland Cod	*Gadus ogas*	-
Gasterosteidae	Ninespine Stickleback	*Pungitius pungitius*	NNST
Lotidae	Burbot	*Lota lota*	BURB
Pleuronectidae	Arctic Flounder	*Liopsetta glacialis*	ARFL
	Starry Flounder	*Platichthys stellatus*	STFL

Family	Common Name	Scientific Name	Code
Cottidae	Slimy Sculpin	*Cottus cognatus*	SLCS
	Fourhorn Sculpin	*Triglopsis quadricornis*	FRSC

Sources:
Species codes were taken from Sawatzky et al. (2007) and Tyson et al. (2011)
Dashes = no species code
LSA = Local Study Area and RSA = Regional Study Area.
1: Formerly known as Lake Cisco (Nelson et al. 2004; Sawatzky et al. 2007).

Fish communities of lakes and streams of the LSA and RSA were sampled using eight methods, as follows:

- Backpack electrofishing in streams and along the shorelines of lakes;
- Minnow traps in streams and ponds and along the shorelines of lakes;
- Gillnets in lakes, ponds, and large streams/rivers;
- Angling in lakes and large streams;
- Beach seining on lake shorelines and in large streams/rivers;
- Fyke nets in lakes and large streams/rivers;
- Fish fence on Roberts Outflow and Little Roberts Outflow; and
- Hydroacoustic techniques to estimate number and density of fish in lakes.

Fish Community Survey Methods

Table 6.2-7 presents a list of surveyed waterbodies (i.e., lakes and ponds) by study area, watershed, type of waterbody, and fish community survey method, and Table 6.2-8 presents a list of surveyed watercourses (i.e., streams and rivers) by study area, watershed, type of waterbody, and fish community survey method. Table 6.2-9 presents the numbers of surveyed waterbodies by method, study area, and watershed. Figures 6.2-12 to 6.2-15 present the locations of fish community surveys conducted from 1993 to 2017. Appendix V5-6Y lists each waterbody surveyed for fish community from 1993 to 2017 by sampling year including study area, waterbody name, survey method, and data source. The following sections describe each of the eight fish community survey methods employed.

Tail Lake is not included in these tables and figures because it was reclassified as a tailings impoundment area under Schedule 2 of the MMER and was fished out and converted to the TIA in 2011. However, records for Tail Lake and Tail Outflow are retained in Appendix V5-6Y as described in Section 6.2.5.2.

Backpack Electrofishing

Backpack electrofishing was the most widely used fish sampling method and was used to collect fish in streams and lakes from 1993 to 2017. Stream electrofishing surveys employed reconnaissance and depletion methods. For reconnaissance surveys, the objective was to identify the fish species present and their relative abundance. (e.g., Rescan 1993, 1994; Rescan 1995). Hence, stop nets were not used to isolate the sampling area. The operator sampled in an upstream direction and the accompanying netter collected stunned fish with a dip net and placed them in a water-filled holding bucket. Recorded information at each site included UTM coordinates, date and time of sampling, length of channel sampled, sampling effort (seconds of electrofishing), and electrofisher settings. After processing for species, number, and biological information, fish were released live back into the area of capture.

Figure 6.2-12
Freshwater Fish Community Surveys in Lakes and Ponds, North Belt, 1993-2017

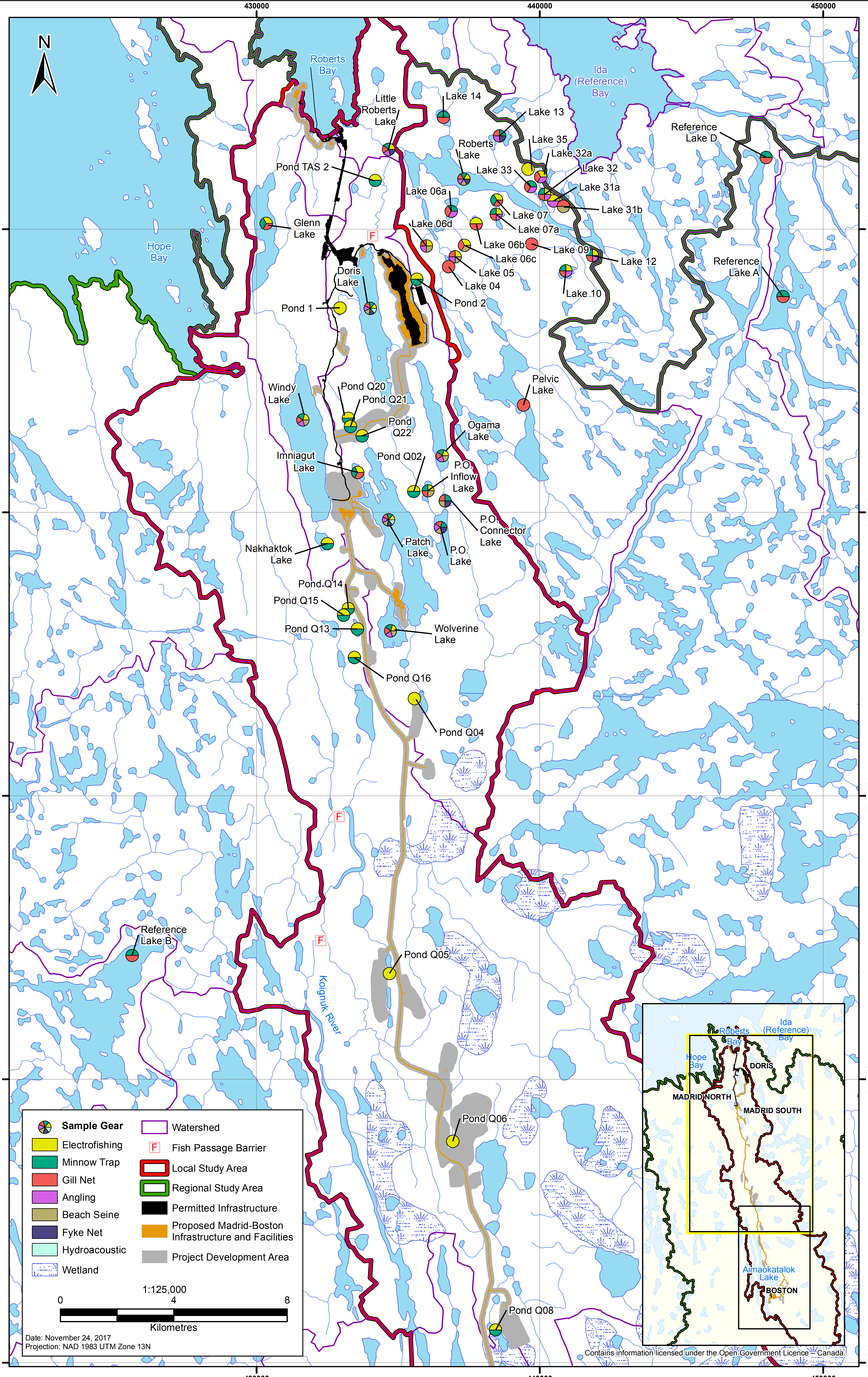


Figure 6.2-13

Freshwater Fish Community Surveys in Lakes and Ponds, South Belt, 1993-2017

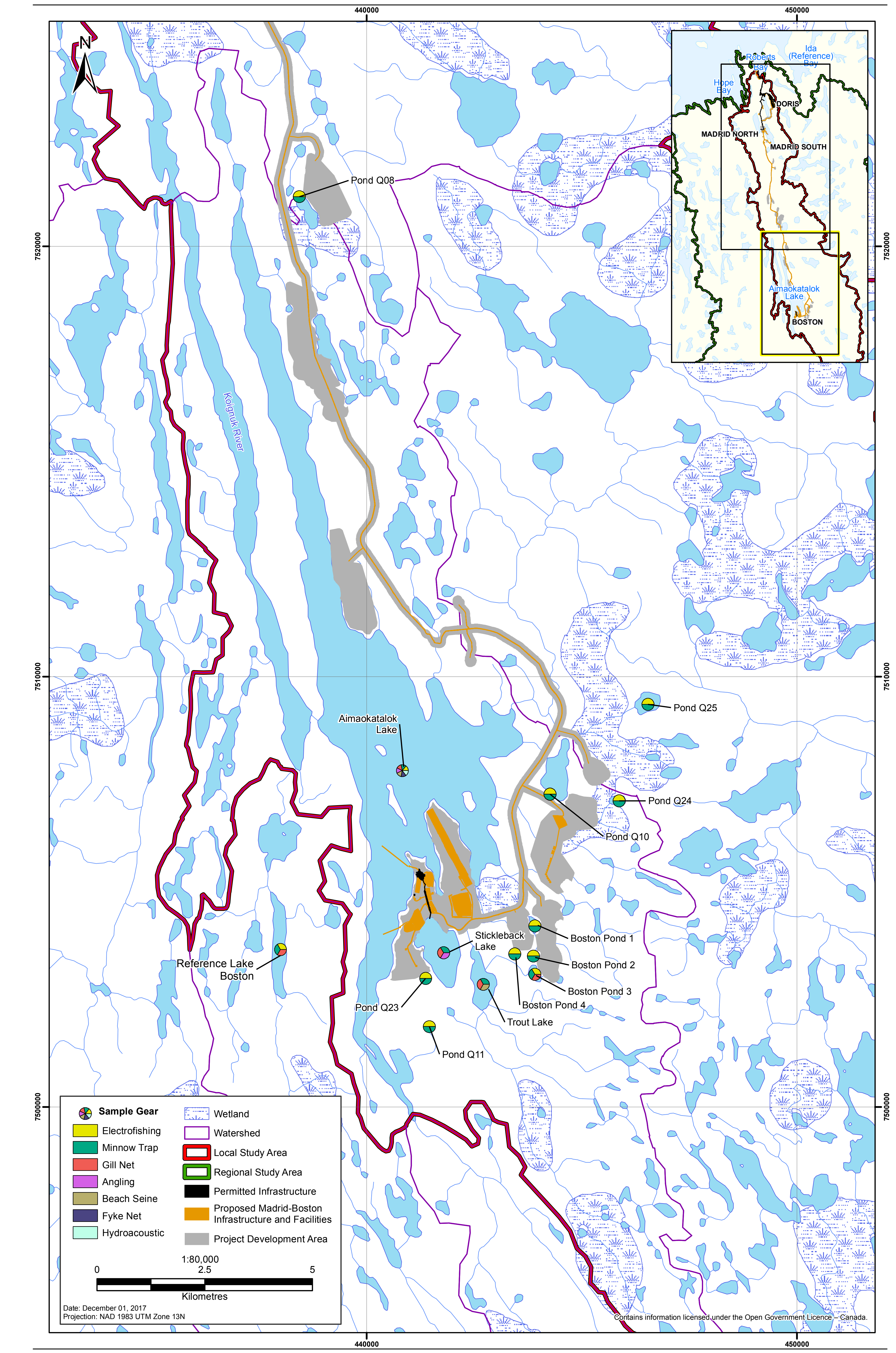


Figure 6.2-14
Freshwater Fish Community Surveys in Streams, North Belt, 1993-2017

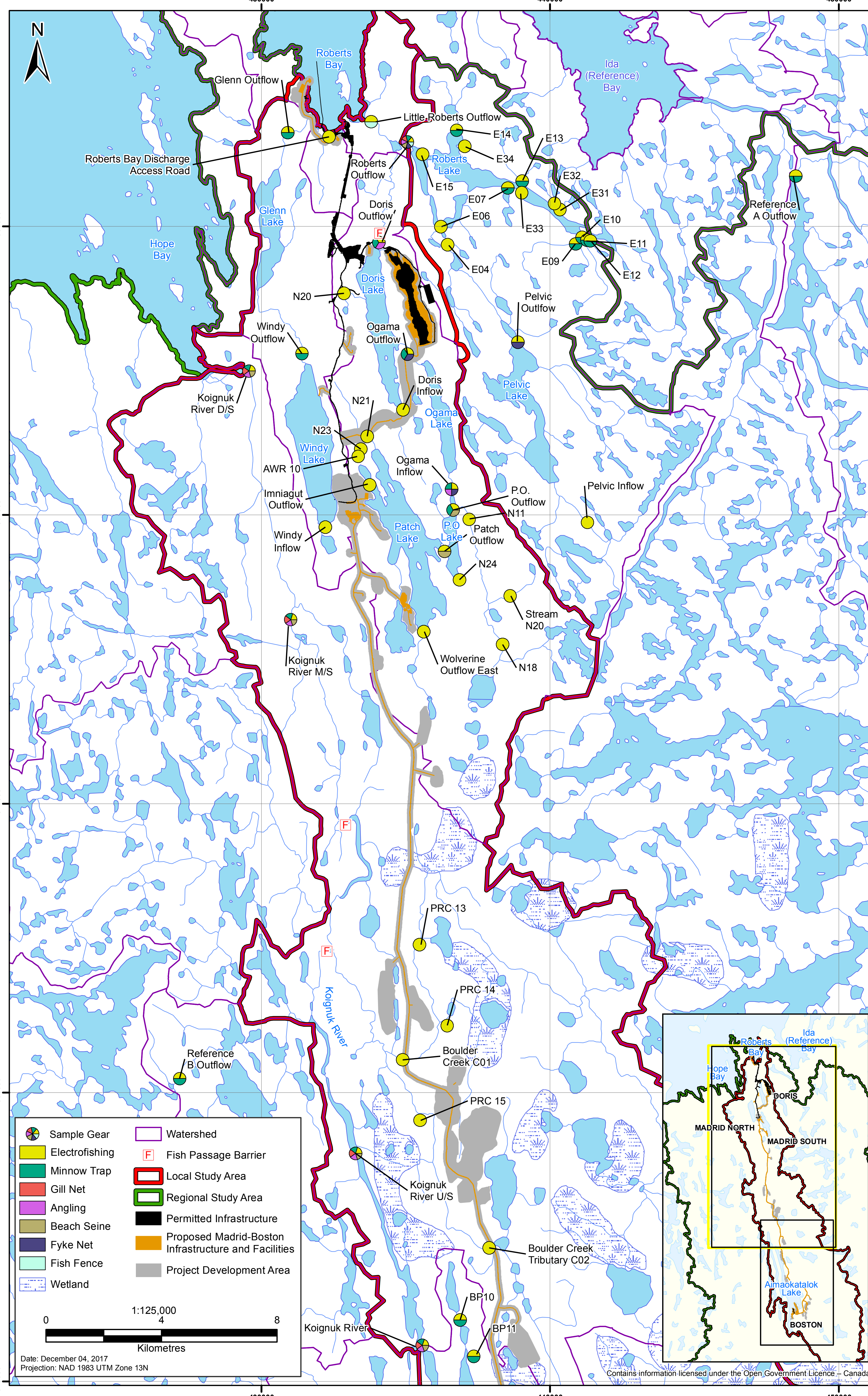


Figure 6.2-15
Freshwater Fish Community Surveys in Streams, South Belt, 1993-2017

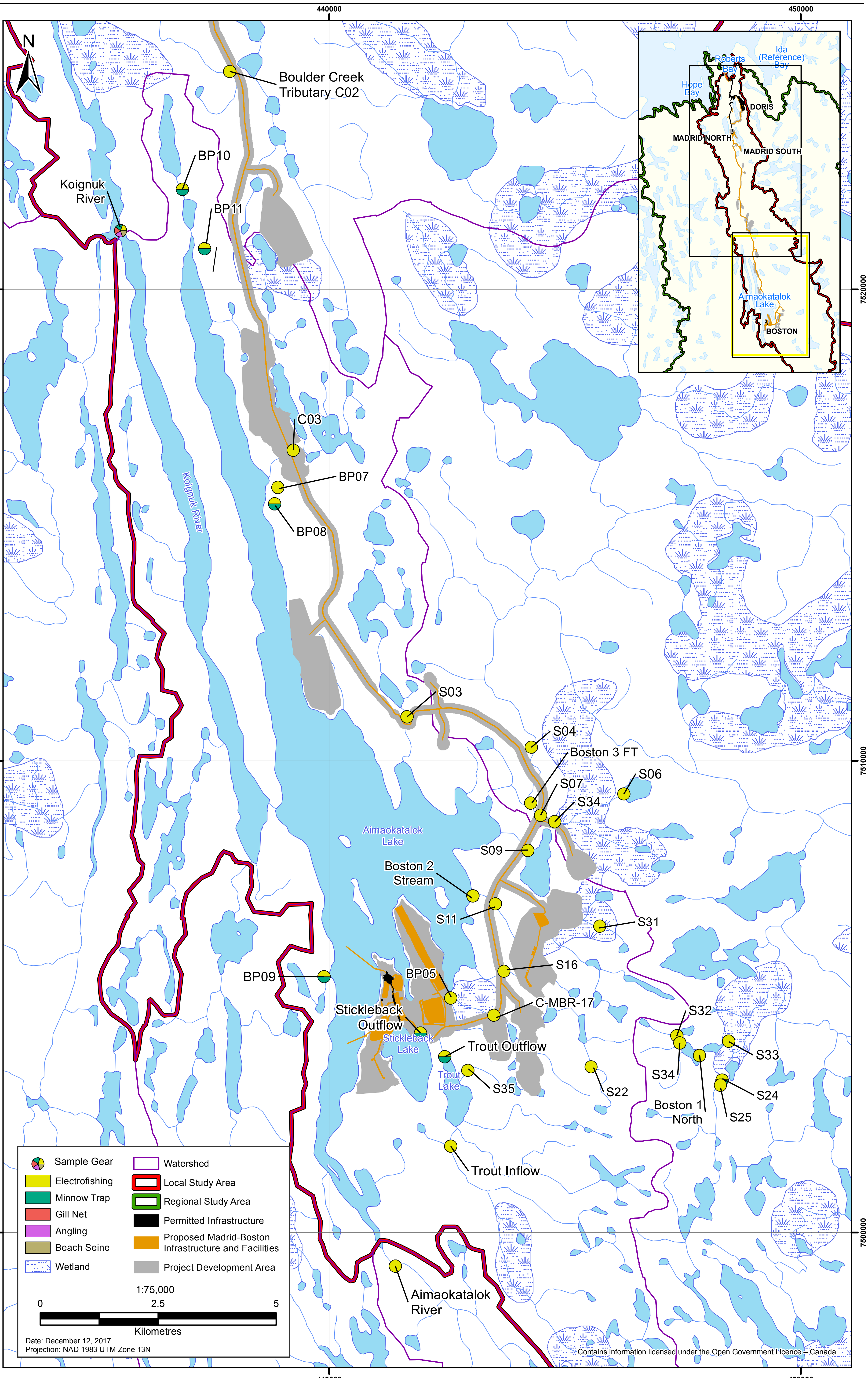


Table 6.2-7. Lakes and Ponds Surveyed for Fish Communities in the LSA and RSA, 1993-2017

Area	Waterbody	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Hydroacoustics
LSA - North Belt	Doris Lake	Doris	Lake	X	X	X	X	X	X	X
LSA - North Belt	Imniagut Lake	Doris	Lake	X	X	X	-	-	-	-
LSA - North Belt	Ogama Lake	Doris	Lake	X	X	X	X	X	-	-
LSA - North Belt	P.O. Connector Lake	Doris	Lake	-	X	X	-	X	X	-
LSA - North Belt	P.O. Inflow Lake	Doris	Lake	X	X	X	-	X	-	-
LSA - North Belt	P.O. Lake	Doris	Lake	-	X	X	X	X	X	-
LSA - North Belt	Patch Lake	Doris	Lake	X	X	X	X	X	X	X
LSA - North Belt	Wolverine Lake	Doris	Lake	X	X	X	X	X	-	-
LSA - North Belt	Little Roberts Lake	Roberts	Lake	X	X	X	X	-	X	-
LSA - North Belt	Glenn Lake	Windy	Lake	X	X	X	-	-	-	-
LSA - North Belt	Nakhaktok Lake	Windy	Lake	X	X	-	-	-	-	-
LSA - North Belt	Windy Lake	Windy	Lake	X	X	X	X	X	-	-
LSA - North Belt	Pond 1	Doris	Pond	X	-	-	-	-	-	-
LSA - North Belt	Pond Q04	Doris	Pond	X	-	-	-	-	-	-
LSA - North Belt	Ponds Q02, Q20 to Q22	Doris	Pond	X	X	-	-	-	-	-
LSA - North Belt	Pond TAS 2	Doris	Pond	X	X	-	-	-	-	-
LSA - North Belt	Pond Q13 to Q16	Koignuk	Pond	X	X	-	-	-	-	-
LSA - North Belt	Ponds Q05, Q06	Koignuk	Pond	X	-	-	-	-	-	-
LSA - North Belt	Pond 2	Roberts	Pond	X	X	-	-	-	-	-
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	X	X	X	X	X	X
LSA - South Belt	Stickleback Lake	Aimaokatalok	Lake	-	X	X	X	-	-	-
LSA - South Belt	Trout Lake	Aimaokatalok	Lake	-	X	X	-	X	-	-
LSA - South Belt	Boston Pond 1	Aimaokatalok	Pond	X	X	-	-	-	-	-
LSA - South Belt	Boston Pond 2	Aimaokatalok	Pond	X	X	-	-	-	-	-
LSA - South Belt	Boston Pond 3	Aimaokatalok	Pond	X	X	X	-	-	-	-
LSA - South Belt	Boston Pond 4	Aimaokatalok	Pond	X	X	-	-	-	-	-
LSA - South Belt	Pond Q10	Aimaokatalok	Pond	X	-	-	-	-	-	-
LSA - South Belt	Ponds Q08, Q11, Q23 to Q25	Aimaokatalok	Pond	X	X	-	-	-	-	-
RSA	Boston Reference Lake	Aimaokatalok	Lake	X	X	X	-	-	-	-
RSA	Reference Lake A	Reference A	Lake	-	X	X	-	-	-	-

(continued)

Table 6.2-7. Lakes and Ponds Surveyed for Fish Communities in the LSA and RSA, 1993-2017 (completed)

Area	Waterbody	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Hydroacoustics
RSA	Reference Lake B	Reference B	Lake	-	X	X	-	-	-	-
RSA	Reference Lake D	Reference D	Lake	-	X	X	-	-	-	-
RSA	Lake 04	Roberts	Lake	-	-	X	-	-	-	-
RSA	Lake 05	Roberts	Lake	X	-	X	X	X	-	-
RSA	Lake 06a	Roberts	Lake	-	X	X	X	-	-	-
RSA	Lake 06b	Roberts	Lake	X	-	X	-	-	-	-
RSA	Lake 06c	Roberts	Lake	X	-	X	-	X	-	-
RSA	Lake 06d	Roberts	Lake	X	-	X	X	X	-	-
RSA	Lake 07	Roberts	Lake	X	X	X	-	-	-	-
RSA	Lake 07a	Roberts	Lake	X	X	X	X	-	-	-
RSA	Lake 09	Roberts	Lake	-	-	X	-	-	-	-
RSA	Lake 10	Roberts	Lake	X	X	X	X	-	-	-
RSA	Lake 12	Roberts	Lake	X	X	X	X	-	-	-
RSA	Lake 13	Roberts	Lake	-	X	X	X	-	X	-
RSA	Lake 14	Roberts	Lake	-	X	X	-	-	-	-
RSA	Lake 31a	Roberts	Lake	X	-	-	X	-	-	-
RSA	Lake 31b	Roberts	Lake	-	-	X	-	X	-	-
RSA	Lake 32	Roberts	Lake	X	X	X	X	-	-	-
RSA	Lake 32a	Roberts	Lake	X	-	X	X	-	-	-
RSA	Lake 33	Roberts	Lake	-	X	X	X	-	-	-
RSA	Lake 35	Roberts	Lake	X	-	-	-	-	-	-
RSA	Pelvic Lake	Roberts	Lake	-	-	X	-	-	-	-
RSA	Roberts Lake	Roberts	Lake	X	X	X	X	X	X	-

X = survey conducted. Dashes = no surveys were conducted.

LSA = Local Study Area and RSA = Regional Study Area.

Table 6.2-8. Rivers and Streams Surveyed for Fish Communities in the LSA and RSA, 1993-2017

Area	Watercourse	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Fish Fence
LSA - North Belt	Koignuk River	Koignuk	River	X	X	X	X	X	-	-
LSA - North Belt	Doris Area N20	Doris	Stream	X	-	-	-	-	-	-
LSA - North Belt	Doris Inflow	Doris	Stream	X	-	-	-	-	-	-
LSA - North Belt	Doris Outflow	Doris	Stream	X	X	-	X	-	-	-
LSA - North Belt	Doris Stream N20	Doris	Stream	X	-	-	-	-	-	
LSA - North Belt	Imniagut Outflow	Doris	Stream	X	-	-	-	-	-	-
LSA - North Belt	Ogama Inflow	Doris	Stream	X	X	-	X	-	X	-
LSA - North Belt	Ogama Outflow	Doris	Stream	X	X	-	-	-	X	-
LSA - North Belt	P.O. Inflow N11	Doris	Stream	X	-	-	-	-	-	-
LSA - North Belt	P.O. Outflow	Doris	Stream	X	X	-	-	X	-	-
LSA - North Belt	Patch North Inflow N21	Doris	Stream	X	-	-	-	-	-	-
LSA - North Belt	Patch Outflow	Doris	Stream	X	-	-	-	X	-	-
LSA - North Belt	Wolverine Outflow East	Doris	Stream	X	-	-	-	-	-	-
LSA - North Belt	Boulder Creek C01 (C-MBR-7)	Koignuk	Stream	X	-	-	-	-	-	-
LSA - North Belt	Boulder Creek PRC 13 and PRC 14	Koignuk	Stream	X	-	-	-	-	-	-
LSA - North Belt	Boulder Creek Tributary C02 (C-MBR-8)	Koignuk	Stream	X	-	-	-	-	-	-
LSA - North Belt	Boulder Creek Tributary PRC 15	Koignuk	Stream	X	-	-	-	-	-	-
LSA - North Belt	Little Roberts Outflow	Roberts	Stream	X	-	-	-	-	-	X
LSA - North Belt	Roberts Bay Discharge Access Road	Roberts Bay	Stream	X	-	-	-	-	-	-
LSA - North Belt	Glenn Outflow	Windy	Stream	X	X	-	-	-	-	-
LSA - North Belt	Windy Inflow	Windy	Stream	X	-	-	-	-	-	-
LSA - North Belt	Windy Outflow	Windy	Stream	X	X	-	-	-	-	-
LSA - South Belt	Aimaokatalok River	Aimaokatalok	River	X	-	-	-	-	-	-
LSA - South Belt	Koignuk River	Koignuk	River	X	X	X	X	X	-	-
LSA - South Belt	Aimaokatalok Inflow BP05	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Aimaokatalok Inflow BP07	Aimaokatalok	Stream	X	-	-	-	-	-	
LSA - South Belt	Aimaokatalok Inflow C03 (C-MBR-9)	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Aimaokatalok Inflow C-MBR-17	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Aimaokatalok Inflow S03 (C-MBR-11)	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Aimaokatalok Inflow S04	Aimaokatalok	Stream	X	X	-	-	-	-	-
LSA - South Belt	Aimaokatalok Inflow S10/S11 (C-MBR-15)	Aimaokatalok	Stream	X	-	-	-	-	-	-

(continued)

Table 6.2-8. Rivers and Streams Surveyed for Fish Communities in the LSA and RSA, 1993-2017 (completed)

Area	Watercourse	Watershed	Waterbody Type	Backpack Electrofisher	Minnow Trap	Gillnet	Angling	Beach Seine	Fyke Net	Fish Fence
LSA - South Belt	Aimaokatalok Inflow S16 (C-MBR-16)	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Aimaokatalok Inflows BP08 to BP11	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Boston Stream S33	Aimaokatalok	Stream	X	X	-	-	-	-	-
LSA - South Belt	Boston Streams S31, S32, S34	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Boston Stream S25	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Boston 1 Tailings Stream S22	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Boston 1 East S24	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Boston 1 North	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Boston 2 Stream	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Boston 3 FT	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Stickleback Outflow	Aimaokatalok	Stream	X	X	-	-	-	-	-
LSA - South Belt	Trout Inflow	Aimaokatalok	Stream	X	-	-	-	-	-	-
LSA - South Belt	Trout Outflow	Aimaokatalok	Stream	X	X	-	-	-	-	-
RSA	Pelvic Inflow	Roberts	Stream	X	-	-	-	-	-	-
RSA	Pelvic Outflow	Roberts	Stream	X	-	-	-	-	X	-
RSA	Reference A Outflow	Reference A	Stream	X	X	-	-	-	-	-
RSA	Reference B Outflow	Reference B	Stream	X	X	-	-	-	-	-
RSA	Roberts Inflow E04, E06, E10, E15	Roberts	Stream	X	-	-	-	-	-	-
RSA	Roberts Inflow E07, E09, E11 to E14	Roberts	Stream	X	X	-	-	-	-	-
RSA	Roberts Inflow E31 to E34	Roberts	Stream	X	-	-	-	-	-	-
RSA	Roberts Outflow	Roberts	Stream	X	X	X	X	X	X	X

X = survey conducted. Dashes = no surveys were conducted.

LSA = Local Study Area and RSA = Regional Study Area.

Table 6.2-9. Number of Waterbodies and Watercourses Surveyed for Fish Communities in the LSA and RSA, 1993-2017

	LSA - North Belt			LSA - South Belt			RSA			Total			
Method	**Lake**	**Pond**	**Stream**	**Lake**	**Pond**	**Stream**	**Lake**	**Pond**	**Stream**	**Lake**	**Pond**	**Stream**	**Years**
Electrofisher	10	14	23	1	10	27	14	0	19	25	24	69	1993-2017
Minnow trap	12	10	7	3	9	5	14	0	9	29	19	21	1994-2017
Gillnet	11	0	1	3	1	1	23	0	1	37	1	3	1993-2017
Angling	7	0	3	2	0	1	12	0	1	21	0	5	1995-2017
Beach seine	8	0	3	2	0	1	5	0	1	15	0	5	1996-2008
Fyke net	5	0	2	1	0	0	2	0	2	8	0	4	2002-2012
Fence	0	0	1	0	0	0	0	0	1	0	0	2	2002-2015
Hydroacoustic	2	0	0	1	0	0	0	0	0	3	0	0	2009-2015

LSA = Local Study Area and RSA = Regional Study Area.

The objective of the depletion method was to determine the species composition of the fish community and to estimate the number and density of each species (number/m^2; e.g., Golder 2007a; Rescan 2011d). Small-mesh stop nets were placed at both ends of a stream survey reach, and the electrofishing team waded from the downstream to the upstream end collecting fish and recording fishing effort (i.e., number of electrofishing seconds). Then, the fish were identified to species, enumerated and processed for biological information, but were not released. Instead, they were held live in water-filled buckets. Up to three additional passes were conducted with fish processing between passes to achieve adequate depletion to estimate fish populations. Then stop nets were removed and all fish were released live to the stream. The decline in fish captures between consecutive passes was used to estimate the total number of fish in the survey area. Dividing the estimated total number of fish by the area of the survey (based on stream length and mean width) provided fish density.

Electrofishing surveys of lakes were conducted in shallow water (< 1 m depth) along the shoreline of lakes where habitat characteristics allowed for wading. Electrofishing was not possible in boulder habitat for safety reasons. A total of 118 waterbodies were surveyed with backpack electrofishers: 69 streams, 25 lakes, and 24 ponds (Table 6.2-9). The number of sampling sites/events was greater than the total number of waterbodies because many streams and lakes were surveyed multiple times at different sites.

Minnow Traps

Minnow traps were used to collect small-bodied fish in lakes and streams from 1994 to 2017. Each trap consisted of two wire mesh cylinders that were locked together using a clip attached to a rope and marker buoy. Mesh size was 3.2 mm. Each end had a small opening for fish to enter. Each minnow trap was baited with a small amount of dry crab bait or another type of commercial bait. Minnow traps were placed on the streambed or along the shore of lakes or ponds in shallow water, usually less than 2 m deep, and allowed to fish for up to 24 hours. Recorded information at each site included UTM coordinates, the number of traps, and the date and time of installation and retrieval.

Minnow traps were installed in a total of 69 waterbodies: 21 streams, 29 lakes, and 19 ponds (Table 6.2-9). The number of installed traps was greater than the total number of sampled waterbodies because clusters of traps were installed in streams and lakes at multiple times at different sites.

Gillnets

Gillnets were used for sampling large-bodied fish in lakes and large streams/rivers. For all gillnetting efforts from 1993 to 2017, information recorded for each gillnet set included UTM coordinates, date and time of set and lift, and water depth. A variety of gillnet gang, panel, and mesh sizes were used from 1993 to 2017. The following summarizes the diversity of gillnets used through the 25 year long sampling period.

Gillnets were used in 1993 and 1994, but the panel and mesh sizes were not reported (Rescan 1993, 1994). In 1995, three-panel gillnets were used with each panel being 15.3 m long and 2.4 m deep with mesh sizes of 3.8 cm, 6.4 cm, and 8.9 cm stretched mesh (Rescan 1995). Gillnets were set at the surface or they were weighted so they sat at the lake bottom.

In 2003, gillnet gangs were comprised of either single panels, and/or variable mesh size experimental gill nets (RL&L/Golder 2003). Each panel was 1.5 m deep by 15.2 m long. Sinking nets with mesh sizes ranging from 1.9 to 10.2 cm were used. The 1.9 cm mesh nets were used most frequently in Roberts, Little Roberts, and Doris lakes to target small fish.

In 2008, variable mesh experimental gill nets were employed to sample large-bodied fish (Golder Associates Ltd. 2009). Each experimental gill net was composed of three panels measuring 15.2 by 1.8 m each. Mesh sizes were 3.81, 5.08, and 6.35 cm. Set times were limited to between one and three hours to minimize capture related mortalities. In 2010,2011, 2014, and 2017 lakes were sampled using monofilament index gillnet gangs consisting of six panels, ranging from 25 to 89 mm stretched mesh (Rescan 2011d). Each gillnet gang was tied in the following order: Panel 1 – 25 mm; Panel 2 – 76 mm; Panel 3 – 51 mm; Panel 4 – 89 mm; Panel 5 – 38 mm; and Panel 6 – 64 mm. Each panel measured 15.2 m long by 2.4 m deep for an area of 36.48 m^2 and a total area of 218.88 m^2 per gang. All gillnets had a lead line at the bottom and a floating line at the top of the net. Both floating and sinking nets were used.

Gillnets were set in a total of 41 waterbodies: 37 lakes, one pond, and three large streams/ rivers (Table 6.2-9). The three sampled streams were the Koignuk River, Roberts Outflow, and Little Roberts Outflow.

Angling

Angling was used to capture large-bodied fish in lakes and streams from 1995 to 2017. It was conducted by casting from shore or from a boat, and barbless lures were used to reduce mortality. Recorded data included UTM coordinates, date and time of capture, hours fished, and the number of rods that were used. A total of 26 waterbodies were angled: 21 lakes and five large streams (Table 6.2-9).

Beach Seining

Beach seining was used to capture small-bodied fish in shallow areas of lakes and streams from 1996 to 2008. Sandy beaches were the most suitable habitat for beach seining. The net was 9 m long, with a mesh size of 6 mm, and was equipped with a central collection bag (i.e., the bunt) with a mesh size of 3 mm. One end of the net was fixed to the shoreline and the other end was quickly swung around with a small boat or on foot to enclose a volume of nearshore habitat. The whole net was then pulled ashore and the catch was removed from the bunt. Information collected included UTM co-ordinates, date, time, water temperature, substrate type, and the length and effective width of each haul (to determine CPUE). Beach seines were used in a total of 20 waterbodies: 15 lakes and five large streams (Table 6.2-9).

Fyke Nets

Fyke nets are used to capture fish moving along lake shores and migrating up or down streams. They were used in the LSA and RSA from 2002 to 2012. In lakes, fyke net sets were placed approximately 30 m off shore. Each fyke net consisted of a single trap net with two 7.6 m wings and a 7.6 m lead to shore. The trap was 0.9 m long and 0.9 m wide, contained two throats (7.5 × 7.5 cm each), and was constructed of 1.0 cm dark grey knotless nylon mesh. Wings and lead were also constructed of 1.0 cm dark grey knotless nylon and were 0.9 m deep. The lead panel was set perpendicular from shore and bisected the trap entrance. Wing net panels were attached to either side of the trap entrance and were stretched out parallel to shore. The combination of the lead panel and wings acted to confine and guide fish into the trap. Fyke nets were held in place by metal stakes driven into the lake bottom. In streams, the fyke net was set up with two wings that stretched from the trap to shore. No centre lead was used. This arrangement blocked off the entire stream channel and funneled all migrants into the trap.

Information collected from fyke net sampling included UTM co-ordinates, water temperatures, and the dates and times at which the trap was opened and fish were retrieved for collection of biological information. After processing, fish were released back to their lake or stream in the direction of travel.

Fyke nets were installed in a total of twelve waterbodies: eight lakes and four streams (Table 6.2-9). They were used in five lakes in the LSA North (Doris, Little Roberts, Patch, P.O. Connector, and P.O.), two lakes in the RSA (Roberts and Lake 15), and Aimaokatalok Lake in the LSA South. The four streams were Roberts Outflow and Pelvic Outflow in the RSA and Ogama Inflow and Ogama Outflow of the LSA North.

Fish Fence

Two fish fences were installed annually in Roberts Outflow during the ice-free season from 2002 to 2015 (and for two years in Little Roberts Outflow) as part of the Doris fish habitat compensation program. Objectives and methods of the fence changed over those 13 years, as summarized by ERM (2016c).

From 2002 to 2005, the two objectives of the fences were, first, to monitor the August-September migration of adult Arctic Char returning from the ocean to spawn and overwinter in Roberts Lake, and, second, to measure the mortality of char as they migrated through a boulder garden between the two fences. In 2006 and 2007, the location of the fence study was moved to Little Roberts Outflow and the objective changed to monitor the June-July migration of Arctic char smolts from Roberts Lake to the sea using only one fence.

The two fences were re-installed in Roberts Outflow in 2010. From 2010 to 2015, the objective of the fence study was to monitor both the upstream migration of adults and the downstream migration of smolts. In 2013, the traps, which were previously manually operated, were replaced by an automated counting system – the Vaki Riverwatcher system. This avoided encounters between fish biologists and Grizzly Bears that fed on the Arctic Char migration. From 2002 to 2012, the traps of the fish fence were checked daily to monitor movement patterns of fish. During each daily check of the fence, the date, time of day and water temperature were recorded and fish were removed from the traps, processed for biological information, and released in their direction of movement. From 2013 to 2015, much of that information was collected remotely.

Hydroacoustics

Mobile hydroacoustics were used to measure fish number (with 95% confidence intervals), fish density (fish/m^3), and spatial distribution of fish species in Doris (2009 and 2015), Patch (2009), and Aimaokatalok (2010) lakes (Rescan 2010a, 2011d; ERM 2016a). Survey methods generally followed protocols for the sampling of fish populations with hydroacoustics described in Thorne (1983), Brandt (1996), and MacLennan and Simmonds (1992). Hydroacoustic estimates of fish number were assigned to species using relative proportions of species captured in gillnet sampling performed before or after the hydroacoustic survey.

<u>Fish Processing Methods</u>

Biological Information

All captured fish were identified to species, and most were measured for fork length to the nearest 1 mm and for weight to the nearest 0.1 g. When catch was high a representative sample of the catch was measured for length and weight to minimize fish holding and handling times. The incidence of parasites or deformities, erosion, lesions, or tumors (DELTs) was recorded. Fish, except incidental mortalities and those sacrificed for biological or tissue sampling, were released live back to the waterbody from which they were caught.

Many fish were sampled for ageing structures such as scales, fin rays, and otoliths. Scales were collected with a knife below the posterior margin of the dorsal fin on the left side of the fish. Two to three rays of the left pelvic fin were collected with scissors or pliers. Otoliths (i.e., ear bones) were only collected from incidental mortalities or from fish lethally sampled for tissues.

Age was estimated by aging specialists/laboratories by counting the number of annuli (or yearly rings) in each structure. Scales were attached to plastic fiches and annuli were counted with a microfiche reader. Fin rays were air-dried and then mounted in a 50:50 epoxy medium. Microsections were cut and mounted on slides and annuli were counted with a compound microscope. Otoliths were air-dried, cracked and passed over a flame to increase the visibility of annuli. Otoliths were then mounted in Plasticine and immersed in oil for better inspection using a compound microscope. When more than one structure was used for aging, the one with the highest confidence in the annuli count was used.

Fish that died during to capture or handling were autopsied and sex and sexual maturity were identified. Otoliths were usually taken for ageing. In some years, and for some waterbodies, tissue samples (e.g., muscle and liver) were taken from Lake Trout, Lake Whitefish, Arctic Char, Cisco, Arctic Grayling or Ninespine Stickleback for metals analysis. Gonads and livers were also weighed to calculate gonadosomatic index (gonad weight/body weight) and hepatosomatic index (liver weight/body weight).

Fish population sampling in lakes, ponds, and streams of the RSA between 1993 and 2015 has resulted in a large database of waterbody-specific information including fish-bearing status of waterbodies, species richness (number of species in a waterbody), species incidence (number of waterbodies with specific species), and population number and density (i.e., fish/ha). This information is presented and discussed in Section 6.2.6.3.

The fish community sampling database also contains population-level information on fish length, weight, the incidence of DELTs, age, sex ratio, sexual maturation, gonadosomatic index, and hepatosomatic index in sampled waterbodies. Due to the extensive nature of the database, this information is not summarized here but it is available in baseline reports (see Section 6.2.4) for use as historical data to be compared with similar data collected during construction, operations, and closure of the Project.

Fish Tagging

In selected lakes and streams, fish longer than 300 to 500 mm were tagged with uniquely numbered Hallprint or Floy T-bar anchor tags. Tags were inserted below the dorsal fin. In more recent years, tagged fish were also injected with Passive Integrated Transponder (PIT) tags (e.g., Golder 2008b).

The purpose of tagging fish was two-fold: to track fish as they moved through rivers and lakes and to enable mark-recapture estimates of the Lake Trout populations in Tail and Patch lakes. Tag recovery information was mainly used to track Arctic Char and Lake Trout as they moved into and out of the Roberts Lake drainage through Little Roberts Outflow, Little Roberts Lake, Roberts Outflow, Roberts Lake, and headwater lakes of Roberts Lake. Fish distribution information is presented and discussed in Section 6.2.6.3 (Life Histories and Habitat Preferences of Fish Species). Results of the mark-recapture population studies are presented and discussed in Section 6.2.6.3 (Estimates of Lake Fish Population Number and Density).

Lake Trout were tagged in ten lakes: seven lakes of the LSA North (Doris, Ogama, Patch, P.O., P.O. Connector, Little Roberts and Windy), Aimaokatalok Lake in the LSA South, and two lakes in the RSA (Roberts, Little Roberts, and Pelvic) (Table 6.2-10). Lake Trout were also tagged in Tail Lake in 2000, 2002, 2004 before it was fished out and became the TIA (Appendix V5-6Y). Streams in which Lake Trout were tagged include Doris Outflow, Glenn Outflow, Roberts Outflow, Little Roberts Outflow, Pelvic Outflow, and tributaries to Roberts Lake. Arctic Char were tagged in lakes and streams of the Roberts Watershed. Lake Whitefish were tagged in five lakes: Doris, Patch, Pelvic, Windy, and Aimaokatalok. Broad Whitefish were tagged in Little Roberts Lake.

Tagging of Lake Trout and Arctic Char was conducted on Roberts Outflow or Little Roberts Outflow every year that the fish fences were operational from 2000 to 2013. Tagging on other lakes and streams was done intermittently from 1997 to 2009. All Lake Trout and Arctic Char that were subsequently caught in lakes with historical tagging were examined for the presence of a tag. Once PIT tags were introduced, captured lake trout were scanned with a PIT tag reader to determine if they had been previously tagged. For tagged fish, the tag number and type of tag was recorded and that fish was labelled as a ‘recapture’ in data entry and analysis.

Table 6.2-10. Fish Species Tagged in the LSA and RSA, 1993-2017

Area	Water Body	Watershed	Waterbody Type	Lake Trout	Lake Whitefish	Broad Whitefish	Arctic Char	Tagging Years
LSA - North Belt	Doris Lake	Doris	Lake	X	X	-	-	1997, 2009
LSA - North Belt	Ogama Lake	Doris	Lake	X	-	-	-	2008
LSA - North Belt	P.O. Connector Lake	Doris	Lake	X	-	-	-	2006
LSA - North Belt	P.O. Lake	Doris	Lake	X	-	-	-	2006, 2008
LSA - North Belt	Patch Lake	Doris	Lake	X	X	-	-	1997, 2006-2009
LSA - North Belt	Little Roberts Lake	Roberts	Lake	X	-	X	X	2000, 2002, 2003
LSA - North Belt	Windy Lake	Windy	Lake	X	X	-	-	1997
LSA - North Belt	Doris Outflow	Doris	Stream	X	-	-	-	2003
LSA - North Belt	Little Roberts Outflow	Roberts	Stream	X	-	-	X	2006, 2007
LSA - North Belt	Glenn Outflow	Windy	Stream	X	-	-	-	2003
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	X	-	-	1997
RSA	Pelvic Lake	Roberts	Lake	X	X	-	-	1998
RSA	Roberts Lake	Roberts	Lake	X	-	-	X	2002-2007, 2010-2012
RSA	Pelvic Outflow	Roberts	Stream	X	-	-	X	2003, 2005
RSA	Roberts Inflows*	Roberts	Stream	X	-	-	X	2007, 2010-2013
RSA	Roberts Outflow	Roberts	Stream	X	-	-	X	2002-2005, 2010-2013

X = fish tagged. Dashes = no fish tagged.

LSA = Local Study Area and RSA = Regional Study Area.

**Sites E04, E06, E09, E13, E14, E31, E33, E36*

Stomach Contents

Stomach contents were collected from fish that died from capture or handling, as well as fish that were sacrificed for tissue metals analysis. For many stomachs, the contents were examined in the field and dominant prey items were noted. For selected fish, stomachs were removed, preserved in formalin and sent to taxonomists for detailed analysis.

Stomach contents were collected to determine the diet of different species and life stages of fish and to infer their trophic position. Results of analyses of stomach contents are briefly presented in Section 6.2.6.3 (Life Histories and Habitat Preferences of Fish Species).

Stomach contents were examined from five fish species: Lake Trout, Lake Whitefish, Arctic Char, Least Cisco, and Cisco (Table 6.2-11). Lake Trout stomach contents were examined from nine lakes and two streams. Stomach contents from Lake Trout captured in Tail Lake in 2000, 2002, and 2011 (before it was a TIA) were also examined. Lake Whitefish stomach contents were examined from eight lakes. Arctic Char stomach contents were examined from Little Roberts Lake and Roberts Outflow. Least Cisco stomach contents were examined from Roberts Lake and Little Roberts Lake and Cisco stomach contents were examined from Roberts Lake only.

Tissue Metals Concentrations

Tissue samples were collected from 1993 to 2010 and analyzed for metal concentrations as a baseline for monitoring the uptake of metals by fish that reside in waterbodies that may potentially be affected by Hope Bay Project activities. Figures 6.2-16 and 6.2-17 present the locations of fish community surveys conducted from 1993 to 2017.

Samples of muscle and/or liver were taken from large-bodied fish species. For each fish, after collection of biological data, up to 5 g of muscle tissue was taken, stripped of bones and skin, rinsed in clean lake water, and placed in an individually labelled Whirl-Pak bag. Whole livers from each fish were removed and stored in the same manner. Due to their small body size, Ninespine Stickleback were prepared as composite, whole-body samples to meet minimum tissue requirements for analysis. Tissue samples were placed on ice in the field, frozen immediately upon return to camp and were kept frozen until they were delivered to an analytical laboratory.

Fish tissue samples were collected from five species of large-bodied fish: Lake Trout, Lake Whitefish, Cisco, Arctic Grayling, and Arctic Char (Table 6.2-12). Beginning in 2010, Ninespine Stickleback samples were collected as part of the Doris AEMP. Lake Trout tissue samples were collected from 13 lakes: six in the LSA North, two in the LSA South, and five in the RSA. Lake Whitefish tissue samples were collected from six lakes: three in the LSA North, one in the LSA South, and two in the RSA. Ninespine Stickleback tissue samples were collected from five lakes (Doris, Little Roberts, Aimaokatalok, Reference B, and Reference D) and five streams in the LSA South. Tissue samples for Cisco, Arctic Grayling, and Arctic Char were collected from Doris Lake, Trout Lake, and Roberts Outflow, respectively. ALS Environmental analyzed the tissue samples for metals concentrations according to procedures adapted from the United States Environmental Protection Agency (EPA; US EPA 1995). Samples were divided into two parts: one part for measurement of metal concentrations (on a wet weight basis) and a second part for measurement of percent moisture so that the results could be converted to dry weight concentrations. Each sample was homogenized either mechanically or manually prior to digestion. The hotplate digestion method involved the use of nitric acid followed by repeated additions of hydrogen peroxide. Total concentrations of 25 metals were measured by Inductively Coupled Plasma – Mass Spectroscopy.

Results of the analysis of fish tissue metals concentrations are presented in Volume 6, Chapter 5 (Human Health and Environmental Risk Assessment).

Table 6.2-11. Fish Stomach Content Sampling in the LSA and RSA, 1993-2017

Area	Water Body	Watershed	Waterbody Type	Lake Trout	Lake Whitefish	Broad Whitefish	Arctic Char	Least Cisco	Cisco	Sampling Year
LSA - North Belt	Doris Lake	Doris	Lake	X	X	-	-	-	-	1997, 2002
LSA - North Belt	P.O. Lake	Doris	Lake	X	-	-	-	-	-	2009
LSA - North Belt	Patch Lake	Doris	Lake	X	X	-	-	-	-	1997
LSA - North Belt	Little Roberts Lake	Roberts	Lake	X	X	-	X	X	-	2000, 2002, 2009
LSA - North Belt	Windy Lake	Windy	Lake	X	X	-	-	-	-	1997, 2009
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	X	-	-	-	-	1993, 1997, 2010
RSA	Reference Lake D	Reference D	Lake	X	X	-	-	-	-	2010
RSA	Pelvic Lake	Roberts	Lake	X	X	-	-	-	-	1998
RSA	Roberts Lake	Roberts	Lake	X	X	-	-	X	X	2005
RSA	Reference A Outflow	Reference	Stream	X	-	-	-	-	-	2009
RSA	Reference B Outflow	Reference B	Stream	X	-	-	-	-	-	2009
RSA	Roberts Outflow	Roberts	Stream	-	-	X	X	-	-	2002, 2003, 2005

X = stomach content sampled. Dashes = stomach content not sampled.

LSA = Local Study Area and RSA = Regional Study Area.

Figure 6.2-16
Freshwater Fish Tissue Sampling Locations, North Belt, 1993 – 2017

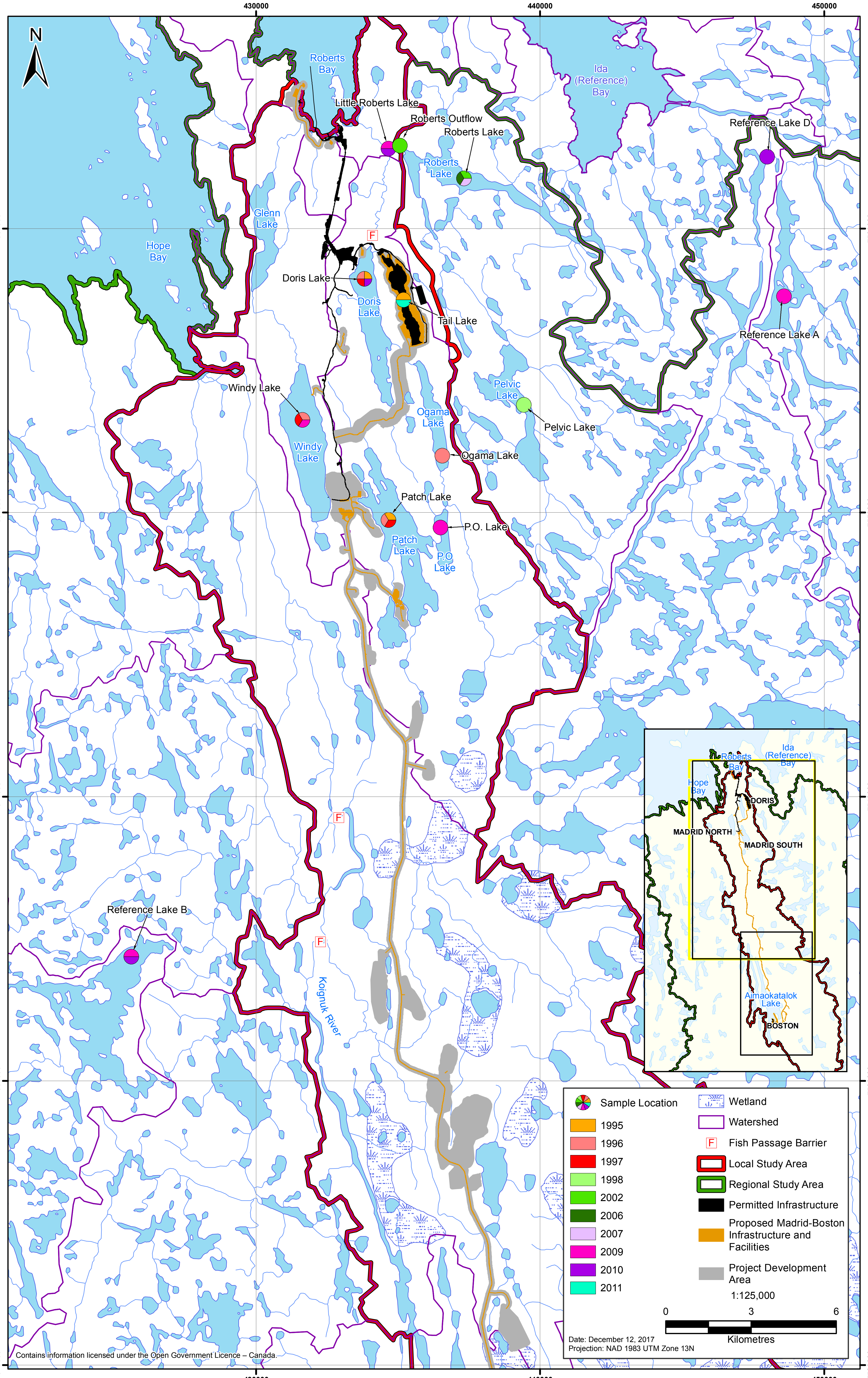


Figure 6.2-17
Freshwater Fish Tissue Sampling Locations, South Belt, 1993 - 2017

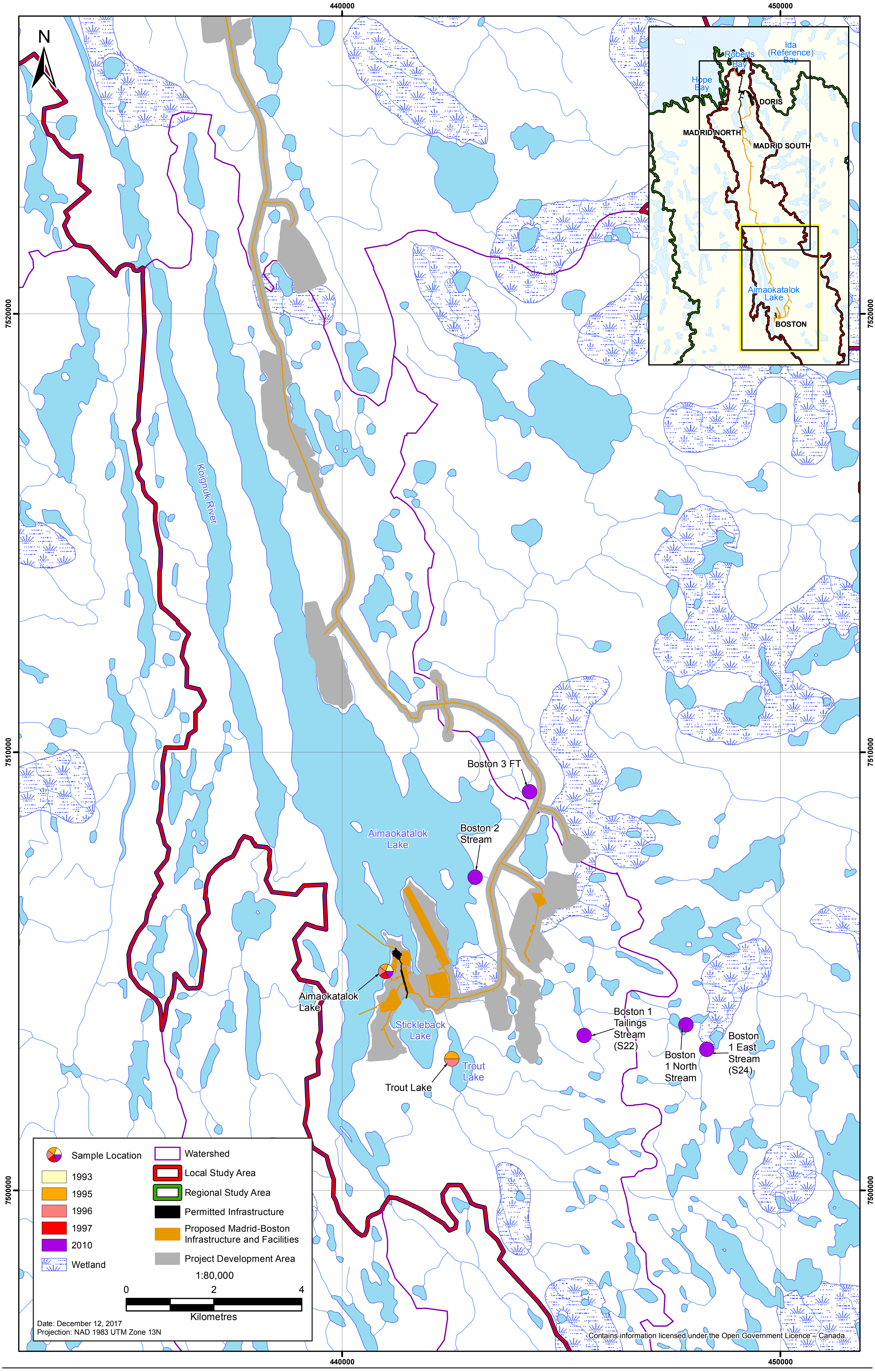


Table 6.2-12. Fish Tissue Sampling in the LSA and RSA, 1993-2017

Area	Water Body	Watershed	Waterbody Type	Lake Trout	Ninespine Stickleback	Lake Whitefish	Cisco	Arctic Grayling	Arctic Char	Sampling Years
LSA - North Belt	Doris Lake	Doris	Lake	X	X	X	X	-	-	1995-1997, 2010
LSA - North Belt	Ogama Lake	Doris	Lake	X	-	-	-	-	-	1996
LSA - North Belt	P.O. Lake	Doris	Lake	X	-	X	-	-	-	2009
LSA - North Belt	Patch Lake	Doris	Lake	X	-	X	-	-	-	1995-1997
LSA - North Belt	Tail Lake	Doris	Lake	X	-	-	-	-	-	1995, 2011
LSA - North Belt	Little Roberts Lake	Roberts	Lake	X	X	-	-	-	-	2009, 2010
LSA - North Belt	Windy Lake	Windy	Lake	X	-	-	-	-	-	1996, 1997, 2009
LSA - South Belt	Aimaokatalok Lake	Aimaokatalok	Lake	X	-	X	-	-	-	1993, 1995-1997, 2010
LSA - South Belt	Trout Lake	Aimaokatalok	Lake	X	-	-	-	X	-	1995, 1996
LSA - South Belt	Boston 1 Tailings Stream (S22)	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston 1 East (S24)	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston 1 North	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston 2 Stream	Aimaokatalok	Stream	-	X	-	-	-	-	2010
LSA - South Belt	Boston 3 FT	Aimaokatalok	Stream	-	X	-	-	-	-	2010
RSA	Reference Lake A	Reference A	Lake	X	-	-	-	-	-	2009
RSA	Reference Lake B	Reference B	Lake	X	X	-	-	-	-	2009, 2010
RSA	Reference Lake D	Reference D	Lake	X	X	X	-	-	-	2010
RSA	Pelvic Lake	Roberts	Lake	X	-	X	-	-	-	1998
RSA	Roberts Lake	Roberts	Lake	X	-	-	-	-	-	2002, 2006, 2007
RSA	Roberts Outflow	Roberts	Stream	-	-	-	-	-	X	2002

X = fish tissue sampled. Dashes = fish tissue not sampled.

LSA = Local Study Area and RSA = Regional Study Area.

Quality Assurance and Quality Control

The Vaki Riverwatch video monitoring system was used from 2013 to 2015 on fish counting fences installed on Roberts Outflow. The QA/QC for this system was to double-check a subset of video images. After the initial assessment of underwater videos, a second fish biologist randomly selected and reviewed 10% of the videos to check the accuracy of species identification.

All age structures were read a minimum of two times. If consistency was not met between the first two reads, a third was undertaken. If consistency was not accomplished within three reads, the structure was deemed un-ageable and no age was assigned. Age readers were given no information on weight, length or sex, so that age estimates were based solely on the annular structure of the fin ray. All readings were conducted as “blind” (independent from each other). Quality assurance and quality control (QA/QC) was then conducted by an alternate ageing technician on 10% of randomly selected structures. The QA/QC readings were also conducted “blind” to determine consistency and accuracy.

To assess the accuracy of the metal analyses, ALS conducted two measures of quality control: method blanks and comparison with reference material. A method blank is a test in which no tissue was added. A reference material such as lobster hepatopancreas, certified by the National Research Council of Canada, was subjected to the same analytical procedures as the fish tissue samples. The measured concentrations of each metal were then compared to the known metal concentrations in the certified material to determine if they fell within the 95% confidence limits expected for each metal.

To assess the variability of fish tissue metal analysis, and hence the homogeneity of the samples, a small number of samples were each split into two replicates and the relative percent difference (RPD) between replicate metal concentrations (and percent moisture) was calculated as:

$$RPD = 100((sample - duplicate)/((sample + duplicate)/2))).$$

RPD were not calculated if one or both of the values were less than the Method Detection Limit (MDL). In general, analytical variability is much higher near the MDL than is considered acceptable. Therefore, those RPD were classified as “RPD-not available” or RPD-NA.

Other potential RPD were not calculated because both values were between one and five times higher than the MDL. The *British Columbia Field Sampling Manual* (BCMWLAP 2003) recommends that only RPD calculated from concentrations each of which is greater than five times the MDL should be used for assessing data quality. Instead of an RPD, the absolute difference between the values was calculated.

All remaining RPD were assumed to be valid. RPD were considered acceptable if they met the RPD limits established by ALS (30% for percent moisture and 45% for metals). ALS interpreted these results as showing low variability of analyses.

6.2.6 Characterization of Baseline Conditions

The key findings of surveys of freshwater fish habitat, inclusive of biological resources (i.e., phytoplankton, periphyton, zooplankton, and benthic invertebrates), physical characteristics, and fish communities in the LSA and RSA are summarized below.

6.2.6.1 Freshwater Fish Habitat – Biological Resources

Lake Phytoplankton

Phytoplankton biomass and phytoplankton abundance were highly variable among lakes in the LSA and RSA. In general, lakes in the North Belt LSA and the RSA fell into one of two broad categories: 1) lakes with low phosphorus concentrations, low phytoplankton biomass and abundance levels, and communities dominated by diatoms, cryptophytes, chrysophytes, or chlorophytes, and 2) lakes with high phosphorus concentrations, high phytoplankton biomass and abundance levels, with communities dominated by cyanobacteria.

LSA – North Belt

In the North Belt LSA, most lakes had relatively low mean chlorophyll *a* concentrations (< 2 µg/L) and low mean phytoplankton abundance levels (< 700 cells/mL; Table 6.2-13). These low biomass and abundance lakes included: Glenn, Imniagut, P.O., Patch, Windy, and Wolverine lakes. Diatoms tended to be the most abundant phytoplankton group within these lakes, followed by cryptophytes (Table 6.2-13). The most common phytoplankton species in these lakes included the centric diatom *Cyclotella ocellata* and the small cryptomonad *Rhodomonas minuta* (Table 6.2-13).

In contrast, Doris, Ogama, Little Roberts, and Nakhaktok lakes all had higher phytoplankton biomass with mean biomass levels ranging from 5.1 to 18.0 µg chl *a*/L, and maximum levels ranging from 10.2 to 56.4 µg chl *a*/L. These lakes also had high phytoplankton abundance, with means ranging from 6,310 to 18,669 cells/mL and maxima ranging from 16,641 to 62,303 cells/mL (Table 6.2-13); these abundances were roughly one to two orders of magnitude greater than those observed in the low abundance lakes. The highest biomass and abundance levels were recorded in Doris Lake. Cyanobacteria (also known as blue-green algae) were the predominant phytoplankton group in the high biomass and abundance lakes, and the most abundant species of cyanobacteria were *Aphanizomenon flos-aquae* and *Oscillatoria tenuis* (Table 6.2-13).

The phytoplankton communities were likely influenced by nutrient concentrations in the lakes as the high biomass, cyanobacteria-dominated lakes generally had higher phosphorus concentrations and were categorized as mesotrophic to eutrophic lakes (based on total phosphorus concentrations while the low biomass, diatom-dominated lakes generally contained lower concentrations of phosphorus and were categorized as ultra-oligotrophic to meso-eutrophic. However, total phosphorus concentrations in lakes were variable, and there were instances that typically high phosphorus lakes had sporadically low phosphorus concentrations (e.g., Doris Lake dropped to oligotrophic status in 2014), or that typically low phosphorus lakes had sporadically high phosphorus concentrations (e.g., P.O. Lake reached hyper-eutrophic status in 2007; Volume 5, Chapter 4).

The mean Simpson's Diversity Indices ranged from 0.22 to 0.87 in the North Belt LSA, and mean genus richness ranged from 8 to 16. The North Belt lakes that had the lowest Simpson's Diversity Index and richness levels were cyanobacteria-dominated lakes (Doris and Nakhaktok lakes).

LSA – South Belt

In the South Belt LSA, Aimaokatalok and Stickleback lakes had relatively low mean biomass levels of 1.64 and 2.62 µg chl *a*/L, respectively, while Trout Lake had a higher mean biomass of 4.51 µg chl *a*/L (Table 6.2-13). Trout Lake also had the highest concentrations of total phosphorus and was categorized as mesotrophic to eutrophic, while Aimaokatalok Lake was categorized as ultra-oligotrophic to meso-eutrophic and Stickleback Lake as oligotrophic to meso-eutrophic (see Volume 5, Chapter 4). Mean phytoplankton abundances ranged from 1,171 to 2,355 cells/mL in the South Belt lakes and were intermediate to abundances in the North Belt lakes. Cyanobacteria were the most abundant phytoplankton group in all three lakes, though chlorophytes (also known as green algae) were also abundant in Aimaokatalok Lake. The most common phytoplankton species in Aimaokatalok Lake were the cyanobacteria *Gomphosphaeria* sp. and *Oscillatoria tenuis* and the chlorophyte *Crucigenia tetrapedia*. The cyanobacteria *Anacystis elachista* and *Anabaena affinis* were the dominant species in Stickleback and Trout lakes, respectively (Table 6.2-13).

The South Belt LSA had the highest phytoplankton diversity among the study areas. The mean Simpson's Diversity Indices ranged from 0.79 to 0.81 and the mean genus richness ranged from 19 to 23.

Table 6.2-13. Summary of Lake Phytoplankton Biomass, Abundance, and Taxonomy in the LSA and RSA

Lake	Chlorophyll Biomass (µg chl *a*/L)			Phytoplankton Abundance (cells/mL)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max	Min	Mean	Max		
LSA - North Belt								
Doris Lake	0.56	9.23	56.4	2,971	18,669	62,303	Cyanobacteria	*Aphanizomenon flos-aquae* (cyanobacteria) and *Oscillatoria tenuis* (cyanobacteria)
Glenn Lake	0.80	1.35	2.41	546	-	546	Diatoms	*Cyclotella ocellata* (diatom)
Imniagut Lake	0.63	-	0.63	414	-	414	Cryptophytes	*Rhodomonas minuta* (cryptophyte)
Little Roberts Lake	0.95	5.55	26.9	1,858	13,638	39,509	Cyanobacteria	*Oscillatoria* spp. (cyanobacteria)
Nakhaktok Lake	18.0	-	18.0	16,937	-	16,937	Cyanobacteria	*Aphanizomenon flos-aquae* (cyanobacteria)
Ogama Lake	1.18	5.06	10.2	1,338	6,310	16,641	Cyanobacteria	*Aphanizomenon flos-aquae* (cyanobacteria) and *Oscillatoria tenuis* (cyanobacteria)
P.O. Lake	0.34	1.34	2.50	69	-	69	Diatoms, Cryptophytes	*Cryptomonas erosa* (cryptophyte)
Patch Lake	0.11	0.77	2.02	168	253	364	Diatoms, Cryptophytes	*Cyclotella ocellata* (diatom) and *Rhodomonas minuta* (cryptophyte)
Windy Lake	0.06	1.32	8.19	21	164	259	Diatoms, Cyanobacteria	*Oscillatoria tenuis* (cyanobacteria) and *Cyclotella ocellata* (diatom)
Wolverine Lake	0.57	1.91	4.50	439	640	840	Diatoms, Chlorophytes	*Diatoma tenue* (diatom) and *Chlamydomonas sp.* (chlorophyte)
LSA - South Belt								
Aimaokatalok Lake	0.21	1.61	8.80	125	1,171	3,471	Cyanobacteria, Chlorophytes	*Gomphosphaeria* sp. (cyanobacteria), *Oscillatoria tenuis* (cyanobacteria) and *Crucigenia tetrapedia* (chlorophyte)
Stickleback Lake	0.76	2.62	14.7	527	2,355	7,962	Cyanobacteria	*Anacystis elachista* (cyanobacteria)
Trout Lake	0.65	4.51	24.9	53	1,277	3,900	Cyanobacteria	*Anabaena affinis* (cyanobacteria)
RSA								
Boston Reference Lake	1.24	3.87	10.2	172	8,237	15,883	Cyanobacteria	*Anabaena affinis* (cyanobacteria)
Naiqunnguut Lake	0.62	-	0.62	260	-	260	Chlorophytes, Cryptophytes	*Rhodomonas minuta* (cryptophyte)
Pelvic Lake	3.12	11.5	19.5	24,698	44,336	63,973	Cyanobacteria	*Oscillatoria* spp. (cyanobacteria)

Lake	Chlorophyll Biomass (µg chl *a*/L)			Phytoplankton Abundance (cells/mL)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max	Min	Mean	Max		
Reference A Lake (2003)	3.17	8.9	16.3	-	-	-	-	-
Reference Lake A	0.86	-	0.86	478	-	478	Diatoms	*Cyclotella ocellata* (diatom)
Reference Lake B	0.21	0.66	2.06	181	198	215	Chrysophytes, Diatoms	*Rhodomonas minuta* (cryptophyte) and *Cyclotella ocellata* (diatom)
Reference Lake D	0.34	1.81	11.9	253	-	253	Diatoms	*Cyclotella stelligera* (diatom)
Roberts Lake	0.52	3.31	9.80	-	-	-	-	-

Note:
[a] *Lowest available taxonomic level (usually genus or species).*

RSA

In the RSA, there was a clear distinction between lakes that had high phytoplankton biomass and abundance and lakes with low biomass and abundance as was observed in the North Belt LSA lakes. Four lakes in the RSA, Naiquunguut Lake and Reference lakes A, B, and D, all had relatively low mean chlorophyll *a* concentrations (< 2 µg chl *a*/L) and low mean phytoplankton abundance levels (< 700 cells/mL; Table 6.2-13). The most abundant phytoplankton group in Reference lakes A and B was diatoms. In Reference Lake D, diatoms and chrysophytes made up the majority of the phytoplankton community, while chlorophytes and cryptophytes were most abundant in Naiqunnguut Lake. As was the case in the North Belt LSA low biomass and abundance lakes, the most common phytoplankton species in the four low biomass and abundance RSA lakes included the diatom *Cyclotella ocellata* and the cryptomonad *Rhodomonas minuta* (Table 6.2-13). With the exception of Reference Lake D, which covered a wide range of trophic categories from ultra-oligotrophic to eutrophic, the remaining three low biomass and abundance lakes had the lowest phosphorus concentrations among RSA lakes, and were categorized as ultra-oligotrophic to mesotrophic (based on total phosphorus concentrations; Volume 5, Chapter 4).

In contrast, Boston Reference Lake and Pelvic Lake had relatively high mean biomass (3.87 and 11.5 µg chl *a*/L, respectively) and abundance levels (8,237 and 44,336 cells/mL, respectively), and were dominated by cyanobacteria (Table 6.2-13). The most prevalent cyanobacteria species in these lakes were *Anabaena affinis* and *Oscillatoria* spp. Boston Reference and Pelvic lakes also had relatively high phosphorus concentrations and were categorized as mesotrophic to hyper-eutrophic (see Volume 5, Chapter 4).

The mean Simpson's Diversity Indices for phytoplankton in the RSA ranged from 0.26 to 0.86, and the mean genus richness ranged from 8 to 21.

<u>Stream and River Periphyton</u>

LSA – North Belt

In the North Belt LSA, mean periphyton biomass ranged from 0.025 µg chl *a*/cm^2 in Patch Outflow to 0.283 µg chl *a*/cm^2 in AWRb stream (Table 6.2-14). Mean periphyton abundance was highly variable across sites, ranging from 37,113 cells/cm^2 in AWRa stream to 1,521,312 cells/cm^2 in Ogama Outflow (Table 6.2-14). The periphyton abundance in Ogama Outflow was markedly higher than any other monitored stream in the study areas, and was more than five times higher than the North Belt site with the next highest mean abundance (Little Roberts Outflow: 276,636 cells/cm^2). Diatoms were the dominant periphyton group in all North Belt streams and rivers, and *Diatoma tenue* was generally the most abundant species. In Doris Outflow, downstream of the productive Doris Lake, both diatoms and cyanobacteria were abundant, and the cyanobacterium *Oscillatoria tenuis* was the most common species (Table 6.2-14). The mean Simpson's Diversity Indices ranged from 0.31 to 0.86 and genus richness ranged from 9 to 21 in North Belt streams and rivers. Windy Outflow had particularly low mean Simpson's Diversity Index diversity (0.31) and richness (9) for periphyton.

LSA – South Belt

In the South Belt LSA, periphyton biomass ranged from 0.041 µg chl *a*/cm^2 in AWRd stream to 0.440 µg chl *a*/cm^2 at Aimaokatalok Outflow (Table 6.2-14). Mean periphyton abundance was highly variable, ranging from 11,773 cells/cm^2 in AWRc stream to 407,347 cells/cm^2 in Aimaokatalok NE Inflow (Table 6.2-14). Aimaokatalok NE Inflow also had the highest total phosphorus concentrations among South Belt LSA streams, and was categorized as either meso-eutrophic or eutrophic (see Volume 5, Chapter 4). Diatoms were the dominant periphyton group in most streams and rivers, and the most common diatom species were *Synedra radians* and *Achnanthes minutissima*. The cyanobacterium *Gomphosphaeria naegelianum* was the most common species in Aimaokatalok NE Inflow, and an unidentified cyanobacterium was the dominant taxon in Trout Outflow (Table 6.2-14). Simpson's Diversity Indices ranged from 0.56 to 0.88 in South Belt streams and rivers, and genus richness ranged from 11 to 23.

Table 6.2-14. Summary of Stream and River Periphyton Biomass, Abundance, and Taxonomy in the LSA and RSA

Stream	Chlorophyll Biomass (µg chl *a*/cm^2)			Periphyton Abundance (cells/cm^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max	Min	Mean	Max		
LSA - North Belt								
AWRa	0.197	-	0.197	37,113	-	37,113	Diatoms	*Diatoma tenue* (diatom)
AWRb	0.283	-	0.283	53,218	-	53,218	Diatoms	*Achnanthes linearis* (diatom)
Doris Outflow	0.038	0.257	1.06	72,392	183,487	278,725	Diatoms, Cyanobacteria	*Oscillatoria tenuis* (cyanobacteria)
Glenn Outflow Downstream	0.034	-	0.034	115,204	-	115,204	Diatoms	*Diatoma tenue* (diatom)
Koignuk River (Upstream, Midstream, Downstream)	0.010	0.106	0.216	6,220	185,395	382,983	Diatoms	*Diatoma tenue* (diatom) and *Achnanthes minutissima* (diatom)
Little Roberts Outflow	0.007	0.216	1.30	58,352	276,636	484,340	Diatoms	*Diatoma tenue* (diatom)
Ogama Outflow	0.250	-	0.250	427,234	1,521,312	3,187,329	Diatoms	*Diatoma* spp. (diatom)
P.O. Outflow	0.053	-	0.053	70,236	-	70,236	Diatoms	*Diatoma tenue* (diatom)
Patch Outflow	0.025	-	0.025	102,400	119,095	135,789	Diatoms	*Diatoma tenue* (diatom)
Windy Outflow	0.030	-	0.030	63,053	88,551	128,547	Diatoms	*Diatoma tenue* (diatom)
LSA - South Belt								
Aimaokatalok NE Inflow	0.196	-	0.196	113,868	407,347	987,472	Cyanobacteria	*Gomphosphaeria naegelianum* (cyanobacteria)
Aimaokatalok Outflow	0.440	-	0.440	158,614	-	158,614	Diatoms	*Tabellaria flocculosa* (diatom)
AWRc	0.084	-	0.084	11,773	-	11,773	Diatoms	*Synedra radians* (diatom)
AWRd	0.041	-	0.041	13,903	-	13,903	Diatoms	*Synedra radians* (diatom)
Koignuk River	0.285	-	0.285	142,222	-	142,222	Diatoms	*Achnanthes minutissima* (diatom)
Stickleback Outflow	0.161	-	0.161	29,465	259,030	563,973	Diatoms	*Achnanthes minutissima* (diatom)
Trout Outflow	0.132	-	0.132	84,165	352,393	601,529	Cyanobacteria, Chlorophytes	unidentified cyanobacterium
RSA								
Aimaokatalok River	0.111	-	0.111	26,158	213,854	582,187	Cyanobacteria, Diatoms	*Gomphosphaeria naegelianum* (cyanobacteria)
Angimajuq River Reference	0.185	-	0.185	378,164	-	378,164	Diatoms	*Tabellaria flocculosa* (diatom)

Stream	Chlorophyll Biomass (µg chl *a*/cm^2)			Periphyton Abundance (cells/cm^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max	Min	Mean	Max		
Boston Reference Outflow	-	-	-	174,996	210,974	246,952	Cyanobacteria	*Diatoma tenue* (diatom)
Pelvic Outflow	0.600	-	0.600	252,467	377,993	453,109	Diatoms, Cyanobacteria	*Oscillatoria tenuis* (cyanobacteria) and *Diatoma tenue* (diatom)
Reference A Outflow	0.059	-	0.059	149,118	-	149,118	Diatoms	*Diatoma tenue* (diatom)
Reference B Outflow	0.006	0.075	0.372	15,841	77,966	140,090	Diatoms	*Achnanthes minutissima* (diatom)
Reference D Outflow	0.027	0.112	0.410	188,720	-	188,720	Diatoms	*Achnanthes minutissima* (diatom)
Roberts Outflow	0.018	0.189	0.856	-	-	-	-	-

Notes:
Chlorophyll biomass data from 1997 and 1998 were not included as they were roughly 2 to 3 orders of magnitude higher than the rest of the values in the dataset.
[a] *Lowest available taxonomic level (usually genus or species).*

RSA

In the RSA, mean periphyton biomass ranged from 0.059 µg chl *a*/cm^2 in Reference A Outflow to 0.600 µg chl *a*/cm^2 in Pelvic Outflow (Table 6.2-14). Mean periphyton abundance ranged from 77,966 cells/cm^2 in Reference B Outflow to 378,000 cells/cm^2 in both Angimajuq River Reference and Pelvic Outflow (Table 6.2-14). Diatoms were generally the most abundant group, though cyanobacteria also made up a major fraction of the periphyton assemblage in some streams and rivers. The most common periphyton species in the RSA were similar to those observed in the LSA streams and rivers (Table 6.2-14). In the RSA, mean Simpson's Diversity Indices ranged from 0.57 to 0.87 and genus richness ranged from 8 to 23.

Lake Zooplankton

LSA – North Belt

Mean zooplankton abundance in the North Belt LSA lakes ranged from 2,939 organisms/m^3 in Glenn Lake to 282,282 organisms/m^3 in Nakhaktok Lake (Table 6.2-15). The lakes with relatively high mean and maximum zooplankton abundances (Nakhaktok, Doris, and Ogama lakes) were the same lakes that had the highest phytoplankton biomass and abundance, suggesting that zooplankton abundance was related to the abundance of their prey. Imniagut Lake was the exception, as this lake had relatively high zooplankton abundance (Table 6.2-15), but relatively low phytoplankton biomass and abundance (Table 6.2-15). The most common zooplankton taxa in the North Belt lakes were cyclopoid copepods and rotifers. Most of the copepods observed in the North Belt lakes were in their early life stages (nauplii or copepodites), and were not identified to the level of genus or species. The most abundant rotifer species were *Keratella quadrata* and *Kellicottia longispina*. The calanoid copepod species *Limnocalanus macrurus* was the most abundant zooplankton taxon in Glenn Lake (Table 6.2-15). The mean Simpson's Diversity Indices in North Belt LSA lakes ranged from 0.14 in Glenn Lake to 0.71 in Imniagut and Patch lakes. Mean genus richness ranged from 3 in Glenn Lake to 12 in Wolverine Lake. Glenn and Windy lakes had the least abundant zooplankton communities (Table 6.2-15), as well as the least diverse (mean Simpson's Diversity Index and genus richness were 0.25 and 4, respectively, in Windy Lake).

LSA – South Belt

In the South Belt LSA, mean zooplankton abundance ranged from 28,977 organisms/m^3 in Aimaokatalok Lake to 129,355 organisms/m^3 in Stickleback Lake (Table 6.2-15). Zooplankton abundance in South Belt lakes was intermediate to the range of abundances recorded in North Belt Lakes. Similar to the North Belt LSA, the most common zooplankton groups in the South Belt LSA were cyclopoid copepods and rotifers. The most abundant species were *Cyclops* spp. (cyclopoid copepod) and *Kellicottia longispina* (rotifer, Table 6.2-15). The mean Simpson's Diversity Indices ranged from 0.34 in Stickleback Lake to 0.58 in Aimaokatalok Lake, and mean genus richness ranged from 8 in Stickleback Lake to 11 in Trout Lake.

RSA

In the RSA, mean zooplankton abundance ranged from 4,345 organisms/m^3 in Reference Lake A to 50,308 organisms/m^3 in Naiqunnguut Lake (Table 6.2-15). Rotifers were the most common group in the RSA lakes. *Kellicottia longispina* was the most abundant zooplankton species in three of the surveyed lakes (Boston Reference Lake, Little Roberts Lake, and Reference Lake A) and *Keratella quadrata* was the most abundant species in Pelvic Lake. Cladocerans were the most abundant group in Naiqunnguut Lake and Reference Lake D, and *Daphnia longiremis* and *Bosmina longirostris* were the most common cladoceran species in these lakes. Calanoid copepods were also abundant in Reference lakes A and B (Table 6.2-15). Reference Lake D had the least diverse zooplankton community (Simpson's Diversity Index of 0.3 and genus richness of 7). Naiqunnguut Lake had the highest mean diversity (0.78), and Little Roberts Lake had the highest mean genus richness (13).

Table 6.2-15. Summary of Lake Zooplankton Abundance and Taxonomy in the LSA and RSA

Lake	Zooplankton Abundance (organisms/m^3)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max		
LSA - North Belt					
Doris Lake	8,861	36,931	85,496	Rotifers	*Kellicottia longispina* (rotifer)
Glenn Lake	2,939	-	2,939	Copepods (Calanoid)	*Limnocalanus macrurus* (calanoid copepod)
Imniagut Lake	255,194	-	255,194	Copepods	copepod nauplii
Nakhaktok Lake	282,282	-	282,282	Rotifers	*Keratella quadrata* (rotifer)
Ogama Lake	13,456	60,736	95,399	Copepods (Cyclopoid)	cyclopoid copepodites
P.O. Lake	23,845	-	23,845	Copepods (Cyclopoid)	cyclopoid copepodites
Patch Lake	13,127	15,309	18,799	Copepods (Cyclopoid)	cyclopoid copepodites
Windy Lake	835	4,628	8,333	Rotifers	*Conochilus sp.* (rotifer)
Wolverine Lake	5,221	8,926	12,630	Rotifers	*Kellicottia longispina* (rotifer) and *Conochilus unicornis* (rotifer)
LSA - South Belt					
Aimaokatalok Lake	1,816	28,977	78,652	Copepods (Cyclopoid) and Rotifers	*Kellicottia longispina* (rotifer) and *Cyclops spp.* (cyclopoid copepod)
Stickleback Lake	684	129,355	911,697	Copepods (Cyclopoid) and Rotifers	*Kellicottia longispina* (rotifer) and *Cyclops spp.* (cyclopoid copepod)
Trout Lake	3,750	79,787	269,733	Rotifers	*Kellicottia longispina* (rotifer)
RSA					
Boston Reference Lake	2,001	7,442	16,589	Rotifers	*Kellicottia longispina* (rotifer)
Little Roberts Lake	4,206	5,432	7,187	Rotifers	*Kellicottia longispina* (rotifer)
Naiqunnguut Lake	50,308	-	50,308	Cladocerans	*Daphnia longiremis* (cladoceran)
Pelvic Lake	13,303	44,797	76,290	Rotifers	*Keratella quadrata* (rotifer)
Reference Lake A	4,345	-	4,345	Rotifers and Copepods (Calanoid)	*Kellicottia longispina* (rotifer)
Reference Lake B	39,050	40,153	41,256	Copepods (Calanoid) and Rotifers	diaptomid copepodites
Reference Lake D	6,931	-	6,931	Cladocerans	*Bosmina longirostris* (cladoceran)

Note:
[a] *Lowest available taxonomic level (usually genus or species).*

Lake Benthic Invertebrates

LSA – North Belt

Benthic invertebrate abundance was highly variable among lakes in the study areas. Mean benthic invertebrate abundance in the North Belt LSA lakes ranged from 119 organisms/m^2 in Windy Lake (mid-depth) to 42,118 organisms/m^2 in P.O. Lake (shallow depth; Table 6.2-16). In general, benthic invertebrate abundance decreased with increasing sampling depth (i.e., shallow sites had the highest abundances), but there were exceptions to this trend (Table 6.2-16). In most lakes within the North Belt LSA, dipterans were the most common benthic taxon. Chironomids (a family within the order Diptera) were particularly abundant, especially the genus *Chironomus*. However, ostracods (small crustaceans also known as seed shrimp) were the most common benthic group at the sites with the highest mean benthic abundances (Imniagut Lake: 23,597 organisms/m^2, P.O. Lake: 42,118 organisms/m^2, and Wolverine Lake: 24,768 organisms/m^2; Table 6.2-16).

In the North Belt, mean Simpson's Diversity Indices ranged from 0.15 (Glenn Lake, deep depth) to 0.75 (Imniagut Lake, shallow depth) and genus richness ranged from 1 (Glenn Lake, deep depth) to 11 (Little Roberts and Nakhaktok lakes, shallow depth). In general, sites with relatively low benthic invertebrate abundance (e.g., deep site in Glenn Lake, mid-depth site in Patch Lake) also tended to have low levels of genus diversity and richness.

LSA – South Belt

In the South Belt LSA, mean benthic invertebrate abundance ranged from 1,334 organisms/m^2 in Aimaokatalok Lake (deep depth) to 23,551 organisms/m^2 in Stickleback Lake (shallow depth, Table 6.2-16). In Aimaokatalok Lake, the only lake in the South Belt LSA that was sampled at multiple depths, mean benthic abundance was highest in the shallow sites. The benthic communities in each of the three South Belt LSA lakes were dominated by different benthic groups; Trout Lake was dominated by dipterans, whereas the benthic assemblages in Aimaokatalok and Stickleback lakes consisted of more even mix of taxonomic groups. Bivalve molluscs belonging to the family Sphaeriidae (pea clams) were the most common benthic invertebrates in Aimaokatalok Lake, ostracods were the most abundant group in Stickleback Lake (though dipterans were also very abundant), and the dipteran genus *Zalutschia* (in the chironomid family) was the most common taxon in Trout Lake (Table 6.2-16).

In the South Belt, mean Simpson's Diversity Indices ranged from 0.36 (Trout Lake, shallow depth) to 0.85 (Stickleback Lake, shallow depth). Genus richness in the South Belt lakes ranged from 7 (Aimaokatalok Lake, deep depth) to 17 (Stickleback Lake, shallow depth).

RSA

In the RSA, mean benthic invertebrate abundance ranged from 147 organisms/m^2 in Reference Lake A (deep depth) to 16,746 organisms/m^2 in Reference Lake D (shallow depth; Table 6.2-16). Dipterans were typically the most abundant benthic group in the RSA lakes. The most common dipteran genera in the RSA lakes were *Paratanytarsus*, *Stictochironomus*, *Tanytarsus*, and *Chironomus* (all within the chironomid family; Table 6.2-16). Mean values for Simpson's Diversity Indices for benthic organisms in the RSA ranged from 0.38 (Reference Lake A, deep depth) to 0.74 (Naiqunnguut Lake, shallow depth) and richness ranged from 2 (Reference Lake A, deep depth) to 8 (Reference Lake B, mid depth).

Table 6.2-16. Summary of Lake Benthic Invertebrate Abundance and Taxonomy in the LSA and RSA

Lake	Depth Interval[a]	Benthic Invertebrate Abundance (organisms/m^2)			Predominant Group (numerically)	Predominant Genera (numerically)[b]
		Min	Mean	Max		
LSA - North Belt						
Doris Lake	Shallow	1,366	2,078	3,496	Dipterans	various chironomids (dipterans)
	Mid	2,059	2,148	2,237	Dipterans	*Chironomus* and *Phaenopsectra* (dipterans)
	Deep	601	2,249	5,079	Dipterans	*Chironomus* and *Stictochironomus* (dipterans)
Glenn Lake	Shallow	700	1,484	2,267	Ostracods and Dipterans	Ostracods and *Procladius* (dipteran)
	Deep	179	419	658	Ostracods and Dipterans	Ostracods and *Heterotrissocladius* (dipteran)
Imniagut Lake	Shallow	23,597	-	23,597	Dipterans	Ostracods
Little Roberts Lake	Shallow	859	14,260	28,545	Dipterans	*Paratanytarsus and Tanytarsus* (dipteran)
Nakhaktok Lake	Shallow	7,743	-	7,743	Dipterans	*Chironomus* (dipterans)
	Mid	7,602	-	7,602	Dipterans	*Chironomus* (dipterans)
Ogama Lake	Shallow	1,007	2,521	4,800	Dipterans	*Tanytarsus* and *Procladius* (dipterans)
	Mid	1,867	-	1,867	Dipterans	Chironomini (diptera)
P.O. Lake	Shallow	583	42,118	83,653	Ostracods	Ostracods
Patch Lake	Shallow	829	9,510	41,261	Ostracods and Dipterans	Ostracods
	Mid	342	1,001	1,659	Dipterans	*Sergenta* (dipteran)
	Deep	800	1,056	1,542	Ostracods and Dipterans	Ostracods and *Stictochironomus* (dipteran)
Windy Lake	Shallow	89	764	2,444	Ostracods and Dipterans	Ostracods
	Mid	119	-	119	Dipterans	*Cricotopus* (dipteran)
	Deep	77	1,741	7,733	Ostracods	Ostracods
Wolverine Lake	Shallow	1,713	24,768	61,267	Ostracods	Ostracods
LSA - South Belt						
Aimaokatalok Lake	Shallow	193	5,755	21,988	Dipterans and Molluscs	Sphaeriidae (mollusc)
	Mid	1,677	1,739	1,801	Dipterans and Molluscs	*Sphaerium* (mollusc) and *Procladius* (dipteran)
	Deep	18	1,334	4,652	Dipterans and Molluscs	Sphaeriidae and *Pisidium* (molluscs)
Stickleback Lake	Shallow	479	25,156	41,339	Ostracods and Dipterans	Ostracods

Lake	Depth Interval[a]	Benthic Invertebrate Abundance (organisms/m^2)			Predominant Group (numerically)	Predominant Genera (numerically)[b]
		Min	Mean	Max		
Trout Lake	Shallow	136	14,919	43,258	Dipterans	*Zalutschia* (dipteran)
RSA						
Boston Reference Lake	Shallow	4,237	11,650	30,969	Ostracods, Dipterans, and Molluscs	Ostracods and Sphaeriidae (mollusc)
Naiqunnguut Lake	Shallow	1,019	-	1,019	Dipterans	*Stictochironomus* (dipteran)
Pelvic Lake	Shallow	1,378	6,081	12,627	Ostracods and Dipterans	Ostracods and *Tanytarsus* (dipteran)
	Mid	3,659	-	3,659	Dipterans	*Phaenopsectra* (dipteran)
	Deep	133	339	604	Dipterans	*Chironomus* (dipteran)
Reference Lake A	Shallow	1,235	-	1,235	Dipterans	*Stictochironomus* (dipteran)
	Deep	147	-	147	Dipterans	*Chironomus* (dipteran)
Reference Lake B	Shallow	1,034	-	1,034	Dipterans	*Micropsectra* (dipteran)
	Mid	2,662	4,420	6,178	Dipterans	*Tanytarsus* (dipteran)
	Deep	1,656	2,287	3,677	Molluscs and Dipterans	*Pisidium* (mollusc) and Tubificinae (oligochaete)
Reference Lake D	Shallow	8,800	16,584	26,812	Dipterans	*Paratanytarsus* (dipteran)
Roberts Lake	Shallow	8,720	-	8,720	Dipterans	*Paratanytarsus* (dipteran)

Notes:
[a] *Shallow = 0-5 m, Mid = 5-10 m, Deep = 10+ m*
[b] *Lowest available taxonomic level (usually genus).*

Stream and River Benthic Invertebrates

LSA – North Belt

Mean benthic invertebrate abundance in streams and rivers of the North Belt LSA ranged from 1,695 organisms/m^2 in Patch Outflow to 25,054 organisms/m^2 in Doris Outflow (Table 6.2-17). There was not only high variability in benthic abundance between streams, but also within streams. In Doris Outflow, for example, benthic abundance ranged from 761 (in 1997) to 207,867 organisms/m^2 (in 2000). Dipterans were the predominant benthic group in all streams. A diverse variety of dipteran genera were recorded in North Belt LSA streams, including the black fly *Simulium* and the chironomids *Hydrobaenus*, and *Rheotanytarsus* (Table 6.2-17). Mean values for Simpson's Diversity Indices ranged from 0.65 (Glenn Outflow Downstream) to 0.85 (AWRb and Little Roberts Outflow), and genus richness ranged from 9 (AWRa) to 21 (Little Roberts Outflow) for the benthic community.

LSA – South Belt

In the South Belt LSA, mean benthic invertebrate abundance ranged from 726 organisms/m^2 in the Koignuk River to 24,482 organisms/m^2 in Aimaokatalok Outflow (Table 6.2-17). The relatively large population of benthic invertebrates in Aimaokatalok Outflow consisted almost entirely of *Hydra* (small animals belonging to the phylum Cnidaria). In the remaining streams and rivers of the South Belt LSA, ostracods and dipterans (mostly chironomids) were abundant (Table 6.2-17). Benthic diversity was particularly low in Aimaokatalok Outflow (0.12), which can be explained by the nearly homogenous benthic assemblage consisting of 94% *Hydra*. In the remaining streams and rivers in the South Belt, mean Simpson's Diversity Indices ranged from 0.66 (Trout Outflow) to 0.84 (Koignuk River). Mean benthic genus richness ranged from 10 (Aimaokatalok Outflow) to 19 (Koignuk River).

RSA

In the RSA, mean abundance ranged from 664 organisms/m^2 in Aimaokatalok River to 21,777 organisms/m^2 in Pelvic Outflow (Table 6.2-17). Ditperans were the dominant benthic group in all RSA streams and rivers. The chironomid genera *Paratanytarsus* and *Rheotanytarsus* and the black fly family Simuliidae were among the most abundant dipteran taxa. Mean Simpson's Diversity Indices and richness were lowest in Reference A Outflow (0.45 and 9, respectively) and highest in Aimaokatalok River (0.87 and 20).

6.2.6.2 Freshwater Fish Habitat – Physical Characteristics

LSA – North Belt

Lakes are the predominant form of fish habitat in the North Belt LSA and supply most of the perennial fish habitat. Bathymetric surveys showed that lakes in the North Belt LSA are small to medium sized, with maximum depths ranging from 4.0 m (Wolverine) to 21.2 m (Windy) (Table 3.2-6 in Volume 5, Chapter 3). Several lakes in the area are shallower than 10 m. Surface areas of surveyed lakes range from 102,000 m^2 (Little Roberts) to 5,674,000 m^2 (Patch) and volumes range from 229,700 m^3 (Little Roberts) to 59,137,500 m^3 (Windy). There are un-surveyed lakes in this area with surface areas less than 102,000 m^2.

Fines (e.g., silt clay or mud) are the predominant substrate type in lakes of the North Belt LSA. Fine substrates are especially dominant in lakes in relatively close proximity to the ocean and for turbid lakes such as Glenn and Doris lakes. Gillnet and hydroacoustic assessments conducted at Doris and Patch lakes showed concentrations of fish associated with deep habitat over substrates of mud or fines.

Table 6.2-17. Summary of Stream and River Benthic Invertebrate Abundance and Taxonomy in the LSA and RSA

Stream	Benthic Invertebrate Abundance (organisms/m^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max		
LSA - North Belt					
AWRa	2,051	-	2,051	Dipterans	*Sergenta* (dipteran)
AWRb	9,256	-	9,256	Dipterans	Osctracods
Doris Outflow	761	25,054	207,867	Dipterans	various chironomids (dipterans)
Glenn Outflow Downstream	7,021	-	7,021	Dipterans	*Hydrobaenus* (dipteran)
Koignuk River (Upstream, Midstream, Downstream)	599	3,126	10,951	Dipterans	various chironomids (dipterans)
Little Roberts Outflow	85	6,419	25,042	Dipterans	various chironomids (dipterans)
Ogama Outflow	7,178	13,443	23,194	Dipterans	*Rheotanytarsus* and *Simulium* (dipterans)
P.O. Outflow	5,028	-	5,028	Dipterans	Nematodes
Patch Outflow	146	1,695	3,156	Dipterans	*Orthocladius* (dipteran)
Windy Outflow	358	2,075	4,097	Dipterans	*Simulium* (dipteran)
LSA - South Belt					
Aimaokatalok NE Inflow	267	2,403	4,407	Dipterans and Ostracods	Ostracods and *Valvata sincera sincera* (mollusc)
Aimaokatalok Outflow	24,482	-	24,482	Cnidarians	*Hydra* (cnidarian)
AWRc	1,203	-	1,203	Dipterans	*Psectrocladius* (dipteran)
Koignuk River	726	-	726	Dipterans	*Paratanytarsus* (dipteran)
Stickleback Outflow	251	3,110	10,043	Dipterans and Ostracods	Ostracods
Trout Outflow	1,451	5,325	13,896	Dipterans	Chironomidae larvae (dipteran)
RSA					
Aimaokatalok River	286	664	1,067	Dipterans	various chironomids
Angimajuq River Reference	774	-	774	Dipterans	*Paratanytarsus* (dipteran)
Boston Reference Outflow	462	19,704	38,946	Dipterans	*Rheotanytarsus* (diptera)
Pelvic Outflow	3,068	21,777	51,757	Dipterans	Simuliidae (dipteran)
Reference A Outflow	2,462	-	2,462	Dipterans	*Hydrobaenus* (dipteran)
Reference B Outflow	1,151	1,894	3,157	Dipterans	*Paratanytarsus* (dipteran)

Stream	Benthic Invertebrate Abundance (organisms/m^2)			Predominant Group (numerically)	Predominant Genera/Species (numerically)[a]
	Min	Mean	Max		
Reference D Outflow	2,064	8,872	24,015	Dipterans	*Pseudokiefferiella parva* (dipteran)
Roberts Outflow	3,740	6,816	15,801	Dipterans	*Hydra* (cnidarian)

Note:
[a] *Lowest available taxonomic level (usually genus or species).*

The Koignuk River within the North Belt LSA is large enough that it may provide perennial habitat for fish in some deep pools in the lower reaches, though the river has not been sampled for fish or dissolved oxygen concentrations during winter. For clarity, the Koignuk River is labelled as North Belt LSA even though it stretches from Aimaokatalok Lake to Hope Bay. Two barriers, a 5-m high waterfall 18.5 km from the mouth of the river and a 10-m high waterfall 23.8 km from the mouth of the river, appear to be high enough to prevent upstream migration of anadromous fish during average flows, although downstream migration may be possible. Their status as barriers is supported by the presence of two separate fish communities in the river: 1) resident fish in the upper river above the barriers; and 2) resident, anadromous (e.g., Arctic Char), and brackish water (e.g., Arctic Flounder) fish species in the lower river below the barriers. “Resident” in this river may simply mean resident during the ice-free season. In the absence of deep pools in the upper river, resident freshwater fish are expected to migrate to lakes to overwinter. The substrate of the Koignuk River is predominantly fines, which limits habitat use for various fish species, particularly for spawning salmonids.

Streams in the North Belt LSA are typical of slow-moving streams flowing through tundra wetlands. Most are ephemeral and provide temporary habitat for fish during periods of relatively high flow (i.e., spring and early summer months). Outflow streams from lakes are typically larger and flow throughout the open-water season, but freeze to the substrates in winter (e.g., Glenn Outflow, Doris Outflow). Channel and instream habitat characteristics are generally similar among these streams with some exceptions: Glenn Outflow and Doris Outflow differ substantially in habitat type. Streams supply relatively high quality habitat, especially for small-bodied fish species such as Ninespine Stickleback. Juvenile Lake Trout and Arctic Char have also been observed using larger streams for rearing habitat. All streams in the RSA (with the possible exception of deep pools in the lower reaches of the Koignuk River) freeze to the bottom in winter.

A waterfall on Doris Outflow is an impassable barrier to upstream fish migration hence there are two separate fish communities in the Doris Watershed: a freshwater resident community that inhabits lakes and streams upstream of the waterfall and a second community downstream of the waterfall that includes freshwater resident, anadromous, and marine fish species.

Most ponds in the North Belt LSA have poor habitat quality and many are non-fish-bearing because they contain little or no overwintering or spawning habitats and they have poor connectivity to larger waterbodies. Generally, ponds with maximum depths greater than 2 m and/or connectivity to larger bodies of water were found to contain small-bodied species such as Ninespine Stickleback. The generally poor habitat quality of ponds is due mainly to their small size – which is why they are distinguished as ponds rather than lakes. Ponds also tend to have other characteristics associated with their small size such as a relative absence of surface waves (due to short fetch) and uniform temperatures.

<u>LSA – South Belt</u>

The South Belt LSA is dominated by one large lake (Aimaokatalok Lake; formerly named Spyder Lake) that has a surface area of 22,969,460 m^2, a volume of 147,125,400 m^3, and a maximum depth of 30 m (Table 3.2-6 in Volume 5, Chapter 3). Stickleback and Trout lakes, two smaller lakes south of Aimaokatalok Lake, are both shallow (maximum depth = 4.1 m and 6.1 m, respectively) and have surface areas of 995,000 m^2 and 552,000 m^2, respectively.

Within the Ore Deposit area of Aimaokatalok Lake, relatively small and soft substrates including sand/gravel and mud made up 79% of the total substrate area. The Reference area also had a high proportion of small, soft substrates (57%). while cobble/large rock covered 42% of the area. Visual observations of shoreline habitat at Stickleback and Trout lakes indicated that fines and cobble are the dominant and subdominant forms of substrate, respectively.

Fish habitat assessments were conducted over 24 years at various sites in streams and ponds adjacent to potential infrastructure sites. In 2010, detailed stream assessments were conducted at 25 sites at freshet and 16 sites in low summer flows. A total of 7,678 m of the Aimaokatalok watershed was assessed, and split into 249 habitat units. These sites ranged from bankfull width of 53.3 m to 0.5 m, with an average bankfull width of 11.7 m and an average bankfull depth of 0.6 m. Glides were the most common habitat type followed by riffles and pools. Fine substrate was by far the most common substrate type (80%). Bedrock was uncommon, representing only 1.8% of the substrates. Instream vegetation accounted for over half of the total cover, and pool habitat was also common. Only one site had small woody debris cover, and it represented only 2.5% of cover at that site.

RSA

Surveyed lakes in the RSA vary widely in size and depth. Reference Lake D has the smallest surface area of 1,482,200 m^2, and Reference Lake B has the largest surface area of 7,695,000 m^2 (Table 3.2-6 in Volume 5, Chapter 3).Roberts Lake is the deepest lake surveyed (maximum depth = 37.5 m).

Small headwater lakes in the Roberts Lake drainage range in surface area from 6,000 m^2 to 360,000 m^2 and in maximum depth from < 2.0 m to 13.6 m (Table 6.2-18). The mean area of these headwater lakes is 99,000 m^2 (SE = 20,000, n = 20) and mean maximum depth is 4.7 m (SE = 0.8, n = 18).

Table 6.2-18. Surface Areas and Maximum Depths of Headwater Lakes of the Roberts Watershed

Lake	Area (m^2)	Max depth (m)
04	139,000	4.3
05	58,000	5.4
06a	360,000	3.0
06b	97,000	6.0
06c	55,000	4.0
06d	58,000	1.0[a]
07	51,000	3.0
07a	143,000	4.0
09	42,000	1.0[a]
10	198,000	13.6
12	45,000	5.7
13	259,000	4.5
14	185,000	4.2
31	6,000	1.0[a]
31a	17,000	-
31b	76,000	3.7
32	55,000	-
32a	28,000	8.0
33	69,000	11.0
35	31,000	1.2

Source: Golder (2007a).
a = half of maximum possible depth.
Dashes indicate no data available.

In the RSA, fish habitat was surveyed in 2009 and 2010 at Reference Lakes A, B, and D, and Little Roberts Lake (previously in RSA, now in LSA). Habitat in other lakes of the RSA such as Pelvic and

Roberts lakes was surveyed in previous years and was found to be generally similar to that of the reference lakes. Shoreline substrates of the reference lakes were predominantly bedrock with minimal littoral zone due their steep shorelines. Subdominant substrate types included boulder, fines, and cobble. Potential Lake Trout spawning shoals were characterized by clean, round cobble and boulder with large interstitial spaces within the substrate. In contrast, the littoral habitat of Little Roberts Lake was predominantly fines and organics, particularly at the inflows and at the outflow of the lake. Boulder and bedrock were also observed along the relatively steep western and northern shorelines.

Stream habitat was also surveyed in 2009 and 2010 in the outflows of three reference lakes, and one river. Streams were predominantly low gradient and consisted of riffle and glide habitat. Stream bed material was a mixture of gravel, cobble, boulder, and bedrock. Boulders were observed as the predominant substrate type and identified as the greatest source of cover for fish. Reference streams generally displayed a high amount of total cover.

A 200 m section of the Aimaokatalok River upstream of Aimaokatalok Lake was assessed as a reference site during freshet. During low summer flows, 106 m of the same section was assessed again. Two glides and one riffle were identified at the site, with glides making up over 90% of the total length of the site. The site was 83 m wide during freshet flows and 9.5 m wide in the summer. The substrates were predominantly boulders with lesser amounts of cobble, gravel, and fine materials mixed in. All cover at the site was cover from boulders.

6.2.6.3 Freshwater Fish Community

<u>Fish Species Richness</u>

Tables 6.2-19, 6.2-20, and 6.2-21 show the number of fish species (i.e., fish species richness) for lakes, ponds, and streams, respectively. A total of nine 9 species were found in lakes, 2 species in ponds, and 14 species in streams. None of these species are currently considered threatened or endangered (COSEWIC 2010). Figures 6.2-18 and 6.2-19 show waterbodies in the LSA and RSA that have been sampled for fish. Waterbodies where fish have been captured (any species) are identified as “fish presence confirmed”. Waterbodies that were sampled, but where no fish of any species were captured are identified as “no fish caught”.

Lakes

One lake in the North Belt LSA (Little Roberts Lake) has a species richness of seven. Four lakes (Doris, Patch, P.O., and Windy lakes) each have five species (Table 6.2-19). The other seven lakes sampled in the North Belt LSA have between one species (Nakhaktok and Imniagut lakes) and four species (Ogama and Glenn lakes).

In the South Belt LSA, Aimaokatalok Lake has a species richness of seven and the other two lakes that were sampled have between two species (Stickleback Lake) and three species (Trout Lake).

In the RSA, one lake (Roberts Lake) has a documented species richness of seven and the other 24 lakes have a species richness ranging from zero (Lakes 05, 06c, 07, 07a, 09, 14, 31, and 35) to four (Reference Lake B, Lake 04, and Pelvic Lake).

There are at least two factors influencing fish species richness in lakes (as well as in streams and ponds): size of waterbody and connection to the sea. Trophic status, as indexed by nutrient concentration, is known to influence fish production in lakes (Plante and Downing 1993), but not fish species richness.

Positive relationships between fish species richness and lake surface area have been reported for many regions of the world. Examples include Ontario (Eadie et al. 1986) and large lakes around the globe (Vadeboncoeur, McIntyre, and Vander Zanden 2011). The relationship is due to the increase in the diversity of habitat types with increasing lake size. The more habitat types there are, the more species can be supported. Similar relationships have been reported between fish species richness and stream area (e.g., Eadie et al. 1986).

A regression of log(fish species richness) on log(lake surface area) for 25 pooled lakes from the LSA and RSA was highly significant ($P < 0.001$) and explained 50% of the variance in log(fish species richness) (Figure 6.2-20). (Logarithmic transformation was required because of the three orders of magnitude range in lake area. This regression included Tail Lake to maximize sample size. Before it was fished out and converted to the TIA, Tail Lake supported Ninespine Stickleback and Lake Trout.)

A second factor affecting fish species richness in lakes and streams is access to the sea for anadromous and brackish water species. For example, Little Roberts Lake has a surface area that is less than 3% that of Roberts Lake and less than 0.5% that of Aimaokatalok Lake but it has the same species richness (seven) as those two lakes. One reason is the presence in Little Roberts Lake of anadromous species such as Arctic Char that migrate from Roberts Bay through Little Roberts Lake and Roberts Outflow to Roberts Lake.

Trophic status of waterbodies may influence fish species richness as well as fish production. Table 4.2.6 in Volume 5, Chapter 4 shows the trophic status of lakes in the RSA and LSA as indexed by Total Phosphorus (TP) trigger ranges shown in *Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems* (CCME 2004). There are six classes: ultra-oligotrophic ($TP < 0.004$ mg/L), oligotrophic ($TP = 0.004$-0.01 mg/L), mesotrophic ($TP = 0.01$-0.02 mg/L), meso-eutrophic ($TP = 0.02$-0.035 mg/L), eutrophic ($TP = 0.035$-0.1 mg/L), and hyper eutrophic ($TP > 0.1$ mg/L). Section 6.2.5.1 discusses the use of those trophic statuses in explaining variation in phytoplankton densities and biomasses among lakes in the LSA and RSA.

Mean fish species richness was calculated for each of the six classes of trophic status using the richness values of lakes that were assigned to each class (Table 6.2-22). Mean richness ranged from 3.8 to 4.5 and there were no increasing or decreasing trends with trophic class. The standard errors (SE) of the means ranged from 0.4 to 0.6, which is similar in magnitude to the differences among means. This data does not support the hypothesis that fish species richness is influenced by trophic status.

Ponds

Ninespine Stickleback and Cisco are the only fish species found in ponds (Table 6.2-20), hence species richness ranged from zero to two. In the North Belt LSA, Q13 was the only pond with both species. Of the remaining 13 ponds in the North Belt LSA, nine had only Ninespine Stickleback and six had no fish. In the South Belt LSA, five ponds contained Ninespine Stickleback. The remaining four ponds that were sampled had no fish. No ponds were surveyed in the RSA.

The low species richness for ponds compared to lakes is likely due to the much smaller size of ponds and the fact that many freeze to the bottom during winter, or nearly so, due to shallow depths. However, since surface areas are not available for ponds it is not possible to test that hypothesis. Ponds may also have low species richness because they tend to be less connected to other waterbodies than lakes and to be more ephemeral on annual and decadal time scales than lakes.

Table 6.2-19. Fish Communities of Lakes in the LSA and RSA, 1993-2017

Area	Waterbody	Watershed	Ninespine Stickleback	Lake Trout	Lake Whitefish	Cisco	Arctic Char	Least Cisco	Arctic Grayling	Broad Whitefish	Slimy Sculpin	Number of Species	Sampling Years
LSA - North Belt	Doris Lake	Doris	X	X	X	X	-	X	-	-	-	5	1995, 1996, 1997, 2003, 2005, 2007, 2009, 2015
LSA - North Belt	Imniagut Lake	Doris	X	-	-	-	-	-	-	-	-	1	2014, 2017
LSA - North Belt	Ogama Lake	Doris	X	X	X	X	-	-	-	-	-	4	1995-1996, 2006, 2009
LSA - North Belt	P.O. Connector Lake	Doris	X	X	X	-	-	-	-	-	-	3	2006
LSA - North Belt	P.O. Inflow Lake	Doris	X	-	-	X	-	-	-	-	-	2	2006
LSA - North Belt	P.O. Lake	Doris	X	X	X	X	-	X	-	-	-	5	2006, 2009
LSA - North Belt	Patch Lake	Doris	X	X	X	X	-	X	-	-	-	5	1995-1996, 1997, 2006, 2007, 2008, 2009
LSA - North Belt	Wolverine Lake	Doris	X	-	-	-	-	X	-	-	-	2	2006, 2007, 2008
LSA - North Belt	Little Roberts Lake	Roberts	X	X	X	X	X	X	-	X	-	7	2000, 2002-2003, 2009
LSA - North Belt	Glenn Lake	Windy	-	X	X	X	X	-	-	-	-	4	2007, 2009
LSA - North Belt	Nakhaktok Lake	Windy	X	-	-	-	-	-	-	-	-	1	2014
LSA - North Belt	Windy Lake	Windy	X	X	X	X	-	-	-	-	X	5	1995-1996, 2008-2009, 2012-2014
LSA - South Belt	Aimokatalok Lake	Aimaokatalok	X	X	X	X	-	X	X	-	X	7	1993-1994, 1996, 2006, 2008, 2010
LSA - South Belt	Stickleback Lake	Aimaokatalok	X	-	-	-	-	-	X	-	-	2	1995, 2006, 2010, 2017
LSA - South Belt	Trout Lake	Aimaokatalok	X	X	-	-	-	-	X	-	-	3	1995-1996, 2006, 2010
RSA	Boston Reference Lake	Aimaokatalok	X	X	-	X	-	-	-	-	-	3	2006
RSA	Reference Lake A	Reference A	X	X	X	-	-	-	-	-	-	3	2009
RSA	Reference Lake B	Reference B	X	X	-	-	X	-	-	-	X	4	2009-2010
RSA	Reference Lake D	Reference D	-	X	X	X	-	-	-	-	-	3	2010
RSA	Lake 04	Roberts	-	X	X	X	-	-	-	X	-	4	2006
RSA	Lake 05	Roberts	-	-	-	-	-	-	-	-	-	0	2006
RSA	Lake 06a	Roberts	-	-	-	-	X	-	-	-	-	1	2006
RSA	Lake 06b	Roberts	X	-	-	-	-	-	-	-	-	1	2006
RSA	Lake 06c	Roberts	-	-	-	-	-	-	-	-	-	0	2006
RSA	Lake 06d	Roberts	X	-	-	-	-	-	-	-	-	1	2006
RSA	Lake 07	Roberts	-	-	-	-	-	-	-	-	-	0	2006
RSA	Lake 07a	Roberts	-	-	-	-	-	-	-	-	-	0	2006
RSA	Lake 09	Roberts	-	-	-	-	-	-	-	-	-	0	2006
RSA	Lake 10	Roberts	X	X	-	-	X	-	-	-	-	3	2006-2007
RSA	Lake 12	Roberts	X	-	-	-	-	-	-	-	-	1	2006
RSA	Lake 13	Roberts	-	-	-	-	X	-	-	-	-	1	2006
RSA	Lake 14	Roberts	-	-	-	-	-	-	-	-	-	0	2006
RSA	Lake 31a	Roberts	X	-	-	-	-	-	-	-	-	1	2006
RSA	Lake 31b	Roberts	X	-	-	-	-	-	-	-	-	1	2006
RSA	Lake 32	Roberts	X	X	-	-	X	-	-	-	-	3	2006-2007
RSA	Lake 32a	Roberts	X	-	-	-	X	-	-	-	-	2	2006
RSA	Lake 33	Roberts	-	-	-	-	X	-	-	-	-	1	2006
RSA	Lake 35	Roberts	-	-	-	-	-	-	-	-	-	0	2006
RSA	Pelvic Lake	Roberts	-	X	X	X	-	X	-	-	-	4	1998, 2002, 2005
RSA	Roberts Lake	Roberts	X	X	X	X	X	X	-	X	-	7	2002-2007, 2010-2012
	Number of Lakes		**26**	**19**	**14**	**14**	**10**	**8**	**3**	**3**	**3**		

X = species reported. Dashes = species not reported.

LSA = Local Study Area and RSA = Regional Study Area.

Figure 6.2-18
Fish Presence in Sampled Freshwater Habitats, North Belt, 1993 - 2017

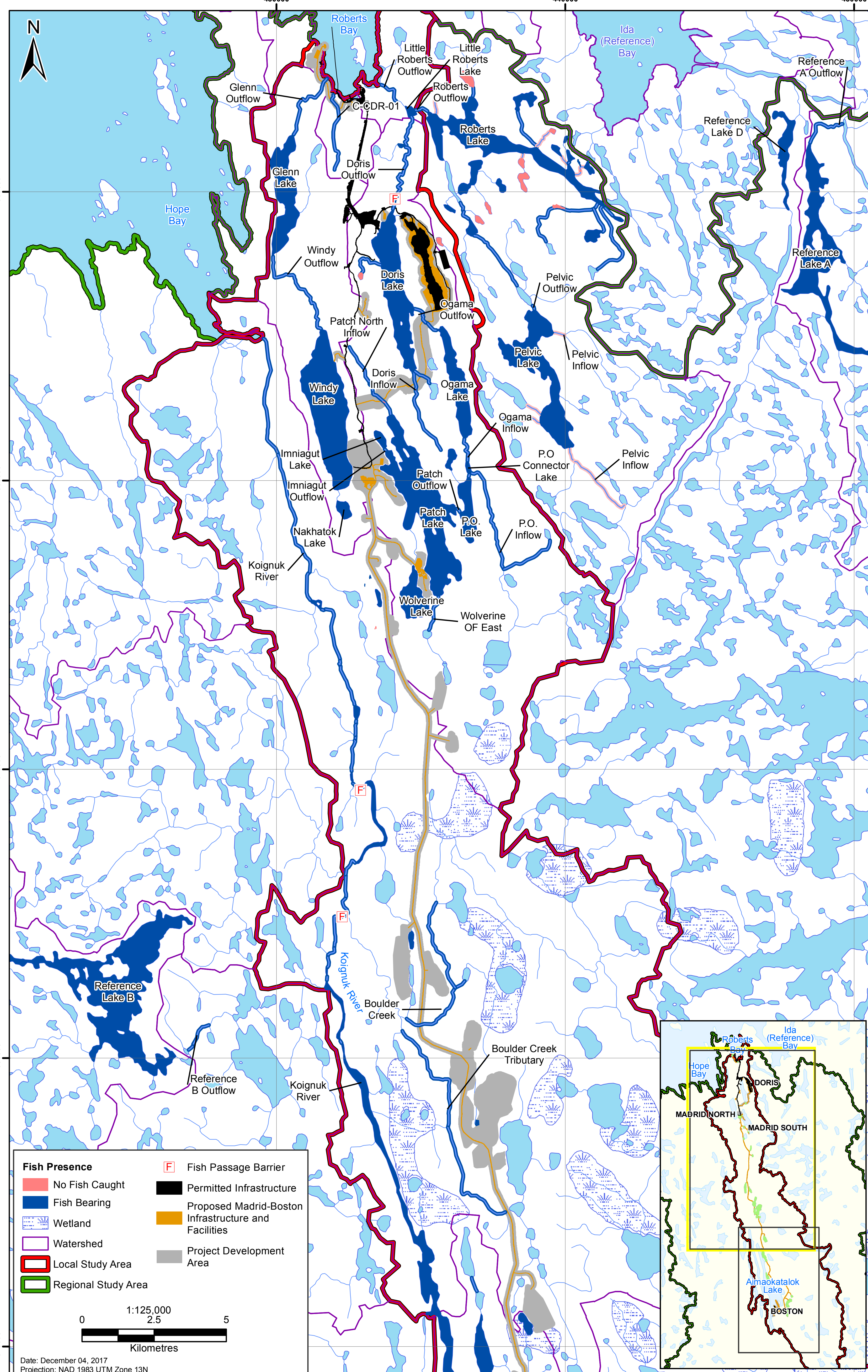
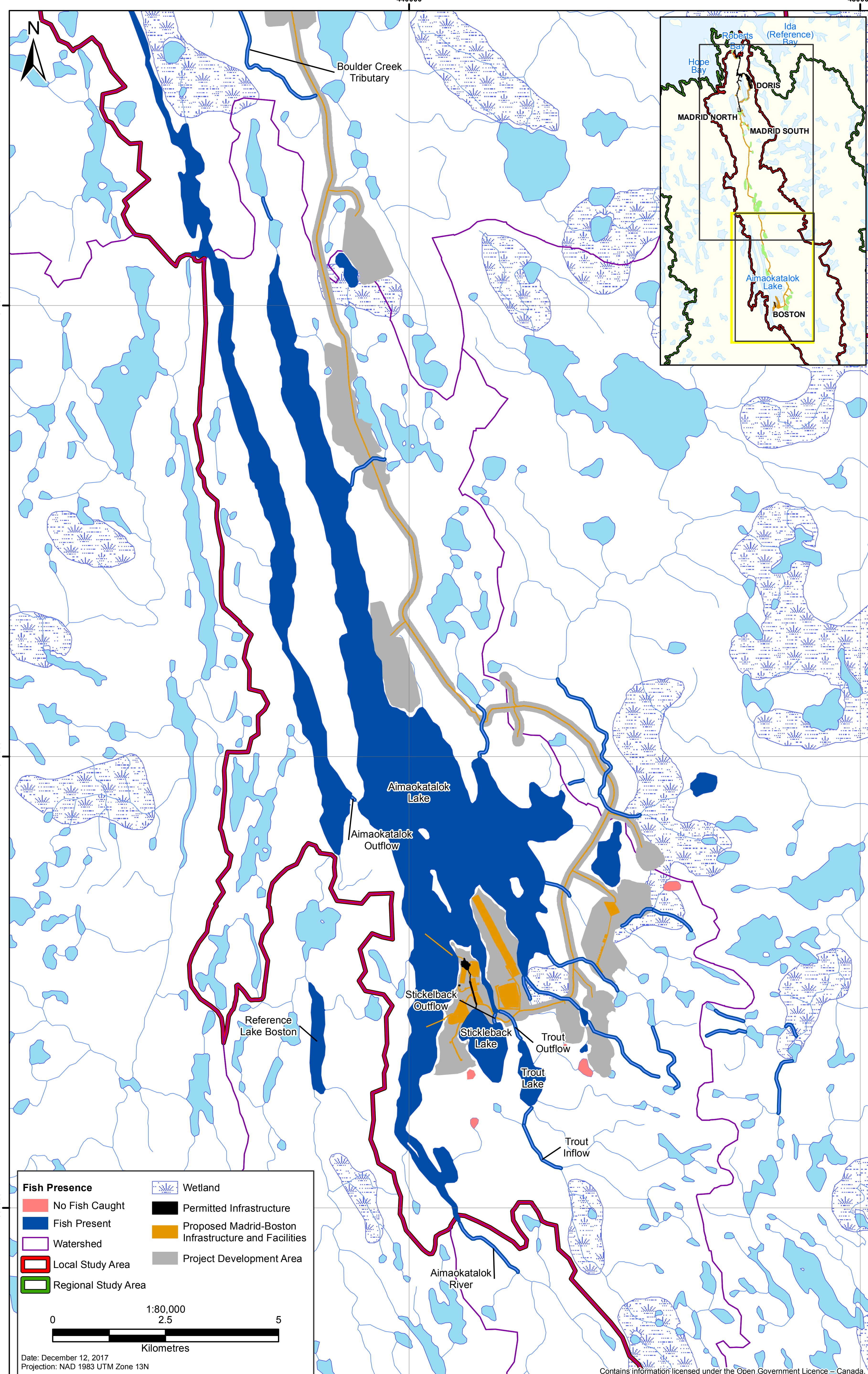


Figure 6.2-19
Fish Presence in Sampled Freshwater Habitats, South Belt, 1993 - 2017



Regression of Fish Species Richness on Lake Surface Area of Lakes in the LSA and RSA

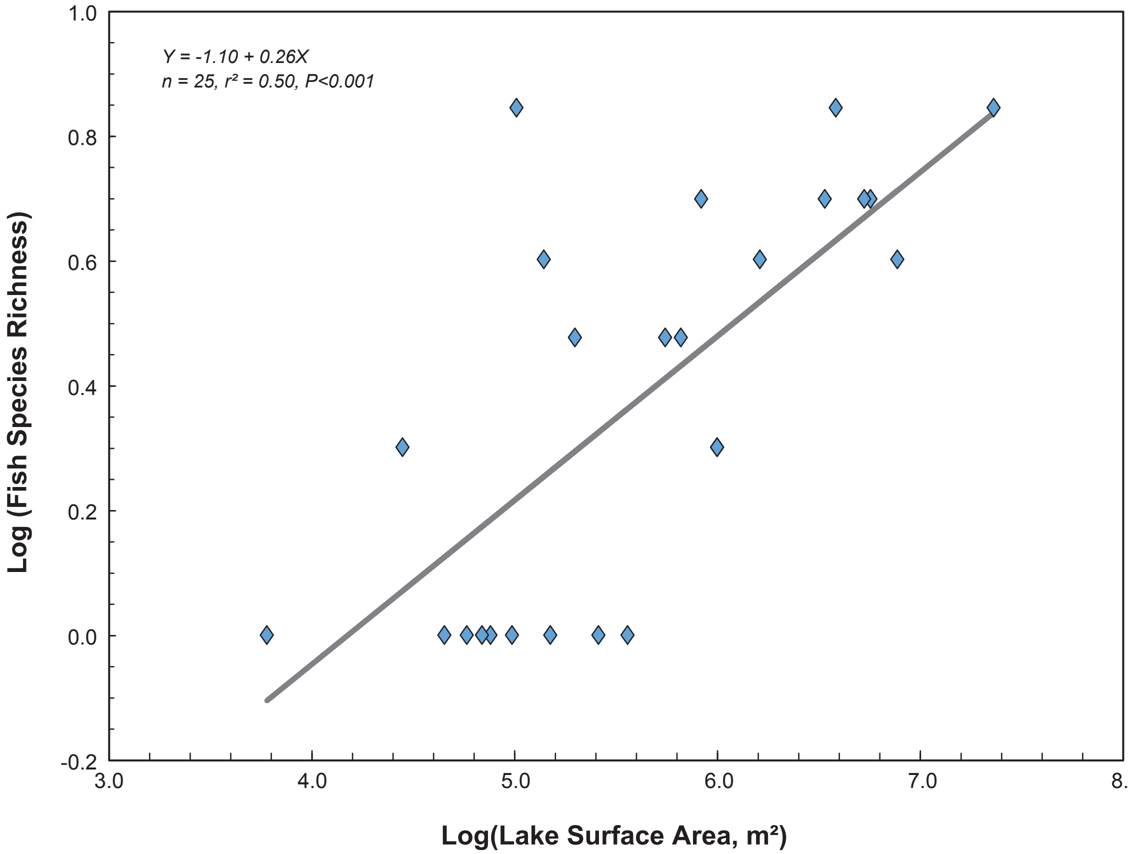


Table 6.2-20. Fish Communities of Ponds in the LSA, 1993-2017

Area	Waterbody	Watershed	Ninespine Stickleback	Cisco	Number of Species	Sampling Years
LSA - North Belt	Pond 1	Doris	-	-	0	2009
	Pond Q02	Doris	X	-	1	2010
	Pond Q04	Doris	X	-	1	2010
	Pond Q20	Doris	X	-	1	2014
	Pond Q21	Doris	X	-	1	2014
	Pond Q22	Doris	-	-	0	2014
	Pond TAS 2	Doris	X	-	1	2005
	Pond Q05	Koignuk	X	-	1	2010
	Pond Q06	Koignuk	X	-	1	2010
	Pond Q13	Koignuk	X	X	2	2014
	Pond Q14	Koignuk	X	-	1	2014
	Pond Q15	Koignuk	X	-	1	2014
	Pond Q16	Koignuk	-	-	0	2014
	Pond 2	Roberts	-	-	0	2009, 2014
LSA - South Belt	Boston Pond 1	Aimaokatalok	X	-	1	2017
	Boston Pond 2	Aimaokatalok	X	-	1	2017
	Boston Pond 3	Aimaokatalok	-	-	0	2017
	Boston Pond 4	Aimaokatalok	-	-	0	2017
	Pond Q08	Aimaokatalok	X	-	1	2010
	Pond Q10	Aimaokatalok	X	-	1	2010, 2014
	Pond Q11	Aimaokatalok	-	-	0	2014
	Pond Q23	Aimaokatalok	-	-	0	2014
	Pond Q25	Aimaokatalok	X	-	1	2014
Number of Ponds			**15**	**1**		

Notes:
X = species reported. Dashes = species not reported.
LSA = Local Study Area and RSA = Regional Study Area.

Rivers and Streams

Fourteen species were found in streams and rivers (Table 6.2-21), which was five species more than were found in lakes. The five species found in streams and rivers, but not lakes, were Burbot, Arctic Flounder, Fourhorn Sculpin, Greenland Cod, and Starry Flounder. The latter four species reside in the sea, but are able to tolerate brackish water and move short distances up rivers and streams. Arctic Flounder, Fourhorn Sculpin, and Greenland Cod were found in the Koignuk River and Arctic Flounder and Fourhorn Sculpin were found in Little Roberts Outflow. Starry Flounder was found in Glenn Outflow; each of these waterbodies is connected directly to the ocean.

The Koignuk River has the highest species richness (10) of any river or stream in the RSA and LSA, followed by Little Roberts Outflow (nine), Roberts Outflow (seven), and Pelvic Outflow (six). In the North Belt LSA, the remaining streams have observed species richness ranging from one (e.g., 12 different streams) to five (e.g., Doris Outflow and Glenn Outflow). In the South Belt LSA, the remaining streams have species richness ranging from zero (e.g., three different Aimaokatalok outflows) to five (e.g., Trout Outflow). In the RSA, the remaining streams have fish species richness ranging from zero (e.g., four different Roberts inflows) to 4 (e.g., Reference A Outflow and Roberts Inflow E04).

Table 6.2-21. Fish Communities of Rivers and Streams in the LSA and RSA, 1993-2017

Area	Watercourse	Watershed	Ninespine Stickleback	Lake Trout	Arctic Char	Arctic Grayling	Slimy Sculpin	Lake Whitefish	Cisco	Least Cisco	Burbot	Broad Whitefish	Arctic Flounder	Fourhorn Sculpin	Greenland Cod	Starry Flounder	Unidentified	Number of Species	Sampling Years
LSA - North Belt	Koignuk River	Koignuk	X	X	X[a]	X	X	X	-	-	X	-	X	X	X	-	-	10	1995, 1998, 2006, 2009-2010
LSA - North Belt	Doris Area N20	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - North Belt	Doris Inflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1997
LSA - North Belt	Doris Outflow	Doris	X	X	X[a]	-	-	X[a]	X	-	-	-	-	-	-	-	-	5	1995, 1997, 2000, 2003, 2005, 2009, 2010, 2016
LSA - North Belt	Doris Stream N20	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2014
LSA - North Belt	Imniagut Outflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2014, 2017
LSA - North Belt	Ogama Inflow	Doris	X	X	-	-	-	X	X	-	-	-	-	-	-	-	-	4	1995, 1997, 2006, 2017
LSA - North Belt	Ogama Outflow	Doris	X	X	-	-	-	X	X	-	-	-	-	-	-	-	-	4	1995, 1997, 2005, 2006, 2009, 2010, 2017
LSA - North Belt	P.O. Inflow N11	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - North Belt	P.O. Outflow	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2006, 2009
LSA - North Belt	Patch North Inflow 21	Doris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	1	2010, 2014
LSA - North Belt	Patch Outflow	Doris	-	X	-	-	-	-	-	-	-	-	-	-	-	-	X[b]	2	2006, 2017
LSA - North Belt	Wolverine Outlfow East	Doris	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2017
LSA - South Belt	Boulder Creek C01 (C-MBR-7)	Koignuk	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	2010, 2017
LSA - North Belt	Boulder Creek PRC 13	Koignuk	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2000
LSA - North Belt	Boulder Creek PRC 14	Koignuk	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2000
LSA - South Belt	Boulder Creek Tributary C02 (C-MBR-8)	Koignuk	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	2017
LSA - North Belt	Boulder Creek Tributary PRC 15	Koignuk	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	2000
LSA - North Belt	Little Roberts Outflow	Roberts	X	X	X	-	-	X	X	X	-	X	X	X	-	-	-	9	1997, 2000, 2003-2004, 2006-2007, 2016
LSA - North Belt	Roberts Bay Discharge Access Road	Roberts Bay	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2009
LSA - North Belt	Glenn Outflow	Windy	X	X	X	-	X	-	-	-	-	-	-	-	-	X	-	5	1997, 2000, 2003, 2009, 2010, 2017
LSA - North Belt	Windy Inflow	Windy	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1997
LSA - North Belt	Windy Outflow	Windy	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	1997, 2009, 2010
LSA - South Belt	Aimaokatalok River	Aimaokatalok	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2006
LSA - South Belt	Koignuk River	Koignuk	X	X	X[a]	X	X	X	-	-	X	-	-	-	-	-	-	8	1995, 1998, 2006, 2009, 2010
LSA - South Belt	Aimaokatalok Inflow BP05	Aimaokatalok	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	1997
LSA - South Belt	Aimaokatalok Inflow BP07	Aimaokatalok	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1997
LSA - South Belt	Aimaokatalok Inflow C03 (C-MBR-9)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2017
LSA - South Belt	Aimaokatalok Inflow C-MBR-17	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2017
LSA - South Belt	Aimaokatalok Inflow S03 (C-MBR-11)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010, 2017
LSA - South Belt	Aimaokatalok Inflow S04	Aimaokatalok	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	2010
LSA - South Belt	Aimaokatalok Inflow S11 (C-MBR-15)	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010, 2017
LSA - South Belt	Aimaokatalok Inflow S16 (C-MBR-16)	Aimaokatalok	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	2	2010, 2017
LSA - South Belt	Aimaokatalok Inflow BP08	Aimaokatalok	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1997
LSA - South Belt	Aimaokatalok Inflow BP09	Aimaokatalok	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	1997
LSA - South Belt	Aimaokatalok Inflow BP10	Aimaokatalok	X	X	-	X	-	-	-	-	-	-	-	-	-	-	-	3	1997
LSA - South Belt	Aimaokatalok Inflow BP11	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1997
LSA - South Belt	Boston Stream S33	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010, 2014
LSA - South Belt	Boston Stream S31	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Boston Stream S32	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Boston Stream S34	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010, 2014
LSA - South Belt	Boston Stream S25	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Boston 1 Tailings Stream S22	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Boston 1 East S24	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Boston 1 North	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Boston 2 Stream	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Boston 3 FT	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2010
LSA - South Belt	Stickleback Outflow	Aimaokatalok	X	-	-	X	X	-	-	-	-	-	-	-	-	-	-	3	1993, 1996, 1997, 2006, 2010, 2017

(continued)

Table 6.2-21. Fish Communities of Rivers and Streams in the LSA and RSA, 1993-2017 (completed)

Area	Watercourse	Watershed	Ninespine Stickleback	Lake Trout	Arctic Char	Arctic Grayling	Slimy Sculpin	Lake Whitefish	Cisco	Least Cisco	Burbot	Broad Whitefish	Arctic Flounder	Fourhorn Sculpin	Greenland Cod	Starry Flounder	Unidentified	Number of Species	Sampling Years
LSA - South Belt	Trout Inflow	Aimaokatalok	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1997, 2006
LSA - South Belt	Trout Outflow	Aimaokatalok	X	X	-	X	X	-	-	-	X	-	-	-	-	-	-	5	1993, 1996, 1997, 2006, 2010, 2017
RSA	Pelvic Inflow	Pelvic	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2005
RSA	Pelvic Outflow	Pelvic	X	X	X	-	-	X	X	X	-	-	-	-	-	-	-	6	2003, 2005
RSA	Reference A Outflow	Reference A	-	X	-	-	X	-	X	-	-	-	-	-	-	-	-	4	2009
RSA	Reference B Outflow	Reference B	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	2	2009
RSA	Roberts Inflow E04	Roberts	X	X	X	-	-	-	-	X	-	-	-	-	-	-	-	4	2006, 2007, 2010
RSA	Roberts Inflow E06	Roberts	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	2	2010
RSA	Roberts Inflow E07	Roberts	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	2	2003, 2006 2005
RSA	Roberts Inflow E09	Roberts	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	2003-2006, 2009-2015
RSA	Roberts Inflow E10	Roberts	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	2006, 2007
RSA	Roberts Inflow E11	Roberts	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	1	2003-2005, 2007
RSA	Roberts Inflow E12	Roberts	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	1	2003, 2005, 2006
RSA	Roberts Inflow E13	Roberts	X	-	X	-	-	-	-	-	-	-	-	-	-	-	-	2	2003, 2005, 2006
RSA	Roberts Inflow E14	Roberts	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	3	2003-2007, 2010-2014
RSA	Roberts Inflow E15	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2003, 2005
RSA	Roberts Inflow E31	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2005
RSA	Roberts Inflow E32	Roberts	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	1	2005, 2006
RSA	Roberts Inflow E33	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2005, 2006
RSA	Roberts Inflow E34	Roberts	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	2005
RSA	Roberts Outflow	Roberts	X	X	X	-	-	X	X	X	-	X	-	-	-	-	-	7	2002-2005, 2010-2015, 2016
	Number of Streams		**54**	**20**	**19**	**12**	**6**	**8**	**7**	**4**	**3**	**2**	**2**	**2**	**1**	**1**	**2**		

X = species reported. Dashes = species not reported.

LSA = Local Study Area and RSA = Regional Study Area.

a = present downstream of barrier

b = Coregonus sp

Table 6.2-22. Fish Species Richness of Lakes for Six Trophic Classes

Trophic Status	Total Phosphorus Concentration (mg/L)	Lakes	Mean	SE	n
Ultra-Oligotrophic	< 0.004	Windy, Reference A, Reference B, Reference D	3.8	0.5	4
Oligotrophic	0.004-0.01	Doris, Patch, P.O., Imniagut, Glenn, Windy, Aimaokatalok, Stickleback, Reference A, Reference B, Reference D, Roberts	4.3	0.5	12
Mesotrophic	0.01-0.02	Doris, Patch, P.O., Glenn, Windy, Ogama, Wolverine, Aimaokatalok, Stickleback, Trout, Boston Reference, Little Roberts, Reference B, Reference D, Roberts	4.4	0.4	15
Meso-eutrophic	0.02-0.035	Doris, P.O., Glenn, Ogama, Aimaokatalok, Stickleback, Trout, Boston Reference, Little Roberts, Pelvic, Reference D, Roberts	4.5	0.5	12
Eutrophic	0.035-0.1	Doris, Patch, Ogama, Wolverine, Nakhaktok, Trout, Little Roberts, Pelvic, Reference D	3.8	0.6	9
Hyper-eutrophic	> 0.1	P.O., Boston Reference, Pelvic	4.0	0.6	3

The same two factors drive fish species richness in river and streams as in lakes: a positive correlation between species richness and stream area (e.g., Eadie et al. 1986) and access by anadromous and brackish water species. The high species richness of the Koignuk River is partly due to the presence of brackish water species such as Arctic Flounder, Fourhorn Sculpin, Greenland Cod, and Starry Flounder in the lower river below the first of two barriers to upstream migration.

Fish Species Incidence

Ninespine Stickleback is the most common of the nine fish species in lakes, being found in 26 of the 40 lakes surveyed or 65% of all lakes (Table 6.2-19). The other eight species in lakes are, in order of descending incidence, Lake Trout (19 lakes or 48%), Lake Whitefish (14 lakes or 35%), Cisco (14 lakes or 35%), Arctic Char (10 lakes or 25%), Least Cisco (eight lakes or 20%), Arctic Grayling (three lakes or 7.5%), Broad Whitefish (three lakes or 7.5%), and Slimy Sculpin (three lakes or 7.5%).

Ninespine Stickleback is also the most common species in ponds, being found in 15 of the 23 surveyed ponds or 65% (Table 6.2-20). The only other fish found in ponds, Cisco, was captured in one pond or 4%.

Ninespine Stickleback is also the most common species in streams and rivers, being found in 54 of the 69 surveyed stream and river sites, or 78% (Table 6.2-21). The other 13 species found in streams and rivers are, in order of descending incidence, Lake Trout (20 streams or 29%), Arctic Char (19 streams or 28%), Arctic Grayling (12 streams or 17%), Lake Whitefish (eight streams or 12%), Cisco (seven streams or 10%), Slimy Sculpin (six streams or 9%),Least Cisco (four streams or 6%), Burbot (three streams or 4%), Broad Whitefish (two streams or 3%), Arctic Flounder (two streams or 3%), Fourhorn Sculpin (two streams or 3%), Greenland Cod (one stream or 1%), and Starry Flounder (one stream or 1%).

Estimates of Lake Fish Population Number and Density

Fish population estimates for lakes in the LSA were conducted with two methods: mark-recapture and hydroacoustics. Table 6.2-23 shows the estimates of fish population and density.

Table 6.2-23. Estimates of Lake Fish Population Number and Density

Lake	Species	Year	Method	Fish Number	Lower 95% CL	Upper 9% CL	Lake Area (ha)	Fish Density (no./ha)	Source
Tail	Lake Trout	2002	Peterson	2,630	1,313	4,275	76.6	34.3	RL&L/Golder (2003a)
Tail	Lake Trout	2002	Schnabel	2,632	1,725	5,511	76.6	34.4	RL&L/Golder (2003a)
Patch	Lake Trout	2007	MARK	1,159	825	1,680	567.4	2.0	Golder (2008a)
Doris	All fish	2009	Hydroacoustic	55,806	41,982	69,629	337.8	165.2	Rescan (2010)
Doris	Lake Trout	2009	Hydroacoustic	3,408	-	-	337.8	10.1	Rescan (2010)
Doris	Lake Whitefish	2009	Hydroacoustic	15,813	-	-	337.8	46.8	Rescan (2010)
Doris	Cisco	2009	Hydroacoustic	36,584	-	-	337.8	108.3	Rescan (2010)
Patch	All fish	2009	Hydroacoustic	33,619	17,499	49,740	567.4	59.3	Rescan (2010)
Patch	Lake Trout	2009	Hydroacoustic	18,259	-	-	567.4	32.2	Rescan (2010)
Patch	Lake Whitefish	2009	Hydroacoustic	14,142	-	-	567.4	24.9	Rescan (2010)
Patch	Cisco	2009	Hydroacoustic	1,218	-	-	567.4	2.1	Rescan (2010)
Aimaokatalok (Ore Body - Day)	All fish	2010	Hydroacoustic	-	-	-	-	12.0	Rescan (2011a)
Aimaokatalok (Ore Body - Dusk)	All fish	2010	Hydroacoustic	-	-	-	-	2.0	Rescan (2011a)
Aimaokatalok (Reference - Day)	All fish	2010	Hydroacoustic	-	-	-	-	48.0	Rescan (2011a)

Dashes indicate no data available.

In 2002, a mark-recapture study of Lake Trout in Tail Lake of the North Belt LSA was conducted using the numbers of tagged trout and the numbers of recovered tagged and untagged trout, all caught by gillnets. A population of 2,360 trout (with 95% confidence limits (CL) of 1,313 to 4,275) was calculated with the Peterson method and a population of 2,362 (95% CL: 1,725 to 5,511) was calculated with the Schnabel method. Using the estimate of Tail Lake surface area of 76.6 ha measured in 2000 gave a Lake Trout density of 34 fish/ha.

In 2007, a mark-recapture study of Lake Trout in Patch Lake of the North Belt LSA was conducted using the MARK method to calculate a population of 1,159 trout (95% CL: 825 to 1,680). The surface area of Patch Lake is 567.4 ha so Lake Trout density was 2.0 fish/ha. A 2009 hydroacoustic survey of Patch Lake estimated a total of 33,619 fish in the lake (95% CL: 17,499 to 49,740), which gave a total fish density of 59.3 fish/ha. Gillnet sampling in that same year showed that the three major fish species made up the following percentages of the catch: Lake Trout (54.3%), Lake Whitefish (42.1%), and Cisco (3.6%). Therefore, numbers and densities in 2009 were as follows: Lake Trout (18,258 and 32.2 fish/ha), Lake Whitefish (14,142, and 24.9 fish/ha), and Cisco (1,218 and 2.1 fish/ha).

In 2009, hydroacoustic surveys were also conducted in Doris Lake for fish. The total number of fish in Doris Lake was estimated to be 55,806 (95% CL: 41,982 to 69,629). The surface area of Doris Lake is 337.8 ha so total fish density was 165.2 fish/ha. Gillnet sampling conducted before and after the hydroacoustic survey showed that the three major fish species made up the following percentages of the catch: Lake Trout (6.1%), Lake Whitefish (28.3%), and Cisco (65.5%). Therefore, numbers and densities were as follows: Lake Trout (3,408 and 10.1 fish/ha), Lake Whitefish (15,183 and 46.8 fish/ha), and Cisco (36,584 and 108.3 fish/ha).

Gillnet and hydroacoustic assessment data collected in 2009 in Doris Lake showed that Lake Trout and Cisco relative abundance and density increased with depth, while Lake Whitefish relative abundance was highest in shallow locations (0 to 5 m).

In 2010, hydroacoustic surveys were conducted at two areas of Aimaokatalok Lake: the Ore Body area and the Reference area. Fish density at the Ore Body area was 12.0 fish/ha during the day and 2.0 fish/ha at dusk. Fish Density at the Reference area was 48.0 fish/ha during the day. The mean density for both areas was 20.7 fish/ha.

In summary, there are two estimates of whole-lake fish density: 59.3 fish/ha for Patch Lake and 165.2 fish/ha for Doris Lake. A third estimate of whole-lake fish density of 20.7 fish/ha is available for Aimaokatalok Lake, if one makes a reasonable assumption that surveys of the Ore Body and References areas are representative of the entire lake.

These three estimates of fish density agree with the ranking of trophic status of lakes as indexed by TP trigger ranges (CCME 2004). Aimaokatalok and Patch lakes, which have the lowest estimates of fish density, are both classified as oligotrophic-mesotrophic (Table 6.2-22). Doris Lake, which has the highest fish density, is classified as oligotrophic-eutrophic (Table 6.2-22).

<u>Life Histories, Habitat Preferences, and Distributions of Fish Species</u>

Tables 6.2-24 and 6.2-25 summarize the life histories and habitat preferences for fish species found in the LSA and RSA from 1993 to 2017. This information was summarized from Scott and Crossman (1973) and Richardson, Reist, and Minns (2001) plus other sources with information on fish distribution, migration, and diet that were derived from baseline surveys of the RSA and LSA.

Table 6.2-24. Life History Characteristics of Fish Species Captured during Freshwater Fish Community Surveys in the LSA and RSA

			Spawning		Fry Emergence	Habitat Preference		
Species	**Scientific Name**	**Primary Habitat-Depth Range**	**Timing**	**Habitat Preference**	**Timing**	**Juvenile Rearing**	**Adult Rearing**	**Overwintering**
Arctic Char (anadromous)	*Salvelinus alpinus*	Marine/ Freshwater - Benthopelagic	Sep-Oct	Freshwater lakes	Apr-Jul	Freshwater lakes and rivers	Marine, nearshore coastal areas, benthopelagic	Freshwater lakes
Arctic Grayling	*Thymallus arcticus*	Freshwater-Benthopelagic	May-Jun	Freshwater rivers and streams; gravel or rocky substrate	13-18 days after spawning	Freshwater lakes and rivers	Freshwater, benthopelagic	Freshwater lakes; deep pools in large rivers
Broad Whitefish	*Coregonus nasus*	Marine Estuaries / Freshwater - Benthopelagic	Aug-Oct	Freshwater rivers	Apr-May	Freshwater lakes and rivers	Freshwater, brackish, benthopelagic	Freshwater lakes
Burbot	*Lota lota*	Freshwater-Demersal	Jan-Mar	Freshwater lakes; bays and shoals with sand or gravel substrate	Feb-Jun	Freshwater lakes and rivers	Freshwater, benthopelagic	Freshwater lakes
Cisco	*Coregonus artedi*	Marine Estuaries / Freshwater - Benthopelagic	Sep-Oct	Freshwater lakes and rivers	Apr-May	Freshwater lakes and rivers	Freshwater, brackish, benthopelagic	Freshwater lakes
Least Cisco	*Coregonus sardinella*	Marine Estuaries / Freshwater - Benthopelagic	Sep-Nov	Freshwater, deep pools of rivers and lakes over sand and gravel substrates	Spring	Marine, nearshore, estuaries, move downstream to sea upon hatching	Freshwater (upriver migration in spring and summer), marine, nearshore, estuaries (downstream migration following spawning)	Estuaries, brackish water
Lake Trout	*Salvelinus namaycush*	Marine Estuaries / Freshwater - Benthopelagic	Sep-Nov	Freshwater lakes	Mar-Apr	Freshwater	Freshwater, brackish, benthopelagic	Freshwater lakes
Lake Whitefish	*Coregonus clupeaformis*	Marine Estuaries / Freshwater - Benthopelagic	Nov-Dec	Freshwater rivers and lakes	Apr-May	Freshwater or brackish	Freshwater, brackish, benthopelagic	Freshwater lakes
Ninespine Stickleback	*Pungitius pungitius*	Marine Estuaries / Freshwater - Benthopelagic	Jun-Jul	Freshwater, nearshore areas in lakes, ponds, streams	15 days after spawning	Freshwater or brackish, shallow, sheltered	Brackish, shallow, sheltered	Freshwater, brackish
Slimy Sculpin	*Cottus cognatus*	Marine Estuaries / Freshwater-Demersal	Jun	Freshwater, nearshore areas with rocky substrate	30 days after spawning	Freshwater lakes and rivers	Freshwater, demersal	Freshwater lakes

Note: Demersal = bottom feeders; Benthopelagic = feed in open water and on bottom

Table 6.2-25. Spawning and Fry Emergence Timing for Freshwater Species in the LSA and RSA

Species	Life stage	Habitat	Substrate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Arctic Char (anadromous)	Spawning	Freshwater lakes	Gravel or rocky shoals												
	Fry emergence	Freshwater lakes	Gravel or rocky shoals												
Arctic Grayling	Spawning	Freshwater rivers and streams	Small gravel or rocky substrate												
	Fry emergence	Freshwater rivers and streams	Small gravel or rocky substrate												
Broad Whitefish	Spawning	Freshwater rivers	Gravel or rocky substrate												
	Fry emergence	Freshwater rivers	Gravel or rocky substrate												
Burbot	Spawning	Freshwater lakes; bays and shoals	Sand or gravel substrate												
	Fry emergence	Freshwater lakes; bays and shoals	Sand or gravel substrate												
Cisco	Spawning	Freshwater rivers and lakes	Any; Gravel or rocky substrate preferred												
	Fry emergence	Freshwater rivers and lakes	Any; Gravel or rocky substrate preferred												
Least Cisco	Spawning	Freshwater, deep pools of rivers and lakes	Sand or gravel substrate												
	Fry emergence	Freshwater, deep pools of rivers and lakes	Sand or gravel substrate												
Lake Trout (anadromous)	Spawning	Freshwater lakes; shorelines and shoals	Large cobble, boulder or rubble												
	Fry emergence	Freshwater lakes; shorelines and shoals	Large cobble, boulder or rubble												
Lake Whitefish	Spawning	Freshwater rivers and lakes	Sand, gravel or rock												
	Fry emergence	Freshwater rivers and lakes	Sand, gravel or rock												
Ninespine Stickleback	Spawning	Freshwater, nearshore areas in lakes, ponds, streams	Organics, aquatic vegetation												

Species	**Life stage**	**Habitat**	**Substrate**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
	Fry emergence	Freshwater, nearshore areas in lakes, ponds, streams	Organics, aquatic vegetation												
Slimy Sculpin	Spawning	Freshwater, nearshore areas with rocky substrate	Gravel and rock												
	Fry emergence	Freshwater, nearshore areas with rocky substrate	Gravel and rock												

Note: Orange = spawning, green = fry emergence

Arctic Char

Arctic Char are present in northern coastal regions in rivers, lakes, estuaries, and marine environments. They exhibit both anadromous and lake resident (i.e., lacustrine) life histories. Arctic Char are the most economically important fish to the Inuit. In the Melville Sound area, commercial fisheries operate during upstream runs in Elu Inlet and the Kolgayok River (Fisheries and Oceans Canada 2004). TK shows that they are also a prized food fish (Section 6.1.1.1).

In the central Canadian Arctic, spawning of Arctic Char takes place in lakes, because most rivers freeze completely in winter (Johnson 1980; Tables 6.2-24 and 6.2-25). Spawning occurs in the fall, usually September or October, over gravel or cobble shoals and shorelines of lakes. Males arrive first on the spawning grounds and establish and defend territories. Females arrive later and are courted by males. Depending on substrate size, a female may either dig a nest or redd, in which the eggs are deposited, or broadcast eggs in water 3 to 6 m deep. Eggs incubate under ice for about six months.

In most systems, char are ready to take their first migration to sea at age four to five years and at a length of 150 to 250 mm (Johnson 1980). Smolts out-migrate to the sea in spring and early summer and feed throughout summer. Young Arctic Char do not venture much past the brackish water of river estuaries, but as they grow, they develop a tolerance to higher salinity sea water. They feed in nearshore areas along the coast for the duration of the summer. More abundant food resources in marine waters allow anadromous Arctic Char to grow faster and larger than the freshwater form. In the autumn, all char return to freshwater to overwinter to escape freezing in the sea (Johnson 1980). Arctic Char overwinter in lakes. Freshwater populations of Arctic Char feed on planktonic crustaceans, amphipods, molluscs, insects, and fishes, while marine populations are primarily piscivorous.

Arctic Char of the LSA and RSA are only found in lakes and streams with access to the sea either current or historical. In the North Belt LSA, Arctic Char have been found in Glenn Lake and in Glenn Outflow, in Doris Outflow below the barrier, in Little Roberts Lake and Little Roberts Outflow and in the lower Koignuk River below the first barrier located 18.5 km from the mouth of the river (Tables 6.2-19 and 6.2-21). (There is a second, higher barrier at kilometre 23.8.) Arctic Char are not present in lakes and streams of South Belt LSA nor are they present in any of the ponds surveyed in the LSA.

In the RSA, Arctic Char are present in the Roberts Watershed, including Roberts Outflow, Roberts Lake, and the headwaters of Roberts Watershed including lakes 06a, 10, 13, 31b, 32, 32a, and streams E04 Outlet, Roberts Inflows E06, E09, E10, E11, E13, E14, E32, and Pelvic Outflow. Their presence in Pelvic Outflow suggests they may also be present in Pelvic Lake, although they have not been captured there.

Arctic Char are present in Reference Lake B and in Reference B Outflow, both of which are connected to the Koignuk River. The population in Reference Lake B is most likely a resident population because of the barrier to upstream migration at kilometre 18.5 on the Koignuk River. Also, spawning of Arctic Char in the Koignuk River is unlikely because most rivers in the central Arctic freeze to the bottom during winter. Those few Arctic Char that have been found in the Koignuk River may be strays from other river-lake systems such as the Roberts system or they may have out-migrated as juveniles from Reference Lake B through Reference B Outflow and then fallen over the 5 m high barrier waterfall. After feeding and growing in the sea, some of those fish would have returned to the Koignuk River in the autumn, failed to swim up the waterfall, and then left the river in search of overwintering possibilities in other nearby systems such as the Roberts system.

Arctic Char have never been captured in Aimaokatalok Lake, the headwater lake of the Koignuk River, most likely because of the two waterfalls at 18.5 km and 23.8 km from the mouth of the river.

The Arctic Char population of Glenn Lake may also follow a mixture of resident and anadromous life histories. The lack of Arctic Char catches in Glenn Outflow suggests a predominantly resident life history. However, Glenn Outflow was rated as good for migration and rearing (Rescan 2001) in one year, so some Arctic Char may migrate from the lake to the sea and back again through Glenn Outflow. Surveys in other years have shown that upstream migration through the riffles of Glenn Outflow would be difficult at low flows.

Arctic Char found in Doris Outflow downstream of the impassable waterfalls are juveniles and appear to use that stream only for rearing. Those juveniles have to overwinter in lakes and so they most likely use lakes in the Roberts system.

The Arctic Char populations of the Roberts Watershed may follow both resident and anadromous life histories (Swanson et al. 2010b). Multiple years of sampling with fish fences at Roberts Outflow and Little Roberts Outflow and with fyke nets in Roberts Lake and gillnets in headwater lakes has provided a large database on Arctic Char migration timing and biological characteristics such as body size and age.

Lake Trout

Lake Trout are found throughout Nunavut, mostly in deep lakes, but they may also be found in large, clear rivers. Lake Trout typically exhibit both lacustrine and adfluvial life history forms and some populations contain anadromous individuals. TK shows that they are an important food fish (Section 6.1.1.1).

In the central Canadian Arctic, spawning of Lake Trout takes place in lakes, because most rivers freeze completely in winter (Tables 6.2-24 and 6.2-25). Lake Trout typically spawn from late September through to November. Spawning grounds are almost always associated with cobble, boulder and gravel substrates, where there is no vegetative cover, in depths less than 1 m to greater than 10 m. Eggs settle into interstitial spaces amongst the rocks, where they incubate for four to five months, with eggs usually hatching in March or April. To avoid mortality, Lake Trout lay eggs at a depth deep enough to avoid freezing in winter (ice can reach depths of up to 2 m).

After spawning, Lake Trout disperse into deeper water habitats, greater than 10 m in depth, and are often found in the pelagic zone. All Lake Trout overwinter in lakes.

Eggs incubate over the winter in interstices of the substrate and fry emerge in March to April. Young-of-the-year remain in spawning areas from several weeks to several months, moving into deeper areas as water temperatures rise to greater than 15°C. Young-of-the-year may briefly venture into streams. Juveniles both prefer areas of cobble and boulder substrate for cover, and inhabit waters with a depth range of 2 m to greater than 10 m. Juveniles are often associated with large boulders, which they use for cover.

Adult Lake Trout generally remain in lakes, utilizing deep water habitat. Exceptions occur in larger rivers, where Lake Trout may be found in large, deep pools that do not freeze in winter, and at deep river mouths. Juvenile and adult Lake Trout are known for long migrations within lake-stream chains, presumably in search of habitat and prey.

Anadromous populations of Lake Trout have been reported from four Arctic lakes in the West Kitikmeot region of Nunavut (Swanson et al. 2010b). Two of these lakes (Glenn Lake and Roberts Lake) are within the North Belt LSA and RSA, respectively (Tables 6.2-19 and 6.2-21). Swanson et al. (2010a) reported that 37 of 135 (or 27%) Lake Trout from Roberts Lake that were examined for otolith microchemistry made annual marine migrations. Anadromous Lake Trout were in significantly better condition than resident Lake Trout. Mean age of first migration for Lake Trout was 13 years, which was significantly older than that for Arctic Char (five years).

Lake Trout are apex predators and feed on a wide variety of prey including fish, molluscs, crustaceans, freshwater sponges, small mammals, and birds. Analyses of stomach contents from fish caught in the RSA and LSA found prey items derived from both marine and freshwater sources. For example, the diet of Lake Trout in Aimaokatalok Lake by weight was approximately 55% salmonids and 41% aquatic invertebrates (mainly the isopod *Saduria entomon*). Lake Trout from Reference Lake B fed primarily on Ninespine Stickleback (66% by weight), with the remainder of the diet comprised of aquatic invertebrates. Marine and freshwater isopods and amphipods were also found in relatively high abundance. Some species of isopods and amphipods found in freshwater were originally of marine ancestry but were trapped in some lakes of the RSA as the land rose after the most recent de-glaciation.

Lake Trout are widely distributed throughout the LSA and RSA because of their lake-resident and anadromous life histories. In the North Belt LSA, Lake Trout have been found in the Koignuk River and in eight lakes (Doris, Ogama, P.O., Patch, P.O. Connector, Windy, Glenn and Little Roberts (Table 6.2-19). They were also present in Tail Lake before it was converted to the TIA. Lake Trout have also been found in the streams connecting those lakes (Doris Inflow, Doris Outflow, Ogama Inflow, Ogama Outflow, Patch Outflow, Windy Outflow, Glenn Outflow and Little Roberts Outflow) (Table 6.2-21). Lake Trout are not present in four small lakes (P.O. Inflow, Wolverine, Imniagut, and Nakhaktok) or in the streams connecting those lakes (P.O. Inflow, P.O. Outflow, and Imniagut Outflow) or in smaller inflows to Doris Lake. Lake Trout are not present in any of the ponds surveyed in the North or South Belt LSA (Table 6.2-20).

In the South Belt LSA, Lake Trout have been found in two lakes (Aimaokatalok and Trout) and in the streams connecting those lakes (Aimaokatalok Inflows, Aimaokatalok River, Aimaokatalok Outflow, and Trout Outflow) (Table 6.2-19 and 6.2-21). Lake Trout have not been found in Stickleback Lake, Stickleback Outflow, Trout Inflow, and many small streams in the Boston area.

In the RSA, Lake Trout have been found in the larger lakes of the Roberts system (Roberts, 04, 10, 32, and Pelvic) and their connecting streams (Roberts Outflow, E04 Outflow, Roberts Inflows E06, E09, E10, E13, and E14, and Pelvic Outflow) (Table 6.2-19 and 6.2-21). Multiple years of sampling with fish fences at Roberts Outflow and Little Roberts Outflow and with fyke nets in Roberts Lake and gillnets in headwater lakes has provided a large database on Lake Trout migration timing and biological characteristics such as body size and age.

Lake Trout are also present in Reference Lake A, Reference A Outflow, Reference Lake B, Reference Lake D, and Boston Reference Lake. The presence of Lake Trout in the lower Koignuk River and Reference Lake B suggests that they may also be present in Reference B Outflow during the ice-free period.

In summary, the widespread distribution of Lake Trout in the LSA and RSA indicates the presence of multiple spawning populations – at least one for each medium and large lake. There are probably two separate populations in the Koignuk River: one in the upper river that overwinters in Aimaokatalok Lake, and another group of trout that rear in the lower river and overwinters in headwater lakes of other river systems.

Lake trout are not found in small lakes and ponds because those waterbodies most likely lack overwintering or spawning habitat. The presence of Lake Trout in so many streams indicates extensive migrations, a well-known aspect of Lake Trout behaviour, and consequent mixing of populations.

Arctic Grayling

Arctic Grayling are commonly found in clear water of large cold rivers, streams, and lakes throughout Nunavut. They exhibit lacustrine, adfluvial (i.e., lake-river), and fluvial (i.e., river resident) life histories. They are not anadromous and are never found in marine or brackish water. TK shows that they are a food fish (Section 6.1.1.1).

Arctic Grayling spawn from late-May through June, primarily in streams although they have been observed spawning in shallow water in Alaskan lakes, in association with inlet and outlet streams (Tables 6.2-24 and 6.2-25). Grayling generally prefer to spawn over gravel or coarse sand substrates; however, they have been observed to spawn over substrates ranging from mud to boulder (Bishop 1971; Hubert et al. 1985). Spawning generally occurs at warmer water temperatures near mid-day, and no nest or redd is prepared. The female may spawn only once, or several times in different areas. Eggs incubate for 13 to 18 days before hatching, with young grayling remaining in the gravel for three to four days before emerging.

Juveniles are found in lotic and littoral areas at shallow depths (< 0.5 m). Adults are found associated with sand, silt and gravel substrates in lakes, as well as rocky shorelines, and are typically a shallow water species, inhabiting depths less than 3.0 m deep. Although no specific information on overwintering habitat was found, grayling are assumed to overwinter in deep pools in rivers and in deep portions of lakes (Richardson, Reist, and Minns 2001).

Adult grayling feed on a variety of aquatic and terrestrial insects including mayflies, caddisflies, midges, bees, wasps, grasshoppers, ants, and a variety of beetles. Items occasionally found in the diet include fish, fish eggs, lemmings, and planktonic crustaceans.

Arctic Grayling have a more restricted distribution in the LSA and RSA than Lake Trout. In the LSA North, Arctic Grayling have been found only in the Koignuk River (Table 6.2-21). In the South Belt LSA, they have been found in three lakes (Aimaokatalok, Trout, and Stickleback; Table 6.2-19), in the streams that connect those lakes (Aimaokatalok River, Aimaokatalok Inflows, Trout Outflow, Stickleback Outflow; Table 6.2-21), and in several small streams of the Boston area that are tributaries to Aimaokatalok Lake (at sites C01, S04, and S16). They have not been found in Trout Inflow or Aimaokatalok Outflow. Arctic Grayling have not been found in any ponds in the LSA. In the RSA, Arctic Grayling have only been found in Reference B Outflow.

In summary, there are at least three populations of Arctic Grayling in the LSA and RSA: 1) one above the waterfalls of the Koignuk River that uses habitat in Aimaokatalok, Trout and Stickleback lakes and their connecting streams; 2) a second in Reference Lake B that uses spawning habitat in Reference B Outflow; and 3) a third population that uses spawning and rearing habitat in the lower Koignuk River and whose overwintering lakes are unknown.

Lake Whitefish

Lake Whitefish are found throughout Nunavut, predominantly in lakes, although they are also found in large rivers and brackish waters. Lake Whitefish may exhibit lacustrine, adfluvial, or anadromous life histories. TK does not indicate that they are a common food fish (Section 6.1.1.1).

Lake Whitefish spawn in both lakes and rivers over gravel, cobble, and boulders at depths less than 5 m (Tables 6.2-24 and 6.2-25). Eggs are released over the substrate and fall into interstices between rocks where they incubate for several months, hatching sometime from April to May. All Lake Whitefish overwinter in lakes.

Young-of-the-year are commonly found in the spawning area in shallow water (< 1 m) near the surface, and prefer substrates of boulder, cobble, and sand with abundant emergent vegetation and woody debris. Adults are usually found in the open water at depths greater than 10 m and do not show a preference for substrate. Adults are predominantly benthic, although they may be found in the pelagic zone. Lake Whitefish have been reported to make onshore movements into shallow water at night, possibly to feed.

Lake Whitefish typically feed on a wide variety of benthic invertebrates, planktonic crustaceans, and small fish; however they have been known to also eat insects at the surface of the water. The diet of Lake Whitefish in Aimaokatalok Lake was primarily mysid shrimp.

Lake Whitefish are widely distributed in the LSA and RSA, largely overlapping the distribution of Lake Trout. In the North Belt LSA, Lake Whitefish have been found in eight lakes (Doris, Ogama, P.O., Patch, P.O. Connector, Windy, Glenn and Little Roberts (Table 6.2-19). They have also been found in Ogama Inflow, Ogama Outflow and Little Roberts Outflow. This distribution suggests occasional use by Lake Whitefish of habitat in Patch Outflow, P.O. Outflow, and Windy Outflow.

Lake Whitefish are not present in any of the ponds surveyed in the North Belt LSA or South Belt LSA (Table 6.2-20).

In the RSA, Lake Whitefish have been found in lakes of the Roberts system (Roberts, E04, and Pelvic) and in the outflow streams of those lakes (Roberts Outflow, and Pelvic Outflow). They have also been found in Reference A Lake and Reference D Lake.

In the South Belt LSA, Lake Whitefish have been found in Aimaokatalok Lake, but not in Trout Lake or Stickleback Lake. They have not been found in any of the streams connecting those lakes or in small streams of the Boston area.

In summary, the lack of Lake Whitefish in small lakes and ponds indicates that they prefer deep lakes. This also follows from their focus on benthic prey. The relative absence of Lake Whitefish in streams indicates that they do not migrate among lakes to the same degree as Lake Trout.

Most of the Lake Whitefish found in lakes of the North Belt LSA and South Belt LSA are assumed to be lake-resident, i.e., not anadromous, because of the lack of direct access to the sea. The absence of Lake Whitefish in Glenn Outflow suggests that the population in Glenn Lake is also mainly resident. The absence of Lake Whitefish in Reference A Outflow and Reference D Outflow suggests that the populations in Reference Lake A and Reference Lake D are also resident. However, the presence of Lake Whitefish in Little Roberts Outflow, Roberts Outflow, and Pelvic Outflow suggests some degree of anadromy in Lake Whitefish of that drainage.

Cisco

The Cisco is one of three related species found in the central Arctic; the other two are Arctic Cisco and Least Cisco. Arctic Cisco has not been confirmed present in the freshwater fish LSA and RSA. Cisco used to be known as Lake Cisco. It primarily exhibits a lacustrine life history, although anadromous forms are known to occur.

Spawning takes place in the fall of the year in lakes and streams, usually from September to October (Scott and Crossman 1973; Tables 6.2-24 and 6.2-25). It typically takes place in shallow water 1 to 5 m deep, but deep-water spawning has been known to occur. Spawning most often takes place over sand and gravel substrates, but it has also been reported to occur over boulders, rubble, clay, mud and vegetation. Eggs incubate over the winter and hatch in the following spring just before ice breakup.

Juveniles rear in lakes and streams, initially close to shore and then further out in pelagic habitat over deeper water. In the LSA and RSA, all cisco overwinter in lakes.

Being a pelagic species the Cisco feeds primarily on plankton and to a lesser extent on large crustaceans, chironomid larvae, and young fish.

Ciscos are distributed in a similar manner as Lake Whitefish. In the North Belt LSA, Ciscos have been found in most of the larger lakes (Doris, Patch, Ogama, P.O., P.O. Inflow, Windy, Glenn and Little Roberts) (Table 6.2-19), as well as in Ogama Inflow, Ogama Outflow, Little Roberts Outflow plus Doris Outflow below the barrier. Ciscos were found in only one pond – Q13 (Table 6.2-20).

In the RSA, they have been found in Roberts Outflow, Roberts Lake, Lake 04, Pelvic Outflow, and Pelvic Lake (Table 6.2-20). They are also present in Reference A Outflow, Reference Lake D, and Boston Reference Lake. This distribution suggests that they are also present in Reference Lake A.

In the South Belt LSA, Ciscos have been found in Aimaokatalok Lake, but not in Trout Lake or Stickleback Lake or in any streams in South Belt LSA.

In summary, this distribution suggests that, like Lake Whitefish, Ciscos prefer to live in lakes and, unlike Lake Trout, only occasionally use stream habitat. Ciscos prefer deep lakes and rarely reside in small lakes and ponds.

It also suggests the presence of at least seven populations or population clusters of Cisco. The first resides in Doris, Patch, Ogama, P.O., and P.O. Inflow lakes. Migrants use Patch Outflow, P.O. Outflow, Ogama Inflow and Ogama Outflow to move among these lakes. The second population resides in Windy and Glenn lakes and uses Windy Outflow to move between lakes. The third population resides in Aimaokatalok Lake. The fourth population resides in lakes of the Roberts system and uses Little Roberts Outflow, Roberts Outflow, E04 Outflow, and Pelvic Outflow to move among lakes. The Ciscos that use habitat in Doris Outlet probably overwinter in lakes of the Roberts system. The remaining three populations reside in Reference Lake A, Reference Lake D, Boston Reference Lake, and their outflow streams.

Least Cisco

The Least Cisco has similar life histories and biology to Cisco (Tables 6.2-24 and 6.2-25). It has both lacustrine and semi-anadromous populations. Spawning occurs from September to November in lakes and deep pools in river over sandy substrate. Eggs hatch in spring and juveniles remain near the spawning site for the first year. They are largely pelagic and feed on zooplankton, crustaceans, and small fish.

Least Ciscos were found in a reduced sub-set of lakes and streams of the LSA and RSA where Cisco were present. In the North Belt LSA, Least Ciscos were found in Doris, Patch, P.O., Wolverine and Little Roberts lakes (Table 6.2-19), but not in their connecting streams except for Little Roberts outflow. This suggests that they rarely migrate among lakes and so they were rarely captured in streams.

Least Ciscos were not found in streams or ponds of the LSA (Table 6.2-20).

In the RSA, Least Ciscos were found in Roberts Outflow, Roberts Lake, E04 Outflow, Pelvic Outflow, and Pelvic Lake. This suggests they must be present in Lake E04. They were also found in Reference A Outflow, which suggests they must also be present in Reference Lake A.

In the South Belt LSA, Least Ciscos were found only in Aimaokatalok Lake (Table 6.2-19). They were not found in any streams of the South Belt LSA.

This distribution is similar to that of Cisco, but with fewer lakes and streams. Like Ciscos, Least Ciscos prefer deep lakes and are found in Aimaokatalok Lake and throughout the Roberts system. They are even more reluctant than Ciscos to migrate through streams. There appear to be three populations or clusters of populations of Least Ciscos: one that lives in Doris, Patch, P.O., and Wolverine lakes, a second that lives in Aimaokatalok Lake, and a third that lives in the Roberts system.

Broad Whitefish

Broad Whitefish are harvested for food by Inuit (Section 6.1.1.1). They are most commonly found in streams, but can also be found in lakes as well as in brackish waters (Tables 6.2-24 and 6.2-25). They spawn in rivers from May to October on gravel bottoms, especially those with finer gravel. Fry emerge in March and April. Juveniles rear in lakes and rivers. Adults and juveniles overwinter in lakes. Adults are much larger than Lake Whitefish, and their maximum age is reported to be 15 years. Broad Whitefish are benthic feeders and mainly eat aquatic insect larvae, small molluscs, and crustaceans.

Broad Whitefish have a restricted distribution in the LSA and RSA. They were not found in lakes, streams, and ponds of the South Belt LSA. However, they were found in lakes and streams of the Roberts system in the North Belt LSA and RSA, including Little Roberts Lake, Roberts Lake, Lake 04, Little Roberts Outflow, and Roberts Outflow (Tables 6.2-19 and 6.2-21). It is reasonable to suggest that the tributary leading from Roberts Lake to Lake E04 has been used as a migration corridor. It is also reasonable to assume that some of the Broad Whitefish that reside in this system migrate to and from brackish water in Roberts Bay.

The Roberts system appears to facilitate anadromy in the fish species that reside in its lakes and streams, including Arctic Char, Lake Trout, Lake Whitefish, and Broad Whitefish.

Burbot

Burbot are the only freshwater member of the cod (Gadidae) family. They are widespread in northern Canadian lakes and streams. TK does not indicate that they are a common food fish (Section 6.1.1.1).

Burbot generally inhabit deep waters in lakes; however, they migrate into the shallow littoral zones to spawn in mid-winter (Scott and Crossman 1973; Tables 6.2-24 and 6.2-25). Juvenile Burbot often spend the early summer feeding in tributary streams to lakes. By July, most Burbot have returned to the deepest portions of the lakes.

Adult Burbot are apex predators, with a diet similar to Lake Trout (Scott and Crossman 1973; Cott, Johnston, and Gunn 2011). Juvenile Burbot feed on aquatic insects and crustaceans, while adults feed primarily on fish.

The distribution of Burbot in the LSA and RSA is less well known because they are more difficult to catch in lakes than other species due to their preference for deep, benthic habitat. Burbot were not found in any lakes in the LSA or RSA (Table 6.2-19). In the North Belt LSA, they were found only in the Koignuk River. It is not known where they overwinter. In the South Belt LSA, Burbot were only found in Trout Outflow (Table 6.2-21), which suggests they are present in Aimaokatalok Lake. They were not found in any streams in the RSA or in any ponds in the LSA.

Burbot in the LSA and RSA may have a population structure similar to that of Arctic Grayling: one population above the waterfalls of the Koignuk River that uses overwintering habitat in Aimaokatalok Lake and juvenile rearing habitat in its tributaries, and a second group that rears in the lower Koignuk River, Reference B Outflow, and Reference Lake B.

Ninespine Stickleback

Ninespine Stickleback is widely distributed throughout Canada, occupying both freshwater and marine habitats. Stickleback may occupy a variety of habitats, including small streams and deep lakes (Tables 6.2-24 and 6.2-25). Ninespine Stickleback has the smallest body size of any of the 14 fish species captured in the RSA and can live in water too shallow for most other species. It has a wide tolerance ranges for temperature and dissolved oxygen. Ninespine Stickleback is not a food fish (Section 6.1.1.1). However, it is an important prey species for Lake Trout.

Ninespine Stickleback spawns in summer, usually in shallow water with organic, fines or mud substrates and aquatic vegetation (Scott and Crossman 1973; Arai and Goto 2005). Stickleback feed primarily on small aquatic insects and plankton (Scott and Crossman 1973).

Ninespine Stickleback is the most widely distributed fish species in the LSA and RSA as a result of its small size and wide tolerance for extremes of temperature and water quality (Tables 6.2-19, 6.2-20, and 6.2-21). It was found in every lake of the North Belt LSA with the apparent exception of Glenn Lake (Table 6.2-19). This exception may have been the result of low sampling effort or the use of a gear such as gillnets that do not easily catch such a small-bodied fish because there is no reason to suggest that Glenn Lake lacks their preferred habitat. Ninespine Stickleback has also been found in every surveyed stream of the North Belt LSA with the exception of Patch Outflow and Patch North Inflow (Table 6.2-21). Their presence in Glenn Outflow and Windy Outflow strongly suggests they are also present in Glenn Lake.

Ninespine Stickleback is present in all three lakes of the South Belt LSA and in all streams of the South Belt LSA with the exception of three Aimaokatalok inflows (sites BP07, BP08 and BP09) of the Boston area. In the RSA, they have been found in 12 of the 25 surveyed lakes and in nine of the 19 surveyed streams. They were also found in 15 of the 23 ponds surveyed in South Belt LSA and the RSA (Table 6.2-20). Their absence in the other eight ponds was assumed to reflect real absence, considering the small, shallow nature of those ponds.

In summary, Ninespine Stickleback has been found in every waterbody of the LSA and RSA except for small lakes and ponds that are too shallow, ephemeral, and unconnected to support them.

Slimy Sculpin

Slimy Sculpin is a common species in cold, rocky streams and lakes of northern Canada. It is not a common food fish (Section 6.1.1.1)

Slimy Sculpin spawn in early summer in shallow habitat of lakes and streams (Scott and Crossman 1973; Tables 6.2-24 and 6.2-25). Fry emerge approximately 30 days later. Juveniles rear in lakes and streams. All Slimy Sculpin overwinter in lakes. Prey is mainly benthic invertebrates plus drifting insects captured while resident in streams.

In the North Belt LSA, they were found in the Koignuk River, Windy Lake, Glenn Outflow, and Doris Outflow below the barrier (Tables 6.2-19 and 6.2-21). Their presence in Windy Lake and Glenn Outflow suggests that they are also present in Windy Outflow and Glenn Lake.

In the South Belt LSA, Slimy Sculpin were found in Aimaokatalok Lake, Trout Outflow, Stickleback Outflow, and one small stream in the Boston area (site S05). In the RSA, they were found in Reference Lake B and Reference A Outflow. This suggests that they are present in both Reference Lake A and Reference B Outflow.

In summary, there appear to be four populations of Slimy Sculpin in the LSA and RSA. The first overwinters in Windy Lake and Glenn Lake and uses rearing habitat in Windy Outflow and Glenn Outflow. The second population uses rearing habitat in Doris Outflow below the waterfall, but it has to overwinter in one or more lakes – most likely in Little Roberts Lake since Slimy Sculpin were not commonly caught in the fish fence on Roberts Outflow. The third population overwinters in Reference Lake B and rears in Reference B Outflow and the Koignuk River. The fourth population overwinters in Aimaokatalok Lake and uses rearing habitat in tributaries to that lake and in the upper Koignuk River above the two waterfalls.

6.3 VALUED COMPONENTS

6.3.1 Potential Valued Components and Scoping

Valued Ecological Components (VECs) are those components of the freshwater environment considered to be of scientific, ecological, economic, social, cultural, or heritage importance (Volume 2, Chapter 4). The selection and scoping of VECs considers biophysical conditions and trends that may interact with the Project, variability in biophysical conditions over time, and data availability as well as the ability to measure biophysical conditions that may interact with the Project and are important to the communities potentially impacted by the Project.

6.3.1.1 Scoping Process and Identification of VECs

The scoping of VECs follows the process outlined in the Effects Assessment Methodology (Volume 2, Chapter 4). VECs considered for inclusion in the freshwater fish effects assessment relate to the role of fish and fish habitat in the freshwater aquatic environment as well as the value placed on fish and fish habitat for commercial, recreational, traditional, and cultural use (NIRB 2012a).

The EIS guidelines (NIRB 2012a) propose a number of VECs that were considered for inclusion in the freshwater fish effects assessment. These are identified in the EIS guidelines as components of the freshwater aquatic environment, as follows:

- Aquatic ecology;
- Aquatic biota (including representative fish as defined in the Fisheries Act, benthic invertebrates, and other aquatic organisms);
- Habitat including fish habitat as defined in the *Fisheries Act*; and
- Commercial, recreational, and Aboriginal fisheries as defined in the *Fisheries Act*.

The VECs identified in the EIS guidelines represent an appropriate starting point to guide the identification and scoping of VECs (NIRB 2012a). The selection of VECs began with those proposed in the EIS guidelines and was further informed through consultation with communities, regulatory agencies, available TK, professional expertise, regulatory considerations, and the NIRB's final scoping report (Appendix B of the EIS Guidelines; NIRB 2012a). For an interaction to occur there must be spatial and temporal overlap between a VEC and Project components and/or activities. The determination of VECs and potential effects for inclusion in the freshwater fish effects assessment considered and was informed by:

- The Environmental Impact Statement (EIS) guidelines and appendices (NIRB 2012a);
- Available traditional knowledge information from the *Inuit Traditional Knowledge for TMAC Resources Inc., Hope Bay Project, Naonaiyaotit Traditional Knowledge Project* (NTKP) report

(Banci and Spicker 2016) which presents summary information and distribution maps of valued fish species, freshwater fish habitat, and traditional land use activities;

- Consultation and engagement with local and regional Inuit groups (for example, the KIA);
- The public, during public consultation and open house meetings held in the Kitikmeot communities (see Volume 2, Chapter 3; Public Consultation and Engagement);
- Consultation with regulatory agencies;
- Regulatory consideration of the legislation that exists to protect fish and fish habitat including the *Fisheries Act*, MMER Regulations, and SARA (no fish species listed under SARA identified in freshwater baseline studies); and
- Review of the freshwater fish and fish habitat sections of recently completed Nunavut EAs (e.g., Back River, Mary River).

The content and results of other EIS chapters were also reviewed to inform the selection of freshwater fish VECs and effects including Surface Hydrology (Volume 5, Chapter 1), Limnology and Bathymetry (Volume 5, Chapter 3), Freshwater Water and Sediment Quality (Volume 5, Chapter 4 and 5, respectively) and the Human Health and Environmental Risk Assessment (Volume 6, Chapter 5). These chapters are referenced in the assessment, where appropriate.

6.3.1.2 NIRB Scoping Sessions

Scoping sessions hosted by NIRB (NIRB 2012b) with key stakeholders and local community members (i.e., the public) focused on identifying the components that are important to local residents, as related to the Madrid-Boston Project. Comments made during these sessions were compiled and analysed as part of VEC scoping. Notably, the main remarks related to the freshwater environment and linked to freshwater fish were those concerned with water quality (fish habitat) and fishing as a traditional land use and harvesting activity. The comments received can be summarized as follows:

Freshwater Quality

- Dust during spring-run off could impact the environment.
- Water should be left as clean as when the mine first started.

Land Use and Inuit Harvesting

- Fish are eaten when Inuit go out on the land. The connection to the land is important and is a part of healing group.

6.3.1.3 TMAC Consultation and Engagement Informing VEC Selection

Community meetings for the 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 and public feedback (questions, comments, and concerns) about the Project was obtained through open dialogue during presentations, through discussions that arose during the presentation of Madrid-Boston Project materials and comments provided in feedback forms. Questions, comments, and concerns related to freshwater fish included:

- Workers ability/permission to fish while at camp;
- Impacts to fish and fish health; and

- Plenty of whitefish and trout in Patch Lake.

6.3.2 Valued Components Included in the Assessment

The scoping analysis identified the following VECs for inclusion in the assessment:

1. Fish habitat
2. Fish community: Lake Trout
3. Fish community: Arctic Grayling
4. Fish community: Arctic Char (freshwater life history)
5. Fish community: Cisco/Whitefish (freshwater life histories)

The VECs selected to guide the assessment of the potential effects of the Madrid-Boston Project on freshwater fish are those:

- that have potential to interact with the activities and components of the Project;
- identified as important by local communities, Inuit organizations, governments, regulators, and other stakeholders during consultation and engagement;
- protected under legislation including the *Fisheries Act,* and MMER Regulations; and
- informed by Inuit IQ (Volume 2, Chapter 2; Traditional Knowledge) and professional judgement.

Table 6.3-1 summarizes the VECs included in the freshwater fish assessment. The components of the freshwater aquatic environment proposed as VECs by the EIS guidelines (NIRB 2012a) were considered in the scoping process and recognized as being included in relevant freshwater environment assessment areas (e.g., surface hydrology, freshwater water quality, freshwater sediment quality) and/or as belonging to one of two broader categories of freshwater fish VECs: 1) fish habitat; and 2) fish community as represented by VEC fish species (See Table 4.3-1, Volume 2, Chapter 4).

Freshwater aquatic ecology (proposed as a VEC by the EIS guidelines) includes relationships between aquatic organisms and their environments and relationships among aquatic organisms. Potential Project effects on the freshwater aquatic environment are assessed in the preceding chapters of Volume 5 of this EIS including, Chapter 1 (Surface Hydrology), Chapter 4 (Freshwater Water Quality), and Chapter 5 (Freshwater Sediment Quality). In these chapters, effects on aquatic organisms through their interactions with the freshwater aquatic environment are also considered. For example, water quality and sediment quality indicators were used that have quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life and derived site-specific water quality objectives. The assessment of effects on aquatic ecology is also incorporated into the assessment of the freshwater fish habitat VEC in this chapter through examination of potential effects on fish habitat, which includes physical characteristics (e.g., water quality, sediment quality, available area, flow) and biological resources (e.g., primary and secondary producers and forage fish). The freshwater fish habitat VEC assessment therefore considers aquatic ecology through potential Project effects that may impact relationships between the aquatic environment (i.e., fish habitat) and aquatic organisms (i.e., components of fish habitat and fish.)

Table 6.3-1. Valued Ecosystem Components Included in the Freshwater Fish Assessment

VEC	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Regulations and Regulators	
Fish Habitat	X	X	X	TK and land users indicated freshwater fish habitats that are used as areas of general fishing effort in the Project area (Banci and Spicker 2016). Habitat including fish habitat as defined in the *Fisheries Act* is identified as a candidate VEC in the EIS guidelines (NIRB 2012a). Fish habitat as defined in the *Fisheries Act* includes both biological resources and physical characteristics. Aquatic ecology, aquatic biota (including representative fish as defined in the *Fisheries Act*, benthic invertebrates, and other aquatic organisms) and habitat (including fish habitat as defined in the *Fisheries Act* which comprises both biological resources and physical characteristics) were identified as candidate VECs in the EIS guidelines (NIRB 2012a). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish which includes any permanent alteration to, or destruction of fish habitat. Information from TK, land users, and baseline studies in the Project area indicate that multiple freshwater fish habitats overlap with Project activities.
Fish Community - Lake Trout	X	X	X	TK and land users identified Lake Trout as important food fish for Inuit (Banci and Spicker 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish that are part of a CRA fishery. As a CRA fishery species, Lake Trout were identified as a candidate VEC and information on Lake Trout was specifically requested in the EIS guidelines with respect to the biophysical environment and impact assessment (NIRB 2012a). Information from TK, land users, and baseline studies in the Project area indicate that the distribution of Lake Trout overlaps with Project activities.
Fish Community - Arctic Grayling	X	X	X	TK and land users identified Arctic Grayling as a species fished for by Inuit (Banci and Spicker 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish that are part of a CRA fishery. As a CRA fishery species, Arctic Grayling were identified as a candidate VEC and information on Arctic Grayling was specifically requested in the EIS guidelines with respect to the biophysical environment and impact assessment (NIRB 2012a). Information from TK, land users, and baseline studies in the Project area indicate that the distribution of Arctic Grayling overlaps with Project activities.

VEC	Identified by			Rationale for Inclusion
	TK	NIRB Guidelines	Regulations and Regulators	
Fish Community - Arctic Char (freshwater life history)	X	X	X	TK and land users identified Arctic Char as an important food fish for Inuit (Banci and Spicker 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish that are part of a CRA fishery. As a CRA fishery species, Arctic Char were identified as a candidate VEC and information on Arctic Char was specifically requested in the EIS guidelines with respect to the biophysical environment and impact assessment (NIRB 2012a). Information from TK, land users, and baseline studies in the Project area indicate that the distribution of Arctic Char (freshwater life history) overlaps with Project activities.
Fish Community - Cisco/Whitefish (freshwater life history)	X	X	X	TK and land users identified cisco and whitefish as important food fish for Inuit (Banci and Spicker 2016). Section 35 of the *Fisheries Act* prohibits "serious harm" to fish that are part of a CRA fishery. As CRA fishery species, cisco and whitefish were identified as candidate VECs in the EIS guidelines (NIRB 2012a). Information from TK, land users, and baseline studies in the Project area indicate that the distributions of Cisco, Least Cisco, Broad Whitefish, and/or Lake Whitefish overlap with the Project activities.

Freshwater aquatic biota including benthic invertebrates and other aquatic organisms (proposed as a VEC by the EIS guidelines), are incorporated into the freshwater fish effects assessment as part of the fish habitat VEC. Fish habitat was assessed as defined in the *Fisheries Act*, and therefore includes both the physical habitat and the forage fish and other biological resources (i.e., aquatic biota) that are essential to the productivity of fisheries.

Finally, fish habitat and commercial, recreational, and Aboriginal fisheries as defined in the *Fisheries Act* (proposed as VECs by the EIS guidelines) are incorporated as individual VECs in the freshwater fish effects assessment. Thus, all VECs proposed by the EIS guidelines have either been included in the freshwater fish effects assessment as indicated in Table 6.3-1 and/or are otherwise addressed elsewhere in the EIS.

The **freshwater fish habitat** VEC comprises both the physical habitat and the forage fish and other biological resources that are essential to the productivity of fisheries. Forage fish species are those species that are dietary resources for other fish and are included in the fish habitat VEC based on their role as food supply or "fish that support" CRA fisheries as informed by the EIS guidelines (NIRB 2012a) and the *Fisheries Act*, respectively. Biological resources, as defined here and informed by the EIS guidelines (NIRB 2012a), include the primary producers (phytoplankton, diatoms, and periphyton) and secondary producers (zooplankton, benthic invertebrates,) that make up the lower trophic levels which form the base of fish dietary resources. Finally, freshwater water quality and/or freshwater sediment quality also form part of the freshwater aquatic environment that acts as habitat for fish and are considered under the fish habitat VEC.

This chapter assesses Project effects on the VEC of fish habitat. Direct effects may result from specific Project/environment interactions between Project activities and components, and the fish habitat VEC. Indirect effects may be the result of direct effects on the environment that lead to secondary or collateral effects on the fish habitat VEC. The assessment of Project effects on the fish habitat VEC includes only the *direct* effects of Project infrastructure and activities on the physical aspects of the aquatic environment that provide distinct habitat for CRA fisheries and fish that support CRA fisheries (i.e., forage fish). These activities include the loss or alteration of fish habitat due to encroachment of the Project infrastructure footprint, water withdrawal, and accidental spills and releases of contaminants. *Indirect* effects of Project activities on the fish habitat VEC may result through effects on water quality, sediment quality, and biological resources. Freshwater Water Quality and Freshwater Sediment Quality are treated as stand-alone VECs in other chapters of this EIS (Volume 5, Chapters 4 and 5) and are considered to adequately assess the potential indirect effects of Project activities on aspects of the fish habitat VEC, including water quality, sediment quality, and biological resources based on the following logic:

1. Potential Project-related effects on fish habitat are mediated *indirectly* through trophic interactions between fish and their biological/dietary resources (primary and secondary producers).
2. Potential Project-related effects on primary and secondary producers predominantly arise *indirectly* from changes to water quality and/or sediment quality.
3. Potential Project-related effects on water quality and/or sediment quality arise *directly* from Project activities and are assessed individually, as the VECs Freshwater Water Quality (Volume 5, Chapter 4) and Freshwater Sediment Quality (Volume 5, Chapter 5).
4. No significant residual effects are predicted for Freshwater Water Quality or Sediment Quality after mitigation, management, and monitoring measures are considered (Volume 5, Chapters 4 and 5, respectively).

As a result of there being no predicted significant residual effects of the Project on freshwater water quality or sediment quality, indirect effects on fish habitat resulting from these VECs have not been further assessed in this chapter.

The freshwater **fish community** comprises the survival and abundance of individual fish VECs including **Lake Trout, Arctic Grayling,** and the freshwater life histories of **Arctic Char** and **Cisco/Whitefish.** Rationale for the selection of individual species VECs relied on guidance from the EIS guidelines, TK information, and the definition of commercial, recreational, and Aboriginal fisheries species under the *Fisheries Act* (Table 6.3-1). A single VEC was defined to represent the freshwater life histories of cisco and whitefish species (Cisco/Whitefish; including Cisco, Least Cisco, Broad Whitefish, and Lake Whitefish).

A combined Cisco/Whitefish VEC was selected for several reasons. First, strict and consistent differentiations between cisco, whitefish, and the different species of each were not consistently made in descriptions of fish distribution and use in available TK information. Second, it is difficult or impossible to differentiate among cisco species in the field, in some cases preventing confirmation of individual species distributions in baseline studies. Finally, the most common cisco and whitefish species present in the Project area (i.e., Cisco, Least Cisco, and Lake Whitefish) occupy similar habitats/ecological niches and thus effects on cisco and whitefish can be assessed based on habitat preferences, prey species, and life history timing considerations that are generally similar among species. Arctic Cisco is not included in the Cisco/Whitefish VEC. While available TK information specifically identified Arctic Cisco as a fish species used by Inuit in the TK study area (Banci and Spicker 2016), baseline studies in the Hope Bay Project area since 1993 have not captured Arctic Cisco in the freshwater fish RSA (which encompasses a smaller area than the TK study area). Further, Arctic Cisco are anadromous and only enter freshwater river habitats to spawn in the fall, before returning to sea (Scott and Crossman 1973). Freshwater habitats appropriate for Arctic Cisco spawning (i.e., river habitats that do not freeze to the substrates in winter) are either not present, or limited to the Koignuk River, in the freshwater fish RSA.

This chapter assesses Project effects on fish community VECs. *Direct* effects may result from specific Project/environment interactions between Project activities and components, and the fish community VECs. *Indirect* effects may be the result of *direct* effects on the environment that lead to secondary or collateral effects on the fish community VECs. This chapter assesses the potential *direct* effects of the Project on the survival and population abundance of individual fish species VECs. These *direct* effects may be caused by water use and/or by Project activities that physically harm fish (e.g., spills, blasting, interactions with industrial equipment, and water withdrawal). Individual fish health and survival could also potentially be *indirectly* affected by the Project through the contamination of water or sediment as well as through the bioaccumulation of contaminants in fish through trophic interactions with primary and secondary producers. The *indirect* effects of Project activities on individual fish species VECs are not included in this chapter because they are assessed in other chapters within the EIS. The potential for adverse effects to fish health and survival due to changes in water quality and/or sediment quality has been scoped out of the assessment of fish community VECs because Freshwater Water Quality and Freshwater Sediment Quality are assessed in Volume 5, Chapters 4 and 5, respectively. The assessments of water quality and sediment quality consider the potential for adverse effects on fish health and survival as they are based on indicators that have quantitative relationships or thresholds associated with supporting aquatic organisms, including established guidelines for the protection of aquatic life and derived site-specific water quality objectives. The potential for bioaccumulation of contaminants in Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish is quantitatively assessed in the Human Health and Environmental Risk Assessment (Volume 6, Chapter 5) using receptor fish species representative of different freshwater trophic levels and habitat preferences (i.e., Ninespine Stickleback, Lake Whitefish, and Lake Trout).

6.3.3 Valued Components Excluded from the Assessment

The freshwater aquatic environment VECs proposed in the EIS guidelines (NIRB 2012a) are included in the assessment as part of the selected freshwater fish habitat and fish community VECs or, have been adequately assessed by inclusion in one or more other relevant assessment areas such as Surface Hydrology (Volume 5, Chapter 1), Freshwater Water Quality (Volume 5, Chapter 4), and Freshwater Sediment Quality (Volume 5, Chapter 5). Thus, none of the proposed components of the freshwater aquatic environment VEC have been excluded from the assessment.

6.4 SPATIAL AND TEMPORAL BOUNDARIES

The freshwater fish spatial and temporal boundaries define the maximum spatial and temporal extent within which the potential effects assessment was conducted. The spatial boundaries selected to shape this assessment are determined by the Project's potential effects on the freshwater environment. The freshwater water quality VEC spatial and temporal boundaries are defined as the maximum limits within which the assessment is conducted. The boundaries are determined by the criteria specified in the EIS guidelines (NIRB 2012a), and outlined in the Effects Assessment Methodology (Volume 2, Chapter 4). The boundaries of watersheds containing and adjacent to the Project's infrastructure footprint were used in consideration of the spatial extent of the Project's potential impacts on freshwater fish VECs. 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 the Project as well as the total potential effects of the additional Project activities in combination with the existing and approved Projects including the Doris Project and advanced exploration activities at Madrid and Boston.

6.4.1 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 projects are described below.

6.4.1.1 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).

<u>The Doris Project</u>

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.

Boston Advanced Exploration

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.

6.4.1.2 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 by way of underground portals and Crown Pillar Recovery;
- 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
- ongoing maintenance of transportation infrastructure at all sites (cargo dock, jetty, roads, and quarries).

Reclamation and Closure

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 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.

6.4.2 Spatial Boundaries

6.4.2.1 Project Development Area

The Project Development Area (PDA) is shown in Figure 6.2-1 and is defined as the area which 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 latitude in the final placement of a structure through later design and construction phases, reflecting the certainty of design and construction. Compounds with buildings and other infrastructure in close proximity are defined as pads with buffers whereas roads are defined as linear corridors with buffers. The buffers for pads varied depending on the local physiography and other buffered features such as sensitive environments or riparian areas. The average engineering buffer for roads is 100 m on either side.

Since the infrastructure for the Doris Project is in place, the PDA exactly follows the footprints of these features. In all cases, the PDA does not include the Madrid-Boston Project design buffers applied to potentially environmentally sensitive features. These are detailed in Volume 3, Chapter 2 (Project Description and Alternatives).

6.4.2.2 Local Study Area

The Local Study Area (LSA) is defined as the PDA and the area surrounding the PDA within which there is a reasonable potential for immediate effects on a VEC due to an interaction with a Project component(s) or physical activity.

The LSA used for the assessment of effects on freshwater fish VECs for the North Belt area is 461.1 km^2 and includes the PDA and the boundaries of the Koignuk/Aimaokatalok sub-watershed, the Doris Watershed, the Windy Watershed, and the 2 – Roberts Bay Watershed (Figure 6.2-1). The LSA used for the assessment of the effects on freshwater fisheries VECs for the South Belt area is 528.5 km^2 and includes the PDA and the boundaries of the Aimaokatalok Watershed and the East Watershed (Figure 6.2-1). The total area of the LSA (North and South Belt) is 990 km^2. Overall, the outer boundary of the LSA follows the boundaries of watersheds and sub-watersheds where direct effects of the Project on freshwater fish VECs are possible.

6.4.2.1 Regional Study Area

The Regional Study Area (RSA) is defined as the broader spatial area representing the maximum limit where potential direct or indirect effects may occur.

The freshwater RSA used for the assessment of effects on freshwater fisheries VECs is 4,560 km^2 and includes watersheds immediately adjacent to the LSA watersheds and sub-watersheds, including the Roberts, Angimajuq, Reference B, Reference C, Upper Koignuk, and Upper Aimaokatalok watersheds (Figure 6.2-1). Overall, the outer boundary of the RSA follows the boundaries of watersheds and sub-watersheds where direct or indirect effects of the Project on freshwater fish VECs are possible.

6.4.3 Temporal Boundaries

The Project represents a significant development in the mining of the Hope Bay Greenstone Belt. Even though this Project spans the conventional Construction, Operation, Reclamation and Closure, and Post-closure phases of a mine project, the Madrid-Boston Project is a continuation of development currently underway. The Hope Bay 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 (EAAs) for the Hope Bay Project and the extension of activities.

For the purposes of the EIS, distinct phases of the Project are defined (Table 6.4-1). It is understood that construction, operation, and closure activities will, in fact, overlap among sites; this is outlined in Table 6.4-1 and further described in Volume 3: Project Description and Alternatives.

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 6.4-1. Temporal Boundaries for the Effects Assessment for Freshwater Fish

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	14	• **Roberts Bay**: shipping operations (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); and processing ore (Year 5 – Year 11)
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	NA	NA	NA	• **All Sites:** Care and maintenance activities, generally consisting of closing down operations, securing infrastructure, removing surplus equipment and supplies, and implementing on-going monitoring and site maintenance activities

6.5 PROJECT-RELATED EFFECTS ASSESSMENT

6.5.1 Methodology Overview

This assessment follows 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. The effects assessment evaluates the potential direct and indirect effects of the Madrid-Boston Project on the environment and follows the general methodology provided in Volume 2, Chapter 4: Effects Assessment Methodology, and comprises a number of steps that collectively assess the manner in which the Madrid-Boston Project will interact with VECs defined for the assessment (Section 6.3).

To provide a comprehensive understanding of the potential effects, the Madrid-Boston Project components and activities are assessed on their own as well as in the context the Approved Projects within the Hope Bay Greenstone Belt. The effects assessment process is summarized as follows:

1. Identify potential interactions between the Madrid-Boston Project and the VECs
2. Identify the resulting potential effects of those interactions
3. Identify mitigation or management measures to eliminate, reduce, or offset 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 Approved Projects.
6. Determine the significance of combined residual effects.

After the identification of potential interactions and potential effects (Steps 1 and 2), mitigation and management measures (including fisheries offsetting, see Section 6.2.3.1) were considered (Step 3). Madrid-Boston Project residual effects to freshwater fish VECs were then identified through characterization of potential effects (Step 4). If the application of mitigation and management measures were considered to effectively mitigate or offset the effect, the Madrid-Boston Project-related effects to freshwater fish VECs were characterized as *negligible* and not identified as residual effects. Potential effects of the Madrid-Boston Project in combination with Approved Projects were also characterized to identify residual effects of the overall Hope Bay Project, and characterized as *negligible* if the mitigation and management measures were considered effective (Step 5).

The characterization of potential effects on freshwater fish VECs incorporated guidance from DFO's *Fisheries Protection Policy Statement* (DFO 2013c) and Request for Review Process (DFO 2014b) regarding the determination of whether a project is likely to cause serious harm to fish as defined in the *Fisheries Act*. This guidance from DFO recommends consideration of the duration, geographic scale, probability, and reversibility of effects, as well as the availability and condition of nearby fish habitat and effectiveness of mitigation and management measures. Overall, effects were considered *negligible* and were not carried forward in the assessment as residual effects if:

- Habitat changes and/or reduction in population abundance were unlikely and were unlikely to have an effect on fisheries productivity distinguishable from natural variation; or
- Effects on fisheries productivity resulting from habitat changes and/or reduction in population abundance could be feasibly and effectively mitigated or offset through mitigation, management, and fisheries offsetting measures.

If residual effects were identified, the significance of residual effects was determined (Step 6) by considering the characterization of each residual effect based on the primary criteria of direction and magnitude and additional attributes (Volume 2, Chapter 4; Table 4.3-6) including an assessment of the probability of occurrence of effects and the confidence in the baseline data and predictions of the effects of the Madrid-Boston Project on the freshwater fish VECs (Volume 2, Chapter 4; Table 4.3-7).

6.5.2 Identification of Potential Effects

The potential effects of Project activities on the VECs of fish habitat and fish community (Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish) were determined using the initial matrix provided in Volume 2, Chapter 4 (Table 4.3-3), and further refined using the EIS guidelines (NIRB 2012a), DFO's Pathways of Effects (DFO 2014a), available TK, professional judgement, and experience at other projects in Nunavut and the Northwest Territories. Activities throughout the duration of the Madrid-Boston Project were considered for their potential interactions with the fish habitat VEC and each fish community VEC.

6.5.2.1 Potential Effects on Freshwater Fish Habitat VEC

Freshwater fish habitat may interact with and be affected by Madrid-Boston Project activities along two general pathways: through a direct **loss or alteration of fish habitat** by permanent alteration or destruction (PAD), or through **changes to water quality and/or sediment quality** arising from the deposition of deleterious substances (Table 6.5-1). An alteration of fish habitat is considered a permanent alteration if the spatial scale, duration, or intensity limits or diminishes the ability of fish use the habitat to carry out one or more of their life processes. Destruction of fish habitat occurs when fish can no longer rely upon the habitat to carry out one or more of their life processes.

A PAD is a *direct* **loss or alteration of fish habitat** area potentially incurred through planned construction (e.g., encroachment of infrastructure on existing fish habitat) or water withdrawal. Direct loss or alteration of fish habitat may also occur as a result of spills, accidents or malfunctions (e.g., slope failures). Spills, accidents and malfunctions are addressed in Package P4-3: Hope Bay Project Spill Contingency Plan and Volume 7, Chapter 1: Accidents and Malfunctions.

The introduction of deleterious substances could alter fish habitat *directly* by **changes in water quality and/or sediment quality** to the extent that fish health decreases and mortality occurs, or *indirectly*, through trophic interactions with biological resources used by fish. The *direct* effect on fish health and mortality potentially caused by the introduction of deleterious substances in water (e.g., via effluent discharged from site and mine surface drainage, accidental releases, or spills) is assessed as part of the fish habitat VEC. Spills, accidents and malfunctions that may result in changes to water and sediment quality are also addressed in Package P4-3: Hope Bay Project Spill Contingency Plan and Volume 7, Section 1: Accidents and Malfunctions. The *indirect* effect on fish habitat (i.e., through trophic interactions) potentially resulting from the introduction of deleterious substances into water and sediment is assessed in two chapters: Volume 5, Chapter 4 for Freshwater Water Quality and Volume 5, Chapter 5 for Freshwater Sediment Quality.

The EIS guidelines identify potential impacts on the freshwater aquatic environment for inclusion in a comprehensive impact analysis of all Madrid-Boston Project components and activities. The potential impacts identified in the EIS guidelines and the corresponding potential effects assessed in the effects assessment for the freshwater fish habitat VEC are listed in Table 6.5-2. Specific Madrid-Boston Project activities that link potential interactions/effects with the VEC freshwater fish habitat, prior to the application of mitigation and management measures, are described in Table 6.5-3.

Table 6.5-1. Potential Effects of the Madrid-Boston Project on Freshwater Fish VECs

Freshwater Fish VEC	Potential Effect	Cause	Description	General Project Activity	Regulation	Effect Assessment
Fish Habitat	Loss or alteration of fish habitat	Permanent alteration or destruction (PAD) of habitat	Loss or damage of fish habitat through encroachment of infrastructure and water withdrawal.	1. Project Infrastructure Footprint 2. Water Withdrawal and Use	Fisheries Act (1985) Section 35(2)	This chapter: Vol. 5, Chapter 6 (Freshwater Fish)
	Changes in water quality and/or sediment quality resulting in: 1. Direct fish mortality or reduction in fish health 2. Indirect reduction in biological resources of fish through trophic interactions	Deposition of deleterious substances	Mine and camp effluent, hydrocarbon contaminants, accidental releases or spills, increased nutrient loading including through blasting activities, introduced sediment (increased TSS or deposition in spawning areas)	Management of Surface Drainage, Effluent, Dust	Metal Mining Effluent Regulations (SOR/2002-222)	1. This chapter: Vol. 5, Chapter 6 (Freshwater Fish) 2. Vol. 5, Chapters 4 and 5 (Freshwater Water Quality and Freshwater Sediment Quality)
Fish Community: Lake Trout, Arctic Grayling, Arctic Char, Cisco/Whitefish	Direct mortality and population abundance	Activities that physically harm fish or affect the ability of fish to carry out their life processes	Any impact that causes the death of fish directly (e.g., entrainment/impingement, blasting, fishing, accidental releases or spills) or reduction in population abundance (e.g., stress, effects on migration)	1. Project Infrastructure Footprint 2. Water Withdrawal and Use 3. Blasting	Fisheries Act (1985) Sections 35, 36	This chapter: Vol. 5, Chapter 6 (Freshwater Fish)
	Changes in water quality and/or sediment quality resulting in indirect mortality or reduction in fish health	Deposition of deleterious substances	Any impact that affects individual fish health and longevity, tissue quality, or parasite load	Management of Surface Drainage, Effluent, Dust	Metal Mining Effluent Regulations (SOR/2002-222)	1. Vol. 6, Chapter 5 (Human Health and Environmental Risk Assessment) 2. Vol. 5, Chapters 4 and 5 (Freshwater Water Quality and Freshwater Sediment Quality)

Table 6.5-2. NIRB EIS Guidelines for Impact Assessment of the Madrid-Boston Project on the Freshwater Aquatic Environment and Identified Potential Effects on Freshwater Fish VECs

	Potential Effect			
	Fish Habitat VEC		Fish Community VECs	
EIS Guidelines (NIRB 2012)	Loss or alteration of fish habitat	Changes in water and/or sediment quality	Direct mortality and population abundance	Changes in water and/or sediment quality
Potential impacts to fish, invertebrates, and freshwater habitat including potential impacts to water and sediment quality. Consideration should be given to impacts associated with the following: water withdrawals; discharge; redirection of natural flows; explosives use; nutrient and contaminant inputs; and sewage and grey water effluent discharge	X	X	X	X
Potential direct or indirect effects on fish and invertebrate biota and habitat of both, including aquatic Species at Risk, from any changes to the aquatic or riparian environments, as a result of any in-water works or Project activities in close proximity to waterbodies	X	X	X	X
Potential impacts to fish due to blasting in or near waterbodies, including noise and vibration impacts	X	X	X	X
Potential impacts to fish and fish habitat from any infilling of lake, wetland or stream habitats associated with road construction(s)	X		X	
Potential impacts to freshwater fish, invertebrates and habitat from planned containment structures (e.g., sediment control structures and fuel containment structures) and potential accidental spills.	X	X	X	X
Potential impacts on identified fish habitat critical for spawning, rearing, nursery and feeding, seasonal migration, winter refuges and migration corridors.	X	X	X	X
Evaluation of the ability of fish to pass at water crossings along access roads taking into consideration periods of extreme low and extreme high stream flows	X		X	
Potential impacts to fish health, distributions and population especially taking in to consideration contamination and fugitive dust and potential impact to human health due to consumption of these fish		X	X	X
Potential impacts on contamination of traditional foods as a result of bioaccumulation, i.e., food chain uptake through air, water and soil, including a discussion of proposed monitoring		X		X
Environmental receptivity-including ecological, physical and/or climatic factors that influence exposure to harmful substances		X		X
Quantitative assessment of the ecological risks to freshwater VECs from the potential elevated contaminant loadings as a result of the Project		X	X	X

Table 6.5-3. Summary of Potential Interactions between Freshwater Fish VECs and the Madrid-Boston Project

Project Phase and General Project Activity	Specific Project Activity	Project(s)		Fish Habitat		Fish Community (Lake Trout, Arctic Grayling, Arctic Char, Cisco/Whitefish)	
		Madrid-Boston	Approved	Loss or alteration of fish habitat	Changes in water and sediment quality	Direct mortality and population abundance	Changes in water and sediment quality
Construction							
Project Infrastructure Footprint	Water Crossings	●	●	X	X	X	X
	Infrastructure Facilities	●	●	X	X	X	X
	Water Intake/Discharge Pipes	●		X	X	X	X
	Madrid-Boston winter road		●	X	X	X	X
Water Use	Water use		●	X	X	X	X
Blasting	Quarry	●	●	X	X	X	X
Management of Surface Drainage, Effluent, and Dust	All-weather access roads	●			X		X
	Airstrip and lighting	●	●		X		X
	Road use and maintenance	●	●		X		X
	Quarry	●	●		X		X
	Equipment and Vehicle Emissions	●	●		X		X
	Fuel storage and handling	●	●	X	X	X	X
	Incinerator	●			X		X
	Construction camps	●			X		X
	Site surface infrastructure and pads	●	●		X		X
	Ore stockpiles	●	●		X		X
	Overburden pile	●			X		X
	Waste rock piles	●	●		X		X
	Water management system	●	●		X		X
	Water discharge to receiving environment	●			X		X
Operation							
Project Infrastructure Footprint	Water Crossings	●	●	X	X	X	X
	Infrastructure facilities	●	●	X	X	X	X
	Water Intake/Discharge Pipes	●		X	X	X	X
	Madrid-Boston winter road		●	X	X	X	X
Water use	Water use	●	●	X	X	X	X
Blasting	Quarry	●	●	X	X	X	X
Management of Surface Drainage, Effluent, and Dust	Airstrip and lighting	●	●		X		X
	Road use and maintenance	●	●		X		X
	Quarry	●	●		X		X

Project Phase and General Project Activity	Specific Project Activity	Project(s)		Fish Habitat		Fish Community (Lake Trout, Arctic Grayling, Arctic Char, Cisco/Whitefish)	
		Madrid-Boston	Approved	Loss or alteration of fish habitat	Changes in water and sediment quality	Direct mortality and population abundance	Changes in water and sediment quality
	Equipment and Vehicle Emissions	●	●		X		X
	Fuel storage and handling	●	●	X	X	X	X
	Storage and handling of explosives		●	X	X	X	X
	Chemical and hazardous material management		●	X	X	X	X
	Incinerator	●	●		X		X
	Site surface infrastructure and pads	●	●		X		X
	Ore stockpiles	●	●		X		X
	Overburden pile	●			X		X
	Waste rock piles	●	●		X		X
	Water management system	●	●		X		X
	Water discharge to receiving environment	●	●		X		X
Reclamation and Closure							
Project Infrastructure Footprint	Water Crossings	●	●	X	X	X	X
	Water Intake/Discharge Pipes	●		X	X	X	X
	Madrid-Boston winter road		●	X	X	X	X
	Inter-site roads	●	●		X		X
Water use	Water use	●	●	X	X	X	X
Management of Surface Drainage, Effluent, and Dust	All-weather access roads	●	●		X		X
	Airstrips		●		X		X
	Quarry	●			X		X
	Equipment and Vehicle Emissions	●	●		X		X
	Construction camps		●		X		X
	Surface and mining infrastructure	●	●		X		X
	TIA/TMA and associated infrastructure	●			X		X
	Water management system	●	●		X		X
	Water discharge to receiving environment	●	●		X		X
Post-closure							
	Post-closure monitoring	●		X	X	X	X
Temporary Closure							
	Care and maintenance	●		X	X	X	X

● *= Project specific activity anticipated; X = Potential interaction between VEC and Project-specific activity*

6.5.2.2 Potential Effects on Freshwater Fish Community VECs

The freshwater fish community may interact and be affected by Madrid-Boston Project activities along two general pathways: through *direct* **mortality and changes to population abundance**, or through decreased health and *indirect* mortality resulting from **changes in water quality and/or sediment quality** (Table 6.5-1).

The effects assessment for freshwater fish community VECs focuses on the interactions and potential effects associated with the pathway of *direct* **mortality and changes to population abundance** of the VECs Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish. Direct mortality and changes to population abundance may potentially occur during the construction of in-water infrastructure and any Madrid-Boston Project activities that physically harm fish through blasting, water withdrawal, impact injury (e.g., interactions with industrial equipment), and spills, accidents and malfunctions. Spills, accidents, and malfunctions are addressed in Package P4-3: Hope Bay Project Spill Contingency Plan and Volume 7, Chapter 1: Accidents and Malfunctions. Fishing activities can also physically harm fish due to handling and hook and release mortality. However, although fish mortality rates may increase with increased fishing pressure, a “no fishing” policy for personnel and contractors while on site will be in place. On-site monitoring activities targeting fish will also take the least invasive approach as appropriate to minimize impacts on fish. This policy/approach will remove potential effects on fish communities that may result from an increase in fishing pressure, therefore the effects of fishing are not discussed further in the assessment for fish community VECs.

For Through the pathway of decreased health and *indirect* mortality, potential **changes in water quality and/or sediment quality** resulting from surface drainage, fugitive dust, and planned discharge of water/effluent to the receiving environment could have chronic effects on fish community VECs. The potential effects of these Madrid-Boston Project activities are assessed as part of the VECs of Freshwater Water Quality and Sediment Quality in Volume 5, Chapters 4 and 5, respectively. The potential effects on fish health due to bioaccumulation of contaminants in Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish is quantitatively assessed in the Human Health and Environmental Risk Assessment in (Volume 6, Chapter 5) using receptor fish species representative of different freshwater trophic levels and habitat preferences (i.e., Lake Trout, Whitefish, and Ninespine Stickleback). Spills, accidents and malfunctions may also result in changes to water and sediment quality and are addressed in Package P4-3: Hope Bay Project Spill Contingency Plan and Volume 7, Chapter 1: (Accidents and Malfunctions) and in Volume 8, Section 2.4.

The EIS guidelines identify potential impacts on the freshwater aquatic environment for inclusion in a comprehensive impact analysis of all Madrid-Boston Project components and activities. The potential impacts identified in the EIS guidelines and the corresponding potential interactions/effects assessed in the effects assessment for freshwater fish community VECs are listed in Table 6.5-2. Specific Madrid-Boston Project activities that link potential interactions/effects with freshwater fish community VECs (Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish), prior to the application of mitigation and management measures are described in Table 6.5-3.

6.5.3 Mitigation and Adaptive Management for Freshwater Fish VECs

Mitigation and adaptive management measures applicable to freshwater fish VECs were identified through a review of best management practices at similar mining projects in the Arctic (including the Doris Project), available TK, regulatory guidance and considerations, scientific literature, and professional judgement. Mitigation and monitoring specific to potential effects on individual freshwater fish VECs are identified where necessary in the individual VEC effects assessments in Section 6.5.4 and Section 6.5.5.

6.5.3.1 Mitigation by Project Design

The Madrid-Boston Project has been designed to avoid impacts on freshwater fish habitat and freshwater fish community VECs where possible. The major aspects of mitigation by design include:

- Where possible, Project infrastructure has been located outside of fish bearing water;
- Minimum 31 m setbacks, and 51 m setbacks where possible were applied near water features to avoid affecting riparian functions;
- Roads were routed, as far as was practical, to avoid streams, channel crossings, and wet, boggy areas where fish habitat may be disturbed;
- Fish-bearing streams will be spanned using bridge structures (clear span bridge structures will be used where practical). Fish-bearing streams of very low flow will be spanned using culverts sized for fish passage provided the required conditions necessary to sustain fish habitat can be achieved;
- Road rights-of-way will cross each stream as close to perpendicular as possible to minimize the amount of riparian vegetation that may be disturbed during construction;
- Where pumps/intakes are used in fish-bearing watercourses or where fish salvage has not occurred, intakes will be screened following DFO’s Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e); and
- Water will be recycled where possible to reduce the demand for water withdrawals (Volume 3, Section 4.4.5: Water Management).

6.5.3.2 Best Management Practices

The Madrid-Boston Project will be constructed and managed following government guidelines and industrial best management practices as much as possible to avoid unnecessary impacts to freshwater fish habitat and fish communities. Government guidelines to avoid harm to fish habitat and fish communities include DFO’s Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e), federal and territorial guidelines to preserve water and air quality (e.g., CCME guidelines for the protection of aquatic life; CCME 2016a), and federal and territorial environmental protection regulations. In addition, standard industrial best management practices will be implemented, many of which are featured in water management plans (Packages P4-4 to P4-12). General best management practices are as follows:

- Prevent the release of sediment or sediment laden water into water frequented by fish by employing erosion and sediment control measures;
- Discharge of compliant water to the receiving environment; and
- Vehicular access across a watercourse or waterbody will be by road or bridge, or other acceptable method according to DFO’s Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e).

Mitigation measures from DFO’s Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e) that will be implemented to ensure that fish and fish habitat are not adversely affected by development include:

<u>Timing</u>

- Timing of in-water construction activities will conform, when possible, to Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013f) of May 1 to

July 15 for spring spawning fish (Arctic Grayling) and August 15 to June 30 for fall spawning fish (Lake Trout, Arctic Char, cisco and whitefish); and

- The duration of in-water work will be minimized to the extent possible.

<u>Site Selection</u>

- In-water works will be designed and planned such that loss or disturbance to aquatic habitat is minimized and sensitive spawning habitats are avoided;
- Where possible, approaches will be designed to be perpendicular to the watercourse to minimize loss or disturbance to riparian vegetation;
- Where possible, crossing locations will avoid unstable areas such as meander bends, braided sections, and active floodplains to avoid introduction of sediments to the watercourse; and
- Instream activities will be undertaken, where possible, in isolation of open or flowing water, or when frozen, to maintain the natural flow of water downstream and avoid introducing sediment into the watercourse.

<u>Contaminant and Spill Management</u>

- A spill response plan will be in place that will be implemented in the event of a sediment release or spill of a deleterious substance and emergency spill kits will be available (Package P4-3);
- Construction materials will have been handled and treated to prevent the release or leaching of deleterious substances into the waterbody; and
- Excess materials will be removed from the construction site upon Project completion.

<u>Erosion and Sediment Control</u>

- Effective erosion and sediment control measures will be installed before starting work to prevent sediment from entering the waterbody.
- Where practical, site isolation measures (e.g., silt boom or silt curtain) will be used to contain suspended sediment where in-water work is required.
- Regular inspection and maintenance of erosion and sediment control measures and structures will be conducted during the course of construction and until disturbed ground has been stabilized.
- Repairs to erosion and sediment control measures and structures will be promptly completed if damage occurs.
- Removal of non-biodegradable erosion and sediment control materials will be completed once site is stabilized.

<u>Shoreline/Bank Re-vegetation and Stabilization</u>

- Clearing of riparian vegetation will be kept to a minimum to avoid disturbance to the riparian vegetation and prevent soil compaction.
- Shorelines or banks disturbed by any activity will be stabilized promptly to prevent erosion and/or sedimentation.
- Where disturbed, the bed and banks of waterbodies will be restored to their original contour and gradient, where possible, or to a stable gradient that does not obstruct fish passage.

- If rock is required to stabilize eroding or exposed areas, appropriately-sized, clean rock will be used and it will be installed at a similar slope to maintain a uniform bank/shoreline and natural stream/shoreline alignment.

Fish Protection

- In-water activities or associated in-water structures (i.e., culverts and bridges) will not interfere with fish passage, constrict channel width, or reduce flows.
- A qualified professional will be retained, where needed, to ensure applicable permits for relocating fish are obtained and to capture any fish trapped within an isolated/enclosed area and safely relocate them to an appropriate location in the same waterbody (i.e., fish salvage activities).

Operation of Machinery

- Machinery undertaking in-water work will be in a clean condition and maintained free of fluid leaks, invasive species, and noxious weeds.
- Whenever possible, machinery will be operated on land above the high water mark or on ice in a manner that minimizes disturbance to the banks and bed of the waterbody.
- Whenever possible, machine fording of a watercourse will be limited to a one-time event (i.e., over and back), and only if no alternative crossing method is available. If repeated crossings of the watercourse are required, a temporary crossing structure will be constructed.
- Service machinery will be washed, refueled and fuel and other materials for the machinery stored in such a way as to prevent any deleterious substances from entering the water.
- If minor rutting is likely to occur, stream bank and bed protection methods (e.g., swamp mats, pads) will be used, provided they do not constrict flows or block fish passage.
- If the stream bed and banks are steep and highly erodible (e.g., dominated by organic materials and silts) and erosion and degradation are likely to occur as a result of equipment fording, then a temporary bridge will be used in order to protect these areas.

Detailed best management practices for specific Project activities are described in Sections 6.5.4 and 6.5.5 under Mitigation and Management Measures for Specific Potential Effects.

6.5.3.3 Proposed Monitoring Plans and Adaptive Management

Proposed Monitoring Plans

Aquatic Effects Monitoring Program

The 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 Madrid-Boston Project and a reference area well away from Project activities;
- monitoring freshwater water quality, sediment quality, and aquatic biology; and
- monitoring fish populations and fish tissues if and where required based on monitoring results and as required under the MMER.

Fisheries Offsetting Plan

A FOP typically contains the design, implementation, and monitoring actions required to offset potential serious harm to CRA fisheries resulting from a project, as concluded by DFO and as per the guidance provided in DFO's *Fisheries Protection Policy Statement* (DFO 2013c). If deemed necessary by DFO through the *Fisheries Authorization* process, the FOP will eventually address all potential serious harm to CRA fish through mitigation and/or offsetting using methods from DFO's *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013b) such as the restoration or enhancement of habitats or the creation of habitat elsewhere in the landscape. TMAC therefore commits to working with DFO's Fisheries Protection Program (FPP) and local Inuit to develop a freshwater offsetting plan commensurate with anticipated effects. Discussion with DFO and other stakeholders have already been initiated (refer to Appendix V5-6AB for additional information). A monitoring program will be developed to monitor the effectiveness of the FOP. The monitoring program will be developed in conjunction with regulatory agencies, and will assess the effectiveness of the offsetting activities over time in reference to specific performance objectives. These performance objectives may include:

- stability of constructed habitat;
- primary productivity;
- benthic invertebrate community;
- fish presence/habitat use; and
- local density, production, or population size estimated for fish species.

For the purposes of this EIS, where the effects conclusion relies on the successful implementation of a FOP to mitigate potential residual effects resulting from the Madrid-Boston Project, a conceptual approach to developing a FOP is provided in Appendix V5-6AA. If deemed necessary by DFO, a final FOP will be developed, satisfying the requirements of the EIS guidelines (NIRB 2012a; refer to Volume 8, Section 1 for additional information) as discussed in Volume 8, Chapter1.

Other Management Plans

Other management plans which form the Environmental Management System (Volume 8) address particular issues through specific mitigation and management measures to maintain air and water quality through the management of contaminants and waste. These plans, presented in Package 4: Management and Other Plans, address spills and contingencies, management of water, waste, waste rock, ore, and tailings, as well as air quality management and monitoring.

Adaptive Management

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

- results from the Aquatic Effects Monitoring Program, which will monitor the receiving environment around the mine infrastructure and activities, show adverse effects to fish habitat and/or fish communities; and
- results from the Fisheries Offsetting Monitoring Program, should this be required as part of a *Fisheries Authorization*, show that the offsetting program is not successful.

6.5.4 Characterization of Potential Effects - Fish Habitat VEC

Project residual effects are the effects that are remaining after mitigation and management measures are taken into consideration. If the implementation of mitigation measures eliminates a potential effect and no residual effect is identified on that VEC, the effect is eliminated from further analyses. If the proposed implementation controls and mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and a significance determination. Residual effects of the Project can occur directly or indirectly. Direct effects result from specific Project/environment interactions between Project activities and components, and VECs. Indirect effects are the result of direct effects on the environment that lead to secondary or collateral effects on VECs.

The following characterization of specific potential Project effects on the fish habitat VEC describes the potential effects of interactions of fish habitat with the Madrid-Boston Project and the Hope Bay Project (including Madrid-Boston Project activities), identifies mitigation measures (including fisheries offsetting), and assesses whether residual effects remain after mitigation and management measures are taken into consideration. Residual effects from Project-related interactions associated with the fish habitat VEC may be avoided and/or considered mitigable even when serious harm (as per the *Fisheries Act*) may be concluded by DFO, as long as it is considered feasible to offset the serious harm.

6.5.4.1 Loss or Alteration of Fish Habitat: Project Infrastructure Footprint

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

Madrid-Boston Project infrastructure has the potential to interact with the VEC freshwater fish habitat wherever the locations of infrastructure overlap with fish-bearing freshwater. Effects on the freshwater fish habitat VEC may occur during all phases of the Madrid-Boston Project, beginning in Construction when the building of most infrastructure will take place, and occurring through Post-Closure (Table 6.5-3). Figures 6.5-1 and 6.5-2 indicate the waterbodies in the LSA and RSA where there is the potential for freshwater fish habitat loss or alteration as a result of interaction with the Madrid-Boston Project. Waterbodies with the potential for effects from the Madrid-Boston Project infrastructure footprint include waterbodies crossed by all-weather roads and Windy and Aimaokatalok lakes, where a discharge pipe and/or water intakes will be constructed. Waterbodies with the potential for effects on the fish habitat VEC due to water withdrawal/use are discussed further in Section 6.5.4.2.

Water Crossings

Based on DFO Pathways of Effects, the placement of any structures in or near water, including water crossings, may affect fish habitat amount and quality, in addition to reducing the physical area available to fish. The physical footprint of the structure may reduce available habitat. Placement of structures in water may create obstructions to fish passage if poorly designed and/or by altering flow conditions, which may result in reduced access to upstream and/or downstream fish habitat. Fish habitat loss or alteration related to Madrid-Boston Project infrastructure may occur at locations where Madrid-Boston Project roads cross freshwater fish habitats. Four all-weather roads (AWRs) are proposed that will cross stream habitats including the Roberts Bay Cargo Dock Access Road, Madrid North-TIA AWR, the Madrid South AWR, and the Madrid-Boston AWR. Various crossing types have been proposed including culverts, fish-bearing culverts, and bridges (see Volume 3, Section 3.7.4.3 and Table 3.7-1).

Culvert crossings (non-fish-bearing) will be used at crossing locations confirmed not to be fish habitat. Streams with non-fish-bearing culverts will be spanned using 1 m diameter culverts. Culvert crossings will be used for fish-bearing streams with minimal flow, and culverts will be sized to allow fish passage during normal flow conditions (1:2 year, 24-hour storm event). A typical fish-bearing culvert will have a minimum diameter of 1 m and riprap will be placed inside the culvert to dampen the flow velocity to allow the passage of fish. Culvert diameter and riprap size will vary depending on the catchment area reporting to the crossing, the species of fish present in the waterbody being crossed, and the water depth within the culvert required to maintain fish passage. Bridges will be constructed at stream crossings that are fish-bearing and free flowing. Bridges will be clear-span structures constructed above the ordinary high water mark (HWM). The HWM is the usual or average level to which a body of water rises at its highest point and remains at this level long enough to change the land characteristics.

Crossing locations and fish-bearing status (based on available fish and fish habitat information) for each crossing site are presented in Table 6.5-4. Crossing locations identified as fish-bearing are those where fish have been captured during fish community surveys. Crossing locations identified as assumed fish-bearing are those where fish have been captured upstream or downstream in fish community surveys, and where there are no known barriers that may prevent fish access to the crossing site. Crossings identified as likely non-fish-bearing were in generally wet areas with no preferential flow path and identified as having no or marginal fish habitat. Crossing types have been selected based on fish habitat quality, stream flow characteristics, to maintain fish passage and, to the extent possible, to minimize alteration of fish habitat through effects on stream beds and banks.

The fish species that utilize streams being crossed by AWRs include rearing and migrating Lake Trout, Arctic Char, Lake Whitefish, Cisco, and Burbot as well as all life stages of Arctic Grayling, and forage fish species such as Ninespine Stickleback and Slimy Sculpin. Culverts and bridges located in or over fish-bearing habitats will be constructed during the Construction phase and will be breached during the Reclamation and Closure phase. During closure, breached openings will be sloped and armoured with rock to ensure natural drainage and stability. Therefore, habitat losses and other potential alterations will be initiated during the Construction phase and will persist through Post-Closure.

Fish habitat loss (permanent alteration to, or destruction; PAD) at crossing locations was estimated from fish habitat data collected in 2017 (ERM 2017d). The potential road infrastructure footprint below the HWM was estimated based on the measured bankfull and wetted widths of the watercourses at the crossing locations and a road infrastructure footprint of 16 m width (i.e., 8 m road crest width, 2 m fill thickness with 2H:1V side slopes; Package P5-11; Table 6.5-5). PAD will be incurred at culvert sites, in the area under the culvert which is equal to the potential footprint below the HWM. The potential footprint below the bankfull HWM at low flow was used to estimate PAD. All bridges are proposed as clear-span structures with abutments of a minimum of 1.5 m from the HWM on either side of the stream. Therefore, no PAD will be incurred at streams crossed by bridges (Table 6.5-6)).

Fish habitat value was assigned to each crossing location during high and low flow surveys in 2017 based on habitat suitability for spawning, rearing, migration, and overwintering for fish species known or predicted to be present (ERM 2017d). Habitat values for each crossing at high and low flow are presented in Table 6.5-5. The total estimated PAD of stream fish habitat due to infrastructure footprint at road crossings is presented in Table 6.5-6 by crossing type and habitat quality. The total estimated PAD for all crossing types is 267 m^2. Two crossings (C-MBR-11 and C-MBR-20) with moderate to high quality habitat throughout the open water season account for 87% of estimated PAD. Fish habitat assessments at the crossing locations did not identify habitats that were critical for any life stages of the fish species present (ERM 2017d). The remaining 13% of PAD is estimated at six fish-bearing crossings characterized as providing low habitat quality at high flow and no fish habitat or low quality fish habitat at low flow.

Figure 6.5-1
Madrid-Boston Infrastructure Footprint and Waterbodies with Potential Habitat Loss or Alteration, North Belt

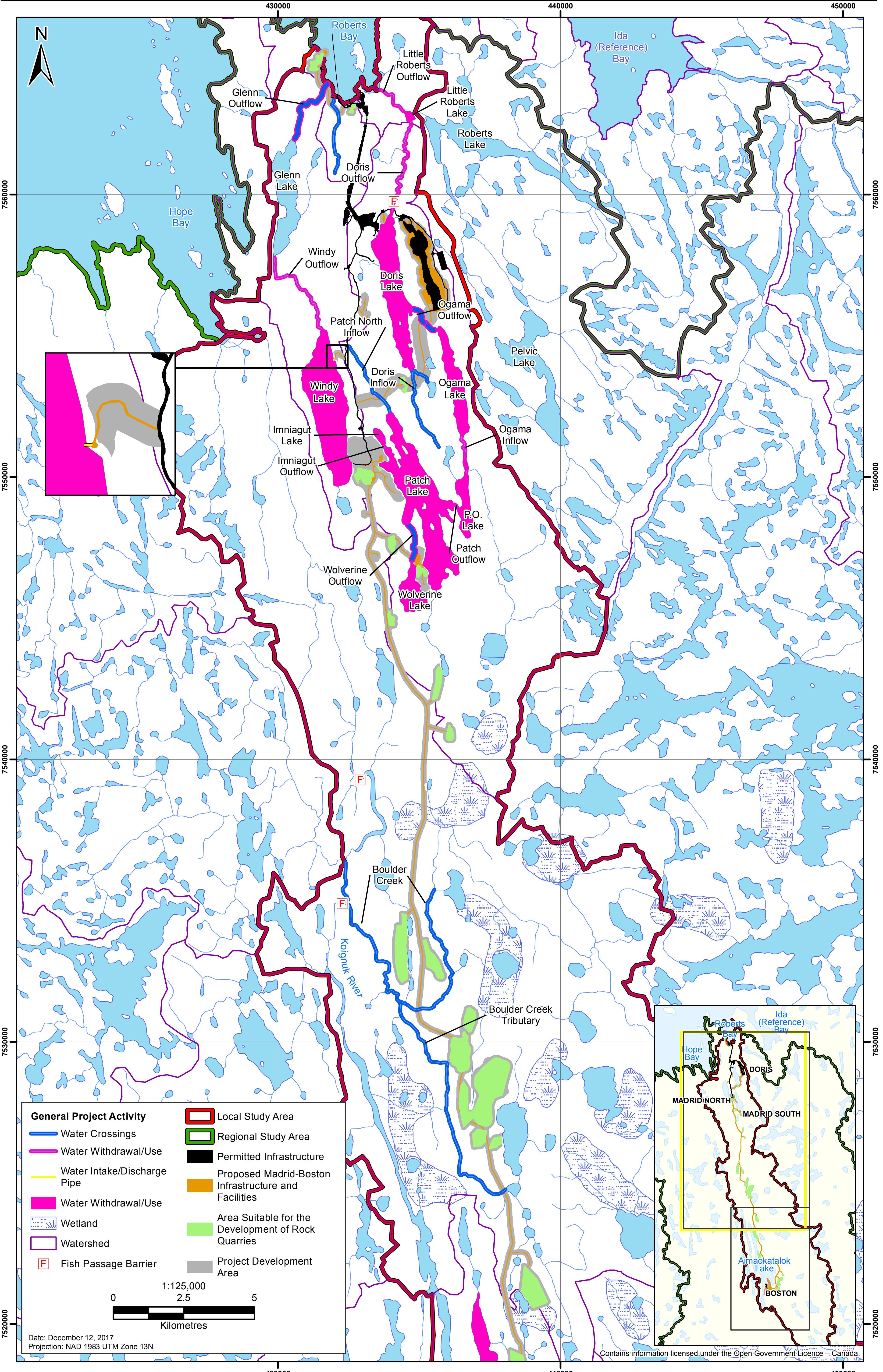


Figure 6.5-2
Phase 2 Infrastructure Footprint and Waterbodies with Potential Fish Habitat Loss or Alteration, South Belt

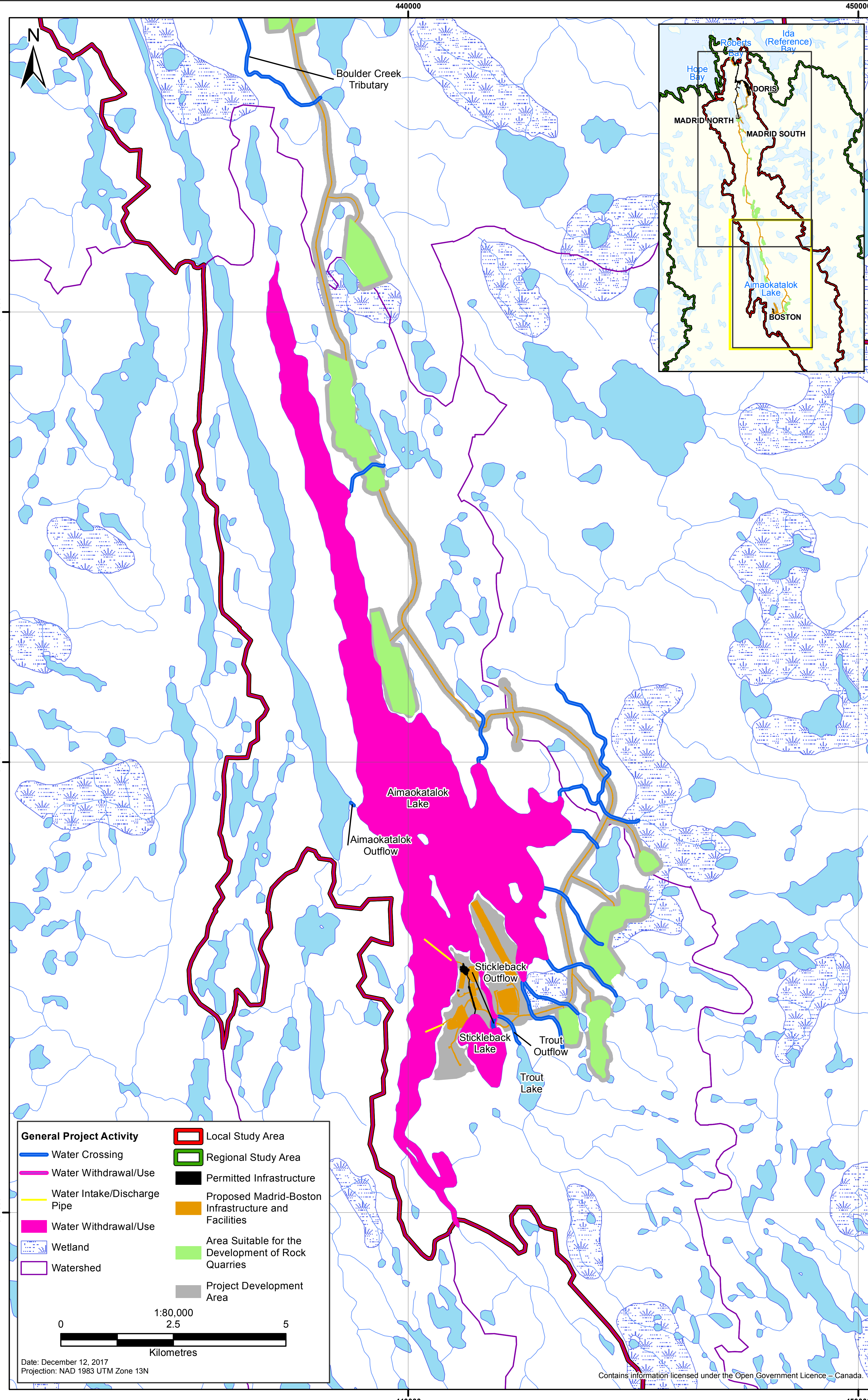


Table 6.5-4. Locations and Fish-Bearing Status at Water Crossings by Madrid-Boston Project All-Weather Roads

Access Road	Crossing ID	UTM		Watershed	Waterbody Name	Fish-bearing Status	Confirmed or Predicted Fish Species*
		Easting	Northing				
Roberts Bay Cargo Dock Access Road	C-CDR-01	432108	7562941	2 - Roberts Bay	Roberts Bay Inflow	Fish-bearing	NSSB
Roberts Bay Cargo Dock Access Road	C-CDR-02	431627	7563806	Windy	Glenn Outflow	Fish-bearing	LKTR, ARCH, SLSC, NSSB, STFL
Madrid North to Doris TIA AWR	C-TIA-01	433622	7552784	Doris	Patch Inflow	Assumed fish-bearing	***NSSB***
Madrid North to Doris TIA AWR	C-TIA-02	434781	7553327	Doris	Doris Inflow	Fish-bearing	NSSB
Madrid North to Doris TIA AWR	C-TIA-03	435039	7553604	Doris	Doris Inflow	Fish-bearing	NSSB
Madrid North to Doris TIA AWR	C-TIA-04	435094	7555505	Doris	Ogama Outflow	Fish-bearing	LKTR, LKWH, CISC, NSSB
Madrid South AWR	C-MS-01	434760	7547111	Doris	Wolverine Outflow	Likely non-fish-bearing	-
Boston-Madrid AWR	C-MBR-7	434964	7531135	Koignuk/Aimaokatalok	Boulder Creek	Fish-bearing	ARGR, NSSB
Boston-Madrid AWR	C-MBR-8	437979	7524706	Koignuk/Aimaokatalok	Boulder Creek Tributary	Fish-bearing	ARGR, NSSB
Boston-Madrid AWR	C-MBR-9	439158	7516576	Aimaokatalok	Aimaokatalok Inflow	Fish-bearing	NSSB
Boston-Madrid AWR	C-MBR-10	439433	7515859	Aimaokatalok	Aimaokatalok Inflow	Likely non-fish-bearing	-
Boston-Madrid AWR	C-MBR-11	441626	7510781	Aimaokatalok	Aimaokatalok Inflow	Fish-bearing	NSSB
Boston-Madrid AWR	C-MBR-12	444365	7509635	Aimaokatalok	Aimaokatalok Inflow	Fish-bearing	NSSB, ARGR
Boston-Madrid AWR	C-MBR-13	444444	7508833	Aimaokatalok	Aimaokatalok Inflow	Assumed fish-bearing	***NSSB, ARGR***
Boston-Madrid AWR	C-MBR-14	444109	7508180	Aimaokatalok	Aimaokatalok Inflow	Likely non-fish-bearing	-
Boston-Madrid AWR	C-MBR-15	443420	7507037	Aimaokatalok	Aimaokatalok Inflow	Fish-bearing	NSSB
Boston-Madrid AWR	C-MBR-16	443649	7505485	Aimaokatalok	Aimaokatalok Inflow	Fish-bearing	NSSB, ARGR
Boston-Madrid AWR	C-MBR-17	443490	7504607	Aimaokatalok	Aimaokatalok Inflow	Fish-bearing	NSSB
Boston-Madrid AWR	C-MBR-18	442718	7504389	Aimaokatalok	Aimaokatalok Inflow	Likely non-fish-bearing	-
Boston-Madrid AWR	C-MBR-19	442298	7504222	Aimaokatalok	Trout Outflow	Fish-bearing	LKTR, ARGR, BURB, SLSC, NSSB
Boston-Madrid AWR	C-MBR-20	441941	7504209	Aimaokatalok	Stickleback Outflow	Fish-bearing	NSSB, SLSC, ARGR

Note:

**Predicted species italicized; based on habitat characterization and/or confirmed species presence in upstream or downstream waterbodies, additional species may be present*

Table 6.5-5. Proposed Crossing Types and Estimated PAD at Water Crossings by Madrid-Boston Project All-Weather Roads

Crossing ID	Waterbody Name	Fish-bearing Status	Habitat Value High Flow**	Habitat Value Low Flow**	Low Flow: Mean Channel Width: Wetted (m)	Low Flow: Mean Channel Width: Bankfull (m)	Low Flow: Potential Footprint Below HWM*: Wetted (m^2)	Low Flow: Potential Footprint Below HWM*: Bankfull (m^2)	Proposed Crossing Type§	Estimated PAD[I] (m^2)
C-CDR-01	Roberts Bay Inflow	Fish-bearing	Low	None	0.1	0.2	1.6	3.2	Fish-bearing culvert	3.2
C-CDR-02	Glenn Outflow	Fish-bearing	High	High	14.0	21.0	224.0	336.0	End bearing pile bridge	0.0
C-TIA-01	Patch Inflow	Assumed fish-bearing	Low	None	0.1	0.3	1.6	4.8	Culvert - type TBD	4.8
C-TIA-02	Doris Inflow	Fish-bearing	Low	None	0.0	0.5	0.0	8.0	Fish-bearing culvert	8.0
C-TIA-03	Doris Inflow	Fish-bearing	Low	None	0.0	0.0	0.0	0.0	Fish-bearing culvert	0.0
C-TIA-04	Ogama Outflow	Fish-bearing	High	High	10.2	15.2	163.2	243.2	End bearing pile bridge	0.0
C-MS-01	Wolverine Outflow	Likely non-fish-bearing	Low	None	0.0	0.0	0.0	0.0	Culvert	0.0
C-MBR-7	Boulder Creek	Fish-bearing	High	High	8.1	15.9	129.6	254.4	End bearing pile bridge	0.0
C-MBR-8	Boulder Creek Tributary	Fish-bearing	High	High	1.7	14.4	27.2	230.4	End bearing pile bridge	0.0
C-MBR-9	Aimaokatalok Inflow	Fish-bearing	Moderate	Moderate	1.4	2.6	22.4	41.6	End bearing pile bridge	0.0
C-MBR-10	Aimaokatalok Inflow	Non-fish-bearing	None	None	0.0	0.0	0.0	0.0	Culvert	0.0
C-MBR-11	Aimaokatalok Inflow	Fish-bearing	Moderate	Moderate	1.4	6.3	22.4	100.8	Fish-bearing culvert	100.8
C-MBR-12	Aimaokatalok Inflow	Fish-bearing	High	High	15.0	18.8	240.0	300.8	End bearing pile bridge	0.0
C-MBR-13	Aimaokatalok Inflow	Assumed fish-bearing	Low	None	0.0	0.0	0.0	0.0	Fish-bearing culvert	0.0
C-MBR-14	Aimaokatalok Inflow	Non-fish-bearing	None	None	0.0	0.0	0.0	0.0	Culvert - type TBD	0.0
C-MBR-15	Aimaokatalok Inflow	Fish-bearing	Moderate	Moderate	10.2	16.2	163.2	259.2	End bearing pile bridge	0.0
C-MBR-16	Aimaokatalok Inflow	Fish-bearing	High	High	1.3	4.1	20.8	65.6	End bearing pile bridge	0.0
C-MBR-17	Aimaokatalok Inflow	Fish-bearing	Low	Low	1.1	1.1	17.6	17.6	Fish-bearing culvert	17.6
C-MBR-18	Aimaokatalok Inflow	Likely non-fish-bearing	Low	None	0.0	0.0	0.0	0.0	Culvert	0.0
C-MBR-19	Trout Outflow	Fish-bearing	High	Moderate	2.4	12.5	38.4	200.0	End bearing pile bridge	0.0
C-MBR-20	Stickleback Outflow	Fish-bearing	High	Moderate	1.0	8.3	16.0	132.8	Fish-bearing culvert	132.8

Notes:

HWM = High water mark; PAD = Permanent alteration or destruction of fish habitat as per the Fisheries Act *(1985)*

**Potential footprint below HWM = Channel width (wetted or bankfull) * maximum road infrastructure width of 13 m*

***ERM 2017d*

[I] *Estimated PAD = Potential footprint below HWM based on channel bankfull width at low flow.*

§ *Bridge structures will be clear-span*

Table 6.5-6. Total Estimated PAD of Fish Habitat at Water Crossings by Madrid-Boston Project All-Weather Roads

Habitat Quality	Crossing Type						Total PAD (m^2)
	Bridge		Fish-bearing Culvert		Culvert		
	No. of Crossings	PAD (m^2)	No. of Crossings	PAD (m^2)	No. of Crossings	PAD (m^2)	
High	6	0.0	-	-	-	-	0.0
Moderate - High	1	0.0	1	132.8	-	-	132.8
Moderate	2	0.0	1	100.8	-	-	100.8
Low	-	-	1	17.6	-	-	17.6
None - Low	-	-	5	16.0	2	0.0	16.0
None	-	-	-	-	2	0.0	0.0
Total							267.2

Additional habitat loss outside of the infrastructure footprint may occur if any of the crossing structures are improperly sized or installed. Improperly sized or installed crossing structures could create physical or flow barriers to fish passage, altering access to habitats by fish. Both construction and closure activities in and near water may alter riparian and aquatic vegetation, mobilize sediment, destabilize stream banks, and change streambed substrate composition. At stream crossing sites, these impacts could alter or eliminate spawning, rearing, feeding, and/or migration habitat for fish.

Culverts and bridges located in or over fish-bearing habitats may also require maintenance over their period of operation. Materials may accumulate (i.e., vegetation, ice build-up, etc.) inside culverts or on bridge structures, potentially preventing the passage of water and/or fish through the structure. Flooding may occur upstream of blocked water crossings or downstream of crossings when materials and debris are removed. This flooding could result in alteration of riparian habitat, stream bank destabilization, and/or erosion and mobilization of sediments. The accumulation of debris at water crossings could alter access to habitats by fish by creating physical or flow barriers. It could also alter the composition of substrates that comprise spawning, rearing, feeding, and/or migration habitats. Water crossing structures will be monitored regularly for blockages and material and debris removal will be performed as required.

Water Intakes and Discharge Pipes

Water intakes will be used to withdraw water from lakes in the LSA for domestic and industrial uses. Water discharge pipes will be used to discharge compliant effluent to the receiving environment. The Madrid-Boston Project will continue to use existing water intake points in Doris and Windy Lakes in addition to the TIA discharge line, which discharges TIA and groundwater effluent to Roberts Bay. A water intake will be constructed in the north of Windy Lake (see Package P5-23 for preliminary design) and water intake and discharge lines will also be established in Aimaokatalok Lake (See Package P5-24 for preliminary design). All water intakes will be screened to prevent the entrainment or impingement of fish.

Domestic, industrial, and potable water will be pumped from Windy and Aimaokatalok lakes at water intake structures. Design specifications for the intake pipelines are summarized in Table 6.5-7. The intake pipelines will consist of 0.15 m diameter HDPE-insulated and heat-traced systems laid primarily along access roads, transitioning from shoreline to lakebed beneath protective rock berms. The pipelines will extend to 5 m depth in the lakes (40 m total length in Windy Lake and 420 m total length in Aimaokatalok Lake). The pipelines will be anchored to the lakebed beneath the rock berms until the lake depth reaches a minimum of 3 m, occurring approximately 20 m from the shoreline in Windy Lake, and 360 m from the shoreline in Aimaokatalok Lake. The rock berms will protect the pipeline from annual lake ice development. The rock berms will be designed with a top width of 2 m, a minimum height of 1 m, and 1.2H:1V side slopes. The total lakebed footprint of the rock berms will be 4.4 m^2 per lineal metre and the total 3D surface area of the rock berms will be 4.88 m^2 per lineal metre. Below 3-m depth, the pipeline will be anchored to the lakebed by concrete counter buoyancy weights, each with a 1 m^2 lakebed footprint, spaced every 5 m. Between anchor blocks and exposed (i.e., not buried under armor rock or anchor blocks) pipeline lengths, the pipeline will sit on the lakebed, where the footprint habitat loss will be equivalent to the pipe diameter multiplied by pipe length. A fish screen will be constructed at the end of the pipeline intake, following DFO's Measures to Avoid Harm to Fish and Fish Habitat (DFO 2013e) to protect fish from entrainment/impingement during water uptake. Engineering design of the fish screens will take place as part of the detailed design phase.

Table 6.5-7. Total Estimated PAD of Fish Habitat from Freshwater Intake and Discharge Pipelines for the Madrid-Boston Project

	Windy Lake	Aimaokatalok Lake	
Design Specifications	**Intake**	**Intake**	**Discharge**
Pipeline diameter	0.15 m	0.15 m	0.25 m
Total pipeline length along lakebed	40 m	420 m	800 m
Portion of pipeline covered by rock berm	20 m	360 m	205 m
Rock berm dimension	2 m wide x 1 m high; side slopes 1.2H:1V	2 m wide x 1 m high; side slopes 1.2H:1V	2 m wide x 1 m high; side slopes 1.2H:1V
Rock berm lakebed footprint on per lineal metre	4.4 m^2	4.4 m^2	4.4 m^2
Rock berm 3D surface area per lineal metre	4.88 m^2	4.88 m^2	4.88 m^2
Rock berm total lakebed footprint	88 m^2	1584 m^2	902 m^2
Rock berm total 3D surface area	97.6 m^2	1,756.8 m2	1,000.4 m2
Portion of pipeline supported with anchor blocks	20 m	60	595 m
Anchor block dimension	1 m X 1 m X 0.3 m	1 m X 1 m X 0.3 m	1 m X 1 m X 0.3 m
Anchor block lakebed footprint	1 m^2	1 m^2	1 m^2
Anchor block spacing	5 m	5 m	5 m
Total number of anchor blocks	4	12	119
Anchor block total footprint	4 m^2	12 m^2	119 m^2
Length of pipe on lakebed*	16 m	48 m	1021 m^2
Footprint of pipe on lakebed*	2.4 m^2	7.2 m^2	119 m^2
Total lakebed footprint of infrastructure (PAD)	94.4 m^2	1,603.2 m2	1,140 m2
Total 3D surface area of infrastructure	97.6 m^2	1,756.8 m2	1,000.4 m2
Fish Habitat Characterization			
Littoral substrate	30% Fines, 30% Cobble, 20% Bedrock	-	-
Sublittoral substrate	-	Dominant = Sand and gravel Subdominant = Cobble and larger rock	Dominant = Sand and gravel Subdominant = Cobble and larger rock
Shoreline description	Mostly steep bedrock, some gently sloping gravel	-	-
Fish density	-	low (0.03 to 19 fish/ha)	low (0.015 to 0.07 fish/ha)

Notes:

Dashes = data not available

**not on anchor blocks or beneath rock berm*

Effluent from the Boston water treatment plant will be discharged into Aimaokatalok Lake through a pipeline and diffuser system. Design specifications for the discharge pipeline are summarized in Table 6.5-7. An insulated heat-traced 0.25 m diameter HDPE pipeline will run from the treatment plant to the discharge access road, north of the existing camp and down to the shoreline. The design of the pipeline will be the same as for the intakes. The discharge pipe will also extend up to the 5-m depth in the lake (800 m total length). The rock berm will extend to approximately 205 m from the shoreline of the lake and the remaining 595 m of the pipeline will be anchored by anchor blocks. The end of the pipeline will comprise an approximately 40-m long diffuser with outlets spread over that length of the pipeline. Engineering design of the diffuser system will take place in the detailed design stage.

During the Reclamation and Closure phase, intake and discharge pipes armoured with rock berms as well as anchor blocks will be left in place to minimize additional disturbance to lake substrates and fish habitat. The pipelines will be removed over the portions anchored with anchor blocks. The installation of the Windy Lake north water intake and Aimaokatalok Lake water intake and discharge pipes during the Construction phase will result in a loss of fish habitat (PAD) in the areas under the intake and discharge pipes, and in any part of the in-water construction zone where lake substrates are altered due to the placement of structures (e.g., screens, pipes, anchors) and materials (e.g., rock berm armouring).

The total PAD (lakebed footprint) of the intake pipe will be 94.4 m^2 in Windy Lake. This estimate is based on the lakebed footprint of the rock berm, the sum of the lakebed footprint of each anchor block, and the footprint of the pipeline on the lakebed where the pipeline is not supported by anchor blocks and laying exposed directly on the lakebed (i.e., not covered by the rock berm; Packages P5-23 and P5-24; Table 6.5-7). The habitat loss/alteration calculation assumes that the fish screen structure is included in the total pipeline length and has a lakebed footprint equivalent to the anchored section of the pipeline. Baseline surveys indicate that the north intake footprint in Windy Lake will be located in littoral habitats comprised of 20% fines, 20% cobble, and 20% bedrock (Rescan 2010b). Cobbles are suitable spawning substrates for Lake Trout while both fines and cobbles are potential spawning substrates for Lake Whitefish and Cisco (Table 6.2-25). Baseline littoral habitat surveys in Windy Lake (Rescan 2010b) indicate that fines and cobbles are the dominant and subdominant substrate types in the littoral zone, respectively. Therefore, they are not unique to the proposed intake location or limiting in the littoral zone throughout the lake. Potentially important Lake Trout spawning habitats were identified on the west side of the lake, opposite the intake location.

The total PAD (lakebed footprint) of the intake in Aimaokatalok Lake is estimated to be 1,603.2 m^2 (calculated using the same method as presented for the Windy Lake north intake; Package P5-24; Table 6.5-7). The total PAD (lakebed footprint) of the discharge pipe in Aimaokatalok Lake is estimated to be 1,140 m^2 (Package P5-24; Table 6.5-7). The footprint of the discharge pipeline footprint is calculated using the same method as the intakes and assumes that the diffuser structure is included in the total pipeline length, with a lakebed footprint equivalent to the anchored section of the pipeline.

Baseline surveys indicate that the intake and discharge footprints in Aimaokatalok Lake will be located in littoral and sublittoral habitats comprised mostly of sand and gravel with patches of cobble and larger rock (Rescan 2011d). Sand and gravel substrates in the intake footprint may provide spawning habitat for Lake Whitefish and Cisco, and patches of cobble substrates may act as spawning shoals for Lake Trout. Sand/gravel and cobble/rock substrates are not limiting in the southern part of Aimaokatalok Lake, comprising 40% and 15% of sublittoral substrates, respectively.

Potential direct effects on fish mortality and population abundance resulting from the design and operation of water intakes and discharge pipes (i.e., screening to avoid entrainment/impingement) are considered under the effects assessment for fish community VECs (Section 6.5.5.1)

Winter Road Construction and Use

Use of the established Madrid-Boston winter road route or other short localized winter routes may be required during the Construction phase to enable efficient construction of the Boston accommodations and the Madrid-Boston AWR. The proposed established winter road route is presented on Figure 6.5-3. The route crosses two large lakes (Windy Lake and Aimaokatalok Lake) in addition to several streams and ponds, most of which are tributaries or connected to tributaries of the Koignuk River. The seasonal use of winter roads has the potential to restrict the temporal availability of fish habitat in streams and degrade habitat quality in streams and along the shorelines of lakes and ponds.

The construction and presence of winter roads over streams in the Madrid-Boston Project footprint is most likely to affect Arctic Grayling, which rely on stream habitat for migration and spawning in the spring, and for juvenile rearing and migration throughout the summer (Stewart et al. 2007) and forage fish species that rely on streams as migratory habitat (Ninespine Stickleback and Slimy Sculpin). For example, improper decommissioning of winter road crossings may result in temporary barriers to fish passage where ice and snow may block access to spawning areas during the spring spawning season, and erosion of stream banks may increase sedimentation, smothering spawning gravels, and increasing suspended sediment loads in the water column (DFO 2007c). Winter roads also have the potential to affect Lake Trout, Lake Whitefish, Cisco, and Least Cisco which rely on rocky habitats and shoals along the shorelines of lakes for spawning. If improperly constructed, winter roads may lead to shoreline erosion, increased suspended sediment, and increased sediment deposition (DFO 2007c). Sediment eroded from shorelines and stream crossings may settle along the rocky shorelines of lakes and ponds, possibly affecting the quality of Lake Trout, Lake Whitefish, Cisco, and Least Cisco spawning habitat (Marcus, Hubert, and Anderson 1984), or the spawning habitats of forage fish species (e.g., Slimy Sculpin).

Increased erosion and suspended sediments may also reduce water quality in streams and ponds, and could potentially result in an indirect effect on fish habitat through water quality and/or sediment quality effects on primary and secondary producers (biological resources; (DFO 2007c). The assessment of Project effects on Freshwater Water Quality and Freshwater Sediment Quality are completed individually in Volume 5, Chapters 4 and 5, and are not included in this assessment as outlined in Section 6.3.2 of this chapter.

Mitigation and Management Measures for Specific Potential Effects

The majority of Project infrastructure has been sited to avoid fish-bearing water and, wherever possible, to avoid encroaching on freshwater fish habitat by adhering to a minimum 31-m setback from all water. A 51-m setback has been applied, where possible. The TIA/TMA, waste rock piles, ore stockpiles, and overburden piles have all been sited to avoid fish habitat and have been confined to local watersheds close to the main infrastructure at the Doris and Boston Project areas. The following additional mitigation will be implemented to avoid adverse effects on fish habitat resulting from the design, construction, and use of Madrid-Boston Project infrastructure including water crossings, water intakes and discharge pipes, and winter roads. Where Project activities overlap with fish-bearing waters and fish habitat loss or alteration is anticipated, mitigation will be applied through fisheries offsetting measures.

Water Crossings

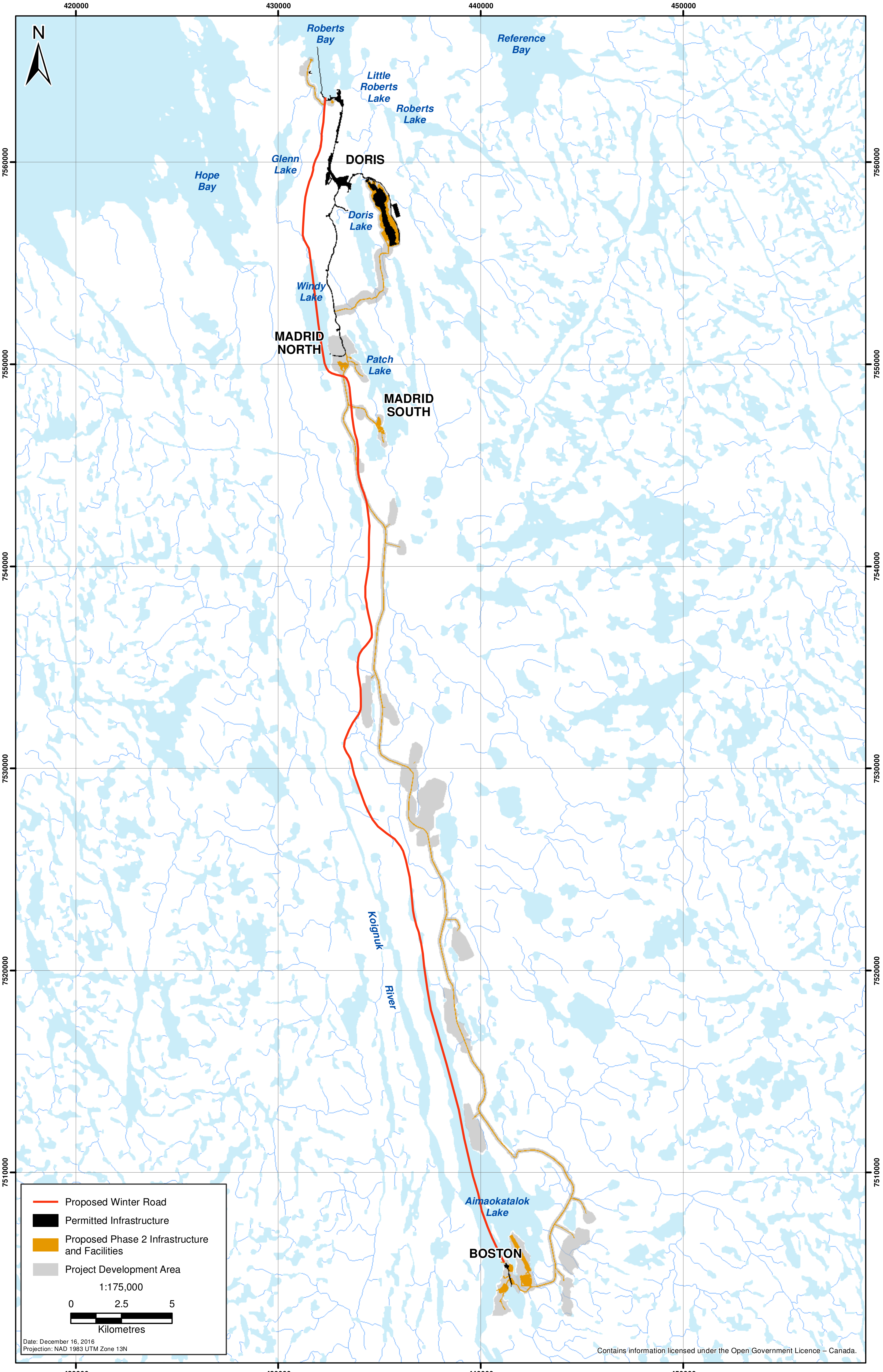
The construction of stream crossings, roads, and berms will follow DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2). Timing of in-water construction activities will conform, when possible, to Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013f). For stream activities, the window is in place from May 1 to July 15 during which in-water activities should be minimized to avoid the spring spawning period for Arctic Grayling. In streams used as migration corridors between marine and freshwater habitats by spawning anadromous Arctic Char, Lake Trout, cisco, and/or whitefish (e.g., Roberts Bay Cargo Dock Access Road crossing at Glenn Outflow), stream activities will also avoid the fall migration window (beginning on August 15 and lasting until freeze-up). Winter construction activities will not be initiated until streams are considered isolated from flows (i.e., frozen to the substrate).

Fish-bearing crossings along the Roberts Bay Cargo Dock Access Road, the Madrid North-TIA AWR, the Madrid South AWR, and the Madrid-Boston AWR will continue to serve as migration corridors between upstream and downstream waterbodies. Bridges will be used or fish-bearing culvert crossings will be designed to maintain fish passage by keeping water velocities and depths within acceptable limits such that they do not present a velocity or depth barrier to migration of fish species known to be present. In addition, culverts will be embedded in the natural channel and fill material added to promote fish passage and habitat suitability. Bridge crossings will be clear-span structures constructed outside of the HWM to avoid alteration or destruction of fish-bearing habitats.

Mitigation measures for the maintenance of bridges and culverts at crossing locations will incorporate DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013; Section 6.5.3.2) and additional best management practices demonstrated to effectively mitigate the effects of bridge/culvert maintenance (DFO 2007a, 2007b) which include:

- Existing trails or roads will be used for access wherever possible to avoid disturbance to riparian vegetation;
- Removal of vegetation will be kept to a minimum;
- Unless accumulated material (i.e., vegetation, ice build-up, etc.) is preventing the passage of water and/or fish through the structure, material and debris removal will be completed according to the Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013f);
- The removal of accumulated material will be limited to the area within the culvert/bridge, immediately upstream of the culvert/bridge, and to that which is necessary to maintain culvert/bridge function and fish passage; and
- Accumulated material and debris will be removed gradually such that flooding downstream, extreme flows downstream, release of suspended sediment, and fish stranding can be avoided.
- If replacement rock reinforcement/armouring is required to stabilize eroding inlets and outlets of culverts or bases of bridge supports, the following measures will be incorporated:
  - Appropriately sized rocks will be placed into the eroding area;
  - Only clean, non-acid generating rocks will be used;
  - Rocks will not be obtained from below the ordinary high water mark of any waterbody;
  - Rock will be installed at a similar slope to maintain a uniform stream bank and natural stream alignment; and
  - Rocks installed will be done so as to not interfere with fish passage or constrict the channel width.

Figure 6.5-3
Proposed Phase 2 Winter Road



Water Intakes and Discharge Pipes

Mitigation to avoid adverse effects on fish is required to avoid habitat degradation during construction of water intake and discharge pipelines and to offset habitat losses in lakes in the locations of intake and discharge pipelines. Timing of in-water construction activities will conform, when possible, to Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013f). For lake activities, the applicable window is in place from August 15 to June 30 during which in-water activities should be minimized to avoid disturbance of fall spawning fish, (e.g., Lake Trout, Arctic Char, cisco and whitefish) and to avoid the disturbance of their eggs incubating in the substrates over the winter. Mitigation measures that will be applied during the construction of intake and discharge pipelines follow DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2). The design and operation of water intakes and discharge pipes (i.e., screening to avoid entrainment/impingement) are considered under the effects assessment for fish community VECs (Section 6.5.5.1).

Winter Road Construction and Use

Mitigation measures for the construction of winter roads and of ice bridges and snow fills along winter road routes will incorporate DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2) and additional best management practices demonstrated to effectively mitigate the effects of ice bridges and snow fills on fish habitats (DFO 2007c) which include:

- Existing trails or winter ice roads will be used wherever possible as access routes to limit unnecessary clearing of additional vegetation and prevent soil compaction;
- Approaches and crossings will be constructed perpendicular to watercourses wherever possible.
- Ice bridges and snow fill approaches will be constructed using clean, compacted snow and ice to a sufficient depth to protect the banks of the lake, river or stream;
- Crossings will not impede water flow at any time of the year;
- When the crossing season is over and where it is safe to do so, a v-notch will be created in the center of ice bridges to allow them to melt from the center and to prevent blockage of fish passage, channel erosion and flooding. Compacted snow will be removed from snow fills prior to spring freshet;
- The site will be stabilized using effective sediment and erosion control measures. In areas with permafrost, care will be exercised to ensure these measures do not cause thawing or frost heave; and
- Speed limits during road use will be established to prevent ice scour along shorelines.

Fisheries Offsetting

The purpose of a Fisheries Offsetting Plan (Appendix V5-6AA), as per the guiding policies of DFO, is to maintain or improve the productivity of CRA fisheries. The FOP will address fish habitat losses related to the encroachment of Madrid-Boston Project infrastructure, as deemed necessary by DFO. Localized areas of fish-bearing stream habitat loss or permanent alteration will occur in eight streams as a result of the placement of culverts at road crossings (refer to Table 6.5-6 for further detail). Localized habitat losses or permanent alterations will also occur in Aimaokatalok and Windy lakes due to the construction of water intakes and/or discharge pipes and associated armouring of these structures (refer to Table 6.5-7 for further detail).

Unavoidable habitat loss or alteration due to Madrid-Boston Project infrastructure will be restricted to the five watersheds within the LSA (Doris Watershed, Windy Watershed, Koignuk/Aimaokatalok sub-Watershed, Aimaokatalok Watershed, and East Watershed). Where possible, final infrastructure designs will consider how to include forms of "self-offsetting", through the consideration of how the placement of material or structures in fish habitat can help to make up (i.e., offset) for the losses or alterations resulting from construction. For example, the final design of the water intakes/discharge pipe in Aimaokatalok and Windy lakes will consider how the amount, angle, and wetted surface area of rock berms replaces or enhances existing habitat. Where deemed necessary by the DFO *Fisheries Authorization* process, final mitigation and monitoring requirements for the lost/altered habitat will be incorporated during the development of a FOP in consultation with DFO and discussed through NIRB and NWB processes.

The objective of the FOP will be to compensate for the alteration or destruction of fish-bearing habitat by creating or modifying fish habitat elsewhere on the landscape should a *Fisheries Authorization* be deemed necessary for Madrid-Boston to proceed (see section 6.5.3.4). TMAC will work with DFO's FPP and local Inuit to develop a freshwater FOP. All habitat losses related to the Madrid-Boston Project infrastructure footprint will be offset with the objective of maintaining the productivity of CRA species. The conceptual approach to fisheries offsetting proposed to balance all losses of fish habitat from Madrid-Boston Project infrastructure can be found in Appendix V5-6AA. A summary of recent communication between TMAC, DFO and other stakeholders is also provided in Appendix V5-6AB. The requirement for a FOP will be determined as described in Volume 8: Environmental Management System (Section 2.19) with the intention of meeting the EIS guidelines requirement for a No Net Loss Plan as the *Fisheries Protection Policy Statement* (DFO 2013c) no longer includes the "no net loss" principle.

As a result of mitigation, balancing potential fisheries losses with fisheries offsetting, and monitoring plans there are no residual effects anticipated on the VEC freshwater fish habitat due to interaction with the Madrid-Boston Project infrastructure footprint.

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

Fish habitat loss and/or alteration resulting from the Project Infrastructure footprint of Approved Projects generally has been or will be limited to one time construction events. Seasonal winter road construction and use is an exception, however with appropriate mitigation and management, winter road construction in not anticipated to result in residual effects on fish habitat. Habitat loss and/or alteration resulting from the Project Infrastructure footprint of Approved Projects has been or will be mitigated or has been or will be offset through compliance with the *Fisheries Act*. This has been achieved through the implementation of biophysical management plans including an AEMP (Volume 8, Environmental Management System; Table 1.1-1), through the implementation of fisheries offsetting plans (e.g., for the loss of fish and fish habitat in Tail Lake when it was reclassified as a tailings impoundment area under Schedule 2 of the MMER and was fished out; Golder 2007b; Rescan 2012b), and through commitments to develop and implement fisheries offsetting plans, where required. Therefore, there are no residual effects resulting from fish habitat loss or alteration from Approved Projects which could combine with Madrid-Boston Project effects.

As a result of mitigation, balancing fisheries losses with fisheries offsetting, and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on the VEC freshwater fish habitat due to the Hope Bay Project infrastructure footprint.

6.5.4.2 Loss or Alteration of Fish Habitat: Water Withdrawal and Use

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

Water withdrawal and use for the Madrid-Boston Project has the potential for effects on the freshwater fish habitat VEC through changes in surface hydrology which may result in the loss or alteration of fish habitat. The assessment of Madrid-Boston Project effects on Surface Hydrology was completed separately and independently in Volume 5, Chapter 1. Volume 5, Chapter 1 assessed Madrid-Boston Project-related changes in water quantity using indicators that have quantitative relationships or thresholds that consider fish habitat requirements (i.e., streamflow requirements). The following assessment of water withdrawal and use on the freshwater fish habitat VEC also considers the effects on streamflow, particularly with respect to mitigation and offsetting measures. In addition to effects on streamflow, the following assessment also characterizes the effects of water withdrawal and use on lake volume and lake surface elevation.

Activities that have the potential to interact with the freshwater fish habitat VEC through water withdrawal and use can be grouped into the following five categories:

1. *Water withdrawal for domestic and industrial use*: Water for domestic and industrial use for the Madrid-Boston Project will be drawn from Doris, Windy, and Aimaokatalok lakes (Table 6.5-8);
2. *Construction and use of underground mines – drawdown through talik*: Doris, Madrid North, and Madrid South mines are expected to intercept taliks (Package P5-4). Water levels in lakes can be drawn down through taliks, potentially resulting in a decrease in water elevation, volume, or discharge in fish-bearing freshwater waterbodies (Table 6.5-8);
3. *Modification of natural drainages*: Surface drainage diversion and discharge (e.g., water transfer to, and discharge from, the TIA), modification of runoff coefficient at disturbed surfaces (e.g., stockpiles), and access roads where crossings are not sized to pass natural flows could affect drainage pathways (Table 6.5-8);
4. *Winter road construction and use*: Lakes and ponds along the established Madrid-Boston winter road corridor or other short localized winter routes will be selected for water withdrawal as required for seasonal construction; and
5. *Exploration activities*: Permitted exploration activities will continue throughout the Project life and will include diamond drilling which requires a drilling fluid that uses water (heated or salinated; Volume 3, Section 4.8). For Madrid drill locations, Patch, Windy and Wolverine Lakes may serve as the sources of water. For Boston drill locations, Aimaokatalok Lake, and possibly Trout and Stickleback lakes may provide drill water.

All these activities contribute to the water withdrawal and use effects pathways associated with freshwater fish VECs. These are anticipated to occur during all phases of the Madrid-Boston Project, though at various intensities, with the possible exception of the Post-Closure phase (Table 6.5-3). Figures 6.5-1 and 6.5-2 indicate the waterbodies in the LSA and RSA where there is the potential for freshwater fish habitat loss or alteration as a result of interactions with the first three activities of the Madrid-Boston Project listed above. These include the lakes that may be directly affected through water withdrawal and use, as well as downstream outflow streams and lakes that may be indirectly affected by those same upstream lakes (e.g., reductions in lake volumes and surface elevations leading to reduced discharge in outflows; Table 6.5-8). The potential effects from water withdrawal and use pathways listed in Tables 6.5-8 on fish habitat were characterized using results of the *Hope Bay Project Water and Load Balance* (i.e., the water balance model; Package P5-4). Results of the water balance model include streamflow predictions at 13 assessment nodes during different phases of the Project (Appendix V5-1P), as well as lake volume and surface elevation predictions at nine lakes during different phases of the Project (Appendices V5-1Q and V5-1R).

Table 6.5-8. Lakes and Lake Outflows in the LSA and RSA with Potential Effects from Water Withdrawal and Use

Watershed	Waterbody		Water Withdrawal and Use			
	Lake	Stream	Domestic and/or Industrial Use	Underground Mines - Drawdown through Talik	Modification of Natural Drainage	Upstream Withdrawal and Use
Doris	Imniagut Lake		-	X	-	-
Doris		Imniagut Outflow	-	-	-	X
Doris	Wolverine Lake		-	X	X	-
Doris		Wolverine Outflow	-	-	-	X
Doris	Patch Lake		-	X	X	X
Doris		Patch Outflow	-	-	-	X
Doris	P.O. Lake		-	-	-	X
Doris		P.O. Outflow	-	-	-	X
Doris	Ogama Lake		-	-	-	X
Doris		Ogama Outflow	-	-	-	X
Doris	Doris Lake		X	X	-	X
Doris		Doris Outflow	-	-	-	X
Doris	Little Roberts Lake		-	-	-	X
Doris		Little Roberts Outflow	-	-	-	X
Windy	Windy Lake		X	X	X	-
Windy		Windy Outflow	-	-	-	X
Windy	Glenn Lake		-	-	-	X
Windy		Glenn Outflow	-	-	-	X
Aimaokatalok	Trout Lake*		-	-	-	-
Aimaokatalok		Trout Outflow*	-	-	-	-
Aimaokatalok	Stickleback Lake		-	-	X	-
Aimaokatalok		Stickleback Outflow	-	-	-	X
Aimaokatalok	Aimaokatalok Lake		X	-	-	-
Aimaokatalok		Aimaokatalok Outflow	-	-	-	X
Koignuk		Koignuk River 1	-	-	-	X
Koignuk		Koignuk River 2	-	-	-	X

Notes:
Bolded waterbodies are those modeled for lake volume and lake surface elevation
Waterbodies are ordered from upstream to downstream within a watershed
Dashes indicate no potential effect from water withdrawal and use
**no potential effects from water withdrawal and use; not carried forward for further assessment*

Waterbodies in the LSA and RSA where there is the potential for effects on the freshwater fish habitat VEC as a result of water withdrawal from under ice for winter road construction and water withdrawal for drilling are not identified on Figures 6.5-1 and 6.5-2. Instead, the specific lakes and ponds from which water will be withdrawn for these activities will be identified as required and water withdrawal will be from waterbodies of at least 15,000 m^2 and will comply with DFO's *Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut* (DFO 2010a).

For the purpose of the effects assessment of water withdrawal and use on the fish habitat VEC, the potential effect of the Madrid-Boston Project in isolation of Approved Projects is not assessed. Instead, the assessment is based on the Madrid-Boston Project in combination with Approved Projects (i.e., the overall Hope Bay Project) relative to baseline flow projections as carried out in the effects assessment for surface hydrology (Volume 5, Section 1.5.4). Rationale for this method is summarized as follows.

Assessment of Madrid-Boston Project potential effects in isolation of Approved Projects would include comparison of Project-affected lake volume, lake surface elevation, and streamflows during the Construction, Operation, Closure, and Post-closure phases of the Madrid-Boston Project, with conditions before Construction of the Madrid-Boston Project (hereafter referred to as Year 0). Lake volumes, lake surface elevations, and stream flows in Year 0 are not pre-development natural conditions since they include the predicted effects of the Doris Project. In contrast, assessment of the Madrid-Boston Project in combination with Approved Projects compares Project-affected lake volume, lake surface elevation, and streamflows during the Construction, Operation, Closure, and Post-closure phases of the Madrid-Boston Project (Appendices V5-1P, V5-1Q, V5-1R), with baseline projections without any development (Appendices V5-1M, V5-1N, V5-1O).

Assessment of the Madrid-Boston Project in combination with Approved Projects results in greater lake volume, lake surface elevation, and streamflow effects than those of the Madrid-Boston Project in isolation of Approved Projects (Volume 5, Chapter 1; e.g., for streamflow see Table 1.5-2). In this way the assessment provides conservative predictions of the effects of the Madrid-Boston Project in isolation of Approved Projects. Therefore, for the purpose of the fish habitat VEC effects assessment, characterization of potential effects is based on the Madrid-Boston Project in combination with Approved Projects (i.e., the Hope Bay Project) relative to baseline lake volume, lake surface elevation, and streamflow projections. This is consistent with the natural flow regime paradigm (Poff et al. 2010) and best practices for hydrologic effects assessments. It was applied to the fish habitat assessment to allow for consistent interpretation of potential effects on freshwater fish VECs relative to the surface hydrology VEC.

The water balance model (Package P5-4) also includes a sensitivity case for higher than expected groundwater inflows into underground mine workings. Results of this sensitivity case are summarized in (Appendix V5-1T). This high groundwater sensitivity case may result in differences in the effects of water withdrawal and use on the fish habitat VEC in lakes and streams in the Doris and Windy Watersheds relative to the water balance model base case. Therefore, both the effects of the base case and high groundwater sensitivity case were evaluated.

Water withdrawal from lakes has the potential to affect fish habitat through multiple pathways, including a reduction in available fish habitat, changes to primary and secondary producers, and a reduction in discharge volume at lake outflows. Water withdrawal from lakes may cause a decrease in the amount and suitability of overwintering or spawning habitat available for fish or potentially expose overwintering eggs of Lake Trout, Arctic Char, cisco or whitefish species to air (Cott 2007). Reduction in discharge at lake outflow streams may result in a reduction of available or suitable fish habitat for migration and rearing (all VEC fish species), and spawning (Arctic Grayling). Lower stream flows may influence the ability for fish passage through changes in water depth and velocity (i.e., passage barriers and stranding), changes in the timing and frequency of flows, decrease in the number of days stream habitat is accessible, and increase the duration of sensitive periods (flow less than 30% Mean Annual Discharge; DFO 2013d). Smaller, shallow lakes and ponds are more susceptible to habitat changes due to water withdrawals than large lakes.

Water withdrawal also has the potential to modify water quality and/or sediment quality. The suspension and deposition of sediments during lake water withdrawal could result in an *indirect* loss of fish habitat through water quality and/or sediment quality effects on primary and secondary producers. Sedimentation could also affect the physical availability and quality of spawning habitats for fish that rely on gravel and rock substrates for spawning (e.g., gravel for Arctic Grayling in streams and rock shoals for Lake Trout, Arctic Char, cisco and whitefish in lakes).The assessment of Project effects on Freshwater Water Quality and Freshwater Sediment Quality are completed individually in Volume 5, Chapters 4 and 5, and thus not included in this assessment as outlined for the reasons provided in Section 6.3.2 of this chapter.

Mitigation and Management Measures for Specific Potential Effects (Madrid-Boston Project)

Mitigation and management measures for specific potential effects on fish habitat from water withdrawal and use are presented for the overall Hope Bay Project in the following sections, rather than independently for the Madrid-Boston Project.

Characterization of Hope Bay Project Potential Effect

Characterization of effects of the Hope Bay Project on lake volume, lake surface elevation, and streamflow were assessed for both the water balance model base case and the high groundwater sensitivity case in the following sections.

Lake Volume and Lake Surface Elevation

Base Case:

Effects of the Hope Bay Project on lake volume and lake surface elevation were assessed for lakes in the Doris Watershed (Doris, Ogama, P.O., Patch, Wolverine, and Imniagut lakes), the Windy Watershed (Windy Lake), and the Aimaokatalok Watershed (Aimaokatalok and Stickleback lakes) based on simulated results of the water balance model. Although water withdrawal effects may also occur in Glenn and Little Roberts lakes (in the Doris and Windy Watersheds, respectively) as listed in Table 6.5-8, the effects on lake volume and surface elevation in these lakes were not simulated in the water balance model. The potential for effects in these lakes result from upstream water withdrawal and use, rather than a direct interaction with Project activities (Table 6.5-8). In the absence of simulated effects on lake volume and lake surface elevation for these lakes, the potential for effects of upstream water withdrawal and use on fish habitat have been characterized through effects on streamflows at lake outflows.

Because fish life histories are represented by annual cycles that rely on different habitats for different life processes, even temporary loss or alteration in fish habitat that occurs during specific periods when fish rely on those habitats have the potential to influence the survival and population abundance of fish. Fish rely on lakes as overwintering habitats based on the premise that they all have sufficient depths (i.e., more than 3 m max depth) to provide habitat under thick winter ice cover. Water withdrawal during the ice-covered period may cause a decrease in the amount and suitability of overwintering habitat by decreasing the under ice habitat area and potentially affecting water quality (i.e., oxygen depletion). Additionally, Lake Trout, Arctic Char, cisco and whitefish spawn in the fall over rock substrates and shoals in lakes and their eggs overwinter in the substrates. Water withdrawal from lakes could decrease the water surface elevation under the ice and potentially expose overwintering eggs to air, resulting in mortality (Cott 2007).

To prevent adverse effects on over-wintering habitat, DFO has developed a guideline for water withdrawal from ice-covered lakes in the Northwest Territories and Nunavut (DFO 2010a) that limits the total water withdrawal from a single waterbody in one ice-covered season to less than 10% of the available water volume. This guideline has been applied as a first step for assessing the potential for effects of the Hope Bay Project on water volume in affected lakes. The limitation of solely applying a lake volume guideline is that it does not allow for assessment of how water withdrawal may impact available fish habitats located in shallow areas (e.g., littoral zone, shoals) where a small drop in elevation due to reduction in lake volume may result in the loss of high value habitats (e.g., spawning along shallow shoals, rearing habitats for juvenile fish in sheltered littoral habitats with complex substrates). Therefore, an assessment of the potential effects of changes in lake surface elevation from the Madrid-Boston Project was also applied. This assessment was applied to under-ice changes in lake surface elevation because in arctic lakes, littoral habitats are sensitive to water level changes when covered by ice. Thick ice cover results in conditions where the littoral zones of lakes up to 1.5 to 2.0 m depth are frozen to the substrates. Additionally, lake inflows and outflows are frozen during the winter months, preventing recharge in lakes from which water is withdrawn and potentially exposing littoral areas to air before freeze-up and/or when water levels continue to drop below the ice layer.

The effects of the Hope Bay Project on lake volume and lake surface elevation in lakes were characterized using the following two methods, respectively:

1. Lake Volume : Baseline and Hope Bay Project-affected average annual and monthly under-ice lake volumes from the water balance model over the life of the Madrid-Boston Project (Years 1 to 22) were compared baseline lake volumes under average hydrologic conditions to assess whether simulated reductions in volume exceed 10% of baseline values (Table 6.5-9).
2. Lake Surface Elevation: Baseline maximum reduction in under-ice lake surface elevation was compared to the Project-affected reduction in under-ice lake surface elevation. Natural variation in both water surface elevation and ice thickness were considered to apply this comparison (Table 6.5-10).

The maximum annual change in lake volume and the maximum change in monthly under-ice volume from baseline in any Madrid-Boston Project year was determined and compared to a 10% reduction threshold (Table 6.5-9). Then, to provide an assessment of the duration of effects, the number of years where the Project-affected lake volume was reduced by more than 10% of annual baseline volume or where a single monthly was also determined. Where the simulated change in average annual lake volume was less than 10% of average annual baseline volume, the Hope Bay Project-affected lake volume was considered to be within the range of natural variation and thus effects of the Hope Bay Project on the fish habitat VEC due to a change in lake volume over the life of the Madrid-Boston Project were considered negligible. The sum of the baseline average change in lake surface elevation during the open water season (typically June to September; Volume 5, Chapter 1; Table 1.2-6) and the average lake ice thickness (Golder Associates Ltd. 2008; Rescan 2010a, 2011c) were calculated to represent the reduction in under-ice lake surface elevation in an average baseline year (Table 6.5-10). The sum of the maximum baseline change in lake surface elevation during the open water season (Volume 5, Chapter 1; Table 1.2-6) and the maximum lake ice thickness (Golder Associates Ltd. 2008; Rescan 2010a, 2011c) were calculated to represent the maximum baseline reduction in under-ice lake surface elevation. Then, the maximum monthly Project-affected under-ice reduction in lake surface elevation was added to the average baseline reduction to simulate the maximum Madrid-Boston Project effects in an average year for water level variation and ice thickness. If the resulting value was less than the maximum baseline reduction by more than 10 cm, the area below the ice unusable as fish habitat will be within the limit of the natural range of water level and ice thickness. Therefore, the effects of the Hope Bay Project on the fish habitat VEC due to a change in lake surface elevation over the life of the Madrid-Boston Project were considered negligible. If the resulting calculated reduction in under-ice lake surface elevation during the Madrid-Boston Project was greater than or within 10 cm of the maximum baseline reduction, further investigation into the presence of high value habitats in the area of surface elevation reduction was undertaken.

Table 6.5-9. Base Case Hope Bay Project-affected Reductions in Average Annual Lake Volume and Monthly Under-Ice Lake Volume during the Life of the Madrid-Boston Project

Watershed	Waterbody	Fish Species Present	Maximum Depth (m)	Maximum Reduction in Annual Lake Volume[a] % Reduction from Baseline	Maximum Reduction in Annual Lake Volume[a] Year (s)	No. of Years with Reduction in Annual Lake Volume >10%[b]	Maximum Reduction in Monthly Under-Ice Lake Volume[c] % Reduction from Baseline	Maximum Reduction in Monthly Under-Ice Lake Volume[c] Year (s)	No. of Years with Reduction in Monthly Under-Ice Lake Volume >10%[d]
Doris	Imniagut Lake	NSSB	4.9	85.6	2032	19	87.4	2031	19
Doris	Wolverine Lake	NSSB, LSCS	4.0	1.0	2031, 2032	0	1.8	2031, 2032	0
Doris	Patch Lake	LKTR, LKWH, CISC, LSCS, NSSB	14.3	0.8	2030, 2031	0	1.4	2031	0
Doris	P.O. Lake	LKTR, LKWH, CISC, LSCS, NSSB	5.0	0.5	2030, 2031	0	0.5	2030 - 2032	0
Doris	Ogama Lake	LKTR, LKWH, CISC, NSSB	5.0	0.3	2030, 2031	0	0.2	2024 - 2032	0
Doris	Doris Lake	LKTR, LKWH, CISC, LSCS, NSSB	19.4	1.9	2030, 2031	0	4.7	2030, 2031	0
Windy	Windy Lake	LKTR, LKWH, CISC, SLSC, NSSB	21.2	0.1	2018-2034	0	0.1	2018 - 2035	0
Aimaokatalok	Stickleback Lake	NSSB, ARGR	4.1	0.3	2023, 2024, 2026 - 2031	0	0.3	2022 - 2031	0
Aimaokatalok	Aimaokatalok Lake	LKTR, LKWH, CISC, LSCS, ARGR SLSC, NSSB	30.0	0.1	2021, 2030, 2031	0	0.1	2020 - 2032	0

Notes:

Waterbodies are ordered from upstream to downstream within a watershed

All simulated lake volumes and surface elevations represent average conditions including climate change effects

[a] maximum annual reduction of simulated Hope Bay Project-affected lake volume compared to simulated baseline lake volume during the life of the Madrid-Boston Project (i.e., Years 1 to 22)

[b] number of Hope Bay Project-affected years where reduction of simulated Hope Bay Project-affected lake volume exceeds 10% of simulated baseline lake

[c] maximum monthly reduction of simulated Hope Bay Project-affected lake volume compared to simulated montly baseline lake volume in ice-covered months during the life of the Madrid-Boston Project (i.e., Years 1 to 22)

[d] number of Hope Bay Project-affected years where reduction of simulated Hope Bay Project-affected lake volume exceeds 10% of simulated baseline lake

NSSB = Ninespine Stickleback, LSCS = Least Cisco, LKTR = Lake Trout, LKWH = Lake Whitefish, CISC = Cisco, ARGR = Arctic Grayling

Table 6.5-10. Base Case Hope Bay Project-affected Reductions in Monthly Under-Ice Lake Surface Elevation during the Life of the Madrid-Boston Project Compared to Baseline Variation

					Baseline Variation in Open-Water Lake Surface Elevation[a]			Baseline Lake Ice Thickness[b]			Baseline Variation in Under-Ice Lake Surface Elevation[c]		Maximum Monthly Project-affected Reduction in Under-Ice Lake Surface Elevation[d]			
Watershed	**Waterbody**	**Fish Species Present**	**Average Depth (m)**	**Maximum Depth (m)**	**Average (m)**	**Maximum (m)**	**Baseline Years**	**Average (m)**	**Maximum (m)**	**Baseline Years**	**Average Reduction (m)**	**Maximum Reduction (m)**	**Change from Baseline (m)**	**Year(s)**	**Reduction in Under-Ice Lake Surface Elevation during Madrid-Boston Project (m)**	**No. of Years with Project-affected Reduction in Lake Surface Elevation within 10 cm of Baseline Maximum[e]**
Doris	Imniagut Lake	NSSB	2.5	4.9	0.09*	0.09*	N/A	1.76**	1.91**	N/A	1.85	2.00	1.76	2032	3.61	20
Doris	Wolverine Lake	NSSB, LSCS	2.1	4.0	0.19	0.26	2006, 2008 - 2011	1.57	1.75	2006, 2007, 2009	1.76	2.01	0.05	2032	1.81	0
Doris	Patch Lake	LKTR, LKWH, CISC, LSCS, NSSB	4.1	14.3	0.24	0.44	2006 - 2011	1.81	2.05	2006, 2007, 2009	2.05	2.49	0.07	2030, 2031	2.12	0
Doris	P.O. Lake	LKTR, LKWH, CISC, LSCS, NSSB	2.1	5.0	0.42	0.64	2007 - 2011	1.85	1.85	2009	2.27	2.49	0.01	2024 - 2032	2.28	0
Doris	Ogama Lake	LKTR, LKWH, CISC, NSSB	2.5	5.0	0.32	0.46	2006 - 2008	1.72	1.95	2006, 2007, 2009	2.04	2.41	0.01	2022 - 2032	2.05	0
Doris	Doris Lake	LKTR, LKWH, CISC, LSCS, NSSB	8.1	19.4	0.53	0.74	2004 - 2015	1.76	2.00	2006, 2007, 2009	2.29	2.74	0.40	2030, 2031	2.69	2
Windy	Windy Lake	LKTR, LKWH, CISC, SLSC, NSSB	11.2	21.2	0.17	0.24	2007 - 2015	1.86	1.90	2006, 2007, 2009, 2010	2.03	2.14	0.01	2018 - 2034	2.04	0
Aimaokatalok	Stickleback Lake	NSSB, ARGR	2.3	4.1	0.12*	0.12*	N/A	1.63	1.80	2006, 2007, 2010	1.75	1.92	0.01	2021 - 2032	1.76	0
Aimaokatalok	Aimaokatalok Lake	LKTR, LKWH, CISC, LSCS, ARGR SLSC, NSSB	6.0	30.0	2.35	3.04	2007 - 2010	1.71	1.95	2006, 2007, 2010	4.06	4.99	0.01	2020 - 2031	4.07	0

Notes:

Waterbodies are ordered from upstream to downstream within a watershed

All simulated lake volumes and surface elevations represent average conditions including climate change effects

[a] average and maximum of field collected baseline variation in lake surface elevation during the open water season (June to September), values obtained from Volume 5, Chapter 1; Table 1.2-6

[b] average and maximum of field collected baseline lake ice thickness; values obtained from Golder (2008), Rescan (2010), Rescan (2011)

[c] average and maximum of field collected baseline variation under-ice lake surface elevation (i.e., "a" + "b")

[d] maximum monthly reduction of simulated Hope Bay Project-affected lake surface elevation compared to simulated baseline lake surface elevation in ice-covered months during the life of the Madrid-Boston Project (i.e., Years 1 to 22)

[e] number of Hope Bay Project-affected years where reduction of simulated Hope Bay Project-affected under-ice lake surface elevation exceeded "c" (i.e., variation in baseline under-ice lake surface elevation)

** field collected baseline data not available, calculated as the average difference between simulated baseline lake surface elevation in September and June (Years 1 to 22)*

***no baseline ice-thickness available; calculated as averages of values from all other lakes with baseline data*

N/A = field collected baseline data not available.

NSSB = Ninespine Stickleback, LSCS = Least Cisco, LKTR = Lake Trout, LKWH = Lake Whitefish, CISC = Cisco, ARGR = Arctic Grayling

(Golder Associates Ltd. 2008 ; Rescan 2010a , 2011c)

The maximum simulated reductions in average annual lake volume and maximum monthly under-ice lake volume over the life of the Madrid-Boston Project in Doris, Ogama, P.O., Patch, Wolverine, Windy, Aimaokatalok, and Stickleback lakes was less than 10% (Table 6.5-9). The maximum simulated reductions in lake volume in lakes in the Doris Watershed generally occurred over one or two years near the end of the Operations phase (Table 6.5-9). In lakes in the Windy and Aimaokatalok watersheds, reductions in lake volume were generally minimal (i.e., < 1%) and reached their greatest amounts at various points throughout the Construction and Operations phases (Table 6.5-9). Overall, the effect of the Hope Bay Project on the fish habitat VEC due to a change in lake volume over the life of the Madrid-Boston Project in these lakes (i.e., all lakes assessed excluding Imniagut Lake, discussed below) was considered negligible.

The maximum reduction in lake surface elevation in any single ice-covered month in Ogama, P.O., Patch, Wolverine, Windy, Aimaokatalok, and Stickleback lakes was over 10 cm less than the maximum baseline reductions in under-ice lake surface elevation (Table 6.5-10). Therefore, effects on the fish habitat VEC due to a reduction in lake surface elevation in these lakes due to water withdrawal and use is also considered to be negligible. Two lakes (Doris and Imniagut, discussed below) had Project-affected reductions in under-ice lake surface elevation that were greater than or within 10 cm of the maximum baseline reduction.

The lake surface elevation reduction in Doris was only 5 cm less than the maximum baseline reduction in two years near the end of the Operations phase (2030 and 2031). Therefore, a more detailed assessment of potential fish habitat loss due to lake surface elevation reduction in Doris Lake was undertaken. Due to the relative importance of spawning habitats and the potential effects of reductions in lake surface elevation on eggs incubating over winter in lake substrates, the assessment focused on spawning habitats. Furthermore, unlike fish that are mobile and capable of moving to deeper water with changes in surface elevation, once laid, the relatively static nature of incubating eggs and larvae makes them more susceptible to environmental fluctuations. The known presence and locations of high value spawning habitats for fall-spawning fish species present in Doris Lake (i.e., Lake Trout, Lake Whitefish and Cisco) were compared with the areas of potential habitat loss due to water withdrawal and use for the Madrid-Boston Project. Detailed information on the distribution of spawning habitats for Lake Trout, Lake Whitefish, and Cisco was collected in 2015 (ERM 2016a). All habitats shallower than 1.84 m were categorized as unsuitable for spawning because this is the minimum depth of baseline ice penetration. All habitats between 1.84 and 2.74 m depth were categorized as unsuitable or of low quality because they are within the natural range of ice and drawdown (i.e., maximum baseline reduction in Table 6.5-10). Between 2.74 m and 4 m depth high quality habitat for Lake Trout and Lake Whitefish spawning was identified in five of 47 habitat units and high quality habitat for Cisco spawning was identified in seven of 47 habitat units. Further, deep-water transect surveys identified extensive good-quality spawning habitats for Lake Trout and Lake Whitefish at depths of up to 10 m.

Overall, high value spawning habitats are not present in the areas predicted to be affected by the Madrid-Boston Project (i.e. lake surface reduction up to 2.69 m depth under average water level variation and ice thickness conditions; Table 6.5-10). If extreme water level variation and ice thickness conditions coincided with maximum Project effects (i.e., maximum baseline reduction added to Project-affected reduction; Table 6.5-10) lake surface elevation reduction up to 3.14 m depth could result. While this case would be rare based on modeled predictions, it is still unlikely to cause adverse effects on spawning in Doris Lake because high value spawning habitats are not limited to the shallowest 3.14 m (ERM 2016a). Based on the amount and locations of high value spawning habitats in Doris Lake for the fish species present, the anticipated effect of reduction in lake surface elevation on fish habitat is anticipated to be negligible.

The maximum simulated reduction in average annual lake volume in Imniagut Lake was 85.6%, and the maximum reduction in monthly under-ice lake volume was 87.4%, occurring during the last two years of the Operations phase (i.e., Years 13 and 14 or 2031 and 2032; Table 6.5-9). The simulated reduction in average annual lake volume was greater than 10% of baseline values for 19 years over the life of the Project, beginning in Madrid-Boston Project Year 4 (2022, Year 4 of Construction phase) and continuing until Madrid-Boston Project Year 22 (2040; last year of Post-Closure phase). The simulated reduction in lake surface elevation in at least one ice-covered month was greater than the maximum baseline reduction in under-ice lake surface elevation for 20 years over the life of the Madrid-Boston Project (Table 6.5-10), beginning in Madrid-Boston Project Year 3 (2021; Year 3 of Construction phase) and continuing until Project Year 22 (2040; the final year of Post-Closure phase). Reduction in average annual lake volume in the final Project Year was simulated at 65.8% (Appendix V5-1R) and the simulated average annual reduction in lake surface elevation in the final Project Year was 1.16 m less than the simulated baseline (Appendix V5-1Q). Although surface hydrology has the potential to recover and effects are expected to be fully reversible, the magnitude of effects on lake volume and lake surface elevation that persist in Imniagut Lake until the final year of the Madrid-Boston Project suggest that recovery of fish habitat in Imniagut Lake may extend beyond the Post-closure phase.

Imniagut Lake is fish-bearing, with confirmed occurrence of Ninespine Stickleback, a forage fish known to support CRA fisheries. During fish community assessments in 2014 and 2017, no large-bodied (CRA) fish species were captured (ERM 2015d, 2017d). Imniagut Lake is located upstream of Patch Lake to which it is connected by an ephemeral outflow stream. Due to this connectivity, Ninespine Stickleback in Imniagut Lake may partially support CRA fish in Patch Lake as food supply, although to a small extent given that the two lakes are only ephemerally connected. Imniagut Lake is a relatively shallow lake (maximum depth = 4.9 m), likely providing only poor and limited overwintering conditions for most species other than low oxygen tolerant fish such as Ninespine Stickleback. Under-ice dissolved oxygen data are unavailable from Imniagut Lake (Rescan 2010a) however, it is anticipated to be similar to LSA lakes with similar maximum and average depths (e.g., Stickleback, Ogama, P.O.; Table 6.5-10). In these lakes, the under-ice DO varied among lakes and years but in some cases was below the CCME guideline for the protection of cold-water aquatic life of 6.5 mg/L (CCME 2016b) throughout the water column (e.g., Ogama in 2008; Golder Associates Ltd. 2009) and near anoxic (0 to 1.3 mg/L) in others (e.g., Stickleback Lake in 2006 and 2010; Golder Associates Ltd. 2008; Rescan 2010a). Imniagut Lake is anticipated to have similar concentrations of DO and thus overwintering habitat quality may be very poor in some years. Due to its already shallow depth, a reduction in surface elevation of 1.31 m could exacerbate effects on the availability of overwintering habitat and under-ice water quality, though no overwintering spawning habitat (i.e., egg incubation) would be affected since fall-spawning species (e.g., Lake Trout) are absent from this lake. Therefore, given that only Ninespine Stickleback have been documented in this lake, it is likely that overall habitat quality is already of low value even under natural conditions.

Activities associated with the Madrid-Boston Project will likely result in the permanent loss of fish habitat for most or all of Imniagut Lake. The total area of fish habitat loss (PAD) could be up to the total surface area of Imniagut Lake of 146,543 m^2 (Appendix V5-3A). However, the value of Imniagut Lake as a contributor of forage fish production towards CRA fisheries within Patch Lake is likely of low value. Notwithstanding, habitat loss resulting from reduction in water volume and lake surface elevation in Imniagut Lake may require offsetting. Offsetting would be commensurate with the productivity contribution that Imniagut Lake may provide to Patch Lake CRA fish populations. As previously described, this characterization of potential effects is based on the Hope Bay Project (Madrid-Boston in combination with Approved Projects), but is conservatively also used for Madrid-Boston in isolation of Approved Projects.

High Groundwater Sensitivity Case:

The effects of the Hope Bay Project on lake volume and lake surface elevation under the high groundwater sensitivity case were characterized using the same methods as for the base case. Results of the assessment on lake volume are presented in Table 6.5-11 and results of the assessment on lake surface elevation are provided in Table 6.5-12.

Similar to the base case, effects on lake volume were predicted only in Imniagut Lake where the duration of effect was the same as the base case (i.e., up to 19 years) but the magnitude of effect was greater (i.e., up to 100% maximum reduction in under-ice lake volume compared to 87.4% under base case; Tables 6.5-11 and 6.5-12). Because the base case assessment considered reductions in lake volume and water surface elevation to result in habitat loss for most or all of Imniagut Lake, the effect on fish habitat under the high groundwater sensitivity case is considered equivalent to the base case for Imniagut Lake.

As in the base case, effects on lake surface elevation were also only predicted in Doris Lake in the high groundwater sensitivity case. The duration and magnitude of these effects are the same as under the base case (Table 6.5-12) and therefore, the effect on fish habitat from changes in lake surface elevation under the high groundwater sensitivity case is considered equivalent to the base case for Doris Lake.

Streamflow

Base Case:

In the effects assessment for the surface hydrology VEC (Volume 5, Section 1.5.2), the following potential effects on streamflow were assessed:

- Alteration of streamflow in Doris Watershed (i.e., Wolverine Outflow, Patch Outflow, P.O. Outflow, Ogama Outflow, Doris Outflow, and Little Roberts Outflow);
- Alteration of streamflow in Windy Watershed (i.e., Windy Outflow and Glenn Outflow); and
- Alteration of streamflow in Aimaokatalok Watershed (i.e., Trout Outflow, Stickleback Outflow, Aimaokatalok Outflow, Koignuk River 1, and Koignuk River 2).

Predictions of the water balance model (Volume 5, Chapter 1; Table 1.5-3) showed that these potential effects on the surface hydrology VEC would not be fully eliminated after implementation of the mitigation measures applied in Section 1.5.3. Therefore, they were carried forward as residual effects for characterization of significance on the surface hydrology VEC. They were concluded to be not significant, based on magnitude, duration, frequency, geographic extent, and reversibility of effects. While residual effects on the surface hydrology VEC as a key component of the biophysical environment are not significant, alterations in stream flows also have the potential to affect fish habitat and thus require further assessment as part of the fish habitat VEC.

Water withdrawal and use from lakes can reduce discharge in lake outflow streams. Lower stream flows can influence fish habitat use in streams through numerous pathways associated with changes in water depth and velocity, changes in the timing and frequency of flows, decreases in the number of days stream habitat is accessible, and increases in the duration of already sensitive low flow periods (flow less than 30% Mean Annual Discharge; DFO 2013d). Fish life histories are represented by annual cycles that rely on different habitats for different life processes and even temporary loss or alteration in fish habitat that occurs during specific periods when fish rely on access to those high value habitats (e.g., spawning, migration) has the potential to influence the survival and population abundance of fish. This is particularly relevant for arctic-dwelling species where access to stream habitat and movement across the landscape is limited to the open-water season (Hershey et al. 2006).

Table 6.5-11. High Groundwater Sensitivty Case Hope Bay Project-affected Reductions in Average Annual Lake Volume and Monthly Under-Ice Lake Volume during the Life of the Madrid-Boston Project

Watershed	Waterbody	Fish Species Present	Maximum Depth (m)	Maximum Reduction in Annual Lake Volume[a] (%)	Maximum Reduction in Annual Lake Volume[a] Year (s)	No. of Years with Reduction in Annual Lake Volume >10%[b]	Maximum Reduction in Under-Ice Lake Volume[a] (%)	Maximum Reduction in Under-Ice Lake Volume[a] Year (s)	No. of Years with Reduction in Monthly Under-Ice Lake Volume >10%[d]
Doris	Imniagut Lake	NSSB	4.9	97.5	2031	18	100	2031, 2032	19
Doris	Wolverine Lake	NSSB, LSCS	4.0	7.0	2032	0	8.8	2033	0
Doris	Patch Lake	LKTR, LKWH, CISC, LSCS, NSSB	14.3	3.1	2031	0	4.7	2031	0
Doris	P.O. Lake	LKTR, LKWH, CISC, LSCS, NSSB	5.0	2.1	2031	0	1.8	2031, 2032	0
Doris	Ogama Lake	LKTR, LKWH, CISC, NSSB	5.0	1.0	2031	0	0.9	2031	0
Doris	Doris Lake	LKTR, LKWH, CISC, LSCS, NSSB	19.4	2.0	2030, 2031	0	4.7	2030, 2031	0
Windy	Windy Lake	LKTR, LKWH, CISC, SLSC, NSSB	21.2	0.1	2018 - 2034	0	0.1	2018 - 2035	0

Notes:

Waterbodies are ordered from upstream to downstream within a watershed

All simulated lake volumes and surface elevations represent average conditions including climate change effects

[a] maximum annual reduction of simulated Hope Bay Project-affected lake volume compared to simulated baseline lake volume during the life of the Madrid-Boston Project (i.e., Years 1 to 22)

[b] number of Hope Bay Project-affected years where reduction of simulated Hope Bay Project-affected lake volume exceeds 10% of simulated baseline lake

[c] average of field collected baseline variation in lake surface elevation during the open water season (June to September), values obtained from Volume 5, Chapter 1; Table 1.2-6

[d] maximum monthly reduction of simulated Hope Bay Project-affected lake surface elevation compared to simulated baseline lake surface elevation in ice-covered months during the life of the Madrid-Boston Project (i.e., Years 1 to 22)

[e] number of Hope Bay Project-affected years where reduction of simulated Hope Bay Project-affected lake surface elevation exceeded "c" (i.e., variation in baseline lake surface elevation)

*** field collected baseline data not available, calculated as the average difference between simulated baseline lake surface elevation in September and June (Years 1 to 22)*

N/A = field collected baseline data not available.

NSSB = Ninespine Stickleback, LSCS = Least Cisco, LKTR = Lake Trout, LKWH = Lake Whitefish, CISC = Cisco, ARGR = Arctic Grayling

Table 6.5-12. High Groundwater Sensitivity Case Hope Bay Project-affected Reductions in Monthly Under-Ice Lake Surface Elevation during the Life of the Madrid-Boston Project Compared to Baseline Variation

					Baseline Variation in Open-Water Lake Surface Elevation[a]			Baseline Lake Ice Thickness[b]			Baseline Variation in Open-Water Lake Surface Elevation + Ice Thickness[c]		Maximum Reduction in Under-Ice Lake Surface Elevation[d]		Reduction in Under-Ice Lake Elevation during Madrid-Boston Project	No. of Years with Project-affected Reduction in Lake Surface Elevation within 10 cm of Baseline Maximum[e]
Watershed	**Waterbody**	**Fish Species Present**	**Average Depth (m)**	**Maximum Depth (m)**	**Average (m)**	**Maximum (m)**	**Baseline Years**	**Average (m)**	**Maximum (m)**	**Baseline Years**	**Average (m)**	**Maximum (m)**	**Change from Baseline (m)**	**Year(s)**	**(m)**	
Doris	Imniagut Lake	NSSB	2.5	4.9	0.09*	0.09*	N/A	1.76**	1.91**	N/A	1.85	2.00	3.66	2032	> 4.90 (max lake depth)	20
Doris	Wolverine Lake	NSSB, LSCS	2.1	4.0	0.19	0.26	2006, 2008 - 2011	1.57	1.75	2006, 2007, 2009	1.76	2.01	0.24	2033	2.00	2
Doris	Patch Lake	LKTR, LKWH, CISC, LSCS, NSSB	4.1	14.3	0.24	0.44	2006 - 2011	1.81	2.05	2006, 2007, 2009	2.05	2.49	0.25	2031	2.30	0
Doris	P.O. Lake	LKTR, LKWH, CISC, LSCS, NSSB	2.1	5.0	0.42	0.64	2007 - 2011	1.85	1.85	2009	2.27	2.49	0.04	2030, 2031	2.31	0
Doris	Ogama Lake	LKTR, LKWH, CISC, NSSB	2.5	5.0	0.32	0.46	2006 - 2008	1.72	1.95	2006, 2007, 2009	2.04	2.41	0.03	2026 -2029, 2031, 2032	2.07	0
Doris	Doris Lake	LKTR, LKWH, CISC, LSCS, NSSB	8.1	19.4	0.53	0.74	2004 - 2015	1.76	2	2006, 2007, 2009	2.29	2.74	0.40	2030, 2031	2.69	2
Windy	Windy Lake	LKTR, LKWH, CISC, SLSC, NSSB	11.2	21.2	0.17	0.24	2007 - 2015	1.86	1.9	2006, 2007, 2009, 2010	2.03	2.14	0.01	2028, 2030 - 2032	2.04	0

Notes:

Waterbodies are ordered from upstream to downstream within a watershed

All simulated lake volumes and surface elevations represent average conditions including climate change effects

[a] *average and maximum of field collected baseline variation in lake surface elevation during the open water season (June to September), values obtained from Volume 5, Chapter 1; Table 1.2-6*

[b] *average and maximum of field collected baseline lake ice thickness; values obtained from Golder (2008), Rescan (2010), Rescan (2011)*

[c] *average and maximum of field collected baseline variation under-ice lake surface elevation (i.e., "a" + "b")*

[d] *maximum monthly reduction of simulated Hope Bay Project-affected lake surface elevation compared to simulated baseline lake surface elevation in ice-covered months during the life of the Madrid-Boston Project (i.e., Years 1 to 22)*

[e] *number of Hope Bay Project-affected years where reduction of simulated Hope Bay Project-affected under-ice lake surface elevation exceeded "c" (i.e., variation in baseline under-ice lake surface elevation)*

** field collected baseline data not available, calculated as the average difference between simulated baseline lake surface elevation in September and June (Years 1 to 22)*

***no baseline ice thickness available; calculated as averages of values from all other lakes with baseline data*

N/A = field collected baseline data not available.

NSSB = Ninespine Stickleback, LSCS = Least Cisco, LKTR = Lake Trout, LKWH = Lake Whitefish, CISC = Cisco, ARGR = Arctic Grayling

Arctic Char (and other anadromous species including Lake Trout, cisco, and whitefish) rely on stream habitats as migratory corridors during their seasonal migrations between freshwater overwintering/spawning and seasonal marine feeding habitats (Johnson 1980). Unimpeded access to high value summer feeding in marine habitats during freshet high flows and return migration during low flows (August to October) to high value spawning/overwintering habitats is key to maintaining fisheries productivity of anadromous species such as juvenile and adult Arctic Char. Juvenile and adult fish of multiple species (e.g., Arctic Char, Lake Trout, Arctic Grayling, cisco, and whitefish) and forage fish rely on stream habitats as migratory corridors to move between waterbodies during the open water season (Evans, Reist, and Minns 2002; Hershey et al. 2006). Juvenile fish also rely on stream habitats for rearing/feeding opportunities and predator avoidance (Evans, Reist, and Minns 2002). Finally, Arctic Grayling rely on stream habitats for spawning/egg incubation habitat in the spring which requires unimpeded access to and from overwintering habitats, as well as for providing rearing/feeding habitat for newly-emerged fry and juveniles throughout the open water season (Stewart et al. 2007). Since most arctic streams freeze to the bottom during winter, unimpeded access to overwintering habitat leading up to freeze-up is also important for survival.

Fish depend on natural flow regimes in streams to support these various life processes and DFO has developed guidance for assessing the probability of alterations in flow to result in degradation to systems that sustain fish (DFO 2013d). Based on this guidance, cumulative flow alterations of less than 10% of the magnitude of actual flow in the river/stream relative to a natural flow regime are considered to have a low probability of detectable adverse effects to systems that support CRA fisheries (DFO 2013d). However, instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of impacts to systems that support CRA fisheries. These guidelines form the basis of the assessment of effects of changes in streamflow on the fish habitat VEC. The application of these guidelines in this assessment is in agreement other recent EIS studies in the region of the Madrid-Boston Project (e.g., Back River and Mary River).

The following steps describe how the effects of the Hope Bay Project on streamflow were characterized:

1. A variation of 10% from baseline conditions was initially used to identify waterbodies that may be affected by reduced streamflows, allowing "least risk" watercourses to be scoped out (Table 6.5-13).
2. The "higher risk" watercourses were then further assessed by:
    a. Using a minimum flow threshold of 30% of the MAD to determine periods of highest risk for fish and potential effects on habitat use (Table 6.5-14); and
    b. Calculating the area of potential fish habitat loss using information from baseline fish habitat assessments (ERM 2016d, 2017d) and hydraulic models (ERM 2016d; 2017a; Table 6.5-15).

Simulated baseline and Hope Bay Project-affected stream flows from the water balance model based on preliminary mine design aspects were compared for average hydrologic conditions over the life of the Madrid-Boston Project (Years 1 to 22) to assess whether simulated reductions in streamflow exceeded 10% of baseline values during high and low flow periods (Table 6.5-13). To proceed with this comparison, the maximum reduction in monthly streamflow at high flow (June) and low flow (July, August, or September) in all Madrid-Boston Project Years was determined. Then, to provide an assessment of duration of effect, the number of years where the Hope Bay Project-affected streamflow was reduced by more than 10% of baseline flow in at least one month at high and/or low flow was also determined. Where the simulated change in monthly streamflow at high or low flow was less than 10% of baseline monthly streamflow, the Hope Bay Project-affected streamflow was considered to have a low probability of detectable adverse effects to fish habitat and thus effects of the Hope Bay Project on the fish habitat VEC due to a change in streamflow over the life of the Madrid-Boston Project were considered negligible.

Table 6.5-13. Baseline and Base Case Hope Bay Project-affected Reductions in Monthly Flow over the Life of the Madrid-Boston Project

		Open-water High Flow Period (June)				Open-water Low Flow Period (July, Aug, Sept)			
		Max. Reduction in Monthly Hope Bay Project-affected Stream Flow*				Max. Reduction in Monthly Hope Bay Project-affected Stream Flow*			
Watershed	Stream	Streamflow (m^3/s)	% Reduction from Baseline	Year(s)	No. of Years with Reduction in Flow > 10%	Streamflow (m^3/s)	% Reduction from Baseline	Year(s)/Month	No. of Years with Reduction in Flow > 10%
Doris	Imniagut Outflow[§]	0	*100*	2020 - 2040	21	N/A	N/A	N/A	N/A
Doris	Wolverine Outflow	0.023	*55.9*	2032	4	N/A	N/A	N/A	N/A
Doris	Patch Outflow	0.322	*28.4*	2031	10	0.181	*19.9*	2031 (Jul)	10
Doris	P.O. Outflow	0.454	*21.5*	2031	10	0.200	*19.0*	2031 (Jul)	10
Doris	Ogama Inflow	1.746	6.7	2031	0	0.419	*10.0*	2031 (Jul)	0
Doris	Ogama Outflow	1.721	6.2	2031	0	0.422	*11.1*	2031 (Jul)	1
Doris	Doris Outflow	1.204	*39.9*	2031	17	0.629	*19.2*	2031 (Jul)	15
Doris	Little Roberts Outflow	5.652	*22.1*	2031	12	1.556	*13.4*	2032 (Jul)	3
Windy	Windy Outflow	0.174 - 0.178	7.4	2025 - 2031	0	0.022	9.4	2031 (Sep)	0
Windy	Glenn Outflow	0.725 - 0.734	1.9	2025 - 2031	0	0.104 - 0.105	4.5	2024 - 2031 (Jul)	0
Aimaokatalok	Stickleback Outflow	0.029	*10.9*	2027 - 2031		0.001	*25.0*	2031 (Sep)	
Aimaokatalok	Aimaokatalok Outflow	33.179 - 33.684	0.2	2021 - 2030	0	4.809 - 4.872	0.3	2022 - 2030 (Aug)	0
Koignuk	Koignuk River 2	58.372 - 59.529	0.1	2020, 2021, 2023 - 2028, 2030, 2031	0	8.038 - 12.059	0.1	2020 - 2031 (Jul - Sep)	0
Koignuk	Koignuk River 1	38.484 - 38.812	0.2	2020 - 2031	0	5.471 - 5.552	0.5	2023 - 2025, 2027 - 2029 (Aug - Sep)	0

Notes:

Waterbodies are ordered from upstream to downstream within a watershed

Italicized values indicate those with modeled change in streamflow >10%

Simulated streamflows represent average conditions including climate change effects

**maximum reduction of simulated monthly Hope Bay Project-affected streamflow compared to simulated monthly baseline streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22)*

[§] streamflow reduction in Imniagut Outflow assumed to be 100% based on lake evelation reduction starting in 2020

Table 6.5-14. Base Case Hope Bay Project-affected Monthly Flow as a Percentage of Mean Annual Discharge

				Habitat Function		High Flow (June)				Low Flow (July)				Low Flow (Aug)				Low Flow (Sept)			
Watershed	Stream	MAD[a] (m^3/s) (open water)	30% of MAD (m^3/s)	High Flow	Low Flow	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD
Doris	Imniagut Outflow[§]	-	-	Migration	N/A (ephemeral)	0.000	2020 - 2040	*0*	21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Doris	Wolverine Outflow	0.011	0.003	Migration	N/A (ephemeral)	0.023	2032	209	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Doris	Patch Outflow	0.179	0.054	Migration	Migration, Rearing	0.322	2031	180	0	0.181	2031	101	0	0.097	2031	54	0	0.084	2031	47	0
Doris	P.O. Outflow	0.216	0.065	Migration	Migration, Rearing	0.454	2031	210	0	0.200	2031	93	0	0.112	2031	52	0	0.105	2031	49	0
Doris	Ogama Inflow	0.616	0.185	Migration	Migration, Rearing	1.746	2031	283	0	0.419	2031	68	0	0.308	2031	50	0	0.306	2031	50	0
Doris	Ogama Outflow	0.582	0.175	Migration	Migration, Rearing	1.721	2031	296	0	0.422	2031	73	0	0.288	2031	49	0	0.273	2031	47	0
Doris	Doris Outflow	1.174	0.352	Migration	Migration, Rearing	1.204	2031	103	0	0.509	2031	43	0	0.281	2031	*24*	22	0.283	2031	*24*	22
Doris	Little Roberts Outflow	2.402	0.721	Migration	Migration, Rearing	5.652	2031	235	0	1.556	2031	65	0	1.044	2031	43	0	1.053	2031	44	0
Aimaokatalok	Stickleback Outflow	0.009	0.003	Migration	Migration, Rearing	0.029	2027 - 2031	322	0	0.009	2031	100	0	0.001	2031	*11*	22	0.001	2031	*11*	22

Notes:

MAD = Mean annual discharge

Simulated streamflows represent average conditions including climate change effects

Italicized values indicate those with modeled streamflow <30% of MAD

[a] *calculated as the mean of annual average open-water simulated baseline streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22*

[b] *minimum simulated monthly Hope Bay Project-affected streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22*

[§] *streamflow reduction in Imniagut Outflow assumed to be 100% based on lake evelation reduction starting in 202*

N/A = not applicable; ephemeral streams with simulated baseline streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22) of 0 m^3/s.

Dashes = data not simulated

Table 6.5-15. Total Estimated PAD of Stream Fish Habitat from Water Withdrawal and Use for the Madrid-Boston Project

		Max. Reduction in Hope Bay Project-affected September Streamflow*			PAD (m^2)				
Watershed	**Stream**	**Streamflow (m^3/s)**	**% Reduction from Baseline**	**Year**	**Glide**	**Pool**	**Riffle**	**Cascade**	**Total**
Doris	Imniagut Outflow[◊]	N/A	N/A	N/A	120.0	-	-	-	120.0
Doris	Patch Outflow	0.084	18.4	2031	19.6	52.0	-	-	71.6
Doris	P.O. Outflow[§]	0.105	15.6	2031	16.7	-	-	-	2063.3
Doris	Ogama Inflow	0.306	6.0	2031	258.3	47.7	33.6	1.4	341.0
Doris	Ogama Outflow	0.273	6.9	2031	97.1	59.2	38.9	-	195.2
Doris	Doris Outflow	0.283	18.4	2031	786.8	93.8	20.6	144.1	1045.2
Doris	Little Roberts Outflow	1.053	20.3	2031	218.2	93.4	18.6	-	330.2
Aimaokatalok	Stickleback Outflow[ƚ]	0.001	25.0	2031	61.1	4.3	-	-	65.4

Notes:

PAD = Potential alteration to, or destruction of, fish habitat; calculated as reduction in channel top width estimated from hydraulic modeling multiplied by channel length

** maximum reduction of simulated September Hope Bay Project-affected streamflow compared to simulated September baseline streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22)*

[◊] No hydraulic model; PAD is equal to total habitat area

[§] No hydraulic model; PAD estimated based on relationship between streamflow reduction from baseline and glide habitat loss in Patch Outflow (nearest upstream channel)

[ƚ] No hydraulic model; PAD estimated as 25% of total habitat area

For waterbodies where the simulated change in monthly streamflow at high or low flow was greater than 10%, the MAD of the stream was calculated from simulated baseline flows during the open-water period for average hydrologic conditions over the life of the Madrid-Boston Project (Years 1 to 22) from the water balance model (Appendix V5-1P). Once the MAD was calculated for each stream, maximum Project-affected flow reductions over the life of the Madrid-Boston Project were calculated for each month of the open-water season (i.e., June, July, August, September) (Table 6.5-14). The timing and duration of a “highest risk” period was determined based on the timing (i.e., month) and number of years in which there was a period of streamflow less than 30% of MAD (DFO 2013d) as well as the habitat functions of the affected streams. The area of potential fish habitat loss (PAD) was calculated using a combination of fish habitat assessment data (ERM 2016d, 2017d) and hydraulic modeling results (ERM 2016d, 2017a) as described in Appendix V5-6AA. The PAD areas presented in this effects assessment reflect the flows with the maximum simulated reduction from baseline under stable low flow conditions over the life of the Madrid-Boston Project (i.e., maximum reduction in September).

The maximum simulated reductions in monthly streamflow over the life of the Madrid-Boston Project in streams in the Windy and Koignuk Watersheds and in Aimaokatalok Outflow in the Aimaokatalok Watershed were less than 10% in both the open-water high flow and low flow periods (Table 6.5-13). Therefore, effects on fish habitat due to a reduction in stream flow are considered negligible based on the application of a 10% variation from baseline threshold.

The maximum simulated reductions in monthly streamflow over the life of the Madrid-Boston Project in all streams in the Doris Watershed and in Stickleback Outflow in the Aimaokatalok Watershed were greater than or equal to 10% in the open-water high and/or low flow periods (Table 6.5-13). Therefore, there is a higher risk of effects on fish habitat due to reduction in streamflow based on the application of a 10% variation from baseline threshold. The effects of reduced streamflow were therefore further assessed for each Doris Watershed stream and for Stickleback Outflow based on a threshold of monthly Hope Bay Project-affected stream flow of 30% of MAD (Table 6.5-14).

The primary potential effect of decreased streamflow in Little Roberts, Doris, Patch, P.O. and Ogama outflows and Ogama Inflow is related to their function of providing suitable rearing/feeding and migratory habitat for juvenile and adult stages of Arctic Char (limited to Little Roberts Outflow and section of Doris Outflow downstream of impassable barrier only), Lake Trout, cisco, and/or whitefish. Stickleback Outflow provides similar habitat functions for rearing/feeding and migrating Ninespine Stickleback, Slimy Sculpin, and Arctic Grayling. Little Roberts Outflow serves as a migratory corridor for Arctic Char (and other anadromous species such as Lake Trout, cisco, and whitefish) between marine/estuarine habitats found in Roberts Bay and freshwater spawning and/or overwintering habitats in Roberts Lake. Patch, P.O., and Stickleback Outflows, and Ogama Inflow and Outflow serve as migratory corridors between lakes, allowing for seasonal distribution of fish across the landscape (Hershey et al. 2006). Finally, Little Roberts Outflow and the entire lower section of Doris Outflow (i.e., downstream of the impassable barrier) are also accessible for rearing to fish originating from Little Roberts Lake and Roberts Lake during the open water season. Reduced high and/or low flows have the potential to hinder or prevent migration, reduce the amount of useable habitat for fish for rearing/feeding (i.e., through reduction in stream area), and to alter the timing of flow by delaying the onset of freshet or inducing the onset of freeze-up, further limiting the fish use over the open water season.

The assessment based on the 30% of MAD threshold indicated that, during high flows when the primary habitat use of these streams is for migratory purposes, fish habitat function will likely not be affected in these streams (Table 6.5-14). Simulated monthly stream flows were between 103% and 296% of MAD suggesting that reductions during the high flow period will not result in barriers to early-season migration. The assessment based on the 30% of MAD threshold indicated that, during low flows (July, August, and September) when the primary use of stream habitats is for rearing/feeding as well as late-season migratory purposes, fish habitat function will likely not be affected in Little Roberts, Patch, and P.O. outflows, nor in Ogama Inflow and Outflow (simulated monthly streamflows > 30% of MAD in all months; Table 6.5-14), but may be affected in Doris and Stickleback outflows (simulated monthly streamflows of 24% and 11%, respectively in both August and September of all Madrid-Boston Project Years; Table 6.5-14).

Although flows were less than 30% of MAD in Doris and Stickleback outflows in September and August, it is important to note that the MAD was calculated using discharge values from the open-water period only because inclusion of months where streams were frozen to the substrates (i.e., values where discharge = 0 m^3/s) influenced the overall MAD value such that it was considered too low to provide an appropriately stringent assessment threshold at 30%. However, as a consequence of this higher calculated MAD value, late-season flows in certain streams (i.e., Doris and Stickleback outflows) were occasionally below 30% of MAD under both Project-affected and baseline conditions (Appendices V5-1M and V5-1P). Therefore, the extent of effects on fish habitat predicted based on comparison of flows to a threshold of < 30% of MAD in these streams may be less severe than predicted as similar conditions are simulated for baseline flows.

Fish in Doris and Stickleback outflows in August and September may be rearing/feeding or migrating to overwintering habitats in lakes. Stream habitat use for migration generally decreases later in the season depending on the timing of freeze-up, and thus reduced streamflow in September may only partially affect migratory potential. However, reduced streamflow in Doris Creek may reduce the ability of Arctic Char (below the barrier only), Lake Trout, Lake Whitefish, and Cisco to migrate to overwintering habitats due to decreased water depth in specific habitat units that may pose migration barriers. The maximum channel depths in model transects completed in Doris Outflow were modelled as outputs of the Doris Creek hydraulic model (Appendix V5-6AA). All transects had maximum depths of at least 0.2 m depth under maximum September flow reduction conditions except for one glide, located upstream of the falls, which had a maximum depth of 0.14 m. There is limited information on water depth requirements for successful passage for fish species using stream habitats in the Arctic. However, existing data for other salmonids with similar adult body size and shape are available. Thompson (1972) assessed the minimum water depths that enable upstream migration of various adult salmon and trout. Most salmonids require around 0.18 m water depth except the larger Chinook, who required 0.24 m. In a study on adult Alaskan chum salmon, fish could successfully pass through sections of creek with water depths greater than 0.12 m if there was coarse substrate and 0.08 m in sections with finer substrate (Sautner, Vinin, and Rundquist 1984). Based on these studies, the modeled channel depths, and typically cobble/gravel dominated substrates in affected habitat units of Doris Creek, water depth will be sufficient for fish passage.

Wolverine and Imniagut outflows are ephemeral streams that provide seasonal migratory habitat, primarily for Ninespine Stickleback between Patch and Wolverine lakes, and between Patch and Imniagut lakes, respectively. Ninespine Stickleback and Least Cisco are present in Wolverine Lake and Ninespine Stickleback are present in Imniagut Lake. Ninespine Stickleback in these lakes may partially support CRA fish in Patch Lake as food supply. Based on the 30% of MAD threshold, migration potential will be maintained in Wolverine Outflow during high flows. Baseline conditions indicate that Wolverine Outflow is ephemeral; therefore, streamflow under low flow conditions was not simulated in the water balance model. However, because connectivity will be maintained at high flow, effects on stream habitat (i.e., through provision of a migratory corridor to fish) are considered negligible.

Streamflow in Imniagut Lake was not simulated in the water balance model because it is an intermittent outflow that does not flow consistently for a minimum period of one month during the open-water season. The water balance model uses a monthly time-step model method that is not suitable for simulating flows that are intermittent over periods shorter than the duration of the time-step. However, because Imniagut Outflow is intermittent under baseline conditions and it is expected to experience reductions in lake volume and lake surface elevation beginning in 2020 (Year 2 of the Construction phase; Table 6.5-9 and 6.5-10), streamflow reduction was conservatively estimated to be 100% (total loss of fish habitat) at high flow starting in 2020 (Year 2 of the Construction phase; Table 6.5-13) and persisting for the life of the Madrid-Boston Project (up to Year 22). Simulated baseline conditions and field surveys indicate that an ephemeral stream between Imniagut and Patch lakes allows for migration of Ninespine Stickleback. Therefore, Hope Bay Project-affected streamflow may result in the complete loss of connectivity between Imniagut and Patch lakes for the life of the Madrid-Boston Project. Given that only Ninespine Stickleback have been documented in Imniagut Lake and its outflow, it is likely that overall habitat quality is already of low value even under natural conditions. However, activities associated with the Madrid-Boston Project would still likely result in the permanent loss of fish habitat in Imniagut Outflow, although its value as a contributor of forage fish production towards CRA fisheries within Patch Lake is likely also of low value. Notwithstanding, the effects of reduction in on Imniagut Outflow may require offsetting. Offsetting would be commensurate with the forage fish productivity contribution Imniagut Outflow provides to Patch Lake CRA fish populations.

To quantify potential fish habitat losses (PAD) in streams resulting from water withdrawal and use, the area of potential PAD was calculated for all streams with simulated variation from baseline of 10% or more. Total estimated PAD calculated using information from baseline fish habitat assessments (ERM 2016d, 2017d) and hydraulic models (ERM 2016d, 2017a) are presented in Table 6.5-15.

High Groundwater Sensitivity Case:

The effects of the Hope Bay Project on streamflow under the high groundwater sensitivity case were characterized using methods applied to the base case. Results of the assessment on streamflow are provided in Table 6.5-16 and 6.5-17.

The maximum simulated reductions in monthly streamflow over the life of the Madrid-Boston Project in Glenn Outflow were less than 10% in both the open-water high flow and low flow periods (Table 6.5-16). Therefore, effects on fish habitat due to a reduction in stream flow are considered negligible based on the application of a 10% variation from baseline threshold.

The maximum simulated reductions in monthly streamflow over the life of the Madrid-Boston Project in all streams in the Doris Watershed and in Windy Outflow in the Windy Watershed were equal to or greater than 10% in the open-water high and/or low flow periods (Table 6.5-16). Therefore, there is a higher risk of effects on fish habitat due to reduction in streamflow based on the application of a 10% variation from baseline threshold. The effects of reduced streamflow were therefore further assessed for each Doris Watershed stream and for Windy Outflow based on a threshold of monthly Hope Bay Project-affected stream flow of 30% of MAD (Table 6.5-17).

The assessment based on the 30% of MAD threshold indicated that, during high flows when the primary habitat use of streams is for migratory purposes, fish habitat function will likely only be affected in Imniagut and Wolverine Outflows (Table 6.5-17). Simulated monthly stream flows were 0% of MAD in Imniagut and Wolverine Outflows and between 61% and 279% of MAD in other streams. Therefore, while migratory habitat during high flow would be lost in Imniagut and Wolverine Outflows, reductions during the high flow period will not result in barriers to early-season migration in other streams.

The assessment based on the 30% of MAD threshold indicated that, during low flows (July, August, and September) when the primary use of stream habitats is for rearing/feeding as well as late-season migratory purposes, fish habitat function will likely not be affected in Little Roberts Outflow, nor in Ogama Inflow and Outflow (simulated monthly streamflows > 30% of MAD in all months; Table 6.5-17), but may be affected in Doris, Patch, and P.O. outflows (simulated monthly streamflows between 18% and 26%; in August and September of all Madrid-Boston Project Years; Table 6.5-17).

Table 6.5-16. Baseline and High Groundwater Sensitivity Case Hope Bay Project-affected Reductions in Monthly Flow over the Life of the Madrid-Boston Project

Watershed	Stream	Open-water High Flow Period (June): Max. Reduction in Monthly Hope Bay Project-affected Stream Flow*				Open-water Low Flow Period (July, Aug, Sept, Oct): Max. Reduction in Monthly Hope Bay Project-affected Stream Flow*			
		Streamflow (m^3/s)	% Reduction from Baseline	Year(s)	No. of Years with Reduction in Flow > 10%	Streamflow (m^3/s)	% Reduction from Baseline	Year(s)/Month	No. of Years with Reduction in Flow > 10%
Doris	Imniagut Outflow§	0.000	*100*	2021 - 2040	20	N/A	N/A	N/A	N/A
Doris	Wolverine Outflow	0.000	*100*	2030 - 3034	6	N/A	N/A	N/A	N/A
Doris	Patch Outflow	0.109	*75.8*	2031	13	0.077	*65.8*	2031 (Jul)	13
Doris	P.O. Outflow	0.250	*54.6*	2031	13	0.091	*63.5*	2031 (Jul)	13
Doris	Ogama Inflow	1.543	*17.5*	2031	9	0.310	*33.3*	2031 (Jul)	11
Doris	Ogama Outflow	1.542	*15.9*	2031	9	0.304	*36.0*	2031 (Jul)	11
Doris	Doris Outflow	1.204	*39.9*	2031	17	0.379	*39.9*	2031 (Jul)	17
Doris	Little Roberts Outflow	5.382	*25.8*	2031	15	1.296	*27.9*	2031 (Jul)	12
Windy	Windy Outflow	0.175 - 0.177	7.9	2027 - 2031	0	0.022	10.0	2031 (Sep)	0
Windy	Glenn Outflow	0.731	2.1	2029	0	0.103 - 0.104	4.8	2028 - 2031 (Jul)	0

Notes:

Waterbodies are ordered from upstream to downstream within a watershed

Italicized values indicate those with modeled change in streamflow >10%

Simulated streamflows represent average conditions including climate change effects

**maximum reduction of simulated monthly Hope Bay Project-affected streamflow compared to simulated monthly baseline streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22)*

§ Streamflow reduction in Imniagut Outflow based on lake evelation reduction starting in 2021

Streamflow in Imniagut Lake was simulated as having no flow in the water balance model because it is an intermittent outflow and the monthly time-step model method is not suitable for simulating intermittent flows

Potential fish habitat losses (PAD) in streams resulting from water withdrawal and use under the high groundwater sensitivity case were not quantified by calculating the area of potential PAD. The calculation of PAD estimates was limited to the base case (Table 6.5-13). Potential effects on streamflow in the high groundwater sensitivity case based on threshold of 30% of MAD are not anticipated until 2030 (i.e., Project Year 12). Between the initiation of the Madrid-Boston Project in 2019 and the time at which effects of the high groundwater case would be anticipated, provided that this alternative case is realized, the potential effects to fish habitat loss would be monitored on an ongoing basis through adaptive management. Data from proposed monitoring programs, including the AEMP (Volume 8, Environmental Management System) will be available to evaluate the probability of the high groundwater sensitivity case occurring. If simulated streamflows under the high groundwater sensitivity case are likely based on initial monitoring data, appropriate measures to evaluate and quantify fish habitat losses under this case will be applied.

As previously described, this characterization of potential effects is based on the Hope Bay Project (Madrid-Boston Project in combination with Approved Projects), but is conservatively also used for the Madrid-Boston Project in isolation of Approved Projects.

Mitigation and Management Measures for Specific Potential Effects (Hope Bay Project)

Domestic and Industrial Use, Underground Mines, Modification of Natural Drainage

The primary mitigation measure for effects of water withdrawal and use on freshwater fish habitat is to protect habitat necessary for life stages of freshwater fish by limiting the amount of water withdrawn from each waterbody. This is accomplished by recycling water where possible to reduce the demand from water withdrawals, limiting groundwater inflows to underground workings were practical, and returning compliant effluent to waterbodies from which they were withdrawn where not prohibited by salinity (i.e., Aimaokatalok Lake; Volume 3, Section 4.4.5; Water Management). Other measures for the mitigation and management of water withdrawal and use are applied to the surface hydrology VEC and are included in Volume 5, Section 1.5.3.

Winter Road Construction and Exploration Activities

To mitigate the effects of water withdrawal for the construction of winter roads and drilling, these activities will adhere to DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2) and the *Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut* (DFO 2010a):

- In one ice-covered season, total water withdrawal from a single waterbody is not to exceed 10% of the available water volume.
- In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume is not to exceed 10% of the available water volume.
- Only waterbodies with maximum depths that are ≥1.5 m than their corresponding maximum expected ice thickness will be considered for water withdrawal.

Further, water to supply drill sites will be provided by a lake nearby to the drill that has a surface area of at least 15,000 m^2.

Table 6.5-17. High Groundwater Sensitivity Case Hope Bay Project-affected Monthly Flow as a Percentage of Mean Annual Discharge

				Habitat Function		High Flow (June)				Low Flow (July)				Low Flow (Aug)				Low Flow (Sept)			
Watershed	Stream	MAD[a] (m^3/s) (open water)	30% of MAD (m^3/s)	High Flow	Low Flow	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD	Flow in Month with Max. Hope Bay Project-affected Flow Reduction[b] (m^3/s)	Year	% of MAD	No. Project Years with Minimum Flow <30% MAD
Doris	Imniagut Outflow[§]	-	-	Migration	N/A (ephemeral)	0.000	2021 - 2040	*0*	20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Doris	Wolverine Outflow	0.011	0.003	Migration	N/A (ephemeral)	0.000	2030 - 2034	*0*	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Doris	Patch Outflow	0.179	0.054	Migration	Migration, Rearing	0.109	2031	61	0	0.077	2031	43	0	0.042	2031	*23*	2	0.037	2031	*21*	3
Doris	P.O. Outflow	0.216	0.065	Migration	Migration, Rearing	0.250	2031	116	0	0.091	2031	42	0	0.055	2031	*25*	1	0.056	2031	*26*	2
Doris	Ogama Inflow	0.616	0.185	Migration	Migration, Rearing	1.543	2031	250	0	0.310	2031	50	0	0.251	2031	41	0	0.257	2031	42	0
Doris	Ogama Outflow	0.582	0.175	Migration	Migration, Rearing	1.542	2031	265	0	0.304	2031	52	0	0.222	2031	38	0	0.223	2031	38	0
Doris	Doris Outflow	1.174	0.352	Migration	Migration, Rearing	1.204	2031	103	0	0.379	2031	32	0	0.206	2031	*18*	22	0.227	2031	*19*	22
Doris	Little Roberts Outflow	2.402	0.721	Migration	Migration, Rearing	5.382	2031	224	0	1.296	2031	54	0	0.895	2031	37	0	0.942	2031	39	0
Doris	Windy Outflow	0.063	0.019	Migration	Migration, Rearing	0.176	2028	279	0	0.071	2031	113	0	0.023	2031	37	0	0.022	2031	35	0

Notes:
MAD = Mean annual discharge
Simulated streamflows represent average conditions including climate change effects
Italicized values indicate those with modeled streamflow <30% of MAD
[a] calculated as the mean of annual average open-water simulated baseline streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22)
[b] minimum simulated monthly Hope Bay Project-affected streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22)
[§] streamflow reduction in Imniagut Outflow assumed to be 100% based on lake evelation reduction starting in 2021
N/A = not applicable; ephemeral streams with simulated baseline streamflow during the life of the Madrid-Boston Project (i.e., Years 1 to 22) of 0 m^3/s.
Dashes = data not simulated

Fisheries Offsetting

The purpose of a FOP (Appendix V5-6AA), as per the guiding policies of DFO, is to maintain or improve the productivity of CRA fisheries. The Offsetting Plan will address permanent fish habitat losses/alterations related to water withdrawal and use from the Madrid-Boston Project, as deemed necessary and approved by DFO. The potential loss or alteration of fish habitat was assessed using simulated results from the water balance report (Package P5-4) and the application of steps for characterizing the effects of water withdrawal and use in lakes and streams.

Based on this assessment, habitat losses or permanent alteration to fish habitats that may occur as a result of water withdrawal and use from the Hope Bay Project (including the Madrid-Boston Project and Approved Projects; conservatively used to describe habitat losses or permanent alteration from the Madrid-Boston Project in isolation of Approved Projects) include:

- Partial or total loss of habitat for Ninespine Stickleback in Imniagut Lake (as a contributor of forage fish production towards CRA fisheries within Patch Lake);
- Total loss of migratory habitat for Ninespine Stickleback in Imniagut Outflow (as a contributor of forage fish production towards CRA fisheries within Patch Lake); and
- Potential partial loss of migratory and rearing habitat for CRA and forage fish species in Little Roberts, Doris, Ogama, P.O., Patch, Wolverine, and Stickleback outflows and Ogama Inflow.

Unavoidable habitat loss or alteration due to water withdrawal and use for the Hope Bay Project is predicted to occur in the Doris and Aimaokatalok watersheds within the LSA (Figure 6.2-1). Where deemed necessary by the DFO *Fisheries Authorization* process, final mitigation and monitoring requirements for the lost/altered habitat will be incorporated during the development of a FOP in consultation with DFO, and discussed through NIRB and NWB processes. Habitat losses have been calculated based on a combination of hydraulic modeling (ERM 2015a, 2017a), baseline fish habitat data, baseline fish community data (ERM 2016d, 2017d) and may be updated based on results of proposed monitoring programs (i.e., hydrology surveys as part of the AEMP; Volume 8, Environmental Management System). Fish habitat loss and alteration resulting from water use by Approved Projects generally has been or will be mitigated or offset and/or commitments to develop and implement offsetting plans have been made. Because waterbodies in which effects of water withdrawal and use for Approved Projects are the same as those that will be further affected by Madrid-Boston Project activities, future offsetting deemed necessary by DFO for both the Madrid-Boston Project and Approved Projects may be considered as a whole such that all fish habitat losses from the Hope Bay Project are offset.

The objective of the FOP will be to compensate for the alteration or destruction of fish-bearing habitat should a Fisheries Authorization be deemed necessary for Madrid-Boston to proceed (see Section 6.5.3.4). TMAC will work with DFO's FPP and local Inuit to develop a freshwater FOP. Habitat losses related to the Madrid-Boston Project infrastructure footprint/water withdrawal and use will be offset with the objective of maintaining the productivity of CRA species. The conceptual approach to fisheries offsetting proposed to balance all losses of fish habitat from the Madrid-Boston Project can be found in Appendix V5-6AA. Recent communication between TMAC, DFO and other stakeholders is provided in Appendix V5-6AB. The requirement for a FOP will be determined as described in Volume 8, Environmental Management Systems (Section 2.19) with the intention of meeting the EIS guidelines requirement for a No Net Loss Plan as the *Fisheries Protection Policy Statement* (DFO 2013c) no longer includes the "no net loss" principle.

As previously described, the characterization of potential effects of water withdrawal and use on the fish habitat VEC is based on the Hope Bay Project (the Madrid-Boston Project in combination with

Approved Projects), but is conservatively also used for the Madrid-Boston Project in isolation of Approved Projects.

As a result of mitigation, balancing fisheries losses with fisheries offsetting, and monitoring plans there are no residual effects anticipated on the VEC freshwater fish habitat due to Madrid-Boston Project water withdrawal and use.

As a result of mitigation, balancing fisheries losses with fisheries offsetting, and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on the VEC freshwater fish habitat due to Hope Bay Project water withdrawal and use.

6.5.4.3 Changes in Water and Sediment Quality: Management of Surface Drainage, Effluent, and Dust

Characterization of Madrid-Boston Project Potential Effect

Potential effects of Madrid-Boston Project activities on the VEC freshwater fish habitat may occur through the deposition of deleterious substances in surface drainage, effluent (water discharge to the receiving environment), and/or dust. The deposition of deleterious substances could affect fish habitat through effects water quality, sediment quality, and/or on biological resources (primary and secondary producers, forage fish). As described in Section 6.3.2, Project activities that affect primary and secondary producers through the deposition of deleterious substances result from *indirect* trophic level interactions which are predominantly due to changes in water quality and/or sediment quality. The assessment of Madrid-Boston Project effects on Freshwater Water Quality and Freshwater Sediment Quality were completed separately and independently in Volume 5, Chapters 4 and 5, respectively. These chapters assessed Madrid-Boston Project-related changes in freshwater water quality and sediment quality using indicators that have quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life and derived site-specific water quality objectives.

Project activities that result in the deposition of deleterious substances could also affect fish habitat through effects on forage fish species including mortality and/or reduction in fish health. The assessment of Project effects on the mortality and population abundance of fish community VECs is found in Section 6.5.5.4 of this chapter. Fish community VEC species of Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish are assessed and these assessments are considered representative of the potential effects on freshwater forage fish species in the LSA and RSA.

The assessment of residual effects on the VECs Freshwater Water Quality and Freshwater Sediment Quality can be found in Volume 5, Chapters 4 and 5, respectively. No significant residual effects were identified. Therefore, the potential for effects of changes in water quality and/or sediment quality on physical fish habitat and biological resources are not carried forward into subsequent sections of the assessment of the VEC freshwater fish habitat.

Mitigation and Management Measures for Specific Potential Effects

Mitigation and management measures to avoid potential Madrid-Boston Project effects from changes in water quality and sediment quality can be found in Volume 5, Section 4.5.3 and Volume 5, Section 5.5.3. Mitigation measures will also incorporate DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2), which specifically consider effects on water quality and sediment quality during in-water work that may affect fish and fish habitat (e.g., site selection, contaminant and spill management, erosion and sediment control). Finally, the AEMP (Volume 8, Environmental Management System; Section 2.17 and Package P4-18) will monitor freshwater water quality and sediment quality, and results will indicate the need for adaptive management to avoid effects on fish and fish habitat.

As a result of mitigation and monitoring plans there are no residual effects anticipated on the VEC freshwater fish habitat due to changes in water quality and/or sediment quality resulting from Madrid-Boston Project activities.

Characterization of Hope Bay Project Potential Effect

Effects on fish habitat resulting from changes in freshwater water quality and/or sediment quality resulting from Approved Project activities have been or will be mitigated through the implementation of biophysical management plans including an AEMP (Volume 8, Environmental Management System; Table 1.1-1). Therefore, there are no residual effects resulting from fish habitat loss or alteration from Approved Projects which could combine with Madrid-Boston Project effects.

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on the VEC freshwater fish habitat due to changes in water quality and/or sediment quality resulting from Hope Bay Project activities.

6.5.5 Characterization of Potential Effects - Fish Community VECs

Project residual effects are the effects that are remaining after mitigation and management measures are taken into consideration. If the implementation of mitigation measures eliminates a potential effect and no residual effect is identified on that VEC, the effect is not carried forward for further analyses. If the proposed implementation controls and mitigation measures are not sufficient to eliminate an effect, a residual effect is identified and carried forward for additional characterization and a significance determination. Residual effects of the Project can occur directly or indirectly. Direct effects result from specific Project/environment interactions between Project activities and components, and VECs. Indirect effects are the result of direct effects on the environment that lead to secondary or collateral effects on VECs.

The following characterization of specific potential Project effects on the fish community VECs describes the potential effects of interactions of fish with the Madrid-Boston Project and the Hope Bay Project (including Madrid-Boston Project activities), identifies mitigation measures (including fisheries offsetting), and assesses whether residual effects remain after mitigation and management measures are taken into consideration. Residual effects from Project-related interactions associated with the fish community VECs may be avoided and/or considered mitigable even when serious harm (as per the *Fisheries Act*) may be concluded by DFO, as long as it is considered feasible to offset the serious harm.

6.5.5.1 Direct Mortality and Population Abundance: Project Infrastructure Footprint

Characterization of Madrid-Boston Project Potential Effect

Madrid-Boston Project infrastructure has the potential to interact with the freshwater fish community VECs wherever the locations of infrastructure overlap with fish-bearing freshwater. Potential effects freshwater fish community VECs are anticipated during all phases of the Madrid-Boston Project, beginning in Construction when the building of most infrastructure will take place, and occurring through Post-Closure (Table 6.5-3). Figures 6.5-1 and 6.5-2 indicate the waterbodies in the LSA and RSA where there is the potential for freshwater fish habitat loss or alteration as a result of interaction with the Madrid-Boston Project. These waterbodies also represent the locations were fish community VECs may interact with Madrid-Boston Project construction activities and include waterbodies crossed by all-weather roads, and Windy and Aimaokatalok lakes, where a discharge pipe and/or water intakes will be constructed. Waterbodies with the potential for effects on fish community VECs due to water withdrawal/use are discussed further in Section 6.5.5.2.

Water Crossings

The potential for direct mortality or reduction in population abundance of Lake Trout, Arctic Grayling, Cisco, and Arctic Char during the construction of water crossings along the proposed AWRs (Roberts Bay Cargo Dock Access Road, Madrid North-TIA AWR, Madrid-Boston AWR) exists only if in-water work is completed outside of restricted activity timing windows and if appropriate mitigation is not followed (DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2)). In the absence of proposed mitigation, in-water work in fish habitat has the potential to cause direct mortality of fish and their eggs. This could occur, for example, through interactions with industrial equipment, the resuspension of sediments, or through oil, grease or fuel leaks from equipment. In addition, improperly placed or sized culverts may result in the restriction of migration and access to spawning, rearing, feeding habitat (Arctic Grayling) or juvenile rearing habitat (Lake Trout, Arctic Char, Lake Whitefish, and Cisco). Restriction of access to overwintering habitats or spawning habitats (for anadromous species) may also occur where these species rely on stream crossing locations as part of migratory corridors.

Water Intakes and Discharge Pipes

Madrid-Boston Project infrastructure that interacts with freshwater fish VECs is restricted to a water discharge pipeline and/or water intakes associated with domestic and industrial water use and water discharge to the receiving environment. Water intakes will be used to withdraw water from lakes (Aimaokatalok and Windy lakes) in the LSA for domestic water use and industrial uses. A water discharge pipe will be used to discharge effluent to the receiving environment in Aimaokatalok Lake. The Madrid-Boston Project will continue to use existing water intake points in Doris and Windy Lakes in addition to the TIA discharge line, which discharges TIA and groundwater effluent to Roberts Bay. A new water intake will be constructed in the north of Windy Lake (see Package P5-23 for preliminary design), and new water intake and discharge lines will also be established in Aimaokatalok Lake (see Package P5-24 for preliminary design).

The potential for direct mortality or reduction in fish populations during the installation of the water intake and discharge pipes in Windy and Aimaokatalok lakes during the Construction phase exists if in-water work is completed outside of restricted activity timing windows and if appropriate mitigation is not followed (DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e); Section 6.5.3.2). In the absence of proposed mitigation, in-water work in fish habitat has the potential to cause direct mortality of fish and their eggs for example through interactions with industrial equipment, the resuspension of sediments, or through oil, grease or fuel leaks from equipment.

Direct mortality to freshwater fish community VECs may also be caused by improper design and installation of pumps and intake and discharge pipe systems located in fish habitats and used for water withdrawal. Entrainment may occur where fish are drawn into water intakes and cannot escape. Impingement may occur where fish are held in contact with water intake screens and are unable to free themselves (DFO 1995). In order to prevent entrainment or impingement, end-of-pipe fish screens will be designed and installed according to DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2).

Winter Road Construction and Use

Use of the established Madrid-Boston winter road route or other short localized winter routes may be required during the Construction phase to enable efficient construction of the Boston accommodations and the Madrid-Boston AWR. The established Madrid-Boston winter road route is presented on Figure 6.5-3.

Lake Trout and Cisco/Whitefish

If improperly constructed, winter roads may lead to shoreline erosion, increased suspended sediment, and increased sediment deposition along the shorelines of lakes and ponds. Sediment eroded from shorelines and stream crossings may settle along the rocky shorelines of lakes and ponds, possibly affecting the quality of Lake Trout, cisco, and whitefish spawning habitat (Marcus, Hubert, and Anderson 1984) and may result in the smothering of incubating eggs or failure of these species to spawn or emerge.

Arctic Grayling

The potential effects of winter roads are likely to be more evident in streams than in lakes due to the necessity of constructing and decommissioning ice bridges and snow fills. Arctic Grayling may be adversely affected by winter road development. Arctic Grayling spawn in streams and rivers early in the spring when the ice melts and spawning success appears to be affected by stream blockages (Stewart et al. 2007). Improper decommissioning of ice bridges and snow fills could cause stream channels to become blocked to fish migration during the spring migration, which could in turn lead to Arctic Grayling failing to spawn.

Arctic Char

The established winter road route does not cross any waterbodies that are known to contain Arctic Char during any season. Therefore, Arctic Char will not be affected by these activities.

Other potential impacts on fish communities arising from the construction and use of winter roads arise from accidents and malfunctions, including spills and vehicle accidents. These potential impacts are covered under Accidents and Malfunctions (Volume 7, Chapter 1).

<u>Mitigation and Management Measures for Specific Potential Effects</u>

Water Crossings

The construction of stream crossings, roads, and berms will follow DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2). Timing of in-water construction activities will conform, when possible, to Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013f). For stream activities, the restricted activity window is in place from May 1 to July 15 to avoid the spring spawning period for Arctic Grayling. In streams used as migration corridors between marine and freshwater habitats by spawning anadromous Arctic Char, Lake Trout, cisco, and/or whitefish, stream activities will also avoid the fall migration window (beginning on August 15 and lasting until freeze-up). Winter construction activities will not be initiated until streams are considered isolated from flows (i.e., frozen to the substrates).

Fish-bearing crossings along the Roberts Bay Cargo Dock Road, the Madrid North-TIA AWR and the Madrid-Boston AWR will continue to serve as migration corridors between upstream and downstream waterbodies. Bridges will be used or fish-bearing culvert crossings will be designed to maintain fish passage by keeping water velocities and depths within acceptable limits such that they do not present a velocity or depth barrier to migration of species known to be present. In addition, culverts will be embedded in the natural channel and filled with material added to promote fish passage and habitat suitability. Bridge crossings will be clear-span structures constructed outside of the HWM to avoid alteration or destruction of fish-bearing habitats.

Mitigation measures for the maintenance of bridges and culverts at crossing locations during Construction and Operations phases will incorporate DFO's Measures to Avoid Causing Harm to Fish and

Fish Habitat (DFO 2013e; Section 6.5.3.2) and additional best management practices (DFO 2007a, 2007b) which include:

- Unless accumulated material (i.e., vegetation, ice build-up, etc.) is preventing the passage of water and/or fish through the structure, material and debris removal will be completed according to the Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013f);
- Accumulated material and debris will be removed gradually such that flooding downstream, extreme flows downstream, release of suspended sediment, and fish stranding can be avoided; and
- If replacement rock reinforcement/armouring is required to stabilize eroding inlets and outlets of culverts, the following measures will be incorporated:
  - Only clean, non-acid generating rocks will be used; and
  - Rocks installed will be done so as to not interfere with fish passage or constrict the channel width.

Water Intakes and Discharge Pipes

Mitigation to avoid adverse effects on fish is required during construction of water intake and discharge pipelines. Timing of in-water construction activities will avoid, when possible, the Nunavut Restricted Activity Timing Windows for the Protection of Fish and Fish Habitat (DFO 2013f). For lake activities, the applicable window is in place from August 15 to June 30 to avoid disturbance of fall spawning fish, e.g., Lake Trout, Arctic Char, cisco and whitefish and to avoid the disturbance of their eggs incubating in the substrates over the winter. Mitigation measures that will be applied during construction of intake and discharge pipelines follow DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e) as well as best management practices demonstrated to effectively mitigate the direct effects of in-water construction on fish include the following:

- The in-water construction zone may be isolated from the main water body using a turbidity curtain or silt booms if construction activities are anticipated to result in turbidity issues that could affect fish survival; and
- Fish salvage activities will be undertaken to relocate fish that may be stranded in isolated areas during the water intake construction to a location nearby in the waterbody.

Mitigation measures that will be applied during the design, and operation of any intakes or pumps (i.e., water supply for drilling or winter road construction), as well as intake and discharge pipelines in Aimaokatalok and Windy lakes include DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e) and best management practices demonstrated to effectively mitigate the direct effects of water discharge /intake pipelines on fish (DFO 1995) include the following:

- Water intakes or outlet pipes will be screened to prevent entrainment or impingement of fish.
- Screens will be located away from natural or artificial structures that may attract fish that are in migrating, spawning, or rearing habitat.
- In flowing water, the screen face will be oriented in the same direction as the flow.
- Openings in the guides and seals will be less than the opening criteria to make them "fish tight".

- Uptake points will be located a minimum of 300 mm (12 in.) above the bottom of the watercourse to prevent entrainment of sediment and aquatic organisms associated with the bottom area.
- Structural support will be provided to the screen panels to prevent sagging and collapse of the screen.
- Large cylindrical and box-type screens will be constructed to ensure even water velocity distribution across the screen surface. The ends of the structure will be made out of solid materials and the end of the manifold capped.
- Heavier cages or trash racks may be fabricated out of bar or grating to protect the finer fish screen, especially where there is organic debris loading. A 150-mm (6 in.) spacing between bars is typical.
- Provisions will be made for the inspection, removal, and cleaning of screens.
- Screen mesh size will be a maximum of 2.54 cm.
- Maintenance and repair of cleaning apparatus, seals, and screens will be carried out when needed to prevent debris-fouling and impingement of fish.
- Pumps will be shut down when fish screens are removed for inspection and cleaning.

Winter Road Construction and Use

Mitigation measures for the construction of ice bridges and snow fills along winter roads will incorporate DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2) and additional best management practices demonstrated to effectively mitigate the direct effects of ice bridges and snow fills on fish (DFO 2007c) which include:

- Where water is pumped, intakes will be sized and adequately screened to prevent debris blockage and fish mortality. Fish screen mesh size will not be larger than 2.54 mm.
- Crossings will not impede water flow at any time of the year.
- When the crossing season is over and where it is safe to do so and indicated, a v-notch will be created in the centre of ice bridges to allow them to melt from the centre and to prevent blockage of fish passage, channel erosion and flooding. Compacted snow will be removed from snow fills prior to spring freshet.

Fisheries Offsetting

The purpose of a FOP (Appendix V5-6AA), as per the guiding policies of DFO, is to maintain or improve the productivity of CRA fisheries. Where deemed necessary by DFO through the *Fisheries Authorization* process, serious harm to fish resulting from Madrid-Boston Project activities will be mitigated through the application of offsetting measures. However, mitigation and management measures other than offsetting that will be applied to the construction and operation of water crossings along Madrid-Boston AWRs, water intakes and discharge pipes, and winter roads, have high anticipated effectiveness in preventing the death of fish or any effects on fish population abundance. Thus, fisheries offsetting is not anticipated to be required to mitigate residual effects on the survival and population abundance of fish community VECs due to Madrid-Boston Project activities. For further information on fish habitat loss, refer to Section 6.5.4.

As a result of mitigation, and monitoring plans there are no residual effects anticipated on freshwater fish community VECs due to interaction with the Madrid-Boston Project infrastructure footprint.

Characterization of Hope Bay Project Potential Effect

The potential for direct mortality and reduction in population abundance of fish community VECs due to interaction with the Project Infrastructure footprint of Approved Projects has been or will be mitigated or has been or will be offset. This has been achieved through the implementation of biophysical management plans including an AEMP (Volume 8, Environmental Management System; Table 1.1-1), through the implementation of fisheries offsetting plans ((e.g., for the loss of fish and fish habitat in Tail Lake when it was reclassified as a tailings impoundment area under Schedule 2 of the MMER and was fished out; Golder 2007b; Rescan 2012b), and through commitments to develop and implement fisheries offsetting plans, where required. Therefore, there are no residual effects resulting from the potential for direct mortality and reduction in population abundance of fish community VECs from Approved Projects which could combine with Madrid-Boston Project effects.

As a result of mitigation, balancing fisheries losses with fisheries offsetting, and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on freshwater fish community VECs due to interactions with the Hope Bay Project infrastructure footprint.

6.5.5.2 Direct Mortality and Population Abundance: Water Withdrawal and Use

Characterization of Madrid-Boston Project Potential Effect

Activities that have the potential to interact with the freshwater fish habitat VEC through water withdrawal and use can be grouped into the following five categories:

1. *Water withdrawal for domestic and industrial use*: Water for domestic and industrial use for the Madrid-Boston Project will be drawn from Doris, Windy, and Aimaokatalok lakes (Table 6.5-8).
2. *Construction and use of underground mines – drawdown through talik*: Doris, Madrid North, and Madrid South mines are expected to intercept taliks (Package P5-4). Water levels in lakes can be drawdown through taliks, potentially resulting in a decrease in water elevation, volume, or discharge in fish-bearing freshwater waterbodies (Table 6.5-8).
3. *Modification of natural drainages*: (Surface drainage diversion and discharge (e.g., water transfer to, and discharge from, the TIA), modification of runoff coefficient at disturbed surfaces (e.g., stockpiles), and access roads where crossings are not sized to pass natural flows could affect drainage pathways (Table 6.5-8).
4. *Winter road construction and use*: Lakes and ponds along the established Madrid-Boston winter road corridor or other short localized winter routes will be selected for water withdrawal as required for seasonal construction.
5. *Exploration activities*: Permitted exploration activities will continue throughout the Project life and will include diamond drilling which requires a drilling fluid that uses water (heated or salinated; Volume 3, Section 4.8). For Madrid drill locations, Patch, Windy and Wolverine Lakes may serve as the sources of water. For Boston drill locations, Aimaokatalok Lake, and possibly Trout and Stickleback lakes may provide drill water.

All these activities contribute to the water withdrawal and use effects pathways associated with freshwater fish community VECs. These are anticipated to occur during all phases of the Madrid-Boston Project, though at various intensities, with the possible exception of the Post-closure phase (Table 6.5-3). Figures 6.5-1 and 6.5-2 indicate the waterbodies in the LSA and RSA where there is the potential for freshwater fish habitat loss or alteration as a result of interactions with the first three activities of the Madrid-Boston Project listed above. These include the lakes that may be directly affected through water withdrawal and use, as well as downstream outflow streams and lakes that may be indirectly affected by those same upstream lakes (e.g., reductions in lake volumes and surface elevations leading to reduced discharge in outflows; Table 6.5-8).

Lake Trout, Arctic Char, Cisco/Whitefish

Lake Trout, Arctic Char, cisco and whitefish rely on the lakes listed in Table 6.5-8 as high value overwintering habitats based on the premise that they all have sufficient depths (i.e., > 3 m max depth) to provide habitat under thick winter ice cover. Water withdrawal during the ice-covered period may cause a decrease in the availability and suitability of overwintering habitat by potentially affecting water quality (i.e., oxygen depletion). Extreme decreases in dissolved oxygen can result in the death of fish. Additionally, Lake Trout, Arctic Char, cisco and whitefish spawn in the fall over rock substrates and shoals in lakes and their eggs overwinter in the substrates. In Arctic environments, spawning must occur below the depth to which ice forms — typically 1.5 to 2 m in the LSA lakes (Volume 5, Chapter 3; Limnology and Bathymetry). Water withdrawal from lakes could decrease the water surface elevation under the ice, decreasing the availability of spawning habitat and potentially exposing overwintering eggs to air, resulting in mortality (Cott 2007).

Water withdrawal and use from lakes can also reduce discharge in lake outflow streams. Lower stream flows can influence fish habitat use in streams through numerous pathways associated with changes in water depth and velocity, changes in the timing of flows, decreases in the number of days stream habitat is accessible, and increases in the duration of already sensitive low flow periods (flow less than 30% Mean Annual Discharge; DFO 2013d). Arctic Char and other anadromous species including Lake Trout, cisco, and whitefish rely on stream habitats as migratory corridors during their seasonal migrations between freshwater overwintering/spawning and seasonal marine feeding habitats (Johnson 1980; Swanson et al. 2010a). Unimpeded access to summer feeding in marine habitats during freshet high flows (outmigration) and return migration during low flows (August to October) to spawning/overwintering habitat is key to maintaining fisheries productivity of anadromous species such as juvenile and adult Arctic Char. Lower stream flows can influence water depth and velocity and the timing and duration of flow. In certain areas, reductions in streamflow can result in stream conditions that are impassable by fish and fish may become stranded and die (Rescan 2013b). Juvenile fish of the VEC species Arctic Char, Lake Trout, cisco, and whitefish as well as forage fish also rely on stream habitats as migratory corridors to move between freshwater waterbodies during the open water season (Evans, Reist, and Minns 2002; Hershey et al. 2006) and for rearing/feeding opportunities and predator avoidance (Evans, Reist, and Minns 2002). Since most arctic streams freeze to the bottom during winter, unimpeded access to overwintering habitat is also important for survival.

Arctic Grayling

Arctic Grayling rely on stream habitats for spawning/egg incubation habitat in the spring, as well as for providing rearing/feeding habitat for newly-emerged fry and juveniles throughout the remainder of the open-water season (Stewart et al. 2007). Arctic Grayling spawn in streams in the early spring soon after ice-off (Stewart et al. 2007). Eggs incubate for two to three weeks, and alevins remain the gravel for up to five days after hatching. Fry typically stay in small streams throughout the summer, migrating towards lakes in the late summer before freeze-up (Scott and Crossman 1973; Stewart et al. 2007). Water withdrawal and use may potentially result in a reduction in the population abundance of Arctic Grayling if it causes spawning habitat to become exposed while eggs or alevins are incubating resulting in mortality, or if it inhibits spawning or migration. Arctic Grayling are also susceptible to stranding during the summer in isolated habitats if water levels drop.

As described above, the potential for direct mortality and reduction in population abundance of the fish community VECs due to water withdrawal and use is primarily due to losses or alterations of fish habitat (i.e., reductions in water volume and surface elevation in lakes and flow in streams) that result in the death of fish (i.e., stranding, exposure of eggs to air, under-ice oxygen depletion) or prevent fish from carrying out their life processes (i.e., changes in availability and access to spawning, rearing, migration, and overwintering habitats). As such, the assessment of effects of water withdrawal and use on the fish habitat VEC through the pathway of habitat loss or alteration (Section 6.5.4.2) is considered to adequately and comprehensively assess the effects of water withdrawal and use on the fish community VECs via the pathways of direct mortality and population abundance. Therefore, the effects of water withdrawal and use on fish community VECs are not discussed in this section.

The potential effects of water withdrawal and use on the fish habitat VEC are assessed in detail in Section 6.5.4.2. For the purpose of the assessment of water withdrawal and use on the fish habitat VEC, the potential effect of the Madrid-Boston Project in isolation of Approved Projects is not assessed. Instead, the assessment is based on the Madrid-Boston Project in combination with Approved Projects (i.e., the overall Hope Bay Project) relative to baseline flow projections as carried out in the effects assessment for surface hydrology (Volume 5, Section 1.5.4). Rationale for this method is summarized in Section 6.5.4.2; Characterization of Madrid-Boston Potential Effects. Briefly, the assessment of the fish habitat VEC was based on the Hope Bay Project (the Madrid-Boston Project in combination with Approved Projects), but is conservatively also used for the Madrid-Boston Project in isolation of Approved Projects.

Mitigation and Management Measures for Specific Potential Effects

Domestic and Industrial Use, Underground Mines, Modification of Natural Drainage

Mitigation and management measures for specific potential effects on fish community VECs due to withdrawal for domestic and industrial use, drawdown through talik, and modification of natural drainage are reflected in the measures used to mitigate these same effects on fish habitat and are presented for the overall Hope Bay Project in Section 6.5.4.2 (Mitigation and Management Measures for Specific Potential Effects (Hope Bay Project)). These mitigation and management measures address effects to fish habitat that could result in the direct mortality or reduction in population abundance of the fish community VEC species.

While the fish habitat assessment and the applied mitigation were based on the Hope Bay Project (the Madrid-Boston Project in combination with Approved Projects), they are also conservatively also applied for the Madrid-Boston Project in isolation of Approved Projects.

Winter Road Construction and Exploration Activities

To prevent declines in water quantity and quality that could affect the survival of fish, water withdrawal for the construction of winter ice roads and drilling will adhere to DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2) and the *Protocol for Winter Water Withdrawal from Ice-Covered Waterbodies in the Northwest Territories and Nunavut* (DFO 2010b):

- In one ice-covered season, total water withdrawal from a single waterbody is not to exceed 10% of the available water volume;
- In cases where there are multiple users withdrawing water from a single waterbody, the total combined withdrawal volume is not to exceed 10% of the available water volume; and
- Only waterbodies with maximum depths that are ≥1.5 m than their corresponding maximum expected ice thickness should be considered for water withdrawal.

Fisheries Offsetting

The purpose of a Fisheries Offsetting Plan (Appendix V5-6AA), as per the guiding policies of DFO, is to maintain or improve the productivity of CRA fisheries. As described in Section 6.5.4.2, the FOP will address fish habitat losses related to water withdrawal and use from the Madrid-Boston Project, as deemed necessary and approved by DFO. Because the potential for direct mortality and reduction in population abundance of the fish community VECs due to water withdrawal and use results from losses or alterations of fish habitat, offsetting proposed to mitigate the effects on the fish habitat VEC will also be relevant for fish community VECs (refer to Section 6.5.4 for further information).

As a result of mitigation, balancing fisheries losses with fisheries offsetting, and monitoring plans there are no residual effects anticipated on the freshwater fish community VECs due to Madrid-Boston Project water withdrawal and use.

Characterization of Hope Bay Project Potential Effect

As previously described, potential effects on the fish community VECs due to water withdrawal and use from the Hope Bay Project were adequately and comprehensively assessed in the assessment of the fish habitat VEC. The fish habitat assessment was based on the Hope Bay Project (the Madrid-Boston Project in combination with Approved Projects), but is conservatively also used for the Madrid-Boston Project in isolation of Approved Projects. Therefore potential effects of the Approved Projects that may interact with the Madrid-Boston Boston have been considered.

As a result of mitigation, balancing fisheries losses with fisheries offsetting, and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on the freshwater fish community VECs due to Hope Bay Project water withdrawal and use.

6.5.5.3 Direct Mortality and Population Abundance: Blasting

Characterization of Madrid-Boston Project Potential Effect

Detonation of explosives in or adjacent to fish habitat has been demonstrated to cause mortality, injury, and/or behavioural changes in fish and/or fish eggs and larvae (Wright and Hopky 1998; Faulkner et al. 2006). The detonation of explosives in or near water produces post-detonation compressive shock waves that result in a pressure deficit that can cause adverse impacts on fish such as swimbladder damage, hemorrhaging in various organs (e.g., kidney, liver, spleen and sinus venous), as well as death of fish eggs and larvae (Wright 1982; Faulkner et al. 2006; Kolden and Aimone-Martin 2013 and references therein). Vibrations from the detonation of explosives may also cause damage to incubating eggs (Wright 1982). Finally, noise produced by explosives can cause sublethal effects, such as changes in behaviour of fish. These effects may be intensified near ice and hard substrates.

Because the detonation of explosives in or adjacent to fish habitat may cause harm to fish or fish habitat (DFO 2013e), works involving the use of explosives near waterbodies must follow the recommendations developed by DFO provided in the "Guidelines for the use of explosives in or near Canadian fisheries waters" (Wright and Hopky 1998). These guidelines provide minimum setback distances for safe detonation based on type of fish habitat (e.g., active spawning [includes egg incubation] versus non-spawning-specific habitat). It is stipulated that no explosive can be detonated in or near fish habitat that produces, or is likely to produce, a peak particle velocity that is greater than 13 mm/s at spawning habitat during the period of egg incubation. Furthermore, no explosive can be detonated such that an instantaneous pressure change (IPC; i.e., instantaneous overpressure change) greater than 100 kPa in the swimbladder of a fish is produced. Further DFO recommendations suggest that IPC should be limited to 50 kPa in order to be effectively protective of fish. Proper adherence to these guidelines is not limited to, but may include knowing which waterbodies are in the vicinity of proposed blasting activities, the distance separating each waterbody and the point of detonation, species composition and associated life history information of each waterbody (i.e., least-risk timing windows, including spawning and egg incubation; DFO 2013f), and substrate type where the explosive will be detonated (Wright and Hopky 1998). TMAC commits to engaging further with DFO to determine the most appropriate threshold limit to use to reduce the risk of serious harm to fish.

Effects on fish community VECs from blasting may occur where areas suitable for Madrid-Boston Project quarry development (i.e., Madrid-Boston quarries) are located adjacent to waterbodies that contain Lake Trout, Arctic Grayling, Arctic Char, cisco and/or whitefish or forage fish that support these species (e.g., Ninespine Stickleback and Slimy Sculpin). Prior to quarry development, the fish-bearing status of nearby waterbodies will be confirmed (based on fish community sampling and habitat conditions). Tables 6.2-22 and 6.2-23 describe the life history characteristics, spawning timing, and fry emergence timing for fish species present in the freshwater LSA and RSA. Blasting activities will consider seasonal variations in habitat use by the species present over the year. Potential effects of blasting on fish present in waterbodies located near quarries will be mitigated by adjusting the timing of blasting to avoid sensitive life stages of fish (e.g., incubating eggs) and by limiting the weight of explosive charges detonated simultaneously to avoid producing overpressure or ground vibrations that exceed DFO guidelines (Wright and Hopky 1998).

Waterbodies located in proximity to Madrid-Boston quarries where blasting has the potential to affect fish are identified, and the fish species captured in those waterbodies during baseline studies are presented, in Table A5-6Z-1 of Appendix V5-6Z. These waterbodies were identified based the waterbody being located within setback distance contours calculated based on DFO guidelines of 100 kPa and 50 kPa for overpressure and 13 mm/s for ground vibration (Wright and Hopky 1998) and representative worst-case blasting charges (two charge values were assessed based on historic blasting data at Doris; 90 kg and 162 kg). As indicated in Annex V1-8, prior to initiating blasting activities, TMAC will engage further with DFO to determine the most appropriate threshold limit to use to reduce the risk of serious harm to fish, including consideration of "Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2016), and Wright and Hopky (1998). The same representative blasting charges were used to assess noise and vibration effects on human and wildlife receptors (Volume 4, Chapter 3; Noise and Vibration). Setback distances were calculated for rock substrates because areas suitable for quarry development are located in hard rock benches. Visual representations of setback distance contours around quarries are presented in Figures A5-6Z-1 to A5-6Z-8 in Appendix V5-6Z.

<u>Mitigation and Management Measures for Specific Potential Effects</u>

When explosives are required to be used in or adjacent to fish bearing water, the potential for impacts to fish and fish habitat will be minimized by implementing the following measures based on DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e):

- In-water work requiring the use of explosives will adhere to appropriate fisheries timing windows prevent disruption of vulnerable fish life stages, including eggs and larvae.
- When necessary, the work site will be isolated to exclude fish from within the blast area by using bubble/air curtains (i.e., a column of bubbled water extending from the substrate to the water surface as generated by forcing large volumes of air through a perforated pipe/hose), cofferdams or aquadams.
- Any fish trapped within the isolated area will be removed and released unharmed beyond the blast area prior to initiating blasting.
- Blast charge weights will be minimized, possibly by subdividing each charge into a series of smaller charges in blast holes with a minimum 25 millisecond (1/1000 seconds) delay between charge detonations.

- o Blast holes will be back-filled with sand or gravel to grade or to streambed/water interface to confine the blast.
- o Blasting mats will be placed over top of holes to minimize scattering of blast debris around the area.
- o Ammonium nitrate based explosives will not be used in water due to the production of toxic by-products.
- o All blasting debris and other associated equipment/products will be removed from the blast area once compete.

Explosives use will employ the following additional guidelines for the use of explosives in or near waters taken from Wright and Hopky (1998):

- o No explosive is to be detonated in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (IPC) greater than 100 kPa (14.5 psi) in the swimbladder of a fish. TMAC commits to engaging further with DFO to determine the most appropriate threshold limit to use to reduce the risk of serious harm to fish.
- o For confined explosives, setback distances from the land-water interface (e.g., the shoreline), or burial depths from fish habitat (e.g., from under the riverbed) that will ensure that explosive charges meet the 100 kPa overpressure guideline are shown in Table 1 of Wright and Hopky (1998). TMAC commits to engaging further with DFO to determine the most appropriate threshold limit to use to reduce the risk of serious harm to fish.
- o No explosive is to be detonated that produces, or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation.
  - For confined explosives, setback distances or burial depths from spawning beds that will ensure that explosive charges meet the 13 mm/s guideline criteria are shown in Table 2 of Wright and Hopky (1998).
  - For unconfined explosives, the appropriate DFO Regional/Area authorities may be contacted for further guidance.

Explosives products will be stored on site in accordance with Territorial and Federal regulations. The main storage of ammonium nitrate is located at Doris, with secondary storage areas at Boston.

As a result of mitigation there are no residual effects anticipated on freshwater fish community VECs due to blasting associated with Madrid-Boston Project activities.

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

The potential for direct mortality and reduction in population abundance of fish community VECs due to blasting has been and will continue to be mitigated through the application of mitigation and management measures and the implementation of management plans (Packages P4-18, P4-17, and P4-23).

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on freshwater fish community VECs due to blasting associated with Hope Bay Project activities.

6.5.5.4 Changes in Water Quality and/or Sediment Quality: Management of Surface Drainage, Effluent, and Dust

Characterization of Madrid-Boston Project Potential Effect

Potential effects of Project activities on the freshwater fish community VECs may occur through the deposition of deleterious substances in surface drainage, effluent (water discharge to the receiving environment), and/or dust. The deposition of deleterious substances and resulting potential changes in water quality and/or sediment quality could affect fish community VECs through the pathway of decreased health and indirect mortality. The assessment of Project effects on Freshwater Water Quality and Freshwater Sediment Quality were completed separately and independently in Volume 5, Chapters 4 and 5 using indicators that have quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life and derived site-specific water quality objectives. The assessment of residual effects on the VECs Freshwater Water Quality and Freshwater Sediment Quality can be found in Volume 5, Chapters 4 and 5, respectively. No significant residual effects were identified. Therefore, the potential for effects of changes in water quality and/or sediment quality on freshwater fish community VECs through decreased health and indirect mortality, are not carried forward into subsequent sections of the assessment of the freshwater fish community VECs.

The potential for bioaccumulation of contaminants in Lake Trout, Arctic Grayling, Arctic Char, cisco and whitefish is quantitatively assessed in the Human Health and Environmental Risk Assessment (Volume 6, Chapter 5) using receptor fish species representative of different freshwater trophic levels and habitat preferences (i.e., Ninespine Stickleback, Lake Whitefish, and Lake Trout). The primary exposure pathway for fish is direct contact with water and/or sediment. They could also be indirectly exposed through trophic effects if a bioaccumulative contaminant of potential concern (COPC; e.g., mercury and selenium). Estimation of risk to aquatic life ecological receptors including fish from COPCs were evaluated through the calculation of hazard quotients for existing conditions (see Volume 6, Section 5.5.4.2 for further information); no adverse effects to freshwater aquatic life were anticipated via this pathway under existing conditions. Similarly, because freshwater water quality is anticipated to meet all CCME water quality guidelines, no significant residual effects were concluded, thus no COPCs were identified and carried forward; Madrid-Boston Project-related changes to the health of ecological receptors including fish are therefore not expected and are not carried as a potential effect (Volume 6, Section 5.6.1.3).

Mitigation and Management Measures for Specific Potential Effects

Mitigation and management measures to avoid potential Madrid-Boston Project effects from changes in water quality and sediment quality can be found in Volume 5, Section 4.5.3 and Volume 5, Section 5.5.3. Mitigation measures will also incorporate DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e; Section 6.5.3.2), which specifically consider effects on water quality and sediment quality during in-water work that may affect fish and fish habitat (e.g., site selection, contaminant and spill management, erosion and sediment control). Finally, the AEMP (Volume 8, Management Plans; Section 2.17 and Package P4-18) will monitor freshwater water quality and sediment quality, and results will indicate the need for adaptive management to avoid effects on fish and fish habitat.

As a result of mitigation and monitoring plans there are no residual effects anticipated on freshwater fish community VECs due to changes in water quality and/or sediment quality resulting from Madrid-Boston Project activities.

Characterization of Hope Bay Project Potential Effect

Effects on fish habitat resulting from changes in freshwater water quality and/or sediment quality resulting from Approved Project activities have been or will be mitigated through the implementation of biophysical management plans including an AEMP (Volume 8, Environmental Management System; Table 1.1-1). Therefore, there are no residual effects resulting from fish habitat loss or alteration from Approved Projects which could combine with Madrid-Boston Project effects.

As a result of mitigation and monitoring plans for both the Madrid-Boston Project and Approved Projects, there are no residual effects anticipated on freshwater fish community VECs due to changes in water quality and/or sediment quality resulting from Hope Bay Project activities.

6.5.6 Characterization of Project-related Residual Effects

6.5.6.1 Fish Habitat VEC

After considering mitigation, fisheries offsetting, and monitoring, no residual effects on the VEC fish habitat are anticipated as a result of Project-related activities. Consequently, no potential residual effects were evaluated for significance or carried forward to a cumulative effects assessment. Potential effects of the Madrid-Boston Project and other aspects of the Hope Bay Project on fish habitat are expected to be Not Significant.

6.5.6.2 Fish Community VECs

After considering mitigation, fisheries offsetting, and monitoring, no residual effects on the VECs Lake Trout, Arctic Grayling, Arctic Char, or Cisco/Whitefish are anticipated as a result of Project-related activities. Consequently, no potential residual effects were evaluated for significance or carried forward to a cumulative effects assessment. Potential effects of the Madrid-Boston Project and other aspects of the Hope Bay Project on fish habitat are expected to be Not Significant.

6.6 CUMULATIVE EFFECTS ASSESSMENT

6.6.1 Methodology Overview

The potential for cumulative effects arises when the potential residual effects of the Project affect (i.e., overlap and interact with) the same VEC that is affected by the residual effects of other past, existing or reasonably foreseeable projects or activities. When residual effects are present, the cumulative effects assessment (CEA) follows the general methodology described in Volume 2, Chapter 4 (Effects Assessment Methodology).

6.6.2 Potential Interactions of Residual Effects with Other Projects

6.6.2.1 Fish Habitat VEC

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VEC fish habitat are predicted. Thus, there exists no potential for interactions with Projects – past, existing, or in the foreseeable future – for the VEC freshwater fish habitat and a CEA was not conducted (see CEA Methodology; Volume 2, Chapter 4).

6.6.2.2 Fish Community VECs

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VECs Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish are predicted. Thus, there exists no potential for interactions with Projects – past, existing, or in the foreseeable future – for the freshwater fish community VECs and a CEA was not conducted (see CEA Methodology; Volume 2, Chapter 4).

6.7 TRANSBOUNDARY EFFECTS

6.7.1 Methodology Overview

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

6.7.2 Potential Transboundary Effects

6.7.2.1 Fish Habitat VEC

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VEC fish habitat are predicted. Thus, no transboundary effects on the VEC freshwater fish habitat are expected to occur.

6.7.2.2 Fish Community VECs

After considering mitigation, fisheries offsetting, and monitoring, no residual effects of Madrid-Boston Project activities or Hope Bay Project activities on the VECs Lake Trout, Arctic Grayling, Arctic Char, and Cisco/Whitefish are predicted. Thus, no transboundary effects on the freshwater fish community VECs are expected to occur.

6.8 IMPACT STATEMENT

The VEC freshwater fish habitat comprises both the physical habitat and the biological resources that are necessary for the productivity of fisheries species. Freshwater fish habitat may interact with and be affected by Madrid-Boston Project activities along two general pathways: through a direct loss or alteration of fish habitat by permanent alteration or destruction (PAD), or through changes to water quality and/or sediment quality arising from the deposition of deleterious substances.

A PAD is a *direct* loss or alteration of fish habitat area potentially incurred through planned construction (e.g., encroachment of infrastructure on existing fish habitat) or water withdrawal. Waterbodies with the potential for effects from encroachment of the Madrid-Boston Project infrastructure footprint include waterbodies crossed by all-weather roads, Aimaokatalok and Windy lakes where a discharge pipe and water intakes will be constructed, and lakes, streams, and ponds along seasonal winter road routes. The primary mitigation measure is siting Project infrastructure to avoid fish-bearing water. Additional mitigation includes best management practices to minimize alteration of fish habitat during in-water work including DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e). Localized areas of fish-bearing stream habitat loss or permanent alteration will occur in up to eight streams as a result of the placement of culverts at road crossings. Localized habitat losses or permanent alterations will also occur in Aimaokatalok and Windy lakes due to the construction of a discharge pipeline and/or water intakes, as well as associated armouring of these structures (which may be considered a form of self-offsetting). Unavoidable habitat loss or alteration due to Madrid-Boston Project infrastructure may be mitigated through fisheries offsetting to balance habitat losses. A FOP, if deemed necessary by DFO, including the detailed description of habitat losses, fisheries offsetting options, and proposed monitoring plan, will be developed prior to an

Application for a *Fisheries Act Authorization* and prior to effects occurring. TMAC will work with DFO's Fisheries Protection Program and local Inuit to develop such a freshwater FOP.

Water for domestic and industrial use for the Madrid-Boston Project will be drawn from Doris, Windy, and Aimaokatalok lakes. Other Madrid-Boston Project-related effects that may result in a decrease in water elevation, volume, or discharge in fish-bearing freshwater waterbodies include drawdown of water through talik to underground workings and the modification of natural drainages (i.e., surface drainage diversion and discharge and modification of runoff at disturbed sites). Water withdrawal from lakes has the potential to affect fish habitat through multiple pathways, including a reduction in available fish habitat, changes to primary and secondary producers, and a reduction in discharge volume at lake outflows. Water withdrawal from lakes may cause a decrease in the amount and suitability of overwintering or spawning habitat available for fish or potentially expose overwintering eggs of Lake Trout, Arctic Char, cisco or whitefish species to air (Cott 2007). Reduction in discharge at lake outflow streams can result in a reduction of available or suitable fish habitat for migration, rearing, and spawning (Arctic Grayling). Lower stream flows can influence the ability for fish passage and result in fish stranding through changes in water depth and velocity, changes in the timing of flows, decrease in the number of days stream habitat is accessible, and increase the duration of sensitive periods (flow less than 30% Mean Annual Discharge; DFO 2013d).

The primary mitigation measure for effects of water withdrawal and use is by limiting the amount of water withdrawn from each waterbody by recycling water, limiting groundwater inflows to underground workings, and returning compliant effluent to waterbodies from which they were withdrawn. Habitat loss or alteration is predicted to occur at various locations in the Project area due to reductions in lake volume, lake surface elevation, and/or discharge in lake outflow streams, and will be mitigated through fisheries offsetting to balance all fish habitat losses, as deemed necessary by DFO. A FOP, as deemed necessary by DFO, including the detailed description of habitat losses, fisheries offsetting options, and proposed monitoring plan, will be developed prior to an Application for a *Fisheries Act Authorization* and prior to effects occurring. TMAC will work with DFO's Fisheries Protection Program and local Inuit to develop such a freshwater FOP.

The introduction of deleterious substances could alter fish habitat *directly* by changes in water quality and/or sediment quality to the extent that fish health decreases and mortality occurs, or *indirectly*, through trophic interactions with biological resources used by fish. Potential effects of Madrid-Boston Project activities on the VEC freshwater fish habitat may occur through the deposition of deleterious substances in surface drainage, effluent (water discharge to the receiving environment), and/or dust. The deposition of deleterious substances could affect fish habitat through effects water quality, sediment quality, and/or on biological resources (primary and secondary producers, forage fish). Project activities that affect primary and secondary producers through the deposition of deleterious substances result from *indirect* trophic level interactions which are predominantly due to changes in water quality and/or sediment quality. No significant residual effects were concluded for either the Freshwater Water Quality and/or Freshwater Sediment Quality VECs (Volume 5, Chapters 4 and 5, respectively).

As a result of mitigation, which may include the balancing fisheries losses with fisheries offsetting as deemed necessary by DFO, and monitoring plans, there are no residual effects anticipated on the VEC freshwater fish habitat due to the Madrid-Boston Project or the Hope Bay Project.

As no Project residual effects are anticipated, there are no potential residual effects that could act cumulatively with other Project potential effects. Therefore no cumulative effects or transboundary effects are expected on the VEC freshwater fish habitat.

The freshwater fish community comprises the survival and abundance of individual fish VECs including Lake Trout, Arctic Grayling, and the freshwater life histories of Arctic Char and Cisco/Whitefish (including Lake Whitefish, Broad Whitefish, Cisco, and Least Cisco). The freshwater fish community may interact and be affected by Madrid-Boston Project activities along two general pathways: through *direct* mortality and changes to population abundance, or through decreased health and *indirect* mortality resulting from changes in water quality and/or sediment quality.

Direct mortality and changes to population abundance may potentially occur during the construction of in-water infrastructure and any Madrid-Boston Project activities that physically harm fish through blasting, water withdrawal, impact injury (e.g., interactions with industrial equipment), and spills, accidents and malfunctions. The potential for direct mortality or reduction in population abundance of fish community VECs during the construction of water crossings along the all-weather roads and the construction of the discharge pipe and/or water intakes in Aimaokatalok and Windy lakes exists only if in-water work is completed outside of restricted activity timing windows and if appropriate mitigation is not followed (i.e., DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat; DFO 2013e). Direct mortality to freshwater fish community VECs may also be caused by entrainment or impingement through improper design and installation of pumps and intake and discharge pipe systems located in fish habitats and used for water withdrawal. To mitigate this effect, intakes will be screened according to DFO’s Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e). Finally, fish population abundance could be affected through alterations in lake and stream spawning habitats, and alterations in access to stream habitats by fish community VECs resulting from seasonal construction of winter road routes. Best management practices demonstrated to effectively mitigate the direct effects of ice bridges and snow fills on fish will be applied.

The potential for direct mortality and reduction in population abundance of the fish community VECs due to water withdrawal and use is primarily due to losses or alterations of fish habitat (i.e., reductions in water volume and surface elevation in lakes and flow in streams) that result in the death of fish (i.e., stranding, exposure of eggs to air, under-ice oxygen depletion) or prevent fish from carrying out their life processes (i.e., changes in availability and access to spawning, rearing, migration, and overwintering habitats). As such, the assessment of effects of water withdrawal and use on the fish habitat VEC through the pathway of habitat loss and/or alteration also is considered to be adequately and comprehensively inclusive of the potential effects of water withdrawal and use on the fish community VECs via the pathways of direct mortality and population abundance. Mitigation measures, including fisheries offsetting, applied to the effects on fish habitat due to water withdrawal and use are also effective in mitigating and offsetting the effects to fish community VECs.

Effects on fish community VECs from blasting may occur where areas suitable for Madrid-Boston Project quarry development (i.e., Madrid-Boston quarries) are located adjacent to waterbodies that contain Lake Trout, Arctic Grayling, Arctic Char, cisco and/or whitefish or forage fish that support these species (e.g., Ninespine Stickleback and Slimy Sculpin). Detonation of explosives in or adjacent to fish habitat has been demonstrated to cause mortality, injury, and/or behavioural changes in fish and/or fish eggs and larvae (Wright and Hopky 1998; Faulkner et al. 2006). When explosives are required to be used in or adjacent to fish bearing water, the potential for impacts to fish and fish habitat will be minimized by implementing the following measures based on DFO’s Measures to Avoid Causing Harm to Fish and Fish Habitat (DFO 2013e). Explosives use will consider, at minimum, guidelines for the use of explosives in or near waters where no explosive is to be detonated in or near fish habitat that produces, or is likely to produce, an instantaneous pressure change (IPC) greater than 100 kPa (14.5 psi) in the swimbladder of a fish or is likely to produce, a peak particle velocity greater than 13 mm/s in a spawning bed during the period of egg incubation. TMAC commits to engaging further with DFO to determine the most appropriate threshold limit to use to reduce the risk of serious harm to fish.

For the pathway of effects on fish community VECs of decreased health and *indirect* mortality, potential changes in water quality and/or sediment quality resulting from surface drainage, fugitive dust, and planned discharge of water/effluent to the receiving environment could have chronic effects on fish community VECs. The deposition of deleterious substances and resulting potential changes in water quality and/or sediment quality could affect fish community VECs through the pathway of decreased health and indirect mortality. The assessment of Project effects on Freshwater Water Quality and Freshwater Sediment Quality were completed separately and independently in Volume 5, Chapters 4 and 5 using indicators that have quantitative relationships or thresholds associated with supporting aquatic organisms and biogeochemical processes, including established guidelines for the protection of aquatic life and derived site-specific water quality objectives. The potential for bioaccumulation of contaminants in Lake Trout, Arctic Grayling, Arctic Char, cisco and whitefish is quantitatively assessed in the Human Health and Environmental Risk Assessment (Volume 6, Chapter 5) using receptor fish species representative of different freshwater trophic levels and habitat preferences (i.e., Ninespine Stickleback, Lake Whitefish, and Lake Trout). The primary exposure pathway for fish is direct contact with water and/or sediment. They could also be indirectly exposed through trophic effects if a bioaccumulative contaminant of potential concern (COPC; e.g., mercury and selenium). Estimation of risk to aquatic life ecological receptors including fish from COPCs were evaluated through the calculation of hazard quotients for existing conditions (see Volume 6, Section 5.5.4.2 for further information); no adverse effects to freshwater aquatic life were anticipated via this pathway under existing conditions. Similarly, because freshwater water quality is anticipated to meet all CCME marine water quality guidelines, no significant residual effects were concluded, thus no COPCs were identified and carried forward; Madrid-Boston Project-related changes to the health of ecological receptors including fish are therefore not expected and are not carried as a potential effect (Volume 6, Section 5.6.1.3).

As a result of mitigation, balancing fisheries losses with fisheries offsetting, and monitoring plans there are no residual effects anticipated on the freshwater fish community VECs due to the Madrid-Boston Project or the Hope Bay Project.

As no Project residual effects are anticipated, there are no potential residual effects that could act cumulatively with other Project potential effects. Therefore no cumulative effects or transboundary effects are expected on the freshwater fish community VECs.

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