Appendix V5-6AA

Conceptual Freshwater Fisheries Offsetting Approach for Madrid-Boston

TMAC RESOURCES

Memorandum

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Subject: **Conceptual Freshwater Fisheries Offsetting Approach for Madrid-Boston**

The purpose of this memorandum is to identify a procedural framework and potential offset options for completing a Freshwater Fisheries Offsetting Plan, should its development be deemed necessary by Fisheries and Oceans Canada (DFO) for the Madrid-Boston Project (the Project).

1. INTRODUCTION

Three main mechanisms of potential permanent fish habitat loss (permanent alteration to, or destruction; PAD) and fish productivity in the freshwater environment may result from Project activities. These include:

1. Habitat loss at road crossings of fish-bearing streams, specifically the areas under culverts that fall below the high water mark;
2. Habitat loss in lakes at the locations of discharge pipeline and/or water intakes, specifically the area below the high water mark that may be lost/altered to (underlie) this infrastructure; and
3. Habitat loss in streams and lakes resulting from water withdrawal, specifically from reduced lake volumes and lake surface elevations, and reduced discharge in outflow streams downstream of direct effects based on base case water balance model outputs.

As a consequence of these potential habitat losses, fish habitat and fish populations may be adversely impacted in affected waterbodies resulting in the potential for *serious harm* to fisheries productivity. According to the *Fisheries Protection Policy Statement* (DFO 2013b), if a project is likely to cause *serious harm to fish* after the application of avoidance and mitigation measures, then the proponent must develop a plan to undertake offsetting measures to counterbalance the unavoidable residual *serious harm* to fish. These offsetting measures, also known as offsets, are implemented with the goal of maintaining or improving the productivity of commercial, recreational or Aboriginal (CRA) fisheries (DFO 2013a).

2. REGULATORY AND POLICY FRAMEWORK

The *Fisheries Protection Policy Statement* (DFO 2013b) supports the 2012 updates made to the *Fisheries Act (1985)*. The *Fisheries Protection Policy Statement* replaces Fisheries and Oceans Canada's (DFO) no net loss guiding principle for fish habitat within the *Policy for the Management of Fish Habitat* (DFO 1991). The changes to the *Fisheries Act* include a prohibition against causing *serious harm to fish* that are part of, or support, a CRA fishery (section 35 of the *Fisheries Act*); provisions for flow and passage (sections 20 and 21 of the *Fisheries Act*); and a framework for regulatory decision-making (sections 6 and 6.1 of the *Fisheries Act*). These provisions guide the Minister's decision-making process in order to provide for sustainable and productive fisheries.

The amendments center on the prohibition against *serious harm to fish* and apply to fish and fish habitat that are part of or support CRA fisheries. Proponents are responsible for avoiding and mitigating *serious harm to fish* that form part of or support CRA fisheries. When proponents are unable to completely avoid or mitigate *serious harm to fish*, their projects will normally require authorization under subsection 35(2) of the *Fisheries Act* in order for the project to proceed without contravening the Act.

DFO interprets *serious harm to fish* as:

- The death of fish.
- A permanent alteration to fish habitat of a spatial scale, duration, or intensity that limits or diminishes the ability of fish to use such habitats as spawning grounds, nursery, rearing, food supply areas, migration corridors, or any other area in order to carry out one or more of their life processes. The destruction of fish habitat of a spatial scale, duration, or intensity that results in fish no longer being able to rely on such habitats for use as spawning grounds, nursery, rearing, food supply areas, migration corridor, or any other area in order to carry out one or more of their life processes.

After efforts have been made to avoid and mitigate impacts, any residual *serious harm to fish* is required to be offset. An offset measure is one that counterbalances unavoidable *serious harm to fish* resulting from a project with the goal of maintaining or improving the productivity of the CRA fishery. Where possible offset measures should support available fisheries' management objectives and local restoration priorities.

3. FISHERIES OFFSETTING APPROACH

A procedural approach is proposed for developing a Freshwater Fisheries Offsetting Plan (the Offsetting Plan) for Madrid-Boston, if deemed necessary by DFO. This approach is proposed to satisfy the *Fisheries Protection Policy Statement* (DFO 2013b) and the federal *Fisheries Act*, and to allow for flexibility in finding a solution to offsetting Project-related effects.

The proposed approach for the development of an Offsetting Plan is identified below and will be discussed in the following six sections:

- Section 3.1 – Assessment of fish habitat availability and quality in the Madrid-Boston Project Area, particularly in potentially impacted lakes and streams, with focus on 2015, 2016, and 2017 field study results;
- Section 3.2 – Assessment of fish populations and their abundance in the Madrid-Boston Project Area, particularly in potentially impacted lakes and streams, with focus on 2016 and 2017 field study results;

- Section 3.3 – Detailed assessment of the amount (in m^2) of fish habitat to be lost/altered in the freshwater environment. Quantification of fish habitat loss area (in m^2) was a commitment made by TMAC during the technical review of the DEIS and Pre-hearing Conference Decision issued by the NIRB after the technical meetings ((NIRB 2017); for further information, referV1-8).
- Section 3.4 – Description of the Habitat Evaluation Procedure (HEP) to assign quantity as well as quality to lost habitat;
- Section 3.5 – Description of process for identification of offsetting options, as discussed during the November 2017 meeting with DFO and KIA (for further information, refer to ERM 2017 in Appendix V5-6AB); and
- Section 3.6 – Description of potential data requirements associated with offsetting option assessments.

The proposed approach was developed based upon the guidance provided in the *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013b). The approach was also based upon the review of existing fisheries and fish habitat information for Madrid-Boston. Based upon this review a number of preliminary offsetting options, commensurate with anticipated potential losses to fisheries productivity, were identified and are discussed in the following sections.

The *Fisheries Protection Policy Statement* (DFO 2013b), the *Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting* (DFO 2013a), and the federal *Fisheries Act* refer to fish productivity as the metric for offsetting. Since fish productivity, defined as the number of kilograms of fish tissue estimated per m^2 of stream habitat or per hectare of lake habitat per year, is difficult to measure in practice, fish habitat continues to be used as a practical surrogate for productivity.

3.1 Assessment of Fish Habitat

The first step in developing an offsetting plan is to quantify the amount and quality of habitat that will be lost to development after avoidance and mitigation measures have been applied. Avoidance and mitigation measures are planned during Madrid-Boston activities such that potential serious harm through habitat loss will be minimized. These measures include mitigation by design, best management practices (including DFO's Measures to Avoid Causing Harm to Fish and Fish Habitat; DFO 2013d), monitoring, and adaptive management (Volume 5, Chapter 6, Section 6.5.3).

Habitat data form the basis of quantifying the potential serious harm to fisheries required to be offset, validate the habitat-based approach to offsetting, and support future monitoring (a federal requirement of a Fisheries Offsetting Plan, FOP). A FOP typically includes a habitat budget that quantifies the loss of habitat in terms of area (m^2), habitat equivalency units (HEU) if possible and the expected gain (in m^2 and/or HEU) in the proposed offsetting habitat. Streams and lakes are typically treated separately because different methods are used to measure habitat in streams than in lakes.

A large database on fish habitat currently exists for streams and lakes of the Hope Bay Greenstone Belt. Surveys of fish populations and fish habitat began in 1993 and continued to 2017. Surveys were conducted in 23 of those 25 years; no surveys were conducted in the years 1999 and 2001. Information collected from 1993 to 2008 was used for planning, permitting, and development at Doris. Sampling covered the Doris area, the Madrid and Boston areas, and selected lakes and streams outside the Project Development Area (PDA) such as the Roberts drainage and Reference Lakes A, B, C, and D and their inflow and outflow streams. Baseline aquatic studies for Madrid-Boston were conducted in 2009 and 2010. Additional studies in support of the Doris Aquatic Effects Monitoring Program (AEMP) and other environmental compliance programs were conducted from 2010 to 2016. In 2015 and 2016, fisheries and hydraulic modelling assessments were completed in Doris and Little Roberts Outflows and a spawning habitat assessment was completed in Doris Lake. In 2016, a reconnaissance program looking for potential offsetting sites was also completed. Although focused on Doris, this baseline information is relevant to Madrid-Boston.

The development and submission of Draft Environmental Impact Statement (DEIS) for the Madrid-Boston Project to the Nunavut Impact Review Board (NIRB) in December 2016 (TMAC 2016), and updated with newest project information as presented in the FEIS (Volume 5, Chapter 6), identified streams and lakes that had the potential to interact with Project components. PAD of fish habitat resulting from these interactions may require mitigation through fisheries offsetting. While baseline data had been previously collected in the majority of streams and lakes that may experience PAD of fish habitat as a result of interactions with the Madrid-Boston Project, in 2015, 2016, and 2017, freshwater fisheries baseline assessments were undertaken that supplement and/or augment the characterization of fish habitat and fish communities in these waterbodies.

The following sections briefly summarize baseline fish and fish habitat data collected to date, starting in 1993, in addition to describing in greater detail the methods and presenting the results of fish habitat surveys carried out from 2015 to 2017 or in other years where streams/lakes with the potential to interact with the Madrid-Boston Project were surveyed.

3.1.1 Streams

From 1993 to 2017, multiple fish habitat survey methods were conducted on streams, as follows:

- Aerial surveys by helicopter (42 streams from 1995 to 2006);
- Reconnaissance surveys on foot (7 streams from 1995 to 2016);
- Habitat assessment (41 streams from 1995 to 2017);
- Fish Habitat Assessment Procedure (FHAP; Johnston and Slaney (1996); 70 streams from 2009 to 2017);
- Sensitive Habitat Inventory Mapping (SHIM; Mason and Knight 2001; 17 streams in 2010); and
- Hydraulic modeling (two streams in 2015 and three streams in 2017).

All of the data collected by these methods was geo-referenced and is useful in assessing the quantity and quality of fish habitat. However, data collected using FHAP and SHIM is most relevant to quantifying stream habitat because both methods divide streams up into habitat units (pools, riffles, glides, and cascades), provide areas (in m^2) for each unit, and characterize the quality of fish habitat in each habitat unit as good, fair, poor, or none. FHAP is sometimes applied to discrete sections of streams under the assumption that data collected in one or more sections could be extrapolated over an entire stream. In contrast, SHIM was applied to the whole lengths of streams. For some of the streams assessed in 2017, FHAP assessments were undertaken over the entire length of the stream in order to provide the basis for potential habitat loss calculations (ERM 2017b).

3.1.1.1 Water Crossings

Fish habitat at 21 proposed Madrid-Boston all-weather road (AWR) crossing locations was evaluated under high and low flow conditions in 2017 (ERM 2017b). Habitats were surveyed using methods based on the Fish Habitat Assessment Procedures (FHAP; Johnston and Slaney 1996). Representative sections of each reach within 100 m upstream and downstream of the crossing location were assessed. Habitats units were classified as cascades, riffles, glides, and pools. Barriers or seasonal restrictions to fish migration were also noted and measured, where appropriate. Habitat suitability for spawning, rearing, migration, and overwintering was described and an overall habitat quality ranking was applied (i.e., good, fair, poor, none).

At high flow, eight sites had overall high habitat value, three had moderate habitat value, eight had low habitat value, and two were assessed as not providing any fish habitat. At low flow, six, five, and one sites were assessed as having overall high, moderate, and low habitat value, respectively. Nine sites were assessed to have no fish habitat at low flow. Habitat values for each crossing at high and low flow are presented in Table 3.1-1. The total estimated PAD of stream fish habitat due to Madrid-Boston infrastructure has been estimated based on the potential footprint below the high water mark (HWM) based on channel bankfull width at low flow and the proposed crossing type.

3.1.1.2 Streams with Potential for Water Withdrawal and Use

Fish habitat along the entire length of nine streams with potential for water withdrawal and use from Madrid-Boston was evaluated in 2016 (two streams; ERM 2016) and 2017 (seven streams; ERM 2017b). Habitats were surveyed using methods based on the Fish Habitat Assessment Procedures (FHAP; Johnston and Slaney 1996). Habitats units were classified as cascades, riffles, glides, and pools. Barriers or seasonal restrictions to fish migration were also noted and measured, where appropriate. Habitat suitability for spawning, rearing, migration, and overwintering was described and an overall habitat quality ranking was applied (i.e., good, fair, poor, none). Boundaries between habitat units were visually assessed, habitat type was classified, and coordinates were collected at the upstream and downstream boundaries of each habitat unit using a handheld GPS. Habitat types recorded during the low flow survey which represent stable stream conditions are summarized in Table 3.1-2.

Table 3.1-1. Proposed Crossing Types and Fish Habitat at Water Crossings by Madrid-Boston Project All-Weather Roads

Crossing ID	Waterbody Name	Fish-bearing Status	Confirmed or Predicted Fish Species[a]	Habitat Value High Flow[b]	Habitat Value Low Flow[b]	Low Flow: Mean Channel Width Wetted (m)	Low Flow: Mean Channel Width Bankfull (m)	Low Flow: Potential Footprint below HWM[c] Wetted (m^2)	Low Flow: Potential Footprint below HWM[c] Bankfull (m^2)	Proposed Crossing Type[d]	Estimated PAD[e] (m^2)
C-CDR-01	Roberts Bay Inflow	Fish-bearing	NSSB	Low	None	0.1	0.2	1.6	3.2	Fish-bearing culvert	3.2
C-CDR-02	Glenn Outflow	Fish-bearing	LKTR, ARCH, SLSC, NSSB, STFL	High	High	14.0	21.0	224.0	336.0	End bearing pile bridge	0.0
C-TIA-01	Patch Inflow	Assumed fish-bearing	***NSSB***	Low	None	0.1	0.3	1.6	4.8	Culvert - type TBD	4.8
C-TIA-02	Doris Inflow	Fish-bearing	NSSB	Low	None	0.0	0.5	0.0	8.0	Fish-bearing culvert	8.0
C-TIA-03	Doris Inflow	Fish-bearing	NSSB	Low	None	0.0	0.0	0.0	0.0	Fish-bearing culvert	0.0
C-TIA-04	Ogama Outflow	Fish-bearing	LKTR, LKWH, CISC, NSSB	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	ARGR, NSSB	High	High	8.1	15.9	129.6	254.4	End bearing pile bridge	0.0
C-MBR-8	Boulder Creek Tributary	Fish-bearing	ARGR, NSSB	High	High	1.7	14.4	27.2	230.4	End bearing pile bridge	0.0
C-MBR-9	Aimaokatalok Inflow	Fish-bearing	NSSB	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	NSSB	Moderate	Moderate	1.4	6.3	22.4	100.8	Fish-bearing culvert	100.8
C-MBR-12	Aimaokatalok Inflow	Fish-bearing	NSSB, ARGR	High	High	15.0	18.8	240.0	300.8	End bearing pile bridge	0.0
C-MBR-13	Aimaokatalok Inflow	Assumed fish-bearing	***NSSB, ARGR***	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	NSSB	Moderate	Moderate	10.2	16.2	163.2	259.2	End bearing pile bridge	0.0
C-MBR-16	Aimaokatalok Inflow	Fish-bearing	NSSB, ARGR	High	High	1.3	4.1	20.8	65.6	End bearing pile bridge	0.0
C-MBR-17	Aimaokatalok Inflow	Fish-bearing	NSSB	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	LKTR, ARGR, BURB, SLSC, NSSB	High	Moderate	2.4	12.5	38.4	200.0	End bearing pile bridge	0.0
C-MBR-20	Stickleback Outflow	Fish-bearing	NSSB, SLSC, ARGR	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)
NSSB = Ninespine Stickleback; LKTR = Lake Trout; ARCH = Arctic Char; SLSC = Slimy Sculpin; STFL = Starry Flounder; CISC = Cisco; ARGR = Arctic Grayling; BURB = Burbot
[a] *Predicted species italicized; based on habitat characterization and/or confirmed species presence in upstream or downstream waterbodies, additional species may be present*
[b] *ERM 2017d*
[c] *Potential footprint below HWM = Channel width (wetted or bankfull) * maximum road infrastructure width of 13 m*
[d] *Estimated PAD = Potential footprint below HWM based on channel bankfull width at low flow*
[e] *Bridge structures will be clear-span*

Table 3.1-2. Fish Habitat in Streams with Potential Water Withdrawal and Use from the Madrid-Boston Project

Stream	Watershed	Habitat Type	No. of Units	Combined Stream Length (m)	Percent Composition (%)*	Mean Wetted Width (+1SE)	Total Area (m^2)
Little Roberts Outflow	Doris	Glide	4	747	57	11.9 ± 1.1	9,542
		Pool	3	320	24	22.3 ± 6.6	7,108
		Riffle	2	243	19	9.6 ± 1.8	2,482
Doris Outflow	Doris	Glide	17	3,691	83	4.8 ± 0.5	19,566
		Pool	13	440	10	9.7 ± 0.5	4,171
		Riffle	2	103	2	3.9 ± 1.8	396
		Cascade	3	235	5	5.4 ± 1.1	1,388
Ogama Outflow	Doris	Glide	15	688	54	5.4 ± 0.5	4,153
		Pool	11	433	34	14.1 ± 2.0	8,543
		Riffle	5	155	12	5.2 ± 0.6	855
Ogama Inflow	Doris	Glide	16	639	64	4.9 ± 0.5	3,231
		Pool	8	239	24	12.2 ± 2.8	4,084
		Riffle	2	104	10	2.6 ± 0.2	273
		Cascade	1	16	2	3	48
P.O. Outflow	Doris	Glide	1	39	100	10.3	402
Patch Outflow	Doris	Glide	1	97	63	6.7	650
		Pool	1	58	37	20	1,160
Wolverine Outflow East	Doris	Glide	3	206	43	1.2 ± 0.4	172
		Pool	2	162	34	15.5 ± 3.0	496
		Flat	1	13	3	4	52
		NDC	1	94	20	0	0
Imniagut Outflow	Doris	Glide	1	30	100	4	120
Stickleback Outflow	Aimaokatalok	Glide	5	160	61	1.6 ± 0.8	211
		Pool	1	35	13	0.5	17
		Flat	1	62	24	0.3	34
		Dry Channel	1	5	2	0	0

In addition to fish habitat, data were collected to create hydraulic models of a subset of streams including Little Roberts and Doris Outflows in 2015 and Patch Outflow, Ogama Inflow, and Ogama Outflow in 2017. Hydraulic modelling results are presented in (ERM 2015a, 2017a). To support future fish habitat assessments based on hydraulic models, fish habitats were mapped in these streams.

3.1.2 Lakes

From 1993 to 2015, multiple fish habitat survey methods were conducted in lakes and ponds, as follows:

- Aerial surveys by helicopter (2 lakes from 1995 to 2006);
- Reconnaissance surveys of the shorelines and littoral zones on foot or by small boat (26 lakes from 1995 to 2014);
- Bathymetric surveys using hydroacoustic methods (15 lakes and 1 pond from 1993 to 2010);
- Habitat assessment of littoral zones (20 lakes and 23 ponds from 1995 to 2015);
- Estimation of surface area and maximum depth of small headwater lakes of the Roberts Watershed (20 lakes in 2006);
- Snorkel surveys of littoral lake habitat of Windy Lake from 2010 to 2014; and
- Hydroacoustic and/or underwater video surveys of littoral and deep-water lake substrate (4 lakes from 2009 to 2015).

As with stream data, all lake data is geo-referenced and is useful for assessing the quantity and quality of fish habitat in lakes. Data from surveys using hydroacoustic equipment and/or underwater video cameras may be used should there be a need to calculate the depths and areas of habitat features of special concern for offsetting purposes, such as shoals on which Lake Trout spawn. If such data has not been collected for a lake of interest, then existing additional surveys may be completed.

3.1.2.1 Water Intakes/Discharge Pipe

As part of the Madrid-Boston Project, water intakes will be used to withdraw water from lakes in the LSA for domestic and industrial uses and water discharge pipes will be used to discharge compliant effluent to the receiving environment. 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).

Bathymetric surveys in Windy and Aimaokatalok lakes were conducted during baselines studies in 2006 (Golder 2006). The littoral habitat of Windy Lake was assessed by shoreline habitat assessment in 2009 (Rescan 2010b). Hydroacoustic surveys were used in 2010 to map substrates in the sublittoral and some littoral areas of Aimaokatalok Lake (Rescan 2011b). Lake habitat data from Windy and Aimaokatalok lakes is summarized in Table 3.1-3. Fish community results provided in Table 3.1-3 are discussed in Section 3.2.

3.1.2.2 Lakes with Potential for Water Withdrawal and Use

Based on the effects assessment of the Madrid-Boston Project in the FEIS, lake habitat losses or permanent alteration to fish habitats may occur as a result of water withdrawal and use in Imniagut Lake. A bathymetric survey was conducted in Imniagut Lake in 2010 (Rescan 2011a) and the littoral habitat of Imniagut Lake was assessed by shoreline habitat assessment in 2014 (ERM 2015b). Lake habitat data from Imniagut Lake is summarized in Table 3.1-3. Fish community results provided in Table 3.1-3 are discussed in Section 3.2.

Table 3.1-3. Fish Habitat and Community Characteristics in Lakes with Freshwater Intakes/Discharge Pipeline or Water Withdrawal and Use for the Madrid-Boston Project

Fish Habitat	Sampling Method	Windy Lake Water Intake	Aimaokatalok Lake Water Intake/Discharge	Imniagut Lake Water Withdrawal and Use
Mean depth (m)	Bathymetric survey	11.2	6.0	2.5
Maximum depth (m)	Bathymetric survey	21.2	30.0	4.9
Littoral substrate	Shoreline and littoral habitat survey	*30% Fines, 30% Cobble, 20% Bedrock*	*Dominant = Sand and gravel Subdominant = Cobble and larger rock*	Dominant = Bedrock Subdominant = Fines and Vegetation
Sublittoral substrate	Hydroacoustic survey	-	*Dominant = Sand and gravel Subdominant = Cobble and larger rock*	-
Shoreline description	Shoreline and littoral habitat survey	*Mostly steep bedrock, some gently sloping gravel*	-	Steep bedrock on west side, Bedrock, boulder, and cobble beach on east side. Dominated by vegetation and fines at north and south.

Fish Community	Sampling Method	Windy Lake Species				Aimaokatalok Lake Species			Imniagut Lake Species			
		Total	LKTR	CISC	NSSB	Total	LKTR	LKWH	Total	LKTR	CISC	NSSB
Fish CPUE	Gillnet (fish/100 m^2 net/h)	1.9	0.4	1.6	0.0	7.2	2.2	0.7	0	0	0	0
	Minnow Trap (fish/trap/24 h)	0.1	0.0	0.0	0.1	-	-	-	0.1	-	-	43.3
	Electrofishing (fish/100 s)	-	-	-	-	-	-	-	1.95	-	-	1.95
Fish density	Hydroacoustic survey (Day; fish/ha)	-	-	-	-	12	4	1.2	-	-	-	-
	Hydroacoustic survey (Dusk; fish/ha)	-	-	-	-	2	0.7	0.2	-	-	-	-

Notes:

Dashes = data not available

Data specific to the location of the potential effect are italicized; all other data represent conditions in the entire lake.

LKTR = Lake Trout; CISC = Cisco; LKWH = Lake Whitefish; NSSB = Ninespine Stickleback

3.2 Assessment of Fish Populations and their Abundance

An associated step in developing an offsetting plan is to map the distribution of fish species across the landscape and assess the relative or absolute numbers of fish in specific streams and lakes. Information on fish habitat alone is not sufficient for development of an offsetting plan. While habitat quantity and quality can affect fisheries productivity, productivity also varies among fish species due to variation in growth and reproduction. Therefore, habitat quantity and quality must also be linked to the distribution of fish species across the landscape and to the abundance of fish species. As with habitat, streams and lakes are treated separately because different methods are used to measure fish population abundance in streams than in lakes. However, if necessary, an offsetting plan may combine these data sets for species with anadromous or adfluvial life histories.

From 1993 to 2017, fish communities of streams and lakes of the Hope Bay Belt were sampled using eight fishing methods, as follows:

- Backpack electrofishing in streams and along the shorelines of lakes (69 streams, 25 lakes, and 24 ponds from 1993 to 2017);
- Minnow traps in streams and ponds and along the shorelines of lakes (21 streams, 29 lakes, and 19 ponds from 1994 to 2017);
- Gillnets in lakes, ponds, and large streams (3 streams, 37 lakes and 1 pond from 1993 to 2017);
- Angling in lakes and large streams (5 streams and 21 lakes from 1995 to 2017);
- Beach seining on lake shorelines and large streams (5 streams and 15 lakes from 1996 to 2008);
- Fyke nets in lakes and large streams (4 streams and 8 lakes from 2002 to 2012);
- Fish fence on Roberts Outflow or Little Roberts Outflow from 2002 to 2015; and
- Hydroacoustic techniques to estimate number and density of fish in lakes (three lakes from 2009 to 2015).

The extensive fish sampling provides a large database from which the spatial distribution of fish presence in freshwater systems of the Hope Bay Belt has been mapped (Figures 6.2-16 and 6.2-17 in Volume 5, Chapter 6).

These data have also allowed an assessment of the relative abundance of each species among streams and lakes, and estimates of absolute numbers of fish and their densities (number/m^2 for streams and number/ha for lakes) for a subset of those waterbodies. More surveys of fish abundance in some streams, particularly potential offsetting sites, may be required for development of an offsetting plan.

3.2.1 Streams

A total of 14 species of fish were captured in the freshwater stream and river samples: Ninespine Stickleback, Lake Trout, Lake Whitefish, Cisco, Arctic Char, Least Cisco, Arctic Grayling, Broad Whitefish, Slimy Sculpin, 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. None of the species captured are designated as threatened or endangered by COSEWIC or listed through the *Species at Risk Act* (2002).

3.2.1.1 Water Crossings

Electrofishing surveys were conducted at eleven of the proposed road crossing sites during low flow conditions (ERM 2017c). Surveys were conducted on open stream reaches located within 50 m upstream and/or downstream of crossing locations. Electrofishing effort was not pre-determined because the primary objective was to determine whether fish were present in the stream and, if so, determine fish community composition. One of the proposed road crossing sites that was not surveyed by electrofishing in 2017 was surveyed in a previous baseline program in 2010 (i.e., C-MBR-12; Rescan 2011b)

The 2017 electrofishing data along with data from previous baseline surveys informed the determination of fish-bearing status for the proposed road crossing locations (Table 3.1-1). Four sites were considered unlikely to be fish-bearing and an additional eight sites were predicted to have only Ninespine Stickleback present. The remaining nine sites were confirmed to have Ninespine Stickleback in addition to the presence of at least one species of large-bodied fish (Lake Trout, Lake Whitefish, Cisco, Arctic Grayling, Arctic Char, Burbot). Fish community data for each sampled location are presented in Table 3.2-1.

3.2.1.2 Streams with Potential for Water Withdrawal and Use

The fish communities of eight streams with potential for water withdrawal and use from Madrid-Boston were sampled in 2016 (two streams; ERM 2016) and 2017 (six streams; ERM 2017b). Sampling sites were between approximately 15 m and 40 m in length. They were selected to be representative of the habitat unit that they were within and in locations where sampling was not prevented by stream morphology (e.g., pools that exceeded safe wading depths of approximately 0.8 m).

A standard multiple-pass, depletion electrofishing method was used to collect fish at sample sites (Ptolemy 1993; Riley, Haedrich, and Gibson 1993; Peterson, Thurow, and Guzevich 2004; Rosenberger and Dunham 2005). Depletion estimates are particularly useful in small streams where the population to be estimated is relatively small (Zippin 1956). Historical sampling and experience indicated that the streams sampled were suitable candidates for this approach. A multiple-pass removal was not performed in Stickleback Outflow or Imniagut Outflow due to the presence of multiple channels and/or extensive instream vegetation that prevented isolation of the site using block nets. In Stickleback Outflow and Imniagut Outflow, a single electrofishing pass was conducted on an open stream reach resulting in species presence/absence and relative abundance data but no population estimate.

Table 3.2-1. Electrofishing Effort and Catch at Proposed Road Crossing Locations of the Madrid-Boston Project

			Catch (No. of fish)					CPUE (No. of fish/100 s)				Visual Observation	
Crossing ID	Watershed	Waterbody Name	NSSB	ARGR	LKTR	SLSC	Effort(s)	NSSB	ARGR	LKTR	SLSC	NSSB	ARGR
C-CDR-02	Windy	Glenn Outflow	2	0	1	1	200	1.00	0.00	0.50	0.50	-	-
C-TIA-04*	Doris	Ogama Outflow											
C-MBR-7	Koignuk/Aimaokatalok	Boulder Creek	2	16	0	0	748	0.27	2.14	0.00	0.00	-	-
C-MBR-8	Koignuk/Aimaokatalok	Boulder Creek Tributary	42	1	0	0	504	8.33	0.20	0.00	0.00	> 15	5.00
C-MBR-9 (Below Falls)	Aimaokatalok	Aimaokatalok Inflow	30	0	0	0	263	11.41	0.00	0.00	0.00	> 100	-
C-MBR-9 (Above Falls)	Aimaokatalok	Aimaokatalok Inflow	2	0	0	0	238	0.84	0.00	0.00	0.00	-	-
C-MBR-11	Aimaokatalok	Aimaokatalok Inflow	11	0	0	0	402	2.74	0.00	0.00	0.00	-	-
C-MBR-12	Aimaokatalok	Aimaokatalok Inflow	3	2	0	0	1403	0.21	0.14	0.00	0.00	-	-
C-MBR-15	Aimaokatalok	Aimaokatalok Inflow	20	0	0	0	840	2.38	0.00	0.00	0.00	-	-
C-MBR-16	Aimaokatalok	Aimaokatalok Inflow	2	2	0	0	598	0.33	0.33	0.00	0.00	-	-
C-MBR-17	Aimaokatalok	Aimaokatalok Inflow	19	0	0	0	253	7.51	0.00	0.00	0.00	-	-
C-MBR-19	Aimaokatalok	Trout Outflow	26	1	0	0	702	3.70	0.14	0.00	0.00	> 300	-
C-MBR-20	Aimaokatalok	Stickleback Outflow	30	4	0	**1**	619	4.85	0.65	0.00	0.16	> 500	-

Notes:

CDR = Roberts Bay Cargo Dock Road; TIA = Madrid North to Boston TIA Road; MS = Madrid South All-Weather Road; MBR = Boston-Madrid All-Weather Road

NSSB = Ninespine Stickleback; ARGR = Arctic Grayling; LKTR = Lake Trout; SLSC = Slimy Sculpin

Dashes = no visual observations noted

** Shaded cells = fish population estimated by multiple pass electrofishing, see Table 3.2-4 for results*

CPUE = Catch-Per-Unit-Effort

For sites where a multiple-pass removal was performed, a minimum of three passes were completed. To collect fish from within a site, nets were installed at the upstream and downstream ends of the site to isolate it from the surrounding stream. To estimate the population, an adequate number of fish must be removed so there is a decline towards zero in each subsequent pass. Methods for the calculation of population density estimates are described in (ERM 2016); ERM (2017b). An insufficient number of Lake Trout and Cisco were captured to complete meaningful population estimate calculations (four of each species from 17 sites). These species were excluded from further data analysis.

A total of 244 Ninespine Stickleback were captured in multiple-pass removal surveys and an additional 31 Ninespine Stickleback were captured in single-pass surveys (Table 3.2-2). In the streams where multiple-pass surveys were performed and therefore, the density of Ninespine Stickleback could be calculated, densities ranged from 0.00 fish/m^2 to 2.30 fish/m^2 (Table 3.2-3). Although not captured in the single-pass electrofishing survey at Imniagut Outflow, two Ninespine Stickleback were visually observed in the mouth of the stream near Imniagut Lake. The presence and high relative abundance of Ninespine Stickleback in all of the surveyed streams indicates that this species is distributed across the Project area and thus able to occupy a broad range of habitat types.

A total of 12 Arctic Char were captured; 20 were captured at three sites in Roberts Outflow, nine were captured at 11 sites in Doris Outflow, and three were captured in three sites in Little Roberts Outflow (Table 3.2-2). Arctic Char ranged in fork length from 102 mm to 230 mm and in age from one to five years; all were juvenile fish (Scott and Crossman 1973). For all stream sections, juvenile Arctic Char density was significantly higher in riffles and cascades when compared to glides (ERM 2016).This is consistent with observations made during the habitat assessment, which indicated that habitat quality for rearing juvenile salmonids was low in glides and high in riffles and cascades (ERM 2016). The maximum density of juvenile Arctic Char in Doris Outflow was 0.10 fish/m^2 in a cascade and 0.06 fish/m^2 in a riffle in Little Roberts Outflow (Table 3.2-4).

The site with the highest density of juvenile Arctic Char (EF-14; 0.10 fish/m^2; Table 3.2-4) was the site located the farthest from overwintering habitat in Roberts Lake (the only overwintering habitat available to anadromous fish in the watershed). Site EF-14, located just downstream of the waterfall in Doris Outflow, is 4.9 km from the nearest overwintering habitat. To reach this cascade, juvenile Arctic Char migrate through several kilometres of suboptimal rearing habitats predominantly comprised of glides. Of the nine sites sampled in Doris Outflow downstream of EF-14 (i.e., sites closer to overwintering habitat), no Arctic Char were captured at seven sites.

In total, six Lake Trout were captured during low flow conditions (Table 3.2-2). The Lake Trout in Doris Outflow were captured in cascades just downstream of the waterfall and the Lake Trout in Ogama Outflow were both captured in a riffle. The single Lake Trout in Ogama Inflow was captured in a glide. One of the Lake Trout captured in Doris Outflow may have been a juvenile (fork length 320 mm) while all others were adults (396 mm to 720 mm fork length). One adult Lake Whitefish (fork length of 371 mm), was captured in a glide (Table 3.2-2) and three juvenile Cisco were captured in Little Roberts Outflow (Table 3.2-2). Large-bodied salmonids (> 40 cm length) were also observed throughout Ogama Outflow and Ogama Inflow during detailed habitat assessment surveys in 2017.

Table 3.2-2. Effort and Catch from Electrofishing Surveys in Streams with Potential Water Withdrawal and Use from the Madrid-Boston Project

Stream	No. of Sites	Isolated (Y/N)	No. of Passes/Site	Total Fishing Effort (s)	Mean Effort (s/pass)	Catch (No. of fish)								
						NSSB	ARCH	ARGR	LKTR	LKWH	CISC	*Coregonus* sp.	SLSC	Total
Little Roberts	3	Y	2 to 3	2,481	354	3	3	0	0	0	3	0	0	9
Doris Outflow	11	Y	2 to 3	10,400	400	69	9	0	3	0	0	0	0	81
Ogama Outflow	2	Y	3	4,894	816	30	0	0	2	0	0	0	0	32
Ogama Inflow	4	Y	3 to 4	7,098	546	62	0	0	1	1	0	0	0	64
Wolverine Outflow East	1	Y	3	810	270	80	0	0	0	0	0	0	0	80
Imniagut Outflow	1	N	1	250	250	0	0	0	0	0	0	0	0	0
Stickleback Outflow	1	N	1	619	619	31	0	4	0	0	0	0	1	36
Total	**23**			**26,552**	**3,255**	**275**	**12**	**4**	**6**	**1**	**3**	**0**	**1**	**302**

Notes:
NSSB = Ninespine Stickleback; ARGR = Arctic Grayling; LKTR = Lake Trout; LKWH = Lake Whitefish; SLSC = Slimy Sculpin
Isolated = sampling reach isolated using block nets

Table 3.2-3. Number and Density of Ninespine Stickleback from Multiple-pass Electrofishing Surveys in Streams with Potential Water Withdrawal and Use from the Madrid-Boston Project

Stream	Sampling Date	Site	Habitat Type	No. of Passes	Total Fishing Effort(s)	Total No. of NSSB Captured	Estimated No. of NSSB	Lower Confidence Limit	Upper Confidence Limit	Survey Area (m^2)	Estimated Density of NSSB (No. of fish/m^2)
Doris Outflow	21-Aug	EF-1	Glide	3	1,168	16	16	15	17	68.9	0.23
	21-Aug	EF-2	Glide	3	699	5	6	0	14	33.6	0.18
	22-Aug	EF-3	Glide	2	630	4	4	3	5	45.4	0.09
	22-Aug	EF-4	Glide	2	555	1	0	1	1	98.6	0.00
	22-Aug	EF-5	Glide	2	1,005	4	7	0	39	101.5	0.07
	23-Aug	EF-6	Glide	2	856	8	8	6	10	88.7	0.09
	23-Aug	EF-7	Glide	2	1,211	11	11	9	13	153.6	0.07
	23-Aug	EF-8	Glide	3	1,212	2	2	2	2	94.3	0.02
	25-Aug	EF-13	Cascade	2	720	2	2	2	2	65.0	0.03
	25-Aug	EF-14	Cascade	2	846	6	6	5	7	57.7	0.10
	29-Aug	EF-17	Glide	3	1,498	1	1	1	1	129.4	0.01
Little Roberts Outflow	24-Aug	EF-11	Riffle	2	913	2	0	2	2	36.2	0.00
	24-Aug	EF-12	Glide	2	418	0	0	-	-	139.5	0.00
	25-Aug	EF-15	Riffle	3	1,150	1	1	0	2	45.0	0.02
Ogama Outflow	20-Jul	1	Glide	3	1758	7	7	6	8	57.1	0.12
	21-Jul	2	Glide/Riffle/Glide	3	3136	23	25	19	31	159.6	0.14
Ogama Inflow	19-Jul	1	Glide	3	1048	2	2	-	-	60.9	0.03
	19-Jul	2	Riffle/Glide	4	1378	11	24	49	97	63.0	0.17
	20-Jul	3	Glide	3	2347	28	30	25	35	85.2	0.33
	20-Jul	4	Glide	3	2325	21	22	18	26	67.4	0.31
Patch Outflow	21-Jul	1	Glide	3	2026	29	45	7	83	94.4	0.31
Wolverine Outflow East	22-Jul	1	Glide	3	810	80	88	77	99	34.7	2.30

Note:

NSSB = Ninespine Stickleback

Table 3.2-4. Number and Density of Juvenile Arctic Char from Multiple-pass Electrofishing Surveys in Streams with Potential Water Withdrawal and Use from the Madrid-Boston Project

Stream	Sampling Date	Site	Habitat Type	No. of Passes	Total Fishing Effort (sec)	Total No. of Arctic Char Juveniles Captured	Estimated No. of Juvenile Arctic Char	Lower Confidence Limit	Upper Confidence Limit	Survey Area (m^2)	Estimated Density of Juvenile Arctic Char (No. of fish/m^2)
Doris Outflow	21-Aug	EF-1	Glide	3	1,168	0	0	-	-	68.9	0.00
	21-Aug	EF-2	Glide	3	699	2	2	2	2	33.6	0.06
	22-Aug	EF-3	Glide	2	630	0	0	-	-	45.4	0.00
	22-Aug	EF-4	Glide	2	555	0	0	-	-	98.6	0.00
	22-Aug	EF-5	Glide	2	1,005	0	0	-	-	101.5	0.00
	23-Aug	EF-6	Glide	2	856	0	0	-	-	88.7	0.00
	23-Aug	EF-7	Glide	2	1,211	0	0	-	-	153.6	0.00
	23-Aug	EF-8	Glide	3	1,212	1	1	1	1	94.3	0.01
	25-Aug	EF-13	Cascade	2	720	0	0	-	-	65.0	0.00
	25-Aug	EF-14	Cascade	2	846	6	6	6	7	57.7	0.10
	29-Aug	EF-17	Glide	3	1,498	0	0	-	-	129.4	0.00
Little Roberts Outflow	24-Aug	EF-11	Riffle	2	913	2	2	2	2	36.2	0.06
	24-Aug	EF-12	Glide	2	418	0	0	-	-	139.5	0.00
	25-Aug	EF-15	Riffle	3	1,150	1	1	1	1	45.0	0.02

Lake Trout are predaceous, transitioning their diet from invertebrates to fish by the time they reach 350 mm fork length (Scott and Crossman 1973; McPhail 2007). Adult Lake Whitefish consume a wide variety or bottom-living invertebrates, small fishes, zooplankton, and terrestrial insects while adult Cisco are generally planktivorous (Scott and Crossman 1973). The observation of large-bodied salmonids in Doris Outflow, Ogama Outflow and Ogama Inflow indicates that piscivorous Lake Trout and drift feeding adult Lake Whitefish and/or Cisco make use of these streams for rearing and/or migration under stable low flow conditions in the open-water season. The lower density of salmonids less than 300 mm fork length in the surveyed streams indicates that juveniles may rear elsewhere.

Seven *Coregonus* sp. young-of-year fish were captured in abundant macrophyte cover in a glide habitat of site Patch Outflow (Table 3.2-2). More fish of this species and size class were observed during the electrofishing survey but due to the abundant cover, capture efficiency was low. The small size of individuals prevented identification to species in the field. Coregonids spawn along lake shorelines (Scott and Crossman 1973) therefore the presence of rearing young-of-year fish suggests that fish migrated into the stream channel shortly following emergence.

Finally, four rearing juvenile Arctic Grayling (92 to 107 mm in fork length) and one adult Slimy Sculpin (71 mm total length) were captured in Stickleback Outflow (Table 3.2-2). A dry channel barrier upstream of where they were captured would prevent upstream migration to Stickleback Lake on the and past the survey date. Relatively poor connectivity downstream may also limit migration potential to Aimaokatalok Lake during low flow conditions (ERM 2017b).

3.2.2 *Lakes*

A total of nine species of fish were captured in the freshwater lake samples including Ninespine Stickleback, Lake Trout, Lake Whitefish, Cisco, Arctic Char, Least Cisco, Arctic Grayling, Broad Whitefish, and Slimy Sculpin. None are designated as threatened or endangered by COSEWIC or listed through the *Species at Risk Act* (2002).

Gillnets were the predominant method of sampling fish populations of lakes in the Hope Bay Belt. Gillnet CPUE (number of fish/100 m^2 of net/hour fishing) provides an estimate of relative abundance of lake-resident fish, although comparisons among lakes may complicated by the different mesh sizes, net areas, and soak times that were used over the last 24 years. Hydroacoustic surveys in combination with gillnet surveys have also been conducted in some lakes to provide absolute estimates of fish populations (e.g., Aimaokatalok Lake).

3.2.2.1 Water Intakes/Discharge Pipe

In 2009, gillnetting and minnow trapping surveys were conducted in the southern portion of Windy Lake (Rescan 2010b). Although no nets or traps were set near the location of the proposed intake, CPUE provide an index of the fish population present in Windy Lake. Fish community data from Windy Lake are presented in Table 3.1-3.

In 2010, hydroacoustic and gillnetting surveys were conducted in the southern portion of Aimaokatalok Lake, covering the proposed locations of both the intake and discharge pipe (Rescan 2011b). Fish density measured by hydroacoustic survey near the proposed intake location was low compared to other locations in Aimaokatalok Lake during daytime surveys (0.03 to 1.4 fish/ha) and slightly higher during dusk surveys (0.04 to 19 fish/ha). Fish density measured by hydroacoustic survey near the proposed discharge location was also low compared to other locations in Aimaokatalok Lake (0.016 to 0.07 fish/ha during daytime surveys and 0.015 to 0.02 fish/ha during dusk surveys; Rescan 2011b). The CPUE in one gillnet set near the proposed intake location was 0.85 fish/100 m^2/hour (Lake Trout only captured). The average CPUE in four gillnets set near the proposed discharge location was 0.30 fish/100 m^2/hour total (0.12 fish/100 m^2/hour for Lake Trout and 0.18 fish/100 m^2/hour for Lake Whitefish; Rescan 2011b).

The overall CPUE in gillnet surveys and fish density in hydroacoustic surveys in the southern portion of Aimaokatalok Lake are presented in Table 3.1-3. The density of fish in daytime hydroacoustic surveys and the CPUE in gillnet surveys in the southern portion of Aimaokatalok Lake was greater in the 0 to 5 m depth range (0.00032 fish/m^3 and 0.6 fish/net hour) than in the 5.1 to 10 m depth range (0.00002 fish/m^3 and 0.4 fish/net hour) but less than in depths >10.1 m (0.00326 fish/m^3 and 6.2 fish/net hour). Lake Trout were the dominant species captured up to 10 m depth while Cisco were the dominant species captured at depths greater than 10 m. Lake Whitefish were captured in depths less than 5 m and greater than 10 m (Rescan 2011b).

3.2.2.2 Lakes with Potential for Water Withdrawal and Use

Based on the effects assessment of the Madrid-Boston Project in the FEIS, lake 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) is expected to be limited to 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).

Gillnetting, minnow trapping, and electrofishing surveys were conducted in Imniagut Lake in 2014 and 2017 (ERM 2015b, 2017b). No fish were captured in 7.6 hours of gillnetting effort in 2014 and 47.2 hours of gillnetting effort in 2017. Fish community data from Imniagut Lake are presented in Table 3.1-3. Only Ninespine Stickleback were captured in minnow trapping efforts (2014 and 2017) and electrofishing (2017 only).

3.3 Calculation of Potential PAD

Baseline data presented in Section 3.1 and 3.2 were used to calculate estimates of the amounts of fish habitat (in m^2) to be potentially lost/altered in the freshwater environment due to interactions with the Madrid-Boston Project.

3.3.1.1 Road Crossings

Fish habitat loss (permanent alteration to, or destruction; PAD) at crossing locations was estimated from fish habitat data collected in 2017 (ERM 2017b). 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 3.1-1).

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 (Tables 3.1-1 and 3.3-1).

Table 3.3-1. 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**

The estimated PAD of fish habitat at water crossings resulting from Madrid-Boston AWR construction is presented in Table 3.3-1 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) that have moderate to high quality fish habitat throughout the open water season account for 87% of estimated PAD. C-MBR-11 is located on a tributary to Aimaokatalok Lake with good spawning, rearing, and migration habitats for Ninespine Stickleback (CPUE = 2.38 fish/100s; Table 3.2-1). Habitat in C-MBR-11 was also rated as fair for rearing and migration of large-bodied fish, however, no large-bodied fish were captured in electrofishing surveys (Table 3.2-1) and downstream migration potential for large-bodied fish to reach overwintering habitat in Aimaokatalok Lake is unknown. C-MBR-20 is located on Stickleback Outflow where spawning, rearing, and migration habitats are good for Ninespine Stickleback and Slimy Sculpin and poor for Arctic Grayling (CPUE = 4.85, 0.16, and 0.65 fish/100s, respectively; Table 3.2-1). At low flow in 2017, a temporary dry channel barrier interrupted migratory access between Stickleback and Aimaokatalok lakes.

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 (five sites) or low quality fish habitat at low flow (one site). The only fish species known or assumed to be present in these streams is Ninespine Stickleback (Table 3.1-1 and Table 3.2-1). Of these sites, only C-MBR-17 had sufficient water for an electrofishing survey at low flow. The CPUE of Ninespine Stickleback was 7.51 fish/100s. Overall, fish habitat assessments at the crossing locations did not identify habitats that were critical for any life stages of the fish species present (ERM 2017b).

3.3.1.2 *Water Intakes/Discharge Pipe*

<u>Potential Alteration or Destruction of Fish Habitat (PAD)</u>

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 3.3-2. 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 (comprised of cobble and boulder substrates) 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), 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 2013d) 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.

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 3.3-2. 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).

Table 3.3-2. Total Estimated PAD of Fish Habitat from Freshwater Intake and Discharge Pipelines for the Madrid-Boston Project

Design Specifications	Windy Lake Intake	Aimaokatalok Lake	
		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 m^2	1,000.4 m^2
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 m^2	1,140 m^2
Total 3D surface area of infrastructure	97.6 m^2	1,756.8 m-	1,000.4 m^2

The total PAD (lakebed footprint) of the intake pipe will be 94.4 m^2 in Windy Lake. This estimate represents existing substrate in Windy Lake that will be buried under or covered by 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 3.3-2). The PAD 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. The total of 94.4 m^2 of PAD represents a minimum loss of 94.4 m^2 of habitat or 0.00033% of the total area of Windy Lake.

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 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 3.3-2). The footprint of the discharge pipeline 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. PAD estimates represents existing substrate in Aimaokatalok Lake that will be buried under or covered by the lakebed footprint of rock berms, the sum of the lakebed footprint of each anchor block, and the footprint of the pipelines 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 3.3-2). The total PAD from the intake and discharge pipes in Aimaokatalok Lake represents a minimum loss of 2,743 m^2 of habitat or 0.012% of the total area of Aimaokatalok Lake.

According to DFO's Pathways of Effects (PoE), placement of such material below the HWM of Windy Lake may result in the potential alteration or destruction of fish habitat (DFO 2010). Loss of habitat may have direct and indirect effects on aquatic organisms in the lake, including the loss of significant reproductive or feeding habitat, and changes to nutrient and organic material cycling.

For most fish species, the littoral zone of a lake provides good quality spawning, feeding, and rearing habitat. For example, broadcast spawning species such as Lake Trout use cobble/boulder shorelines as spawning habitat (Scott and Crossman 1973), if it is deep enough to fall below the winter ice cover. Species such as Lake Whitefish and Cisco that feed on benthic invertebrates will forage mainly within the littoral zone. Juvenile fish will rear in the littoral zone if cover is available underneath cobble and boulders. 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 (Scott and Crossman 1973). 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.

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 2011b). 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. However, sand/gravel and cobble/rock substrates are not limiting in the southern part of Aimaokatalok Lake, comprising 40% and 15% of sublittoral substrates, respectively. The densities of fish at the potential locations of the intake and discharge pipes in Aimaokatalok Lake were also low compared to other surveyed habitats within the lake suggesting lower quality habitat. Particularly, the total CPUE in gillnets set in 10 to 15 m depths (6.26 fish/100 m^2 net/hour) were more than an order of magnitude greater than the CPUE in gillnets set in the 0 to 5 m depth stratum where the pipelines will be constructed (0.55 fish/100 m^2/hour; Rescan 2011b). Further, the density of fish derived from hydroacoustic surveys was an order of magnitude greater at depths of 10 to 15 m (0.00325 fish/m^3) than in the 0 to 5 m depth stratum where the pipelines will be constructed (0.00032 fish/m^3; Rescan 2011b).

Mitigation of Potential Footprint Effects

New structurally heterogeneous fish habitat will be created through the placement of 3D habitat comprising the rock berms (composed of cobble and boulder riprap substrates). This habitat will effectively replace low complexity habitats (i.e., fines and sand) and will be equivalent to more complex habitats (i.e., gravel, cobble, and boulder) that will be lost underneath the intakes and discharges pipe. This new habitat will be produced by the new surfaces that are incorporated into the design of rock berms.

The rock berms that will cover the pipelines at depths between 0 and 3 m will provide complex, rocky types of habitat that currently comprise only 30% of the littoral zone in Windy Lake (i.e. cobble; Table 3.1-3) at the location of the intake and that is the subdominant substrate type in Aimaokatalok Lake at the location of the intake and discharge pipes (i.e., cobble and larger rock; Table 3.1-3). The crevices can be colonized by juvenile fish and small-bodied fish (e.g., Ninespine Stickleback and Slimy Sculpin) and may provide refuge habitat from predators. Furthermore, these new surfaces will provide new settlement opportunities for algae and sessile invertebrates, which are food sources for small fish and macroinvertebrates. It is anticipated that these substrates will provide similar benefits to those provided by the creation of artificial reefs.

The design of the rock berms results in the creation of a total of 97.6 m^2 of 3D surface area in Windy Lake and 2,757 m^2 of 3D surface area in Aimaokatalok Lake. Therefore, the design of the intakes and discharge pipelines will create slightly more new habitat than will be lost underneath the structures in each lake.

A total of 94.4 m^2 and 2,743 m^2 of existing fish and aquatic habitat in Windy and Aimaokatalok Lakes, respectively, although non-critical or non-limiting, is anticipated to be permanently lost through the construction of the intakes and discharge pipe. However, due to the placement of larger 3D habitat comprising the rock berm (composed of cobble and boulder riprap substrates) construction may increase habitat complexity and diversity (i.e., increase interstitial space and availability of hard substrate), and therefore is viewed as self-offsetting.

3.3.1.3 Lakes and Streams with Potential for Water Withdrawal and Use

Effects of the Hope Bay Project on lake volume, lake surface elevation and streamflow were assessed based on simulated results of the *Hope Bay Project Water and Load Balance* (i.e., the water balance model; Package P5-4).

Streams

The effects assessment of the Madrid-Boston Project in the FEIS determined that stream habitat losses or permanent alteration to fish habitats may occur as a result of water withdrawal and use. The following steps describe how the effects of the Madrid-Boston 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.

2. The "higher risk" watercourses were then further assessed by:
   - Using a minimum flow threshold of 30% of the MAD to determine periods of highest risk for fish and potential effects on habitat use; and
   - Calculating the area of potential fish habitat loss using information from baseline fish habitat assessments (ERM 2016, 2017b) and hydraulic models (ERM 2016, 2017a).

Based on a threshold of 10% variation from baseline flow conditions, eight streams were identified as having effects greater than natural variation resulting from the Madrid-Boston Project (DFO 2013c; Table 3.3-3; see Volume 5, Chapter 6, Section 6.5.4.2 for complete assessment of effects). 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 negative impacts 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 3.3-3. Summary of Simulated Effects on Streamflows Resulting from Water Withdrawal and Use for the Madrid-Boston Project

Watershed	Stream	Change in Monthly Streamflow of >10 % from Baseline Monthly Streamflow*	Period of Monthly Streamflow <30% of MAD*
Doris	Imniagut Outflow	X	X
	Wolverine Outflow	X	
	Patch Outflow	X	
	P.O. Outflow	X	
	Ogama Inflow	X	
	Ogama Outflow	X	
	Doris Outflow	X	X
	Little Roberts Outflow	X	
Windy	Windy Outflow		
	Glenn Outflow		
Aimaokatalok	Stickleback Outflow	X	X
	Aimaokatalok Outflow		
Koignuk	Koignuk River 2		
	Koignuk River 1		

** Complete assessment described in Volume 5, Chapter 6, Section 6.5.4.2*

The primary potential effect of a change in streamflow greater than 10% from baseline flows 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 Ouflow 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.

Streams where the simulated change in monthly streamflow at high or low flow was greater than 10%, were assessed as "higher risk" against a threshold of 30% of Mean Annual Discharge (MAD) to determine potential effects on fish habitat (DFO 2013c; see Volume 5, Chapter 6, Section 6.5.4.2 for complete assessment of effects). Three streams were assessed as having the potential for effects on fish habitat function based on this threshold (Table 3.3-3). 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 2013c) as well as the habitat functions of the affected streams.

During high flows when the primary habitat use of these streams is for migratory purposes, fish habitat function will be affected in Imniagut Outflow. Imniagut Outflow is ephemeral and provides seasonal migratory habitat, primarily for Ninespine Stickleback between Patch and Imniagut lakes. Ninespine Stickleback are the only fish species present in Imniagut Lake and may partially support CRA fish in Patch Lake as food supply.

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;, streamflow reduction was conservatively estimated to be 100% (total loss of fish habitat) at high flow starting in 2020 and persisting for the life of the Madrid-Boston Project. Simulated baseline conditions and field surveys indicate that the 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 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, the effects of reduction in

Imniagut Outflow may require offsetting. Offsetting would be commensurate with the forage fish productivity contribution Imniagut Outflow provides to Patch Lake CRA fish populations.

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 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). 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 Outflow 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 under certain seasonal or climate conditions. Reduced streamflow in Stickleback Outflow may reduce the ability of Ninespine Stickleback, Arctic Grayling, and Slimy Scuplin to migrate to overwintering habitats through the creation of low flow barriers.

Based on the assessment of streamflow reduction, 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:

- 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.

To quantify these potential fish habitat losses (PAD) in streams resulting from water withdrawal and use, the area of potential PAD was calculated. The area of potential fish habitat loss (PAD) was calculated for all streams where the simulated change in monthly streamflow at high or low flow was greater than 10% (Table 3.3-4), though based on the threshold of 30% of MAD, only Doris, Stickleback, and Imniagut Outflows are at higher risk for effects on habitat function.

The PAD was calculated using a combination of fish habitat assessment data (ERM 2016, 2017b) and hydraulic modeling results (ERM 2016; 2017a; Table 3.3-4). The PAD calculations reflect simulated flows from the water balance model 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).

Table 3.3-4. Total Estimated PAD of Stream Fish Habitat from Water Withdrawal and Use for the Madrid-Boston Project

Watershed	Stream	Maximum Reduction in Hope Bay Project-affected September Streamflow*			PAD (m^2)				
		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
	Patch Outflow	0.084	18.4	2031	19.6	52.0	-	-	72
	P.O. Outflow[§]	0.105	15.6	2031	16.7	-	-	-	2,063
	Ogama Inflow	0.306	6.0	2031	258.3	47.7	33.6	1.4	341
	Ogama Outflow	0.273	6.9	2031	97.1	59.2	38.9	-	195
	Doris Outflow	0.283	18.4	2031	786.8	93.8	20.6	144.1	1,045
	Little Roberts Outflow	1.053	20.3	2031	218.2	93.4	18.6	-	330
Aimaokatalok	Stickleback Outflow[ƚ]	0.001	25.0	2031	61.1	4.3	-	-	65

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*

Hydraulic models were created for Doris and Little Roberts Outflows in 2015 (ERM 2015a) and for Patch Outflow, Ogama Inflow, and Ogama Outflow in 2017 (ERM 2017a). The models for Doris and Little Roberts Outflows were created by surveying water level transects in a subsample of habitat units (i.e., glides, pools, riffles, and cascades) to represent habitat units of similar morphology over the length of the entire stream. The models for Patch Outflow, Ogama Inflow, and Ogama Outflow were created by surveying one or more water level transects in every habitat unit over the length of the entire stream. Fisheries habitat assessments were performed in Doris and Little Roberts outflows in 2016 (ERM 2016) and in Patch Outflow, Ogama Inflow, and Ogama Outflow in 2017 (ERM 2017b). Among other variables, these habitat assessments delineated habitat units, assigned habitat types (i.e. morphology; glide, pool, riffle, or cascade) and measured the total channel length of each habitat unit.

The methods for hydraulic model development, modelled flows, and model output results are presented in ERM (2015a, 2017a). Hydraulic models were used in the calculation of PAD through output parameters that describe stream characteristics at each water level transect under different flow conditions. For the calculation of PAD, the modeled flow conditions included baseline flows and the lowest simulated flow in the month of September over the life of the Madrid-Boston Project. The output parameter of primary interest was the channel top width under each flow condition.

To calculate PAD the following steps were undertaken:

1. The difference between the modelled channel top width under baseline conditions and under maximum September Project-affected flow conditions for each transect was calculated. This difference represents the loss of stream width under reduced flow conditions in the habitat unit in which the transect is located.
2. The reduction in top width was multiplied by the length of the habitat unit in which the transect is located to determine the loss of stream area (PAD) in the habitat unit under reduced flow conditions.
3. The total loss of stream area (PAD) was calculated as the sum of PAD in all habitat units along the length of the stream channel.

The method above was modified slightly for calculation of PAD in Doris and Little Roberts outflows because water level transects were not modelled for each individual habitat unit. Instead modelled transects were assumed to represent all habitat units of similar morphology. In this case, the mean top width reduction for each habitat type (i.e., glide, pool, riffle, and cascade) was calculated. The total length of each habitat type along the length of the stream (e.g., total length of all glides combined from the fish habitat survey; Table 3.1-2) was then multiplied by the mean top width reduction to get a representative PAD for that habitat type over the entire stream length. The PAD by stream and by habitat type within each stream is presented in Table 3.3-4.

For streams without hydraulic models, PAD was calculated by different methods on a stream by stream basis. Since the anticipated PAD in Imniagut Outflow is a total loss of fish habitat, the PAD was calculated as the total stream habitat area measured in July 2017 (ERM 2017b). Stickleback Outflow is anticipated to experience a 25% reduction in flow compared to baseline, thus the PAD was calculated as 25% of the total habitat area measured in July 2017 (ERM 2017b).

Finally, PAD in Patch Outflow (which consists of a single glide habitat unit) was calculated based on the simulated reduction in flow (15.6%; Table 3.3-4) and the relationship between flow reduction and glide habitat area loss in Patch Outflow which is the nearest upstream channel with a hydraulic model and considered representative of flow conditions in P.O. Outflow.

Lakes

The effects assessment of the Madrid-Boston Project in the FEIS determined that lake habitat losses (PAD) that may occur as a result of water withdrawal and use from lakes were limited to Imniagut Lake.

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 were compared baseline lake volumes under average hydrologic conditions to assess whether simulated reductions in volume exceed 10% of baseline values.
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.

For the assessment of lake volume, 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 (DFO 2010) 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 (see Volume 5, Chapter 6, Section 6.5.4.2 for complete assessment of effects). For the assessment of lake surface elevation, if the Project-affected reduction (i.e., the sum of average baseline variation in water level, average baseline ice-thickness, and Project-affected reduction in under-ice lake surface elevation) was less than the maximum baseline reduction (i.e., the sum of maximum baseline variation in water level and maximum baseline ice thickness) by more than 10 cm, the area below the ice unusable as fish habitat was considered to 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 (see Volume 5, Chapter 6, Section 6.5.4.2 for complete assessment of effects).

Based on the effects assessment of the Madrid-Boston Project in the FEIS, the only lake in which habitat losses or permanent alteration to fish habitats are likely to occur as a result of water withdrawal and use is Imniagut Lake. 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%. The simulated reduction in average annual lake volume was greater than 10% of baseline values for 19 years over the life of the Project. 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. Reduction in average annual lake volume in the final Project Year was simulated at 65.8% and the simulated average annual reduction in lake surface elevation in the final Project Year was 1.16 m less than the simulated baseline. 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 (minnow trapping CPUE = 0.10 fish/trap/24h and electrofishing CPUE = 1.95 fish/100s; Table 3.1-3). During fish community assessments in 2014 and 2017, no large-bodied (CRA) fish species were ever captured (ERM 2015b; 2017b; Table 3.1-3). Imniagut Lake is located upstream of Patch Lake to which it is connected by an ephemeral outflow stream. Due to this poor 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.; Rescan 2010a; Rescan 2011a). 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 2016) 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 potentially result in the permanent loss of fish habitat for most or all of Imniagut Lake. The total area of fish habitat loss (PAD) is therefore estimated to be as much as the total surface area of Imniagut Lake of 146,543 m^2 (14.65 ha; Rescan 2011a). 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 forage fish productivity contribution that Imniagut Lake may provide to Patch Lake CRA fish populations.

3.4 Habitat Evaluation Procedure

A habitat evaluation procedure (HEP) may be used to construct a habitat budget during development of a freshwater offsetting plan should one be deemed necessary by DFO. HEP is a generalized procedure for assessing habitat suitability in streams and lakes. It was developed by the US Fish and Wildlife Service more than 35 years ago (USFWS 1980), and has been widely used throughout Canada and North America since then. It is a standard tool for developing habitat budgets for offsetting planning in Canada (Diavik 1998; Billiton 2002; RL&L/Golder 2003; Rescan 2005, 2007; Rescan Environmental Services Ltd. 2012).

The HEP approach has two advantages. First, it provides an objective method to characterize the quality or importance of affected habitats to fish species and aquatic resources. Second, it allows standardization of habitat quality ratings relative to other habitats that have different physical characteristics (e.g., lakes versus streams). This facilitates comparisons among habitat types and ultimately allows affected habitats to be evaluated as a single group for the offsetting calculation.

HEP is an appropriate tool for offsetting fisheries effects in Canada. As identified by DFO in *Science Advice to Support Development of a Fisheries Protection Policy for Canada* (DFO 2013e), a pragmatic approach based on habitat quality is an appropriate first step for offsetting (i.e., budgeting) fisheries productivity. Due to difficulties in directly measuring fish productivity, surrogates such as biological indices (e.g., fish biomass, salmonid smolt yield, production/ biomass, vital rates) or habitat variables (e.g., habitat suitability indices or estimates of primary or secondary production), can be used to indirectly evaluate project-related impacts to fish productivity (Minns et al. 2011; Randall et al. 2013). However, it is recognized that data collection and monitoring of biological indices (e.g., fish biomass) may be required to validate a habitat-based approach to offsetting (Randall et al. 2013). Notwithstanding, HSI for Arctic Char and Lake Trout spawning and rearing (nursery) habitat were developed in the original Doris North No Net Loss Plan (Golder 2007; DFO 2016).

The HEP model relies upon HSI curves for depth, velocity, substrate, cover, water quality, and other attributes. Relevant HSI curves for VECs identified through EIS processes (e.g., Arctic Char, Lake Trout, Arctic Grayling, and Whitefish/Cisco) will be researched, collated, and reviewed for applicability to the Project area.

Where the Project has the potential to cause *serious harm to fish* (e.g., from reduced streamflows and lake elevations resulting in habitat losses), as concluded by DFO, affected habitats will be quantified and characterized in terms of their importance to each fish's life history stage. The HEP produces habitat equivalent units (HEU, m^2) that are indices of both habitat quantity and quality. This is calculated by multiplying habitat area (measured in m^2) by a habitat suitability index (HSI). As a result, HEU are the currency of offset budgeting and planning.

Once potential habitat losses have been quantified, an integration of fish habitat quality assessments (e.g., detailed habitat surveys and hydraulic modeling outputs) and fish population data (e.g., CPUE and/or fish densities) should be undertaken to determine the actual value of habitat losses since habitat quality may be highly variable. Habitats that are less valuable should therefore be rated as contributing less to fishery offset calculations. Once the number of HEUs for the affected habitats is known, the identification and budgeting of offsetting options can commence. The objective is to balance any losses to CRA fisheries productivity.

TMAC will work with DFO through the Fisheries Protection Program to determine the most suitable approach to estimating potential fisheries productivity losses during and after the NIRB review of the FEIS.

3.5 Identification of Offsetting Options

Identification of offsetting options is an iterative process requiring knowledge of local Inuit fisheries and community interests/priorities, fish distribution, fish population abundance, and habitat quality within the Madrid-Boston Project area. It requires a combination of stakeholder engagement/consultation, desktop analysis of available data, field-based assessment, and sound professional judgement.

Specifically, the following may be undertaken to support the identification of the most suitable fisheries offsetting options:

- Engagement with DFO and local Inuit such as the Kitikmeot Inuit Association (KIA) and TMAC's Inuit Environmental Advisory Committee;
- Identification of degraded areas (natural or anthropogenically induced) requiring rehabilitation and/or fish passage improvements through stakeholder engagement;
- Review of relevant and existing fisheries management plans (e.g., Arctic Char Integrated Fisheries Management Plan, IFMP) (DFO 2014) and/or identification of commercial/aboriginal (including subsistence) fisheries;
- Review of scientific literature on species-specific habitat limiting factors for valued fish species that occur in the Madrid-Boston Project area based upon peer-reviewed documents and professional knowledge;
- Identification of factors limiting fish productivity within and outside of Madrid-Boston Project area watersheds. For example, identification of species and life history stages present, identification of known key habitats (e.g., over-wintering and spawning areas), and identification of anthropogenic impacts within watersheds;
- Identification of other relevant projects with similar anticipated impacts and approved Fisheries Authorizations to provide example precedence for Madrid-Boston offsetting options; and
- Identification of potential options through remote satellite imagery analysis (e.g., Google Earth).

Once the identification of potential sites is finalized, field reconnaissance and ground-truthing of the preliminary offsetting options are conducted to further refine option list. Field reconnaissance also provides an opportunity to identify additional offsetting options not previously considered or identified. Offsetting options are typically visited and further evaluated to refine site objectives, assess value to fishery, site-specific constraints and opportunities, biological relevance, stability, permanence, target species, target habitat, and target life history stage. Assessment of site-specific constraints and opportunities include:

- connectivity to critical habitats (e.g., overwintering, spawning habitats);
- water supply magnitude and dependability;
- water and sediment quality;
- fluvial geomorphology (stability, flood risk, sediment supply, gradient); and
- construction considerations (access, construction costs, stability and durability of instream structures, and time to full functionality of site).

A qualitative feasibility assessment, based upon professional experience, will be conducted for each preliminary offsetting option. This assessment will be conducted by fisheries biologists and a water resources engineer to determine the technical feasibility of the options. Through an iterative process of elimination and refinement, a technically feasible offsetting option(s) will be identified. TMAC commits to working with DFO's Fisheries Protection Program and local Inuit groups to develop an Offsetting Plan, as deemed necessary by DFO.

3.6 Assessment of Offsetting Options

Additional data should be gathered to support the selected technically feasible offsetting options. Additional data may include biological, hydrological, and topographical data; however the specific data requirements will ultimately depend upon the offsetting option objectives and design. These data requirements will be determined by the fisheries biologist and water resources engineer, in consultation with regulatory agencies (e.g., DFO) and local Inuit groups.

At this exploratory stage, the following field data collection at offsetting stream and lake sites may be useful:

- FHAP or SHIM surveys of fish habitat quantity and quality in previously un-surveyed streams;
- Three-pass electrofishing surveys of fish number and density in previously un-surveyed streams; and
- Hydroacoustic estimates of fish population numbers in previously un-surveyed lakes accompanied by gillnetting to determine fish species composition.

Once sites are selected, depending on the type of project selected, the HEUs for each offsetting option may be calculated and compared to HEUs for the impacted streams and lakes. The ratio of offsetting HEUs to impacted HEUs should be at least 1.0 and may be higher based on the fisheries value of the impacted area as well as the fisheries value of the offsetting area. For example, high quality habitat may require additional offsetting area in order to balance potential losses to fisheries productivity. Alternatively, low quality habitat may be replaced with a smaller area of higher quality habitat.

4. PRELIMINARY OFFSETTING OPTIONS

In advance of measurable predicted effects associated with the Madrid-Boston Project, several options, commensurate with potential anticipated fisheries losses, have been identified that could offset potential serious harm to fisheries, as defined by the *Fisheries Act* (1985) and concluded by DFO, to demonstrate project feasibility during FEIS processes. Based on DFO's guidance to fisheries offsetting (DFO 2013a; Bradford et al. 2016), offsetting projects may be local (in-kind) or off-site (out-of-kind) in nature

Section 4.1 presents three preliminary offsetting options in the vicinity of the Hope Bay Project (local, in-kind), and Section 4.2 discusses the potential for off-site offsetting (out-of-kind), TMAC's preferred approach. Based on the effects assessment of the FEIS, impacts to fish habitats in streams and lakes may result from water withdrawal, from the construction of discharge pipeline and/or water intakes, and from the construction of road crossings (i.e., culverts) at fish-bearing streams.

4.1 Local (in-kind) Options: Project Vicinity Options

As described in Section 3, extensive fieldwork has been completed within the Project area that may help to identify potential offsetting options around the Hope Bay Project. As part of site selection initiatives, preliminary site assessments were completed at several stream and lake sites to determine their suitability as potential offsetting locations. Descriptions of the top three options are summarized below, which were presented during the November 2017 meeting with DFO (Appendix V5-6AB).

4.1.1 Option 1 – Enhance the Quality of Existing Juvenile Stream Rearing Habitats

Increasing the abundance of preferred habitats for rearing juveniles could increase the overall productivity of those streams. A fish sampling program completed in Doris, Roberts, and Little Roberts outflows in 2016 found that juvenile Arctic Char density was statistically higher in riffles and cascades when compared to glides, but glides were the predominant habitat type within those streams. Glides in those streams had a U-shaped cross-section (steep banks and a flat bottom) with little structural complexity, laminar flow, little cover for predator avoidance, and poor quality substrate for rearing salmonids (primarily fine sediments). Riffles and cascades had higher quality habitats for rearing because they were structurally complex, were well oxygenated, provided quality food sources, and provided refuge from predators.

To offset for potential reductions in productivity of stream habitats, more productive habitat types (i.e., riffles and cascades) could be constructed in less productive areas (poor quality glides). This would provide a greater quantity of productive habitats to juvenile fish. A key factor in this type of enhancement would be ensuring that fish passage is not impeded by the new habitat features, particularly in streams used by anadromous fish.

Potential sites for juvenile rearing enhancements were identified in Roberts Outflow, as well as in some other tributaries to Roberts Lake where this type of habitat enhancement could improve overall stream productivity. Suitable sites containing glide habitat that were sampled during fieldwork in 2016 could be sampled prior to enhancement to establish more robust baseline fish densities, and then sampled after enhancement to provide a measure of success.

4.1.2 Option 2 – Improve Access to the Upper Reaches of Stream E09

To partly compensate for the loss of fish and fish habitats in Tail Lake caused by the construction of the Tailings Impoundment Area (TIA), a No Net Loss Plan (NNLP; Golder 2007) proposed the construction of rearing habitat for juvenile Arctic Char in Stream E09, a tributary to Roberts Lake, by creating additional pool habitat. Two pools were constructed in 2012 approximately 350 m upstream from Roberts Lake.

Pre-enhancement sampling determined that most tributaries to Roberts Lake do not support juvenile Arctic Char due to low summer discharge and the presence of barriers to fish passage (Golder 2007). Stream E09 was identified as the best candidate for enhancement as it has adequate baseline flow throughout the summer and it is used by rearing juvenile Arctic Char in low abundance.

However, post-enhancement monitoring results indicated that the enhancement was of limited success. It appears that fish use of the newly created pools is limited by a steep section of creek (gradient of 8%) approximately 100 m in length, between the enhancement site and Roberts Lake, where the stream morphology is step-pool with several chutes. This steep section of creek limits upstream migration by juveniles and upstream habitats have very low fish densities.

An offsetting program that improved access for juveniles in Roberts Lake upstream into the low-gradient reach where the existing enhancement pools are located may increase utilization not only of these pools, but of the entire stream. This section of stream has low gradient (less than 3%), and it exhibits the Arctic "beaded stream" morphology, where a series of relatively deep, natural pools are separated by sections of narrow, shallow creek. By selectively moving boulders within the step-pool section of the creek, the largest drops would be reduced making access from Roberts Lake easier.

4.1.3 Option 3 – Increase the Abundance of Spawning and Juvenile-rearing Habitats in Lakes

Arctic aquatic ecosystems present a unique set of challenges to their inhabitants when compared to more southerly environs. Emergent juveniles must migrate from spawning beds to rearing habitats, and then make annual migrations between summer rearing habitats and overwintering locations. Throughout their juvenile life, these fish are exposed to predation pressure from species such as Lake Trout.

Juvenile Arctic Char in lakes such as Roberts Lake migrate in the spring from overwintering habitats in the lake to rearing habitats in inflows and the outflow. Large, piscivorous Lake Trout target these fish, congregating in locations where they are able to feed on them. On one occasion, a field crew observed 27 adult Lake Trout in Roberts Lake in the fall within a short distance of where Stream E14 enters the lake, presumably feeding on juveniles that had spent the summer rearing in the stream but had to re-enter the lake to seek overwintering habitats. There is high structural complexity within the creek where fish can use cover to avoid predation, but when re-entering the lake there is little structure, exposing them to awaiting predators.

Adding habitat features that provide cover for juveniles as they migrate between critical habitat areas (e.g., between summer rearing and overwintering habitats, or between spawning beds and rearing habitats) would help improve productivity by reducing predation pressure by Lake Trout. Habitat features, such as boulder clusters could be used in locations where juveniles are particularly exposed.

4.2 Off-site (out-of-kind) Offsetting Options

Off-site offsetting may be a suitable alternative where enhancements would be constructed in or around a community (e.g., Cambridge Bay) in Nunavut, rather than within the Hope Bay Project area. Cambridge Bay, located 153 km northeast of the Hope Bay Greenstone Belt, is the largest community in relatively close proximity. As indicated during the November 2017 meeting with DFO (refer to Appendix V5-6AB), TMAC is keen to investigate off-site options for offsetting potential Project-related effects related to the freshwater environment. Off-site, community-based offsetting can provide a broader range of benefits than just improvements to fisheries. These benefits include:

- potential to rehabilitate human-impacted sites such as improperly installed culverts or over-fished populations;
- Increased engagement with local community directly through employment and indirectly through increased activity in the community;
- Transfer of knowledge by training community members in enhancement and monitoring methods; and
- Potential to engage local educational institutions such as the Canadian High Arctic Research Station (CHARS), through Polar Knowledge Canada (POLAR) initiatives, and/ or other university-based research programs (e.g., Université Laval).

In addition to community consultations to identify options, biological, hydrological, topographical, and engineering investigations will be required to determine the technical feasibility of preliminary off-site offsetting options. The following biological data will eventually need to be collected to support the development of the Offsetting Plan:

- habitat assessment and mapping;
- fish passage assessments at potential restrictions; and
- fisheries community, demography, and abundance sampling (e.g., gillnetting, electrofishing, fish stranding enumeration) at potential sites.

Hydrological, topographical, and engineering data requirements are site-specific and will be determined during a field investigation.

Potential offsetting sites occurring in and around Cambridge Bay that have been considered thus far were presented to DFO and the KIA (Appendix V5-6AB). The focus has been placed on Arctic Char since the species was identified in the FEIS (Volume 5, Chapter 6 and 10) as both a marine and freshwater fish community VEC. Identified site options have the potential to ameliorate overall fisheries productivity. Brief descriptions are provided in sections below.

4.2.1 *Freshwater Creek*

Freshwater Creek is located near Cambridge Bay, NU, flowing a distance of 7 km from Greiner Lake, with its river mouth ending near the community of Cambridge Bay. Given its close proximity and therefore easily accessible location for community-based fishers, it is likely the primary subsistence river fishery for the inhabitants of Cambridge Bay.

Historically, Arctic Char were also targeted for commercial purposes in this river, albeit these efforts were relatively short (DFO 2004). The first commercial fisheries effort directed at Arctic Char began in Cambridge Bay at Freshwater Creek in 1960. Within two years, due to evidence of a declining fish stock, the commercial fishery was relocated to the mouth of Ekalluktok (Ekalluk) River (Ferguson Lake is headwater lake), where it empties into Wellington Bay. Over time, the Arctic Char commercial fishery has expanded to include numerous rivers (e.g., Paliryuak, Jayko, Halokvik, Palik), with the commercial aspects all being managed now through the Arctic Char IFMP (DFO 2014). Arctic Char harvesting in Freshwater Creek likely continues to be the most important subsistence fishery for Cambridge Bay community fishers. Given the importance of this fishery, the consideration for the implementation of an offsetting project in the Greiner Watershed makes this a feasible option to pursue. Some examples are briefly discussed below.

The removal of anthropogenic and/or natural barriers to fish migration is a viable approach to fisheries offsetting, and is supported by DFO's Fisheries Protection Policy (DFO 2013a). The result is a net benefit in fisheries productivity upstream by creating/improving access to fish habitat which serves to increase fisheries productivity. The re-establishment of migratory populations upstream of such barriers may also result following removal, further increasing fisheries productivity. Precedence exists for the approval of fish passage improvements through barrier removals in the arctic as part of *Fisheries Authorizations* projects completed locally (e.g., Roberts Lake Outflow) or those proposed for off-site offsetting (e.g., Nulahugyuk Creek system at Bernard Harbour).

A poorly-constructed culvert (UTM coordinates, Zone 13N: 503818E, 7672034N) along the road leading to Ovayok Territorial Park, approximately 10 km from Cambridge Bay, has been identified as a potential barrier to fish passage, preventing access for anadromous Arctic Char (and other salmonids) migrating between freshwater overwintering and marine feeding habitats. Other areas that may require additional consideration include a lower section of Freshwater Creek that is known for fording (DFO 2004), which may have led to habitat degradation over time if the practice is still ongoing, or any other natural areas where passage may be compromised with decreasing water levels over time (e.g., bridge crossing in Cambridge Bay leading to cemetery).

In the headwaters of Freshwater Creek, POLAR has installed a camp along the northern shoreline of Greiner Lake with the purpose of undertaking various research activities in the Greiner Lake Watershed, including, though not exclusively, freshwater lake surveys, installation of weather station, and arthropod monitoring, with the intent to evaluate long-term trends in changes in the Arctic. As discussed by TMAC during the November 2017 meeting with DFO (Appendix V5-6AB), the number of potential barriers within this watershed are not being quantified as part of the current POLAR activities. Obtaining a better understanding of such potential effects would be relevant for the monitoring of long-term environmental changes in the watershed. Char are known to move 40 – 50 km inland in this system, thus there are likely areas during low flows where connectivity may be poor and the number of these barriers (and severity) may vary over the long-term, particularly with changing climate conditions. Quantifying these barriers would add to the long-term dataset being developed by POLAR. Collaboration with other research programs may thus enhance the value of a proposed offsetting program occurring in the Greiner Watershed.

4.2.2 Other Rivers

The engagement of various stakeholders may help to identify other sites that may benefit from rehabilitation and/or fish passage improvements. Based on discussions between KIA and TMAC following a meeting in November 2017 with attendance by KIA (see Appendix V5-6AB for further information) and prior conversations, the KIA has indicated that they may undertake a compilation of potentially degraded sites requiring rehabilitation across the Kitikmeot region that could be suitable for fisheries offsetting. These sites will be reviewed if results of this compilation are made available.

Non-formal preliminary discussions with people local to Cambridge Bay and/or arctic-based researchers working in Nunavut coupled with desktop-based assessments indicate that numerous sites may be suitable for consideration for fisheries offsetting. During TMAC's meeting with DFO (Appendix V5-6AB), such a site, Kitiga Falls, along the Kitiga River (17.3 km), located approximately 50 km northwest of Cambridge Bay, was identified. It is possible that these falls pose a partial barrier to fish migration during low flows, which consequently may reduce access to upstream habitats, reducing overall fisheries productivity upstream of the falls.

Other low-flow barriers may also exist. Through the engagement of various stakeholders, it is TMAC's intention to identify potential sites that may benefit from fisheries offsetting. TMAC commits to working with DFO and local Inuit groups to further these investigations.

4.3 Local (in-kind) versus Off-site (out-of-kind) Offsetting

There are numerous considerations for the selection of a feasible and appropriate offsetting program. Table 4.3-1 summarizes some key advantages and challenges/disadvantages to pursuing local versus off-site offsetting options. Based on these considerations, among other factors, TMAC's preference at this stage is to consider a Cambridge Bay-based project contributing to the overall objectives of the commercial Arctic Char fishery through the Artic Char IFMP and/or to a subsistence fishery (e.g., Freshwater Creek; Appendix V5-6AB).

Table 4.3-1. Advantages and Challenges/Disadvantages of Local (in-kind) versus Off-site (out-of-kind) Offsetting

Advantages	Challenges/Disadvantages
Local	
Direct return of fisheries enhancement to impacted area = local balance of project-related effects	Limited return to active users due to distance from active subsistence/commercial fishery
Availability of baseline datasets and other site-based ongoing monitoring programs	Limited community engagement and localized capacity building
On-site program oversight	Limited potential for project-ownership transfer to communities following implementation
	Site access to construction works and ongoing monitoring may be challenging (i.e., accessible only via helicopter).
	Additional consideration regarding fisheries monitoring pressure
Off-site	
Proximity to local subsistence/commercial fishery: • direct return to active users • potential for project-ownership transfer to local community	Direct return of fisheries productivity enhancement outside of impacted area = decrease in local fisheries productivity
Ongoing community engagement and localized capacity building – training opportunities	Potential limitations of availability or quality of baseline datasets
Responds to concerns/needs identified by local community	Off-site program oversight
Potential for project-ownership transfer to local community following implementation and suitable training	Additional consideration regarding local fishing pressure
Potential for collaboration with existing research programs (e.g., Polar Knowledge Canada)	
Site accessibility via boat or road access	

5. SUMMARY

A fisheries offsetting plan, if deemed necessary by DFO, will be developed to identify and compensate for potential serious harm in accordance with the *Fisheries Act*, the *Fisheries Protection Policy Statement* and *the Fisheries Productivity Investment Policy: A Proponent's Guide to Offsetting*. TMAC's preference at this stage is to consider a Cambridge Bay-based project contribution to the overall objectives of the commercial Arctic Char fishery through the IFMP and/or to a subsistence fishery (e.g., Freshwater Creek). The approach to offsetting will include quantification of habitat and productivity losses, identification of offset habitats and a quantification of habitat and productivity gains relative to losses.

This process will involve engagement with DFO's Fisheries Protection Program and local Inuit groups to align offsetting goals with local and regional sustainability objectives as required for the Madrid-Boston Project. TMAC will therefore continue to work with DFO during the NIRB process, and post project approvals (and pre-construction) to address necessary steps towards any required Fisheries Authorization.

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