Memorandum

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Date: December 23, 2016

To: Sharleen Hamm, Oliver Curran, and John Roberts, TMAC Resources Inc.

From: Fraser Ross

Cc: Erin Forster, Marc Wen

Subject: **Doris, Roberts, and Little Roberts Outflows Fisheries Assessment**

1. INTRODUCTION

TMAC Resources Inc.'s (TMAC) application for amendment to the Project Certificate (Nunavut Impact Review Board No. 003) and the Type A Water Licence (Nunavut Water Board No. 2AM-DOH1323) predicted that mine-related drawdown caused by infiltration into underground workings while mining in a talik zone beneath Doris Lake and surface water withdrawal may reduce water levels in Doris Lake and alter flow patterns in downstream creeks (Doris and Little Roberts outflows; ERM 2015b). ERM Consultants Canada Ltd. (ERM) was retained by TMAC to collect baseline data that would establish whether the predicted effects will require offsetting under the *Fisheries Act* (1985). According to the *Fisheries Protection Policy Statement* (DFO 2013a), if a project is likely to cause *serious harm to fish* as defined by the *Fisheries Act* (1985) 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 are required to be implemented with the goal of maintaining or improving the productivity of commercial, recreational, or Aboriginal fisheries (DFO 2013b).

To predict the effect of mine-related drawdown, ERM sampled fisheries in Doris Lake and completed hydraulic modelling of Doris and Little Roberts outflows in 2015 (ERM 2015a, 2016). This memo presents the results of the 2016 field program which involved sampling fisheries in Doris, Roberts, and Little Roberts outflows. Because Roberts Outflow is upstream of anticipated project-related effects, sampling was completed in this section of stream to provide reference data.

Data presented in this memo are the final components required to predict effects to fisheries. Following the submission of this memorandum, data from the three sampling programs will be combined and the extent of the effect will be predicted during the preparation of a Request for Review that will be submitted to Fisheries and Oceans Canada (DFO) in advance of the anticipated effect.

2. OBJECTIVES

The objective of the 2016 Doris, Roberts, and Little Roberts Outflows Fisheries Assessment was to sample the distribution of fish habitats and fish communities in these streams. The following tasks were prescribed to meet the overall objective of the program:

1. Conduct a fish habitat assessment by mapping habitats along the length of the streams; and
2. Conduct a fish population assessment by estimating fish population densities in stream habitats.

3. METHODS

Fish communities and fish habitats were sampled in three stream sections in 2016; Doris Outflow, Roberts Outflow, and Little Roberts Outflow (Figure 3-1). Doris Outflow discharges from Doris Lake and flows north for approximately 3.4 km where it enters Little Roberts Lake. Roberts Outflow discharges from Roberts Lake to the west into Little Roberts Lake. Since Roberts Outflow is upstream of anticipated project-related effects, sampling was completed in this section of stream to provide reference data. The Doris and Roberts subwatersheds combine in Little Roberts Lake and discharge from that lake to the ocean via Little Roberts Outflow (Figure 3-1).

3.1 Fish Habitat Assessment

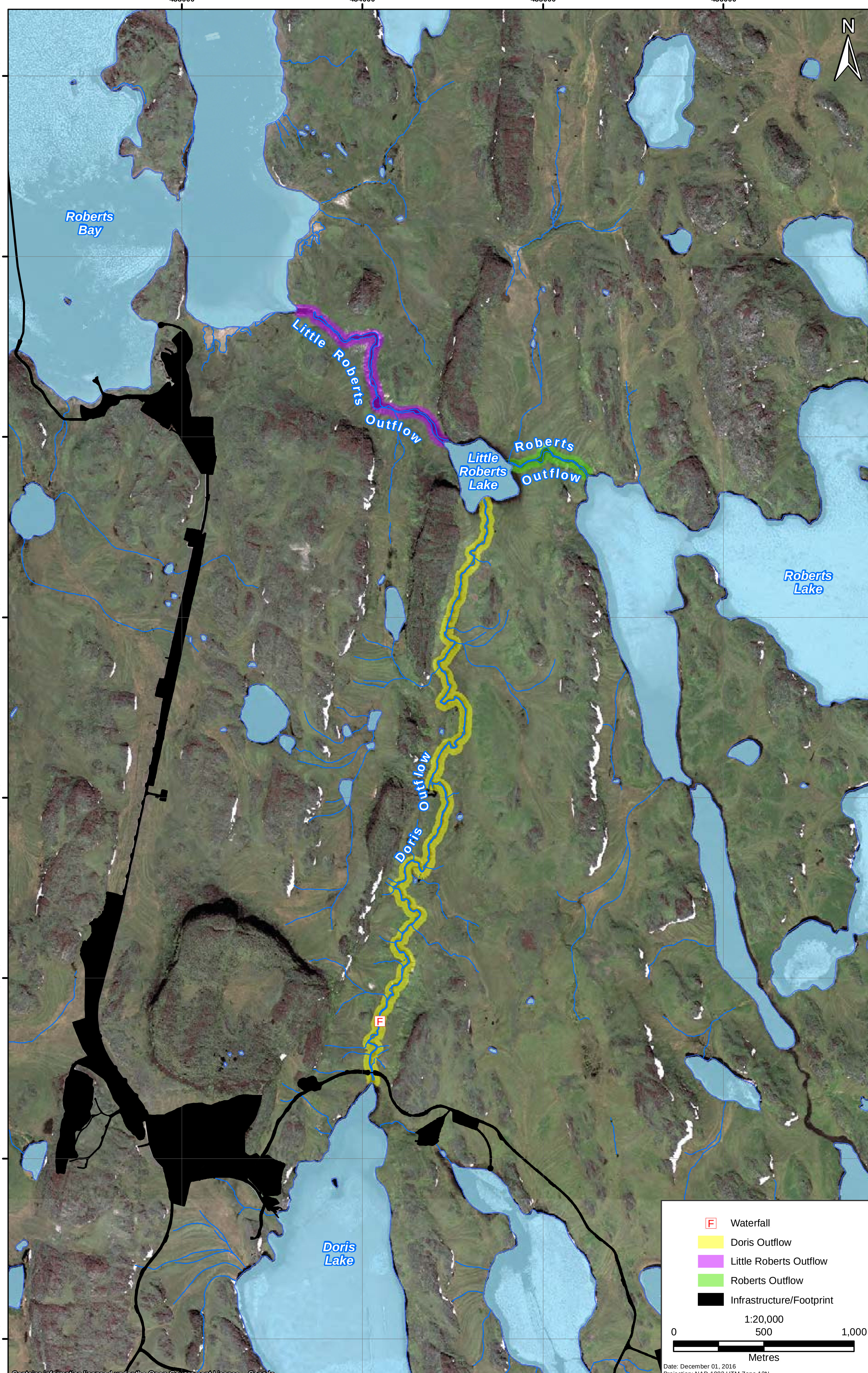
Fish habitats in Doris, Roberts, and Little Roberts outflows were mapped to identify changes in stream structure and morphology that would be likely to affect fish presence and distribution. Stream fish populations are often clustered in their distribution, resulting from numerous influences including biotic interactions and habitat variability (Newman 1989; Kruse, Hubert, and Rahel 1997).

Habitat classifications and data collection methods followed Fish Habitat Assessment Procedures (FHAP; Johnston and Slaney 1996). Habitats units were classified as:

- Cascade: high-energy, steep (gradient > 4%) sections of stream typically dominated by bedrock, boulders, and cobbles;
- Riffle: less steep than cascades, but still with turbulent, fast-flowing water. Riffles are usually shallow in water depth with gravel or cobble substrates that project above the water surface, causing surface turbulence;
- Glide: sections of stream with flowing, non-turbulent water. Glides have relatively flat bottoms in cross-section; or
- Pool: relatively deep, slow flowing sections of stream with a concave longitudinal streambed profile and a surface gradient near 0%.

To map fish habitats, boundaries between habitat units were visually assessed, habitat type was classified, and coordinates were collected at the upstream and downstream boundaries of each

Figure 3-1
Doris, Roberts, and Little Roberts Outflows, Doris Project, 2016



habitat unit using a handheld GPS (Garmin® GPSmap 60Cx). Maps were plotted using ArcGIS® for projection NAD 1983 UTM Zone 13N.

Habitat units were then described with measurements of stream widths (n=3 each for wetted and bank-full widths), depths (n=3 each for wetted and bank-full depths), and streambed substrate was characterized (% abundance of bedrock, boulders, cobble, gravel, and fine; see Johnston and Slaney 1996 for details). Where stream width exceeded measuring tape length, a Bushnell 4x20 laser rangefinder was used. A series of digital photos and habitat notes were also collected to document other characteristics that might further describe each habitat unit (e.g., riparian vegetation, slope, turbidity, amount and type of cover; Appendix 2).

3.2 Fish Population Assessment

Fish sampling was completed in Doris, Roberts, and Little Roberts outflows to determine species distributions and population densities in habitat types throughout each stream section. Streams in this region freeze to the substrate during winter, at which time fish must inhabit lakes to survive. Juvenile fish emigrate from lakes to rearing habitats in streams during spring freshet, and then migrate back to overwintering lakes in the fall prior to freeze-up. Sampling was completed August 21 to 29, 2016 because this is after spring-outmigration and prior to fall migration back to lakes. It is expected that stream utilization by juveniles would be greatest at this time of year.

3.2.1 Site Selection

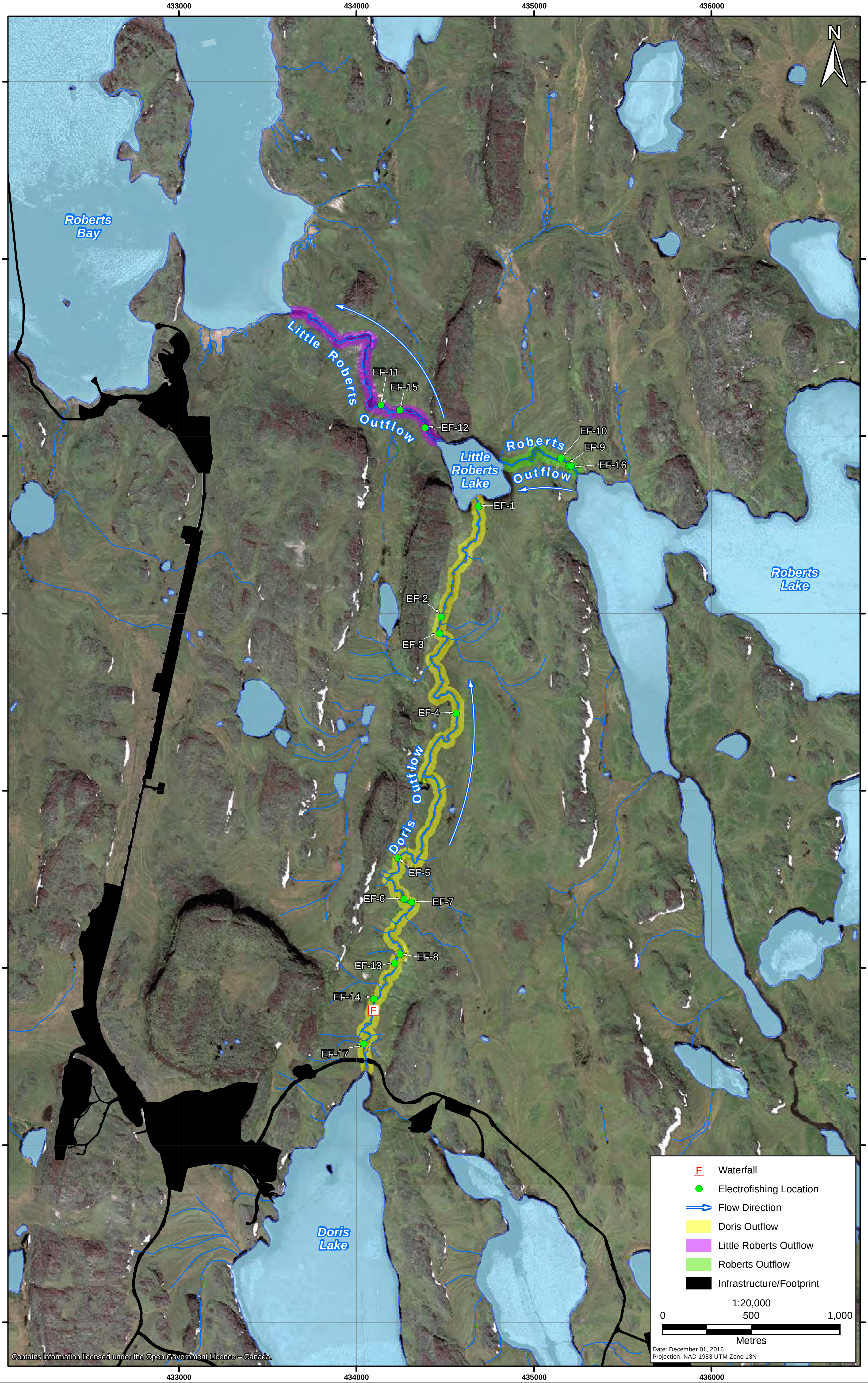
Fish sampling was distributed among 17 sites, including 11 sites in Doris Outflow, three in Little Roberts Outflow, and three in Roberts Outflow in a range of habitat types identified during the habitat assessment (Section 3.1; Figure 3.2-1). Sampling effort was focused in Doris Outflow as the amendment application predicted that that effect would be greatest in this section of stream. Sample sites were selected in locations that were 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 wading depth). Site UTMs were recorded using a handheld GPS and wood stakes were installed at the upstream and downstream ends of each site so sampling can be repeated in the future, if required.

Sample sites were digitally photographed and the surface area was calculated by measuring dimensions using a metered tape along two lengths (left and right banks) and three widths (top, middle, and bottom). Three depth measurements were collected (left, mid, and right bank of channel) using a metered stick across each width transect. Streambed substrate was classified for the site as described in Section 3.1.

3.2.2 Fish Collection

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.

Figure 3.2-1
Fish Community Sample Sites on Doris, Roberts, and Little Roberts Outflows, Doris Project, 2016



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. Electrofishing passes were performed by two crew members. A minimum of two passes were completed at all sites using a Smith-Root LR-24 backpack electrofisher. To estimate the population, an adequate number of fish must be removed so there is a decline towards zero in each subsequent pass. A third pass was done when the number of salmonid fishes caught in the second pass was greater than one third the number caught during the first pass.

The number of fish of each species caught in each pass and the electrofishing effort (seconds) were recorded in addition to electrofisher settings including voltage, frequency, pulse width, and duty cycle.

According to Lockwood and Schneider (2000), depletion estimates require that a series of conditions of sampling be met. These conditions are presented below, as well as a description of how the conditions were satisfied by the Field Program:

1. Immigration and emigration must be prevented.

   Sites were isolated using 5 mm diameter mesh stop nets at upstream and downstream ends of each site. Nets were supported using metal tripods and the bottom of the net was held in place with boulders. Nets were checked between passes to ensure the site remained isolated.

2. All fish must be equally vulnerable to capture during each pass.

   The vulnerability to capture varies by species, and even among different life stages of fish of the same species (e.g., juveniles compared to adults; Lockwood and Schneider 2000). Since this inequality cannot be avoided when sampling, fish were partitioned into groups by species and life stage of equal catch vulnerability for data analysis.

3. Vulnerability to capture must remain constant among passes.

   Between each pass, the site was left for a minimum of 30 minutes to allow fish to recover and return to normal behaviour. The purpose of this break was to ensure that fish were equally likely to be caught in each pass. The equality of the likelihood of capture among passes was assessed *a posteriori* by comparing each catch against the sum of the catch from previous passes.

4. Collection effort must remain constant among passes.

   The level of effort (electrofishing seconds) was approximately the same for each pass at a site (Appendix 3). In addition, the route fished and distribution of effort within the site was consistent among passes. A pass was initiated at the downstream net and consisted of a thorough search in an upstream direction, followed by a systematic sweep towards the downstream net.

5. Sampling conditions must remain constant among passes.

The crew observed conditions within the site immediately prior to each pass to confirm that conditions (e.g., turbidity, discharge) had not changed to a degree that might affect fish capture rates.

3.2.3 *Fish Processing*

All captured fish were identified to species and enumerated. Salmonid fishes were assigned a unique identification number, fork length and weight were recorded, and an ageing structure was removed and preserved for future analysis (see Section 3.2.4). Fish were also assessed for presence of previous marking (i.e., tags or fin clips) and released alive in the same location where they were captured after all sampling was complete at that site.

3.2.4 *Age Determination*

All fin rays and scales were aged by North South Consultants (Winnipeg, Manitoba). Dried fin rays were embedded in epoxy covering the proximal joint and base of the ray. The rays were then cut into thin cross sections (0.5 mm) at approximately a 90° angle nearest to the base of the ray using a Buehler low speed Isomet® saw with a diamond wafering blade. Care was taken to assure that the first thin section encompassed or was slightly posterior to the inflection point of the ray (Beamish 1981). Wafer sections were polished using fine wet-dry sandpaper, and then affixed to a slide in sequential order using thermoplastic glue (Koch and Quist 2007).

Fin ray age was estimated by viewing the cross section with a dissecting scope using transmitted light. A fin ray annulus was defined as the clear opaque zone or ring between the darker areas on the fin ray, which represent periods of growth (DeVries and Frie 1996). Annuli were only counted if bands were continuous around a majority of the fin ray (Shirvell 1981).

Scales were mounted on standard glass microscope slides and viewed under 47 x magnifications using a microfiche reader. Regions of closely spaced circuli on the scale were identified as annuli (i.e., winter growth ‘checks’).

3.2.5 *Data Analysis*

Fish were partitioned into groups by species and life stage to ensure equal vulnerability of capture among cohorts within each group. The following definitions of life stage were used for salmonids:

- ***Fry***. The free-swimming stage that emerges from spawning beds in spring and rears throughout the first summer before migrating to overwintering habitat in fall. For this analysis, the upper size limit for salmonids categorized as fry was 50 mm fork length because salmonids residing in the Arctic are usually less than this length at the end of their first summer. A fry is referred to as such until after its first winter of lake residence, at which time it becomes a juvenile;
- ***Juvenile***. A sexually immature fish that is at least one year old. Juveniles spend winters in lakes, and some make excursions into streams during the spring and summer to rear. This life stage ends when fish reach sexual maturity;

- ***Adult***. The sexually mature life stage. For Arctic salmonids, size at first maturity varies among species and life history (e.g., anadromous versus resident fish), but generally these fish exceed 250 mm in length; and
- ***Spawner***. Adults that are preparing to, or are in the process of spawning. Only a subset of the adults in the population may have sufficient energy reserves to ripen in any year, hence all spawners are adults, but not all adults are spawners.

The size at which Arctic Char mature is varied, but it is typically larger for anadromous fish when compared to their landlocked counterparts (Scott and Crossman 1973; Johnson 1980). In the Roberts Lake watershed, Arctic Char smolts are typically greater than 250 mm in length when they depart on their first ocean migration prior to maturation (Golder 2008; Swanson et al. 2010). Given the size range of captured Arctic Char (102 mm to 230 mm), all fish were classified as juveniles for data analysis. Because the Ninespine Stickleback mostly matures during its first summer and typically live less than four years, all fish of this species were placed in a single group for data analysis. 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.

Population density estimates were calculated using a Bayesian/Maximum Weighted Likelihood method as described in Carle and Strub (1978) and Lockwood and Schneider (2000):

$$T = \sum_{i=1}^{k} C_i,$$

$$X = \sum_{i=1}^{k} (k - i) C_i,$$

where:

i = pass number,
k = number of passes,
C_i = catch in i^{th} sample,
X = an intermediate statistic,
T = total catch in all passes.

The maximum likelihood estimate of the population (N) was determined using an iterative process by substituting values for n until:

$$\left[\frac{n+1}{n-T+1}\right] \prod_{i=1}^{k} \left[\frac{kn - X - T + 1 + (k-i)}{kn - X + 2 + (k-i)}\right] \leq 1.0,$$

where n is the smallest integer satisfying the above equation. Since this method necessitates the use of integers, the model was applied to each pass assuming equal fishing effort. Probability of capture (p) was estimated by the following equation:

$$p = \frac{T}{kN = X},$$

and the variance and standard error of N were estimated as:

$$\text{Variance of } N = \frac{N(N-T)T}{T^2 - N(N-T)\left[\frac{(kp)^2}{(1-p)}\right]}$$

$$\text{Standard error of } N = \sqrt{\text{Variance of } N}.$$

The equality of p among passes must be verified to ensure that $p_1 = p_2 = p_3 = \ldots p_k = p$. This was done by plotting each catch against the sum of all previous passes then visually assessing the trend line to confirm that the decline was linear.

Density of fish (partitioned by species and life stage; fish/m^2) was calculated by dividing N by the surface area (calculated from site measurements described in Section 3.2.1) of the electrofished section. This is the conventional measure of stream fish density because electrofishing samples the entire depth of a stream, hence it automatically integrates population abundance over the depth of the water column.

Differences in fish densities were tested among habitat types (attributed during the habitat assessment described in Section 3.1) using one factor analysis of variance (ANOVA) when the assumptions of the parametric test were met. Error variance for richness (an integer variable) was modelled using a Poisson distribution using a generalized linear model. If ANOVA tests revealed significant differences among groups, pairwise multiple comparisons were performed using the False Discovery Rate test to determine which pairs of habitat types differed significantly (Benjamini and Hochberg 1995).

Where appropriate, the underlying parametric assumptions of ANOVA were examined (i.e., normal distribution and homogeneity of variance among groups) using box and whisker plots and standardized residual plots. In cases where data did not meet these assumptions, appropriate data transformations were used to achieve near normality and equality of variances. In cases where the transformed data did not yield similar variances among groups or approximately normal distributions within groups, the non-parametric Kruskal-Wallis test was used in place of ANOVA. If Kruskal-Wallis tests revealed significant differences among groups, non-parametric pairwise multiple comparisons were performed using the procedure outlined by Siegel and Castellan (1988). For all statistical analyses, significance (p-value) was accepted at $\alpha = 0.05$.

The analysis was performed in R version 3.1.3 (R Core Team 2016) using the package 'FSA' (Ogle 2016).

3.3 Quality Assurance and Control

Quality assurance and quality control were implemented throughout the field program to ensure accurate data collection and analysis. All data were reviewed at the end of each field day to ensure that sampling was complete and that the data were collected properly.

During data entry, field notes were transcribed onto electronic spreadsheets then all records were independently checked for accuracy against the field forms. Population estimate models were run twice and the two sets of results were cross-referenced for accuracy. Statistical methodology, data analyses, and results were reviewed by a senior registered professional biologist.

4. RESULTS AND DISCUSSION

4.1 Fish Habitat Assessment

A total of 51 habitat units were identified; 35 in Doris Outflow, nine in Little Roberts Outflow, and seven in Roberts Outflow (Figure 4.1-1; Table 4.1-1). Glides were the most common habitat type both in number of units and by stream length. For Doris, Roberts, and Little Roberts outflows combined, glides accounted for 75% of the total stream length. Glides were particularly common in Doris Outflow, occupying 83% of the stream length.

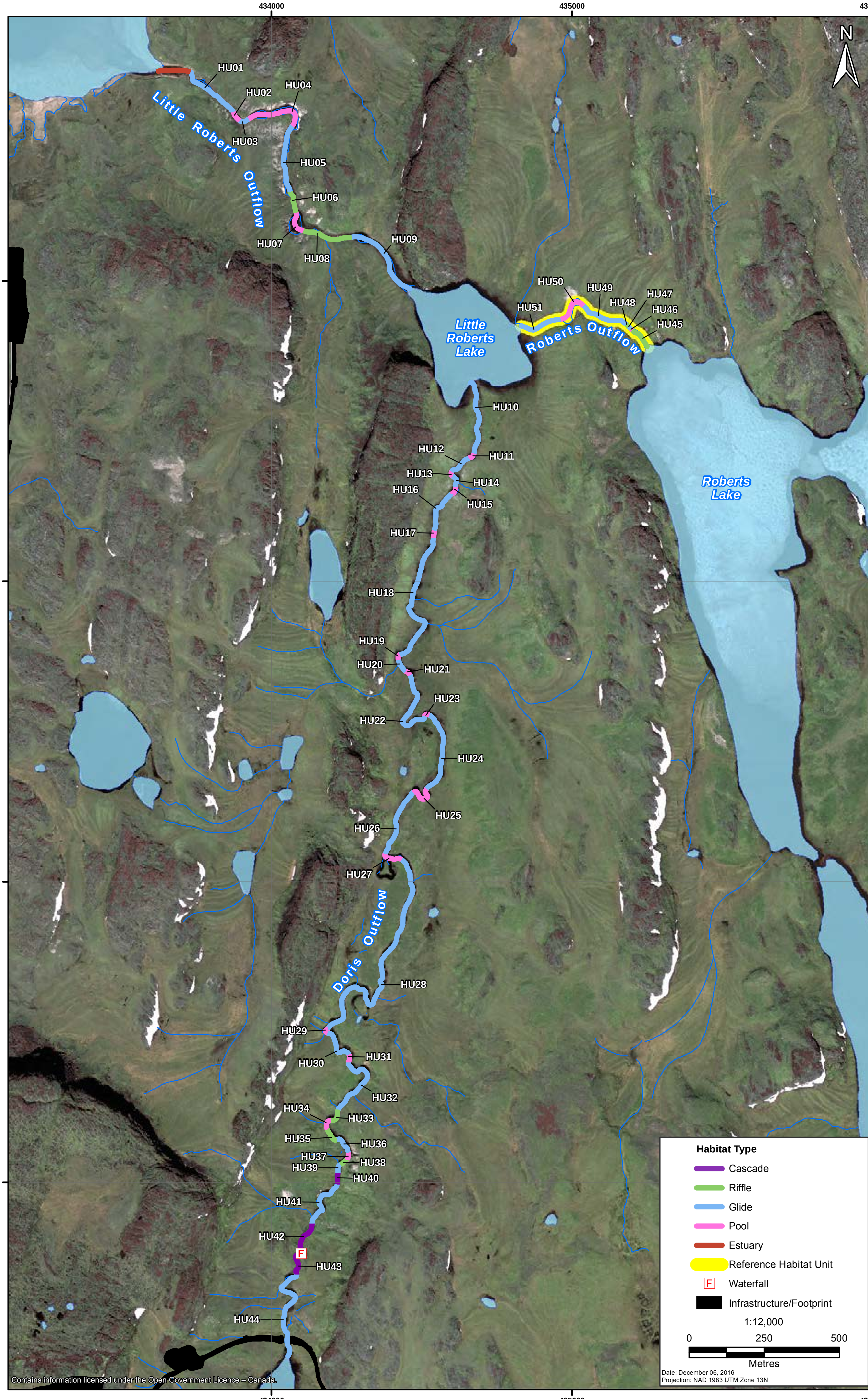
Cascades were recorded only in the upper reaches of Doris Outflow, just upstream and downstream of the impassable waterfall (Figure 4.1-1; Table 4.1-1). In FHAP, cascades are differentiated from riffles by having a gradient in excess of 4%. The gradients of the cascades in Doris Outflow just exceeded this threshold whereas the gradients of many riffles, such as the boulder garden at the outflow of Roberts Lake, were just below the threshold. Given the overall similarity in morphology among many of these sites, slight differences in gradient are not likely to change the functionality of the habitat for fish.

Table 4.1-1. Habitat Types in Doris, Roberts, and Little Roberts Outflow, Doris Project, 2016

Stream	Habitat Type	No. of Units	Combined Stream Length (m)	Percent Composition (%)
Doris Outflow	Cascade	3	235	5
	Riffle	2	103	2
	Glide	17	3,691	83
	Pool	13	440	10
Roberts Outflow	Riffle	2	88	17
	Glide	4	318	61
	Pool	3	119	23
Little Roberts Outflow	Riffle	2	243	19
	Glide	3	747	57
	Pool	2	320	24

Glide habitat units have 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 are higher quality habitats for rearing because they are structurally complex, well oxygenated, provide quality food sources, and provide refuge from predators.

Figure 4.1-1
Habitat Units in Doris, Roberts, and Little Roberts Outflows, Doris Project, 2016



4.2 Fish Population Assessment

In total, 11 electrofishing sites were sampled in Doris Outflow, three in Little Roberts Outflow, and three in Roberts Outflow (Figure 3.2-1). A total of 150 fish were captured (Table 4.2-1). Overall, Ninespine Sticklebacks (*Pungitius pungitius*) were the dominant species captured, making up 73% of the catch, followed by Arctic Char (*Salvelinus alpinus;* 21%). Cisco (*Coregonus sp*.) and Lake Trout (*Salvelinus namaycush*) both comprised 3% of the catch.

Total catch and biological characteristics of fish sampled in electrofishing surveys are presented in Appendices 3 and 4, respectively.

4.2.1 Arctic Char

A total of 32 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. 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 (Kruskal-Wallis, H (test statistic) = 8.78, $P = 0.012$; Table 4.2-2). Juvenile Arctic Char were captured at five out of six sites in riffles and cascades, whereas at sites within glides they were captured at two out of 11 sites (Figure 4.2-1). This is consistent with observations made during the habitat assessment (Section 4.1), which indicated that habitat quality for rearing juvenile salmonids was low in glides and high in riffles and cascades.

Roberts Outflow is utilized by rearing juvenile Arctic Char to a greater extent than Doris and Little Roberts outflows. The density of juvenile Arctic Char was greatest by an order of magnitude in Roberts Outflow (0.12 fish/m^2) compared to Little Roberts Outflow (0.01 fish/m^2) and Doris Outflow (0.01 fish/m^2). The individual sites with the highest densities of juvenile Arctic Char were also both in Roberts Outflow (EF-09 and EF-16 had 0.25 fish/m^2 and 0.18 fish/m^2, respectively; Table 4.2-2). Given its proximity to overwintering habitats in Roberts Lake (the only overwintering habitat available to anadromous fish in the watershed), observing a relatively high density of fish in Roberts Outflow was expected.

The site with the third highest density of juvenile Arctic Char (EF-14; 0.10 fish/m^2; Table 4.2-2) was the site located the farthest from overwintering habitat. 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 kilometers 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.

Table 4.2-1. Effort and Catch from Multiple-Pass Electrofishing Surveys in Doris, Roberts, and Little Roberts Outflow, Doris Project, 2016

Stream	Sampling Date	No .of Sites	No. of Passes/Site	Total Effort (sec)	Mean Effort (sec/pass)	Juvenile Arctic Char	Ninespine Stickleback	Lake Trout	Cisco	Total
Doris Outflow	21 to 29-Aug	11	2 to 3	10,400	400	9	69	3	0	81
Roberts Outflow	24 to 25-Aug	3	2 to 3	2,712	387	20	38	1	1	60
Little Roberts Outflow	24 to 25-Aug	3	2 to 3	2,481	354	3	3	0	3	9
Total	**21 to 29-Aug**	**17**	**2 to 3**	**15,593**	**390**	**32**	**110**	**4**	**4**	**150**

Figure 4.2-1
Arctic Char Densities in Doris, Roberts, and Little Roberts Outflow, Doris Project, 2016

Table 4.2-2. Number and Density of Juvenile Arctic Char from Electrofishing Surveys, Doris Project, 2016

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
Roberts Outflow	24-Aug	EF-9	Riffle	3	1,314	12	12	11	13	48.4	0.25
	24-Aug	EF-10	Glide	2	624	0	0	-	-	83.6	0.00
	25-Aug	EF-16	Riffle	2	774	8	8	8	8	44.1	0.18

4.2.2 *Ninespine Stickleback*

A total of 110 Ninespine Stickleback were captured (Table 4.2-1). There were no significant differences in the density of Ninespine Sticklebacks among habitat types (Kruskal-Wallis, H = 1.722, P = 0.423; Table 4.2-3), indicating that this species is able to occupy a broad range of habitat types.

4.2.3 *Lake Trout*

In total, four Lake Trout were captured; one in Roberts Outflow and three in Doris Outflow (Table 4.2-1). The Lake Trout in Doris Outflow were captured in cascades just downstream of the waterfall (Site EF-13 and EF-14). These were the three largest fish captured of any species at all sites (625 mm, 396 mm, and 320 mm fork length; Appendix 4).

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). The absence of Lake Trout less than 300 mm fork length in Doris Outflow indicates that juveniles feeding on invertebrates rear elsewhere. The presence of three larger fish captured in 11 sample sites indicates that piscivorous Lake Trout make limited use of Doris Outflow.

4.2.4 *Cisco*

Three Cisco were captured in Little Roberts Outflow and one in Roberts Outflow (Table 4.2-1). All were juveniles captured in riffle habitat.

5. SUMMARY

TMAC's application for amendment to the Project Certificate and the Type A Water Licence predicted that mine-related drawdown may reduce water levels in Doris Lake and alter flow patterns in downstream creeks (Doris and Little Roberts outflows; ERM 2015b).

To predict the effect of mine-related drawdown, ERM sampled fisheries in Doris Lake and completed hydraulic modelling of Doris and Little Roberts outflows in 2015 (ERM 2015a, 2016). This memo presents the results of the 2016 field program which involved sampling fisheries in Doris, Roberts, and Little Roberts outflows. Data presented in this memo is the final component required to predict the effect to fisheries.

The habitat assessment of Doris, Roberts, and Little Roberts outflows found that glides were the predominant habitat type, accounting for 75% of the total stream length, but that the glide habitat was of poor quality for rearing juvenile salmonids. Glides were particularly common in Doris Outflow, occupying 83% of the stream length.

Overall, catch rates of fish in streams were low, particularly for salmonids. Juvenile Arctic Char showed a preference for riffles and cascades when compared to glides, even when they were located farther from overwintering habitat.

Table 4.2-3. Number and Density of Ninespine Stickleback from Electrofishing Surveys, Doris Project, 2016

Stream	Sampling Date	Site	Habitat Type	No. of Passes	Total Fishing Effort (sec)	Total No. of Ninespine Stickleback	Estimated No. of Ninespine Stickleback	Lower Confidence Limit	Upper Confidence Limit	Survey Area (m^2)	Estimated Density of Ninespine Stickleback (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
Roberts Outflow	24-Aug	EF-9	Riffle	3	1,314	8	8	6	10	48.4	0.17
	24-Aug	EF-10	Glide	2	624	0	0	-	-	83.6	0.00
	25-Aug	EF-16	Riffle	2	774	6	6	5	7	44.1	0.14

Following the submission of this memorandum, data from the 2015 and 2016 sampling programs will be combined and the extent of the effect will be predicted during the preparation of a Request for Review that will be submitted to DFO in advance of the anticipated effect.

An offsetting program that increases the abundance of riffle or cascade habitats in areas currently occupied by glides may increase stream productivity. Juvenile Arctic Char were primarily captured in riffles and cascades, but these habitat types are relatively scarce, particularly in Doris Outflow.

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— Appendix 1 —

Glossary and Abbreviations

GLOSSARY AND ABBREVIATIONS

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

ANOVA	Analysis of variance
DFO	Fisheries and Oceans Canada
ERM	ERM Consultants Canada Ltd.
FHAP	Fish Habitat Assessment Procedures
the Project Certificate	NIRB Project Certificate No. 003
TMAC	TMAC Resources Inc.
the Type A Water Licence	NWB Type A Water Licence No. 2AM-DOH1323

— Appendix 2 —

Fish Habitat Assessments of Habitat Units in Doris, Roberts, and Little Roberts Outflows, Doris Project, 2016

Appendix 2. Fish Habitat Assessments of Habitat Units in Doris, Roberts, and Little Roberts Outflows, Doris Project, 2016

					Depth		Width		Bed Material				
Outflow	Date	Site	Habitat Type	Length (m)	Mean (m)	Bankfull (m)	Mean (m)	Bankfull (m)	Bedrock (%)	Boulder (%)	Cobble (%)	Gravel (%)	Fines (%)
Little Roberts	19-Aug-16	HU01	Glide	204.7	0.70	0.71	10.48	11.24	5	40	25	15	15
Little Roberts	19-Aug-16	HU02	Pool	35.3	1.00	1.00	12.90	12.90	0	5	15	50	30
Little Roberts	19-Aug-16	HU03	Glide	32.5	0.90	0.90	9.77	9.77	0	20	40	25	15
Little Roberts	19-Aug-16	HU04	Pool	206.7	> 2	> 2	19.00	19.93	0	5	0	0	95
Little Roberts	19-Aug-16	HU05	Glide	228.3	0.37	0.37	12.80	12.97	0	3	5	60	32
Little Roberts	19-Aug-16	HU06	Riffle	75.4	0.62	0.62	7.77	7.77	0	30	40	30	0
Little Roberts	19-Aug-16	HU07	Pool	77.9	> 2	> 2	35*	35*	0	5	0	5	90
Little Roberts	19-Aug-16	HU08	Riffle	167.3	0.53	0.53	11.33	11.33	0	60	40	0	0
Little Roberts	19-Aug-16	HU09	Glide	281.8	0.80	0.80	14.75	14.75	0	5	0	15	80
Doris	20-Aug-16	HU10	Glide	254.9	1.09	1.39	7.60	8.70	0	0	0	0	100
Doris	20-Aug-16	HU11	Pool	23.7	1.27	1.60	9.83	10.30	0	0	0	0	100
Doris	20-Aug-16	HU12	Glide	77.2	0.87	1.14	5.62	6.58	0	0	10	32	58
Doris	20-Aug-16	HU13	Pool	17.7	1.20	1.50	8.00	10.33	0	0	0	20	80
Doris	20-Aug-16	HU14	Glide	43.3	0.60	0.90	1.50	1.50	0	20	20	30	30
Doris	20-Aug-16	HU15	Pool	30.7	> 2	> 2	11.00*	11.00*	0	0	0	0	100
Doris	20-Aug-16	HU16	Glide	145.8	-	-	3.50*	3.50*	-	-	-	-	-
Doris	20-Aug-16	HU17	Pool	26.1	> 2	> 2	10.00*	10.00*	0	0	0	0	100
Doris	20-Aug-16	HU18	Glide	474.5	-	-	5.00*	5.00*	-	-	-	-	-
Doris	20-Aug-16	HU19	Pool	21.3	> 2	> 2	10.50*	10.50*	0	0	0	0	100
Doris	20-Aug-16	HU20	Glide	45.8	-	-	3.50*	3.50*	-	-	-	-	-
Doris	20-Aug-16	HU21	Pool	20.8	> 2	> 2	9.00*	9.00*	0	0	0	0	100
Doris	20-Aug-16	HU22	Glide	273.4		-	4.00*	4.00*	-	-	-	-	-
Doris	20-Aug-16	HU23	Pool	20.7	> 2	> 2	10.50*	10.50*	0	0	0	0	100
Doris	20-Aug-16	HU24	Glide	282.9	-	-	3.70*	3.70*	0	0	0	0	100
Doris	20-Aug-16	HU25	Pool	97.5	> 2	> 2	9.40*	9.40*	0	0	0	0	100
Doris	20-Aug-16	HU26	Glide	234.8		-	3.80*	3.80*	-	-	-	-	-
Doris	20-Aug-16	HU27	Pool	65.3	> 2	> 2	8.70*	8.70*	0	0	0	0	100
Doris	20-Aug-16	HU28	Glide	829.2		-	6.30*	6.30*	0	0	0	0	100
Doris	20-Aug-16	HU29	Pool	21.0	> 2	> 2	14.00*	14.00*	0	0	0	0	100
Doris	20-Aug-16	HU30	Glide	123.0	-	-	4.60*	4.60*	-	-	-	-	-
Doris	20-Aug-16	HU31	Pool	26.7	> 2	> 2	10.10*	10.10*	0	0	0	0	100
Doris	20-Aug-16	HU32	Glide	250.5	-	-	4.40*	4.40*	-	-	-	-	-
Doris	20-Aug-16	HU33	Riffle	51.8	0.53	0.83	2.07	2.23	0	20	40	30	10
Doris	20-Aug-16	HU34	Pool	40.8	0.83	1.13	7.67	8.17	0	0	0	40	60
Doris	20-Aug-16	HU35	Riffle	51.0	0.97	1.27	5.67	5.80	0	2	18	30	50
Doris	20-Aug-16	HU36	Glide	64.9	0.77	1.00	3.07	3.33	0	10	30	30	30
Doris	20-Aug-16	HU37	Pool	27.2	0.83	1.13	7.67	7.97	0	10	20	30	40
Doris	20-Aug-16	HU38	Glide	24.7	0.50	0.80	3.33	3.63	0	5	15	70	10
Doris	20-Aug-16	HU39	Glide	31.5	0.63	0.93	8.67	9.10	0	5	20	60	15
Doris	20-Aug-16	HU40	Cascade	38.1	0.47	0.77	4.00	4.17	0	60	30	10	0

Appendix 2. Fish Habitat Assessments of Habitat Units in Doris, Roberts, and Little Roberts Outflows, Doris Project, 2016

					Depth		Width		Bed Material				
			Habitat	Length	Mean	Bankfull	Mean	Bankfull	Bedrock	Boulder	Cobble	Gravel	Fines
Outflow	Date	Site	Type	(m)	(m)	(m)	(m)	(m)	(%)	(%)	(%)	(%)	(%)
Doris	20-Aug-16	HU41	Glide	183.5	0.87	1.17	6.42	5.28	0	5	30	30	35
Doris	20-Aug-16	HU42	Cascade	110.9	0.53	0.83	7.50	7.80	20	20	30	25	5
Doris	20-Aug-16	HU43	Cascade	86.3	0.53	0.77	4.67	4.97	20	20	40	20	0
Doris	20-Aug-16	HU44	Glide	351.5	0.83	1.13	6.92	7.17	0	10	30	30	30
Roberts	23-Aug-16	HU45	Riffle	76.4	-	-	-	-	0	90	8	2	0
Roberts	23-Aug-16	HU46	Pool	5.1	-	-	-	-	0	10	10	0	80
Roberts	23-Aug-16	HU47	Glide	10.5	-	-	-	-	0	10	5	10	75
Roberts	23-Aug-16	HU48	Riffle	11.2	-	-	-	-	0	15	15	10	60
Roberts	23-Aug-16	HU49	Glide	165.0	-	-	-	-	0	5	5	0	90
Roberts	23-Aug-16	HU50	Pool	113.9	-	-	-	-	0	5	5	0	90
Roberts	23-Aug-16	HU51	Glide	142.5	-	-	-	-	0	5	0	0	95

*Notes: * = approximate measurement made with rangefinder, dashes indicate that data were not collected*

Substrate: Fines (Sand, silt, clay, fine organics) < 2 mm, Gravel = 2-64 mm, Cobble = 64-256 mm, Boulders = 256-4,000 mm, Bedrock > 4,000 mm

— Appendix 3 —

Catch and Sampling Effort for Doris, Roberts, and Little Roberts Outflow, Doris Project, 2016

Appendix 3. Electrofishing Catches in Doris, Roberts, and Little Roberts Outflows, Doris Project, 2016

					Number				
Outflow	Site	Date	Pass	Effort (seconds)	Ninespine Stickleback	Arctic Char	Lake Trout	Cisco sp.	Total
Doris	EF-01	21-Aug-16	1	401	12	-	-	-	12
Doris	EF-01	21-Aug-16	2	397	3	-	-	-	3
Doris	EF-01	21-Aug-16	3	370	1	-	-	-	1
Doris	EF-02	21-Aug-16	1	225	-	2	-	-	2
Doris	EF-02	21-Aug-16	2	254	4	-	-	-	4
Doris	EF-02	21-Aug-16	3	220	1	-	-	-	1
Doris	EF-03	22-Aug-16	1	330	3	-	-	-	3
Doris	EF-03	22-Aug-16	2	300	1	-	-	-	1
Doris	EF-04	22-Aug-16	1	302	1	-	-	-	1
Doris	EF-04	22-Aug-16	2	253	-	-	-	-	0
Doris	EF-05	22-Aug-16	1	483	-	-	-	-	0
Doris	EF-05	22-Aug-16	2	522	4	-	-	-	4
Doris	EF-06	23-Aug-16	1	520	6	-	-	-	6
Doris	EF-06	23-Aug-16	2	336	2	-	-	-	2
Doris	EF-07	23-Aug-16	1	595	8	-	-	-	8
Doris	EF-07	23-Aug-16	2	616	3	-	-	-	3
Doris	EF-08	23-Aug-16	1	406	2	-	-	-	2
Doris	EF-08	23-Aug-16	2	375	-	1	-	-	1
Doris	EF-08	23-Aug-16	3	431	-	-	-	-	0
Roberts	EF-09	24-Aug-16	1	459	3	8	1	-	12
Roberts	EF-09	24-Aug-16	2	444	5	4	-	-	9
Roberts	EF-09	24-Aug-16	3	411	-	-	-	-	0
Roberts	EF-10	24-Aug-16	1	311	-	-	-	-	0
Roberts	EF-10	24-Aug-16	2	313	-	-	-	-	0
Little Roberts	EF-11	24-Aug-16	1	518	2	2	-	-	4
Little Roberts	EF-11	24-Aug-16	2	395	-	-	-	-	0
Little Roberts	EF-12	24-Aug-16	1	200	-	-	-	-	0
Little Roberts	EF-12	24-Aug-16	2	218	-	-	-	-	0
Doris	EF-13	25-Aug-16	1	382	2	-	1	-	3
Doris	EF-13	25-Aug-16	2	338	-	-	1	-	1
Doris	EF-14	25-Aug-16	1	418	10	5	1	-	16
Doris	EF-14	25-Aug-16	2	428	5	1	-	-	6
Little Roberts	EF-15	25-Aug-16	1	370	-	-	-	2	2
Little Roberts	EF-15	25-Aug-16	2	419	1	1	-	1	3
Little Roberts	EF-15	25-Aug-16	3	361	-	-	-	-	0
Roberts	EF-16	25-Aug-16	1	434	30	8	-	1	39
Roberts	EF-16	25-Aug-16	2	340	-	-	-	-	0
Doris	EF-17	29-Aug-16	1	505	1	-	-	-	1
Doris	EF-17	29-Aug-16	2	530	-	-	-	-	0
Doris	EF-17	29-Aug-16	3	463	-	-	-	-	0

— Appendix 4 —

Biological Characteristics of fish sampled from Doris, Roberts, and Little Roberts Outflow, Doris Project, 2016

Appendix 4. Biological Characteristics of Fish Sampled in Electrofishing Surveys, Doris Project, 2016

Outflow	Date	Electrofishing Site	Electrofishing Pass	Fish Sample Number	Species Code	Fork Length (mm)	Weight (g)	Age Structure	Age (years)	Comments
Doris	21-Aug-16	EF-2	1	1	AC	206	102	FR	2	
Doris	21-Aug-16	EF-2	1	2	AC	-	-	-	-	Escaped, jumped over stop net; similar size as fish#1
Doris	23-Aug-16	EF-8	2	3	AC	178	69	FR	1	
Doris	23-Aug-16	EF-8	3	4	AC	274	169	FR, OT	5	Captured outside of sample site- upstream of block net. Possible mortality from predation. Not included in sample estimates.
Roberts	24-Aug-16	EF-9	1	5	AC	223	163	FR	2	
Roberts	24-Aug-16	EF-9	1	6	AC	194	104	FR	3	
Roberts	24-Aug-16	EF-9	1	7	AC	199	85	FR	3	
Roberts	24-Aug-16	EF-9	1	8	AC	179	68	FR	3	
Roberts	24-Aug-16	EF-9	1	9	AC	183	75	FR	3	
Roberts	24-Aug-16	EF-9	1	10	AC	184	76	FR	2	
Roberts	24-Aug-16	EF-9	1	11	LT	224	115	FR	3	
Roberts	24-Aug-16	EF-9	1	12	AC	143	30	FR	1	
Roberts	24-Aug-16	EF-9	1	13	AC	163	46	FR	2	
Roberts	24-Aug-16	EF-9	1	14	AC	102	10	FR	1	
Roberts	24-Aug-16	EF-9	2	15	AC	220	102	FR	2	
Roberts	24-Aug-16	EF-9	2	16	AC	199	115	FR	2	
Roberts	24-Aug-16	EF-9	2	17	AC	216	113	FR	3	
Roberts	24-Aug-16	EF-9	2	18	AC	198	94	FR	3	
Little Robert	24-Aug-16	EF-11	1	19	AC	230	120	FR	5	
Little Robert	24-Aug-16	EF-11	1	20	AC	150	32	FR	3	
Doris	25-Aug-16	EF-13	1	21	LT	320	296	FR	6	
Doris	25-Aug-16	EF-13	2	22	LT	625	-	FR	12	Not sure if FR previously taken, Pelvic Fin clip healed- orange tag #080
Doris	25-Aug-16	EF-14	1	23	LT	396	-	-	-	Too large for scale.
Doris	25-Aug-16	EF-14	1	24	AC	127	-	FR	4	Accidentally released before weight was recorded.
Doris	25-Aug-16	EF-14	1	25	AC	184	73	FR	3	
Doris	25-Aug-16	EF-14	1	26	AC	193	78	FR	1	
Doris	25-Aug-16	EF-14	1	27	AC	127	28	FR	1	
Doris	25-Aug-16	EF-14	1	28	AC	129	24	FR	2	
Doris	25-Aug-16	EF-14	2	29	AC	140	32	FR	-	
Little Robert	25-Aug-16	EF-15	1	30	CIS	42	-	FR	-	Scale malfunctioned
Little Robert	25-Aug-16	EF-15	1	31	CIS	42	-	FR	-	Scale malfunctioned
Little Robert	25-Aug-16	EF-15	2	32	CIS	-	-	FR	1	Scale malfunctioned
Little Robert	25-Aug-16	EF-15	2	33	AC	111	-	FR	2	Scale malfunctioned
Roberts	25-Aug-16	EF-16	1	34	AC	183	-	FR	3	Scale malfunctioned
Roberts	25-Aug-16	EF-16	1	35	AC	168	-	FR	3	Scale malfunctioned
Roberts	25-Aug-16	EF-16	1	36	AC	193	-	FR	4	Scale malfunctioned
Roberts	25-Aug-16	EF-16	1	37	AC	189	-	FR	2	Scale malfunctioned
Roberts	25-Aug-16	EF-16	1	38	AC	164	-	FR	2	Scale malfunctioned
Roberts	25-Aug-16	EF-16	1	39	AC	116	-	FR	1	Scale malfunctioned
Roberts	25-Aug-16	EF-16	1	40	AC	103	-	FR	2	Scale malfunctioned

Appendix 4. Biological Characteristics of Fish Sampled in Electrofishing Surveys, Doris Project, 2016

Outflow	Date	Electrofishing Site	Electrofishing Pass	Fish Sample Number	Species Code	Fork Length (mm)	Weight (g)	Age Structure	Age (years)	Comments
Roberts	25-Aug-16	EF-16	1	41	AC	119	-	FR	-	Scale malfunctioned

Notes:
Dashes indicate data not available.
Species: AC = Arctic Char, LT = Lake Trout, CIS = Cisco species
Age Structure: FR = fin ray, OT = otolith