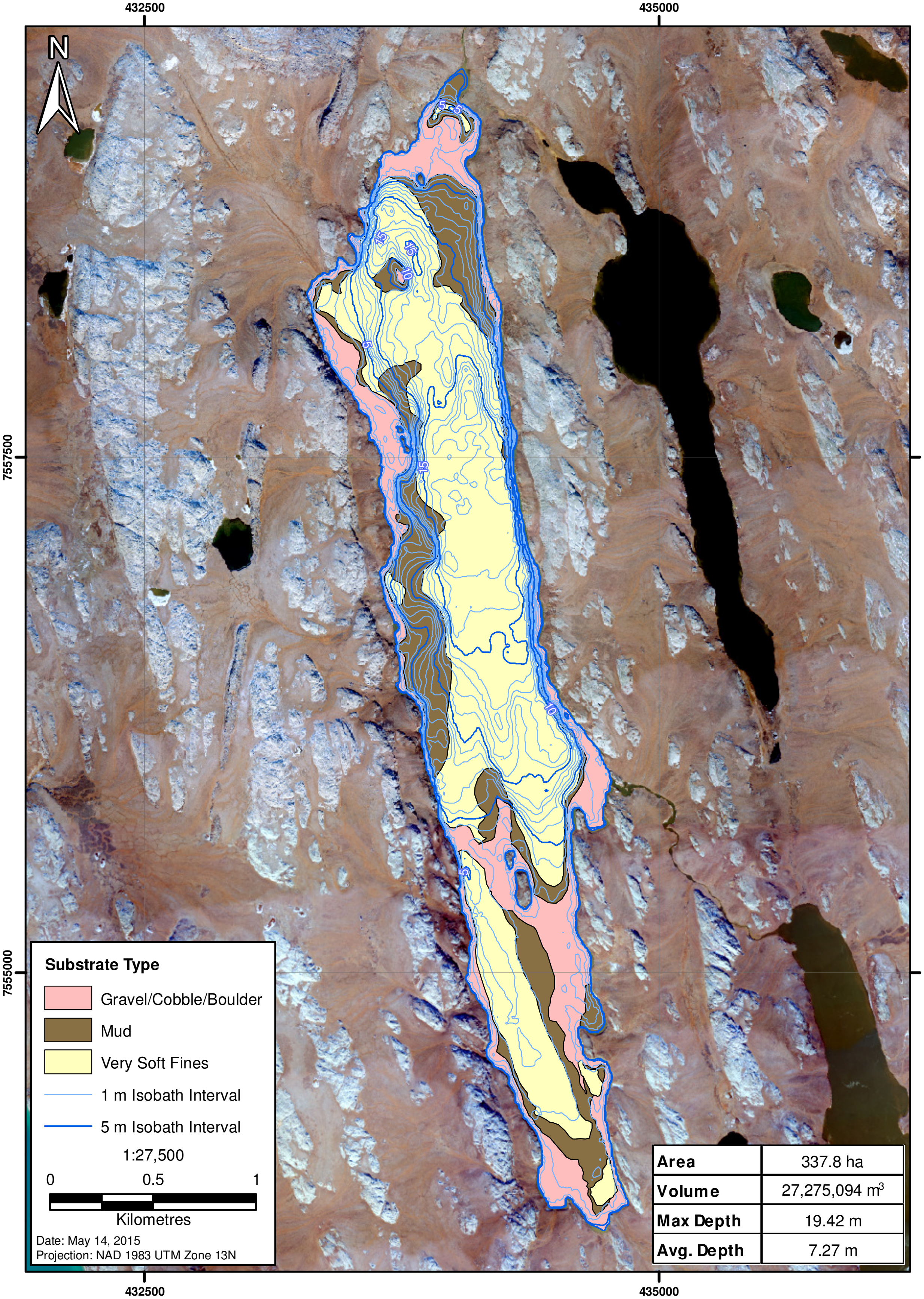
Figure 2.4-2

Substrate Composition of Doris Lake derived from Hydroacoustic Surveys, Doris North Project, 2009



Area	337.8 ha
Volume	27,275,094 m^3
Max Depth	19.42 m
Avg. Depth	7.27 m

Figure 2.4-3

Estimated Fish Density Derived from Gill Netting Surveys for Doris Lake, Doris North Project, 2009

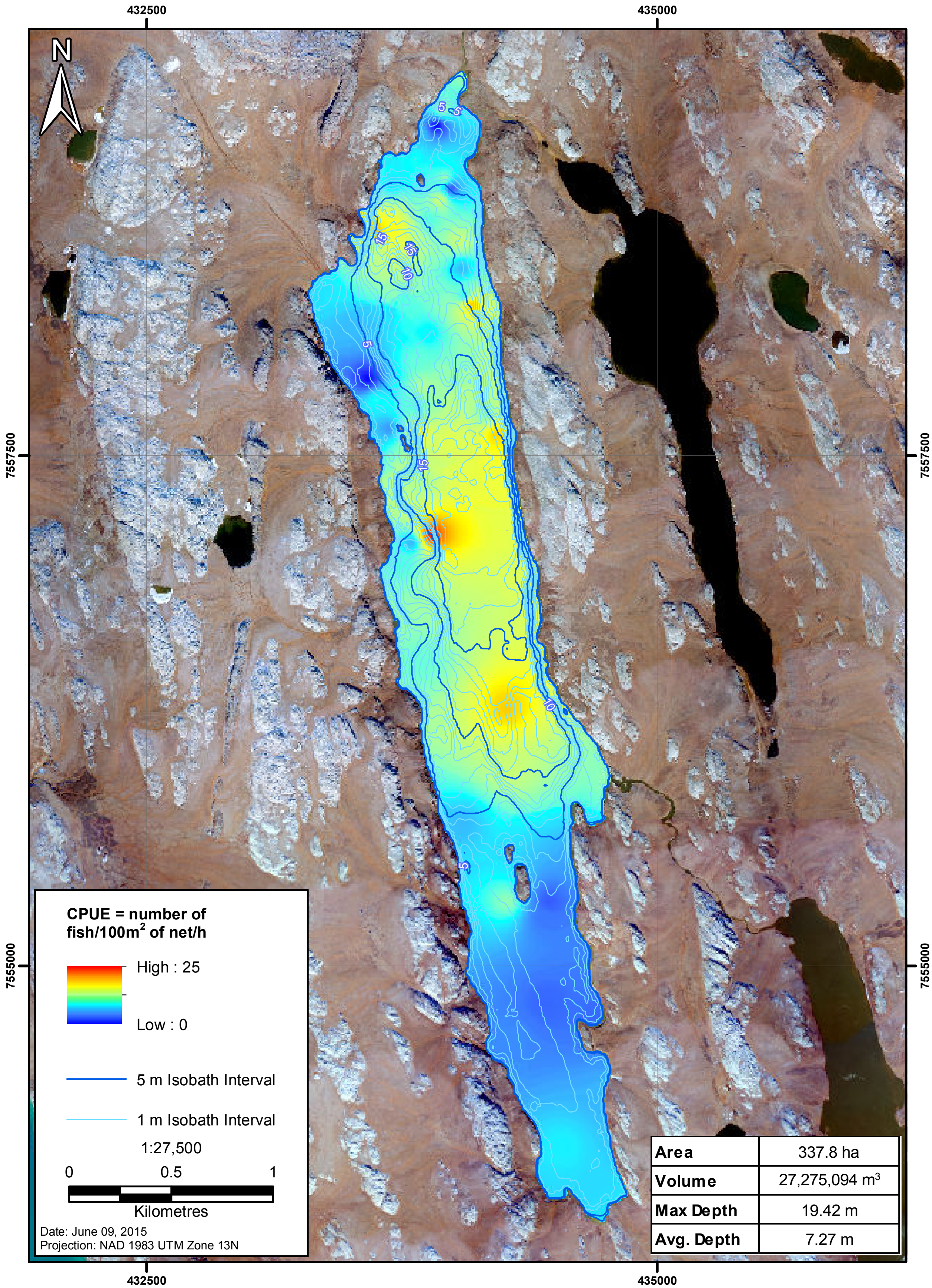
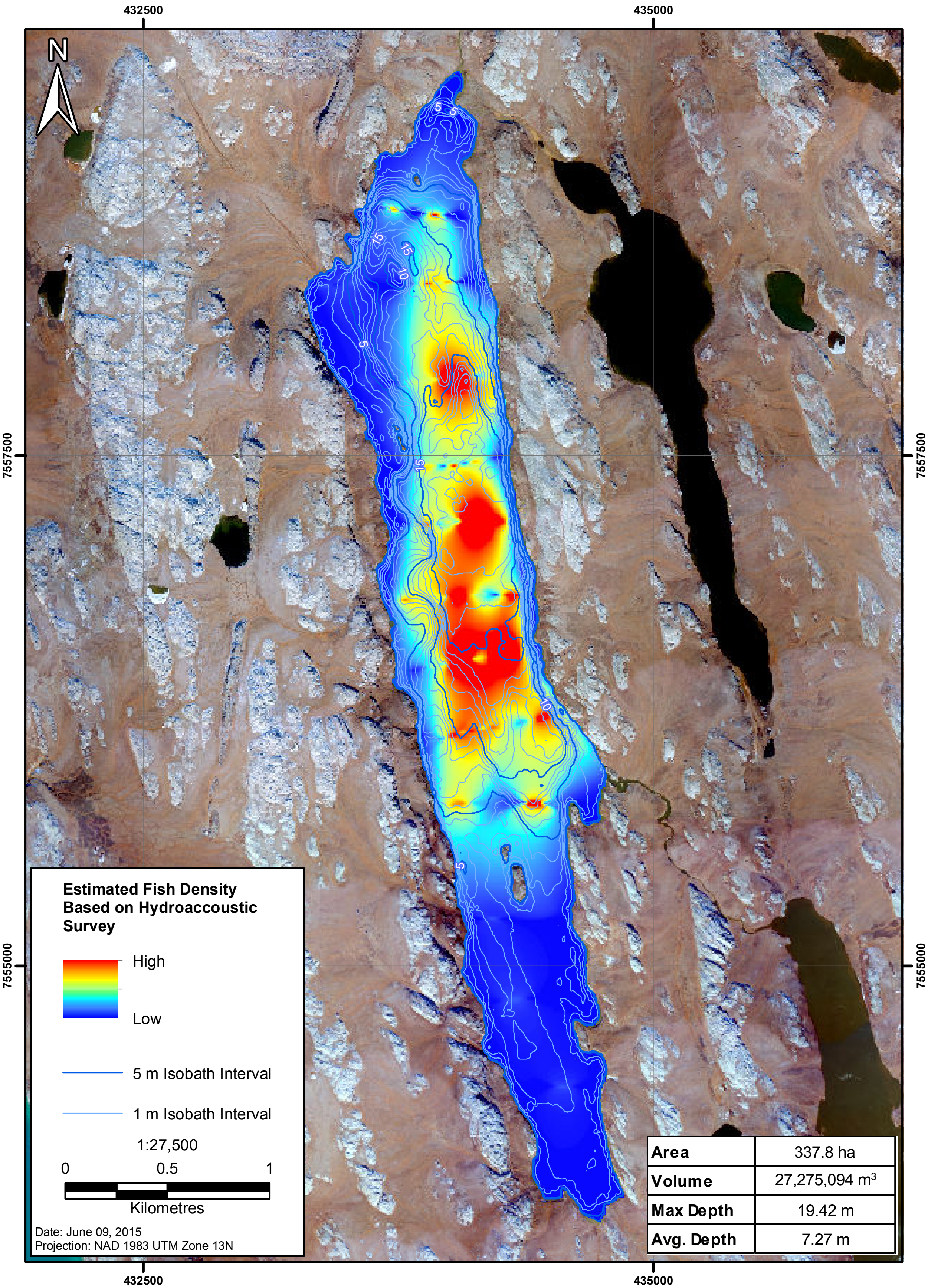


Figure 2.4-4

Estimated Fish Density Indicated from Hydroacoustic Surveys for Doris Lake, Doris North Project, 2009



The principal large-bodied fish species inhabiting Doris Lake include Lake Trout (*Salvelinus namaycush*), Lake Whitefish (*Coregonus clupeaformis*), and Lake Cisco (*Coregonus artedi*), with historical studies showing the latter as being the most abundant species (Rescan 2010a). Each of these species spawns in the fall (early September), with a preference for spawning along shoreline or shoal habitat at depths greater than approximately 2 to 3 m. Eggs incubate overwinter and will typically hatch during late spring/early summer (i.e., May to July). During winter, ice cover typically ranges between 1.5 and 2.0 m, which is consistent for lakes in the Project area. Small-bodied Ninespine Stickleback (*Pungitius pungitius*) also reside in Doris Lake, typically inhabiting near-shore areas.

Metal concentrations in the muscle, liver and kidney of 1 Lake Trout and 3 Lake Whitefish were collected in 1995. Samples of muscle and liver were collected from 22 Lake Trout and 29 Lake Whitefish in 1997 and 1998 respectively. Whole body tissue metal samples were taken for 40 Ninespine Stickleback in 2010. Data for all fish community variables remained relatively consistent from 1995 to 2010.

<u>Doris Lake Outflow</u>

Fish habitat and the fish community in the outflow stream from Doris Lake were studied over five field seasons (Rescan 2010a). The fish community along its entirety consists of Arctic Char (*Salvelinus alpinus*), Lake Trout, Lake Whitefish, Lake Cisco, and Ninespine Stickleback. A waterfall splits the stream into two sections; above the waterfall fish from Doris Lake can access the stream during the open water period, and the downstream section is connected to Little Roberts Lake, Roberts Lake, and the ocean at Roberts Bay. The waterfall is a permanent barrier to upstream migration, so sea-run fish cannot access Doris Lake.

Adult and juvenile Lake Trout, Lake Whitefish, Lake Cisco, and Ninespine Stickleback have been captured in Doris Creek above the waterfalls; as the creek does not contain overwintering habitat, these fish must move back to the lake before the creek freezes in fall. Downstream of the falls, Arctic Char, Lake Trout, and Ninespine Stickleback use the creek for rearing and feeding.

<u>Little Roberts Lake</u>

Fish community and fish habitat studies of Little Roberts have taken place since 2000 (Rescan 2010a). The fish community typically consists of Arctic Char, Lake Trout, Lake Whitefish and Lake Cisco. Although less common, Broad Whitefish (*Coregonus nasus*) were also reported in 2000, in addition to Least Cisco (*Coregonus sardinella*) in 2002 and 2003, although these may have been the result of improper species identification. Gillnet catches were consistently highest for Arctic Char relative other species in nearly all studies (Rescan 2010a). Both juveniles and adult sizes were encountered for all species. Since Little Roberts is located between Roberts Bay and Roberts Lake, Little Roberts Lake will intercept any fish migrating to and from marine habitats. Its importance for providing quality overwintering habitat is likely poor given its relatively shallow depth (only 3.2% of lake volume is greater than 2.5 m in water depth; RL&L Environmental Services Ltd./Golder Associates Ltd. 2003).

Little Roberts Lake Outflow

Little Roberts Lake Outflow acts as a migration corridor for fish species traveling between Roberts Bay and overwintering habitats (e.g., Roberts Lake), in addition to providing rearing/feeding opportunities for juvenile fish. Migratory salmonids using this corridor include Arctic Char and Lake Trout. Whitefish and Cisco species would also be expected to move through this stream on a seasonal basis to access abundant food resources and enhanced growth opportunities at sea. Arctic Char smolts generally migrate at the onset of freshet to capitalize on their time spent at sea and maximize feeding opportunities. Return migrations from marine habitats to freshwater also occur throughout the open water season, though the majority of fish (consisting of Arctic Char and Lake Trout) return to overwintering habitats during the months of August and September.

2.4.2 Commercial, Recreational and Aboriginal Fishery Species Summaries

Baseline fish community sampling identified six freshwater fish species in the Project Area (Table 2.4-2). Life history and habitat preferences of fish of commercial, recreational or Aboriginal (CRA) importance are summarized below (Table 2.4-3). Information was summarized from McPhail and Lindsey (1970), Scott and Crossman (1973), Richardson et al. (2001), and references therein.

Table 2.4-2. Fish Species Captured in the Project Area

Common Name	Scientific Name	Habitat	Spatial Distribution
Lake Trout	*Salvelinus namaycush*	Freshwater/	Benthopelagic
Arctic Char	*Salvelinus alpinus*	Anadromous	Benthopelagic
Lake Whitefish	*Coregonus clupeaformis*	Freshwater	Demersal
Lake Cisco	*Coregonus artedi*	Anadromous	Neritopelagic
Least Cisco	*Coregonus sardinella*	Freshwater	Neritopelagic
Ninespine Stickleback	*Pungitius pungitius*	Freshwater	Benthopelagic

2.4.2.1 Arctic Char

Arctic Char occur in northern coastal regions in rivers, lakes, estuaries, and marine environments. They exhibit both anadromous and resident lacustrine life history types. Anadromous Arctic Char are found in several watersheds with a suitable set of habitats. Lakes must be of sufficient size to provide suitable overwintering habitat and these lakes need to be connected to the ocean by streams that can be navigated by adults, even during periods of low discharge in the fall. Freshwater populations feed on planktonic crustaceans, amphipods, molluscs, insects, and fishes, while marine populations are primarily piscivorous and feed almost exclusively on marine resources. Arctic Char require cold, highly oxygenated water and are extremely sensitive to water pollution. Arctic Char are the most economically important fish to the Inuit population of Nunavut. In the Melville Sound area, commercial fisheries operate during upstream runs in Elu Inlet and the Kulgayuk River (DFO 2004b).

Table 2.4-3. Life History Periodicity for Fish of Commercial, Recreational or Aboriginal Importance in Doris-Roberts Watershed

				Month											
Species	Life stage	Habitat	Substrate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lake Trout (freshwater resident)	Spawning	Lake shoals	Gravel, cobble, boulder												
	Egg/alevin incubation	Lake shoals	Gravel, cobble, boulder												
	Fry emergence	Lake shoals	Gravel, cobble, boulder												
	Adult overwintering	Deep sections of lake													
Arctic Char (anadromous)	Spawning	Lake shoals	Gravel, cobble, boulder												
	Egg/alevin incubation	Lake shoals	Gravel, cobble, boulder												
	Fry emergence	Lake shoals	Gravel, cobble, boulder												
	Migration	Freshwater/marine	Pelagic zone												
	Overwintering	Deep sections of lake	-												
Lake Whitefish	Spawning	Lake shoals	Gravel, cobble, boulder												
	Egg/alevin incubation	Lake shoals	Gravel, cobble, boulder												
	Fry emergence	Lake shoals	Gravel, cobble, boulder												
	Overwintering	Lakes	-												

Dashes indicate data not available.

Arctic Char spawn in freshwater in the fall, usually September or October, over gravel and cobble shorelines of lakes and occasionally larger rivers. In the Belt area, and the central Canadian Arctic in general, spawning usually takes place in lakes because most streams and rivers freeze completely in winter. Males arrive first on the spawning grounds and establish and defend territories. Females are "courted" by males as they arrive later. The female digs a nest or redd in water typically 3 to 6 m deep, in which the eggs are deposited. The eggs incubate under ice for about six months. In most systems char are ready to take their first migration to sea at 4 to 5 years of age and a length of 150 to 250 mm (Johnson 1980). Young Arctic Char do not venture much past the brackish water of river estuaries, but as they grow, they develop a tolerance to higher salinity sea water. They feed in nearshore areas along the coast for the duration of the summer. More abundant food resources in marine waters allow anadromous Arctic Char to grow faster and larger than the freshwater form. At sea, char feed mainly upon invertebrates and fishes. In the fall, all char return to freshwater to overwinter (Johnson 1980).

2.4.2.2 Lake Trout

Lake Trout typically exhibit both lacustrine (lake resident) and adfluvial (river resident) life history types, but in the Hope Bay Belt there are unusual anadromous populations (migrate between freshwater and marine environs (Swanson et al. 2010). Lake Trout spawn in fall, from September to October in northern regions. Spawning grounds are almost always associated with cobble, boulder and gravel substrates, where there is no vegetative cover and may occur at depths less than 1 m to greater than 10 m (Scott and Crossman 1973). Eggs settle into cracks and crevices amongst the rocks, where they incubate for 4 to 5 months, with eggs usually hatching in March or April. Young-of-the-year remain in spawning areas from several weeks to several months, moving into deeper areas as water temperatures rise to greater than 15°C. Young-of-the-year and juveniles both prefer areas of cobble and boulder substrate for cover, and inhabit waters with a depth range of 2 to >10 m or alternatively inflows and outflows of the lake. Juveniles are often associated with large boulders, which they use for cover. Adult Lake Trout disperse into deeper water habitats, >10 m in depth, and are often found in the pelagic zone. Lake Trout feed on a wide variety of prey items including fish, molluscs, crustaceans, freshwater sponges and small mammals.

2.4.2.3 Lake Whitefish

Lake Whitefish are found throughout Nunavut, predominantly in lakes, although they are also found in large rivers and brackish waters. Lake Whitefish may exhibit lacustrine, adfluvial and anadromous life history types. They spawn in both lakes and rivers over gravel, cobble and boulders at depths of less than 5 m. Eggs are released over the substrate and fall into interstices between rocks where they incubate for several months, hatching sometime from March to May. Young-of-the-year are commonly found in the spawning area in shallow water (<1 m) near the surface, and prefer substrates of boulder, cobble and sand with abundant emergent vegetation and woody debris. Adults are usually found in the open water at depths >10 m and do not show a preference for substrate. Adults are predominantly benthic, although they may be found in the pelagic zone. Lake Whitefish have been reported to make onshore movements into shallow water at night, possibly to feed.

2.5 Potential Environmental Effects

2.5.1 Potential Interactions

Water use under 2AM-DOH1323 is currently from Doris and Windy Lakes. TMAC is not seeking an amendment to the currently permitted water use conditions of the licence, however, changes to Project footprint and revisions to the Project water balance suggest screening of potential interactions to support the amendment application.

Potential interactions of the proposed Project changes with the freshwater environment include:

- Potential alteration of Doris Lake outflow;
- Changes in surface water quality from runoff water from proposed expanded laydown area and ore storage pad;
- Reduction in or alteration of habitat (changes in flow) through water losses; and
- Removal or alteration of aquatic habitat for infrastructure, including culvert construction.

These interactions are identified as 'negative and mitigable' and can be mitigated using project design and an adaptive management approach.

2.5.2 Hydrology

The estimated water balance for the 6 year Project life identifies the potential for increased groundwater inflow to the underground mine workings. Updated water balance estimates indicate there is a larger contribution of Doris Lake talik water to this mine inflow than what was previously considered. Accordingly, the effect of the loss of water from Doris Lake to the mine, in addition to the current permitted surface water withdrawal volume, on surface water quantity in Doris Lake and Little Roberts lake was assessed.

Annual withdrawal of 480,000 m^3 from Doris Lake is currently permitted (Type A Water Licence 2AM-DOH1323). TMAC is not requesting an amendment to the water volume or source. For determining environmental effects, it is assumed the maximum permitted water volume is extracted from Doris Lake.

SRK (document P6-10)) estimated that in addition, loss of water from Doris Lake into the underground workings could be up to 610,000 m^3/year at its peak.

For the purpose of evaluating potential environmental effects, the estimated peak withdrawal and seepage rates into the mine workings from Doris Lake are conservatively assumed for the life of the Project and are constant throughout the course of each year.

The relationship between the Doris Lake water surface elevation (at Doris Lake hydrometric station) and streamflow (at Doris TL-2 hydrometric station) has changed during the period of record, i.e., 2004-2014. This change could be due to a combination of a dynamic hydraulics at the lake outlet and varying datum for lake elevation data. However, a consistent relationship with strong correlation was found between daily water surface elevations at Doris Lake and daily streamflows at TL-2 between 2012 and 2014 (Equation 2.5-1). For consistency purposes, this relationship was applied to the entire simulation period (i.e., 2004-2014).

$$Q = 2.81\,H \qquad \text{if } H \leq 0.41 \qquad (n = 373;\ R^2 = 0.92)$$

$$Q = 13.07\,\text{H} - 4.24 \qquad \text{if } 0.41 < H \leq 0.51 \qquad (n = 12;\ R^2 = 0.99)$$

$$Q = 7.32\,H - 1.30 \qquad \text{if } 0.51 < H \qquad (n = 22;\ R^2 = 0.97)$$

Equation (2.5-1)

Where

Q : lake outflow (m^3/s)
H : lake water surface elevation above the invert (m)
n : number of pairs of data
R^2 : Coefficient of Determination

Bathymetric survey results were used to estimate the volume-depth curve for Doris Lake (Golder 2006). Based on this curve, the volume of Doris Lake is 27.28 million cubic metres (mcm), and the lake volume under 2 m ice is 20.76 mcm.

Impacts of water loss on lake outflow and water surface elevation were estimated with a flow continuity scheme. Simulation was performed for the period of record (i.e., 2004 to 2014). Measured daily flows during the period of record were used as the lake baseline outflow time-series. When water surface elevation was below the invert elevation of the lake, the volume-depth curve, based on bathymetry was used to estimate the water surface elevation. For lake levels above the invert elevation of the lake, the water level was back-calculated from outflow estimates (Equations 2.5-1). This elevation may be different from actual water surface elevation because of the inherent uncertainty in relationship between lake outflow and water surface elevation. However, this analysis focuses on the elevation differences before and after the water loss, and therefore, the back-calculated surface water elevations were deemed reliable for this analysis, because they rely on the slope of the rating curve rather than the absolute value of the rating curve functions.

Observed baseline outflows, simulated operational outflows, as well as simulated baseline and operational water surface elevations, as explained above, were used to estimate hydrologic indices for baseline and operational conditions. Effects of water loss on hydrologic indices, i.e., difference between baseline and operational conditions, at Doris and Little Roberts lakes are summarized in Tables 2.5-1 and 2.5-2.

The permitted withdrawal of 480,000 m^3/year, as well as expected maximum leakage, or loss, of 610,000 m^3 per year will decrease Doris Lake outflow by 13.7% on average (Table 2.5-1). Lake level will be drawn down by 23 cm during the winter; this is equivalent of 0.76 mcm water withdrawal (i.e., less than 4% of the lake volume under 2 m ice). As a result of the winter water withdrawal, onset of Doris Lake outflow will be delayed by 10 days compared to baseline conditions.

Table 2.5-1. Summary of Predicted Effects on Doris Lake Hydrology

Parameter		Year											Average 2004-2014
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Mean annual lake outflow	Baseline Flow (m^3/s)	0.18	0.25	0.22	0.24	0.45	0.30	0.39	0.57	0.32	0.12	0.34	**0.31**
	Project-affected Flow (m^3/s)	0.15	0.21	0.18	0.20	0.42	0.26	0.35	0.54	0.28	0.09	0.30	**0.27**
	Change (% of Baseline Flow)	19.5%	13.9%	16.1%	15.8%	7.8%	12.6%	9.4%	6.1%	10.3%	27.9%	10.7%	**13.7%**
Peak daily lake outflow	Baseline Flow (m^3/s)	1.36	1.98	2.72	2.00	4.29	2.29	4.44	5.77	3.56	0.98	2.41	**2.89**
	Project-affected Flow (m^3/s)	1.33	1.94	2.69	1.97	4.26	2.25	4.40	5.73	3.53	0.95	2.38	**2.86**
	Change (% of Baseline Flow)	2.6%	1.8%	1.3%	1.8%	0.8%	1.5%	0.8%	0.6%	1.0%	3.6%	1.5%	**1.6%**
Maximum lake level draw down below invert	Baseline Conditions (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Project-affected Conditions (m)	0.23	0.22	0.23	0.25	0.22	0.23	0.20	0.20	0.19	0.22	0.23	**0.22**
	Change from Baseline (m)	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	**0.23**
Date at onset of lake outflow[1]	Baseline Conditions	13-Jun	7-Jun	31-May	15-Jun	4-Jun	12-Jun	5-Jun	11-Jun	8-Jun	6-Jun	5-Jun	**7-Jun**
	Project-affected Conditions	23-Jun	14-Jun	5-Jun	28-Jun	18-Jun	22-Jun	14-Jun	17-Jun	12-Jun	20-Jun	18-Jun	**17-Jun**
	Delay in onset of flow[1] (days)	10	7	5	13	14	10	9	6	4	14	13	**10**
Date at flow ceasing	Baseline Conditions	15-Oct	30-Sep	25-Sep	12-Oct	12-Oct	31-Oct	13-Nov	10-Nov	15-Oct	5-Oct	12-Oct	**16-Oct**
	Project-affected Conditions	8-Oct	29-Sep	10-Sep	10-Oct	10-Oct	28-Oct	9-Nov	9-Nov	7-Oct	25-Sep	11-Oct	**11-Oct**
	Accelerated flow ceasing (days)	7	1	15	2	2	3	4	1	8	10	1	**5**
Total number of flow days	Baseline Conditions (days)	124	115	117	119	130	141	161	152	129	121	129	**131**
	Project-affected Conditions (days)	107	107	97	104	114	128	148	145	117	97	115	**116**
	Reduction in number of flow days	17	8	20	15	16	13	13	7	12	24	14	**15**

[1] *The delay in onset of lake outflow is assumed to be equivalent to the onset of flow in stream located immediately downstream of lake. A lake will begin to outflow once the volume of the lake is greater than the invert volume of that lake.*

Table 2.5-2. Summary of Predicted Effects on Little Roberts Lake Hydrology

Parameter		Year											Average 2004-2014
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Mean annual lake outflow	Baseline Flow (m^3/s)	0.38	0.57	0.45	0.47	1.01	0.62	0.87	1.12	0.65	0.32	0.78	**0.66**
	Project-affected Flow (m^3/s)	0.35	0.54	0.42	0.44	0.97	0.59	0.83	1.08	0.61	0.29	0.74	**0.62**
	Change (% of Baseline Flow)	9.2%	6.0%	7.7%	7.9%	3.5%	6.0%	4.2%	3.2%	5.1%	10.8%	4.7%	**6.2%**
Peak daily lake outflow	Baseline Flow (m^3/s)	3.76	5.09	6.49	5.04	10.77	4.88	10.39	13.19	7.31	2.98	8.89	**7.16**
	Project-affected Flow (m^3/s)	3.72	5.06	6.45	5.00	10.73	4.84	10.35	13.15	7.28	2.74	8.85	**7.11**
	Change (% of Baseline Flow)	0.9%	0.7%	0.5%	0.7%	0.3%	0.7%	0.3%	0.3%	0.5%	8.0%	0.4%	**1.2%**
Maximum lake level draw down below invert	Baseline Conditions (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Project-affected Conditions (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	Change from Baseline (m)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Date at onset of lake outflow[1]	Baseline Conditions	13-Jun	7-Jun	31-May	15-Jun	4-Jun	10-Jun	4-Jun	11-Jun	8-Jun	20-May	5-Jun	**6-Jun**
	Project-affected Conditions	13-Jun	7-Jun	31-May	15-Jun	4-Jun	10-Jun	5-Jun	12-Jun	8-Jun	21-May	9-Jun	**6-Jun**
	Delay in onset of flow[1] (days)	0	0	0	0	0	0	1	1	0	1	4	**1**
Date at flow ceasing	Baseline Conditions	15-Oct	30-Sep	26-Sep	12-Oct	12-Oct	31-Oct	13-Nov	10-Nov	15-Oct	17-Oct	12-Oct	**17-Oct**
	Project-affected Conditions	14-Oct	30-Sep	21-Sep	10-Oct	10-Oct	31-Oct	12-Nov	10-Nov	8-Oct	17-Oct	11-Oct	**16-Oct**
	Accelerated flow ceasing (days)	1	0	5	2	2	0	1	0	7	0	1	**2**
Total number of flow days	Baseline Conditions (days)	124	115	118	119	130	143	162	152	129	150	129	**134**
	Project-affected Conditions (days)	123	115	113	117	128	143	160	151	122	149	124	**131**
	Reduction in number of flow days	1	0	5	2	2	0	2	1	7	1	5	**3**

[1] *The delay in onset of lake outflow is assumed to be equivalent to the onset of flow in stream located immediately downstream of lake. A lake will begin to outflow once the volume of the lake is greater than the invert volume of that lake.*

Effects of water loss from Doris Lake are diminished downstream of Little Roberts Lake (Table 2.5-2). There will be no water withdrawal from Little Roberts Lake; due to the change in Doris Lake outflow, Little Roberts Lake outflows are predicted to decrease by 6.2% on average. Therefore, the minimum lake elevation and date of onset of lake outflow will remain unchanged and unaffected by water loss from Doris Lake.

2.5.3 Freshwater Aquatic Organisms, Fish and Fish Habitat

Project infrastructure and activities have the potential to impact freshwater organisms, fish and fish habitat through two interaction pathways:

- Reduction in or alteration of habitat (changes in flow) through water withdrawals or losses; and
- Removal or alteration of aquatic habitat for additional infrastructure, including culvert construction due to infrastructure footprint encroaching or encompassing existing aquatic habitat.

These two interactions may result in serious harm through permanent alteration to, or destruction of fish habitat.Effect to Fish Habitat: Project Infrastructure Footprint

Fish habitat may be directly affected if infrastructure overlaps with fish habitat, removing the ability for fish to access and use that habitat. Indirect effects may occur if components such as stream crossing structures are improperly sized or installed or if in-water construction mobilizes sediment, destabilizes stream banks, or alters streambeds, resulting in alterations to fish habitat. These impacts could degrade or eliminate fish spawning, rearing, and feeding habitat.

Effect to Fish Habitat: Stream Crossings

The construction of stream crossings has the potential to cause the loss of fish habitat if the crossing design has an in-stream footprint, if the crossing structure is improperly sized or installed, or if construction mobilizes sediment, destabilizes stream banks, or alters streambeds. These crossings are:

- a combined wastewater pipeline and road crossing is required over a small, unnamed stream that flows into Roberts Bay West. No species targeted by CRA fisheries have been captured in this stream; only Ninespine Sticklebacks have previously been captured. Additional sampling will be completed prior to crossing installation to confirm species composition and distribution; and,
- Doris Connector Vent Raise Access Road crosses a small unnamed tributary to Doris Lake. A desktop assessment of this stream indicated that it likely contains little quality fish habitat, but since this stream has not been previously sampled it will be assessed in advance of crossing installation to determine whether it bears fish or not.

The majority of effects on fish and fish habitat related to road use arise from the construction and maintenance of stream crossings. Several DFO operational statements have been developed to guide these processes and will be used as best management practices, along with DFO's Measures to

Avoid Causing Harm to Fish and Fish Habitat, to ensure that fish habitat is not adversely affected by development. DFO operational statements applicable to the Project include:

- Temporary stream crossings will be constructed according to the DFO Nunavut Operations Statement for Temporary Stream Crossings (DFO 2007b);
- Culvert maintenance will be conducted following the DFO Nunavut Operations Statement for Culvert Maintenance (DFO 2007a); and
- In water work will be conducted during approved timing windows presented in the DFO Nunavut Operations Statement for Timing Windows (DFO 2009).

As a result of mitigation and best management practices, no residual effects are anticipated on freshwater fish and fish habitat due to the construction of stream crossings associated with Project activities contained within this amendment. However, if operational statements and best management practices cannot be followed and if it is determined that stream crossing construction will cause serious harm, an offsetting plan will be developed to mitigate losses in concordance with the *Fisheries Act* (1985).

<u>Effect to Fish Habitat: Water Storage and Use</u>

Losing water from lakes has the potential to affect fish and fish habitat through multiple pathways, including a reduction in or deterioration of available fish habitat and changes to primary and secondary productivity. For example, a reduction in the available volume of water from a large ice-covered lake may cause a decrease in the amount and suitability of overwintering habitat available for fish or potentially expose overwintering eggs of Lake Trout to air or ice (Cott 2007). In addition, a decrease in lake water volume has the potential to modify water and sediment quality such that shifts in lower trophic level prey communities (invertebrate) are altered. Smaller, shallow lakes and ponds are more susceptible to habitat changes due to water volume decrease than large lakes (DFO 2009).

<u>Effect to Fish Habitat: Doris Lake</u>

A revised water balance model for Doris Lake has predicted that the removal of water for domestic and process purposes combined with seepage from the lake into the underground mine would decrease the flow in the lake outflow and drop the surface water level of the lake (Section 2.5.2). However, it is anticipated that the drawdown of water from Doris Lake will not result in adverse effects on fish and fish habitat as natural variability in water level and ice thickness is similar to maximum predicted drawdown depth.

In eleven years of baseline data collection, the surface water level of Doris Lake varied naturally by an average of 0.54 m and by as much as 0.74 m. In addition, ice thickness naturally varies each year from 1.5 to 2.0 m. This indicates that, in an average year, the ice depth and water level change will equal 2.29 m and the maximum change will be 2.74 m. The hydrological assessment concluded that, under the proposed scenario,the lake level will decrease 0.23 m during winter. This decrease of 0.23 m has the potential to expose incubating Lake Trout eggs to desiccation, if spawning shoals are within 0.23 m of the ice bottom. However, when including water loss in the calculation, ice depth, in an average year, and the air space opened from the decrease in water volume will result in unusable habitat for fish up to 2.52 m below the water surface: less than the limit of the natural range of water level and ice thickness (2.74 m). Lake Trout eggs within 2.74 m of the water surface will experience natural mortality due to ice scour in the winter and thus a decrease in lake level of 0.23 m during winter is not expected to result in adverse effects on fish and fish habitat in Doris Lake.

Although desktop analysis suggests no adverse effects on fish beyond that experienced through natural variation in water and ice depth, there is no information on the depth of Lake Trout spawning habitat in Doris Lake. Additional data should be collected to verify locations and depths of Lake Trout spawning habitats so they can be protected in the future. For example, in an extreme year (using the upper limit of natural lake level and ice thickness) there is a potential for an additional 0.23 m of air exposed fish habitat under ice: total depth of ice plus airspace equal to 2.97 m. Should it be identified that important habitats will be impacted, an offsetting plan will be developed in accordance with the *Fisheries Act* (1985).

The volume of water expected to be lost from Doris Lake under the proposed scenario is less than 4% of the lake volume under 2 m of ice cover. This is well within the 10% maximum to protect fish habitat provided as a limit by DFO for the guidance of under-ice water withdrawal (DFO 2010).

<u>Effect to Fish Habitat: Doris Lake Outflow and Doris Creek</u>

Doris Outflow and Creek is a 4,000 m long section of stream connecting Doris Lake to Little Roberts Lake with a fall barrier restricting upstream fish movement into Doris Lake. The upstream section nearest Doris Lake above the falls, referred to as Doris Outflow, is approximately a 400 m length of stream primarily used as rearing habitat for juvenile Lake Trout and Ninespine Stickleback. The downstream section, Doris Creek (approximately 3600 m in length) serves primarily as rearing habitat for juvenile Arctic Char, Lake Trout and Ninespine Stickleback.

The primary effects on Doris Outflow and Creek will be due to a reduction in flow (discharge) throughout the open water season resulting from a decrease in Doris Lake available volume. Following DFO's *Pathways of Effects* for flow reductions, two potential pathways (*Flow Alteration* and *Change in Timing, Duration and Frequency of Flow*) resulted in a potential effect related to *Change in Access to Habitats* in Doris Outflow and Creek. The assessment of the potential effects due to a reduction in discharge involved examining: 1. The potential reduction in the total number of flow days (equal to the number days of fish use in the stream) and 2. The potential reduction in stream wetted widths and resulting fish habitat area.

Reduction in Total Number of Flow Days:

The results of the hydrological modeling (Table 2.5-1) indicate that, on average, the total number of flow days in Doris Lake Outflow and Creek will decrease by 15 days (baseline flow days = 131, project = 116). The reduction in flow days results from first, a delay of 10 days the onset of peak flow during freshet (Baseline = June 7, Project = June 17) due to decreased lake volume in winter , and second, an earlier date of onset of flow ceasing due to decreased lake volume in summer. In addition to average baseline conditions, and to ensure a conservative approach is used, potential effects to fish habitat must also examined for effects in more extreme conditions. For example, in dry years, when water levels are at their lowest, juvenile rearing habitat is less available compared to average and wet years and may be limiting. When the potential effects of water loss from Doris Lake are examined for an extreme year (e.g. 2013 in Table 2.5-1), the total number of flow days in Doris Lake Outflow and Creek will decrease by 24 days. In Doris Outflow and Creek, this represents a reduction in available rearing habitat used by Arctic Char, Lake Trout and Ninespine Stickleback by an 11% (on average) and up to a maximum of 18% (for dry years) for the six years during which the water loss during mining may persist.

TMAC is not requesting an amendment to the water volume or source. For determining environmental effects, it is assumed the maximum permitted water volume is extracted from Doris Lake.

Reduction in Stream Wetted Widths:

The results of the hydrological modeling (Table 2.5-1) indicate that, on average, the mean annual lake discharge will be reduced by 13.7%, up to a maximum of 27.9% in an extreme year. A reduction in discharge of up to 13.7 to 27.9% will result in a reduction in the wetted stream width and thus the amount of available habitat for the duration of water withdrawal for the six years during which water loss during mining may persist.

To quantify the amount of serious harm required to be offset (*i.e.* up to 18% reduction in flow days and the 27.9% reduction in discharge), additional modeling and characterization of Doris Lake Outflow and Creek are requiredThis work is considered in the Approach to Freshwater Fisheries Offsetting memo included in Appendix B.

<u>Effect to Fish Habitat: Little Roberts Lake Outflow</u>

Little Roberts Outflow is an approximately 1,500 m long migratory channel primarily used by Arctic Char and Lake Trout to pass from Roberts Lake, through Little Roberts Lake to feed in Roberts Bay. Little Roberts Outflow also provides rearing and feeding opportunities for juvenile Arctic Char and Lake Trout. Whitefish species may also be expected to move through this stream on a seasonal basis to access abundant food resources and enhanced growth opportunities at sea. Arctic Char smolts generally migrate at the onset of freshet to capitalize on their time spent at sea and maximize feeding opportunities. Return migrations from marine habitats to freshwater also occur seasonally throughout the open water season, though the majority of fish (consisting of Arctic Char) return to overwintering habitats during the months of August and September.

The primary effects on Little Roberts Outflow will be due to a reduction in flow (discharge) throughout the open water season. Following DFO's *Pathways of Effects* for flow reductions, two potential pathways (*Flow Alteration* and *Change in Timing, Duration and Frequency of Flow*) resulted in two potential effects on *Fish Passage (Migration)* and *Change in Access to Habitats* in Little Roberts Outflow. The assessment of the potential effects due to a reduction in discharge involved examining: 1. The potential reduction in the total number of flow days (equal to the number days of fish use in the stream) and 3. The potential reduction in stream wetted widths and resulting fish habitat area.

Reduction in Total Number of Flow Days:

The results of the hydrological modeling (Table 2.5-2) indicate that, on average, the total number of flow days in Little Roberts Lake Outflow will decrease by 3 days per year (baseline flow days = 134, project = 131). The reduction in flow days results from first, a delay of 1 day the onset of peak flow during freshet resulting from a decrease in avaialbe lake volume in winter in Doris Lake (Baseline = June 6, Project = June 6; the one day delay is due to rounding averages), and second, an earlier date of onset of flow ceasing due to summer withdrawal (Baseline = Oct 17, Project = Oct 16; the two day delay is due to rounding averages).

In addition to average baseline conditions, and to ensure a conservative approach is used, potential effects to fish habitat must also be examined for effects in more extreme conditions. When the potential effects of water loss are examined for an extreme year (e.g. 2012 in Table 2.5-2), the total number of flow days in Little Roberts Lake Outflow will decrease by 7 days. In Little Roberts Outflow, this represents a potential reduction in *Fish Passage* (migratory period) and *Access to Habitats* (available rearing habitat) by Arctic Char, Lake Trout by less than 1% (on average) and up to a maximum of 5% (for dry years) for the six years during which the water loss during mining may persist.

Reduction in Stream Wetted Widths:

The results of the hydrological modeling (Table 2.5-2) indicate that, on average, the mean annual lake discharge will be reduced by 6.2%, up to a maximum of 10.8% in an extreme year. This maximum lies just on the upper limit of DFO's recommendation of 10% to mitigating water discharge reduction (DFO 2013b). As modeled, the effects of discharge reduction on fish populations using Little Roberts Lake Outflow are predicted to be indetectable from natural variability and therefore are considered negligible (DFO 2013b).

Overall, the effects of water loss from Doris Lake will be negligible for *Fish Passage* and *Change in Access to Habitats* in Little Roberts Outflow.

2.6 MITIGATION, MANAGEMENT AND MONITORING

2.6.1 Mitigation by Project Design

The following are major mitigation features that have been incorporated into the design of the proposed Project:

- Use of intercepted groundwater for drilling purposes will reduce the demand for fresh water and lake drawdown.
- Minimizing footprint and diversion of surface runoff, minimizes the alteration to runoff patterns. Runoff from the pads will be directed to the Pollution Control Pond.
- Roads and infrastructure pads have been sited to avoid water bodies and are designed to minimize the risk for erosion and use of silt fencing if and where necessary.
- Project design avoidance measures and ensuring a minimum of 30 m setback distance to fish habitat.

2.6.2 Adaptive Management Plans

In addition to Project Design mitigation features, there are also additional mitigation measures that would be in place, which would allow for adaptive management if unexpected environmental concerns arise. These include:

- Spill and emergency response equipment will be established.
- Site water management and compliance with regulatory thresholds and current permits will result in no effect to freshwater aquatic organisms, fish and fish habitat.
- Complete field programs to verify locations and depths of Lake Trout spawning habitats within Doris Lake and incorporate consideration of these areas in water management plan.
- Ensure compliance with DFO Protocol for Winter Water Withdrawal from Ice-covered Waterbodies in the Northwest Territories and Nunavut.

Where effects to fisheries cannot be mitigated, a DFO Fisheries Authorization will be obtained. This application will be supported by the development of a Freshwater Offsetting Plan outlined in Appendix B.

2.6.3 Cumulative Effects

Based on the calculations of this report, the maximum cumulative potential water level decrease due to the permitted extraction of 480,000 mcm/year from Doris Lake is within the range of natural variability, and no adverse effects are anticipated. There is the potential for water loss scenarios greater than this currently permitted volume to result in serious harm to fish due to changes that may affect habitat accessibility and connectivity. Where effects to fisheries cannot be mitigated, a freshwater Offset Plan will be developed based on a proposed Framework (Appendix B) and a DFO Fisheries Authorization will be obtained.

3. ATMOSPHERIC AND TERRESTRIAL ENVIRONMENT

3.1 INTRODUCTION

This report section focuses on the potential effects of the proposed changes to the Doris North Project on the atmospheric andterrestrial environments. Air quality is an important environmental factor in ensuring the conservation of local vegetation, and the wildlife and people that use these resources. Poor air quality has a direct effect on the local terrestrial environment dwhich may indirectly affect wildlife and human health. Changes to Project footprint also result in a direct effect to the terrestrial components and wildlife.

The existing baseline air quality, meteorological andterrestrial conditions in the regional area and at the Project site are discussed and the potential environmental effects on air quality, vegetation, etc are identified. A summary of the mitigation and management measures are provided and information on the various monitoring programs which have been undertaken at Doris North are identified.

3.2 EXISTING ATMOSPHERIC BASELINE CONDITIONS DORIS NORTH

3.2.1 Regional Setting

The Project is located near the northern boundary of the North American Continent, north of the Arctic Circle. The climate in the area is characterized by extremes. Summer is a season of nearly perpetual sunlight, while winter is dominated by night, twilight and extreme cold. Due to the relative absence of obstructions to impede the wind (e.g., trees, buildings, mountains), wind speeds are generally high. The Project area also experiences relatively low amounts of precipitation.

The air quality in Nunavut can generally be classified as pristine. Local emissions are limited to stationary (power generation and heating) and mobile sources (trucks, snowmobiles, all-terrain vehicles, etc.) operated by local residents in the few communities within the region. Mines operating in Nunavut represent the only major industrial emission source. Due to the limited local emission sources, long-range transport of air contaminants is the main influence on ambient air quality. The atmospheric boundary layer in the Arctic is generally very stable and surface inversions occur frequently. As a result, dispersion of air contaminants can be less effective in the Arctic than in other regions.

3.2.2 Local Setting

3.2.2.1 Meteorology

Meteorological monitoring has been conducted in the Project area since 1993. A permanent meteorological station (the Doris North meteorological station) was installed in the Project area in 2004. Also a micro-meteorology station designed to obtain evaporation data has been seasonally installed, during the late spring to early summer, in Doris Lake since 2009. In addition to the temperature and precipitation data required under Section 4.0, Item 8 of the Project certificate, these stations collect wind speed and direction, relative humidity, global solar radiation, barometric pressure, and evaporation data (Table 3.2-1).

Table 3.2-1. Variables Measured at the Doris North Meteorological and Micro-meteorological Stations[a]

Variable Measured (units)	Doris North Meteorological Station[b]	Micro-meteorological Station[c]
Temperature and Relative Humidity (ºC)	✓	✓
Wind Speed and Direction (m/s and degrees)	✓	✓
Rainfall via Tipping Bucket Rain Gauge (mm)	✓	✓
Winter Precipitation via CS705 (mm)	✓[d]	n/a
Solar Radiation (W/m^2)	✓	✓
Barometric Pressure (kPa)	✓[e]	n/a
Water Temperature via Thermistors (ºC)	n/a	✓
Net Radiation (W/m^2)	n/a	✓

Notes:
[a] n/a = This type of sensor was not installed at this meteorological station.
[b] The Doris North meteorological station consisted of two tripods from February 27, 2004 to August 13, 2009 after which its sensors were reinstalled on a EC-MSC recommended 10 m tower.
[c] The micro-meteorological station has been installed seasonally since 2009.
[d] The winter precipitation adapter was first installed in February 2012.
[e] The barometric pressure sensor was installed in September 2010.

The most recent Meteorology Compliance Monitoring Program report provides details of the local meteorological conditions collected between October 2013 and September 2014 (ERM Rescan 2014b). During the 2013/2014 period the annual average temperature was -11.3ºC, with extreme temperatures ranging from -43.0ºC to 27.0 ºC. These values are similar to the long term values recorded by Environment Canada in the Arctic Tundra.

Total annual precipitation was 104.9 mm, with the greatest monthly precipitation occurring in July 2014 (41.7 mm). However, total annual precipitation was likely underestimated due to issues with the monitoring during the winter. Environment Canada data suggests that the winter of 2013/2014 was average. Most precipitation fell during the summer months at the Project.

The Project area experiences almost 24 hours of sunlight per day between mid-May and the end of July and almost 24 hours of darkness per day from late November to early January. The total annual number of bright sunshine hours, where average global solar radiation is greater than 120 W/m^2, was 2,351. There were zero sunlight hours in November, December and January.

Winds in the Project area typically blew from the west-northwest quadrant year round, with winds from the east and southeast also common especially during the summer. Average annual wind speed at the Doris North meteorological station was 5.8 m/s (20.9 km/h), and gusts of up to 22.0 m/s (79.3 km/h) were recorded. The maximum wind gust recorded since compliance reporting began in 2011, was 28.9 m/s (104.0 km/h) in August 2013.

Total evaporation was estimated to be 95.7 and 88.8 mm using the Penman Combination and Priestly-Taylor methods, respectively, from July to September 2014. Evaporation is strongly related to net radiation, and therefore is greatest during early summer months. Daily evaporation rates decreased from July to September.

The mean monthly barometric pressure (adjusted to sea level) recorded at the Doris North meteorological station for the 2013/2014 reporting period was 101.34 kPa. Mean daily barometric pressure remained between 98 and 103 kPa throughout the reporting period. Annual average relative humidity was 78.6%.

3.2.2.2 Air Quality

Air quality monitoring at the site began in 2006. A Passive Air Sampling System (PASS) is used to measure sulphur dioxide, nitrogen dioxide, and ozone (SO_2, NO_2 and O_3). Airborne suspended particulate matter (TSP, PM_{10} and $PM_{2.5}$) concentrations are monitored using Partisol samplers. Dustfall sampling includes particulates (total, soluble and insoluble), anions (sulphate, nitrate, chloride, and ammonia), total metals and various cations.

The most recent Air Quality Compliance Monitoring Program report provides details of the local air quality conditions (ERM Rescan 2014b). TSP, PM_{10} and $PM_{2.5}$ data collected during 2013/2014 were well below objectives and typical of background concentrations for remote undisturbed areas in Canada. The mean monthly concentrations for SO_2, NO_2 and O_3 were 0.7, 1.9 and 62.4 $\mu g/m^3$, respectively, during the monitoring period. Monthly mean concentrations cannot be directly compared to the relevant objectives and guidelines which are based on hourly, daily and annual concentrations; however as a conservative approach, concentrations can be compared to mean annual concentrations. The Project SO_2 and NO_2 measurements were significantly less than the relevant annual guidelines. Measured O_3 concentrations were greater than the annual objective, however, concentrations were within the lower range of concentrations estimated by Health Canada for areas with negligible exposure to anthropogenic pollution.

The most recent baseline dustfall monitoring was carried out in 2012 (Rescan 2012). Dustfall monitoring was undertaken at seven locations co-located with Doris North meteorological station, used an AE sampling method (Alberta AMD 1989), and the other six stations used the ASTM D1739 98 sampling method (ASTM 2010).

For all ASTM method stations, all dustfall results were below the Alberta (commercial and industrial) guideline of 5.25 mg/dm2/day. Five out of the 25 ASTM method dustfall samples were above the Alberta (residential and recreational) limit of 1.75 mg/dm2/day. Most exceedances occurred in March, and no exceedances occurred in April, May or June. All AE method dustfall samples were below both Alberta guidelines. Most of the metal concentrations were below the detection limits and are considered negligible. There are no specific criteria for metal concentrations in dustfall.

3.3 EXISTING TERRESTRIAL BASELINE CONDITIONS

3.3.1 Terrestrial Ecosystems

The distribution of terrestrial ecosystems in the Hope Bay Project area has been assessed through terrestrial ecosystem mapping and surveys conducted during baseline studies in 1996 to 1997, 2010, and 2014. The goal of the baseline studies was to characterize the terrestrial ecology within the LSA to guide Project planning, management and environmental assessment. Through baseline studies a total of 56,138 ha were mapped into 14 vegetated and 12 non-vegetated mapping units.

There is little information available for vegetation communities at risk in Nunavut therefore special landscape features were used to represent rare or sensitive ecosystems (Table 3.3-1). Special landscape features were classified as such due to their limited representation on the landscape, their higher likelihood to support rare or unique plant species or communities, or their inherent value as wildlife habitat. They include shrubby riparian ecosystems, sedge and shrub-dominated wetlands, marsh ecosystems, polygonal ground, marine ecosystems, and bedrock-lichen veneers.

Table 3.3-1. Special Landscape Features Descriptions and Rationale

<table>
<tr><th>Special Landscape Feature</th><th>Map Code</th><th>Description</th><th>Rationale for Inclusion</th></tr>
<tr><td>Betula-Ledum-Lichen</td><td>BL</td><td>Dry to mesic, poor to medium nutrient community occurring on hillslopes of glacial till containing thick covers of low dwarf birth, Labrador tea and a variety of dwarf shrubs, sedges, herbs and lichens.</td><td>• Winter foraging habitat for caribou due to reduced snow depths[2]
• High forage suitability for caribou, given abundance of terrestrial lichens</td></tr>
<tr><td>Emergent Marsh</td><td>EM</td><td>Permanently saturated rich to very rich communities which are rarely extensive and dominated by sedges, some hydrophilic herbs, and no shrubs or lichens, typically occurring along watercourses and ponds.</td><td rowspan="2">• Foraging and calving habitat for caribou
• Denning habitat for foxes
• Nesting habitat for waterfowl and snowy owl
• High sensitivity to anthropogenic disturbance
• High cover of some culturally valued vegetation species including cloudberries and bog cranberries</td></tr>
<tr><td>Wet Meadow</td><td>WM</td><td>Wet to very wet, medium to rich nutrient community occurring on plains and gentle lower slopes with constant water seepage dominated by thick covers of cotton-grass and sedges, few shrubs and lichens, and limited moss cover.</td></tr>
<tr><td>Marine Intertidal</td><td>MI</td><td>Wet, medium nutrient marine community strictly limited to intertidal flats and shorelines containing low floral diversity of salt-tolerant herbs, with no shrubs, mosses, or lichens.</td><td rowspan="2">• Gentle terrain used for trapping of wolves, foxes, and wolverine
• Higher likelihood of supporting rare plants, plant communities
• Exposed soils associated with active and old beaches can support a high cover of some culturally valued vegetation species</td></tr>
<tr><td>Marine Backshore</td><td>MB</td><td>Dry, nutrient poor community occurring directly upslope of marine backshore communities characterized by extensive deposits of washed marine sands with highly variable (but generally sparse) herb layer and few shrub, moss, or lichen species.</td></tr>
<tr><td>Polygonal Ground</td><td>PG</td><td>Mosaic of disjunct communities comprised of drier communities (raised peat mounds with communities similar to birch-ledum-lichen or birch-moss) and wet depressions (normally wet meadows) which typically occur in depressions and valley bottoms near lakes and ponds</td><td>• Unique arctic soil and ecosystem feature
• High sensitivity to anthropogenic disturbance</td></tr>
</table>

(continued)

Table 3.3-1. Special Landscape Features Descriptions and Rationale (completed)

Special Landscape Feature	Map Code	Description	Rationale for Inclusion
Riparian Willow	RW	Wet to very wet, medium to rich nutrient community restricted to active floodplains and seasonally fluctuating water tables with a thick cover of willow species and variable (often extensive) cover of sedges cotton-grass, and moss species.	• Nesting and security habitat with dense shrub cover • Foraging habitat for ungulates

There is no formal ranking system for identification for plant species at risk for Nunavut. A list of potential rare plant and lichen species were generated from collection records, existing literature and expert judgement including the General Status List for Nunavut Plant, Natureserve Canada, Porsild and Cody's Vascular Plants of Continental Northwest (1980) and Additions and Range Extension to the Vascular Plant Flora of Continental Northwest Territories, Nunavut (Cody, Reading, and Line 1993) and Enlichened Consulting Data (Goward and Björk 2010).

3.3.2 Terrestrial Wildlife

Terrestrial vertebrate studies have been conducted in the Hope Bay Belt area from 1996 through 2013. An active Wildlife Mitigation and Monitoring Program (WMMP) has been in place since 2006 across the entire Regional Study Area (RSA) of the Hope Bay Belt, and continues to collect information on wildlife species in the area. Wildlife in the area is evaluated at the RSA scale to account for the extensive home ranges and seasonal movements of large mammals such as Caribou (*Rangifer tarandus*), muskoxen (*Ovibos moschatus*), and Grizzly Bear (*Ursus arctos horribilis*). In 2010 and 2011, deoxyribonucleic acid (DNA) studies were conducted to determine Grizzly Bear and Wolverine (*Gulo gulo*) abundance and distribution patterns.

Additional wildlife surveys have been conducted in the region since the 1970s. These other wildlife surveys have included descriptions and mapping of wildlife habitats, inventories of wildlife sightings and signs (e.g., tracks and scat) collected during ground and helicopter reconnaissance trips, government radio-collar data, academic research projects and other historical work.

3.3.3 Ungulates

Results from the baseline studies and WMMP monitoring have identified two ungulate species in the RSA: Barren Ground Caribou (Ahiak and Dolphin-Union herds) and Muskoxen.

3.3.3.1 Barren Ground Caribou

Barren ground Caribou (a species of Special Concern) is a keystone species in the Arctic, both biologically and culturally (COSEWIC 2007, 2014). Caribou are a main prey item of Grizzly bears, wolves, Wolverines and foxes, and can alter the landscape. Historically, the Inuit have relied on Caribou for food and clothing. Three herds have historically been identified in the Hope Bay Belt area, notably the Bathurst, Ahiak, and Dolphin-Union herds.

Survey results during the period of 1996 to 2011 suggest that Ahiak Caribou used portions of the RSA for calving and post-calving during the late 1990's, reducing their use of the area by 2003. Collar data suggest that the calving range of the Ahiak herd has moved east and out of the RSA during this period. During the late 1990's, when spring (northern) and winter surveys were conducted, Caribou were found to use the RSA, likely Dolphin-Union Caribou. These spring and winter surveys were discontinued in the early 2000's. Spring surveys were again conducted between 2008 to 2010, and 2011 and Caribou use of the area during this period appears consistent with that observed in the late 1990's. A re-analysis of the post-calving Caribou data from 1996 and 2005 was conducted in 2010 to determine whether a zone of influence (ZOI) could be detected with either count or presence-absence data. No consistent ZOI was found, and it was determined that Caribou numbers from recent years (2006 to 2012) are too low to detect a ZOI during the post-calving period, if one exists. As a result, 2011 was the last year of aerial surveys for Caribou. In their place, TMAC contributes to GN regional Caribou monitoring programs,, and utilizes wildlife cameras to monitor wildlife movements near Hope Bay operations as outlined in the WMMP.

Three caribou herds have been documented to use habitats at the Project. Of these three herds, only one herd, the Dolphin and Union herd, is known to use marine habitats in addition to terrestrial. Dolphin and Union caribou are listed as a species of Special Concern under Schedule 1 of the Species at Risk Act (2002). Every spring and fall, Dolphin and Union caribou migrate across the sea ice in the Coronation Gulf, moving between mainland wintering habitats and calving and summering grounds on Victoria Island (Poole et al. (2010)).

Baseline surveys for Dolphin and Union caribou were conducted to examine the spring migration patterns of caribou across the sea ice. Aerial surveys were conducted in June 2010 across Melville Sound, upper Bathurst Inlet, and the Coronation Gulf to examine the broad scale patterns of caribou movement across the sea ice in relation to the Project. In addition, aerial surveys were conducted in May 2011 in Hope Bay, Roberts Bay, and Reference Bay to examine the local scale patterns of caribou movement. The results of these surveys indicate that, at a local scale, caribou movement across the sea ice mostly occurred along Hope Bay and Reference Bay; no caribou trails were recorded within Roberts Bay in May, 2011. At a larger scale, caribou crossings were more common in areas to the west of the Project; the majority of caribou tracks observed in June 2010 were recorded within northern Melville Sound along the southern shoreline of the Kent Peninsula. These results are consistent with satellite collaring studies of Dolphin and Union caribou. Poole et al. (2010) report that collared Dolphin and Union caribou wintering to the east of Bathurst Inlet follow two routes north, either crossing Melville Sound to the Kent Peninsula or travelling directly along the Kent Peninsula where it joins the mainland just east of Melbourne Island. These animals then cross Dease Strait to Victoria Island in May and early June.

3.3.3.2 Muskoxen

Muskoxen are observed in the RSA throughout the year, but numbers between years and seasons are highly variable. Based on historical surveys and incidental observations, muskoxen appear to be more common in the RSA during summer than during winter. Muskox are not a VEC, but were counted during aerial transect surveys for Caribou. In most years, both the proportion of groups with calves and the calf:adult ratio is low. The cause of this low calf:adult ratio is unknown. In 2012, however, a group of

20 young was recorded in a herd of approximately 50 animals. As with Caribou, 2011 was the last year of aerial surveys for Muskox. Moving forward, TMAC will utilize wildlife cameras to monitor wildlife movements near Hope Bay operations as outlined in the WMMP.

3.3.4 Carnivores

Results from the baseline studies and WMMP monitoring have identified five carnivore species in the RSA: Grizzly Bear, Wolverine, Wolf (*Canis lupus*), Arctic Fox (*Vulpes lagopus*), and Red Fox (*Vulpes vulpes*).

3.3.4.1 Grizzly Bears

Grizzly bears are a species of Special Concern (COSEWIC 2002) and are classified as Sensitive in Nunavut (COSEWIC 2005). Approximately 800 grizzly bears are found in the West Kitikmeot region at low densities (COSEWIC 2002). Grizzly bears are vulnerable to decline from increased adult mortality (McLoughlin, Taylor, Cluff, Gau, Mulders, Case and Boutin 2003; McLoughlin, Taylor, Cluff, Gau, Mulders, Case and Messier 2003; Meteorological Services of Canada (MSC) 2004). They also have low ecological resiliency, are sensitive to human activity, and are frequently displaced by industrial developments (Weaver, Paquet, and Ruggiero 1996; Ross 2002). Grizzly bears are regularly observed throughout the Hope Bay Belt area, and in 2009 at least eight individual Grizzly bears were identified in the northern Belt. Between 2005 and 2008, habitat use by Grizzly bears at various distances from the Project footprint was quantified as the proportion of riparian vegetation plots which had been used by Grizzly bears in each year. This study was discontinued due to safety concerns and replaced in 2010 with a more intensive one year-long assessment of Grizzly Bear population and distribution using a DNA hair capture study. Grizzly Bear DNA studies confirmed that this coastal system in northern Nunavut is highly productive for grizzly bears. Although it was not possible to estimate Grizzly Bear density because the study area does not represent a geographically closed population, results suggest that approximately 8 to 11 individual grizzly bears may be detected for every 1,000 km^2. Densities in western Nunavut are approximately 7 bears/1,000 km^2 (M. Dumond, GN-DOE, pers. comm.).

3.3.4.2 Wolverine

Wolverine populations in the central Arctic are stable (COSEWIC 2003) and classified as Secure in Nunavut (CESCC 2005), while the western Canadian population (which includes parts of Nunavut) is listed as a species of Special Concern (COSEWIC 2003). Wolverines use large home ranges and populations are generally of low density in the central Arctic (Mulders 2000). Wolverines use reproductive dens from February through April (Magoun and Copeland 1998). Food availability is the driving factor influencing movement patterns and home range selection by Wolverines (Banci 1994).

Wolverines have been observed in the Hope BayBelt area during aerial surveys and incidental observations. Between 2005 and 2008, Wolverine use of the Hope Bay Belt area was examined through a study of snow tracks across the study area. Wolverine DNA studies conducted in 2010 and 2011 detected a total of eight males and three females in the Hope Bay Belt area. Sample sizes and recapture rates were too small to conduct any population level analyses.

3.3.4.3 Wolves and Foxes

Wolves and foxes are classified as Secure in Nunavut (CESCC 2005); they are found throughout the Hope Bay Belt area and den in the area. Satellite-collar data indicate that wolves in the central Arctic migrate over large areas in the fall, winter and early spring, following the migratory Caribou herds (Walton et al. 2001). Wolves occupy smaller home ranges around the den during parturition and pup rearing (May to September; Walton et al. 2001). Wolf and fox dens are preferentially located in eskers, which can be limiting (McLoughlin et al. 2004). Carnivore den surveys located three wolf dens in the Hope Bay Belt area, with only one den that was active in 2009. Productivity of this den was not determined.

3.3.5 Terrestrial Wildlife - Birds

A number of bird species, including upland breeding birds, waterbirds, and raptors, have been identified in the Hope Bay Project area through baseline and Wildlife Mitigation and Monitoring Program WMMP studies, as well as incidental sightings. Results from previous baseline and monitoring studies have identified 25 species of upland breeding bird, 28 species of waterbirds, and 9 species of raptors to be present in the RSA.

Birds in Nunavut are protected under various forms of federal and territorial legislation. All upland breeding birds and waterbirds identified at Hope Bay through baseline and monitoring studies, with the exception of ptarmigan species, are considered "migratory birds" and are protected under the *Migratory Bird Convention Act* (1994). Raptors and Common Raven are not considered migratory birds under *the Migratory Bird Convention Act*. However, all bird species, including raptors, are protected under the Nunavut *Wildlife Act* (2003).

Several species encountered during baseline and monitoring studies in the Hope Bay Belt are of conservation concern at the federal and territorial level. Of the 62 species identified, two are listed under the federal *Species at Risk Act* (SARA; 2002). Peregrine Falcon and Short-eared Owl are listed as species of Special Concern under Schedule 1 of SARA. Several others are listed as Sensitive in Nunavut by the Canadian Endangered Species Conservation Council, including American Golden-plover, American Pipit, American Tree Sparrow, Arctic Tern, Common Eider, Glaucous Gull, Golden Eagle, Gyrfalcon, Harris' Sparrow, Hoary Redpoll, King Eider, Least Sandpiper, Long-tailed Duck, Red-necked Phalarope, and Rough-legged Hawk, Semipalmated Sandpiper, Snow Bunting, and White-crowned Sparrow.

3.3.5.1 Upland Breeding Birds

Upland breeding birds were surveyed in 2012 using the PRISM method, and the same six ubiquitous passerine species accounted for over 86% of detections. Shorebirds and ptarmigan were detected significantly less often than songbirds. When averaged across plots, results (numbers of species, adults, breeding territories, and nests detected) were similar for plots located within 1 km of Hope Bay Belt infrastructure and those farther away in both 2011 and 2012. Compared to upland habitats, lowland and mixed habitats supported on average one more species of upland breeding birds, and about four more breeding territories per 12 hectares of tundra. Active or recently active nests indicate breeding success is occurring within 1 km of Hope Bay Belt infrastructure.

3.3.5.2 *Raptors*

Raptors are relatively common in the northern Hope Bay Belt. Nest productivity and success, the number of eggs per occupied nest, and the proportion of occupied nests that successfully raised chicks, is highly variable between years. Results from 2012 indicate that raptor breeding success across the northern Hope Bay Belt was low for rough-legged hawks, but within the normal range for all species combined. There were four occupied raptor nests within 1 km of Doris North facilities in 2012, two of which were successful. In 2011, only one of ten occupied raptor nests within 1 km of Hope Bay Belt facilities was successful.

3.4 POTENTIAL ENVIRONMENTAL EFFECTS

3.4.1 Atmospherics

The activities associated with the Project have the potential to effect air quality, through the generation of emissions of criteria air contaminants (CACs) and also dust and acid deposition.

Potential interactions were identified using professional judgement and experience at other similar projects in Nunavut and include:

- Reduced air quality from
  - Emissions due to vehicle use, ore processing, incineration and fuel combustion, which reduce air quality; and
- Fugitive dust from
  - materials handling, vehicle movements, blasting and ; and
  - subaerial deposition of tailings

In the Doris North FEIS, the CAC emission and fugitive dust emission sources associated with the Project were assessed with the main sources to be stack emissions, vehicle exhaust emissions and aircraft emissions. The main sources of fugitive dust emissions were expected to be from vehicles travelling on unpaved roads, material handling, and emissions associated with blasting. Tailings deposition management was subaqueous with the maintenance of a water cover and was not considered a source of fugitive dust.

This current amendment application includes a change in tailings management to subaerial deposition with a dry cover. Subaerial tailings have the potential to generate fugitive dust emissions, however, there are proven mitigation measures that will be incorporated in tailings management to reduce emissions from the tailings.

Mitigation by design incorporates disposal of tailings in a designated area within the TIA, between the Interim Dike and the South Dam. Supernatant will drain from the tailings and pass through the Interim Dike to the Reclaim Pond. The beached tailings will be covered either with a dust suppressing layer of polymer and/or ice, or a rock cover, depending upon the season and point in mine life when deposited. This combination of drainage and cover will control fugitive dust emissions. Details of the monitoring and mitigation measures are provided in the Air Quality Management Plan (document P5-1) and Tailings Management System (document P6-13).

3.4.2 Terrestrial Ecosystems

Potential interactions between the Project and terrestrial ecosystems include:

- direct loss, or alternation,of ecosystems,vegetation and habitat;
- Fragmentation of ecosystems and habitat due to infrastructure development; and
- Dust deposition may result in ecosystem alteration due to effect to vegetation.

A direct loss of ecosystems and vegetation arises from construction of Project componenets on the tundra. The resulting effect is negative and non-mitigable because of a direct loss of vegetation within the constructed footprint. The aerial extent of this effect is minimized by reducing, wherever possible, the additional proposed amendment infrastructure footprint and avoiding critical habitat areas.

Habitat fragmentation is mitigated by design by constructingthe proposed expanded laydown area, and ore storage pads immediately adjacent to existing constructed footprints.

An indirect effect to terrestrial ecosystems and vegetation is the result of dust deposition. Fugitive dust can cause physical injuries to vegetation, including the alteration of photosynthetic receptors, respiration, and transpiration (Farmer 1993). Dust can also promote vegetation growth depending on the amount and frequency of dusting, the chemical properties of dust, and receptor plant species. Plant growth may be positively or negatively affected by a number of factors including dust-induced changes in soil pH and nutrient availability (Walker and Everett 1991; Farmer 1993; Auerbach, Walker, and Walker 1997), radiation absorption and leaf temperature (Eller 1977) and chemistry (McCune 1991; CEPA/FPAC Working Group 1998; Anthony 2001).

In order to determine the extent of potential dust deposition an area was considered around the proposed portion of the TIA (Figure 3.4-1). The area considered for potential dust deposition is based on knowledge of local wind patterns identified during baseline meteorological studies (Rescan 2011c). The area considered for dust effects is oriented along the north-south axis and extends 2 km north of the TIA interim dam, 1 km south of the southern margin of the proposed TIA, and 600 m on both the east and west sides.

The area considered for dust encompasses 465 ha in which 93.6 ha of special landscape features which may be impacted by fugitive dust emissions (Table 3.4-1). This area is primarily comprised wet meadow, riparian willow, and bedrock lichen with minor amounts of polygonal ground and emergent. This is a relatively small area within the footprint of the Project.

One rare plant, circumpolar reedgrass (*Calamagrostis deschampsioides*) is also located within the area considered for dustfall above the lake shore. An additional four species, smooth northern-rockcress (*Braya glabella* ssp. *glabella*), *Endocarpon pusillum, Collema ceraniscum and Campylium laxifolium* were identified on the western side of Doris Lake. These occurrences are outside the proposed infrastructure footprint and mitigation measures to reduce dustfall will reduce the potential to impact this vegetation.

Figure 3.4-1

Potential Alteration of Special Landscape Features and Rare Plants and Lichens

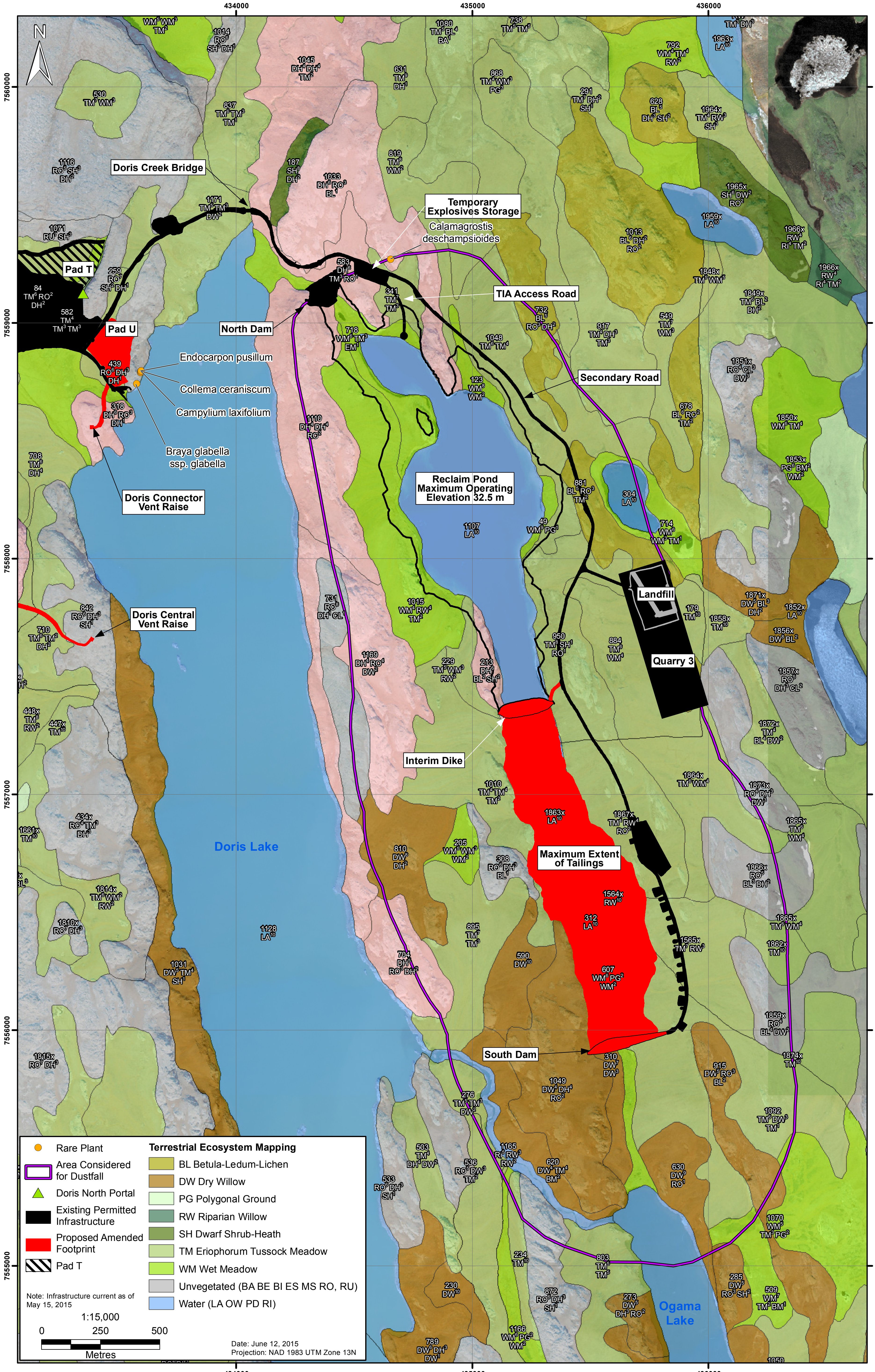


Table 3.4-1. Potential Area effected by Dustfall from TIA by Terrain Type

Component	Map Unit Type	Mapping Unit (Figure 3.3-1)	Area (ha)
Dust			465.5
	Vegetated and Non-vegetated	Betula Moss (BM)	2.0
		Dry Carex-Lichen (CL)	0.3
		Dryas-Herb Mat (DH)	54.5
		Dry Willow (DW)	71.4
		Rock Outcrop (RO)	53.1
		Dwarf Shrub-Heath (SH)	3.2
		Eriophorum Tussock Meadow (TM)	187.4
	Special Landscape Features	Bedrock Lichen (BL)	19.8
		Emergent Marsh (EM)	0.9
		Polygonal Ground (PG)	0.9
		Riparian Willow (RW)	26.8
		Wet Meadow (WM)	45.1
		Wet Meadow (WM)	2.6
		Grand Total	**465.5**

With the implementation of mitigation measures to reduce dust generated from the subaerial tailings and adaptive management incorporated into monitoring plans, no significant residual effects are anticipated to the terrestrial environment.

3.4.3 Terrestrial Wildlife

With the implementation of dust control mitigation measures, potential interactions to terrestrial wildlife is limited to habitat loss due to proposed amendment infrastructure expansion of laydown area, and ore storage pads. This interaction is screened as negative and mitigable. Mitigation measures incorporated at Doris North that will be maintained include:

- Minimizing overall Project footprint and avoiding significant habitat.
- Minimize noise on site
- Prevent wildlife from nesting or denning on project infrastructure
- Manage wastes to prevent attracting wildlife
- Manage vehicles and aircraft to reduce the chance of direct mortality and disturbance
- Avoiding clearing during wildlife sensitive periods or using qualified personnel to conduct pre-clearing surveys if clearing occurs within sensitive wildlife periods.

The construction of the expanded laydown and ore storage area (Pad U) is not expected to affect wildlife. The *Eriophorum*-tussock association is the most common plant community in the area of the proposed expansions. In general, the habitat value of cottongrass and sedge associations (*Eriophorum*-Tussock Meadows and Wetlands) is as a source of early summer forage for caribou and grizzly bears when the emerging leaves of the sedges are high in nutrients needed by lactating animals. Grizzly bear use of the area is unlikely, since the primary effect of developments on bears is through visual and auditory disturbances. Since these disturbances are unchanged at the Project site, no new effects are predicted for grizzly bears. *Eriophorum*-tussock habitats in the Project area were likely used by caribou when the Bathurst herd calved on the eastern side of Bathurst Inlet. However, now that the calving ground is located southwest of the Inlet, there is negligible use of these areas by Bathurst caribou during the early summer. Likewise, Dolphin-Union caribou do not use these areas in summer, because they spend the summer on Victoria Island. Similarly, this habitat is not used by Ahiak caribou because they now calve to the east in the Queen Maude Gulf Sanctuary. There is suitable raptor nesting habitat on the south face of the mesa. Construction of these storage areas, however, is not anticipated to affect these sites. Pad Uis within the extents assessed in the 2005 Final Doris North Environmental Impact Statement and adjacent to existing infrastructure, and therefore no additional impacts associated with these extensions are anticipated.

The Roberts Bay Laydown Area is located in a shallow pan bounded by Roberts Bay to the north and by rocky outcrops to the south and east. The expansion of the Laydown Area is planned to be contiguous with existing infrastructure and will not extend outside of the already-affected shallow pan where it is located. While the footprint of the Laydown Area will increase, the activities that will be carried out are not planned to change. Hence, the same level of disturbance from lights, noise and human presence and movement is expected. The primary effects of the Project on wildlife are expected to stem from disturbance. Since the level of disturbance is expected to remain constant, despite the footprint expansion, and this disturbance will be constrained to the same Laydown Area and shallow pan in which it is located, no additional effects on wildlife are anticipated.

Dolphin and Union caribou pass through the Roberts Bay area when migrating from their wintering grounds to the south to Victoria Island for the summer. When crossing sea ice, caribou are known to preferentially travel along capes, isthmus, and points such that their exposure on the ice is minimized. However, caribou are not expected to preferentially use the Roberts Bay Jetty and Laydown area as a migration corridor and no additional effect is expected due to the footprint expansion at the Roberts Bay Laydown Area. As Dolphin and Union caribou also utilize the marine environment during the migration periods as they cross the sea ice to and from Victoria Island, there is a potential that caribou may be affected by changes to the sea ice caused by the discharge of TIA effluent and groundwater to Roberts Bay (See Section 4.5 for further details). However, no effects are anticipated since Roberts Bay is not a main crossing point for caribou moving between the mainland and the Kent Peninsula and ultimately Victoria Island. Typically, caribou will select narrower crossing points from the points to the east or west of Roberts Bay, as evidenced by the results of aerial surveys conducted over the sea ice in 2011. Secondly, discharge of TIA effluent and groundwater to Roberts Bay is not expected to affect ice thickness and integrity (freeze timing) in Roberts Bay (Section 4.5.4). Therefore, there are no anticipated effects specifically to the Dolphin and Union caribou migration and sea ice crossing patterns due to the discharge of TIA effluent and groundwater to Roberts Bay.

Grizzly bears are known to travel along the coast and have been observed relatively often at the Roberts Bay site. Management plans for wastes (including garbage), fuels, and spills will minimize any attractive scents for grizzly bears and wolverine and ensure that bears do not receive any food rewards for investigating the Project site. No additional effects are anticipated for grizzly bears or wolverine due to the Roberts Bay Laydown expansion. Grizzly bears and wolverine are also the subject of ongoing DNA-based monitoring programs aimed at quantifying the number, habitat use, and effects on these species.

Upland breeding birds use the habitat types identified in the footprint area. Clearing of the expansion area will be conducted outside of the breeding bird season to minimize disturbance to adults and nests. Shorebirds and seabirds are not common in the Roberts Bay expansion area, but are instead observed nesting on the islands in Roberts Bay, where more exposed, rocky habitat is available and nest predators such as arctic foxes are less common. The nearest raptor nests are located approximately 2 km to the east and 3.5 km to the west of the Laydown Area. This distance is considered too great to cause any disturbance to raptors. Moreover, no new activities are planned at the site beyond those already conducted. Hence, no additional effects are expected for upland breeding birds, shorebirds or raptors due to the Laydown footprint expansion.

3.5 MITIGATION, MANAGEMENT AND MONITORING

3.5.1 Atmospherics

The following atmospheric monitoring programs have been implemented, are ongoing and will continue at Doris North. These programs may be complemented with snow core sampling program depending on the environmental conditions (e.g. snow pack and wind direction) to expand the monitoring network. Atmospheric monitoring includes:

- dust deposition using dustfall monitoring;
- particulate concentrations (PM_{10}, $PM_{2.5}$, and TSP) using Partisol samplers;
- SO_2, NO_2 and O_3 concentrations using a PASS; and
- measurements of meteorological data collected at the Doris North meteorological and micro-meteorological stations.

In an ongoing effort to mitigate emissions and dustfall, TMAC implements energy efficiency measures wherever possible, reduces fuel consumption wherever possible, and suppresses dust through application of appropriate dust suppressants, reduces exposed area of dusting sources, using emission control systems and maintain vehicle speed limits on all roads. These mitigation measures are suitable for emissions and potential fugitive dust associated with the proposed subaerial tailings.

Further details of the monitoring program and mitigation measures can be found in the Air Quality Management Plan provided in Package 5-1 and the Tailings Management System in Package 6-13.

3.5.2 Terrestrial

Wildlife mitigation and monitoring requirements for the Project were set out in the Doris North Gold Mine Project Certificate ((the NIRB) No. 003) and the Kitikmeot Inuit Association (KIA) Commercial

Land Lease (No. KTCL313D001). Monitoring activities are summarized in the Wildlife Mitigation and Monitoring Plan, which is revised regularly.

3.6 CUMULATIVE EFFECTS

With the implementation of mitigation measures and adaptive management incorporated into monitoring plans, no residual effects, and subsequent cumulative effects, are anticipated to the atmospheric and terrestrial environment.

4. MARINE ENVIRONMENT

4.1 INTRODUCTION

This section of the report presents the potential effects of the proposed changes to the Doris North Project to the marine environment of Roberts Bay focussing on physical oceanographic processes, water and sediment quality, invertebrate species, fisheries, and birds. The existing baseline marine conditions in the regional area and at the Project site are discussed and the potential environmental effects on water quantity, fisheries and birds are identified. A summary of the mitigation and management measures are provided and information on the various monitoring programs which have been undertaken at Doris North Project are identified.

4.2 REGIONAL SETTING

The Doris North Gold Mine Project (the Project) is located approximately 125 km southwest of Cambridge Bay, Nunavut, on the southern shore of Melville Sound. The proposed subsea pipeline and diffuser will be constructed in Roberts Bay, the marine receiving environment to the north of the Project area (Figure 4.2-1). Roberts Bay is an inlet in Melville Sound located at 68º 12' N, 106º 38' W.

Roberts Bay is typically ice covered from October to June, most of that time with land-fast ice. Roberts Bay is a wide embayment that is exposed to strong winds, which drive circulation in summer. In winter, the waters of the bay are isolated from wind stress by the land-fast ice cover. Water exchange between Roberts Bay and Melville Sound occurs primarily during the summer months when winds drive the upper freshwater layer towards the shoreline of Roberts Bay, and deeper waters move into Melville Sound.

Freshwater enters Roberts Bay from Little Roberts Outflow, Glenn Outflow, and smaller tributaries (Figure 4.2-2). The total volume of Roberts Bay is approximately 512,000,000 m^3, with a maximum depth of 88 m at the mouth between Roberts Bay and Melville Sound (see Figure 4.3-8).

Roberts Bay and the surrounding embayments are generally well oxygenated, low in metals and nutrients, and have very low phytoplankton biomass levels. The marine fish community of Roberts Bay is representative of an Arctic marine ecosystem, and 14 species have been found in Roberts Bay to date.

4.3 EXISTING PHYSICAL MARINE BASELINE CONDITIONS

4.3.1 Proximity to Designated Environmental Areas

Roberts Bay is located along the coastline of Melville Sound, in the West Kitikmeot region of Nunavut.

Environment Canada has indicated that these areas are important habitat for Pacific common eiders and Thayer's gulls, and also provide habitat to grizzly bears and wolverine (species proposed as "special concern" under *the Species at Risk Act* [SARA]).

There are currently no designated marine environmental areas around Roberts Bay. The closest area, by water, would be the proposed Huikitak River Cultural Area which is located in the southern part of Bathurst Inlet (Figure 4.3-1). The Queen Maud Gulf Bird Sanctuary encompasses a marine area along the shoreline and extending off land up to ~50 km distance. However, Roberts Bay is over 300 km away from this area by water, as Melville Sound is isolated from the Queen Maud Gulf by the Kent Peninsula (Figure 4.3-1).

4.3.2 Tidal Processes

Local tides in Roberts Bay were measured by installing a tide gauge operated along the southern shore of Roberts Bay from 2009 to 2011.

Results from the tide gauge have shown that there are the two main tidal cycles in Roberts Bay: the fortnightly spring-neap cycle, and the daily diurnal high-low tidal cycle (Rescan 2012b). Overall the tidal levels in Roberts Bay are small, with only minor differences between the daily tidal ranges of the spring and neap cycles; the spring tidal (new and full moon period) levels rarely exceeded 0.4 m while neap tidal levels (1st and 3rd quarter moons) were typically between 0.2 and 0.3 m. Tidal ranges at regional stations monitored by the Canadian Hydrographic Service (Cambridge Bay, Omingmaktok, Kugluktuk) are similar to those measured in Roberts Bay.

Figure 4.3-2 shows the time series of measured water levels in Roberts Bay for 2010. A tidal eliminator filter was applied to the measured levels to yield the residual, non-tidal signal, which represents water level fluctuations occurring in response to wind stress or other meteorological factors. Meteorological forcing (i.e. direct wind stress) account for changes in water level up to 0.5 m in this record, indicating that water levels in Roberts Bay are more readily influenced by winds rather than by tides.

Because of the weak tides in Roberts Bay, tidal currents will also be weak. For a 0.2 m change in water level during a flood tide, approximately 2,000,000 m^3 of water will enter Roberts Bay. The vertical section area of the bay entrance is approximately 75,000 m^2 (50 m deep × 1,500 m wide). Thus, a horizontal displacement at the entrance of approximately 27 m over the 12 hour period of flood would occur resulting in average currents of approximately 0.06 cm/s.

Under-ice current measurements made in early 2011 (Rescan 2012b) showed generally weaker tidal currents than the steady currents associated with down-slope density flows originating from brine rejection by growing sea ice.

4.3.3 Basin Circulation

The overall circulation of water in Roberts Bay will depend on the season (ice-covered vs. ice-free), as well as other factors, such as freshwater runoff and winds.

Winds and freshwater runoff volume can vary on an annual basis. The dates of freeze-up and break-up can also vary year by year so that the period over which wind stress can affect the waters of Roberts Bay varies. Therefore, annual variability in water column structure, circulation, and flushing are expected.