APPENDIX 8.1

Inventory Air Emissions

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1.0 INTRODUCTION

The emission sources from the construction of the Project include diesel generators, mobile heavy-duty equipment, light-duty passenger vehicles, blasting, and materials production and handling. The inventory of emission sources is based on the information available at the time of the assessment and forms the basis for determining the emissions from the Project. Carbon monoxide (CO), oxides of sulfur (SO_x) and oxides of nitrogen (NO_x), and $PM_{2.5}$ are emitted directly from stationary and mobile combustion sources and from blasting. Total suspended particulate (TSP) and $PM_{2.5}$ are also emitted from drilling and blasting, waste rock and aggregate processing and handling, on site concrete production, and traffic (i.e., road dust). The sources from construction of Project were categorized as follows:

- fuel combustion from stationary sources;
- fuel combustion from mobile sources;
- drilling and blasting;
- aggregate handling;
- on site concrete production; and
- road dust.

The sources of road dust can be further categorized into road dust from access road construction, site preparation, overburden and bedrock hauling, and hauling of concrete.

Emissions factors relate the production of gases and PM to energy production (e.g., kilograms per kilowatt-hour [kg/kW-hr]), fuel volume consumption (e.g., kilograms per 1000 litres [kg/1000 L]), or vehicular traffic (e.g., kilograms per vehicle kilometre travelled [kg/VKT]). Emissions factors recommended by Environment Canada are derived largely from the United States Environment Protection Agency (US EPA) standard summarized in the AP 42 document Compilation of Air Pollutant Emissions Factors, Fifth Edition (US EPA 1995 and 2006). The AP-42 emissions factors are typically listed for 'uncontrolled' emissions (i.e., for direct emissions of air and particulate matter assuming no emissions reduction technologies are associated with the emissions production mechanism). Where information exists, a series of modifiers to these uncontrolled emissions can be used to reflect the following:

- most industrial and mobile combustion sources have emissions reduction technologies incorporated in Project design; and
- road dust emissions can be partially controlled using suppressants such as water.

The Off-Road Compression-Ignition Engine Emission Regulations were promulgated on February 23, 2005 in Canada. These regulations introduced emission standards for model year 2006 and later diesel engines used in off-road applications such as those typically found in construction, mining, farming and forestry machines. These regulations encompassed the US EPA Tier 2 and Tier 3 standards. Thus, the US EPA Tier 2 and Tier 3 standards were used as emission factors for fuel combustion from the stationary and mobile emissions sources from Project. Detailed information on source emission assumptions, emission factors and emission rates can be found in Appendix 8.1 and values used for this assessment are summarized in the following section.

2.0 STATIONARY COMBUSTION SOURCES

Several Project activities will require stationary combustion sources, which will generate emissions during construction, operation and decommissioning and reclamation. A list of typical stationary was created based on the professional experiences on similar projects. Stationary combustion sources include the camp air conditioning and heating system, diesel generators, construction heaters, rock crushing and screening operations, concrete batch plant, and the power tunnel ventilation system. Available information on the make/model and quantity of stationary combustion is limited for this Project, therefore the following assumptions were made based on experience from similar Projects.

- Five 100 kW (kilowatt) generators were assumed to operate during the construction phase to provide electricity and to operate rock crushing and screening equipment, the concrete batch plant, and the tunnel ventilation system. A diesel consumption rate of 25 litres per hour (L/hr) was assumed based on the fuel consumption rates for Caterpillar diesel generators. This is likely a conservative assumption as use of these generators will stop once over-head power from the Saskatchewan grid is established; a construction phase activity.
- Propane will be combusted to provide heating and air conditioning on site. A propane consumption rate of 328 L/hr is assumed for both the construction camp area, and for construction of the power tunnel.

Emissions factors for stationary diesel generators use the Canadian Tier 2/3 Off-Road Compression-Ignition Engine Emission Standards for horse power from 130 kw to 225 kw (Table 1). The combustion emissions for particulate are all effectively smaller than 1.0 μm in aerodynamic diameter (d_{ae}), thus emissions factors are identical for $PM_{2.5}$, $PM_{10,}$ and TSP size classes. Air and particulate matter emissions estimates are summarized in Table 2. Emissions of sulfur dioxide are negligible due to the use of ultra-low sulfur diesel fuel.

Table 1: Emission factors for Diesel Combustion from Stationary Sources

Variable	TSP	PM_{10}	$PM_{2.5}$	NO_x	CO
Emission factors, kg/m^3	2.1	2.1	2.1	33.9	37.1

kg/m^3 = kilogram per cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 μm; $PM_{2.5}$ = Particular Matter with diameter < 2.5 μm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

Table 2: Emission Estimates (tonnes/year) for Diesel Combustion from Stationary Sources

		2014	2015	2016	2017
Annual diesel usage (m^3)		459	1,095	1,095	1,002
Emission rate, tonnes/year	TSP	0.96	2.30	2.30	2.10
	PM_{10}	0.96	2.30	2.30	2.10
	$PM_{2.5}$	0.96	2.30	2.30	2.10
	NO_x	15.56	37.12	37.12	33.97
	CO	17.03	40.62	40.62	37.17

m^3 = cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 μm;$PM_{2.5}$ = Particular Matter with diameter <2.5 μm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

Emission factors for propane combustion are based on the values contained in the Environment Canada NPRI toolbox (Environment Canada, 2013) for 'propane heaters' and are based on US EPA AP-42 Chapter 1.5

emissions factors (SCC #1-05-001-10). The emissions factors are identical for $PM_{2.5}$, $PM_{10,}$ and TPM size classes. The emissions factors for the propane heater are summarized in Table 3 and emissions estimates are summarized in Table 4.

Table 3: Emission Factors for Propane Combustion from Stationary Sources

Pollutant	TSP	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO
Emission factors, kg/m^3	0.2	0.2	0.2	1.0S*	13	7.5

Note: *S: content of sulphur in the fuel assumed to be 15 gr/100 ft^3 (Santa Barbara County Air pollution Control District 1997)
kg/m^3 = kilogram per cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm ;$PM_{2.5}$ = Particular Matter with diameter < 2.5 µm ; NOx = Nitrogen Oxide; CO = Carbon Monoxide

Table 4: Emission Estimates (tonnes/year) for Propane Combustion from Stationary Sources

		2014	2015	2016	2017
Annual propane usage (m^3)		1326	3031	3031	2543
Emission rate, tonnes/year	TSP	0.03	0.07	0.07	0.06
	PM_{10}	0.03	0.07	0.07	0.06
	$PM_{2.5}$	0.03	0.07	0.07	0.06
	SO_2	2.38	5.45	5.45	4.57
	NO_x	2.07	4.72	4.72	3.96
	CO	1.19	2.72	2.72	2.29

m^3 = cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter < 10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

3.0 MOBILE COMBUSTION SOURCES

Experience on other similar projects was used to create a list of mobile equipment that will be used for construction of the Project. The mobile equipment was grouped according to different construction activities based on the proposed construction schedule. The following additional assumptions were made to evaluate air and dust emissions:

- an operating time of all mobile equipment from 7 AM to 7 PM (12 hours) per day;
- a fuel weight of 0.84 kg/L (kilogram per liter) for diesel and 0.72 kg/L for gasoline (FAO 1992);
- a fuel consumption of 0.17 and 0.21 kg/brake hp-hour for diesel and gasoline respectively (FAO 1992); and
- the load factor is in the range of 0.38 to 0.7 with a medium value of 0.54 (FAO 1992).

The EPA Tier 2 – Phase 2 emission standards for heavy duty diesel vehicles was used as the emission factors for diesel combustion from mobile equipment. The emission factors and the emission estimates are summarized in Table 5 and Table 6, respectively. Emissions of sulfur dioxide are negligible due to the use of ultra-low sulfur diesel fuel.

Table 5: Emission Factors for Diesel Combustion from Stationary Sources

Variable	TSP	PM_{10}	$PM_{2.5}$	NO_x	CO
Emission factors, kg/m^3	0.04	0.04	0.04	0.73	14.86

kg/m^3 = kilogram per cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

Table 6: Emission Estimates (tonnes/year) for Diesel Combustion from Stationary Sources

		2014	2015	2016	2017
Annual diesel usage (m^3)		669	8,294	7,964	2,832
Emission rate, tonnes/year	TSP	0.03	0.33	0.32	0.11
	PM_{10}	0.03	0.33	0.32	0.11
	$PM_{2.5}$	0.03	0.33	0.32	0.11
	NO_x	0.49	6.06	5.81	2.07
	CO	17.03	9.94	123.26	118.35

m^3 = cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

The EPA Tier 2 Bin 6 full life emission standards for light duty internal combustion vehicles with all fuel types after 2009 were applied as emission factors for gasoline combustion from mobile sources. The factors and the emission estimates are listed in Table 7 and Table 8.

Table 7: Emission Factors for Diesel Combustion from Stationary Sources

Variable	TSP	PM_{10}	$PM_{2.5}$	NO_x	CO
Emission factors, kg/m^3	0.02	0.02	0.02	0.19	7.88

kg/m^3 = kilogram per cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; PM2.5 = Particular Matter with diameter <2.5 µm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

Table 8: Emission Estimates (tonnes/year) for Diesel Combustion from Stationary Sources

		2014	2015	2016	2017
Annual diesel usage (m^3)		382	2,529	1,602	323
Emission rate, tonnes/year	TSP	0.01	0.05	0.03	0.01
	PM_{10}	0.01	0.05	0.03	0.01
	$PM_{2.5}$	0.01	0.05	0.03	0.01
	NO_x	0.07	0.48	0.30	0.06
	CO	3.01	19.93	12.63	2.55

m^3 = cubic meter; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

4.0 DRILLING AND BLASTING EMISSIONS

During the drilling and blasting activities, particulate matter is emitted from drilling of charge holes, and from the displacement (fracturing, loosening or shifted) of solid rock through the use of explosives. The use of blasting explosives also emit CO, NO_x, and SO_2. The emission factors for estimating the air and dust emission from

drilling and blasting are the US EPA AP-42 document, section 11.9: Western surface coal mining and section 13.3: explosive detonations (US EPA *2006*).

A blasting plan was provided based on the requirements for excavation of the power tunnel and tailrace channel. Blasting is expected to occur 365 days per year at two fronts (headings) in the tunnel, and approximately 210 days per year for the tailrace and other structures. Approximately 160 holes will be drilled per day in the tunnel and 100 holes per day in the tailrace channel. A maximum of one blast in the tailrace/powerhouse area and two blasts in the tunnel/water intake area could be completed per day. For power tunnel blasting, the charge size is assumed to be 1.1 kg/m^3. Surface area blasted per day will be approximately 140 square meters (m^2) in the power tunnel for two headings, and 800 to 1,600 m^2 in the tailrace channel, assuming the contractor will use from four to eight drills in the tailrace channel. Amount of explosives used per day is projected to range from 2,500 to 9,000 kg per day, depending on whether one or two headings are used to develop the power tunnel and tailrace. Water resistant emulsion explosives will be used and the following additional assumptions were made:

- blasting to occur April to December in 2015 (275 days), January to December in 2016 (365 days), and January to June in 2017 (181 days) in the tunnel;
- blasting to occur approximately 210 days in 2015 and 2016 for the tailrace and other structures;
- conservative values of 1600 m^2 for blasting surface area in the tailrace channel and 9000 kg explosive per day;
- wet drilling will be implemented in order to control the production of fugitive dust. A dust control efficiencies of 96% was assumed (USBM 1987); and
- since no emission factor for emulsion explosives is available, the emission factors for ANFO as explosives will be used.

The emission factors for blast hole drilling are listed in Table 9.

Table 9: Emission Factors for Drilling Activity

Variable	TSP	PM_{10}	$PM_{2.5}$
Emission factors, kg/hole	0.59	0.31	0.31

TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter < 2.5 µm

The following emission factors were used to estimate PM emissions from the blasting activities:

$$TSP\ emission\ factor\ (kg/blast) = 0.00022(A)^{1.5}$$
$$PM_{10}\ emission\ factor\ (kg/blast) = 0.00022(A)^{1.5} \times 0.52$$
$$PM_{2.5}\ emission\ factor\ (kg/blast) = 0.00022(A)^{1.5} \times 0.03$$

In which, A is the horizontal area (m^2) that is displaced by blasting.

The emission estimates (tonnes) from drilling and blasting activities are summarized in Table 10.

Table 10: Emissions Estimates From Drilling And Blasting

	2015		2016		2017	
	Drilling	Blasting	Drilling	Blasting	Drilling	Blasting
TSP:, tonnes	1.53	3.03	1.87	3.05	0.68	0.05
PM_{10}, tonnes	0.81	1.57	0.98	1.59	0.36	0.02
$PM_{2.5}$, tonnes	0.81	0.09	0.98	0.09	0.36	0.00

TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm

The emission factors and emission estimate from blasting are listed in Table 11.

Table 11: Emission Factors for Blasting Explosives

Variable	CO	NO_x	SO_2
Emission factors, kg/tonne	34	8	1
Emissions (2015), tonnes	73.44	17.28	2.16
Emissions (2016), tonnes	111.69	26.28	3.29
Emissions (2017), tonnes	55.08	12.96	1.62

CO = Carbon Monoxide; NOx = Nitrogen Oxide; SO_2= sulfur dioxide

5.0 AGGREGATE HANDLING EMISSIONS

During the site preparation and construction, approximately 1,500,000 m^3 of overburden and bedrock will be processed and placed in the designated waste rock disposal areas. Some of the excavated rock may be used as road topping, riprap to armour the walls of the portion of tailrace channel, and to construct the submerged weir across the Fond du Lac River at Grayling Island. Similarly, portions of the overburden comprised of sand and gravel may be used as foundation and backfill material for the intake and powerhouse structures, construction material for the access roads, and aggregate for the production of concrete if deemed suitable.

The Project is estimated to use approximately 110,000 m^3 (220,000 tonnes) of granular fill and topping materials will be required for the construction of access roads. Approximately 10,000 m^3 (20,000 tonnes) of aggregate is required for concrete, and an additional 10,000 m^3 (20,000 tonnes) of granular material for structural backfill will be required. It is anticipated that the following approximate volumes of processed granular material will be used during construction:

- 40,000 tonnes in 2014;
- 170,000 tonnes in 2015;
- 40,000 tonnes in 2016; and
- 10,000 tonnes in 2017.

Particulate matter emissions occur during the handling and transfer material from one process to another during the construction of the Project. Emissions occur during material loading onto the open storage pile and load out from the pile. A predictive emission factor equation from US EPA AP-42 document, section 13.2.4: aggregate handling and storage piles was used in the emission estimation (US EPA 2006).

$$EF = k \times 0.0016 \times \frac{(\frac{U}{2.2})^{1.3}}{(\frac{M}{2})^{1.4}}$$

where, EF is the emission factor (kg/tonne); U is the mean wind speed (m/s); M: material moisture content(%); and k is the particle size multiplier, k_{TPM} = 0.74, $k_{(PM10)}$ = 0.35, and $k_{(PM2.5)}$ = 0.053.

Crushing emissions were estimated by applying emission factors published in section 11.19.2 of the U.S EPA AP-42 Fifth edition: Crushed stone processing and pulverized mineral processing (US EPA 2006). The emission factors for primary crushing, screening, and the conveyor transfer are listed in Table 12.

Table 12: Emission Factors for Particulate Matter from Crushing Plant

Emission Factor	Primary Crushing	Screening	Conveyor Transfer
TSP, kg/tonne	0.0027	0.0125	0.0015
PM_{10}, kg/tonne	0.0012	0.0043	0.00055
$PM_{2.5}$, kg/tonne	0.0006	—	—

Kg/tonne = kilogram per tonne; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter < 10 µm; $PM_{2.5}$ = Particular Matter with diameter < 2.5 µm

Additional assumptions were made in order to estimate the air emissions from the aggregate handling and crushing.

- A moisture content of 1.0 wt.% was assumed in the analysis; a conservative estimate compared to various limestone products (0.5 to 5.0 wt. %) derived from stone quarrying operations (US EPA 2006).
- The total amount of excavated rock and overburden of 1,500,000 m^3 was assumed to be equally processed in the four construction years.
- Although not all of the aggregate used for construction of access roads, concrete batching, and structural backfill will be crushed on site, the assessment conservatively assumes that 100% of aggregate that is used will be crushed and screened. Crushing and screening is assumed to occur equally in 2014 and 2015.

The mean local wind speed from the historical meteorological data at the Stony Rapids weather station is 2 metres per second (m/s). The emission estimates for aggregate handling and crushing are summarized in Table 13 and Table 14, respectively.

Table 13: Emission Estimates (tonne/year) for Aggregate Handling

		2014	2015	2016	2017
Material processing rate, tonne/year		790,000	920,000	790,000	760,000
Emission rate, tonne/year	TSP	2.45	2.85	2.45	2.36
	PM_{10}	1.16	1.35	1.16	1.11
	$PM_{2.5}$	0.18	0.20	0.18	0.17

Tonne/year = tonne per year; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm

Table 14: Emission Estimates (tonne/year) for Crushing in Year 2014 and 2015

Emission rates, tonne/year	Primary Crushing	Screening	Conveyor transfer	Total
TSP	0.35	1.63	0.20	2.17
PM_{10}	0.16	0.56	0.07	0.79
$PM_{2.5}$	0.08	0.00	0.00	0.08

tonne/year = tonne per year; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm

6.0 EMISSIONS FROM ON-SITE CONCRETE PRODUCTION

Concrete is composed essentially of water, cement, fine and coarse aggregate. Particulate matter from concrete production consists primarily of cement and pozzolan dust. Fugitive sources of dust include the transfer of sand and aggregate, truck loading, mixer loading, vehicle traffic, and wind erosion from sand and aggregate storage piles. The emission estimate includes the emissions from cement unloading, weigh hopper loading, mixer loading, and concrete truck loading.

Approximately 11,000 m^3 of concrete will be required for the Project, which will be produced in approximately equal amounts in 2015, 2016 and 2017. It is estimated that approximately 1400 tonnes of cement and cement supplements will be unloaded per year for three years, with an estimated 7000 tonnes of aggregate transferred to hoppers and feed bins per year. Best management practices will be followed so that the release of fugitive dust will be minimized. It is assumed that truck loading and mixer operations are controlled with a rubber sock. Since the cement and cement supplement were not separated in the information provided, the emission factors for cement supplement unloading to elevated storage silos were used for both cement and cement supplement unloading.

The emission factors published in AP-42, section 11.12: concrete batching were applied to estimate the emissions (US EPA 2006). The emission factors and the estimates of emissions were summarized in Table 15.

Table 15: Emission Factors and Emission Rates of Particulate Matter from Concrete Batching

		Cement Unloading	Weigh Hopper Loading	Mixer Loading	Truck Loading	Total
Emission factor, kg/tonne	TSP	0.0045	0.0026	0.0092	0.049	—
	PM_{10}	0.0024	0.0013	0.0028	0.0131	—
Emission rate, tonne/year	TSP	0.01	0.02	0.01	0.07	0.11
	PM_{10}	0.00	0.01	0.00	0.02	0.03

kg/tonne = kilogram per tonne; tonne/year = tonne per year; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm

7.0 ROAD DUST EMISSIONS

Deriving accurate estimates of road dust emissions for unpaved surfaces is complicated by environmental factors (e.g., local weather, silt and moisture content of surface materials), uncertainties in translating vehicle duty cycles into vehicle kilometres travelled (VKT), and uncertainties associated with road dust emissions factors as a function of vehicle type and weight. To derive conservative estimates of road dust emissions for the Project, emissions were broken down into the following four activities:

- access road construction;
- site preparation;
- overburden and bedrock hauling; and
- concrete hauling.

For each activity, silt content of the road surface is assumed to be 10 wt.%; a conservative estimate compared to scraper routes at construction sites (8.5%), plant roads (10%), or pit haul roads (8.3%) at stone quarries (US EPA 1995 and 2006). It was assumed that multiple daily road watering will be used to suppress road dust production during dry conditions in spring, summer and fall. As a result, and per the recommendations of Environment Canada's NPRI toolbox, a dust control efficiency of 70% is applied to the 'uncontrolled' road dust emissions estimate. Natural mitigation of road dust emissions also occurs when precipitation is >0.2 mm or when snow cover is deeper than 1.0 cm. The activity specific information for road dust emissions is summarized in Table 16. The spreadsheet from the NPRI toolbox was applied to estimate the road dust emission after the natural mitigation and watering. It is also assumed that only 25% of dust produced by vehicle traffic remains suspended in the atmosphere, while 75% of the dust is deposited to the surface within a few minutes after suspension (Watson and Chow 2000). The emission factors used in the NPRI toolbox were taken from Section 13.2.2: unpaved road in EPA AP-42 document (US EPA 2006). The emission factor equation is as follows:

$$EF = k\left(\frac{s}{12}\right)^{a}\left(\frac{Wfleet}{2.72}\right)^{b}$$

where, EF is size-specific emission factor (kg/VKT); VKT is the vehicle kilometers traveled (km); s is the surface material silt content (%); W_{fleet} is the fleet average weight of vehicle classes on the segment road (tonnes). The values for the empirical constants: k, a, and b are listed in Table 17.

Table 16: Activity Specific Inputs for Road Dust Emissions Estimates

Parameter	Road Construction	Site Preparation	Overburden and Bedrock Hauling	Concrete Related Hauling	
				Concrete Hauling	Aggregate Hauling
Road Length (km)	17.3	1.5	1	2.5	3.5
Silt Content (%)	10	10	10	10	10
Road watering reducing efficiency (%)	70	70	70	70	70
Fraction of dust suspended in the atmosphere (%)	25	25	25	25	25

km = kilometer; % = percent

Table 17: Empirical Constants in Unpaved Road Dust Emission Factor Equation

Constant	$PM_{2.5}$	PM_{10}	TSP
k (kg/VKT)	0.042	0.423	1.381
a	0.9	0.9	0.7
b	0.45	0.45	0.45

kg/VKT= kilogram per Vehicle Kilometres Travelled; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm

7.1 Road Dust Emissions from Access Road Construction

It is assumed that equal amounts of road construction will occur in 2014 and 2015. Ninety percent of the time allocated to site clearing is for access road construction. The total assess road length of the Project is 17.3 km.

Only large earth moving equipment that is expected to traverse the roadways at speeds greater than 5 km/hr was considered. For example, dozers and graders are considered, while large hydraulic excavators and cranes would not be considered. Table 18 lists the vehicle specific information used to calculate road dust emissions during the construction of the access road to the Project site and within the Project site. Table 19 summarizes the dust emission estimates from access road construction.

Table 18: Vehicle Specific Information for Access Road Construction

Vehicle Class	Average Daily Traffic (trips/day)	Gross Weight (t)	Total Weight (t)	Average Weight (t)
Wheel Tractor Scraper (Cat 673G)	2	52	90	71
Grader (Cat 14M)	3	25	25	25
Rubber Tire Loader (Cat 996k)	4	24	39	32
Articulated Rock Trucks (Cat 735)	3	31	64	48
Compaction equipment (Cat cs56)	4	12	12	12
Tractor dump trailer (Kenworth T800)	3	25	75	50

trips/day = trips per day; t = tonne

Table 19: Dust Emission Rates (tonne/year) from Access Road Construction

	2014	2015
TSP	3.54	4.69
PM_{10}	1.05	1.38
$PM_{2.5}$	0.10	0.14

tonne/year = tonne per year; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter <10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm

7.2 Road Dust Emissions from Site Preparation

The estimated area needed to be cleared and prepared for construction is 2 km^2. The road segment length vehicles travel for site preparation was assumed to be the diameter of a circular surface with the area of 2 km^2, which is approximately 1.5 km. The operating days for site preparation were assumed to be 10% of the total days used for clearing and access road construction.

Table 20 lists the vehicle specific information used to calculate road dust emissions during the site preparation. Table 21 summarizes the dust emission estimates from site preparation.

Table 20: Vehicle Specific Information for Site Preparation

Vehicle Class	Average Daily Traffic (trips/day)	Gross Weight (t)	Total Weight (t)	Average Weight (t)
Wheel Tractor Scraper (Cat 673G)	20	52	90	71
Grader (Cat 14M)	30	25	25	25
Rubber Tire Loader (Cat 996k)	30	24	39	32
Articulated Rock Trucks (Cat 735)	20	31	64	48
Tractor dump trailer (Kenworth T800)	10	25	75	50
Skidder (Cat 535c)	30	18	18	18
Feller Buncher (Cat 551)	20	36	36	36

trips/day = trips per day; t = tonne

Table 21: Dust Emission Rates (tonne/year) from Site Preparation

	2014	2015
TSP	0.28	0.35
PM_{10}	0.08	0.10
$PM_{2.5}$	0.01	0.01

tonne/year = tonne per year; TSP = Total Suspended Particulate matter; PM_{10} = Particulate Matter with diameter < 10 µm; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm

7.3 Road Dust Emissions from Overburden and Bedrock Hauling

The road segment length for haul trucks to move excavated material was assumed to be 1 km. The total overburden and bedrock to be relocated is 1,500,000 m^3, which will be hauled to the waste rock disposal areas throughout the construction phase (Figure 8.2-1). Table 22 lists the vehicle-specific information used to calculate road dust emissions from overburden and bedrock hauling. Table 23 summarizes the dust emission estimates from overburden and bedrock hauling.

Table 22: Vehicle Specific Information for Overburden and Bedrock Hauling

Vehicle Class	Average Daily Traffic (trips/day)	Gross Weight (t)	Total Weight (t)	Average Weight (t)
Rubber Tire Loader (Cat 996k)	25	24	39	32
Tractor dump trailer (Kenworth T800)	20	25	75	50
Rigid rock truck (Cat773)	10	103	164	134

trips/day = trips per day; t = tonne

Table 23: Dust Emission Rates (tonne/year) from Overburden and Bedrock Hauling

	2014	2015	2016	2017
TSP	0.81	4.17	3.7	0.75
PM_{10}	0.24	1.23	1.10	0.22
$PM_{2.5}$	0.02	0.12	0.11	0.02

tonne/year = tonne per year; TSP = Total Suspended Particulate matter ; PM_{10} = Particulate Matter with diameter <10 µm ;$PM_{2.5}$ = Particular Matter with diameter <2.5 µm

7.4 Road Dust Emissions from Concrete-related Hauling

It is assumed that concrete will be produced and consumed all year between 2015 and 2017. The concrete batching plant was assumed to be located in the western-most contractor work area (Figure 8.2-1). The average distance for concrete hauling from concrete plant to construction locations such as the bridge or powerhouse was assumed to be 2.5 km. The average distance for hauling aggregate for concrete production was assumed to be 3.5 km. Table 24 lists the vehicle-specific information used to calculate road dust emissions from concrete related hauling. Table 25 summarizes the dust emission estimates from concrete related hauling.

Table 24: Vehicle Specific Information for Concrete Related Hauling

Vehicle Class	Average Daily Traffic (trips/day)	Gross Weight (t)	Total Weight (t)	Average Weight (t)
Concrete mixing truck	2	13	26	20
Rubber Tire Loader (Cat 996k)	2	24	39	32

trips/day = trips per day; t = tonne

Table 25: Estimated Dust Emissions (tonne/year) from Concrete Related Hauling

Parameter	2015	2016	2017
TSP	0.30	0.30	0.30
PM_{10}	0.09	0.09	0.09
$PM_{2.5}$	0.01	0.01	0.01

tonne/year = tonne per year; TSP = Total Suspended Particulate matter ; PM_{10} = Particulate Matter with diameter <10 µm ;$PM_{2.5}$ = Particular Matter with diameter <2.5 µm

8.0 SUMMARY

Gases and particulate matter are emitted directly from fuel combustion by stationary and mobile equipment. The fossil fuels that are expected to be used for this Project include diesel, propane, and gasoline. The emission factors used to estimate the gas and particulate matter emissions are from EPA AP-42 compilation of air pollutant emission factors, or the EPA emission standards for different type of diesel and gasoline vehicles. The sources of fugitive dust include drilling and blasting, aggregate handling, concrete batching, and road dust. Dust emission estimates were made based on the emission factors published in EPA AP-42 and/or those incorporated in Environment Canada's NPRI toolbox. The emission estimates of gas and dust are summarized in Table 26. The annual emissions of SO_2 are below the NPRI reporting threshold (see Section 8.5.1, Table 8.5-2), whereas the $PM_{2.5}$, NO_x, and CO emissions (except for NO_x emission in 2014) have exceeded the reporting thresholds of NPRI. The annual emission of TSP exceeds the NPRI reporting threshold only in 2015 during the three construction years.

Table 26: Summary of Gas and Dust Emission during Construction of the Project

	Criteria Air Contaminant	2014	2015	2016	2017
Emission rate, tonne/year	TSP	10.3	**22.0**	14.2	6.5
	$PM_{2.5}$	**1.42**	**4.21**	**4.09**	**2.84**
	NO_x	18.2	**65.7**	**74.2**	**53. 8**
	SO_2	2.38	7.61	8.73	6.19
	CO	**31.2**	**260**	**286**	**140**

Bold values indicate those that exceed the NPRI reporting threshold (see Table 8.5.2)
tonne/year = tonne per year; TSP = Total Suspended Particulate matter; $PM_{2.5}$ = Particular Matter with diameter <2.5 µm; NOx = Nitrogen Oxide; CO = Carbon Monoxide

9.0 REFERENCES

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APPENDIX 8.2

Potential for Acid Deposition Due to the Project

February 2014
Report No. 10-1365-0004/DCN-171

1.0 INTRODUCTION

Combustion source emissions of SO_2 and NO_x from the Project have the potential to affect soil and water quality through atmospheric deposition of these acidic compounds. According to the Saskatchewan Ministry of Environment's (MOE) Air Quality Modelling Guideline (MOE 2012), modeling of acid deposition is only required when one or both of two criteria are met. This Appendix summarizes the calculations required to determine whether acid deposition modeling is required for the Tazi Twé environmental assessment. It was found that Tazi Twé Hydroelectric Project (Project) emissions lie below the MOE thresholds and thus, no acid deposition modeling is required for the Tazi Twé environmental assessment.

2.0 REGULATORY REQUIREMENTS

The 2012 Saskatchewan Air Quality Modelling Guideline indicates the following:

- the modeling of acid deposition cannot be undertaken with a screening or refined model and requires the use of a specialized model such as CALPUFF; and
- to ensure that a facility does not result in acid deposition issues, proponents are required to undertake regional acid deposition modelling if:
  a) the proponents combined emissions of SO_2, NO_x and NH_3 are greater than 0.175 t/d (metric tonnes per day) of H+ equivalent (**Criteria #1**); or
  b) the emissions from the facility are >5% of the baseline emissions in the region (**Criteria #2**).

Equation 1 is used to calculate total H^+ equivalents based on facility's emission of SO_2, NO_x and NH_3.

$$H^+ = 2\frac{SO_2}{64} + 1\frac{NO_2}{46} + 1\frac{NH_3}{17}$$

3.0 PROJECT EMISSIONS

Air emissions are highest during the construction phase of the Project. Annual construction emission between 2014 and 2017 for SO_2 and NO_x are summarized in Table 8.5-3 of the Tazi Twé environmental assessment. Table 1 of this memo summarizes the maximum annual emissions and the average annual emissions rate for the 2014 – 2017 construction periods.

Table 1: Tazi Twé Emissions

Parameter	SO_2 Emissions	NO_x Emissions
Maximum Tazi Twé Emission (t/y)	8.7	74.2
Average Tazi Twé Construction Emissions (t/y)	6.2	53.0
Maximum Tazi Twé H+ equivalents (t/d)	0.020[(a)]	
Average Tazi Twé H+ equivalents (t/d)	0.014[(a)]	
% of regional H+ emission (Max)	5.6%	
% of regional H+ emissions (Const. Avg.)	4.0%	

[(a)] = from equation 4
t/y = tonnes per year; t/d = tonnes per day; % = percent

3.1 Accounting for Missing Ammonia Emissions Data

Emissions factors for ammonia are not contained in the resources that Golder typically consults for urban/industrial emissions inventory calculations because ammonia emissions are primarily from agricultural sources (85-95%). However, NH_3 is known to react with SO_x and NO_x through a series of complex atmospheric photo-oxidation reaction pathways according to the following generalized, but unbalanced reactions:

$$SO_2 + NH_3 + H_2O \overset{hv}{\Rightarrow} (NH_4)_2SO_4 \quad \text{(Equation 2)}$$

$$NO_2 + NH_3 + H_2O \overset{hv}{\Leftrightarrow} NH_4NO_3 \quad \text{(Equation 3)}$$

and, whereas the SO_x reaction is irreversible, the NO_x reaction is thermally unstable and therefore reversible.

It is unlikely that Project emissions will provide enough ammonia to fully neutralize the atmospheric acids produced from the Project's sulphur and nitrogen emissions. However, to provide a conservative estimate of acid deposition potential, Golder has assumed that the sulphur and nitrogen conjugate bases have been fully neutralized by ammonium *in-situ*. This is expressed in Equation 4, a conservative modification of Equation 1.

$$H^+ = 2\frac{SO_2}{64} + 1\frac{NO_2}{46} + 1\frac{(2SO_2+1NO_2)}{17} \quad \text{(Equation 4)}$$

4.0 ACID DEPOSITION POTENTIAL

4.1 Ministry of Environment Criteria 1

Using Equation 4 Golder has calculated H^+ equivalents from the Project emissions (see Table 1). As indicated, the maximum annual emissions rate is 0.020 tonnes of H^+ per day (t/d) and the average for the 2014-2017 construction period is 0.014. These values are well below the Saskatchewan Ministry of Environment's threshold of 0.175 t/d, and indicate that acid deposition modelling is not required according to MOE's **Criteria #1**.

4.2 Ministry of Environment Criteria 2

There are eight (8) urban/industrial facilities within 300 km's of the Project who reported SO_x and/or NO_x emissions to Environment Canada's National Pollutant Release Inventory (NPRI[1]) for year 2011. Expanding the region of interest to Saskatchewan's Northern Air Dispersion Modelling Zone, there are 3 additional facilities in the region. The facility type, its name, and its 2011 NPRI emissions are summarized in Table 2. Where emissions are below the NPRI reporting threshold (i.e., 20 tonnes per year; t/y) their values have been calculated as one half of the reporting threshold (i.e., 10 t/y) in order to calculate the region's total baseline emissions.

Table 2: Facilities Reporting Air Emissions to NPRI in 2011

Facility Type	Name	SO_2 Emissions (t/y)	NO_x Emissions (t/y)
Mine/Mill	Key Lake Operation	316	114
Mine/Mill	Cluff Lake Project	<20	20.4
Mine/Mill	McArthur River Mine	<20	303
Mine/Mill	Cigar Lake Operation	<20	28.2
Mine/Mill	McLean Lake Operations	<20	<20
Mine/Mill	Rabbit Lake Operations	<20	47.9
Mine/Mill	Komis/EP Mine Site	<20	27.0
Power Plant	Third Lake Generating Station	<20	124
Power Plant	Manitoba Hydro - Brochet	<20	45.7
Compressor Station	NuVista Primrose Station 07-30	<20	101.4
Compressor Station	NuVista Primrose Station 05-26	<20	22.7
Total Emissions (t/y)		416	843
H^+ equivalents (t/d)		0.36	

t/y = tonnes per year; t/d = tonnes per day; < = less than

Table 1 includes a calculation of the ratio (expressed as a percentage; %) of the Project's H^+ equivalent emissions to those of the active facilities in the region, in order to evaluate "baseline emissions in the region". As indicated, the maximum emissions, which occur in 2016 are 5.6% of the baseline; the 2014 – 2017 average emissions are 4.6% of the regional baseline. Strictly speaking, the MOE requires acid deposition modelling if the proposed facility exceeds 5% of the baseline emissions for the region. However, professional opinion suggests that the proposed facility does not require acid deposition modelling for the following reasons:

1) The facilities emissions for SO_2 and NO_x are conservative;

2) The assumption that SO_2 and NO_x have reacted with sufficient NH_3 to neutralize these conjugate bases is very conservative;

[1] http://www.ec.gc.ca/inrp-npri/default.asp?lang=En&n=4A577BB9-1

3) The Northern Air Dispersion Modelling Zone is largely wilderness with few urban/industrial installation, therefore total emissions are very low compared to airsheds further south;

4) Smaller urban/industrial emissions sources are not required to report their emissions to NPRI;

5) NPRI emissions do not include emissions from mobile combustion sources (e.g., gasoline and diesel powered vehicles found in the region); and

6) The emissions are for the construction phase only and are therefore "low in magnitude, local in extent and reversible".

4.3 Deposition Calculated Using AERSCREEN

Compliance with the Saskatchewan Ministry of Environment's H^+ equivalents emissions criteria does not ensure compliance with the relevant water quality parameters associated with acid deposition. Thus Golder's Air Quality team used the output from the AIRSCREEN model to calculate deposition flux estimates for use by the terrestrial and aquatics teams. These calculations are presented in Section 8.5.3 of the environmental assessment, with the results summarized in Table 8.5-10.

5.0 CLOSURE

The Saskatchewan Ministry of Environment states two criteria which have to be met in order for a proposed facility to forego acid deposition modelling. Using emissions estimates that incorporated conservative to very conservative assumptions, the Project meets these criteria, thus no acid deposition modelling is required.

However, compliance with the air quality guidelines does not necessarily result in compliance with applicable Provincial or Federal water quality guidelines. As a result, the air quality team has provided conservative estimates of the S and N deposition rates to the ambient environment at a 2.5 km radius from the centroid of the region from which the Project's construction phase will produce air emissions.

APPENDIX 8.3

Noise and Blasting Assessment Methods

February 2014
Report No. 10-1365-0004/DCN-171

1.0 NOISE AND BLASTING ASSESSMENT METHODS

1.1 Noise Assessment Technical Terms

To help understand the analysis and recommendations made in this section, the following is a brief discussion of technical noise terms.

Sound pressure level is measured in Pascals (Pa) typically from 0.0002 to 20 Pa. Due to this large range of values, sound pressure levels are typically expressed using a logarithmic scale with units of decibels (dB). The dB scale compresses the values of 0.0002 to 20 Pa into a range of 20 to 120 dB. Since the scale is logarithmic, a sound that is twice the sound pressure of another will be 3 dB higher. However, it should be understood that the human ear also responds logarithmically to changes in sound pressure level. Therefore, a doubling of sound pressure, or in other words, a change in noise level of 3 dB is generally accepted as a slightly perceptible change (Cowan 1994). In other words, 3 dB represents the perceptible change threshold in noise level.

It is common practice to sum sound levels over the entire audible spectrum (20 hertz [Hz] to 20000 Hz) to give an overall sound level. However, to approximate the hearing response of humans, the frequency spectrum must be weighted to account for how the human ear perceives sound. The human auditory system is not equally sensitive to all frequencies of noise; it is most sensitive to noise in the frequency range of 1 kilohertz (kHz) to 4 kHz and less sensitive to noise at higher and lower frequencies. The A-weighting scale has been developed to reflect the frequency sensitivity of the human auditory system by placing more emphasis on noise at frequencies between 1 and 4 kHz and less emphasis on noise at other frequencies. When the A-weighting scale has been applied to a noise level, it is expressed in A-weighted dB, which is abbreviated as dBA. The C-weighting scale weights the frequencies between 70 and 4000 Hz uniformly, but below and above these limits, frequencies are slightly discriminated against. When the C-weighting scale has been applied to a noise level, it is expressed in C-weighted dB, which is abbreviated as dBC. C-weighting is used in conjunction with A weighting (the dBA and dBC levels are compared) for Low Frequency Analysis (LFN).

Environmental noise levels vary over time, and are described using an overall sound level, such as the energy averaged sound level (L_{eq}). The L_{eq} is the equivalent continuous sound level, which in a stated time, and at a stated location, has the same energy as the time varying noise level. It is common practice to measure L_{eq} sound levels to obtain a representative average sound level.

1.2 Noise Prediction Methods

1.2.1 Noise Model

The Type 7810 Predictor® (Predictor®) software, developed by Softnoise GMBH and distributed by Brüel and Kjaer, was identified as the appropriate software to develop a predictive noise model for the Project. Predictor® is capable of assessing the potential noise changes associated with the Project and the effectiveness of potential noise controls. In accordance with Rule 012, the noise propagation algorithms used by the model are consistent with international standards, in particular ISO 9613-2: 1996 Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation (ISO 1996). The model was used to predict daytime $L_{eq,day}$ and nighttime $L_{eq,night}$ in A-weighted decibels (dBA) and C-weighted decibels (dBC) for individual receptors and the entire noise study area.

The model has the ability to simulate a series of point, line, and area emission sources. Each source type can be characterized by entering octave-band sound emissions. Other parameters, such as building dimensions and

equipment enclosure noise attenuation ratings, are also used to define the nature of sound emissions. The Predictor® model also accounts for noise attenuation related to meteorological conditions (such as temperature and humidity), and ground cover and physical barriers that are natural (terrain-based) or man-made.

1.2.2 Model Input Parameters

Table 1 lists the configuration of the calculation parameters used to complete noise modelling for the Project.

Table 1: Noise Model Input Parameters

Parameter	Model Setting	Descriptions/Notes
standards	ISO 9613	■ All sources and attenuators are treated as required by the cited standard.
ground absorption	0.0 – water; 0.5 – rest of the Noise Study Area	■ These values represent the fraction of noise energy absorbed during interaction with each ground type.
temperature/humidity	10°C/ 70% Relative Humidity	■ Average summer conditions for area.
wind conditions	1 to 5 m/s	■ Default ISO 9613-2 – moderate inversion condition, each receptor downwind from each source 100% of the time.
terrain	Height lines (209 m – 344 m) at 5 m resolution	■ Ground elevation contours (i.e., height lines) were used to characterize the topography in the Noise Study Area.
reflection factors	0.8 – building walls 0.2 – disposal Areas	■ These values represent the fraction of noise energy reflected during interaction with building walls and Disposal Areas, respectively.

m = metres; m/s = metres per second; °C = Celsius

1.3 Noise and Blasting Assessment Methods

There are no provincial noise requirements or standard methods for completing assessments of the acoustic environment in Saskatchewan. For the purpose of this Project, Alberta Utility Commission (AUC) *Rule 012: Noise Control Directive* (AUC 2013) will be used; hereafter referred to as Rule 012. However, Rule 012 does not require a quantitative assessment of potential noise effects from energy industry facility construction and AUC does not provide any specific criterion thresholds to assess the construction noise for the Project. The guidance on assessing potential noise effects associated with the Project construction is taken from Health Canada. Health Canada provides some guidance for the assessment of environmental noise in the document *Useful Information for Environmental Assessments* (Health Canada 2010); hereafter referred to as the HC Guidance.

1.3.1 Broadband Noise Assessment

Sound level changes at the receptors need to be compared with the Permissible Sound Level (PSL) in accordance with Rule 012 (AUC 2012). The PSL is an A-weighted equivalent sound level (L_{eq} in dBA) calculated using a Basic Sound Level (BSL) derived from the population density and proximity to travelled roadways.

The BSL is then adjusted for:

- the time of day, to account for the nature of the activity; and
- temporary noise generating activities.

The nighttime PSL is equal to the nighttime BSL at noise receptors and the daytime PSL is 10 dB higher than nighttime PSL according to AUC Rule 012. The applicable daytime (7:00 a.m. to 10:00 p.m.) and nighttime (10:00 p.m. to 7:00 a.m.) PSLs at noise-sensitive receptor locations and at the 1.5 km Boundary are summarized in Table 2. The determination methods and calculation of the PSLs at the selected receptors based on methods in the Rule 012 is provided in Table 3. Among the receptors, NR5 is the closest dwelling. The dwelling density per quarter section of land for the Black Lake Community is within the range of 9 to 160 dwellings. The dwellings in the Black Lake Community (NR5) have the PSL values that are 3 dB higher than the PSLs for the other receptors (NR1 and NR2).

Table 2: Permissible Sound Level for Local Sound-sensitive Receptors

Receptor Location	Permissible Sound Levels[(a)] (dBA)	
	Daytime PSL	Nighttime PSL
NR1 – Permanent Resident's Cabin	50	40
NR2 – Camp Grayling	50	40
NR5 – Black Lake Community	53	43
1.5 km Boundary	50	40

[(a)] The PSL values were determined in accordance with Rule 012 (AUC 2012).

dBA = A-weighted decibels; PSL = Permissible Sound Level.

Table 3: Permissible Sound Level Calculation for Local Sound-sensitive Receptors

Basic Nighttime Sound Level				Nighttime		Daytime	
Proximity to Transportation	Dwelling Unit Density [# per ¼ Section of land]						
	1 to 8 Dwellings	9 to 160 Dwellings	>160 Dwellings	NR5 (Black Lake Community)	Other Receptors and Criteria Boundary	NR5 (Black Lake Community)	Other Receptors and Criteria Boundary
Category 1	40	43	46	43	40	43	40
Category 2	45	48	51				
Category 3	50	53	56				
Basic Sound Level (BSL)				**43**	**40**	**43**	**40**
Daytime Adjustment							
Reason for Adjustment			Value [dBA L_{eq}]				
Adjustment for nighttime hours (22:00 to 07:00)			0	0	0	n/a	n/a
Adjustment for daytime hours (07:00 to 22:00)			10	n/a	n/a	10	10

Table 3: Permissible Sound Level Calculation for Local Sound-sensitive Receptors (continued)

Basic Nighttime Sound Level				Nighttime		Daytime	
Proximity to Transportation	Dwelling Unit Density [# per ¼ Section of land]						
	1 to 8 Dwellings	9 to 160 Dwellings	>160 Dwellings	NR5 (Black Lake Community)	Other Receptors and Criteria Boundary	NR5 (Black Lake Community)	Other Receptors and Criteria Boundary
Nighttime/Daytime Adjustment				**0**	**0**	**10**	**10**
Class A Adjustment							
Class	Reason for Adjustment	Value [dBA L_{eq}]					
A1	Seasonal Adjustment (1 Nov - 31 Mar)	5		n/a	n/a	n/a	n/a
A2	Absence of Both Tonal and Impulse/Impact Components	5		n/a	n/a	n/a	n/a
A3	Ambient Monitoring Adjustment depending on the difference between the BSL and the measured Leq.	-10 to +10		0	0	0	0
Total Class A Adjustments				**0**	**0**	**0**	**0**
Class B Adjustment							
Class	Reason for Adjustment	Value [dBA L_{eq}]					
B1	1 day	15		n/a	n/a	n/a	n/a
B2	1 week	10		n/a	n/a	n/a	n/a
B3	< or = to 2 months	5		n/a	n/a	n/a	n/a
B4	> 2 months	0		0	0	0	0
Class B Adjustment = one only of B1, B2, B3 or B4							
Total Class B Adjustment				**0**	**0**	**0**	**0**
Permissible Sound Level (PSL) [dBA]				**43**	**40**	**53**	**50**

dBA = A-weighted decibels; PSL = Permissible Sound Level; L_{eq} = equivalent sound level.

To demonstrate regulatory compliance, Rule 012 requires that total noise levels be compared to a mandated PSL. The total noise level is calculated as the sum of:

- an assumed Ambient Sound Level (ASL) whose value is specified by Rule 012;
- the noise contribution from existing and approved energy resource and power generating facilities in the area; and
- the noise contribution from the assessed facility under representative operating conditions.

The average nighttime rural ASL in Alberta is about 35 dBA L_{eq} based on research completed by the Environment Council of Alberta. The existing acoustic environment of the Project site is believed to have the same average nighttime ASL of 35 dBA as that in rural areas of Alberta. The methods included in AUC Rule 012 allow this value to be adjusted based on residential density or heavy traffic through the determination of PSL criteria. According to Rule 012, the average nighttime ASL is 5 dB less than the nighttime BSL. The daytime ASLs are 10 dBA higher than nighttime levels as described in Section 2.1 of Rule 012. Based on the method outlined in Rule 012, a nighttime ASL of 35 dBA is considered representative of the NR1 and NR2 receptors. The dwelling density per quarter section of land for the Black Lake Community is within the range of 9 to 160 dwellings. The dwellings in the Black Lake Community have ASL values that are 3 dB higher than the ASLs of the NR1 and NR2 receptors. The ASLs for the receptors and at the 1.5 km Boundary are listed in Table 4.

Table 4: Ambient Sound Level for Local Sound-Sensitive Receptor

Receptor Location	Ambient Sound Levels[(a)] (dBA)	
	Daytime ASL	Nighttime ASL
NR1 – Permanent Resident's Cabin	45	35
NR2 – Camp Grayling	45	35
NR5 – Black Lake Community	48	38
1.5 km Boundary	45	35

[(a)] The Ambient Sound Level values were determined in accordance with Rule 012 (AUC 2012).

dBA = A-weighted decibels; ASL = Ambient Sound Level.

1.3.2 Low Frequency Noise Analysis

AUC Rule 012 requires that LFN effects also be considered. A LFN condition may exist when:

- the value of the predicted sound level (expressed in dBC) minus the predicted sound level (expressed in dBA) equals or exceeds 20 dB; and
- a clear tonal component exists at a frequency below 250 hertz (Hz).

The first condition can be assessed with predictions; the second condition can only be established with sound measurements.

1.3.3 Health Canada Criteria

The guidance on assessing potential noise effects associated with the Project construction is taken from Health Canada. The HC Guidance suggests five specific criteria for assessing noise impact:

- Noise-Induced Hearing Loss (NIHL);
- sleep disturbance;
- speech comprehension;

- complaints; and
- high annoyance.

One of noise criteria recommended by the HC Guidance and used in this assessment is "change in high annoyance (%HA)". The %HA is calculated based on the day-night energy equivalent noise level ($L_{eq,dn}$) using the formula presented below:

$$\%HA = \frac{100}{1 + e^{(10.4 - 0.132 \times L_{eq,dn})}}$$

where $L_{eq,dn}$ is defined in the formula presented below based on the 15 hour daytime equivalent energy noise level ($L_{eq,day}$) and 9 hour nighttime equivalent energy noise level ($L_{eq,night}$):

$$L_{eq,dn} = 10log_{10}\left(\frac{15 \times 10^{L_{eq,day}/10} + 9 \times 10^{(L_{eq,night}+10)/10}}{24}\right)$$

$L_{eq,day}$ and $L_{eq,night}$ here are the HC total daytime and nighttime noise levels calculated through the logarithmic addition of measured or estimated baseline noise levels and predicted noise contribution from the Project construction/operation for the periods of daytime and nighttime respectively.

If the %HA increases by 6.5% or more as a result of the Project, then the HC Guidance recommends mitigation be considered. In other words, a change in %HA greater than 6.5% is indicative of a potential adverse noise impact.

Health Canada considers that there is no known risk of hearing loss associated with sound levels ($L_{eq,day}$ and $L_{eq,night}$) below 70 dBA, regardless of the exposure duration.

To limit sleep disturbance at receptor locations, Health Canada recommends that nighttime total sound levels ($L_{eq,night}$) be maintained below 45 dBA and that there be no more than 10 to 15 discrete events exceeding 60 dBA (Health Canada 2010).

The HC Guidance indicates that outdoor total noise levels should be maintained below ($L_{eq,day}$ and $L_{eq,night}$) 55 dBA so that good outdoor speech clearness. In other words, a total noise level greater than 55 dBA is indicative of a potential adverse noise impact. Health Canada advises that a "no reaction" response corresponded to a normalized outdoor $L_{eq,dn}$ of 55 dBA, and that complaints tend to occur and become more widespread at noise levels above 55 dBA.

1.3.4 Blasting Assessment Methods

Blasting activities are identified as the source for both ground-borne and airborne vibrations. The level of vibration experienced by receptors will be directly related to the amount of charge (explosive material) used for a blast. The intensity of ground vibrations from blasting operations are primarily a function of the maximum explosive weight detonated (set off) per delay period and the distance between the blast and the receptor.

Blasting noise and vibration require a different approach due to the impulse nature of this source. There are no regulatory requirements for environmental noise and vibration from blasting for Saskatchewan; therefore, the blasting vibration limits presented in the Ontario Ministry of Environment (MOE) Noise Pollution Control (NPC) publication 119 (NPC 119) and the Ontario Provincial Standard Specification (OPSS 120) were used as the blasting criteria for the Project.

The NPC 119 addresses both ground and air vibrations. Both ground and air vibration effects produced at private structures adjacent to surface or underground mining operations are subject to guidelines contained in NPC 119 of the model Municipal Noise Control By-law, dated August 1978, published by the Ontario MOE (Ontario MOE 1978). According to NPC 119, the cautionary limits for ground vibration Peak Particle Velocity (PPV) in the unit of (mm/s) and air vibration Peak Pressure Level (L_{peak}) in unit of (dBL) from blasting operations in a mine or quarry at receptors are 10 mm/s and 120 dBL, respectively. Under conditions where monitoring of the blasting operations is routinely carried out, the recommended ground vibration PPV and air vibration L_{peak} limits at the receptors would be 12.5 mm/s and 128 dBL respectively. The limits set by NPC 119 are listed in Table 5. Therefore, limits under conditions of routine monitoring are used for the blasting activity assessment of the Project (i.e., 12.5 mm/s and 128 dBL for ground vibration and air vibration limits).

Table 5: Ground and Air Vibration Guidelines for the Project Blasting Activity (NPC 119)

Vibration Type	Unit	Cautionary Limits	Limits under Conditions of Routine Monitoring
Ground Vibration	Peak Particle Velocity (mm/s)	10	12.5
Air Vibration	Peak Pressure Level (dBL)	120	128

mm/s = millimetres per second; dBL = linear decibel.

The NPC 119 is intended for mines and quarries and not specifically for construction. The Ontario Provincial Standard Specification (OPSS 120) is used as a guideline for construction blasting limits for the ground vibrations as shown in Table 6. There are no specific limit values for air vibration in OPSS 120.

Table 6: Ground Vibration Limits for the Project Blasting Activity (OPSS 120)

Element	Frequency (Hz)	PPV (mm/s)
Structures and Pipelines	≤ 40	20
	> 40	50

Hz = Hertz; PPV = Peak Particle Velocity; ≤ = less than or equal to; > = greater than

The Project will follow Best Management Practices from the Ontario Water Association (OWA) Drilling & Blasting (BMP-021). BMP-021 states that “If ground vibration maximum levels (30 mm/s) are exceeded, all blast operations will cease until a revisited blast design, certified by the Engineer, has been submitted”. Based on the limits presented in the above tables (Tables 5 and 6) and BMP-021 requirements, a set of limits was compiled for the Project construction blasting assessment through combining the limits required by NPC 119, OPSS 120 and BMP-021, which is shown in Table 7. In summary, the blasting vibration limits for ground vibration and air vibration are 30 mm/s for PPV and 128 dBL for L_{peak}.

Table 7: Combined Ground and Air Vibration Limits for the Project Blasting Activity

Vibration Type	Unit	Limits for Construction with Blasting
Ground Vibration	Peak Particle Velocity (mm/s)	30
Air Vibration	Peak Pressure Level (dBL)	128

mm/s = millimetres per second; dBL = linear decibel.

To help provide context for the chosen limits, Table 8 and Table 9 show common ground vibration PPV and air vibration Peak Pressure Level (L_{peak}).

Table 8: Vibration Levels Generated by Everyday Activities

Vibration Level (mm/s)	Activity
0.8	walking
0.8	heel drops
7.1	Jumping
12.7	door slams
22.4	pounding nails

Source: Dowding (1985); mm/s = millimetres per second.

Table 9: Typical Peak Pressure Level Criteria

Peak Pressure Level /Overpressure Level (dBL)	Damage Measure
180	some structural damage possible
171	general window breakage
151	occasional window breakage
140	long-term history of application as safe project specification
134	United States Bureau of Mines recommended maximum for large-scale surface mine blasting

Source: International Society of Explosives Engineers (ISEE 1998); dBL = linear decibel.

Blast-induced vibrations, both surface (as airborne noise) and body (underground) waves, naturally attenuate with increased distance from the blast site. This is due to material damping and geometric spreading. Body waves attenuate more rapidly than the surface waves. This results in the surface waves being more dominant at greater distances. The vibration intensity perceived or measured at the closest off-site points of reception around the Project site would be dominated by air vibration (i.e., surface waves or the blasting noise [L_{peak}]).

1.3.4.1 Ground Vibration Assessment

Ground vibration was calculated to determine the PPV in millimetres per second (mm/s) due to the blast. The rate at which ground vibrations decay or attenuate from a blast site can be expressed by the scaled distance, which is defined as follows:

- scaled distance $SD = D/\sqrt{W}$
  - where D = distance (m) between the blast and receptor
  - W = maximum weight of explosive (kilogram) detonated per delay period

The prediction of maximum ground vibrations can be calculated based on the following equation in Blaster's Handbook of International Society of Explosives Engineers (ISEE 1998):

- $PPV=1725(SD)^{-1.6}$
  - where PPV = Peak Particle Velocity (mm/s)
  - SD = scaled distance (metre per kilogram$^{0.5}$)

1.3.4.2 Air Vibration Assessment

For air vibration or blasting noise, the L_{peak} values were calculated to determine the instantaneous maximum noise level during a blast event. Air vibration levels were predicted using a linear attenuation model. Air vibrations attenuate from a blast site at a slower rate than ground vibrations. The distribution of air vibration energy from a blast is also strongly influenced by the prevailing weather conditions during the blast. Other factors influencing air vibration distribution from a blast include the following:

- the length of collar and type of stemming material;
- differences in types of explosive material; and
- variations in burden distance.

The rate at which air vibrations decay or attenuate from a blast site can be expressed by the scaled distance, which is defined as follows:

- scaled distance $SD = D/\sqrt[3]{W}$
  - where D = distance (m) between the blast and receptor
  - W = maximum weight of explosive (kilogram) detonated per delay period

Prediction of maximum air vibrations was based on the following equation (ISEE 1998), which assumes average burial of the explosive:

- $L_{peak}=20\log_{10}((SD)^{-1.1})+170.75$
  - where L_{peak} = Peak Pressure Level (dBL)
  - SD = scaled distance (foot per pound$^{0.33}$, ft/lb$^{0.33}$)

Or

- $L_{peak}=20\log_{10}((2.52(SD))^{-1.1})+170.75$
  - where L_{peak} = Peak Pressure Level (dBL)
  - SD = scaled distance (metre per kilogram$^{0.33}$, m/kg$^{0.33}$)

No other noise sources were included in the L_{peak} calculation.

1.4 Project Assessment Scenarios and Emissions

1.4.1 Project Construction

The Project infrastructure includes the powerhouse, water intake, bridge, access roads, power tunnel, and tailrace channel. The construction phase was recognized as the major phase resulting in the largest noise effects from the Project at receptor locations, primarily from blasting activities. Project construction is expected

to commence in August 2014 and completed in November 2017. Changes in noise levels at receptor locations during Project construction will vary based on type of construction activity, associated equipment and their proximity to noise receptors. The primary sound sources associated with construction are various pieces of large off-road mobile equipment such as excavators, graders, land cranes, loaders and haul trucks, as well as stationary equipment such as rock crushing and screening operations, and a concrete batch plant. The amount of noise generated by construction activities will depend primarily on the number and type of sound sources and their proximity to noise receptors.

Potential noise effects associated with Project construction will be predicted using computer noise models that account for the major sound sources associated with the different construction activities. Fifteen Project construction components/activities were identified as key sources of sound emission. The major sound emission activities of the Project construction phase are listed in Table 10.

Table 10: Project Construction Activities

Construction Phase	Construction Activities	Timelines
1	Clearing and Access Infrastructure	From August 2014 to November 2014 From April 2016 to July 2016
2	Bridge Construction	From March 2015 to April 2015
3	Camp (on west side) with Power and Communications	From Jan 2015 to March 2015
4	Intake and Powerhouse Excavation	From May 2015 to July 2015
5	Tailrace Excavation	From May 2015 to November 2015 From April 2016 to October 2016
6	Tunnel and Surge Shaft	From April 2015 to June 2017
7	Transmission Line and Communications	From April 2015 to June 2015 (Construction Power); From April 2017 to July 2017 (Transmission Line and Communications)
8	Powerhouse Structure	From April 2015 to November 2015 From April 2016 to September 2016
9	Penstock / Tunnel Tie-in	From July 2016 to October 2016
10	Submerged Weir	From June 2016 to July 2016
11	Intake Structural, Gate & Hoist Installation	From July 2017 to November 2017
12	Powerhouse Maintenance & Evaluation	From October 2016 to November 2017
13	Turbine & Generator Installation	From October 2016 to August 2017
14	Commissioning	From September 2017 to November 2017

According to the Project schedule, the periods with the most construction activities are as follows:

- **From May to June 2015,** there are five activities planned to occur at the same time. This period is referred to as Project Construction 1, and includes the following activities:
  - Clearing and Access Infrastructure;
  - Intake and Powerhouse Excavation;
  - Tailrace Excavation;

- Tunnel and Surge Shaft; and
- Transmission Line & Communications.

- **In July 2016,** there are five activities planned to occur at the same. This period is referred to as Project Construction 2, and includes the following activities:
  - Tailrace Excavation;
  - Tunnel and Surge Shaft;
  - Powerhouse Structure;
  - Penstock / Tunnel Tie-in; and
  - Submerged Weir.

Because for Project Construction 1, the activities "Clearing and Access Infrastructure" and "Transmission Line and Communications" will be completed along the access roads, the noise levels at receptor locations during the Project Construction 1 will vary based on the locations of these two construction activities (i.e., based on their proximity to noise receptors). Noise sensitive receptor NR2 is to the south of the Project site; the other two noise receptors (NR1 and NR5) are on the west side of the Project site (Section 8.2, Figure 8.2-1). Two scenarios are assessed for Project Construction 1.

- Scenario 1:
  - For this scenario, the location of equipment used for the two activities along the west part of the access is chosen to be the closest location to NR1 and NR5 along the access roads.
- Scenario 2:
  - For this scenario, the location of equipment used for the two activities is chosen to be the closest location to NR2, which is a spot located at the southeastern part of the access road.

The total noise levels from the Project construction are needed to assess the noise effect. For a specific period, noise contribution from the simultaneous construction activities was predicted for the noise assessment receptors and within noise study area.

During the construction of the Project, which includes construction of camp, bridge, tunnel, tailrace, intake, powerhouse and access roads, it is anticipated that noise/vibration will be generated by the following sources**.**

Stationary Equipment

- Rock Crushing and Screening Operations including one rock crusher and one vibratory screen;
- Concrete Batch Plant including three concrete mixers;
- Diesel Generators;
- Camp Air Conditioning and Heating System;
- Construction Heaters; and

- Tunnel Ventilation Equipment;

- **Mobile Equipment**
  - Articulated Truck;
  - Rigid Rock Truck;
  - Wheel Tractor Scraper;
  - Motor Grader;
  - Compaction Equipment;
  - Track Drill;
  - Skidder;
  - Feller Buncher;
  - Hydraulic Excavator;
  - Rubber Tire Loaders;
  - Crawler Tractors;
  - Tunnel Rubber Tired Loader;
  - Shaft Drill;
  - Forklift;
  - Skid Steer Loader;
  - Telehandler;
  - Man Lift;
  - Tractor Dump Trailer;
  - Concrete Mixing Truck;
  - Concrete Pump Truck;
  - Fuel Truck;
  - Water Truck;
  - Flat Deck;
  - Boom Truck;
  - 75 Tonne Mobile Crane;
  - 200 Tonne Mobile Crane;

- Pick-Up Trucks; and
- Transport Bus.

- **Other Construction Activities**
  - Blasting

1.4.1.1 Construction Sound Emissions

Sound emissions for the construction sound sources, which include stationary and mobile equipment were established using:

- referenced publications listing sound outputs for the same or similar equipment;
- a database published by the United States Department of Transportation (DOT) (DOT 2006); and
- measurement data for the similar equipment.

During Project construction, changes in noise levels were assessed based on the following assumptions:

- the acoustical usage factor is the actual time that a piece of equipment will operate taking into account breaks and downtime;
- the equipment has an effective source height of 2 metres (m);
- beyond the Project construction area, the terrain consists of moderately adsorptive ground conditions; and
- receptor height is 1.5 m.

Table 11 presents the noise emissions from Project construction equipment as sound power levels (PWLs) at octave bands centre frequencies.

Table 11: Sound Power Levels from Project Construction Equipment

Type	Overall Sound Power Levels (dBA)	Sound Power Levels (dBA)								
		31.5	63	125	250	500	1000	2000	4000	8000
Articulated Truck	**110.8**	70.1	83.3	94.4	97.9	103.3	106.5	104.7	99.5	97.4
Rigid Rock Truck	**113.8**	73.1	86.3	97.4	100.9	106.3	109.5	107.7	102.5	100.4
Wheel Tractor Scraper	**112.6**	74.1	86.7	101.9	106.2	105.7	106.7	105.0	98.2	87.7
Motor Grader	**109.2**	81.5	89.7	102.4	98.1	102.5	104.0	101.3	92.2	78.2
Compaction Equipment	**111.6**	80.2	87.5	97.2	99.9	110.2	102.2	98.0	90.8	36.6
Track Drill	**119.3**	64.1	77.3	87.4	95.9	108.3	109.5	113.7	114.5	112.4
Skidder	**109.2**	81.5	89.7	102.4	98.1	102.5	104.0	101.3	92.2	78.2
Feller Buncher	**114.4**	79.3	88.1	107.7	101.9	103.9	106.8	109.1	106.1	93.3
Hydraulic Excavator	**116.8**	76.1	89.3	100.4	103.9	109.3	112.5	110.7	105.5	103.4
Rubber Tire Loaders	**114.8**	74.1	87.3	97.4	101.9	107.3	110.5	108.7	103.5	101.4
Crawler Tractors	**114.4**	79.3	88.1	107.7	101.9	103.9	106.8	109.1	106.1	93.3
Tunnel Rubber Tired Loader	**114.8**	74.1	87.3	97.4	101.9	107.3	110.5	108.7	103.5	101.4
Shaft Drill	**117.5**	62.3	75.5	85.6	94.1	106.5	107.7	111.9	112.7	110.6
Forklift	**100.2**	59.3	72.5	83.6	87.1	92.5	95.7	93.9	90.5	88.4
Skid Steer Loader	**114.8**	74.1	87.3	97.4	101.9	107.3	110.5	108.7	103.5	101.4
Telehandler	**115.2**	74.3	87.5	98.6	102.1	107.5	110.7	108.9	105.5	103.4
Man Lift	**100.2**	59.3	72.5	83.6	87.1	92.5	95.7	93.9	90.5	88.4
Concrete Mixing Truck	**116.0**	52.3	74.9	98.0	95.8	108.4	112.6	109.3	106.5	97.6
Concrete Pump Truck	**113.8**	73.1	86.3	97.4	100.9	106.3	109.5	107.7	102.5	100.4
Fuel Truck	**113.8**	54.5	79.1	108.4	103.2	106.7	108.1	104.9	97.2	87.9
Water Truck	**113.8**	54.5	79.1	108.4	103.2	106.7	108.1	104.9	97.2	87.9
Flat Deck	**116.3**	57.0	81.6	110.9	105.7	109.2	110.6	107.4	99.7	90.4
Boom Truck	**116.3**	57.0	81.6	110.9	105.7	109.2	110.6	107.4	99.7	90.4
75 Tone mobile Crane	**115.2**	74.3	87.5	98.6	102.1	107.5	110.7	108.9	105.5	103.4
200 Tone Mobile Crane	**116.8**	76.1	89.3	100.4	103.9	109.3	112.5	110.7	105.5	103.4
Pick-Up Trucks	**87.0**	27.8	52.3	81.7	76.5	79.9	81.3	78.1	70.4	61.1
Transport Bus	**87.0**	27.8	52.3	81.7	76.5	79.9	81.3	78.1	70.4	61.1
Generator	**116.8**	63.3	78.2	101.6	109.6	110.8	110.4	109.6	106.1	100.3
Crusher	**112.0**	76.6	89.6	96.2	102.2	107.1	107.5	103.7	95.8	88.9
Screen	**121.7**	78.7	85.4	94.7	102.1	110.3	114.2	116.7	116.3	113.0
Concrete Batch Plant	**117.0**	53.3	75.9	99.0	96.8	109.4	113.6	110.3	107.5	98.6

dBA = A-weighted decibels.

Because at the time of assessment the design and the equipment list were not finalized, the associated equipment for each of the Project construction activities are assigned based on the professional assumptions and previous experience on similar projects. Table 12 presents the assumptions made for construction equipment involved in different construction activities.

Table 12: Project Construction Activities and Associated Equipment

Construction Phase	Construction Activities	Equipment	Quantity
1	Clearing and Access Infrastructure	Wheel Tractor Scraper	1
		Motor Grader	1
		Articulated Truck	1
		Rubber Tire Loaders	1
		Feller Buncher	1
		Skidder	1
		Hydraulic Excavator	1
		Pick-Up Trucks	4
		Forklift	1
		Compaction Equipment	1
		Fuel Truck	1
		Tractor Dump Trailer	1
2	Bridge Construction	200 Tonne Mobile Crane	1
		75 Tonne mobile Crane	1
		Boom Truck	1
		Pick-Up Trucks	4
		Crawler Tractors	1
		Rigid Rock Truck	1
		Concrete Mixing Truck	3
		Concrete Pump Truck	1
		Water Truck	1
		Rubber Tire Loaders	2
3	Camp (on west side) with Power & Communications	Wheel Tractor Scraper	1
		Pick-Up Trucks	4
		Motor Grader	1
		Feller Buncher	1
		Compaction Equipment	1
		Articulated Truck	1
		75 Tonne mobile Crane	1
		Telehandler	1
		Skidder	1
		Man Lift	1
		Boom Truck	1
		Concrete Pump Truck	1
		Water Truck	1
		Concrete Mixing Truck	3

Table 12: Project Construction Activities and Associated Equipment (continued)

Construction Phase	Construction Activities	Equipment	Quantity
4	Intake and Powerhouse Excavation	Blasting	2
		Skid Steer Loader	1
		Hydraulic Excavator	2
		Rigid Rock Truck	2
		Pick-Up Trucks	4
		Tunnel Rubber Tired Loader	2
		Fuel Truck	1
		Shaft Drill	1
		Tractor Dump Trailer	1
		Track Drill	1
5	Tailrace Excavation	Blasting	2
		Skid Steer Loader	1
		Hydraulic Excavator	2
		Rigid Rock Truck	2
		Pick-Up Trucks	4
		Tunnel Rubber Tired Loader	2
		Fuel Truck	1
		Shaft Drill	1
		Tractor Dump Trailer	1
		Track Drill	1
6	Tunnel & Surge Shaft	Shaft Drill	1
		Track Drill	1
		Tunnel Rubber Tired Loader	4
		Hydraulic Excavator	1
		Skid Steer Loader	2
		Blasting	1
		Rigid Rock Truck	4
		Rubber Tire Loaders	2
		Crawler Tractors	1
		Tractor Dump Trailer	2
		Fuel Truck	1

Table 12: Project Construction Activities and Associated Equipment (continued)

Construction Phase	Construction Activities	Equipment	Quantity
7	Transmission Line & Communications	75 Tonne mobile Crane	1
		Telehandler	1
		Man Lift	1
		Boom Truck	1
		Hydraulic Excavator	2
		Concrete Pump Truck	1
		Water Truck	1
		Concrete Mixing Truck	3
		Fuel Truck	1
		Pick-Up Trucks	2
8	Powerhouse Structure	75 Tonne mobile Crane	1
		Man Lift	1
		Forklift	2
		Flat Deck Truck	1
		Boom Truck	1
		Pick-Up Trucks	4
		Hydraulic Excavator	1
		Fuel Truck	1
		Concrete Mixing Truck	3
		Concrete Pump Truck	1
		Water Truck	1
9	Penstock / Tunnel Tie-in	Tunnel Rubber Tired Loader	1
		75 Tonne mobile Crane	4
		Concrete Pump Truck	1
		Concrete Mixing Truck	3
		Water Truck	1
		Pick-Up Trucks	2
		Flat Deck Truck	1
		Boom Truck	1
		Fuel Truck	1

Table 12: Project Construction Activities and Associated Equipment (continued)

Construction Phase	Construction Activities	Equipment	Quantity
10	Submerged Weir	Hydraulic Excavator	2
		75 Tonne mobile Crane	1
		Rubber Tire Loaders	1
		Crawler Tractors	1
		Rigid Rock Truck	2
		Compaction Equipment	1
		Concrete Pump Truck	1
		Concrete Mixing Truck	3
		Water Truck	1
11	Intake Structural, Gate & Hoist Installation	200 Tonne Mobile Crane	1
		Man Lift	1
		Hydraulic Excavator	1
		Concrete Pump Truck	1
		Concrete Mixing Truck	3
		Water Truck	1
		Boom Truck	1
12	Powerhouse M & E T & G Installation	Flat Deck Truck	1
		200 Tonne Mobile Crane	1
		Telehandler	1
		Man Lift	1

Once the sound emissions were established, the sources were applied to the sound prediction models to determine the noise levels associated with the Project construction. General sound sources associated with the construction of the Project would include earth-moving equipment. Most of the mobile equipment would be outfitted with backup warning alarms. However, noise levels during construction will vary depending on the type and level of activity, and will be temporary relative to operations.

1.4.1.2 Construction Blasting Emissions

The Project details provided by SaskPower and used in the calculation of blasting noise and vibration are provided below.

- Blasting could potentially occur 365 days per year at two fronts (headings) in the power tunnel, and approximately 210 days per year for the tailrace channel and other structures.
- Approximately 160 holes will be drilled per day in the tunnel (assuming two headings), and 100 holes per day in the tailrace channel.
- A maximum of one blast in the tailrace/powerhouse area and two blasts in the tunnel/intake area could be completed per day.
- For power tunnel blasting, the charge size is assumed to be 1.1 kilogram per cubic metres (kg/m^3).

- Surface area blasted per day will be approximately 140 square metres (m^2) in the Tunnel for two headings, and 800 m^2 to 1600 m^2 in the tailrace channel, assuming the general contractor will use from four to eight drills in the tailrace channel.
- Amount of explosives used per day is anticipated to range from 2500 kg to 9000 kg per day, depending on whether one or two headings are used in the power tunnel and the number of drills used in the tailrace.
- The power tunnel contour holes will be spaced approximately 500 to 600 millimetre (mm).
- Blasting locations will include the Intake structure foundation, power tunnel, powerhouse foundation, and tailrace channel.

Based on the Project information provided, previous experience of blasting assessment and professional assumptions, blasting activity of the Project construction was assessed based on the following estimates for the maximum weight (W) of explosive (kg) detonated per delay period (i.e., W in the formula in Section 1.3.3 - Blasting Assessment Methods), which is shown in Table 13.

Table 13: Project Construction Blasting Assessment Explosive Estimates

Blast Location	Explosive Weight per Delay (kg)
Tailrace Channel	88
Tunnel	90

kg = kilogram

Basically, the blasting at the tailrace channel will be upground while the blasting in the tunnel will be underground. The effects from blasting are assessed for the structures adjacent to the surface or the underground blasting operations.

1.4.2 Project Operation

1.4.2.1 Operation Sound Emissions

During the operation of the Project, noise may be generated by the following sources.

- Turbine and generator units. These would run almost continuously. They are entirely located within the powerhouse. Turbine units are underwater so their noise contribution is assumed negligible.
- Two generator step-up transformers, located in a switchyard near the powerhouse.
- Supply air fans for powerhouse ventilation, located inside the powerhouse.
- Hydraulic power units (for turbine control), located inside the powerhouse.
- Two 30 horsepower (hp) air compressors located inside the powerhouse.
- Miscellaneous exhaust fans and small HVAC units, located inside the powerhouse.
- Dewatering pump(s) that will only be active occasionally and the noise generated is considerably less than the turbines and generators.
- Drainage pumps that will be active on a regular basis, but since it is anticipated that submersible pumps will be used, inside the drainage sumps, there is little to no noise generated.

- Fire pumps that will be active on a monthly basis for testing and during fire events. Located inside the powerhouse.

Sound emissions for the Project operation sound sources were established using:

- plot plans of the Project;
- referenced publications listing sound outputs for the same or similar equipment;
- measurement data for the similar equipment; and
- equipment specifications and referenced formulae provided in acoustic literature such as Crocker (2007) and Bies and Hansen (2003) to estimate emissions.

Table 14 presents the noise emission of the Project operation equipment as (PWLs at octave bands centre frequencies.

Table 14: Sound Power Levels of Project Operation Equipment

Project Operation Facilities	Overall Sound Power Levels [dBA]	Sound Power Levels [dB]								
		31.5	63	125	250	500	1000	2000	4000	8000
Powerhouse Roof[(a)]	79.5	65.5	66.8	74.9	76.1	68.7	62.6	52.3	38.9	32.3
Powerhouse Walls[(a)]	79.5	65.5	66.8	74.9	76.1	68.7	62.6	52.3	38.9	32.3
Generator Step-Up Transformer	110.1	62.7	80.8	103.9	103.8	106	99.7	94.8	90	82.2
Supply Fan	93.0	54.3	67.5	75.6	81.1	85.5	86.7	88.9	82.7	73.6
Exhaust Fan	93.0	54.3	67.5	75.6	81.1	85.5	86.7	88.9	82.7	73.6
HVAC	93.0	54.3	67.5	75.6	81.1	85.5	86.7	88.9	82.7	73.6
Transfer Fan	93.0	54.3	67.5	75.6	81.1	85.5	86.7	88.9	82.7	73.6

[(a)] PWL is presented in dBA/m2 for area sources
dBA = A-weighted decibels.

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APPENDIX 9.1

Geochemical Characterization Report

February 2014
Report No. 10-1365-0004/DCN-171

January 2014

TAZI TWE HYDROELECTRIC PROJECT

Geochemical Characterization Report

Submitted to:
SaskPower
6SE, 2505 Victoria Ave
Regina, Saskatchewan
S4P 0S1

Report Number: 10-1365-0004 (15000)/DCN-107

REPORT

Golder Associates

Table of Contents

1.0 INTRODUCTION 3
1.1 Project Proponent 3
1.2 Project Overview 3
1.3 Location and Environmental Setting 3
2.0 STUDY OBJECTIVES 4
3.0 METHODS 4
3.1 Data Review 4
3.1.1 Geology and Mineralization 5
3.1.2 Mechanisms for Acid Rock Drainage and Metal Leaching 6
3.2 Primary Data Collection 6
3.2.1 Sample Selection and Collection 6
3.2.1.1 Waste Rock 7
3.2.2 Geochemical Testing Program 8
3.2.2.1 Solid-Phase Metal and Whole Rock Analysis 9
3.2.2.2 Acid-Base Accounting 9
3.2.2.3 Net Acid Generation Testing 10
3.2.2.4 Short-Term Leach Tests 11
3.2.2.5 Humidity Cell Testing 12
4.0 CRITERIA 12
5.0 RESULTS 13
5.1 Static Test Results 13
5.1.1 Elemental Composition 13
5.1.2 Acid Base Accounting 14
5.1.3 Net Acid Generation Testing 15
5.1.4 Short-Term Leach Testing 15
5.2 Kinetic Test Results 17
6.0 SUMMARY AND CONCLUSIONS 18
7.0 REFERENCES 19

Table of Contents (continued)

TABLES

Table 3-1: Rock Sample List
Table 3-2: Acid Generation Potential Criteria
Table 3-3: Net Acid Generation (NAG) Criteria for Acid Generation Potential
Table 5-1: Whole Rock Analysis
Table 5-2: Trace Metal Analysis
Table 5-3: Acid Base Accounting and Net Acid Generation Testing
Table 5-4: Shake Flask Extraction
Table 5-5: NAG Leachate
Table 5-6: Summary of Loading Rates and Depletion Calculation Results

FIGURES

Figure 1-1: General Project Location
Figure 3-1: Site and Borehole Location Plan
Figure 5-1: Total Sulphur vs. Sulphide Sulphur
Figure 5-2: Neutralization Potential vs. Carbonate Neutralization Potential
Figure 5-3: Neutralization Potential vs. Acid Potential
Figure 5-4: Carbonate Neutralization Potential vs. Acid Potential
Figure 5-5: Humidity Cell Results: 12-EF-16

APPENDICES

APPENDIX A
Waste Rock Sample Descriptions

APPENDIX B
Kinetic Test Results

1.0 INTRODUCTION

1.1 Project Proponent

In response to an increasing demand for energy in northern Saskatchewan, Black Lake First Nation (BLFN) together with Saskatchewan Power Corporation are the Proponents of the Tazi Twe Hydroelectric Project (Project). Black Lake First Nation's interest in the Project is being managed by the Elizabeth Falls Hydro Limited Partnership.

1.2 Project Overview

The proposed Project will be a 50 megawatt (MW), run-of-the-river electrical generating station. It will be located on BLFN Chicken Indian Reserve No.224, adjacent to the Fond du Lac River between Black Lake and Middle Lake.

The Project will capitalize on the long term annual average flow of the Fond du Lac River (304 cubic metres per second [m^3/s]) and the gross head of approximately 36 m between the water intake on Black Lake and the outlet on the river. Water from Black Lake will be conveyed from a water intake structure via a power tunnel excavated through rock to a powerhouse, then released into a tailrace channel to re-enter the Fond du Lac River upstream of Middle Lake. This run-of-the-river design is intended to minimize the environmental impact to water levels and flow in Black Lake and the Fond du Lac River.

The Project will consist of three phases of activity: construction, which will take approximately 3 years; operations, which will last up to 90 years or more; and closure. The principal components of the proposed Project are access roads, a construction camp up to a 250 person capacity, waste rock disposal areas, a bridge across the Fond du Lac River, a powerhouse and associated infrastructure, a water intake on Black Lake; a 2.95 km tunnel from Black Lake to the powerhouse; a tailrace channel of a length of approximately 600 to 1,100 m long (with a preference for the shorter length) connecting the powerhouse to the Fond du Lac River to an outlet on the Fond du Lac River, and a weir in the Fond du Lac River at the outlet of Black Lake to maintain water levels and fish habitat in Black Lake.

1.3 Location and Environmental Setting

The proposed Project site is located within the province of Saskatchewan on BLFN Chicken Indian Reserve No. 224, approximately 7 kilometres (km) north of the community of Black Lake and 25 km southeast of the Hamlet of Stony Rapids (Figure 1-1). Highway 905, west of the Fond du Lac River, joins these two communities and is the only all-season road access in the area. The general zone of influence and footprint of the Project will include the area between Black Lake and Middle Lake, extending approximately two to three kilometres on either side of the Fond du Lac River. Elizabeth Falls, a well-known area of cataracts and rapids is located on the Fond du Lac River (59° 11" N, 105° 33' W) between Black Lake and Middle Lake.

The proposed Project is located within two ecoregions separated by the Fond du Lac River, with bedrock to the east and forested glaciolacustrine plain to the west. Black Lake, Middle Lake and the Fond du Lac River dominate surface water in the low to moderate relief, well-drained landscape of the Project area. The subarctic, continental climate of the area contributes to peak flows and water levels in waterbodies in the spring following snowmelt. These water resources, as well as terrestrial resources, are key to the culture, identity, and subsistence of Aboriginal people in the region.

2.0 STUDY OBJECTIVES

The primary objective of the geochemical characterization program is to provide sufficient data for the evaluation of the environmental behaviour of the waste materials expected to be produced during excavation of the hydroelectric tunnel. Components of this objective include:

- identification of waste materials (i.e., overburden, waste rock) that may generate acid rock drainage (ARD) and/or metal leaching (ML); and
- to provide input to engineering design and other environmental evaluations for the Project.

The geochemical characterization includes the following tasks:

- review of the site geology and general location of proposed infrastructure;
- collection of drill core samples;
- static testing of waste material; and
- data evaluation and characterization of ARD/ML potentials of all collected materials.

The characterization of these materials will help develop waste and water management strategies, assist in avoiding, managing and limiting environmental impacts, and assist with the engineering design. The results of the geochemical characterization are integral for the impact assessments related to other disciplines such as water quality, ecological and human health risk, aquatic biology, and socio-economics.

The scope of work is consistent with the guidance documents that have gained regulatory acceptance in jurisdictions around the world and include:

- Draft Guidelines and Recommended Methods for the Prediction of Metal Leaching and Acid Rock Drainage at Minesites in British Columbia (Price 1997);
- Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials (MEND 2009); and
- Global Acid Rock Drainage (GARD) Guide (INAP 2012).

Although these guidelines are specific to mining, they can be extrapolated to this project because waste rock will be produced and stored at surface during the excavation of the tunnel.

3.0 METHODS

The geochemical work was performed to provide baseline data to support the environmental assessment process and permitting and included the review of existing data and primary data collection.

3.1 Data Review

Data sources reviewed for the geochemistry characterization program include:

- published reports and literature that describe the geology and mineralization in the project area;
- drill logs from previous investigations; and

- information included in geochemical guidance documents (i.e., Price 1997, MEND 2009, INAP 2012) and published literature that describe the mechanism of acid rock drainage.

A summary of the information listed above is included in the following sections and data sources are referenced where appropriate.

3.1.1 Geology and Mineralization

Bedrock Geology

The bedrock in the study area consists of Precambrian age crystalline gneiss complex and the Athabasca Formation (conglomerates and sandstones) to the east and west of Fond du Lac River, respectively. The gneiss complex is comprised of quartzo-feldspathic gneiss that is medium to coarse-grained, crystalline, and light-coloured. Mineralogy is predominantly quartz and feldspar with 10% to 20% mafic minerals (primarily biotite and hornblende). The gneiss complex is intruded by a swarm of diabase dykes throughout the study area. The dykes are generally intruded parallel to foliation but in some cases crosscut the foliation (Gilboy 1978).

Structural features within the study area include foliation (most prominent), shear zones (Black Lake Shear Zone), faulting and jointing. The Black Lake Shear Zone is comprised of mylonitic and cataclastic amphibole gneiss and felsic gneiss. The zone strikes northeast parallel to the shore of Black Lake. This zone is the result of faulting cataclysmic milling that produced re-healed rock mass with deformed and stretched mineral grains (Gilboy 1978).

Surficial Geology

The topography surrounding Elizabeth Falls is primarily bedrock controlled with low to moderate relief. The area forms part of the Lake Athabasca drainage basin. Prominent landforms in the study area are a result of glaciations. To the east of Fond du Lac River, well rounded erosion-resistant exposed bedrock and to the west, significant areas of glacial deposits consisting of lacustrine sand, silt, and till were produced by glaciations. Glacial deposits extend westward (approximately 13 km) forming an esker of sand and gravel that is used as a source of aggregate and construction materials in the area. The esker varies in lithology and grain size from east to west from sub-rounded boulders comprised of Precambrian-aged crystalline rocks near the outlet to the Fond du Lac River to pebbles and cobbles of sandstones farther to the west. A terrace deposit on the west side of Black Lake (approximately 100 m wide and 2.5 km in length) is characterized by talus and glacial sands deposits.

Mineralization

Given that there are several known uranium deposits within 5 to 10 km of the Project area, an assessment of the potential for exposure of uranium mineralization during the tunnel and surface excavations was required.

Based on the information obtained from SMDI (2012), the Nisto Mine, located approximately 5 km northeast of the Project area has a maximum uranium grade of 0.612%. Lower grade uranium was also found in a borehole within the same fault zone, approximately 10 km to the south of the Project area. The Nisto Mine, now an inactive mine site, is described as having several shear zones that contain quartz and calcite veins with mineralized fractures or shear zones in a sequence of paragneisses, meta-gabbro and amphibolite sills in the hanging wall of the Black Lake Fault zone. The mineralization includes pitchblende and secondary yellow uranium mineralization, pyrite, galena, chalcopyrite, and stibnite in a series of quart-calcite veins within fractures

in highly hematized mylonite. Uranium mineralization also exists on the west side of the Fond du Lac River, near Woodcock Rapids, approximately 10 km downstream of Elizabeth Falls, located in the Athabasca Sandstone.

Geological mapping of the entire tunnel alignment was conducted in 2004 (Hatch, 2005) and no evidence of uranium mineralization was observed in the surface outcrops along the tunnel alignment at any of the surface outcrops adjoining Black Lake and the Fond du Lac River. In addition, there was no evidence of uranium mineralization noted in the drill core obtained in 2002 (Hatch 2002).

The bedrock cores from the boreholes drilled during the 2012 geotechnical investigation program, located within close proximity to the Black Lake Shear Zone were scanned using a scintillometer to determine radiation levels and potential occurrence of uranium. The radiation levels obtained were typically less than 150 counts per second (cps) and consistent with background levels, well below the 100,000 cps obtained for the known uranium showings in the area (Hatch 2012). No evidence of uranium mineralization was visually observed in the drill core or in the core sampled for petrographic analyses.

3.1.2 Mechanisms for Acid Rock Drainage and Metal Leaching

Waste rock will be produced as a result of the excavation of the tunnel portion for the project and stored in piles at surface. Exposure of waste rock to atmospheric conditions can result in the oxidation of metal sulphide minerals resulting in the generation of acidity and the release of constituents into the dissolved phase. Pore water within the waste rock can migrate through the subsurface and transport oxidation products into the groundwater and nearby surface water bodies. The generation of acidic and metal-rich waters, as a result of sulphide oxidation, is commonly referred to as ARD.

The acidity produced through oxidation reactions may be attenuated by minerals that contain neutralizing capacity. Carbonate minerals, for example, are particularly important neutralizing minerals, since they are generally the most effective in counteracting acidic conditions. Other minerals, such as aluminosilicates or silicates, may also contribute to the overall neutralization potential, but the dissolution of aluminosilicate and silicate minerals is kinetically limited (Jambor et al. 2003) and are only significant neutralizing minerals under low-pH conditions (<4.5) or where water-rock interaction times are very long (Blowes et al. 2004). If the amount of neutralizing minerals is insufficient, significant quantities of acidity may be mobilized and released as a result of the oxidation of sulphide minerals. Although low-pH conditions can enhance metal release and mobility, metals can leach from waste rock and occur at elevated concentrations under near-neutral to basic-pH conditions.

3.2 Primary Data Collection

3.2.1 Sample Selection and Collection

The methods for sample collection for waste rock are provided in the section below.

Table 3-1 provides a summary of the materials and number of samples collected. Detailed descriptions and a listing of these samples are included in Appendix A. Based on the approximate tonnage of waste rock to be excavated during the project at the time of the sampling program (900,000 m^3), twenty-one samples were selected from six boreholes (shown on Figure 3-1). An additional three samples were collected as part of the 2013 drilling investigation to better represent the diabase dyke and quartzo-feldspathic gneiss encountered during the drilling performed in that year It should also be noted that the expected tonnage of waste rock has

increased to 1,0740,000 m^3 of waste rock and 118,000 m^3 of overburden since the original sampling program. Any additional sampling requirements will be addressed during the excavation and construction phase.

Table 3-1: Rock Sample List

Rock Type	Samples Collected	
	Number	Percentage
Waste Rock	**24**	**100%**
Quartzo-feldspathic Gneiss	17	71%
Mylonite	1	4%
Diabase	4	17%
Glacial Drift	2	8%

A description on each of the waste rock types and the methods for waste rock sample collection are provided in the following sections.

3.2.1.1 Waste Rock

The waste rock sampling program included analysis of both major (>10% of waste rock) and minor (<10% of waste rock) rock types. The major rock type was the quartzo-feldspathic gneiss and hence sampling was biased to this material. Minor units include mylonite, diabase and glacial drift.

Waste Rock Sampling

A sampling program including 21 samples was developed, and sample numbers for each lithology were determined based on the rock types observed. Drill holes were selected for sampling based on both lithologies logged and stratigraphical representativeness, using plan views provided by Hatch. Additional sampling was conducted upon completion of the 2013 field investigations to better represent the diabase dyke and quartzo-feldspathic gneiss.

Samples were collected by Golder during two site visits to the core storage facility in Stony Rapids, Saskatchewan in July and September 2012. Core was laid out at site and the identified samples were collected consistent with the following procedures:

- The following information from the drill holes and core was recorded:
  - a description including a unique sample number, drill hole, sample depth/interval;
  - rock type; and
  - photographs and visual description of the core sample (oxidization/weathering characteristics, estimate of sulphide content).
- Approximately 5 kg of core for each sample was collected in order to conduct laboratory tests. The samples were collected as follows:
  - the sample was collected over a continuous 10 m interval. To collect a sample from discreet rock types, in some instances, shorter intervals were sampled where the continuity of the rock type was smaller;

- sub-samples were taken from 1 m intervals (for example a 10 m sample interval required 10 sub-samples of about 0.5 kg each);
- each sub-sample was approximately equal in weight and visually representative of the interval of the core;
- the sub-samples were combined into a single sample bag to develop the sample for the interval; and
- the sample bag was labelled with an unique sample identification number.

- Samples were then packaged and prepared for shipment to the analytical laboratory (SGS Canada Inc., Lakefield, Ontario).

A summary of the samples descriptions, including borehole ID, rock code, and a detailed description by Golder during sampling, are shown in Appendix A.

Waste Rock Types

The following summarizes the main rock types encountered during drilling.

Quartzo-feldspathic Gneiss

The unit is generally fine to medium grained and medium grey to green. The gneiss is composed primarily of potassium feldspar, plagioclase and quartz, with some hematite alteration and iron staining being noted, particularly near surface along fracture surfaces. Generally, trace to no sulphides were observed in this unit.

Mylonite

The unit is coarse grained and generally grey and pink in colour. The unit is highly altered with clay infill along joints and displays evidence of shearing and cataclastic milling in the direction of foliation. Iron staining is pervasive throughout the core collected and no sulphides were observed.

Diabase

The unit is fine grained and generally dark grey in colour. Diabase is primarily composed of plagioclase and clinopyroxene. Some iron staining was observed along fracture surfaces and, generally, trace to no sulphides were observed.

Glacial Drift

The unit is composed of cobbles and boulders with some sand. The cobbles and boulders consist predominantly of the main rock units in the area (quartzo-feldspathic gneiss and diabase). Hematite alteration and iron staining along fracture surfaces were observed. No sulphides were observed in this unit.

3.2.2 Geochemical Testing Program

The analytical program consisted of a series of static tests designed to assess the general physical and geochemical characteristics as follows:

- Elemental composition;
- Acid-base accounting (ABA);

- Net acid generating (NAG) testing;
- Short-term leach tests; and
- Humidity Cell Testing.

All samples were submitted for elemental composition, ABA, NAG and short-term leach testing. In addition, one sample was submitted for kinetic testing. Each of the geochemical analyses listed above are described in greater detail below.

3.2.2.1 Solid-Phase Metal and Whole Rock Analysis

Major and trace element analysis was conducted to quantify the elemental composition of the waste rock. Both analyses were conducted on all 21 waste rock samples. Element analyses were conducted according to the methods listed below:

- Whole rock analysis for major oxides (Al_2O_3, CaO, Cr_2O_3, Fe_2O_3, K_2O, MgO, MnO, Na_2O, P_2O_5, SiO_2, TiO_2, V_2O_5) by borate fusion / x-ray fluorescence (XRF).
- Trace metal analysis for: aluminum, arsenic, antimony, barium, beryllium, bismuth, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, selenium, silver, sodium, strontium, tin, titanium, thallium, uranium, vanadium, yttrium and zinc.

3.2.2.2 Acid-Base Accounting

Acid-base accounting and NAG testing were performed to evaluate the acid generation potential. As part of ABA, the bulk quantities of acid generating minerals (e.g., sulphide minerals) and acid neutralizing minerals (e.g., carbonate minerals) are measured to assess whether the materials tested will have sufficient capacity to neutralize acidity or if the materials have the potential to generate acidity. The methodology performed on the samples is a modified Sobek method (Sobek et al. 1978) that includes analysis for paste pH, sulphur species, acid potential (AP), neutralization potential (NP) and carbon species (total carbon, carbonate content and organic carbon content).

Acid Potential (AP)

The acid potential (AP) represents the bulk amount of acidity that can be produced. The AP is calculated from the sulphide content and assumes that all sulphide minerals occur as pyrite. Total sulphur concentrations often include oxidized, non-reactive forms of sulphur, such as sulphate. Although the dissolution of sulphate minerals can contribute some AP in the short-term, sulphate minerals do not generally contribute to the long-term acid generation potential of a material. Therefore, calculation of AP using the sulphide content (the reactive portion of the pyrite mineral that will contribute acidity) rather than the total sulphur, is the most appropriate method for determining AP.

Neutralization Potential (NP) and Carbonate Neutralization Potential (CaNP)

The neutralization potential (NP) represents the bulk amount of acidity that can potentially be consumed or neutralized by the sample. The “bulk” NP was determined by acidifying the sample with sulphuric acid. Following the acidification of the sample, the amount of acid that is consumed during the test period is determined by a reverse titration. Negative NP values indicate that samples contain stored acidity in the form of soluble phases that contribute acidity on dissolution.

The carbonate neutralization potential (CaNP) is a calculated value that represents the bulk amount of acidity that the sample can potentially consume through the dissolution of carbonate minerals. The CaNP is calculated from the carbonate content (wt% as CO_3).

NP and CaNP are typically compared for the purpose of evaluating the mineralogical source of NP in a sample. The difference between the NP and CaNP is that the NP represents the 'bulk' neutralization potential, whereas CaNP is solely based on the carbonate content of a sample. Thus, in addition to the consumption of acid by readily soluble carbonate minerals, the 'bulk' NP incorporates the consumption of acid by less soluble aluminosilicate, silicate and/or other minerals. If the NP is approximately equal to the CaNP, the NP is likely attributable to the dissolution of carbonate minerals. In cases where the NP is significantly greater than CaNP, the NP could be overestimated due to the partial dissolution of other, non-carbonate minerals. The rate of aluminosilicate or silicate mineral dissolution is generally too slow to provide effective neutralizing capacity under ambient field conditions. Silicate minerals predominantly provide NP if (and when) acidic conditions are achieved, or where water-rock interaction times are very long.

An evaluation of the acid generation potential and neutralization potential was conducted using the ABA results. Acid generation potential is commonly interpreted according to the ratio of NP to AP, referred to as the neutralization potential ratio (NPR), according to the guidelines recommended by MEND (2009) and described in the Table 3-2:

Table 3-2: Acid Generation Potential Criteria

Acid Generation Potential	Criteria	Comments
Potentially Acid Generating	NPR <1	Potentially acid generating unless sulphide minerals are non-reactive.
Uncertain	NPR <2	Possibly acid generating if NP is insufficiently reactive or is depleted at a rate faster than sulphides.
Non-Acid Generating	2 <NPR	Not expected to generate acidity.

Using bulk NP in the NPR calculation accounts for less reactive silicate minerals as well as the more reactive carbonate minerals. CaNP can be used in the NPR calculations (CaNPR = CaNP / AP) to account for buffering capacity from carbonate minerals only and ignores the buffering capacity of other and more slowly reacting minerals. Therefore, CaNPR is also presented and used in assessing ARD potential.

For several reasons, no single NPR is universally applicable with respect to acid generation prediction. The actual threshold values for a particular test sample are material specific, and could depend on several factors, including chemical and mineralogical composition (i.e., presence and amounts of acid generation and neutralization minerals), morphology (i.e., grain size, texture and crystallinity) and site-specific exposure conditions.

3.2.2.3 Net Acid Generation Testing

Samples were submitted for NAG testing, conducted according to the protocols in AMIRA (2002) and Miller et al. (1997). The purpose of the NAG test is to ensure complete oxidation of all sulphide minerals. During the NAG test, hydrogen peroxide is added to a sample in quantities sufficient to completely oxidize all sulphide minerals.

The pH of the oxidized solution was measured after the completion of the reaction to determine the NAG-pH, followed by titration of the solution to a pH of 4.5 with sodium hydroxide. Back-titration to a pH of 7 was completed to provide added information on buffering capacity.

The results of the NAG test are used to assess the potential of a material to produce acidity after a period of exposure and weathering. The NAG pH is a useful indicator of whether a sample contains sufficient internal buffering capacity to neutralize the acidity produced through sulphide oxidation.

According to the recommendations in AMIRA (2002) and MEND (2009), samples reporting a NAG pH value greater than 4.5 are classified as non-potentially acid generating, and samples reporting a pH value below 4.5 are classified as potentially acid generating (Table 3-3).

Table 3-3: Net Acid Generation (NAG) Criteria for Acid Generation Potential

NAG pH	Potentially Acid Generating[(a)]
≥4.5	non-potentially acid generating
<4.5	potentially acid generating

[(a)] Based on AMIRA (2002).

3.2.2.4 Short-Term Leach Tests

The results of short-term leach tests are commonly used as a qualitative screening tool to identify elements of potential environmental concern. The results of these tests do not directly translate to the expected environmental behaviour of materials for several reasons, including:

- the relatively small sample size and volume of the sample;
- potential heterogeneities in the sample;
- the short test duration; and
- the enhanced contact between liquid and the solid test charge due to agitation.

Although there are limitations with the testing, it is a very useful indication of leachable metals of concern and is intended as a screening tool to identify metals of potential concern.

The following notes apply to the application of the above criteria:

- several of the criteria report ranges depending on water hardness or other properties. In these cases, the lowest criterion value was used, with the exception of aluminum;
- CCME criteria for aluminum in waters reporting pH values greater than 6.5 was used based on the neutral to alkaline pH values reported in all materials during leach testing; and
- there is no applicable criteria for total chromium, however the CCME criteria for hexavalent chromium was used when hexavalent chromium was not analyzed.

Two types of short term leach tests were performed; shake flask extraction (SFE), and analysis of the NAG leachate. Leach tests are described below.

Shake Flask Extraction (SFE)

Testing (using distilled water) was performed as described in ASTM (2006). Solids material and de-ionized water were combined at the modified ratio of 4:1 and shaken for an 18-hour period. The generated leachate was analyzed for the following parameters:

- pH, alkalinity, acidity, conductivity, sulphate, chloride, ICP metal scan (including aluminum, arsenic, antimony, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, strontium, tin, uranium, vanadium, zinc) and mercury by CVAAS.

NAG Leachate

Comprehensive analysis of the NAG testing leachate provides an assessment of the waters after complete oxidation of reactive sulphides and buffering by other minerals. The same procedure is followed as described in Section 3.2.2.3 except a sample of the oxidized solution is collected after the completion of the reaction prior to the titration. The results of the NAG test were used to identify parameter mobility after a period of exposure and weathering. It should be noted that the NAG leach test is aggressive and not analogous to field conditions. The NAG supernatant was tested for:

- pH, alkalinity, acidity, conductivity, sulphate, chloride, ICP metal scan (including aluminum, arsenic, antimony, barium, beryllium, bismuth, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, strontium, tin, uranium, vanadium, zinc) and mercury by CVAAS.

3.2.2.5 Humidity Cell Testing

A Humidity cell test (HCT) was conducted on one sample and the results are presented in Figure 5-5 and Appendix B of this appendix. The HCT was performed according to the ASTM D5744-96 Standard Test Method for Accelerated Weathering of Solid Materials Using a Modified Humidity Cell (ASTM, 2001). A humidity cell is a chamber designed to provide control over air, temperature and moisture, while allowing for the removal of weathering products (principally oxidation products) in solution. The HCTs consist of a 1-kg sample (dry equivalent) sample. The samples are leached with 1 L of de-ionized (DI) water on a regular weekly cycle. The results of kinetic testing are used to evaluate the composition of leachates resulting from weathering and to estimate the lag time to the onset of acid generation in each sample under laboratory conditions. Changes in pH and concentrations of sulphate, alkalinity, acidity and key trace metals provide insight with respect to mineral reaction rates.

4.0 CRITERIA

The details and rationale for the criteria used to evaluate acid generation and metal leaching of the materials tested as part of the geochemical characterization have been previously described in Section 3.2 but are summarized here for reference:

- **Crustal Abundances:** The results of the solid-phase metal and whole rock analyses provide a basis for comparison between samples of rock and typical crustal abundances (Price 1997). Concentrations are highlighted based on greater than, five times greater than, and ten times greater than crustal abundances.

These analyses can also be further used to identify samples that contain greater amounts of elements that have environmental significance and assist with selection of sample candidates for short-term leach testing.

- **Acid Generation**: The acid generation potential was interpreted based on the NPR, CaNPR and NAG pH values and according to the guidelines recommended by MEND (2009) and AMIRA (2002). It must be noted that determining the potential for acid generation is not solely based on these criteria, but on the guidance provided in Price (1997), MEND (2009) and INAP (2012) and professional interpretation as no single criterion is universally applicable with respect to acid generation prediction. The actual threshold values for a particular test sample are material specific, and could depend on several factors, including chemical and mineralogical composition (i.e., presence and amounts of acid generation and neutralization minerals), morphology (i.e., grain size, texture and crystallinity), long-term weathering and site-specific exposure conditions.
- **Metal Leaching:** Values for pH and concentration of other parameters were compared to Canadian Council of Ministers of the Environment (CCME 2007), Canadian Environmental Quality Guidelines, for the protection of freshwater aquatic life. Again, the potential for metal leaching is not solely based on the comparison to criteria, but the long-term behaviour of the material, professional judgement and the guidance provided in Price (1997), MEND (2009) and INAP (2012).

It should be noted that these are criteria used in the geochemical characterization and not related to the impact assessment. As there is no impact assessment associated with geochemistry, the development of impact assessment criteria is not appropriate, nor is the development of indicators. These impact assessment criteria and indicators will be developed over the course of the study as part of the water quality work.

5.0 RESULTS

A description of the results and tabulated data are presented in the relevant sections and tables below.

5.1 Static Test Results

5.1.1 Elemental Composition

Major oxides and trace metals analysis was performed on all of the samples. The results of this analysis are summarized in Table 5-1 and 5-2. Some of the pertinent observations are:

Major Oxides

- average silica (SiO_2) content in all rock types was 59.3%. The minimum (47.1%) and maximum (81.3%) silica content were observed in the diabase dyke and glacial drift samples, respectively. The diabase dyke is generally composed of less SiO_2 (47.1 to 51.8%) in comparison to the quartzo-feldspathic gneiss and glacial drift;
- average aluminum oxide (Al_2O_3) content was 13.4%. The minimum (8.3%) and maximum (16.3%) aluminum oxide content was observed in the glacial drift and quartzo-feldspathic gneiss samples, respectively;
- average iron oxide (Fe_2O_3) content was 9.4%. The minimum (1.9%) and maximum (18.6%) iron oxide content was observed in the quartzo-feldspathic gneiss and diabase dyke samples, respectively;

- average magnesium oxide (MgO) content was 4.6%. The minimum (1.1%) and maximum (10.5%) magnesium oxide content was observed in the glacial drift and quartzo-feldspathic gneiss, respectively; and
- average calcium oxide (CaO) content was 5.3%. The minimum (0.1%) and maximum (10.1%) calcium content was observed in the mylonite and diabase dyke, respectively.

Elemental Composition

- concentrations that exceeded typical crustal abundances in at least one sample included; silver, arsenic, barium, bismuth, calcium, cobalt, chromium, copper, iron, potassium, lithium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, selenium, tin, strontium, titanium, uranium, vanadium, yttrium, and zinc;
- concentrations that exceeded the typical crustal abundance by five times in at least one sample included silver (0.43 µg/g, 12-EF-16, and; 0.61 µg/g, 12-EF-09), arsenic (9.8 µg/g, 13-EF-02: and molybdenum (7.8 µg/g, 12-EF-14, and; 6.9 µg/g, 13-EF-01); and
- concentrations that exceeded typical crustal abundance by ten times in at least one sample included silver (1.00 µg/g, 12-EF-19; 4.00 µg/g, 12-EF-18, and; 0.85 µg/g, 13-EF-01), bismuth (0.09 µg/g, 12-EF-11, and 0.12 µg/g, 12-EF-18), and selenium (0.8 µg/g, 12-EF-15; 0.9 µg/g, 12-EF-13; and 1.0 µg/g, 12-EF-19, and 1.6 µg/g, 12-EF-14).

5.1.2 Acid Base Accounting

The ABA results are shown in Table 5-3 and plotted in Figures 5-1 through 5-4. The ABA results are discussed by analysis type below.

Paste pH

The paste pH values reported for all samples were alkaline, ranging from 7 to 10. These paste pH values indicate the samples do not host appreciable concentrations of readily soluble stored acidity.

Sulphur Species

Sulphide contents range from less than 0.01 to 0.40 wt% as S, with the highest concentration observed in the quartzo-feldspathic gneiss (12-EF-16) and the lowest concentration observed in seven samples of quartzo-feldspathic gneiss (12-EF-01, 12-EF-08, 12-EF-09, 12-EF-010, 12-EF-12, 12-EF-13 and 12-EF-21) and two samples of glacial drift (12-EF-18 and 12-EF-19).

The sulphide content was plotted as a function of total sulphur in Figure 5-1. Added to the plot is a 1:1 reference line to assess the speciation of the sulphur minerals in the samples of test material. Samples that lie along this line indicate that the sulphur present is in the form of sulphide, presumably as sulphide minerals. As the sample moves below the reference line, the sulphate sulphur form is increasingly present. The sulphur speciation results for all rock types show that the distribution of data is variable. Generally, sulphur is primarily present in the form of sulphate in the majority of samples with lower sulphur concentrations, while it is primarily in the form of sulphide in samples with >0.15 wt% as S.

Neutralization and Carbonate Neutralization Potentials

Waste rock samples show a relatively wide range of NP values; between 2 to 84 tonnes $CaCO_3$ / 1000 tonnes and CaNP values; between 0.25 to 59.3 tonnes $CaCO_3$ / 1000 tonnes. The CaNP values are consistent with the

elemental results for CaO (see Section 5.1.1). The highest values were observed in the quartzo-feldspathic gneiss and the lowest concentrations were observed in the mylonite.

Carbonate neutralization potential (CaNP) is presented as a function of bulk NP in Figure 5-2. To assess the proportion of NP that consists of CaNP, a 1:1 reference line was added to the graph. Where NP is equal to the CaNP, the NP is derived from carbonate minerals. Sample points that are not located near the 1:1 reference line have a significant proportion of bulk NP from non-carbonate minerals, such as aluminosilicate and silicate minerals. All samples, with the exception of one, plot well below the 1:1 line, thus, the majority of the samples of waste rock have neutralization potentials derived from non-carbonate minerals. Hence, the available neutralization is not as rapid and pH will be buffered at more acidic values as compared to carbonates. Sample 13-EF-01 plots above the 1:1 line and indicates an over estimation of CaNP as a result of graphite identified in the sample.

Acid Potential

The NPR values of the waste rock samples are plotted in Figure 5-3. As per the MEND (2009) criteria (Table 3-2) reference lines representing the PAG classification criteria are also plotted. One sample from the quartzo-feldspathic gneiss (12-EF-16) reported a NPR value of 1.8 and is therefore classified as having uncertain acid generation potential based on MEND (2009). All remaining samples reported NPR values greater than 2 and are classified as non-potentially acid generating (non-PAG).

The CaNPR value was also calculated. The CaNPR is a more conservative estimate of the acid generation potential of a material, as it only accounts for the more reactive buffering minerals. The CaNP versus AP values were plotted in Figure 5-4, along with the MEND (2009) criteria. Based on the CaNPR, two samples (12-EF-16 and 12-EF-21) are classified as potentially acid generating (PAG) (CaNPR <1) and four samples (12-EF-03, 12-EF-17, 13-EF-01 and 13-EF-02) are classified as having an uncertain acid generation potential (1 < CaNPR < 2). The CaNPR classification of 12-EF-16 as PAG is consistent with the NPR classification. The sample, 12-EF-21, has no sulphide content and therefore, even though the CaNPR values classify it as PAG, the sample is not expected to generate acid.

5.1.3 Net Acid Generation Testing

The NAG testing results are presented in Table 5-3. All waste rock samples reported paste pH values greater than 4.5, and therefore all waste rock samples are classified as non-PAG. This is consistent with the ABA results when considering the NPR criteria and not an unexpected comparison considering the lack of sulphide content in the samples.

5.1.4 Short-Term Leach Testing

The results of the two short-term leach tests (SFE and NAG) are presented in the following sections.

Shake Flask Extraction Leach Test

The results of SFE leach testing conducted on samples of waste rock are reported in Table 5-4. The pertinent results and observations from the SFE leach test are summarized as follows:

- leachate pH values are neutral to slightly alkaline, ranging from 7.6 to 9.7 with three samples (12-EF-02, 12-EF-04, and 12-EF-21) exceeding CCME criteria;

- aluminum concentrations ranged from 0.04 to 2.63 mg/L and were greater than the CCME criteria (0.1 mg/L) in all but three quartzo-feldspathic gneiss samples;
- arsenic concentrations ranged from 0.0009 to 0.0148 mg/L and were greater than the CCME criteria (0.005 mg/L) in 11 samples including 9 samples of quartzo-feldspathic gneiss, 1 diabase sample and 1 sample of glacial drift;
- chromium concentrations were greater than the CCME criteria (0.005 mg/L) in 6 samples including; 1 quartzo-feldspathic gneiss sample (12-EF-01, 0.0013 mg/L), 1 mylonite sample (12-EF-21, 0.006 mg/L), 3 diabase dyke samples (12-EF-03, 0.0025 mg/L; 13-EF-02, 0.0011 mg/L, and; 13-EF-03, 0.0013 mg/L) and 1 glacial drift sample (12-EF-19, 0.0025 mg/L);
- copper concentrations were greater than the CCME criteria (0.001 mg/L) in 5 samples including; 3 diabase dyke samples (12-EF-03, 0.0015 mg/L; 13-EF-02, 0.0011, and; 13-EF-03, 0.0015 mg/L) and 2 samples of glacial drift (12-EF-18, 0.0616 mg/L, and; 12-EF-19, 0.006 mg/L);
- iron concentrations ranged from <0.003 to 2.12 mg/L and were greater than the CCME criteria (0.3 mg/L) in 14 samples including; 8 samples of quartzo-feldspathic gneiss, 1 sample of mylonite, 2 samples of glacial drift, and 3 sample of diabase dyke;
- additional parameters that were greater than the PWQOs for four or fewer samples included the following:
  - lead concentrations were greater than the CCME criteria (0.001 mg/L) in one sample of glacial drift (12-EF-19, 0.00193 mg/L);
  - selenium concentrations were greater than the CCME criteria (0.001 mg/L) in one sample of glacial drift (12-EF-19, 0.003 mg/L); and
  - silver concentrations were greater than the CCME criteria (0.0001 mg/L) in two samples of glacial drift (12-EF-18, 0.00434 mg/L, and; 12-EF-19, 0.00048 mg/L) and one diabase sample (13-EF-03, 0.00026 mg/L).

Net Acid Generation Leach Test

The results of NAG leach testing conducted on samples of waste rock are summarized in Table 5-5. The key results and observations from the NAG leach test are summarized as follows:

- NAG pH values ranged from 6.1 to 9.5. The highest and lowest pH values were reported in the NAG leachates from two samples of quartzo-feldspathic gneiss (12-EF-13 and 12-EF-16, respectively);
- aluminum concentrations in the NAG leachate ranged from 0.05 to 1.78 mg/L and were greater than the CCME criteria (0.1 mg/L) in 20 samples (15 quartzo-feldspathic gneiss, one mylonite, and 4 diabase);
- arsenic concentrations ranged from <0.0002 to 0.0062 mg/L and were greater than the CCME criteria (0.005 mg/L) in 3 samples of quartzo-feldspathic gneiss (12-EF-06, 0.0051 mg/L; 12-EF-07, 0.0062, mg/L, and; 12-EF-17, 0.0053 mg/L) and 1 sample of diabase (13-EF-02, 0.0129 mg/L);
- cadmium concentrations ranged from <0.000003 to 0.00203 mg/L and were greater than the CCME criteria (0.000017 mg/L) in 1 sample of quartzo-feldspathic gneiss (12-EF-16, 0.00203 mg/L);

- chromium concentrations ranged from 0.014 to 0.114 mg/L and were greater than the CCME criteria (0.001 mg/L) in all samples;
- copper concentrations ranged from <0.0005 to 0.0583 mg/L and were greater than the CCME criteria (0.001 mg/L) in 3 samples; one sample of quartzo-feldspathic gneiss (12-EF-16, 0.0583 mg/L), 1 sample of mylonite (12-EF-21, 0.0012 mg/L) and 1 sample of diabase (13-EF-03, 0.0012 mg/L);
- nickel concentrations ranged from <0.0001 to 0.0759 mg/L and were greater than the CCME criteria (0.025 mg/L) in 1 sample of quartzo-feldspathic gneiss (12-EF-16, 0.0759 mg/L);
- selenium concentrations ranged from <0.001 to 0.006 mg/L and were greater than the CCME criterion (0.001 mg/L) in 11 samples including 6 samples of quartzo-feldspathic gneiss and 5 samples of diabase;
- silver concentrations ranged from <0.00001 to 0.08 mg/L and were greater than CCME criteria (0.0001 mg/L) in 3 samples including one sample of quartzo-feldspathic gneiss (12-EF-16, 0.00038 mg/L) and 2 samples of glacial drift (12-EF-18, 0.00122 mg/L, and; 12-EF-19, 0.00029 mg/L); and
- zinc concentrations ranged from <0.001 to 0.060 mg/L and were greater than the CCME criteria (0.03 mg/L) in 1 sample of quartzo-feldspathic gneiss (12-EF-16, 0.060 mg/L).

5.2 Kinetic Test Results

Kinetic test work was completed on one sample of quartzo-feldspathic gneiss (12-EF-16). 12-EF-16 was selected for kinetic testing because of the uncertain to PAG classification and elevated arsenic concentrations (above CCME guidelines) in the laboratory leachate tests. The results of the kinetic testing are presented in Figure 5-5 and Appendix B of this appendix. The sample had a sulphide content of 0.4 wt% as S, NPR of 1.8 and CaNP of 0.4. The kinetic test leachate water quality can be summarized as follows:

- pH values were slightly acidic to near-neutral ranging from 6.36 to 7.49. With the exception of the initial flush, all pH values were above the CCME criteria (pH of 6.5).
- Acidity concentrations remained below the detection limit (<2 mg/L as $CaCO_3$) throughout testing.
- Alkalinity concentrations slightly declined throughout testing from 14 mg/L as $CaCO_3$ after the initial flush to 8 mg/L as $CaCO_3$ at week #20.
- Sulphate concentrations increased to a maximum at week #3 (20 mg/L) and then steadily decreased to 4 mg/L at week #20.
- Aluminum concentrations were relatively stable up to week #5 (0.02 to 0.06 mg/L) and then increased at week #15 to 0.11 mg/L, slightly above the CCME criteria (0.1 mg/L). Concentrations decreased to 0.04 mg/L at week #20.
- Arsenic concentrations reached a maximum of 0.002 mg/L at week #3 and then steadily decreased to 0.0004 mg/L at week #20. Concentrations were below the CCME criteria (0.005 mg/L) throughout testing.
- Copper concentrations were less than the detection limit (<0.0005 mg/L) for the majority of testing and reached a maximum of 0.001 mg/L at week #20. Concentrations were below the CCME criteria (0.001 mg/L) throughout testing.

- Uranium concentrations increased to a maximum at week #3 (0.000314 mg/L) and then steadily decreased to 0.000152 mg/L at week #20.
- Zinc concentrations were less than the detection limit (<0.001 mg/L) over the first 3 weeks and then increased to a maximum at week #4 (0.003 mg/L), before remaining relatively stable up to week #20 (0.001 to 0.003 mg/L). Concentrations were below the CCME criteria (0.03 mg/L) throughout testing.

Static testing indicated that this humidity cell sample had either an uncertain potential to generate acidity (based on NPR between 1 and 2) or could potentially generated acidity (CaNPR<1). In order to evaluate the long-term acid generation potential of the sample, the humidity cell testing results were used to complete depletion calculations. The depletion calculations were used to determine the acid generation potential by comparing the rate of depletion of acid producing (i.e., sulphide minerals) and acid neutralizing (i.e., carbonate and aluminosilicate) minerals in the sample. The sulphide and neutralization potential (NP) depletion calculations were performed according to Price (1997) and MEND (2009) and are provided in Appendix B of this appendix. A summary of the depletion calculations are provided in Table 5-6. The calculated depletion rate of sulphide is 4 years, while the calculated depletion rates of NP and CaNP are 25 and 8 years, respectively. Given that the depletion rate of the sulphides in this sample is faster than either of the two neutralization potentials, the quartzo-feldspathic gneiss (12-EF-16) is predicted to be non-PAG over the long term. This is contrary to the NPR and CaNPR, criteria, but the humidity cell data is considered more accurate as it includes the kinetics of sulphide oxidation and dissolution of neutralizing minerals.

6.0 SUMMARY AND CONCLUSIONS

A total of 24 waste rock samples were collected for a geochemical characterization study for the Project. Static geochemical tests were performed to determine the potential for acid generation and metal leaching of these materials. The waste rock is characterized as having low sulphides concentrations (<0.4 wt% as S) and high neutralization potential (NPR and CaNPR values exceeding 2.0 for almost all samples tested). The high neutralization potential however, is attributed to non-carbonate minerals which tend to be less reactive and may not provide sufficient buffering capacity for acid generation under ambient field conditions. Potential acid generation was determined in two samples of quartzo-feldspathic gneiss (12-EF-16 and 12-EF-21) while four samples (12-EF-03, 12-EF-17, 13-EF-01 and 13-EF-02) are classified as having an uncertain acid generation potential when only the carbonate buffering capacity is considered. The one sample (12-EF-21) has no sulphide and is considered to be non-potentially acid generating. Additionally, NAG pH results were greater than 4.5 for all samples and hence, they are unlikely to generate acidity.

Based on the laboratory testing, the waste rock material does not demonstrate significant metal leaching, with the exception of aluminum and arsenic. Aluminum and arsenic concentrations were elevated with respect to the applicable criteria in several samples from the SFE testing. Other metals reporting sporadic concentrations greater than the applicable guidelines in waste rock leach testing included chromium, copper, iron, lead, selenium and silver.

Kinetic testing was completed on one sample of quartzo-feldspathic gneiss (12-EF-16) to evaluate the reaction rates of acid producing and neutralizing minerals in the sample under laboratory conditions. Sample 12-EF-16 was chosen as it had the lowest NAG pH value (4.83), was one of the samples that had a CaNPR <1, and hence had a potential for acid generation, and had elevated arsenic concentrations in the laboratory leachate tests. The results of the kinetic testing showed that all parameters met the applicable criteria by week #20 of kinetic

testing. The depletion calculations indicate that the sample is non-PAG over the longer term, even though it is classified as having uncertain acid generation potential according to the MEND (2009) NPR criteria. The kinetic test work, which is considered more accurate than the static test results as it includes the kinetics of sulphide oxidation and dissolution of neutralizing minerals, indicates that this sample will be non-PAG over the long term.

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Report Signature Page

GOLDER ASSOCIATES

ORIGINAL SIGNED AND STAMP BY

Dan LaPorte, M.Sc., P.Geo.
Hydrogeochemist

ORIGINAL SIGNED BY

Che McRae, M.Sc.
Associate, Geochemist

ORIGINAL SIGNED AND STAMP BY

Michael Tremblay, M.Sc., P.Eng.
Associate, Senior Geotechnical Engineer

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TABLES

Table 5-1
Whole Rock Analysis
Tazi Twe Project

Sample	Rock Type	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	MgO %	CaO %	Na_2O %	K_2O %	TiO_2 %	P_2O_5 %	MnO %	Cr_2O_3 %	V_2O_5 %	LOI %	Sum %
12-EF-01	QFG	65.2	14.5	5.0	3.7	3.4	3.9	2.2	0.4	0.1	0.1	0.0	0.0	1.7	100.1
12-EF-02	QFG	57.8	16.1	8.3	3.7	5.8	3.1	2.4	1.2	0.3	0.1	0.0	0.0	1.2	100.0
12-EF-03	DD	51.8	13.7	13.7	6.0	9.4	2.3	0.6	1.2	0.1	0.2	0.0	0.1	0.7	99.8
12-EF-04	QFG	58.7	16.3	7.9	3.2	5.9	3.3	2.3	1.2	0.3	0.1	0.0	0.0	1.1	100.2
12-EF-05	QFG	53.8	13.8	12.5	5.4	8.6	2.7	0.8	1.0	0.1	0.2	0.0	0.0	0.9	99.8
12-EF-06	QFG	52.5	13.9	12.7	5.8	9.0	2.4	0.9	1.0	0.1	0.2	0.0	0.1	1.2	99.8
12-EF-07	QFG	57.1	16.1	9.2	2.9	5.4	3.8	2.4	1.1	0.2	0.1	0.0	0.0	1.3	99.7
12-EF-08	QFG	65.1	15.6	4.2	2.2	2.5	3.4	4.3	0.5	0.2	0.0	0.0	0.0	1.6	99.7
12-EF-09	QFG	68.9	15.2	1.9	1.1	1.5	4.7	4.1	0.2	0.1	0.0	0.0	0.0	1.3	99.0
12-EF-10	QFG	61.0	13.9	8.0	5.1	3.5	2.6	2.7	0.6	0.1	0.1	0.0	0.0	2.6	100.3
12-EF-11	QFG	63.1	12.7	6.1	5.3	4.8	2.6	1.8	0.4	0.1	0.1	0.0	0.0	3.0	99.9
12-EF-12	QFG	49.7	12.8	16.8	6.3	7.0	1.9	1.5	1.5	0.1	0.2	0.0	0.1	2.0	99.9
12-EF-13	QFG	54.5	11.8	7.0	10.5	3.5	1.6	3.4	0.5	0.2	0.1	0.1	0.0	5.9	99.1
12-EF-14	QFG	57.4	14.0	8.9	5.4	4.4	2.7	2.9	0.8	0.2	0.1	0.1	0.0	2.5	99.3
12-EF-15	DD	47.1	12.2	18.6	5.7	9.6	2.1	0.5	2.0	0.2	0.2	< 0.01	0.1	1.1	99.3
12-EF-16	QFG	62.2	14.4	6.0	3.3	3.8	3.0	4.1	0.5	0.3	0.1	0.0	0.0	1.5	99.1
12-EF-17	QFG	51.4	13.1	16.4	5.3	5.9	1.7	2.2	1.4	0.2	0.1	< 0.01	0.1	2.5	100.2
12-EF-18	GD	81.3	8.8	2.4	1.1	1.5	1.9	2.0	0.3	0.1	< 0.01	0.0	< 0.01	1.5	100.9
12-EF-19	GD	78.4	8.3	4.6	1.9	2.7	1.4	1.3	0.4	0.1	0.0	0.0	0.0	1.0	100.3
12-EF-20	QFG	47.9	10.9	12.1	9.6	9.7	2.0	1.8	1.2	0.5	0.3	0.0	0.1	3.2	99.2
12-EF-21	MYL	72.8	14.6	3.2	1.4	0.1	0.1	3.6	0.3	0.1	< 0.01	0.0	< 0.01	4.0	100.0
13-EF-01	QFG	68.8	13.1	5.77	3.21	0.76	1.04	3.15	0.67	0.03	0.07	0.08	0.01	2.6	99.3
13-EF-02	DD	48.4	12.5	18.0	5.64	9.05	2.24	0.72	1.87	0.16	0.22	0.01	0.09	1.14	100.0
13-EF-03	DD	48.4	13.2	17.2	6.49	10.1	2.02	0.48	1.56	0.16	0.24	0.03	0.07	1.45	101.5
Minimum		**47.1**	**8.3**	**1.9**	**1.1**	**0.1**	**0.1**	**0.5**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.7**	**99.0**
Maximum		**81.3**	**16.3**	**18.6**	**10.5**	**10.1**	**4.7**	**4.3**	**2.0**	**0.5**	**0.3**	**0.1**	**0.1**	**5.9**	**101.5**
Average		**59.3**	**13.4**	**9.4**	**4.6**	**5.3**	**2.4**	**2.2**	**0.9**	**0.2**	**0.1**	**0.0**	**0.0**	**2.0**	**99.9**

Table 5-2
Trace Metal Analysis
Tazi Twe Project

Sample	Rock Type	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Co	Cr	Cu	Fe	K	Li	Mg	Mn
		µg/g	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*	*µg/g*
Price Crustal Abundance[1]		*0.075*	*82300*	*1.8*	*425*	*3*	*0.0085*	*41500*	*3*	*25*	*102*	*60*	*56300*	*20850*	*20*	*23300*	*950*
12-EF-01	QFG	0.1	72000	0.6	280	1.10	< 0.09	23000	0.11	16	210	41	34000	20000	35	21000	460
12-EF-02	QFG	0.12	78000	< 0.5	550	0.97	< 0.09	39000	0.18	20	160	45	56000	22000	27	20000	700
12-EF-03	DD	0.10	62000	0.9	180	0.44	< 0.09	64000	0.19	43	190	95	91000	6300	9	31000	1200
12-EF-04	QFG	0.09	80000	< 0.5	530	0.97	< 0.09	40000	0.2	20	160	44	54000	21000	30	18000	660
12-EF-05	QFG	0.12	60000	3.3	190	0.50	< 0.09	58000	0.17	38	160	67	83000	8200	12	27000	1100
12-EF-06	QFG	0.10	55000	1.3	200	0.43	< 0.09	61000	0.17	38	180	59	84000	8600	15	28000	1200
12-EF-07	QFG	0.1	79000	0.6	560	0.93	< 0.09	36000	0.2	22	130	40	61000	21000	24	16000	740
12-EF-08	QFG	0.07	77000	< 0.5	1160	0.74	< 0.09	17000	0.1	10	140	27	29000	38000	28	12000	330
12-EF-09	QFG	0.61	75000	0.6	1330	1.40	< 0.09	11000	0.1	3	130	9	13000	36000	18	6400	260
12-EF-10	QFG	0.10	69000	0.5	310	0.86	< 0.09	23000	0.09	22	150	29	54000	24000	48	28000	620
12-EF-11	QFG	0.16	64000	1.2	210.0	0.83	0.09	32000	0.16	21	210	60	42000	17000	63	30000	580
12-EF-12	QFG	0.08	45000	1.3	160.0	0.43	< 0.09	48000	0.14	45	130	150	110000	14000	29	28000	1300
12-EF-13	QFG	0.16	28000	1.2	500.0	1.30	< 0.09	23000	0.11	34	480	77	47000	29000	65	45000	760
12-EF-14	QFG	0.35	65000	0.6	290	1.40	< 0.09	29000	0.19	22	260	250	58000	25000	40	29000	810
12-EF-15	DD	0.17	36000	0.5	100	0.57	< 0.09	64000	0.17	44	120	140	120000	4500	12	22000	1600
12-EF-16	QFG	0.43	70000	2.2	520	1.40	< 0.09	26000	0.46	16	150	220	41000	36000	23	18000	700
12-EF-17	QFG	0.09	60000	2.6	300	0.65	< 0.09	39000	0.16	42	63	62	110000	20000	33	28000	800
12-EF-18	GD	4.00	43000	1.0	500	1.10	0.12	9900	0.16	6	180	20	16000	19000	20	6200	210
12-EF-19	GD	1.00	41000	2	250	0.61	< 0.09	18000	0.22	13	230	29	31000	12000	21	11000	360
12-EF-20	QFG	0.20	54000	1.9	260	1.70	< 0.09	64000	0.33	31	120	110	79000	17000	23	52000	1200
12-EF-21	MYL	0.19	70000	2.6	170	2.20	< 0.09	530	0.28	2	67	11	21000	31000	53	7400	29
13-EF-01	QFG	0.85	57000	3.4	510	5.6	< 0.09	4700	0.04	23	350	62	36000	26000	58	16000	550
13-EF-02	DD	0.17	56000	9.8	110	0.47	< 0.09	55000	0.14	43	65	150	110000	6400	14	29000	1300
13-EF-03	DD	0.15	59000	2.2	90	0.39	< 0.09	64000	0.17	48	84	180	110000	4400	15	34000	1400
Minimum		**0.07**	**28000**	**0.50**	**90.00**	**0.39**	**0.09**	**530.00**	**0.04**	**2.10**	**63.00**	**8.60**	**13000.00**	**4400.00**	**9.00**	**6200.00**	**29.00**
Maximum		**4.0**	**80000**	**9.8**	**1330.0**	**5.6**	**0.1**	**64000.0**	**0.5**	**48.0**	**480.0**	**250.0**	**120000.0**	**38000.0**	**65.0**	**52000.0**	**1600.0**
Average		**0.4**	**60625**	**1.9**	**385.8**	**1.1**	**0.1**	**35380.4**	**0.2**	**25.9**	**171.6**	**82.4**	**62083.3**	**19433.3**	**29.8**	**23458.3**	**786.2**

(1) Typical crustal abundance for continental rocks taken from Price (1997).

1 – Concentration greater than typical crustal abundance.

1 – Concentration greater than 5 x the typical crustal abundance.

1 – Concentration greater than 10 x the typical crustal abundance.

Table 5-2
Trace Metal Analysis
Tazi Twe Project

Sample	Rock Type	Mo	Na	Ni	P	Pb	Sb	Se	Sn	Sr	Ti	Tl	U	V	Y	Zn
		µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
Price Crustal Abundance[1]		*1.2*	*23550*	*84*	*1050*	*14*	*0.2*	*0.05*	*2.3*	*370*	*5650*	*0.85*	*2.7*	*120*	*33*	*70*
12-EF-01	QFG	0.6	26000	72	360	10.00	< 0.8	< 0.7	1.2	330	2700	0.41	0.62	80	8	58
12-EF-02	QFG	1.4	20000	66	1100	8.9	< 0.8	< 0.7	1.4	230	6900	0.31	0.63	150	17	110
12-EF-03	DD	0.5	15000	94	440	3.90	< 0.8	< 0.7	1.1	170	7000	0.09	0.27	240	16.0	97
12-EF-04	QFG	1.1	22000	62	1100	9.3	< 0.8	< 0.7	1.2	250	6800	0.27	0.58	140	17	110
12-EF-05	QFG	0.7	17000	72	510	4.40	< 0.8	< 0.7	0.6	170	6100	0.1	0.34	190	17	94
12-EF-06	QFG	0.5	16000	79	460	4.2	< 0.8	< 0.7	0.7	160	5900	0.09	0.40	200	15.0	93
12-EF-07	QFG	1.0	25000	44	840	9	< 0.8	< 0.7	1.1	250	6500	0.29	0.56	170	18	110
12-EF-08	QFG	1	22000	24	710	11	< 0.8	< 0.7	1	220	3200	0.30	0.93	64	10	96
12-EF-09	QFG	0.5	32000	15	300	15	< 0.8	< 0.7	1.6	510	930	0.6	1.60	20	15.0	88
12-EF-10	QFG	0.6	17000	50	230	8.70	< 0.8	< 0.7	1.4	170	3500	0.55	2.10	150	11	69
12-EF-11	QFG	0.7	17000	70	140	9.40	< 0.8	< 0.7	0.9	170	2300	0.27	4.80	89	10.0	49
12-EF-12	QFG	0.6	12000	61	500	1.70	< 0.8	< 0.7	1.1	110	8700	0.05	0.17	310	18.0	85
12-EF-13	QFG	3.4	10000	150	540	3.50	< 0.8	0.9	2	140	2800	0.49	1.30	99	12.0	78
12-EF-14	QFG	7.8	17000	70.0	890	6.10	< 0.8	1.6	3	160	4700	0.42	0.56	73	30	78
12-EF-15	DD	0.5	14000	63	700	2.40	< 0.8	0.8	1.4	96	11000	0.03	0.22	390	23	110
12-EF-16	QFG	1.0	20000	26	1100	15.00	< 0.8	< 0.7	4.9	210	2900	0.33	0.78	84	25	100
12-EF-17	QFG	0.6	11000	47	880	4.40	< 0.8	< 0.7	1.2	220	8100	0.07	0.31	250	20.0	89
12-EF-18	GD	1.0	11000	19	460	11.00	< 0.8	< 0.7	1.2	220	1700	0.38	1.90	27	10	51
12-EF-19	GD	1.0	8700	30	220	5.70	< 0.8	1.0	< 0.5	140	2300	0.19	1.10	73	8	52
12-EF-20	QFG	1.0	12000	54	2000	4.50	< 0.8	< 0.7	4.0	150	7100	0.34	1.90	200	70	120
12-EF-21	MYL	0.9	300	29	180	7.50	< 0.8	< 1	1.0	99	1700	0.43	5.00	37	8	19
13-EF-01	QFG	6.9	6200	170	92	15	< 0.8	< 0.7	< 0.5	69	2400	0.37	1.3	57	5.4	69
13-EF-02	DD	0.9	13000	43	580	2.3	< 0.8	< 0.7	0.8	87	6900	0.09	0.23	310	27	100
13-EF-03	DD	2.5	12000	73	580	3.3	< 0.8	< 0.7	0.6	87	5700	0.04	0.20	290	23	99
	Minimum	**0.5**	**300.0**	**15.0**	**92.0**	**1.7**	**0.0**	**0.8**	**0.6**	**69.0**	**930.0**	**0.0**	**0.2**	**20.0**	**5.4**	**19.0**
	Maximum	**7.8**	**32000.0**	**170.0**	**2000.0**	**15.0**	**0.0**	**1.6**	**4.9**	**510.0**	**11000.0**	**0.6**	**5.0**	**390.0**	**70.0**	**120.0**
	Average	**1.5**	**15675.0**	**61.8**	**621.3**	**7.3**	**#DIV/0!**	**1.1**	**1.5**	**184.1**	**4909.6**	**0.3**	**1.2**	**153.9**	**18.0**	**84.3**

(1) Typical crustal abundance for continental rocks taken from Price (1997).

1 – Concentration greater than typical crustal abundance.

1 – Concentration greater than 5 x the typical crustal abundance.

1 – Concentration greater than 10 x the typical crustal abundance.

Table 5-3
Acid Base Accounting and Net Acid Generation Testing
Tazi Twe Project

Sample	Rock Type	Paste pH	Acid Potential	Neutralization Potential	Carbonate Neutralization Potential	Net Neutralization Potential	NP/AP	CaNP/AP	Total Sulphur	Sulphate - Sulphur	Sulphide - Sulphur	Total Carbon	Carbonate	NAG pH
		units	*t $CaCO_3$/1000 t*	*t $CaCO_3$/1000 t*	*t $CaCO_3$/1000 t*	*t $CaCO_3$/1000 t*	*ratio*	*ratio*	*%*	*%*	*%*	*%*	*%*	*units*
12-EF-01	QFG	9.8	0.3	18	4.0	17.2	56.5	12.9	0.01	0.01	< 0.01	0.09	0.24	8.02
12-EF-02	QFG	10.0	0.4	22	5.6	21.9	58.5	14.7	0.04	0.03	0.01	0.12	0.34	8.2
12-EF-03	DD	9.6	1.8	15	3.1	12.9	8.2	1.7	0.12	0.06	0.06	0.06	0.19	7.39
12-EF-04	QFG	10.0	0.5	21	3.8	20.3	40.6	7.4	0.04	0.03	0.02	0.08	0.23	8.03
12-EF-05	QFG	9.7	1.5	22	5.5	20.1	14.1	3.6	0.09	0.04	0.05	0.10	0.33	8.94
12-EF-06	QFG	9.5	1.1	24	7.2	22.6	21.2	6.4	0.10	0.06	0.04	0.13	0.43	9.58
12-EF-07	QFG	9.7	1.0	25	9.9	24.4	25.2	9.8	0.07	0.03	0.03	0.16	0.60	10.31
12-EF-08	QFG	9.5	0.3	19	5.8	18.3	60.0	18.8	0.01	0.01	< 0.01	0.11	0.35	8.34
12-EF-09	QFG	9.6	0.3	13	5.1	13.1	43.2	16.6	0.02	0.02	< 0.01	0.10	0.31	8.04
12-EF-10	QFG	8.7	0.3	22	8.4	22.0	71.9	27.1	0.03	0.03	< 0.01	0.15	0.51	9.42
12-EF-11	QFG	9.2	0.4	38	22.2	37.3	98.1	58.5	0.03	0.02	0.01	0.35	1.34	9.97
12-EF-12	QFG	9.6	0.3	18	6.4	17.9	58.7	20.5	0.06	0.06	< 0.01	0.10	0.38	9.51
12-EF-13	QFG	9.0	0.3	84	59.3	83.3	270.0	191.2	0.06	0.06	< 0.01	0.83	3.57	10.28
12-EF-14	QFG	9.3	5.5	41	18.3	35.2	7.5	3.4	0.25	0.07	0.17	0.32	1.10	9.92
12-EF-15	DD	9.1	3.4	21	7.8	17.5	6.2	2.3	0.17	0.07	0.11	0.14	0.47	9.77
12-EF-16	QFG	9.4	12.5	23	4.6	10.2	1.8	0.4	0.57	0.17	0.40	0.10	0.28	4.83
12-EF-17	QFG	9.1	2.7	23	4.5	20.2	8.4	1.7	0.15	0.06	0.09	0.10	0.27	7.80
12-EF-18	GD	8.5	0.3	7	1.3	6.8	22.9	4.1	< 0.005	< 0.005	< 0.01	0.20	0.08	6.98
12-EF-19	GD	9.0	0.3	8	1.0	7.2	24.2	3.2	0.03	0.03	< 0.01	0.03	0.06	7.01
12-EF-20	QFG	9.4	1.9	66	37.7	63.9	33.9	19.4	0.12	0.06	0.06	0.55	2.27	10.01
12-EF-21	MYL	7.00	0.3	2	0.2	1.7	6.5	0.8	0.01	0.01	< 0.01	0.03	0.02	7.12
13-EF-01	QFG	10.40	3.44	11	33.2	7.36	3.1	9.7	0.14	0.03	0.11	0.443	2.00	6.95
13-EF-02	DD	9.34	5.62	17	6.6	11.1	3.0	1.2	0.22	0.04	0.18	0.103	0.395	7.00
13-EF-03	DD	9.72	2.81	12	4.6	9.69	4.4	1.6	0.13	0.04	0.09	0.095	0.275	7.18
Minimum		**7.0**	**0.31**	**2.00**	**0.25**	**1.69**	**1.82**	**0.37**	**< 0.005**	**< 0.005**	**< 0.01**	**0.03**	**0.02**	**4.83**
Maximum		**10.0**	**12.50**	**84.00**	**59.26**	**83.30**	**270**	**191.17**	**0.57**	**0.17**	**0.40**	**0.83**	**3.57**	**10.31**
Average		**8.3**	**1.7**	**25.3**	**10.6**	**23.5**	**15.0**	**6.2**	**0.094**	**0.0**	**0.1**	**0.2**	**0.6**	**6.1**
Geomean		**9.2**	**0.8**	**19.8**	**5.7**	**17.9**	**24.9**	**7.2**	**0.1**	**0.0**	**0.0**	**0.1**	**0.3**	**8.4**

Table 5-4
Shake Flask Extraction
Tazi Twe Project

	Rock Type	pH *units*	Alkalinity *mg/L as $CaCO_3$*	Conductivity *µS/cm*	SO_4 *mg/L*	Cl *mg/L*	Hg *mg/L*	Ag *mg/L*	Al *mg/L*	As *mg/L*	Ba *mg/L*	B *mg/L*	Be *mg/L*	Bi *mg/L*	Ca *mg/L*	Cd *mg/L*	Co *mg/L*	Cr *mg/L*	Cu *mg/L*
Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life[1]		*6.5 - 9*						*0.0001*	*0.1*	*0.005*						*0.000017*		*0.001*	*0.001*
12-EF-01	QFG	8.9	43	116	< 2	< 2	< 0.0001	< 0.00001	0.46	0.0059	0.00277	0.1680	< 0.00002	< 0.00001	2.2	< 0.000003	0.000149	0.0013	< 0.0005
12-EF-02	QFG	9.1	51	137	< 2	< 2	< 0.0001	< 0.00001	1.00	0.0025	0.01010	0.169	< 0.00002	< 0.00001	1.5	< 0.000003	0.00022	0.0005	0.0005
12-EF-03	DD	8.9	40	98	< 2	< 2	< 0.0001	< 0.00001	1.04	0.0028	0.0047	0.1440	< 0.00002	< 0.00001	4	< 0.000003	0.000527	0.0025	0.0015
12-EF-04	QFG	9.1	46	122	< 2	< 2	< 0.0001	< 0.00001	1.12	0.0017	0.00978	0.1780	< 0.00002	< 0.00001	1.46	< 0.000003	0.000230	0.0006	< 0.0005
12-EF-05	QFG	8.8	42	104	< 2	< 2	< 0.0001	< 0.00001	0.80	0.0051	0.00446	0.1680	< 0.00002	< 0.00001	2.94	< 0.000003	0.000379	0.0009	0.0008
12-EF-06	QFG	8.9	41	106	< 2	< 2	< 0.0001	< 0.00001	0.50	0.0055	0.00257	0.1530	< 0.00002	< 0.00001	2.89	< 0.000003	0.000223	< 0.0005	< 0.0005
12-EF-07	QFG	9.0	50	133	< 2	< 2	< 0.0001	< 0.00001	1.07	0.0061	0.00538	0.1520	< 0.00002	< 0.00001	1.8	< 0.000003	0.000140	< 0.0005	< 0.0005
12-EF-08	QFG	8.8	50	128	< 2	3.5	< 0.0001	0.00002	0.89	0.0062	0.00771	0.1940	< 0.00002	< 0.00001	1.7	< 0.000003	0.000119	< 0.0005	< 0.0005
12-EF-09	QFG	8.8	42	112	< 2	2.9	< 0.0001	0.00001	0.78	0.0084	0.01080	0.1640	< 0.00002	< 0.00001	2.3	< 0.000003	0.000031	< 0.0005	< 0.0005
12-EF-10	QFG	8.0	42	137	< 2	4.7	< 0.0001	< 0.00001	0.15	0.0051	0.00190	0.1790	< 0.00002	< 0.00001	3.2	< 0.000003	0.000011	< 0.0005	< 0.0005
12-EF-11	QFG	7.9	37	129	3.6	7.0	< 0.0001	< 0.00001	0.13	0.0035	0.00209	0.0472	< 0.00002	< 0.00001	7.9	< 0.000003	< 0.000002	< 0.0005	< 0.0005
12-EF-12	QFG	7.8	33	200	42.0	< 2	< 0.0001	< 0.00001	0.04	0.0017	0.01810	0.1880	< 0.00002	< 0.00001	13.5	< 0.000003	0.000025	< 0.0005	0.0006
12-EF-13	QFG	8.1	57	175	< 2	7.7	< 0.0001	< 0.00001	0.09	0.0071	0.01180	0.0618	< 0.00002	< 0.00001	4.5	< 0.000003	< 0.000002	< 0.0005	< 0.0005
12-EF-14	QFG	8.7	50	154	3.1	3.6	< 0.0001	< 0.00001	0.11	0.0024	0.00150	0.1780	< 0.00002	< 0.00001	3.4	< 0.000003	< 0.000002	< 0.0005	< 0.0005
12-EF-15	DD	8.3	34	98	2.3	< 2	< 0.0001	< 0.00001	0.20	0.0009	0.00060	0.1130	< 0.00002	< 0.00001	5.6	< 0.000003	0.000026	< 0.0005	< 0.0005
12-EF-16	QFG	7.9	34	149	6.1	2.8	< 0.0001	0.00002	0.39	0.0148	0.00302	0.1430	< 0.00002	< 0.00001	3.80	< 0.000003	0.000061	< 0.0005	0.001
12-EF-17	QFG	8.6	44	191	25.0	2.5	< 0.0001	< 0.00001	0.16	0.0036	0.00725	0.283	< 0.00002	< 0.00001	6.14	< 0.000003	0.000041	< 0.0005	< 0.0005
12-EF-18	GD	8.1	44	123	6.4	< 2	< 0.0001	0.00434	2.63	0.0028	0.02440	0.480	0.0001	0.00010	2.0	0.000009	0.000454	< 0.0005	0.0616
12-EF-19	GD	7.6	26	84	3.8	2.5	< 0.0001	0.00048	1.18	0.0096	0.00768	0.246	< 0.00002	< 0.00001	1.9	< 0.000003	0.000096	0.0025	0.006
12-EF-20	QFG	8.6	54	144	< 2	4	< 0.0001	< 0.00001	0.05	0.0034	0.00712	0.0637	< 0.00002	< 0.00001	7.9	< 0.000003	0.000018	< 0.0005	< 0.0005
12-EF-21	MYL	9.6	78	187	< 2	4.7	< 0.0001	< 0.00001	1.68	0.0024	0.00070	0.9050	0.00007	< 0.00001	0.3	0.000016	0.000082	0.006	< 0.0005
13-EF-01	QFG	8.90		90	2.5	3.8	< 0.00001	0.00010	1.54	0.0037	0.0207	0.337	0.00015	< 0.00001	0.41	< 0.000003	0.000337	0.0095	< 0.0005
13-EF-02	DD	9.36		103	< 2	< 2	< 0.00001	0.00002	0.8	0.0115	0.0127	0.0669	< 0.00002	< 0.00001	2.65	< 0.000003	0.000331	0.0011	0.0011
13-EF-03	DD	9.68		76	< 2	< 2	< 0.00001	0.00026	0.72	0.0009	0.0136	0.0580	< 0.00002	< 0.00001	3.75	0.000003	0.000313	0.0013	0.0015
Minimum		**7.6**	**26.0**	**76.0**	**< 2**	**< 2**	**< 0.0001**	**< 0.00001**	**0.04**	**0.0009**	**0.0006**	**0.05**	**< 0.00002**	**< 0.00001**	**0.3**	**< 0.000003**	**< 0.000002**	**< 0.0005**	**< 0.0005**
Maximum		**9.7**	**78.0**	**200.0**	**42.0**	**7.7**	**< 0.0001**	**0.0043**	**2.63**	**0.0148**	**0.0244**	**0.9**	**0.0002**	**0.0001**	**13.5**	**0.000016**	**0.000527**	**0.01**	**0.06**
Average		**8.3**	**45**	**129**	**11**	**4**	**< 0.0001**	**0.0007**	**0.73**	**0.0049**	**0.0080**	**0.20**	**0.0001**	**0.00010**	**4**	**0.000009**	**0.000182**	**0.003**	**0.008**

1) Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment (CCME, 2007).

0.01 - Denotes a value that is greater than CCME guidelines

Table 5-4
Shake Flask Extraction
Tazi Twe Project

	Rock Type	Fe *mg/L*	K *mg/L*	Li *mg/L*	Mg *mg/L*	Mn *mg/L*	Mo *mg/L*	Na *mg/L*	Ni *mg/L*	Pb *mg/L*	Sb *mg/L*	Se *mg/L*	Sn *mg/L*	Sr *mg/L*	Ti *mg/L*	Tl *mg/L*	U *mg/L*	V *mg/L*	W *mg/L*	Y *mg/L*	Zn *mg/L*
Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life[1]		*0.3*							*0.025*	*0.001*		*0.001*									*0.03*
12-EF-01	QFG	0.320	11.10	0.006	0.5	0.0082	0.00506	14.5	0.0009	0.00011	0.0009	< 0.001	1.00E-04	0.010	0.0209	< 0.00002	0.000037	0.03370	0.00088	0.000072	< 0.001
12-EF-02	QFG	0.642	20.70	0.02	0.4	0.0097	0.00118	12.7	0.001	0.00014	0.001	< 0.001	8.00E-05	0.005	0.0571	< 0.00002	0.00003	0.03940	0.00087	0.00008	0.001
12-EF-03	DD	1.41	6.45	0.008	0.77	0.0184	0.00077	14.00	0.0015	0.00007	0.0014	< 0.001	7.00E-05	0.009	0.0746	< 0.00002	0.000037	0.04900	0.00119	0.000224	0.002
12-EF-04	QFG	0.628	19.300	0.016	0.33	0.0087	0.00061	11.90	0.0012	0.00011	0.0007	< 0.001	6.00E-05	0.0041	0.0535	< 0.00002	0.000052	0.03950	0.00498	0.000066	0.002
12-EF-05	QFG	0.963	9.790	0.01	0.523	0.0123	0.00053	13.30	0.0009	0.00016	0.0015	< 0.001	2.00E-05	0.0067	0.0630	< 0.00002	0.00006	0.04480	0.01080	0.000171	0.002
12-EF-06	QFG	0.547	9.85	0.007	0.412	0.0079	0.00087	13.4	0.0006	0.00027	0.0019	< 0.001	4.00E-05	0.0074	0.0315	< 0.00002	0.000108	0.0512	0.01180	0.0001	< 0.001
12-EF-07	QFG	0.499	17.80	0.012	0.3	0.0068	0.00054	14.30	0.0007	0.00011	0.0015	< 0.001	5.00E-05	0.0054	0.0415	< 0.00002	0.000074	0.04000	0.00575	0.000067	< 0.001
12-EF-08	QFG	0.471	14.90	0.008	0.45	0.0058	0.00059	15.70	0.0004	0.00017	0.0019	< 0.001	4.00E-05	0.007	0.0355	< 0.00002	0.000103	0.02190	0.00659	0.0001	< 0.001
12-EF-09	QFG	0.241	9.17	0.007	0.47	0.0057	0.00117	16.00	0.0004	0.00036	0.0011	< 0.001	6.00E-05	0.015	0.0133	< 0.00002	0.000537	0.01580	0.02450	0.00029	< 0.001
12-EF-10	QFG	0.086	15.30	0.013	0.63	0.0014	0.00514	12.50	0.0002	0.00002	0.0059	< 0.001	1.30E-04	0.015	0.0049	< 0.00002	0.000045	0.02740	0.00932	0.000023	< 0.001
12-EF-11	QFG	0.006	10.20	0.022	2.76	0.0004	0.00157	5.90	0.0001	< 0.00002	0.001	< 0.001	< 0.00001	0.059	0.0003	< 0.00002	0.00003	0.01230	0.02510	0.000006	< 0.001
12-EF-12	QFG	0.086	11.20	0.014	3.37	0.0009	0.00139	11.60	0.0003	< 0.00002	0.0007	0.001	1.00E-05	0.130	0.0034	< 0.00002	0.000002	0.04280	0.00331	0.000012	< 0.001
12-EF-13	QFG	< 0.003	34.80	0.015	1.39	0.0003	0.0068	5.25	< 0.0001	< 0.00002	0.0008	< 0.001	2.00E-05	0.054	0.0003	< 0.00002	< 0.000001	0.01870	0.00117	0.000005	< 0.001
12-EF-14	QFG	0.038	21.30	0.011	0.59	0.0008	0.00293	13.50	0.001	< 0.00002	0.0011	< 0.001	2.00E-05	0.019	0.0029	< 0.00002	0.000007	0.01610	0.00534	0.000025	< 0.001
12-EF-15	DD	0.15	2.39	0.003	1.17	0.0019	0.00046	11.90	0.0004	< 0.00002	0.0009	0.001	3.00E-05	0.0123	0.0071	< 0.00002	0.000031	0.04960	0.00114	0.000035	< 0.001
12-EF-16	QFG	0.279	17.300	0.01	0.71	0.0052	0.00258	14.2	0.0004	0.00027	0.0017	< 0.001	7.00E-05	0.0146	0.0153	< 0.00002	0.000071	0.01960	0.00272	0.000111	< 0.001
12-EF-17	QFG	0.169	24.90	0.008	1.690	0.0011	0.00081	12.3	0.0004	< 0.00002	0.0014	< 0.001	4.00E-05	0.7320	0.0087	< 0.00002	0.000005	0.0328	0.00913	0.000036	< 0.001
12-EF-18	GD	2.12	2.24	0.005	1.0	0.0172	0.0193	20.9	0.0081	0.00193	0.0012	0.001	3.40E-04	0.0101	0.1130	< 0.00002	0.003886	0.02700	2.37000	0.00383	0.002
12-EF-19	GD	1.03	6.0	0.012	1.0	0.0081	0.00171	10.90	0.0015	0.00048	0.0008	0.003	1.20E-04	0.0099	0.0380	< 0.00002	0.000495	0.02460	0.89600	0.000544	< 0.001
12-EF-20	QFG	0.022	19.2	0.02	1.8	0.0007	0.00325	6.38	0.0002	0.00002	0.0007	< 0.001	< 0.00001	0.062	0.0014	< 0.00002	0.000033	0.05040	0.00317	0.000016	< 0.001
12-EF-21	MYL	0.304	1.46	0.008	0.24	0.0004	0.0014	38.60	0.0006	0.00012	0.0007	< 0.001	1.20E-04	0.003	0.0045	< 0.00002	0.000209	0.00390	0.00040	0.000112	0.003
13-EF-01	QFG	0.557	8.67	0.026	0.373	0.00458	0.00067	12.1	0.0025	0.00022	0.0006	< 0.001	0.00004	0.0028	0.0342	< 0.00002	0.000295	0.0139	0.00042	0.000030	0.002
13-EF-02	DD	0.732	1.56	0.002	0.547	0.00980	0.00055	16.3	0.0005	0.00006	0.0019	0.001	0.00004	0.0108	0.0439	< 0.00002	0.000205	0.0545	0.00042	0.000196	0.002
13-EF-03	DD	0.608	0.667	0.003	0.715	0.00908	0.00017	11.1	0.0004	0.00032	0.0012	< 0.001	0.00004	0.0089	0.0257	< 0.00002	0.000037	0.0408	0.00019	0.000137	0.001
Minimum		**< 0.003**	**0.667**	**0.002**	**0.236**	**0.0003**	**0.00017**	**5.25**	**< 0.0001**	**0.00002**	**0.0006**	**< 0.001**	**< 0.00001**	**0.0027**	**0.0003**	**< 0.00002**	**0.000002**	**0.0039**	**0.00019**	**0.000005**	**< 0.001**
Maximum		**2.12**	**34.8**	**0.026**	**3.37**	**0.0184**	**0.0193**	**38.6**	**0.0081**	**0.00193**	**0.0059**	**0.003**	**0.00034**	**0.732**	**0.113**	**< 0.00002**	**0.00389**	**0.0545**	**2.37**	**0.00383**	**0.003**
Average		**0.51774**	**12.342**	**0.011**	**0.9172**	**0.0061**	**0.002501**	**13.718**	**0.001052**	**0.0002744**	**0.0014**	**0.0014**	**0.00007**	**0.0505**	**0.028938**	**< 0.00002**	**0.00028**	**0.032071**	**0.141**	**0.0003**	**0.001889**

1) Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment (CCME, 2007).

0.01 - Denotes a value that is greater than CCME guidelines

Table 5-5
NAG Leachate
Tazi Twe Project

	Rock Type	pH *units*	Alkalinity *mg/L as $CaCO_3$*	Conductivity *µS/cm*	Cl *mg/L*	SO_4 *mg/L*	Hg *mg/L*	Ag *mg/L*	Al *mg/L*	As *mg/L*	Ba *mg/L*	B *mg/L*	Be *mg/L*	Bi *mg/L*	Bi *mg/L*	Ca *mg/L*	Cd *mg/L*	Co *mg/L*	Cr *mg/L*	Cu *mg/L*
Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life[1]		*6.5 - 9*						*0.0001*	*0.1*	*0.005*							*0.000017*		*0.001*	*0.001*
12-EF-01	QFG	7.9	55	138	< 2	6.6	< 0.0001	< 0.00001	0.11	0.0019	0.00780	0.0616	< 0.00002	< 0.00001	0.00001	9.5	< 0.000003	0.000181	0.059	0.0009
12-EF-02	QFG	8.0	46	148	< 2	13.0	< 0.0001	< 0.00001	0.49	0.0047	0.00698	0.095	< 0.00002	< 0.00001	0.00001	8.2	< 0.000003	0.00017	0.046	0.0008
12-EF-03	DD	7.2	10	118	< 2	32.0	< 0.0001	< 0.00001	0.45	0.0018	0.0143	0.0371	< 0.00002	< 0.00001	0.00001	12.1	< 0.000003	0.000199	0.033	0.0006
12-EF-04	QFG	7.7	38	123	< 5	13.0	< 0.0001	< 0.00001	1.00	0.0018	0.01230	0.0466	< 0.00002	< 0.00001	0.00001	6.9	< 0.000003	0.000137	0.038	0.0006
12-EF-05	QFG	7.9	42	170	< 2	25.0	< 0.0001	< 0.00001	0.84	0.0042	0.01200	0.0553	< 0.00002	< 0.00001	0.00001	17.5	< 0.000003	0.000152	0.037	< 0.0005
12-EF-06	QFG	8.7	56	191	< 5	26.0	< 0.0001	< 0.00001	0.78	0.0051	0.00871	0.0659	< 0.00002	< 0.00001	0.00001	25.4	< 0.000003	0.000161	0.036	0.0006
12-EF-07	QFG	8.9	74	223	< 2	15.0	< 0.0001	< 0.00001	1.78	0.0062	0.00490	0.0157	< 0.00002	< 0.00001	0.00001	23.6	< 0.000003	0.000027	0.032	< 0.0005
12-EF-08	QFG	7.9	60	159	< 2	6.5	< 0.0001	< 0.00001	0.37	0.0046	0.00738	0.0518	< 0.00002	< 0.00001	0.00001	13.6	< 0.000003	0.000031	0.049	< 0.0005
12-EF-09	QFG	7.8	56	155	< 2	9.9	< 0.0001	< 0.00001	0.30	0.0034	0.00535	0.0474	< 0.00002	< 0.00001	0.00001	18.4	< 0.000003	0.000046	0.046	0.0005
12-EF-10	QFG	8.2	55	171	< 2	11.0	< 0.0001	< 0.00001	0.19	0.0016	0.00436	0.0578	< 0.00002	< 0.00001	0.00001	17.4	< 0.000003	0.000046	0.064	< 0.0005
12-EF-11	QFG	8.7	55	179	< 2	9.4	< 0.0001	< 0.00001	0.05	0.0021	0.00480	0.1830	< 0.00002	< 0.00001	0.00001	24.1	< 0.000003	0.000048	0.088	< 0.0005
12-EF-12	QFG	7.8	30	119	< 2	13.0	< 0.0001	< 0.00001	0.16	0.0033	0.02200	0.1150	< 0.00002	< 0.00001	0.00001	15.8	< 0.000003	0.000061	0.044	0.0006
12-EF-13	QFG	9.5	99	263	< 2	10.0	< 0.0001	< 0.00001	0.09	0.0027	0.01120	1.1600	< 0.00002	< 0.00001	0.00001	19.7	< 0.000003	0.000039	0.114	< 0.0005
12-EF-14	QFG	8.1	42	242	< 2	52.0	< 0.0001	< 0.00001	0.37	0.0029	0.00347	0.1260	< 0.00002	< 0.00001	0.00001	22.2	< 0.000003	0.000051	0.066	< 0.0005
12-EF-15	DD	7.9	40	191	< 2	18.0	< 0.0001	< 0.00001	0.60	0.0007	0.00066	0.1740	< 0.00002	< 0.00001	0.00001	32.4	< 0.000003	0.000045	0.026	< 0.0005
12-EF-16	QFG	6.1	< 2	412	< 2	160.0	< 0.0001	0.00038	0.11	< 0.0002	0.12400	0.1340	< 0.00002	< 0.00001	0.00001	27.7	0.00203	0.054200	0.019	0.0583
12-EF-17	QFG	7.4	10	148	< 2	41.0	< 0.0001	< 0.00001	0.13	0.0053	0.01860	0.173	< 0.00002	< 0.00001	0.00001	11.7	< 0.000003	0.000335	0.026	0.0005
12-EF-18	GD	7.1	6	47	< 2	3.3	< 0.0001	0.00122	0.05	0.0008	0.00724	0.056	< 0.00002	< 0.00001	0.00001	2.8	< 0.000003	0.000142	0.051	< 0.0005
12-EF-19	GD	7.0	13	56	< 2	8.2	< 0.0001	0.00029	0.05	0.0036	0.00521	0.066	< 0.00002	< 0.00001	0.00001	3.0	0.000006	0.000099	0.050	< 0.0005
12-EF-20	QFG	8.9	61	246	< 2	23.0	< 0.0001	< 0.00001	0.16	0.0008	0.00922	0.4410	< 0.00002	< 0.00001	0.00001	21.1	< 0.000003	0.000063	0.032	< 0.0005
12-EF-21	MYL	6.3	2	< 2	10.0	<2	< 0.0001	< 0.08	0.77	0.0007	< 0.005	0.1260	0.00003	0.00005	0.00005	0.3	0.000015	0.000059	0.0142	0.0012
13-EF-01	QFG	7.0	8	127	--	41	--	--	0.23	0.0038	0.0197	--	< 0.00002	< 0.00001	< 0.00001	11.4	0.000027	0.000028	0.0494	< 0.0005
13-EF-02	DD	7.0	7	170	--	66	--	--	0.64	0.0129	0.00197	--	< 0.00002	< 0.00001	< 0.00001	26.7	0.000015	0.000056	0.0265	0.0006
13-EF-03	DD	7.2	10	115	--	38	--	--	0.93	0.0043	0.00195	--	< 0.00002	< 0.00001	< 0.00001	18.3	< 0.000003	0.000050	0.0187	0.0012
Minimum		**6.1**	**2.0**	**47.0**	**< 2**	**< 2**	**< 0.0001**	**< 0.00001**	**0.05**	**< 0.0002**	**0.00066**	**0.016**	**< 0.00002**	**0.00001**	**0.00001**	**0.3**	**< 0.000003**	**0.0**	**0.014**	**< 0.0005**
Maximum		**9.5**	**99.0**	**412.0**	**10.0**	**160.0**	**< 0.0001**	**0.08**	**1.78**	**0.0062**	**0.1**	**1.2**	**0.00003**	**0.00005**	**0.00005**	**32.4**	**0.002030**	**0.1**	**0.114**	**0.0583**
Average		**7.1**	**43**	**175**	**3**	**24**	**< 0.0001**	**0.0039**	**0.421**	**0.0028**	**0.014**	**0.157**	**0.00002**	**0.00001**	**0.00001**	**16**	**0.000100**	**0**	**0.046**	**0.0033**

1) Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment (CCME, 2007).

0.01 - Denotes a value that is greater than CCME guidelines

Table 5-5
NAG Leachate
Tazi Twe Project

	Rock Type	Fe *mg/L*	K *mg/L*	Li *mg/L*	Mg *mg/L*	Mn *mg/L*	Mo *mg/L*	Na *mg/L*	Ni *mg/L*	Pb *mg/L*	Sb *mg/L*	Se *mg/L*	Sn *mg/L*	Sr *mg/L*	Ti *mg/L*	Tl *mg/L*	U *mg/L*	V *mg/L*	W *mg/L*	Y *mg/L*	Zn *mg/L*
Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life[1]		*0.3*							*0.025*	*0.001*		*0.001*									*0.03*
12-EF-01	QFG	0.020	21.90	0.021	0.12	0.00077	0.00214	3.46	0.0001	0.00003	0.0006	< 0.001	0.00027	0.023	0.0099	0.00006	0.000145	0.04520	0.00133	0.000004	< 0.001
12-EF-02	QFG	0.022	28.20	0.012	0.01	0.00063	0.00922	2.55	< 0.0001	< 0.00002	0.001	< 0.001	0.00023	0.009	0.0079	< 0.00002	0.000037	0.07510	0.00055	0.000003	< 0.001
12-EF-03	DD	0.043	9.96	0.014	0.08	0.00084	0.00431	2.20	0.0002	< 0.00002	0.0006	0.004	0.00017	0.014	0.0265	< 0.00002	0.000053	0.04890	0.00061	0.000006	< 0.001
12-EF-04	QFG	0.021	24.50	0.025	0.04	0.00058	0.00575	2.19	< 0.0001	0.00005	0.0003	0.001	0.00039	0.009	0.0140	< 0.00002	0.000034	0.05870	0.00051	0.000002	< 0.001
12-EF-05	QFG	0.032	19.40	0.015	0.02	0.00072	0.00901	2.67	< 0.0001	0.00002	0.0006	0.003	0.00050	0.014	0.0085	< 0.00002	0.000049	0.05880	0.00116	0.000005	< 0.001
12-EF-06	QFG	0.019	16.40	0.014	0.01	0.00046	0.00398	2.74	0.0002	0.00002	0.0009	0.003	0.00041	0.016	0.0049	< 0.00002	0.000132	0.06190	0.00169	0.000002	0.001
12-EF-07	QFG	0.007	31.50	0.007	0.00	0.00027	0.00612	3.22	< 0.0001	< 0.00002	0.0028	< 0.001	0.00002	0.012	0.0031	< 0.00002	0.000023	0.07530	0.00293	< 0.000001	< 0.001
12-EF-08	QFG	0.007	26.00	0.017	0.05	0.00043	0.00417	3.20	< 0.0001	< 0.00002	0.0011	< 0.001	0.00006	0.017	0.0086	0.00003	0.000234	0.05230	0.00260	0.000002	< 0.001
12-EF-09	QFG	0.004	13.70	0.015	1.20	0.00436	0.00103	4.39	< 0.0001	0.00002	0.0006	< 0.001	0.00016	0.055	0.0086	0.00011	0.000995	0.01490	0.00407	0.000005	< 0.001
12-EF-10	QFG	0.018	22.30	0.010	0.06	0.00030	0.00346	2.60	0.0001	< 0.00002	0.0004	< 0.001	0.00005	0.021	0.0054	< 0.00002	0.000517	0.06610	0.00163	0.000002	< 0.001
12-EF-11	QFG	0.007	19.10	0.015	0.02	0.00019	0.00357	4.12	< 0.0001	< 0.00002	0.0005	< 0.001	0.00023	0.036	0.0018	< 0.00002	0.000316	0.03760	0.00260	< 0.000001	< 0.001
12-EF-12	QFG	0.028	7.99	0.012	0.04	0.00048	0.00338	1.94	< 0.0001	0.00004	0.0004	0.003	0.00005	0.058	0.0012	< 0.00002	0.000007	0.07700	0.00271	0.000003	< 0.001
12-EF-13	QFG	0.005	54.90	0.001	0.01	0.00018	0.03330	3.46	< 0.0001	< 0.00002	0.0005	< 0.001	0.00006	0.023	0.0006	< 0.00002	0.000007	0.05690	0.00132	0.000004	0.002
12-EF-14	QFG	0.014	34.60	0.006	0.01	0.00035	0.08820	3.25	< 0.0001	< 0.00002	0.0015	0.005	0.00011	0.019	0.0009	< 0.00002	0.000006	0.03930	0.00146	0.000007	< 0.001
12-EF-15	DD	0.009	2.09	0.005	0.03	0.00025	0.00729	2.46	< 0.0001	< 0.00002	0.0003	0.004	0.00003	0.024	0.0008	< 0.00002	0.000010	0.05820	0.00059	< 0.000001	< 0.001
12-EF-16	QFG	< 0.003	38.60	0.022	10.20	0.52100	0.00070	3.41	0.0759	0.00012	< 0.0002	0.006	< 0.00001	0.061	0.0007	0.00052	0.000044	0.00172	< 0.00003	0.001620	0.060
12-EF-17	QFG	0.061	19.60	0.020	0.26	0.00333	0.00483	1.54	0.0004	< 0.00002	0.0005	0.003	0.00008	0.188	0.0034	< 0.00002	0.000005	0.08310	0.00092	0.000022	< 0.001
12-EF-18	GD	0.03	3.79	0.002	1.90	0.00948	0.00818	1.58	0.0005	0.00005	0.0006	< 0.001	0.00029	0.014	0.0461	0.00003	0.003280	0.03600	0.25000	0.000029	< 0.001
12-EF-19	GD	0.026	6.95	0.003	2.31	0.00675	0.00227	1.58	0.0001	< 0.00002	0.0005	< 0.001	0.00013	0.020	0.0139	0.00003	0.001200	0.02390	0.06780	0.000012	< 0.001
12-EF-20	QFG	0.009	36.10	0.005	0.02	0.00042	0.00404	2.76	< 0.0001	< 0.00002	0.0004	< 0.001	0.00006	0.017	0.0007	< 0.00002	0.000030	0.07950	0.00173	0.000008	< 0.001
12-EF-21	MYL	0.135	2.3	0.003	0.2	0.001	0.00093	0.62	0.0005	0.00012	0.0004	< 0.001	0.00093	0.003	0.0019	< 0.00002	0.001120	0.01710	< 0.01	< 0.003	0.003
13-EF-01	QFG	0.006	13.2	0.022	0.662	0.00028	0.0435	1.23	0.0002	0.00006	0.0015	0.002	0.00009	0.0506	0.0012	< 0.00002	0.000106	0.0184	--	--	< 0.001
13-EF-02	DD	0.022	1.97	0.008	0.387	0.00041	0.00418	1.84	< 0.0001	< 0.00002	0.0010	0.006	0.00008	0.0282	0.0015	0.00003	0.000019	0.0526	--	--	0.003
13-EF-03	DD	0.013	1.35	0.005	0.142	0.00029	0.00410	1.28	< 0.0001	< 0.00002	0.0018	0.006	0.00015	0.0255	0.0007	< 0.00002	0.000006	0.0226	--	--	< 0.001
Minimum		**< 0.003**	**2.09**	**0.001**	**0.004**	**0.00018**	**0.0007**	**0.62**	**< 0.0001**	**< 0.00002**	**< 0.0002**	**< 0.001**	**< 0.00001**	**0.0033**	**0.0006**	**< 0.00002**	**0.000005**	**0.00172**	**< 0.00003**	**< 0.000001**	**< 0.001**
Maximum		**0.135**	**54.9**	**0.025**	**10.2**	**0.521**	**0.0882**	**4.39**	**0.0759**	**0.00012**	**0.0028**	**0.006**	**0.00093**	**0.188**	**0.0461**	**0.00052**	**0.00328**	**0.0831**	**0.25**	**0.00162**	**0.06**
Average		**0.024762**	**20.9462**	**0.0116**	**0.79**	**0.02632**	**0.0098**	**2.664**	**0.00377**	**3.38E-05**	**0.00068**	**0.0021**	**0.000202**	**0.031**	**0.0081**	**0.00005**	**0.0003926**	**0.05083**	**0.016964**	**0.0002257**	**0.004**

1) Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment (CCME, 2007).

0.01 - Denotes a value that is greater than CCME guidelines

TABLE 5-6
Summary of Loading Rates and Depletion Calculation Results
Tazi Twe Project

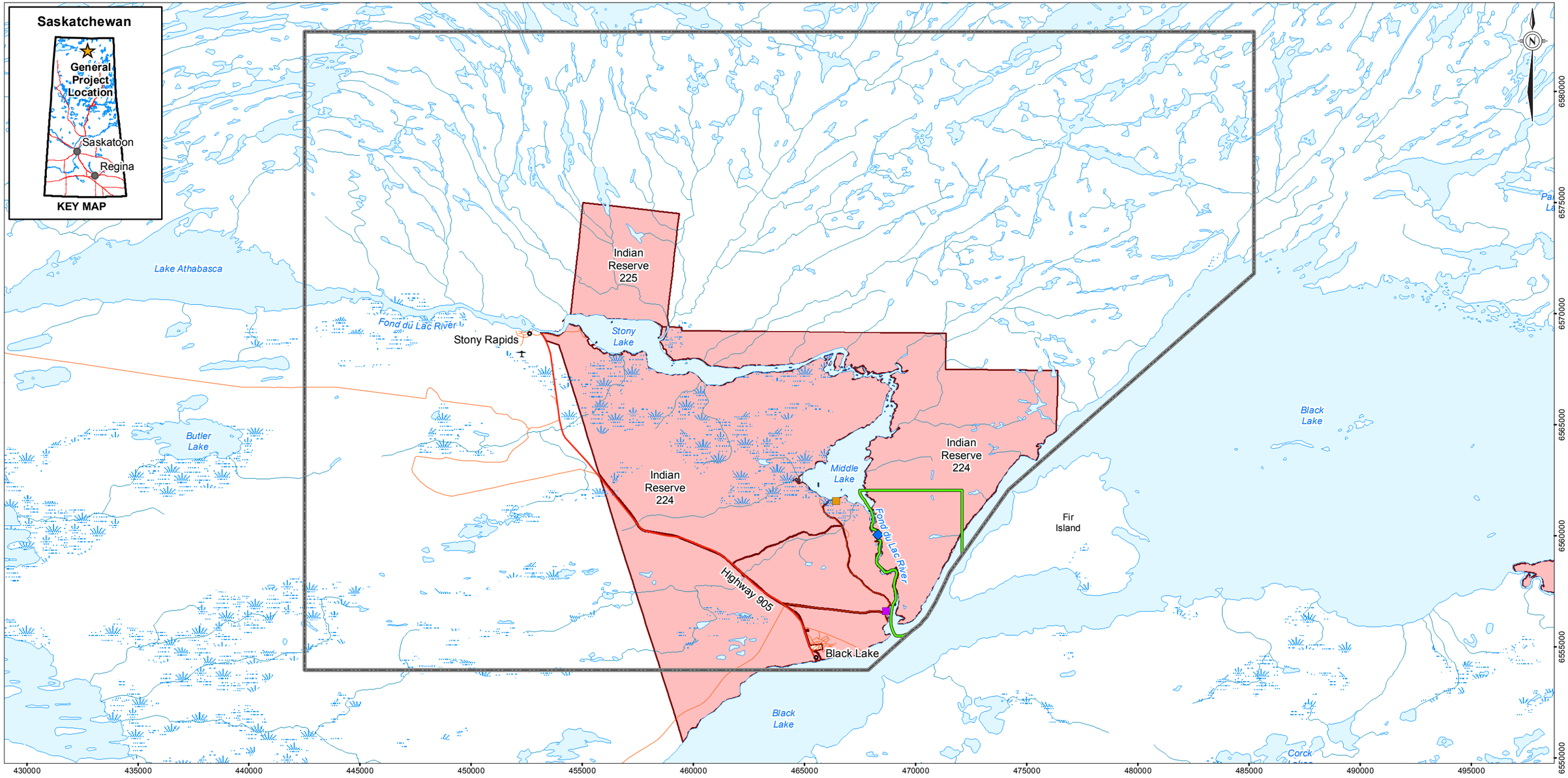
Cell Number	Lithology	Selected Static Test Results			Sulphide			NP (Empirical)			CO_3-NP (Alkalinity-based)		
		NP/AP	CO_3-NP/AP	AP	Initial	Depletion Rate	Time to Depletion	Initial NP	Depletion Rate	Time to Depletion	Initial CO_3-NP	Depletion Rate	Time to Depletion
				(t $CaCO_3$/ 1000t)	(%)	(mg/kg/wk)	Years	(kg/t as $CaCO_3$)	(mg/kg/wk)	Years	(kg/t as $CaCO_3$)	(mg/kg/wk)	Years
1	Quartzo-feldspathic gneiss	**2**	**0.4**	12.5	0.4	2.6	4	23	18	25	5	10	8

Notes:

1.0	This indicates an uncertain potential for acid generation, based on NP/AP and/or CO_3-NP/AP being greater than 1.0, but less than 2.0 (MEND, 2009).
1.0	This indicates a potential for acid generation, based on NP/AP and/or CO_3-NP/AP being less than 1.0 (MEND, 2009).
10.0	This indicates a potential for acid generation − time of depletion of NP and/or CO_3-NP is less than time of depletion of sulphide minerals (or AP).

Calculations based on 51 - 75 weeks of data for waste rock cells and 51 weeks of data for tailings cells.

FIGURES



LEGEND

- VILLAGE
- ROAD
- RIVER
- WETLAND
- WATERBODY
- INDIAN RESERVE
- ELIZABETH FALLS
- CAMP GRAYLING
- RESIDENCE
- GEOTECHNICAL LOCAL STUDY AREA
- GEOTECHNICAL REGIONAL STUDY AREA

REFERENCE

DMTI HIGHWAYS AND ROADS
NTS MAPSHEET 74I, 74J, 74O, 74P
DATUM: NAD 83 PROJECTION: UTM ZONE 13

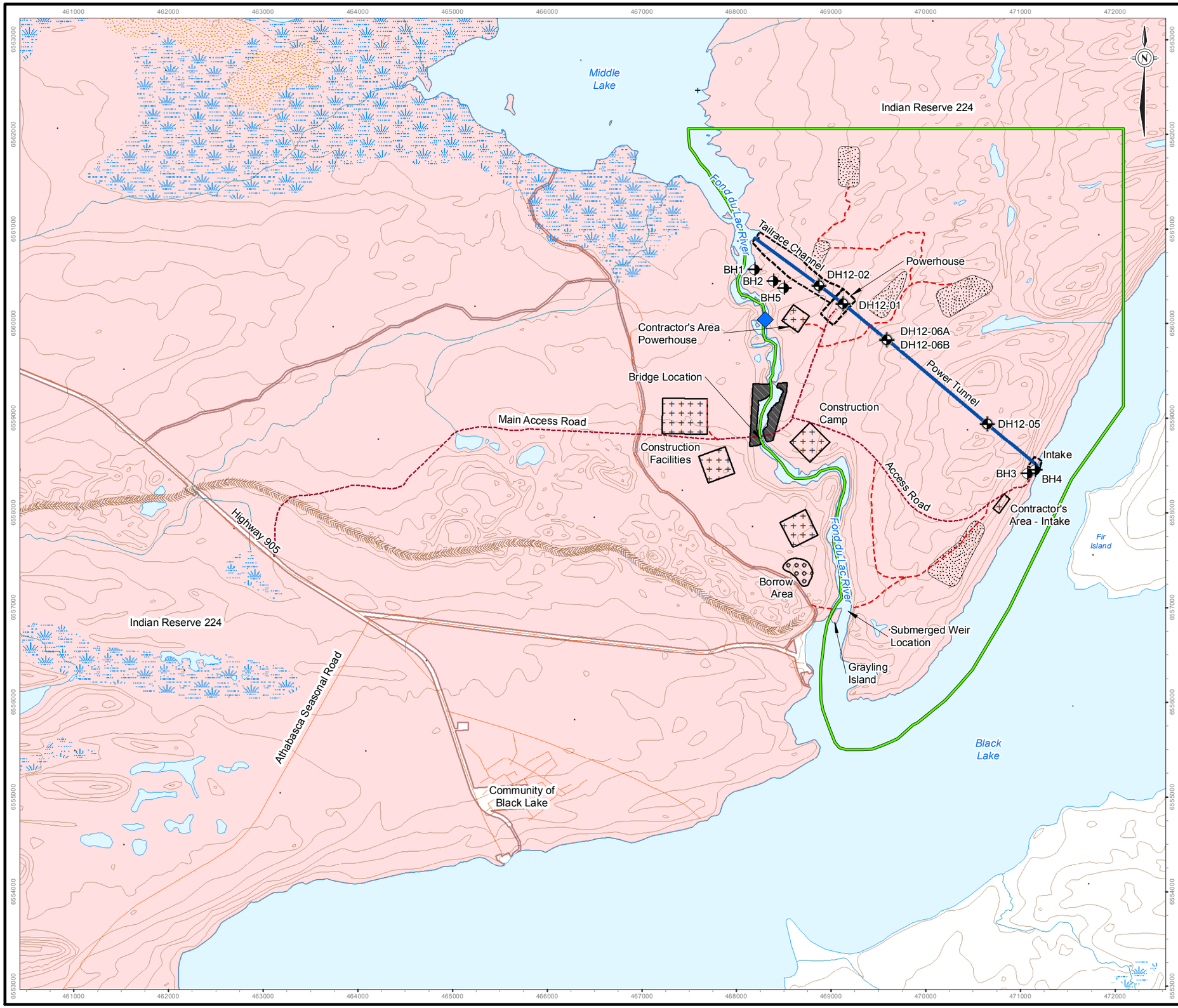
5 0 5
SCALE 1:175,000 KILOMETRES

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
GENERAL PROJECT LOCATION

Golder Associates
Saskatoon, Saskatchewan

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 2
GIS	SM	12/03/13	**FIGURE: 1-1**	
CHECK	DL	24/07/13		
REVIEW	MAT	25/06/13		



LEGEND

- CONTOUR LINE
- ROAD
- RIVER
- WETLAND
- WATERBODY
- INDIAN RESERVE
- GEOLOGY & HYDROGEOLOGY LOCAL STUDY AREA
- ELIZABETH FALLS
- 2012 BOREHOLE LOCATION
- 2002 BOREHOLE LOCATION
- PROPOSED ACCESS ROAD
- PROPOSED TEMPORARY ACCESS ROAD
- PROJECT AXIS
- BORROW AREA
- POTENTIAL BRIDGE ALIGNMENT AREA
- CONTRACTOR/CAMP LOCATION
- DISPOSAL AREA
- FENCE

NOTE: LOCATIONS OF PROPOSED FACILITIES ARE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. FINAL LOCATIONS WILL BE DETERMINED DURING FINAL ENGINEERING AND DESIGN, TAKING INTO CONSIDERATION STAKEHOLDER INPUT.

REFERENCE

DATUM: NAD83 PROJECTION: UTM ZONE 13
SITE PLAN PROVIDED BY KGS GROUP CONSULTING & ENGINEERS

1 0 1
SCALE 1:40,000 KILOMETRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

BOREHOLE LOCATION PLAN

Golder Associates
Saskatoon, Saskatchewan

PROJECT	10-1365-0004		FILE No.		
DESIGN			SCALE AS SHOWN	REV.	7
GIS	SM	10/07/13			
CHECK	EAM	19/07/13			
REVIEW	MT	19/07/13			

FIGURE: 3-1

Figure 5-1
Total Sulphur vs. Sulphide Sulphur
Tazi Twe Project

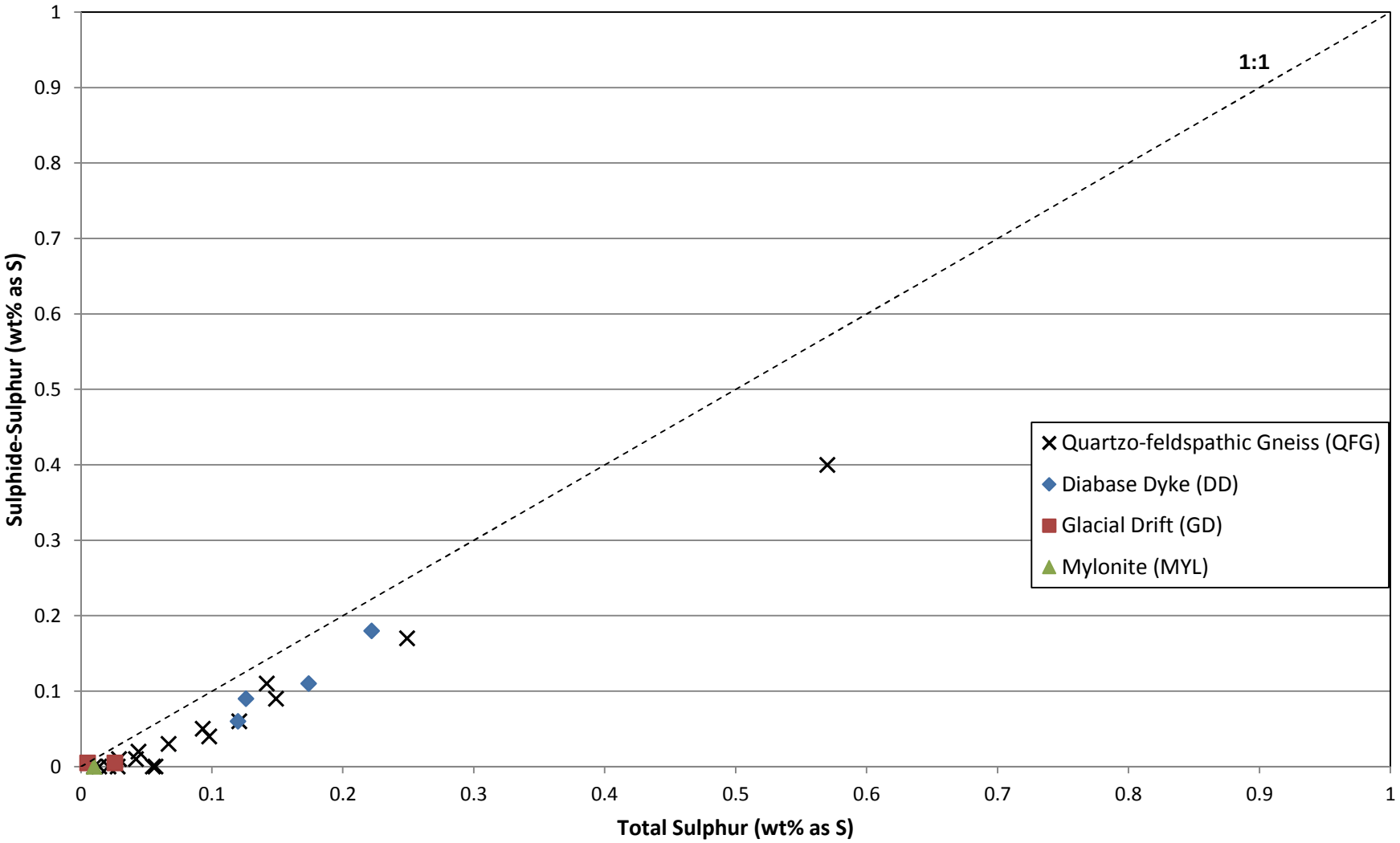


Figure 5-2
Neutralization Potential vs. Carbonate Neutralization Potential
Tazi Twe Project

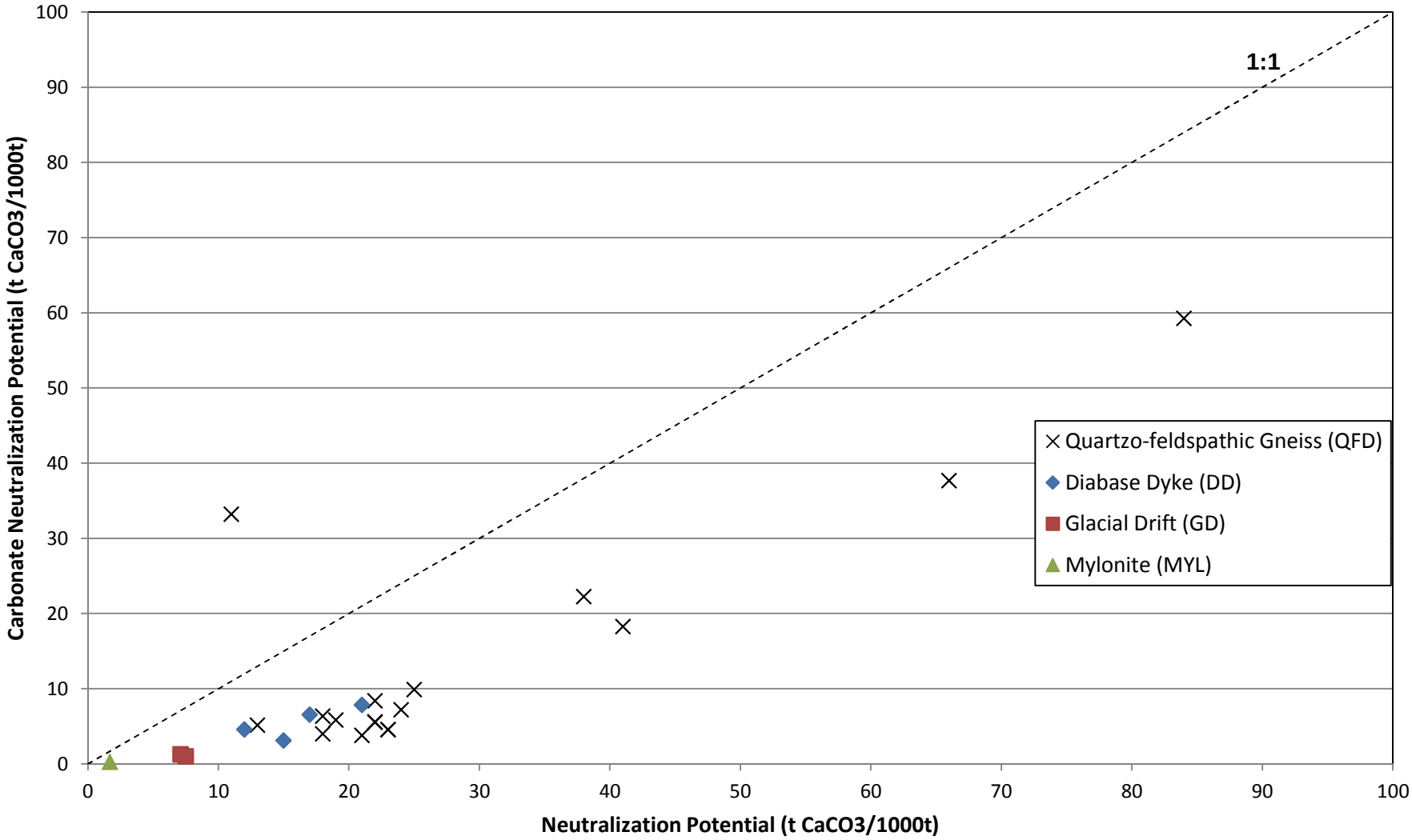


Figure 5-3
Neutralization Potential vs. Acid Potential
Tazi Twe Project

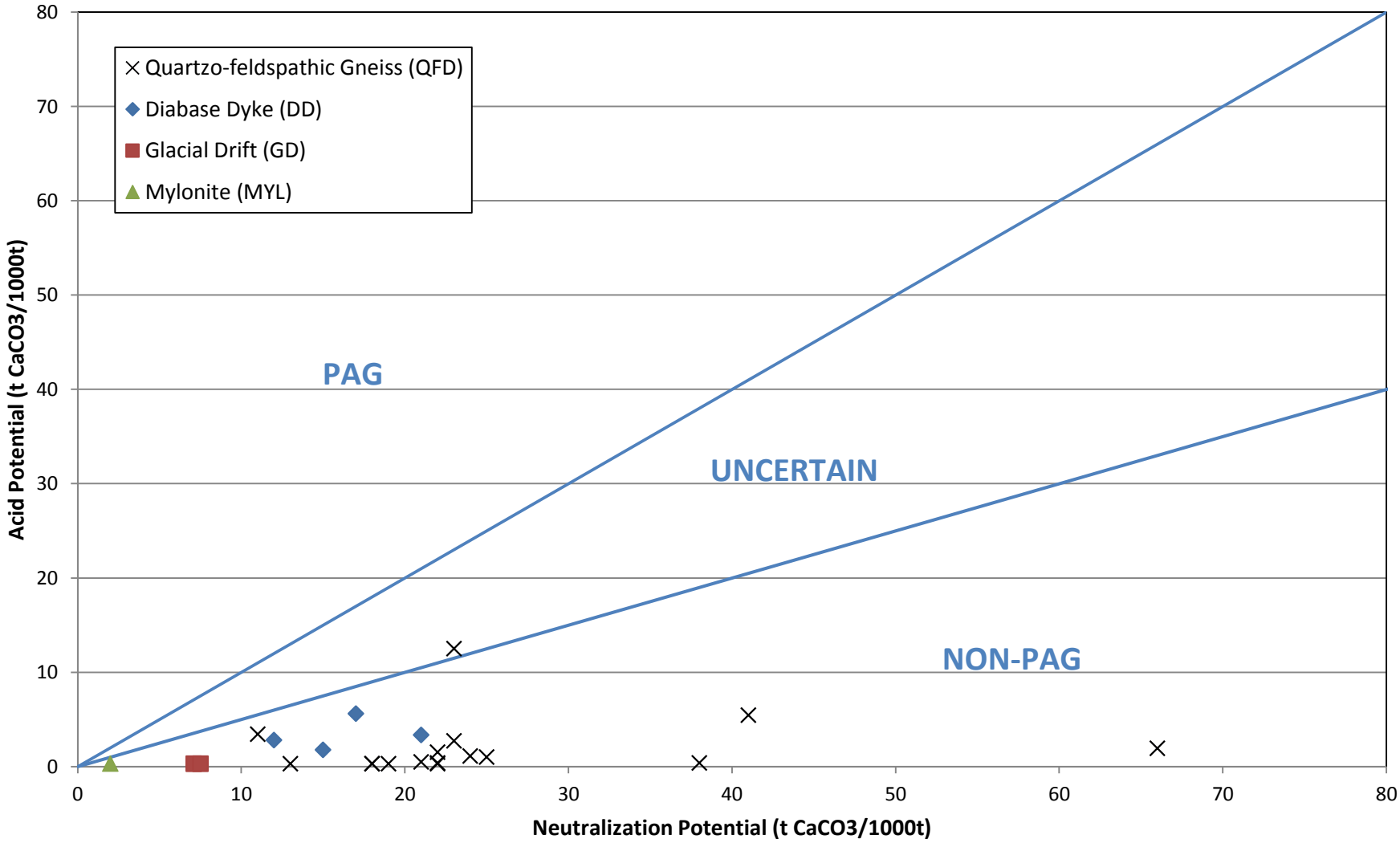


Figure 5-4
Carbonate Neutralization Potential vs. Acid Potential
Tazi Twe Project

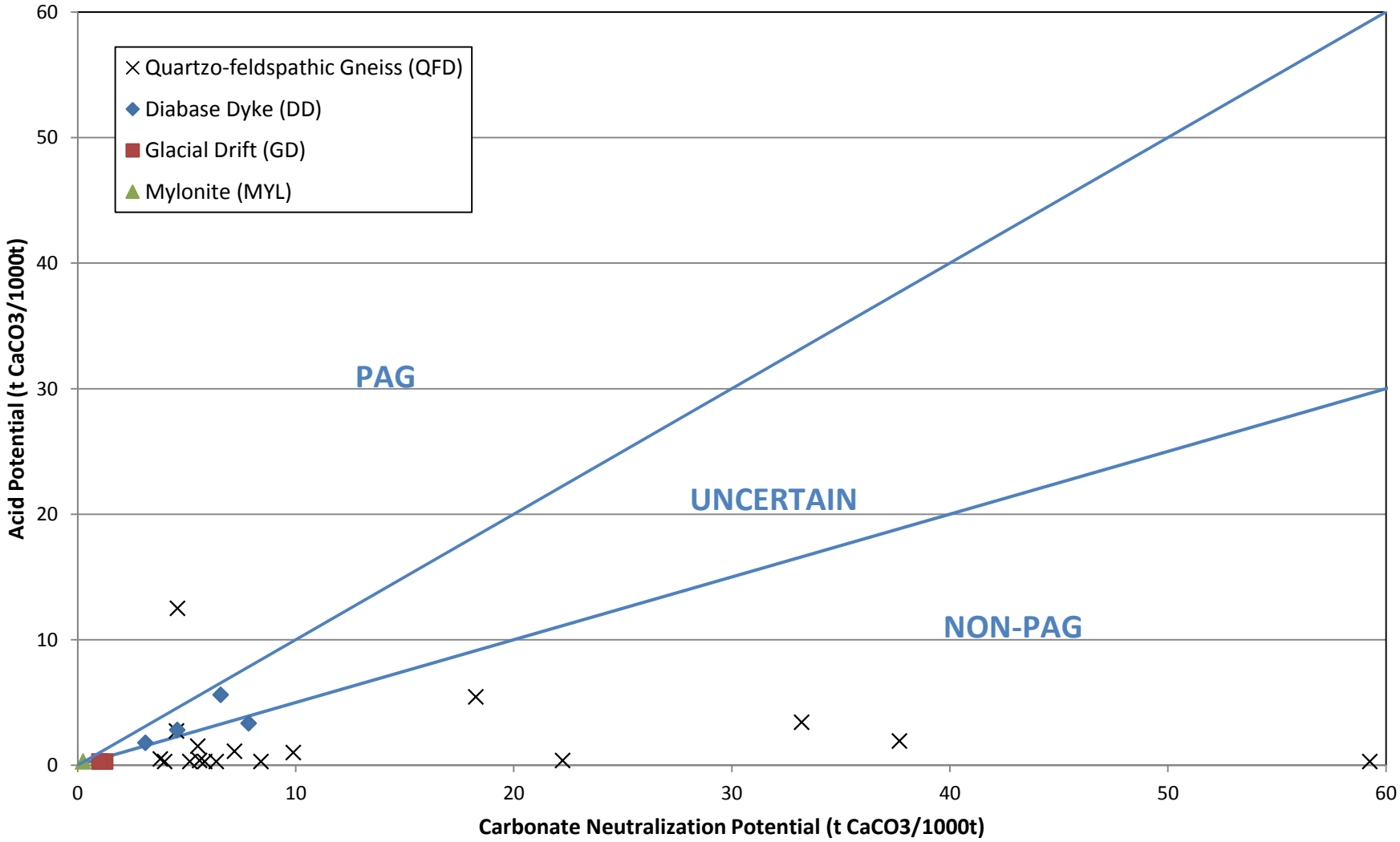


FIGURE 5-5
Humidity Cell Results: 12-EF-16
Tazi Twe Project

<u>Acid-base Accounting & Depletion Data</u>

Sulphide Content = 0.4 wt% as S

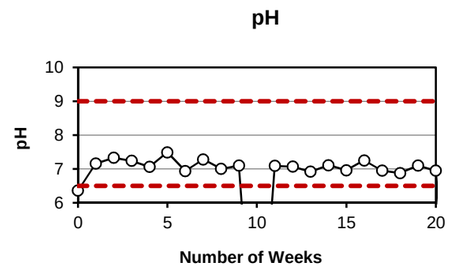
NP = 23 t $CaCO_3$/1000 t

AP = 13 t $CaCO_3$/1000 t

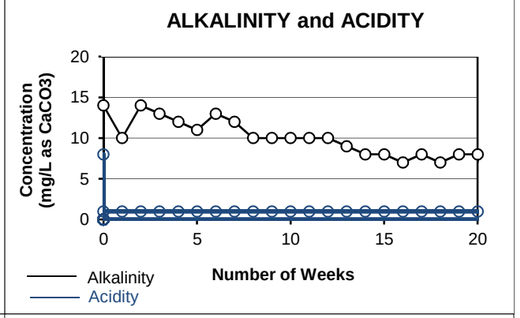
NP/AP = 1.8

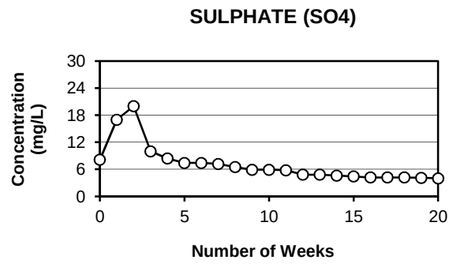
NP Depletion Time = 24.8 years

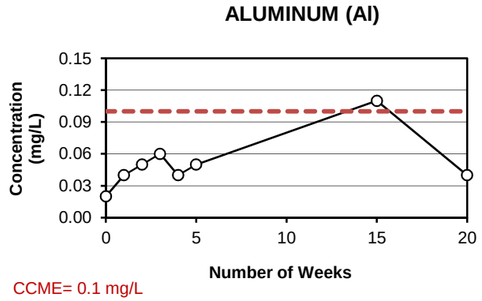
AP Depletion Time = 4.8 years



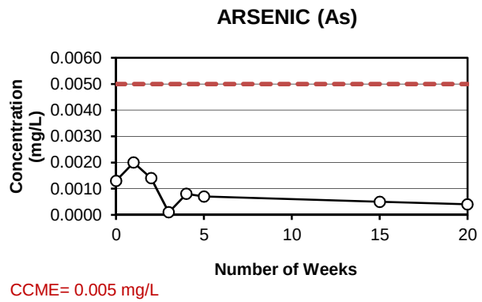
CCME= 6.5 - 9



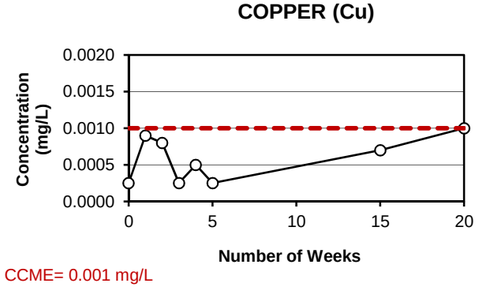




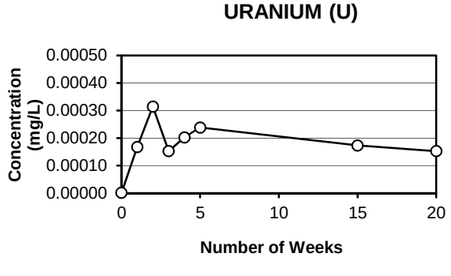
CCME= 0.1 mg/L

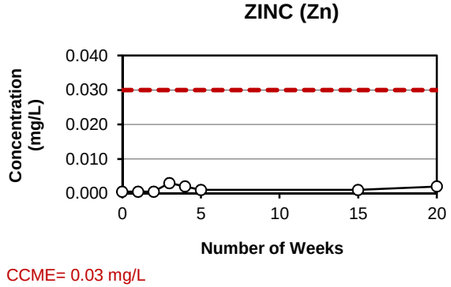


CCME= 0.005 mg/L



CCME= 0.001 mg/L





CCME= 0.03 mg/L

APPENDIX A

Waste Rock Sample Descriptions

Table A-1
Sample Descriptions
Elizabeth Fall Hydroelectric Project

Sample ID	Rock Name	Drillhole ID	From (m)	To (m)	Rock Name	Description
12-EF-01	Quartzo-feldspathic Gneiss	BH12-05	88	98	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained,
12-EF-02	Quartzo-feldspathic Gneiss	BH12-06A	4	14	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, hematite staining on some joints
12-EF-04	Quartzo-feldspathic Gneiss	BH12-06B	7	14	QFG	quartzo-feldspathic gneiss, grey, medium to coarse grained
12-EF-05	Quartzo-feldspathic Gneiss	BH12-06B	24.3	34.3	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained,
12-EF-06	Quartzo-feldspathic Gneiss	BH12-06B	45	55	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, disseminated sulphide (<1%)
12-EF-07	Quartzo-feldspathic Gneiss	BH12-06B	55	64	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, disseminated sulphide (<1%)
12-EF-08	Quartzo-feldspathic Gneiss	BH12-06B	68	78	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, disseminated sulphide (<1%)
12-EF-09	Quartzo-feldspathic Gneiss	BH12-05	52.5	61.5	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, hematite alteration, strongly foliated
12-EF-10	Quartzo-feldspathic Gneiss	BH12-05	64.5	74.5	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, hematite alteration, calcite in some joints
12-EF-11	Quartzo-feldspathic Gneiss	BH12-05	12.4	24.4	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, hematite staining on some joints, sulphide present as blebs and disseminated (<1%)
12-EF-12	Quartzo-feldspathic Gneiss	BH12-01	0.52	11.34	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained,
12-EF-13	Quartzo-feldspathic Gneiss	BH12-01	12	22	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, disseminated sulphide (<1%)
12-EF-14	Quartzo-feldspathic Gneiss	BH12-01	32	42	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, trace hemitate alteration, calcite present in some joints, disseminated sulphide (<1%)
12-EF-16	Quartzo-feldspathic Gneiss	BH12-01	57.92	64.78	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, trace sulphide blebs on some fractures (<1%)
12-EF-17	Quartzo-feldspathic Gneiss	BH12-01	22	32	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained
12-EF-20	Quartzo-feldspathic Gneiss	BH12-02	19.7	25.5	QFG	quartzo-feldspathic gneiss, grey, fine to medium grained, hematite alteration, disseminated and blebs of sulphide (<1%)
13-EF-01	Quartzo-feldspathic Gneiss	BH13-02	36.75	36.96	QFG	quartzo-feldspathic gneiss, black to dark grey to white, very fine to medium grained
12-EF-21	Mylonite	BH12-07	19.5	27	MYL	mylonite, grey, coarse grained, clay infill on joints, iron staining throughout
12-EF-03	Diabase Dyke	BH12-06A	28	38	DD	diabase dyke, green-grey, fine grained
12-EF-15	Diabase Dyke	BH12-01	47.72	57.92	DD	diabase dyke, grey, fine grained, trace sulphide blebs on fractures (<1%)
13-EF-02	Diabase Dyke	BH13-02	83.95	84.19	DD	diabase dyke, dark grey, fine to finely crystalline, pyrite on joint fractures (<1%)
13-EF-03	Diabase Dyke	BH13-03	43.52	43.92	DD	diabase dyke, dark grey, fine to medium crystalline.
12-EF-18	Glacial Drift	BH12-02	1.5	4.3	GD	sandy silt, some clay and gravel
12-EF-19	Glacial Drift	BH12-02	8	18	GD	cobbles and boulders with some sand intervals

APPENDIX B

Kinetic Test Results

Table B-1
Humidity Cell Results: 12-EF-16
Tazi Twe Hydroelectric Project

Weeks		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Date		16-Oct-12	22-Oct-12	30-Oct-12	6-Nov-12	13/Nov/12	20-Nov-12	27-Nov-12	4-Dec-12	11/Dec/12	18/Dec/12	25-Dec-12	31/Dec/12	8/Jan/13	15-Jan-13	22/Jan/13	29/Jan/13	5-Feb-13	12/Feb/13	19/Feb/13	26-Feb-13	5/Mar/13
Leachate	mL	804	981	970	981	981	979	980	983	982	982	980	985	980	976	980	976	971	979	980	980	978
pH	pH	6.36	7.16	7.33	7.24	7.06	7.49	6.94	7.28	7	7.1	---	7.09	7.07	6.92	7.11	6.96	7.25	6.95	6.88	7.1	6.95
Acidity as CaCO3	mg CaCO3/L	<2	<2	<2	<2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Alkalinity as CaCO3	mg CaCO3/L	14	10	14	13	12	11	13	12	10	10	10	10	10	9	8	8	7	8	7	8	8
Conductivity	umhos/cm	57	88	100	65	57	55	49	50	48	45	---	44	41	42	38	38	38	37	37	31	34
Sulphate (SO4)	mg/L	8.1	17	20	10	8.4	7.4	7.4	7.2	6.5	5.9	5.9	5.8	4.8	4.8	4.6	4.4	4.2	4.2	4.2	4.1	4
Nitrate (as N)	mg/L	<0.05	<0.05	<0.05	<0.05	< 0.06	< 0.06	---	---	---	---	---	---	---	---	---	< 0.05	---	---	---	---	< 0.05
Nitrite (as N)	mg/L	<0.06	<0.06	<0.06	<0.06	< 0.05	< 0.05	---	---	---	---	---	---	---	---	---	< 0.06	---	---	---	---	< 0.06
Ammonia (NH3)	mg/L	<0.1	<0.1	<0.1	<0.1	< 0.1	0.2	---	---	---	---	---	---	---	---	---	< 0.1	---	---	---	---	< 0.1
Silver (Ag)	mg/L	<0.00001	<0.00001	<0.00001	<0.00001	< 0.00001	< 0.00001	---	---	---	---	---	---	---	---	---	< 0.00001	---	---	---	---	< 0.00001
Aluminium (Al)	mg/L	0.02	0.04	0.05	0.06	0.04	0.05	---	---	---	---	---	---	---	---	---	0.11	---	---	---	---	0.04
Antmony (Sb)	mg/L	0.0004	0.001	0.0008	0.0002	0.0005	0.0007	---	---	---	---	---	---	---	---	---	0.0004	---	---	---	---	0.0002
Arsenic (As)	mg/L	0.0013	0.002	0.0014	<0.0002	0.0008	0.0007	---	---	---	---	---	---	---	---	---	0.0005	---	---	---	---	0.0004
Barium (Ba)	mg/L	0.00086	0.0021	0.0022	0.00172	0.00167	0.00179	---	---	---	---	---	---	---	---	---	0.00194	---	---	---	---	0.00122
Beryllium (Be)	mg/L	<0.00002	<0.00002	<0.00002	<0.00002	< 0.00002	< 0.00002	---	---	---	---	---	---	---	---	---	< 0.00002	---	---	---	---	< 0.00002
Bismuth (Bi)	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Boron (B)	mg/L	0.0098	0.0153	0.0187	0.0116	0.0092	0.0061	---	---	---	---	---	---	---	---	---	0.002	---	---	---	---	0.0008
Cadmium (Cd)	mg/L	<0.000003	0.000003	0.000003	0.000006	0.000039	0.000003	---	---	---	---	---	---	---	---	---	0.000008	---	---	---	---	0.000008
Calcium (Ca)	mg/L	3.67	5.59	7.24	5.82	5.49	4.94	---	---	---	---	4.94	---	---	---	---	3.66	---	---	---	---	3.5
Chloride (Cl)	mg/L	1.8	3.2	2.8	2			---	---	---	---	---	---	---	---	---	0.7	---	---	---	---	0.6
Chromium (Cr)	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	< 0.0005	< 0.0005	---	---	---	---	---	---	---	---	---	< 0.0005	---	---	---	---	< 0.0005
Cobalt (Co)	mg/L	0.000048	0.000058	0.000062	0.000257	0.000097	0.000071	---	---	---	---	---	---	---	---	---	0.000085	---	---	---	---	0.00011
Copper (Cu)	mg/L	<0.0005	0.0009	0.0008	<0.0005	0.0005	< 0.0005	---	---	---	---	---	---	---	---	---	0.0007	---	---	---	---	0.001
Iron (Fe)	mg/L	0.004	<0.002	<0.002	<0.002	0.004	< 0.002	---	---	---	---	---	---	---	---	---	0.049	---	---	---	---	< 0.002
Lead (Pb)	mg/L	<0.00002	<0.00002	<0.00002	<0.00002	< 0.00002	< 0.00002	---	---	---	---	---	---	---	---	---	0.00016	---	---	---	---	< 0.00002
Lithium (Li)	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Magnesium (Mg)	mg/L	0.579	1.42	2.05	1.39	1.22	1.02	---	---	---	---	---	---	---	---	---	0.487	---	---	---	---	0.396
Manganese (Mn)	mg/L	0.0069	0.0121	0.0115	0.0111	0.0096	0.0096	---	---	---	---	---	---	---	---	---	0.0094	---	---	---	---	0.01
Mercury (Hg)	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	< 0.0001	< 0.0001	---	---	---	---	---	---	---	---	---	0.00001	---	---	---	---	< 0.00001
Molybdenum (Mo)	mg/L	0.0011	0.00237	0.00235	0.00089	0.00084	0.00043	---	---	---	---	---	---	---	---	---	0.0001	---	---	---	---	0.00008
Nickel (Ni)	mg/L	0.0001	0.0003	0.0004	0.0003	0.0003	0.0001	---	---	---	---	---	---	---	---	---	0.0002	---	---	---	---	< 0.0001
Phosphorus (P)	mg/L	<0.03	<0.03	0.11	<0.03	< 0.03	< 0.03	---	---	---	---	---	---	---	---	---	< 0.03	---	---	---	---	< 0.03
Potassium (K)	mg/L	3.86	5.82	6.91	4.38	4.3	3.64	---	---	---	---	---	---	---	---	---	2.45	---	---	---	---	2.47
Selenium (Se)	mg/L	<0.001	<0.001	<0.001	<0.001	< 0.001	< 0.001	---	---	---	---	---	---	---	---	---	< 0.001	---	---	---	---	< 0.001
Silica (SiO2)	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Sodium (Na)	mg/L	2.29	4.14	4.15	1.96	1.34	0.89	---	---	---	---	---	---	---	---	---	0.19	---	---	---	---	0.15
Strontium (Sr)	mg/L	0.0227	0.0426	0.0508	0.0374	0.0275	0.0291	---	---	---	---	---	---	---	---	---	0.0139	---	---	---	---	0.0113
Tellerium (Te)	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Thallium (Tl)	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Thorium (Th)	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Tin (Sn)	mg/L	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.00025	---	---	---	---	0.0002
Titanium (Ti)	mg/L							---	---	---	---	---	---	---	---	---		---	---	---	---	
Uranium (U)	mg/L	0.000001	0.000167	0.000314	0.000152	0.000202	0.000238	---	---	---	---	---	---	---	---	---	0.000173	---	---	---	---	0.000152
Vanadium (V)	mg/L	0.00062	0.00049	0.00057	0.00033	0.00039	0.00038	---	---	---	---	---	---	---	---	---	0.00042	---	---	---	---	0.00024
Zinc (Zn)	mg/L	<0.001	<0.001	<0.001	0.003	0.002	0.001	---	---	---	---	---	---	---	---	---	0.001	---	---	---	---	0.002

Table B-1
Humidity Cell Results: 12-EF-16
Tazi Twe Project

Week	Leachate Volume (L)	SO_4 in Leachate (mg/L)	SO_4 Mass (mg/wk)	SO_4 Production Rate (mg/kg/wk)	Cumulative SO_4 Loading (mg/kg)	S Production Rate (mg/kg/wk)	Cumulative S Loading (mg/kg)	S Remaining (%)	Theoretical NP Consumed from SO_4 Only (mg $CaCO_3$/kg/wk)	Cumulative NP Depletion from SO4 Only (mg $CaCO_3$/kg)	Theoretical Remaining NP from SO_4 Only (%)	Theoretical Remaining CaNP from SO_4 Only (%)	Empirical Open System NP Consumption At Near Neutral pH (mg/kg/wk)	Cumulative Empirical NP Consumption (mg/kg as $CaCO_3$)	Remaining NP Using Empirical NP Consumption (%)	Remaining CaNP Using Empirical NP Consumption (%)	Remaining CaNP Using Alkalinity (%)	Humidity Cell Results: 12-EF-16 Tazi Twe Project	Mass of Alkalinity (mg as $CaCO_3$/wk)	Alkalinity Production Rate (mg/kg as $CaCO_3$/wk)	Cumulative Alkalinity Mass Loading (mg/kg as $CaCO_3$)	Remaining Empirical NP from Alkalinity Production (%)	Remaining Empirical CaNP from Alkalinity Production (%)	Measured Acidity (mg/L as $CaCO_3$)	Mass of Acidity (mg as $CaCO_3$/wk)	Acidity Production Rate (mg/kg as $CaCO_3$/wk)	Cumulative Acidity Mass Loading (mg/kg as $CaCO_3$)	Measured Ca (mg/L)	Assumed Alkalinity (based on Ca) (mg/L as $CaCO_3$)	Mass of Alkalinity (mg as $CaCO_3$/wk)	Alkalinity Production Rate (mg/kg as $CaCO_3$/wk)	Cumulative Alkalinity Mass Loading (mg/kg as $CaCO_3$)	Remaining CaNP Using Ca (%)	Remaining NP Using Ca (%)
0	0.804	8.1	6.5	6.5	6.5	2.2	2.2	99.6	6.8	6.8	100.0	99.85	17.2	17.2	99.9	99.6	99.8	14	11.3	11.3	11.3	100.0	99.8	1	0.8	0.8	0.8	3.67	9.18	7.38	7.4	7.4	99.8	100.0
1	0.981	17.0	16.7	16.7	23.2	5.6	7.7	98.7	17.4	24.2	99.9	99.47	26.2	43.4	99.8	99.1	99.5	10	9.8	9.8	21.1	99.9	99.5	1	1.0	1.0	1.8	5.59	13.98	13.71	13.7	21.1	99.5	99.9
2	0.970	20.0	19.4	19.4	42.6	6.5	14.2	97.6	20.2	44.4	99.8	99.04	32.8	76.3	99.7	98.3	99.2	14	13.6	13.6	34.6	99.8	99.2	1	1.0	1.0	2.8	7.24	18.10	17.56	17.6	38.6	99.2	99.8
3	0.981	10.0	9.8	9.8	52.4	3.3	17.5	97.1	10.2	54.6	99.8	98.81	22.0	98.3	99.6	97.9	99.0	13	12.8	12.8	47.4	99.8	99.0	1	1.0	1.0	3.7	5.82	14.55	14.27	14.3	52.9	98.8	99.8
4	0.981	8.4	8.2	8.2	60.6	2.8	20.2	96.6	8.6	63.2	99.7	98.63	19.4	117.6	99.5	97.4	98.7	12	11.8	11.8	59.2	99.7	98.7	1	1.0	1.0	4.7	5.49	13.73	13.46	13.5	66.4	98.6	99.7
5	0.979	7.4	7.2	7.2	67.9	2.4	22.7	96.2	7.5	70.7	99.7	98.46	17.3	135.0	99.4	97.1	98.5	11	10.8	10.8	69.9	99.7	98.5	1	1.0	1.0	5.7	4.94	12.35	12.09	12.1	50.7	98.9	99.8
6	0.980	7.4	7.3	7.3	75.1	2.4	25.1	95.8	7.6	78.3	99.7	98.30	19.3	154.3	99.3	96.6	98.2	13	12.7	12.7	82.7	99.6	98.2	1	1.0	1.0	6.7	---							
7	0.983	7.2	7.1	7.1	82.2	2.4	27.4	95.4	7.4	85.7	99.6	98.14	18.2	172.5	99.3	96.3	97.9	12	11.8	11.8	94.5	99.6	97.9	1	1.0	1.0	7.7	---							
8	0.982	6.5	6.4	6.4	88.6	2.1	29.6	95.1	6.7	92.3	99.6	97.99	15.5	188.0	99.2	95.9	97.7	10	9.8	9.8	104.3	99.5	97.7	1	1.0	1.0	8.6	---							
9	0.982	5.9	5.8	5.8	94.4	1.9	31.5	94.7	6.0	98.4	99.6	97.86	14.9	202.8	99.1	95.6	97.5	10	9.8	9.8	114.1	99.5	97.5	1	1.0	1.0	9.6	---							
10	0.980	5.9	5.8	5.8	100.2	1.9	33.4	94.4	6.0	104.4	99.5	97.73	14.8	217.7	99.1	95.3	97.3	10	9.8	9.8	123.9	99.5	97.3	1	1.0	1.0	10.6	4.94	12.35	12.10	12.1	62.8	98.6	99.7
11	0.985	5.8	5.7	5.7	105.9	1.9	35.3	94.1	6.0	110.3	99.5	97.60	14.8	232.5	99.0	94.9	97.1	10	9.9	9.9	133.8	99.4	97.1	1	1.0	1.0	11.6	---							
12	0.980	4.8	4.7	4.7	110.6	1.6	36.9	93.8	4.9	115.2	99.5	97.50	13.7	246.2	98.9	94.6	96.9	10	9.8	9.8	143.6	99.4	96.9	1	1.0	1.0	12.6	---							
13	0.976	4.8	4.7	4.7	115.3	1.6	38.5	93.6	4.9	120.1	99.5	97.39	12.7	258.9	98.9	94.4	96.7	9	8.8	8.8	152.4	99.3	96.7	1	1.0	1.0	13.5	---							
14	0.980	4.6	4.5	4.5	119.8	1.5	40.0	93.3	4.7	124.8	99.5	97.29	11.6	270.5	98.8	94.1	96.5	8	7.8	7.8	160.2	99.3	96.5	1	1.0	1.0	14.5	---							
15	0.976	4.4	4.3	4.3	124.1	1.4	41.4	93.1	4.5	129.3	99.4	97.19	11.3	281.8	98.8	93.9	96.3	8	7.8	7.8	168.0	99.3	96.3	1	1.0	1.0	15.5	3.66	9.15	8.93	8.9	71.8	98.4	99.7
16	0.971	4.2	4.1	4.1	128.2	1.4	42.8	92.9	4.2	133.5	99.4	97.10	10.1	291.9	98.7	93.7	96.2	7	6.8	6.8	174.8	99.2	96.2	1	1.0	1.0	16.5	---							
17	0.979	4.2	4.1	4.1	132.3	1.4	44.1	92.6	4.3	137.8	99.4	97.00	11.1	303.0	98.7	93.4	96.0	8	7.8	7.8	182.6	99.2	96.0	1	1.0	1.0	17.5	---							
18	0.980	4.2	4.1	4.1	136.4	1.4	45.5	92.4	4.3	142.1	99.4	96.91	10.2	313.2	98.6	93.2	95.9	7	6.9	6.9	189.5	99.2	95.9	1	1.0	1.0	18.4	---							
19	0.980	4.1	4.0	4.0	140.4	1.3	46.9	92.2	4.2	146.3	99.4	96.82	11.0	324.2	98.6	93.0	95.7	8	7.8	7.8	197.3	99.1	95.7	1	1.0	1.0	19.4	---							
20	0.978	4.0	3.9	3.9	144.3	1.3	48.2	92.0	4.1	150.4	99.3	96.73	10.9	335.1	98.5	92.7	95.5	8	7.8	7.8	205.2	99.1	95.5	1	1.0	1.0	20.4	3.50	8.75	8.56	8.6	80.3	98.3	99.7

Parameter	Remaining	Mass Remaining	Depletion Rate	Time for Depletion	
	(%)	(mg/kg)	(mg/kg/wk)	Weeks	Years
S	93.3	560.0	2.7	210.1	4.0
NP (Empirical)	98.8	22729.5	18.03	1260.5	24.2
NP (Ca)	0.0	0.0	12.94	0.0	0.0
CaNP (Empirical)	94.1	4329.5	18.03	240.1	4.6
CaNP (Ca)	0.0	0.0	12.9	0.0	0.0
CaNP (SO4)	97.3	4475.2	8.3	537.8	10.3
NP (alkalinity)	99.3	22839.8	10.7	2138.7	41.1
NP (SO4)	99.5	22875.2	8.3	2749.2	52.9
CaNP (alkalinity)	96.5	4439.8	10.7	415.7	8.0

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Africa	+ 27 11 254 4800
Asia	+ 86 21 6258 5522
Australasia	+ 61 3 8862 3500
Europe	+ 356 21 42 30 20
North America	+ 1 800 275 3281
South America	+ 55 21 3095 9500

solutions@golder.com
www.golder.com

Golder Associates Ltd.
1721 8th Street East
Saskatoon, Saskatchewan, Canada S7H 0T4
Canada
T: +1 (306) 665 7989

Golder Associates

APPENDIX 9.2

Hydrogeological Modelling

February 2014
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APPENDIX 9.2

Hydrogeological Modelling - Tazi Twé Hydoelectric Project

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Table of Contents

1.0 INTRODUCTION 1

2.0 CONCEPTUAL HYDROGEOLOGICAL MODEL 1

2.1 Hydrostratigraphy and Hydraulic Conductivity 2

2.2 Groundwater Flow – Pre-Power Tunnel and Tailrace Channel Advancement 2

2.3 Groundwater Flow – During Power Tunnel and Tailrace Channel Advancement 2

2.4 Groundwater Flow – During Operation 3

3.0 NUMERICAL HYDROGEOLOGIC MODEL 3

3.1 Model Selection 3

3.2 Model Extent and Finite Element Mesh 3

3.3 Hydrostratigraphy and Model Parameters 4

3.4 Model Boundaries 5

3.4.1 Flow Boundaries 5

3.5 Model Predictions 6

3.5.1 Current Conditions 6

3.5.2 Conditions during Power tunnel and Tailrace Channel Advancement 6

3.5.3 Conditions During Facility Operation 6

3.6 Sensitivity Analyses 6

4.0 CONCLUSION 7

5.0 CLOSURE 9

TABLES

Table 1: Model Assumptions and Limitations 3

Table 2: Model Parameters 5

Table 3: Results of Sensitivity Analysis 7

Table of Contents (continued)

FIGURES

Figure 1: Site Plan ..... in order following text

Figure 2: Conceptual Model – Pre Tunnel Conditions

Figure 3: Conceptual Model – End of Tunneling Conditions

Figure 4: Conceptual Model – Operation Conditions

Figure 5: Model Extent

Figure 6: Finite Elelment Mesh

Figure 7: Location and Extent of Hydrostratigraphic Units

Figure 8: Boundary Conditions – Flow

Figure 9: Predicted Water Table – Pre-Tunnel Conditions

Figure 10: Predicted Water Table – End of Tunnelling Conditions

Figure 11: Predicted Drawdown – End of Tunnelling Conditions

Figure 12: Predicted Water Table – Operation Conditions

1.0 INTRODUCTION

Due to the growing demand for energy in Northern Saskatchewan, SaskPower with the Black Lake First Nation (BLFN) is developing the Tazi Twé Hydroelectric Project (Project). The proposed Project will be a 50 megawatt (MW) water diversion type electrical generating station. The Project is located on the Fond du Lac River between Black Lake and Middle Lake and the natural topography provides 36 metres (m) of available gross head (Figure 1).

This report presents the development and results of a numerical hydrogeological model to assess the groundwater regime before, during power tunnel and tailrace channel construction and operation of the Project. The main objectives of the model simulations were as follows:

- predict groundwater inflow rates into the proposed power tunnel and tailrace channel during construction.
- predict the effects to the groundwater regime during construction and operation of the facility.
- predict potential groundwater effects to an unnamed lake located to the north of the proposed power tunnel alignment.

It should be noted that although the EIS has been updated to include data collected during the fall of 2013 field program, a decision was undertaken not to update the model because the modelling reported in this Appendix considered conservative inputs.

2.0 CONCEPTUAL HYDROGEOLOGICAL MODEL

A conceptual model is a pictorial representation of the groundwater regime that organizes and simplifies the site hydrogeology so that it can be readily modelled. The conceptual model must retain enough complexity so that the numerical model developed from the conceptual model adequately reproduces or simulates, to the degree required to meet project objectives, the actual groundwater flow behaviour. During the development of the conceptual model, the main hydrostratigraphic units are defined and characterized, and the dominant groundwater flow patterns are identified both prior to and during power tunnel and tailrace channel advancement.

The conceptual model is then used as a basis for the construction of the numerical hydrogeological models at the site. The conceptual model for pre-development conditions at the Site is presented in Figure 2.

During advancement, the power tunnel and tailrace channel will act as a sink for groundwater flow, modifying the pre-development groundwater flow field. Drawdown near the power tunnel and tailrace channel is expected to result in a change to the groundwater budget of the unnamed lake. The conceptual model for development conditions at the Site is presented in Figure 3.

During operation, sections of the power tunnel where the hydraulic grade line is below the surrounding water table elevation will continue to act as a sink for groundwater flow. Sections of the tunnel where the hydraulic grade line is above the surrounding water table elevation will act as a source of groundwater flow. The tailrace channel is expected to continue to act as a sink for groundwater during operation. The conceptual model for operation conditions is presented in Figure 3.

2.1 Hydrostratigraphy and Hydraulic Conductivity

Boreholes DH12-01, DH12-05, DH12-06A, and DH12-06B (completed in 2012) and BH-4 (completed in 2002) were used together with surface mapping to draw inferences about the hydrostratigraphy (Figure 1). Hydraulic conductivity testing was undertaken on the subsurface in the vicinity of the proposed power tunnel and tailrace channel (Hatch, 2012).

Overburden material at the boreholes was discontinuous and less than 4 m thick, consisting of topsoil, cobbles, and boulders. One permeability test was conducted in the overburden at BH-4 which gave a result of 10^{-5} metres per second (m/s). (Acres, 2002) This result is consistent with soil descriptions from the borehole logs that suggest that the hydraulic conductivity of the overburden could range from 10^{-6} m/s to 10^{-3} m/s.

Results from packer tests (Lugeon tests), conducted in the boreholes, were used to produce probability distributions of hydraulic conductivity in the bedrock. These probability distributions suggest that there were no meaningful differences in the hydraulic conductivity of the various bedrock units, and that the bedrock at depths of less than 45 m is more permeable than bedrock below this depth. The geometric mean of the hydraulic conductivity values for the upper 45 m of bedrock was estimated to be approximately 3×10^{-7} m/s, whereas the geometric mean of the hydraulic conductivity values for the deeper bedrock was estimated to be approximately 6×10^{-8} m/s. The geometric mean of all the tests in bedrock was approximately 1×10^{-7} m/s.

2.2 Groundwater Flow – Pre-power Tunnel and Tailrace Channel Advancement

There were no monitoring wells installed in the overburden or various bedrock units in the 2002 or 2012 investigations to assess the water table location, hydraulic heads, or to obtain groundwater samples for water quality analysis. Additionally, the water level data provided on borehole logs in the 2012 investigations (Hatch, 2012) cannot be relied upon as there is no description of how these water levels were estimated.

The relatively low hydraulic conductivity of the bedrock suggests that the water table would likely mound near the ground surface even with very low infiltration from precipitation. Therefore, it is assumed that the water table is near the ground surface, and is a subdued expression of topography throughout the Project area. Groundwater is expected to flow with the topographic grade, from high elevation areas in a radial pattern towards Black Lake, Middle Lake, and Fond du Lac River (Figure 2).

When the 2013 field data for the bedrock are included with the hydraulic conductivity data collected in 2012, the geometric mean values are either equal to or less than those presented above: 2×10^{-7} m/s for the shallow bedrock and 6×10^{-8} m/s for the deep bedrock

2.3 Groundwater Flow – during Power Tunnel and Tailrace Channel Advancement

At the time of this report, Golder understands that the power tunnel and tailrace channel will be simultaneously advanced from the water intake excavation at Black Lake and a tunnel adit near the powerhouse, approximately 1 km east of Middle Lake, respectively, at a rate of 5 m/day. Tunnel advancement will occur within the bedrock, 5 to 90 m beneath the ground surface, while tailrace channel construction will involve the excavation of material from the ground surface down to tailrace channel depth. The power tunnel and tailrace channel will act as a sink for groundwater flow, modifying the pre-development groundwater flow field. Drawdown near the power tunnel

and tailrace channel is expected to result in a change to the groundwater budget of the unnamed lake (i.e., change in groundwater inflow/outflow of the lake).

2.4 Groundwater Flow – during Operation

At the time of this report, Golder understands that the hydraulic grade line in the power tunnel will decrease by 5 m from the elevation of Black Lake to the powerhouse. The groundwater elevation in the tailrace channel will remain essentially flat from the powerhouse to the elevation of Middle Lake. Inflow to the power tunnel and tailrace channel is expected to decrease during operation compared to during development.

3.0 NUMERICAL HYDROGEOLOGIC MODEL

A numerical hydrogeologic model was constructed to assess the effects of the Project on the groundwater regime and surface water bodies.

3.1 Model Selection

The numerical model for the area near the Project was constructed using FEFLOW, a finite element modelling package developed by the WASY Institute in Germany (Feflow, 2013). FEFLOW is capable of simulating transient groundwater flow in a three-dimensional heterogeneous and anisotropic porous media under a variety of hydrogeologic boundaries and stresses. This, combined with FEFLOW's capability to incorporate complex hydrostratigraphy, boundary conditions and discrete high permeability structures, resulted in the selection of this modelling code for the analysis.

Table 1 provides an overall summary of the assumptions and limitations of the modelling, including those associated with the FEFLOW code (Version 6.1).

Table 1: Model Assumptions and Limitations

Groundwater flow in the bedrock was simulated as an "equivalent porous media". Flow in bedrock is assumed to be laminar and steady, and governed by Darcy's Law.
Horizontal mesh discretizations of approximately 5 m were considered to provide sufficient spatial resolution for simulation of groundwater flow near the power tunnel and tailrace channel.
Initial values of model input parameters were based on the results and analysis of hydraulic conductivity testing and, where testing results were not available, on typical values published in the literature.
Surface water bodies were simulated using specified head boundaries. It was assumed that the permeability of sediments that may line the beds of these water bodies was similar to the underlying geologic strata. Thus, no restriction of flow between the surface water and individual hydrostratigraphic units was simulated.
Groundwater flow deeper than approximately 450 m below ground surface was assumed to have negligible influence on model predictions.

3.2 Model Extent and Finite Element Mesh

The extent of the numerical model was based on the understanding of groundwater flow conditions near the proposed power tunnel and tailrace channel, with model lateral boundaries set sufficiently far from the development or along surface water bodies to allow adequate representation of pre-development conditions and

groundwater inflows during advancement. The model extent and the finite element mesh are presented in Figures 5 and 6 respectively.

The domain is bounded by Black Lake to the east, Fond du Lac River and Middle Lake to the west. Fond du Lac River and Black Lake join together to bound the domain to the south. The domain extends north approximately 5 km past the midpoint of the power tunnel/tailrace channel alignment. This northern boundary was chosen to be sufficiently far from the power tunnel/tailrace channel alignment to have negligible impact on groundwater inflow rates. The planar area of the model domain was approximately 24 square kilometres (km^2).

The mesh consists of 960,960 triangular elements with a node spacing of approximately 5 m in the area of the power tunnel and tailrace channel, where strong hydraulic gradients are expected to develop during advancement and facility operation. Elements coarsen moving away from the power tunnel and tailrace channel to a maximum node spacing of approximately 250 m along the model's northern perimeter. Overall, the mesh spacing is considered of appropriate detail for simulation of hydrogeologic conditions at the site.

Vertically, the model domain is discretized into multiple layers to take into account the groundsurface, top and bottom boundaries of the power tunnel and tailrace channel, and geometry of the overburden and bedrock layers. The top of the upper-most layer was assigned the ground surface elevation, based on a Digital Elevation Model (DEM) for the area. Ground surface within the domain ranged from about 240 to 370 metres (m) above sea level (ASL). The bottom of the lower-most layer was set to a constant elevation of -150 m ASL, which is about 350 m below the base of the power tunnel and tailrace channel.

3.3 Hydrostratigraphy and Model Parameters

Figure 7 illustrates the hydrostratigraphy incorporated in the hydrogeologic model for the base case simulation; four major hydrostratigraphic units comprise the domain. A thin (between 0 and 20 m thick), discontinuous overburden unit overlies a shallow (<45 metres (m) below ground surface [BGS]) bedrock unit and a deeper (>45 m BGS) bedrock unit. Hydraulic conductivity of the overburden was set to 1×10^{-5} m/s, based on one permeability test conducted in the overburden and the soil descriptions given in the borehole logs. The shallow and deep bedrock units were assigned hydraulic conductivities of 3×10^{-7} m/s and 6×10^{-8} m/s, respectively, based on probability distributions of hydraulic conductivity described above in Section 2.1. Lineaments representing faults within the deeper bedrock unit, intersecting the power tunnel alignment and the unnamed lake, were assigned an effective hydraulic conductivity of 1×10^{-6} m/s, based on experience from other similar sites. This representation of lineaements is considered to represent a conservative case with direct hydraulic connection between the power tunnel and unnamed lake. Table 2 summarizes the Base Case values of hydrogeologic parameters used in the model. Where in-situ values were not available, typical values published in the literature were used.

Table 2: Model Parameters

Unit	Depth Interval (m)	Hydraulic Conductivity (m/s)[a]	Specific Storage (1/m)[b]	Effective Porosity (-)[c]
Overburden	0 – 20[d]	1×10^{-5}	1×10^{-4}	0.2
Bedrock < 45 m BGS	<45	3×10^{-7}	1×10^{-6}	0.002
Bedrock > 45 m BGS	>45	6×10^{-8}	1×10^{-6}	0.002
Lineaments	>45	1×10^{-6} [e]	1×10^{-6}	0.002

[a] Estimated from in-situ testing and experience from other similar sites.
[b] Maidment (1992)
[c] Stober and Bucher (2007) and Guimera and Carrera (1999)
[d] Overburden is discontinuous and varies in thickness from 0 to 20m throughout the model domain
[e] Effective hydraulic conductivity based on assumed fault width of 1m
m = metre; m/s = metres per second; m BGS = metres below ground surface

As presented above, when the results of the 2013 field data are examined together with the data from 2012, the geometric mean of hydraulic conductivity in the shallow and deep bedrock are either equal to or less than the values presented in Table 2. Furthermore, a test conducted over an identified lineament in 2013 calculated a hydraulic conductivity about 4×10^{-7} m/s, which is about 2.5 times less than the value used in the Base Case model.

3.4 Model Boundaries

3.4.1 Flow Boundaries

Three types of boundary conditions were used in the groundwater model:

- specified head,
- specified flux, and
- no-flow.

These boundary conditions are illustrated on Figure 8 and summarized below.

Specified head boundaries were assigned to the top of the model (top of Layer 1) to represent Black Lake, Middle Lake, and Fond du Lac River boundaries along the domain perimeter. Specified head boundaries were also assigned to nodes representing the unnamed lake and other small lakes within the domain. These boundaries were set to the average lake elevations and river elevations derived from site topographic data. A transient seepage face boundary condition was assigned to the power tunnel and tailrace channel nodes by setting a specified head equal to the elevation of each node and applying a flow-rate constraint. The flow rate constraint does not allow the tunnel to act as a source of water during excavtion, only as a sink. These transient boundary conditions simulate the advancement of the power tunnel and tailrace channel are activated when the power tunnel/tailrace channel fronts have reached the nodes.

Specified flux boundary conditions were assigned to the top of the model (top of Layer 1) to represent infiltration from precipitation. In the Base Case scenario, specified flux at the overburden was set to 100 millimetres per year (mm/yr) (22% annual precipitation) and 15 mm/yr at the weathered bedrock (3% annual precipitation). This infiltration was chosen for the base case in order to produce a conservative water table elevation at or just below ground surface in the low lying areas of the model in order to correspond to field observations from the Site.

A no-flow boundary was assigned to the portion of the of the northern boundary that did not contain lakes. This boundary is located sufficiently far from the power tunnel and tailrace channel development to have a negligible impact on model predictions. A no-flow boundary was also assigned along the bottom of the model at elevation of approximately -150 m ASL. Groundwater flow at greater depths is assumed to have negligible impact on model predictions.

3.5 Model Predictions

3.5.1 Current Conditions

Predicted hydrogeologic conditions for the pre-development flow field are presented in Figure 9. Groundwater flows with the topographic grade, from high elevation areas radially outwards to Black Lake, Middle Lake, and Fond du Lac River. A budget analysis was performed to estimate the pre-development groundwater loss from the unnamed lake prior to development of the power tunnel and tailrace channel; the model predicts that outflow from the unnamed Lake is approximately 35 cubic metres per day (m^3/day).

3.5.2 Conditions during Power tunnel and Tailrace Channel Advancement

During the simulation, the power tunnel and tailrace channel were both advanced at 5 m/day. Figure 10 presents the predicted hydrogeologic conditions for the flow field at end-of-advancement, representing conditions at maximum disturbance when groundwater inflows are predicted to be greatest. For the Base Case scenario, groundwater inflows into the entire power tunnel and tailrace channel development are predicted to gradually increase during advancement to a maximum inflow rate of 1100 m^3/day by completion. A budget analysis was performed to determine any changes to the water balance of the unnamed lake during power tunnel and tailrace channel advancement; maximum outflow from the unnamed lake is predicted to be approximately 100 m^3/day. This is equivalent to 65 m^3/day additional outflow than during pre-development conditions. Figure 11 presents the predicted drawdown within the domain at end of construction.

3.5.3 Conditions during Facility Operation

Predicted hydrogeologic conditions for the operation flow field are presented in Figure 12. During operation the tailrace channel and majority of the power tunnel continues to act as a groundwater sink and total inflow to the power tunnel and tailrace channel is predicted to decrease to 680 m^3/day. Groundwater outflow from the power tunnel upstream of the powerhouse is predicted to be 20 m^3/day. A budget analysis on the unnamed lake predicts that the outflow from this lake during operation will be approximately 100 m^3/day, similar to the outflow at the end of tunneling.

3.6 Sensitivity Analyses

Five model simulations were conducted to assess the sensitivity of the model to assumed values of hydraulic conductivity and recharge on predictions of groundwater inflows to the power tunnel and tailrace channel, as well as on the budget analysis (inflow/outflow) of the unnamed lake.

The sensitivity analysis involved the following five additional simulations relative to the Base Case:

- Sensitivity 1: The hydraulic conductivity of the lineaments was increased from 10^{-6} m/s to $1x10^{-5}$ m/s;
- Sensitivity 2: A constant head boundary condition was assigned to low-lying overburden (overburden at <280 m ASL). Constant heads were set equal to ground elevation to represent saturated conditions ;

- Sensitivity 3: A constant head boundary condition, representing saturated conditions, was assigned to all overburden. Additionally, overburden hydraulic conductivity was decreased to $5x10^{-8}$ m/s to represent a lower conductivity layer at the base of the overburden material; and
- Sensitivity 4:A constant head boundary condition, representing saturated conditions, was assigned to all overburden and overburden hydraulic conductivity was decreased to $5x10^{-8}$ m/s. Additionally, hydraulic conductivities of the remaining hydrostratigraphic units were increased by a factor of 3.

Table 3 presents the results of the sensitivity analyses. The groundwater inflow rate was relatively insensitive to changes in effective conductivity of the lineaments; increasing hydraulic conductivity of the lineaments by a factor of 10 resulted in only a 10% higher groundwater inflow rate compared to Base Case. The largest groundwater inflow rate into the power tunnel and tailrace channel occurred in Sensitivity 4; the maximum groundwater inflow rate was 4,700 m^3/day and represents an upper-bound estimate of inflows into the power tunnel and tailrace channel.

This hydrogeological modelling was undertaken prior to the collection of groundwater level data during the 2013 field program. This resulted in the application of a conservative approach to the model predictions because of uncertainty in the location of the water table. The most conservative sensitivity (Sensirtivity 4) assumes that the watertable is located at the ground surface throughout the area of the Project, which together with an assumed hydraulic conductivity of more than 3 times or greater for the bedrock and lineament than measured in the field results in the maximum groundwater driving force and the greatest predicted groundwater inflow. This conservatively high prediction of groundwater inflow of 4,700 m^3/day, was carried forward into the EIS.

The pre-development budget analysis of the unnamed lake is different for each sensitivity run. This lake loses groundwater during the Sensitivity 1 and 2, but gains groundwater in the two scenarios with constant heads applied to all overburden (Sensitivities 3 and 4). The largest change to the unnamed lake from pre-development to end of tunneling conditions occurs in the Base Case scenario. In this scenario groundwater outflow from unnamed lake increases 285% from pre-development conditions.

Table 3: Results of Sensitivity Analysis

Scenario	Max. Groundwater Inflow to Power Tunnel and Tailrace Channel (m^3/day)	Pre-Development Flow Rate from Unnamed Lake (m^3/day)*	Maximum Flow Rate from Unnamed Lake (m^3/day)*
Base Case	1,100	35	100
High K Lineament	1,200	35	90
Low-Lying Constant Head	3,240	150	190
Decreased Overburden K and Constant Head	2,000	-170	-160
Decreased Overburden K and Constant Head/Increased Other K	4,700	-440	-407

* Positive value denotes groundwater loss; negative value denotes groundwater gain.
m^3/ day = cubic metres per day

4.0 CONCLUSION

The current conceptual and numerical hydrogeologic models indicate that the potential groundwater inflows to the proposed power tunnel and tailrace channel could be a maximum of approximately 1,100 m^3/day in the base

case scenario. In this scenario groundwater loss from the unnamed lake north of the power tunnel alignment will increase from approximately 35 m^3/day (pre-tunneling) to approximately 100 m^3/day (end of tunnelling).

Sensitivity analyses was conducted by varying the fault, overburden and bedrock hydraulic conductivities and the recharge through the overburden. The maximum inflow to the power tunnel and tailrace channel (4,700 m^3/day) predicted in these simulations were those for the case when a constant head was applied to the overburden, the overburden hydraulic conductivity was decreased and the bedrock and fault hydraulic conductivity were increased. This sensitivity simulation that considered conservative inputs was carried through in the EIS. The maximum additional groundwater loss at the end of tunneling (285% increase) was observed in the base case scenario.

5.0 CLOSURE

We trust the information provided herein, satisfies your current requirements. If you have any questions or require further assistance, please do not hesitate to contact the undersigned.

Yours very truly,

GOLDER ASSOCIATES LTD.

ORIGINAL SIGNED BY

Nathan Fretz, M.Sc.
Environmental Scientist

ORIGINAL SIGNED BY

Scott McGregor, B.Sc.
Physicist – Hydrogeology Group

ORIGINAL SIGNED BY

Don Chorley, M. Sc.
Principal, Senior Hydrogeologist

ORIGINAL SIGNED AND STAMPED BY

Michael A. J. Tremblay, M.Sc., P.Eng
Associate, Senior Geotechnical Engineer

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6.0 REFERENCES

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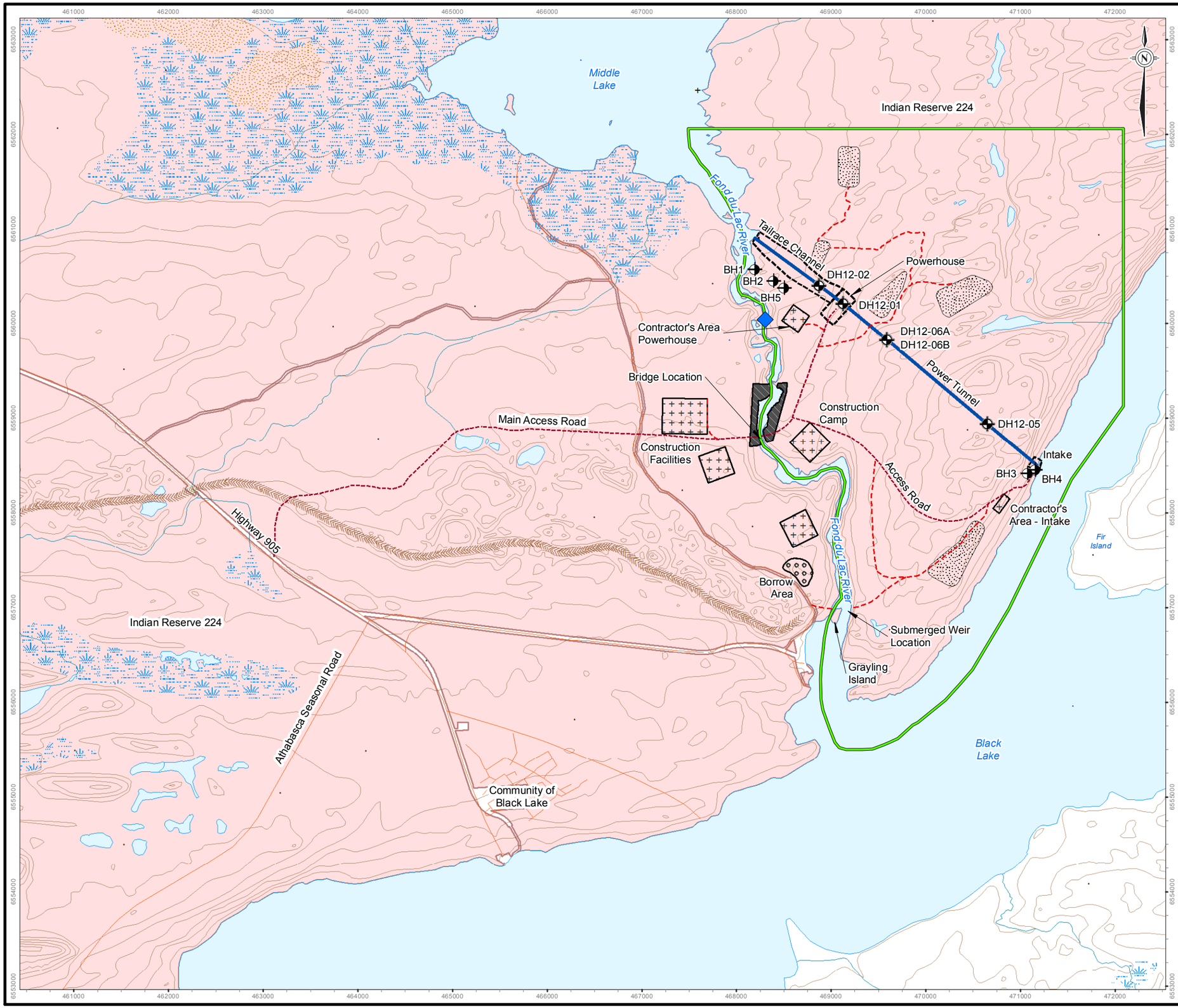
FIGURES



LEGEND

- CONTOUR LINE
- ROAD
- RIVER
- WETLAND
- WATERBODY
- INDIAN RESERVE
- GEOLOGY & HYDROGEOLOGY LOCAL STUDY AREA
- ELIZABETH FALLS
- 2012 BOREHOLE LOCATION
- 2002 BOREHOLE LOCATION
- PROPOSED ACCESS ROAD
- PROPOSED TEMPORARY ACCESS ROAD
- PROJECT AXIS
- BORROW AREA
- POTENTIAL BRIDGE ALIGNMENT AREA
- CONTRACTOR/CAMP LOCATION
- DISPOSAL AREA
- FENCE

NOTE: LOCATIONS OF PROPOSED FACILITIES ARE SHOWN FOR ILLUSTRATIVE PURPOSES ONLY. FINAL LOCATIONS WILL BE DETERMINED DURING FINAL ENGINEERING AND DESIGN, TAKING INTO CONSIDERATION STAKEHOLDER INPUT.

REFERENCE

DATUM: NAD83 PROJECTION: UTM ZONE 13
SITE PLAN PROVIDED BY KGS GROUP CONSULTING & ENGINEERS

1 0 1
SCALE 1:40,000 KILOMETRES

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
SITE PLAN

Golder Associates
Saskatoon, Saskatchewan

PROJECT	10-1365-0004		FILE No.		
DESIGN			SCALE AS SHOWN	REV.	7
GIS	SM	10/07/13	FIGURE: 1		
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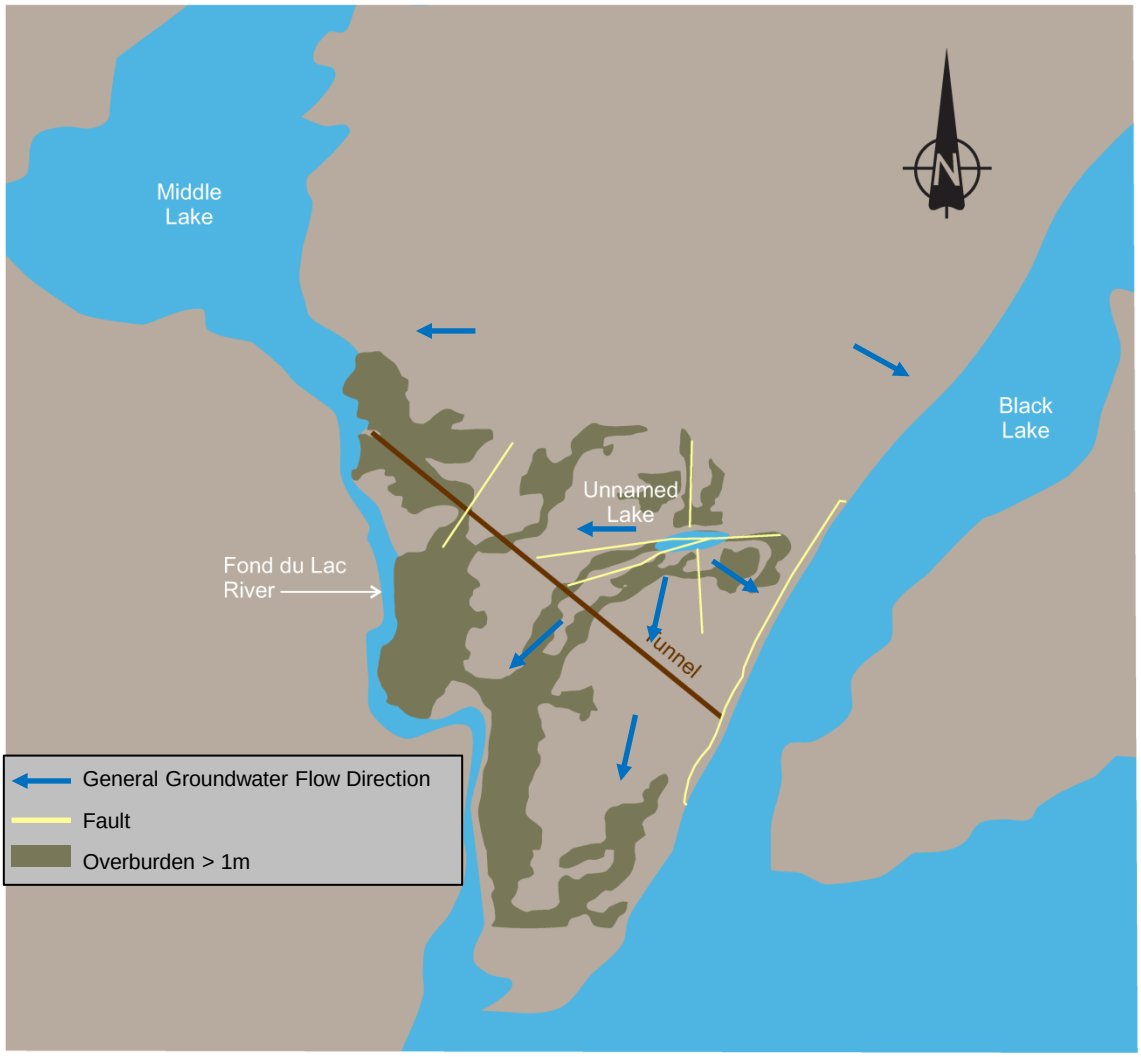
REVIEW	MT	19/07/13			



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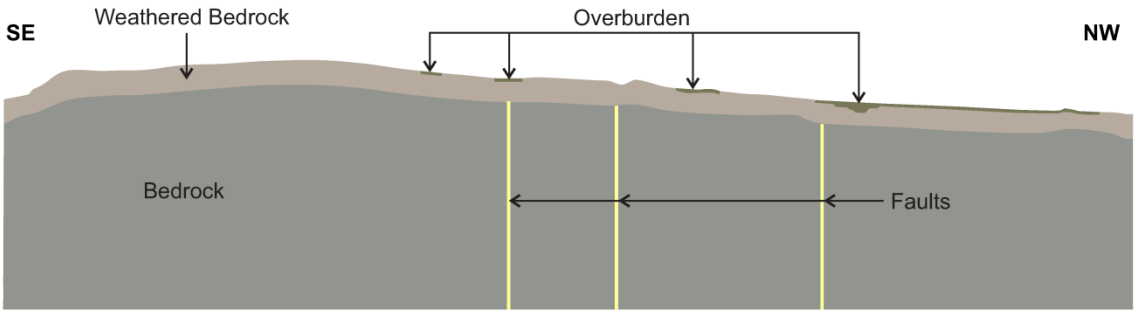

CROSS-SECTION ALONG THE TUNNEL

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

CONCEPTUAL MODEL
PRE-TUNNEL CONDITIONS

Golder Associates

PROJECT No. 10-1365-0004			PHASE No.	
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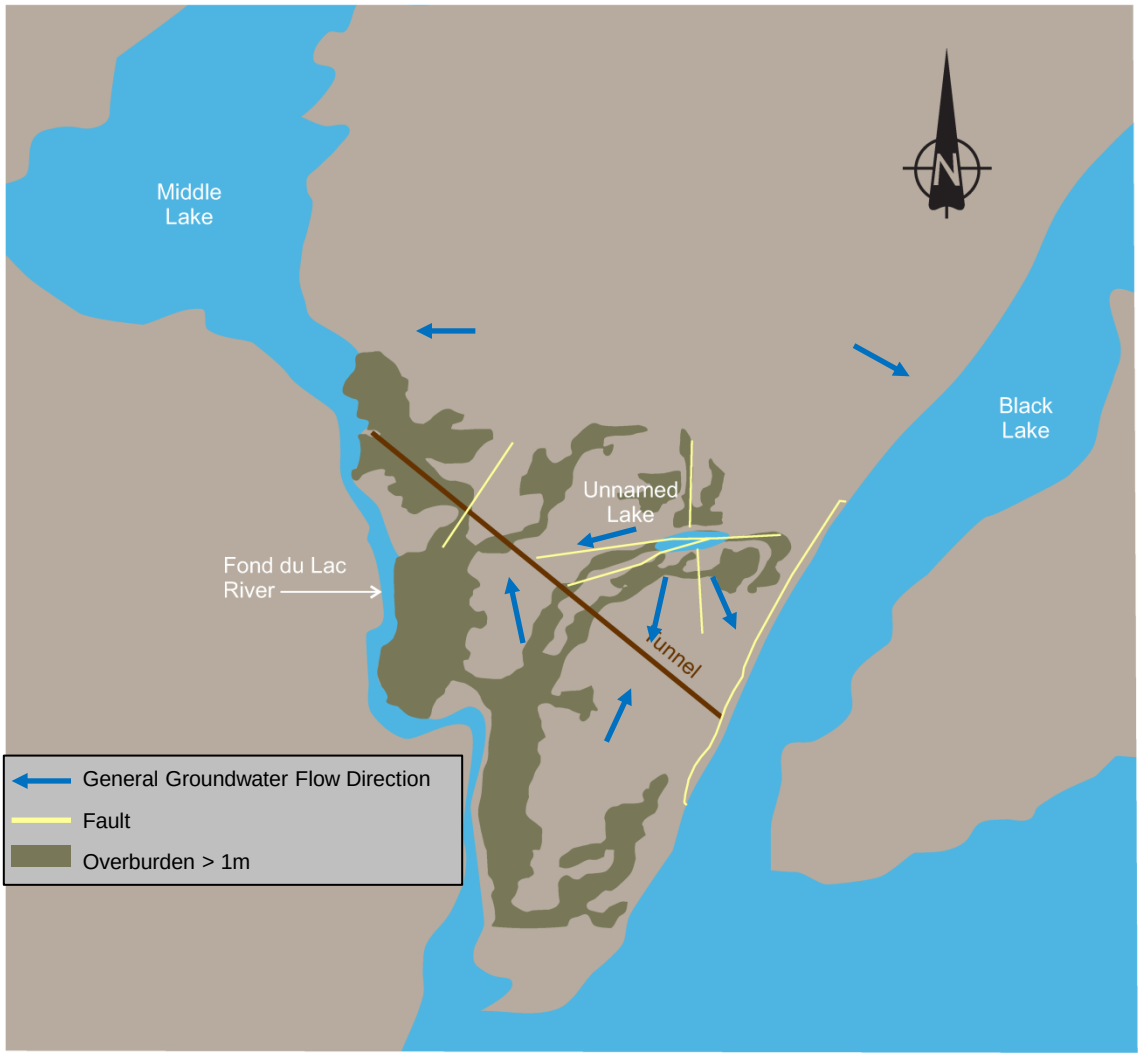

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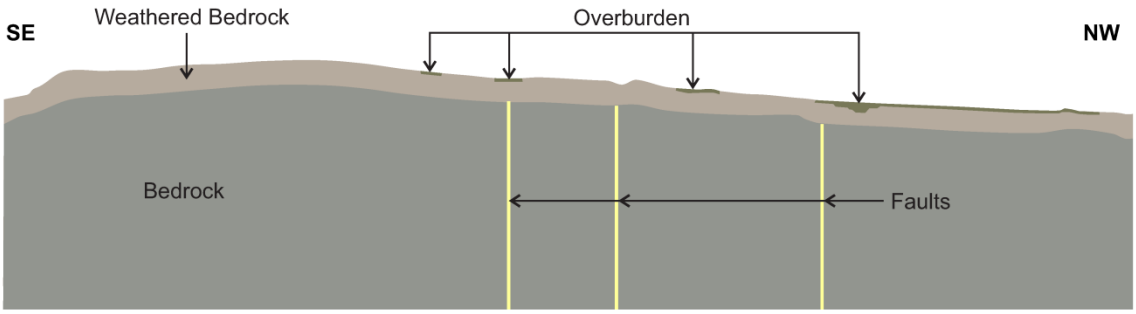

CROSS-SECTION ALONG THE TUNNEL

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

CONCEPTUAL MODEL
END OF TUNNELING CONDITIONS

Golder Associates

PROJECT No. 10-1365-0004			PHASE No.	
DESIGN	SAM	10JUL13	SCALE	REV.
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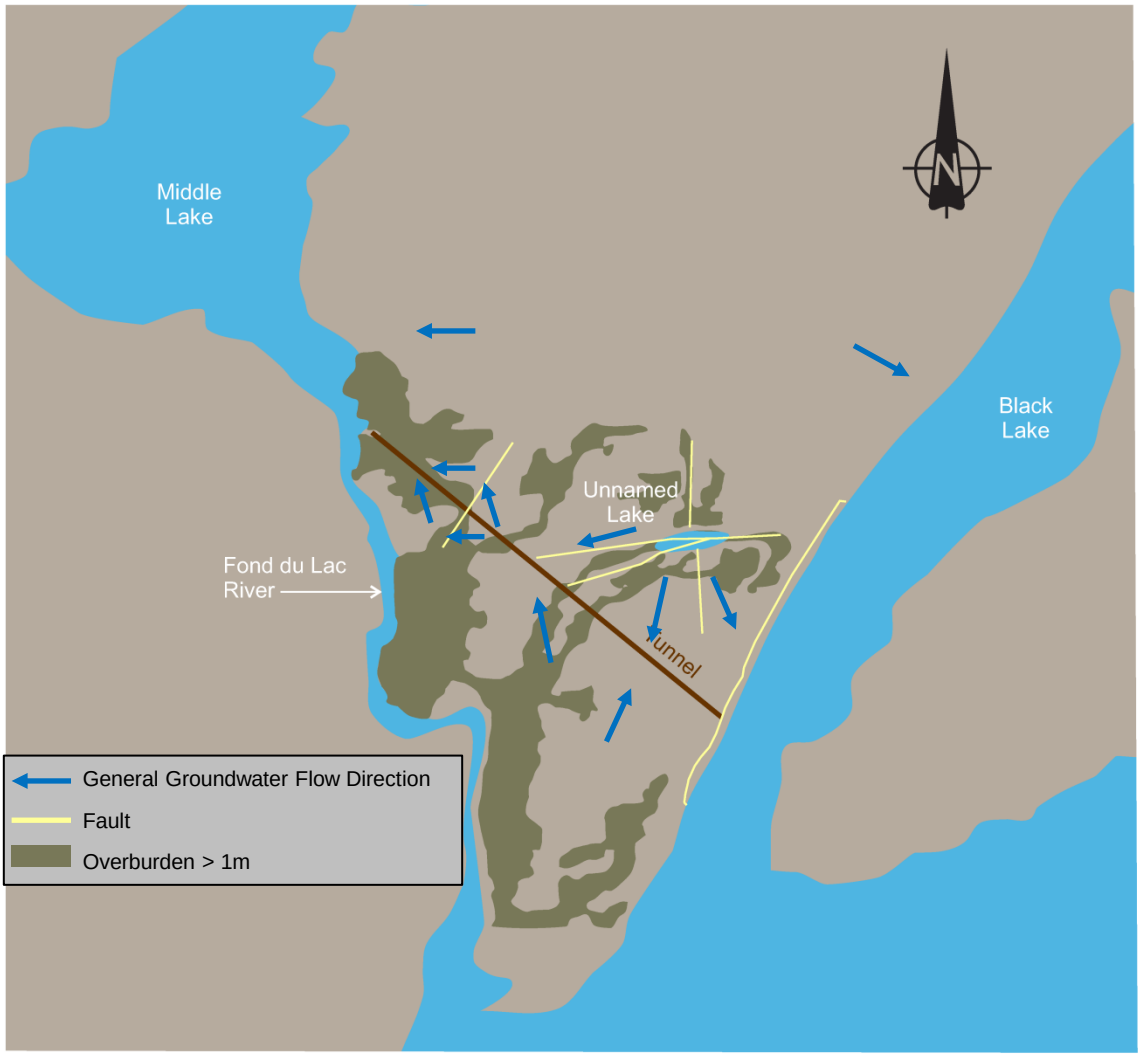

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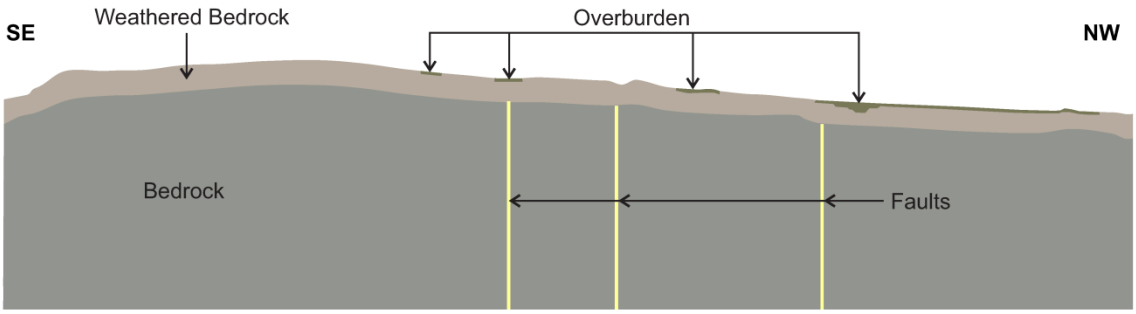

CROSS-SECTION ALONG THE TUNNEL

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

CONCEPTUAL MODEL OPERATION CONDITIONS

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DESIGN	SAM	10JUL13	SCALE	REV.
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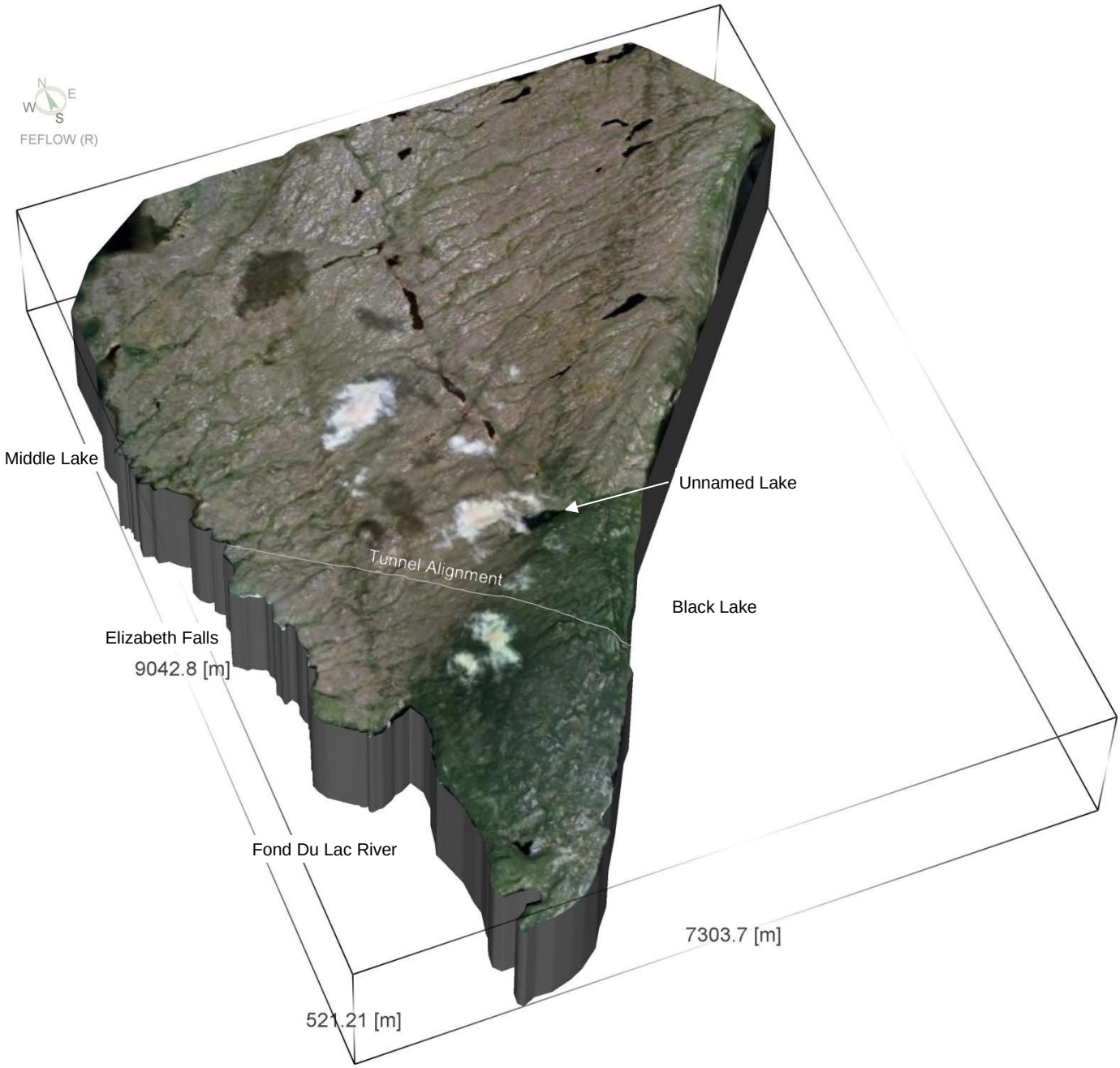

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1. Vertical Exaggeration 3x
2. Image Google Earth 2004

PROJECT: **TAZI TWÉ HYDROELECTRIC PROJECT**

TITLE: **MODEL EXTENT**

Golder Associates

PROJECT No. 10-1365-0004			PHASE No.	
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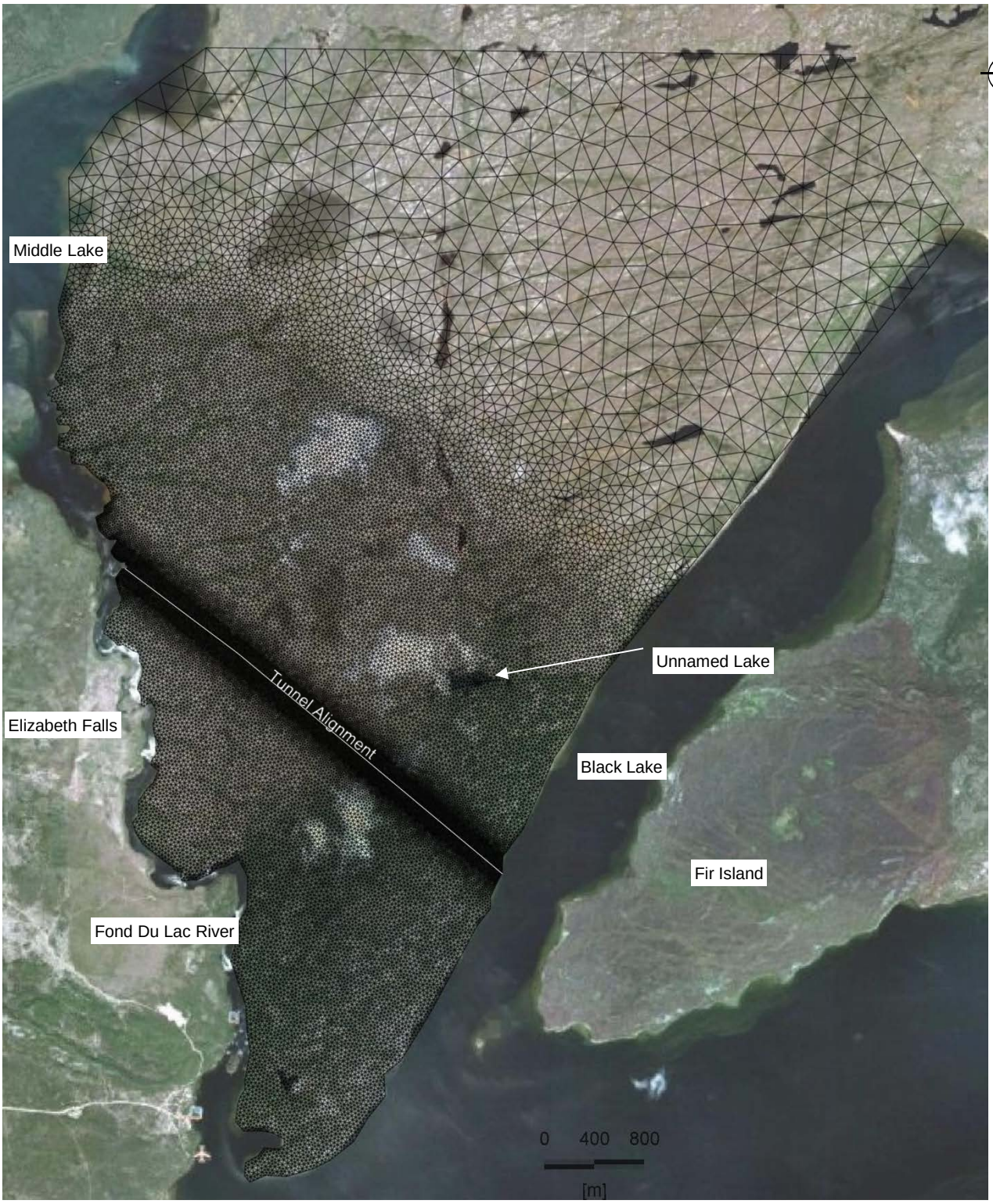

Notes:

1. Image Google Earth 2004
2. All distances in metres.
3. Projection: UTM Zone 15 Datum: NAD 83

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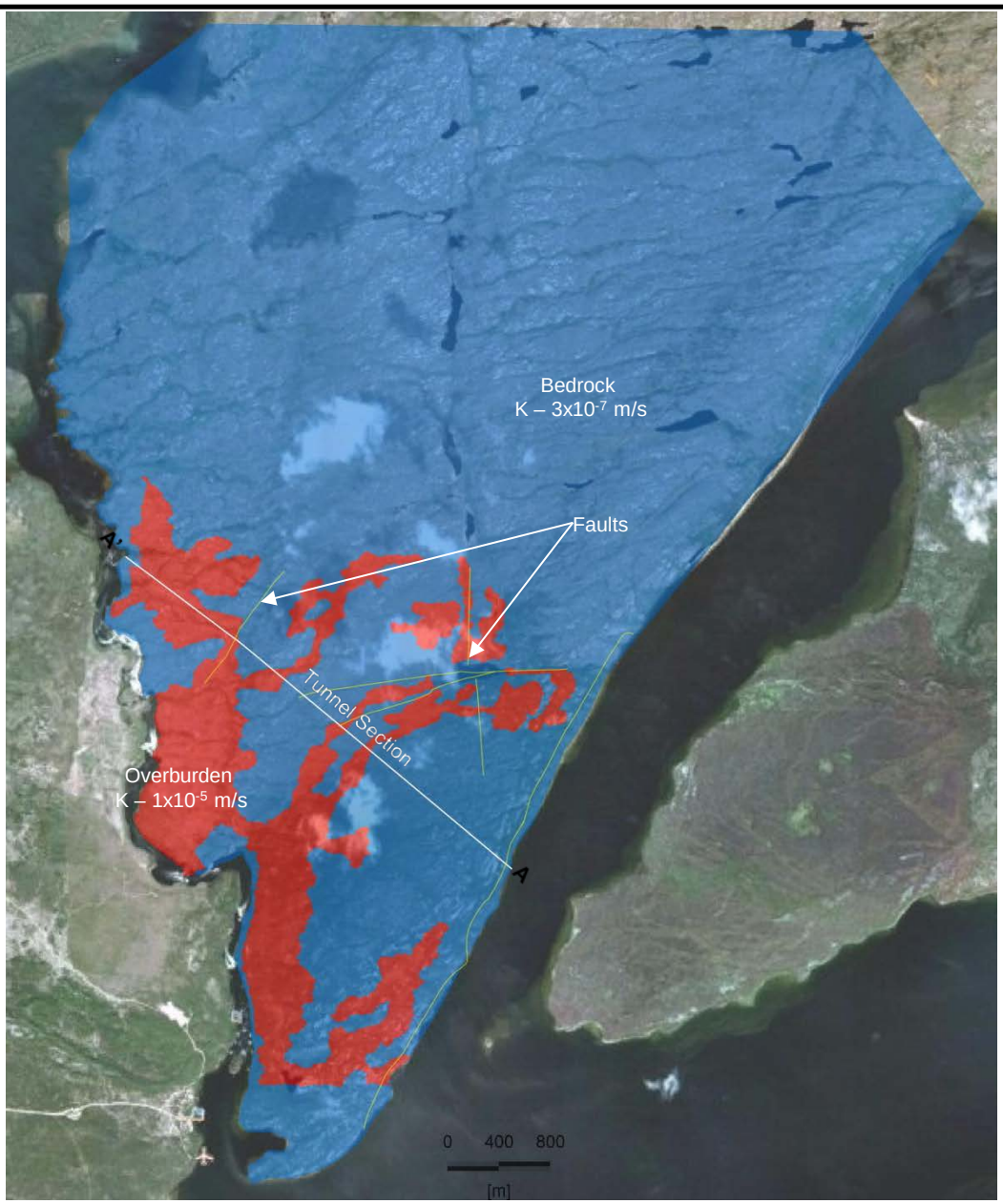
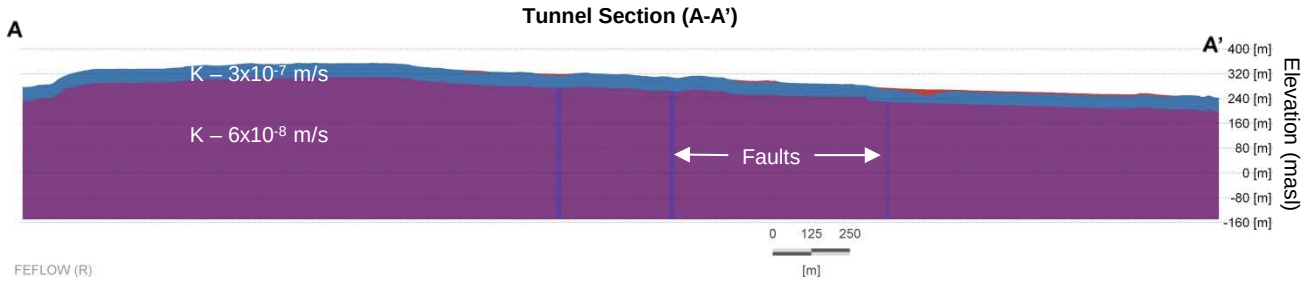
FIGURE 6





Notes:

1. Image Google Earth 2004
2. All distances in metres.
3. Projection: UTM Zone 15 Datum: NAD 83

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
LOCATION AND EXTENT OF HYDROSTRATIGRAPHIC UNITS

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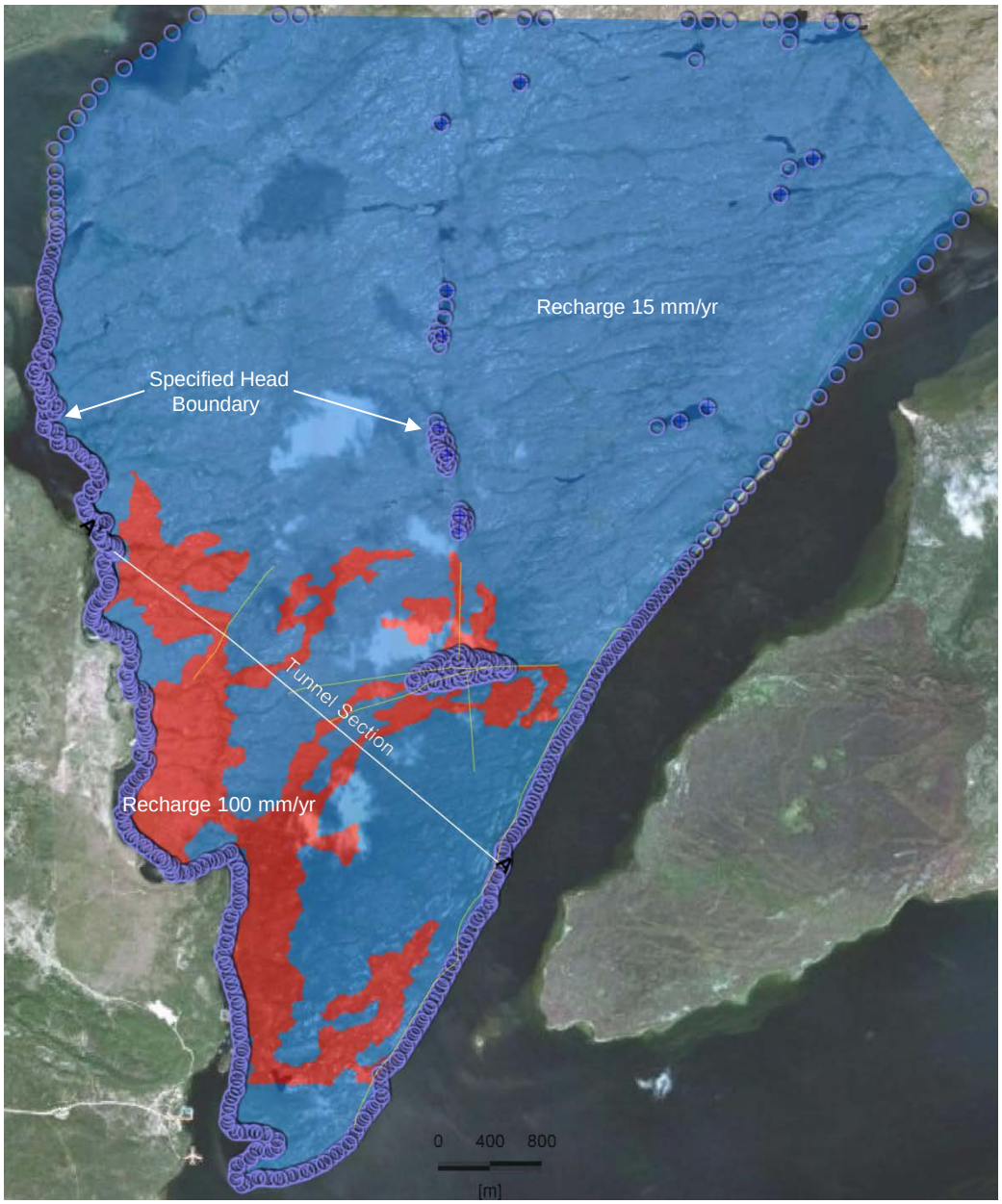
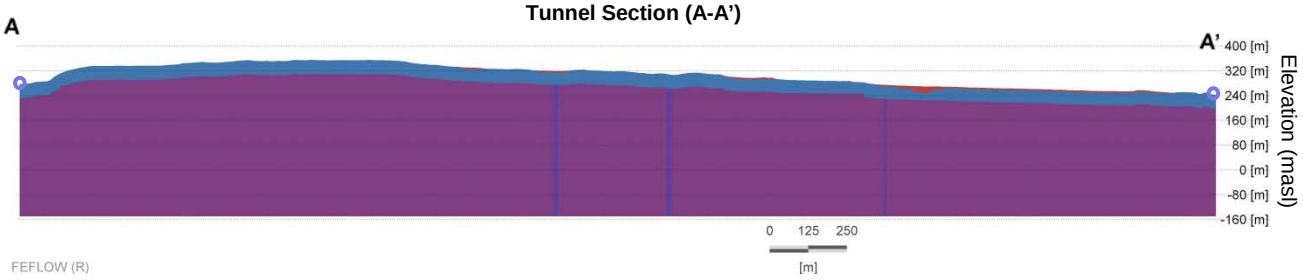


Tunnel Section (A-A')



Specified Head Boundary

Notes:

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2. All distances in metres.
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PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

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BOUNDARY CONDITIONS - FLOW

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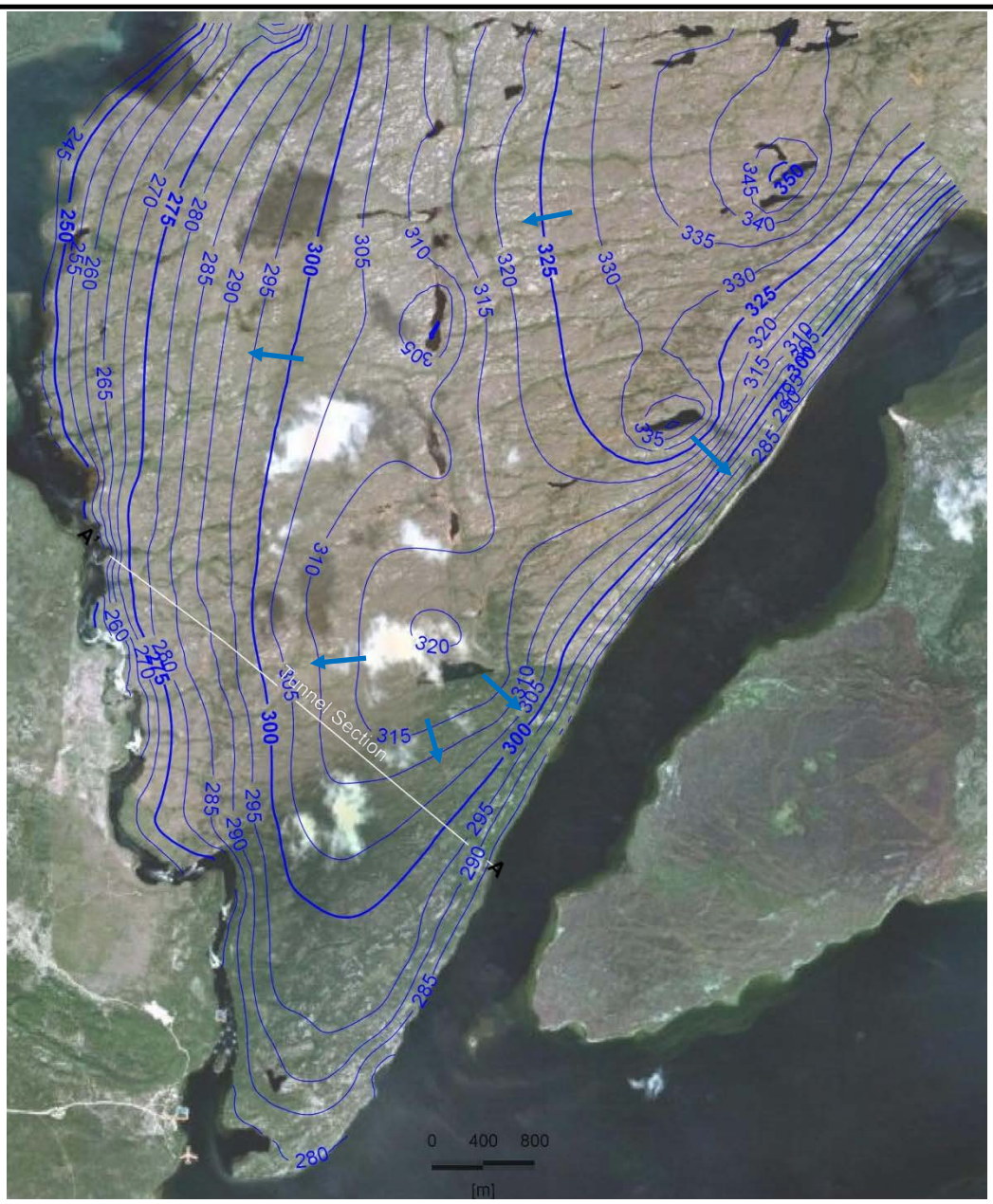
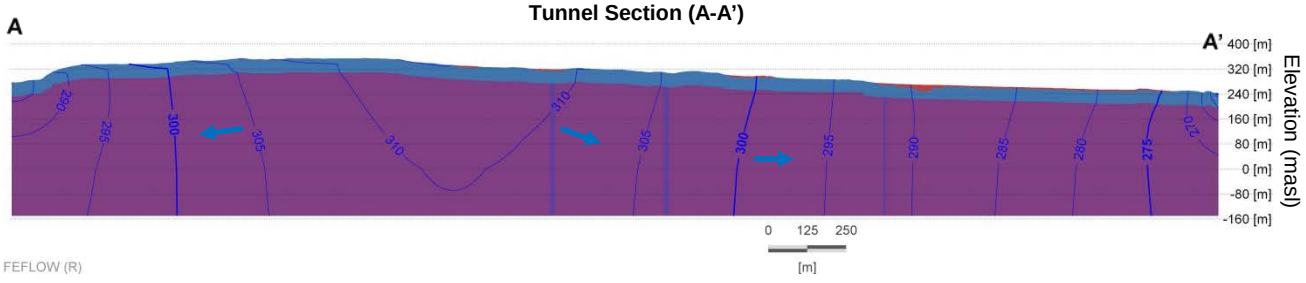
FIGURE 8



Tunnel Section (A-A')



280 Water Table Elevation

General Groundwater Flow Direction

Notes:
1. Image Google Earth 2004
2. All distances in metres.
3. Projection: UTM Zone 15 Datum: NAD 83
4. Hydraulic heads plotted at between 245 to 275 m above sea level at the elevation of the top of the proposed tunnel

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
PREDICTED WATER TABLE PRE-TUNNEL CONDITIONS

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DESIGN	SAM	10JUL13	SCALE AS SHOWN	REV.
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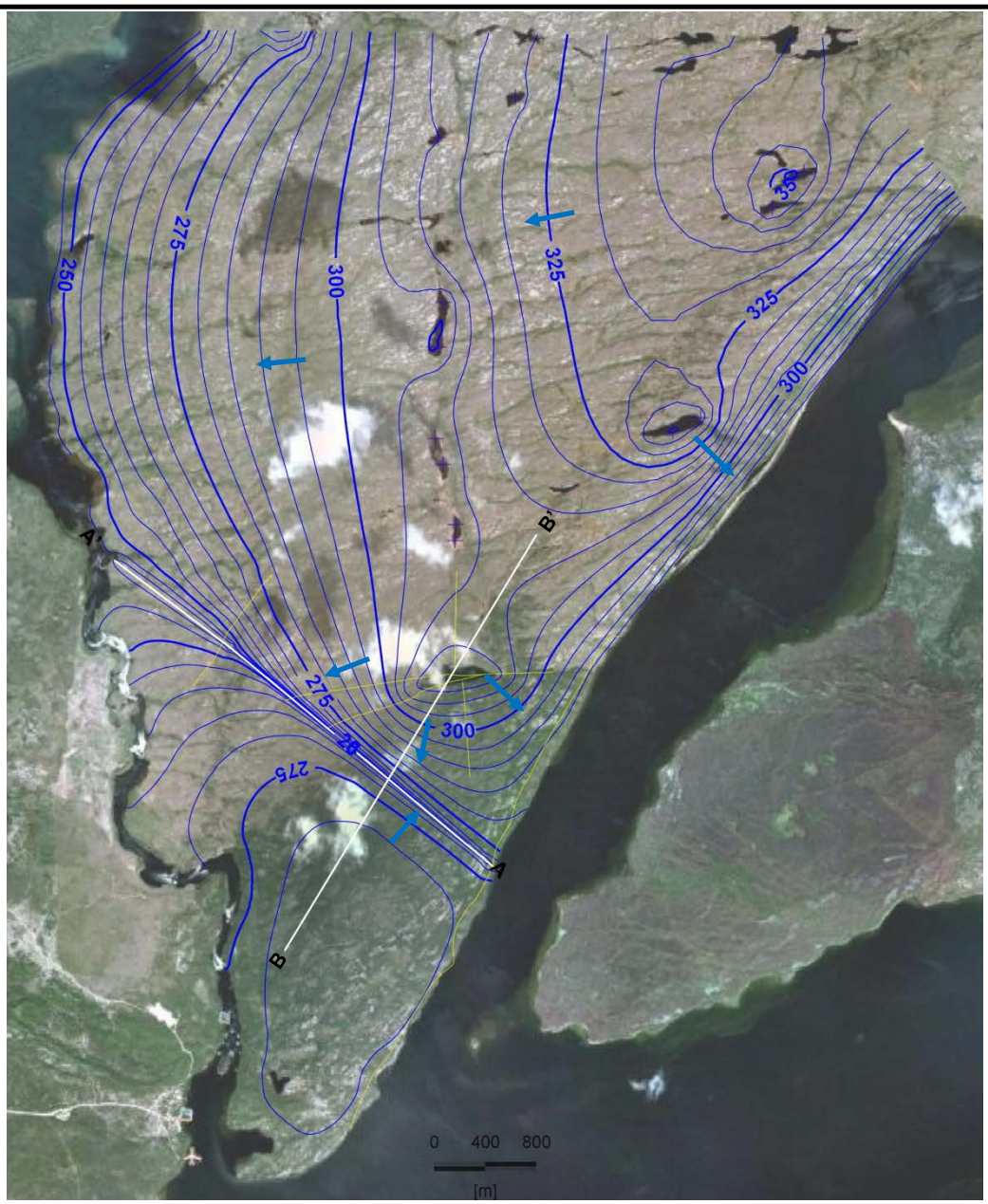
FIGURE 9



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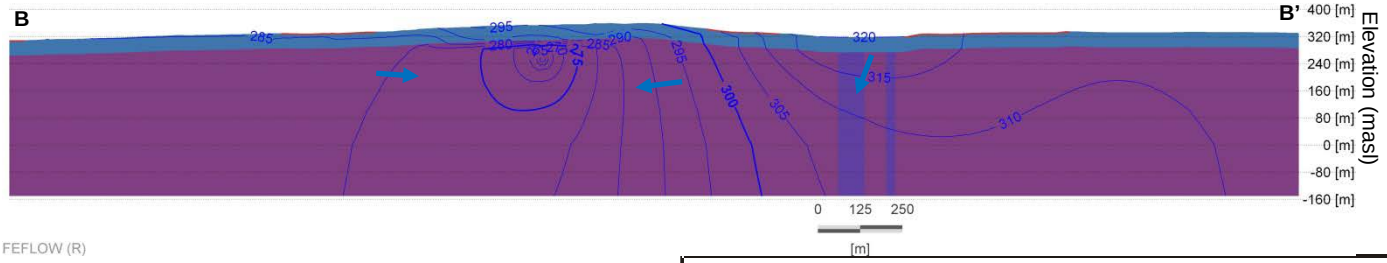

FEFLOW (R)

280 Water Table Elevation

General Groundwater Flow Direction

Notes:
1. Image Google Earth 2004
2. All distances in metres.
3. Projection: UTM Zone 15 Datum: NAD 83
4. Hydraulic heads plotted at between 245 to 275 m above sea level at the elevation of the top of the proposed tunnel

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
PREDICTED WATER TABLE
END OF TUNNELLING CONDITIONS

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PROJECT No. 10-1365-0004			PHASE No.	
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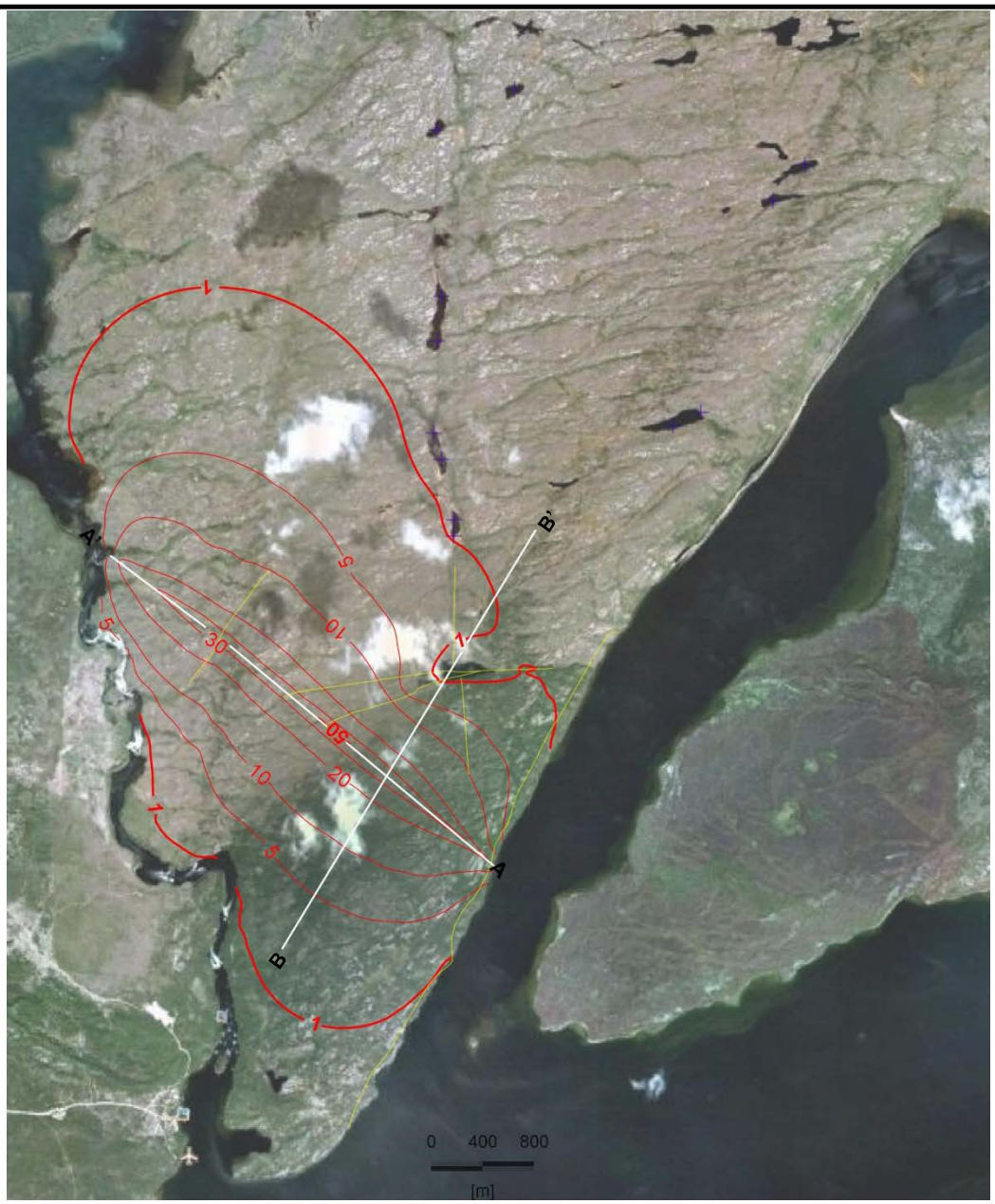

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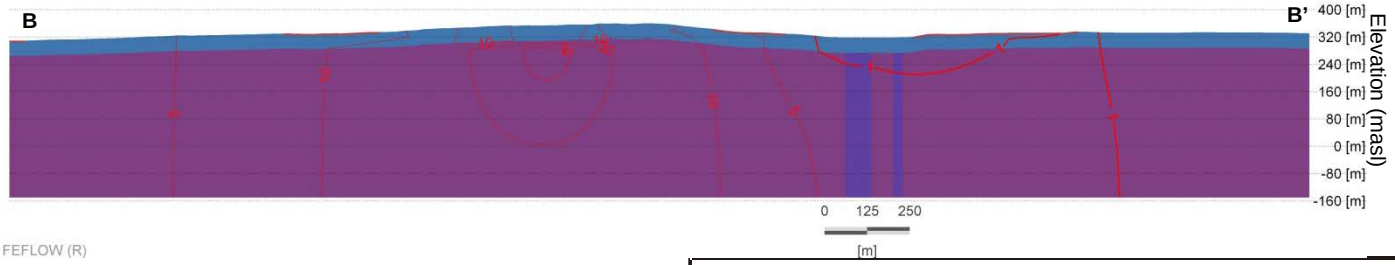

FEFLOW (R)

10 Drawdown

Notes:
1. Image Google Earth 2004
2. All distances in metres.
3. Projection: UTM Zone 15 Datum: NAD 83
4. Drawdown plotted at between 245 to 275 m above sea level at the elevation of the top of the proposed tunnel non-linear scale (1m, 5m, 10m, 20m, 30m, 50m)

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
PREDICTED DRAWDOWN END OF TUNNELING CONDITIONS

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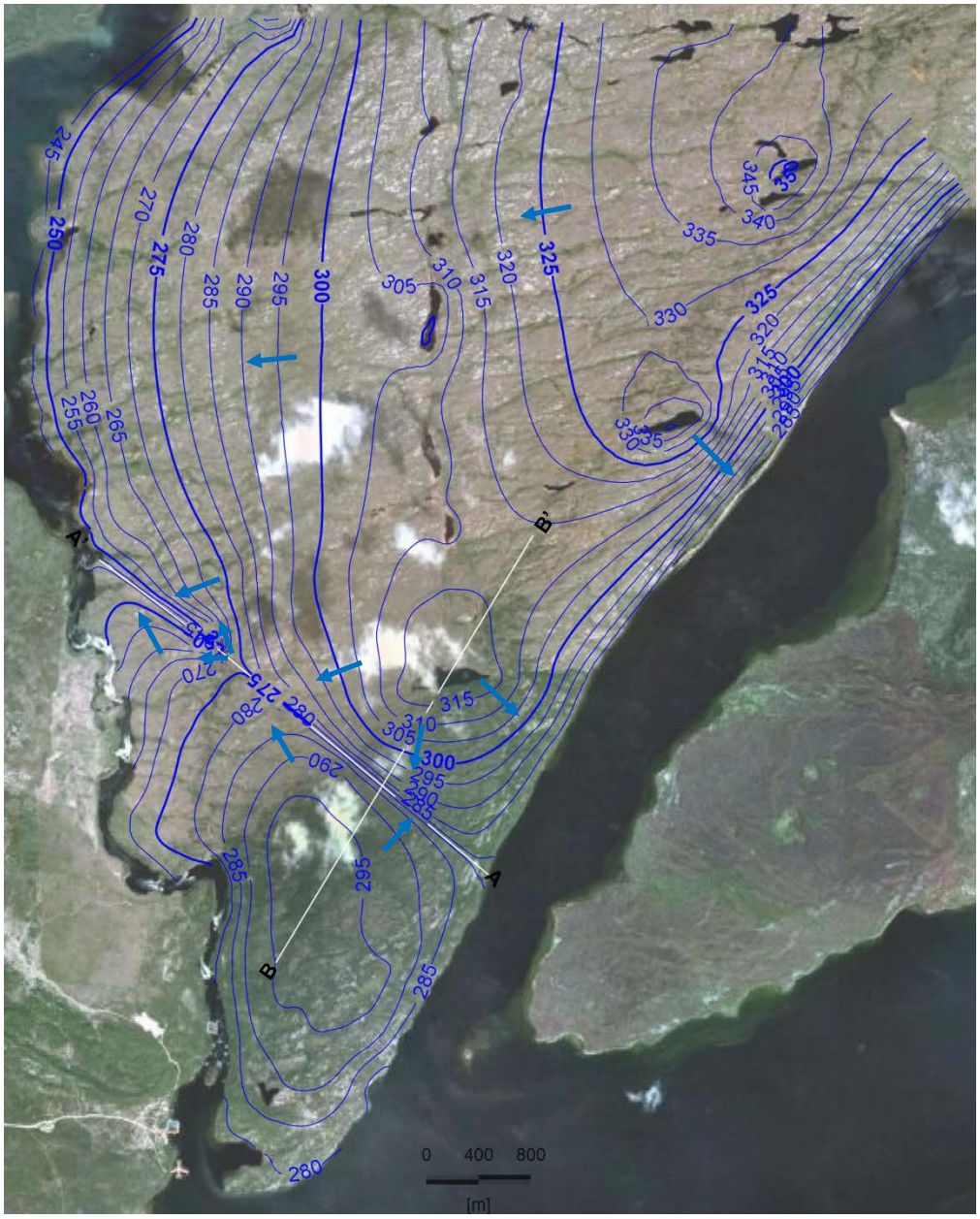
FIGURE 11



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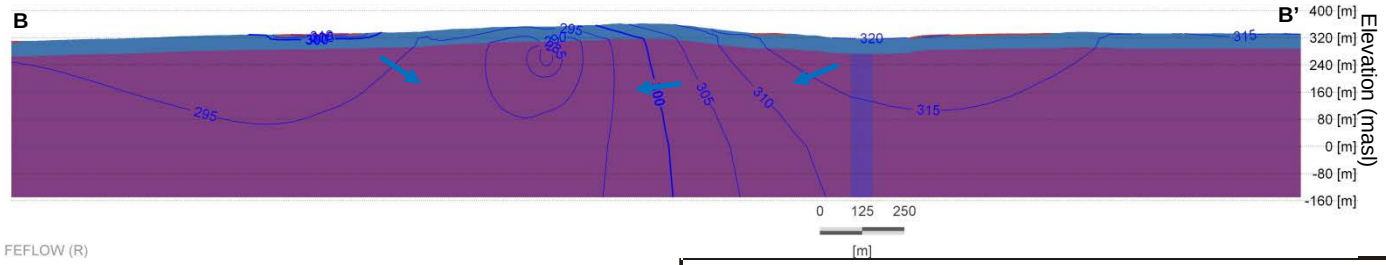

FEFLOW (R)

280 Water Table Elevation

General Groundwater Flow Direction

Notes:

1. Image Google Earth 2004
2. All distances in metres.
3. Projection: UTM Zone 15 Datum: NAD 83
4. Hydraulic heads plotted at between 245 to 275 m above sea level at the elevation of the top of the proposed tunnel

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

PREDICTED WATER TABLE OPERATION CONDITIONS

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PROJECT No. 10-1365-0004			PHASE No.	
DESIGN	SAM	10JUL13	SCALE AS SHOWN	REV.
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REVIEW	MAT			

FIGURE 12

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solutions@golder.com
www.golder.com

Golder Associates Ltd.
500 - 4260 Still Creek Drive
Burnaby, British Columbia, V5C 6C6
Canada
T: +1 (604) 296 4200

Golder Associates

APPENDIX 10.1

Hydrological Modelling

February 2014
Report No. 10-1365-0004/DCN-171

1.0 INTRODUCTION

The Tazi Twé Hydroelectric Project (Project) is a proposed water diversion type hydroelectric generation station located in Northern Saskatchewan on the Fond du Lac River between Black Lake and Middle Lake. The Project proposes to withdraw water from Black Lake, divert it through a power tunnel and turbines, and discharge it into the Fond du Lac River immediately upstream of Middle Lake. The withdrawal of water from Black Lake, the diversion of this water around the Fond du Lac River, and the resulting adjustments to its temporal flow characteristics has potential to change local hydrological conditions. To reduce environmental effects and to minimize changes to Black Lake and downstream water levels, the proponent proposes the installation of a submerged weir at the outflow of Black Lake and the implementation of water management strategies.

The Proponent plans to design the Project such that power generation is maximized and environmental effects minimized to the extent possible. To achieve this, environmental science and engineering are integrated using an interdisciplinary and iterative approach to optimize objectives. To combine environmental, Project specific considerations, and fully explore project options from both environmental and power generation perspectives, a physically and empirically based spreadsheet model was created. This model describes the physical hydrological environment associated with Project operations and incorporates Project variables in a way that allows for rapid assessment of various scenarios. The model outputs are developed to address hydrological and design queries, and are tailored to help address other environmental or Project related considerations. While various Project scenarios have been assessed during the development of the Project alongside an Energy Production Module, this document presents the inputs and corresponding results associated with the specific Project details as described in the Project Description (Section 5).

The spreadsheet model was developed using Microsoft Excel and incorporates various inputs that describe the physical hydrologic environment and the Project. For comparison purposes, the model was run without the project to derive “natural” conditions, and with the project, to represent potential effects. The model was run at daily timesteps for the period 1963-2011, as there are datasets to sufficiently represent the natural system for this period.

2.0 MODEL INPUTS

2.1 Fond du Lac River Flow Rate

The recorded daily flow record from Water Survey of Canada (WSC) gauge 07LE002 for 1963 to 2011 was used as an input for the model. The dataset was missing 863 daily flow rates, primarily within a three-year period (1998-2000). For the purposes of hydrological modeling, these gaps were filled in with calculated daily averages to maintain a continuous record.

2.2 Black Lake Water Level

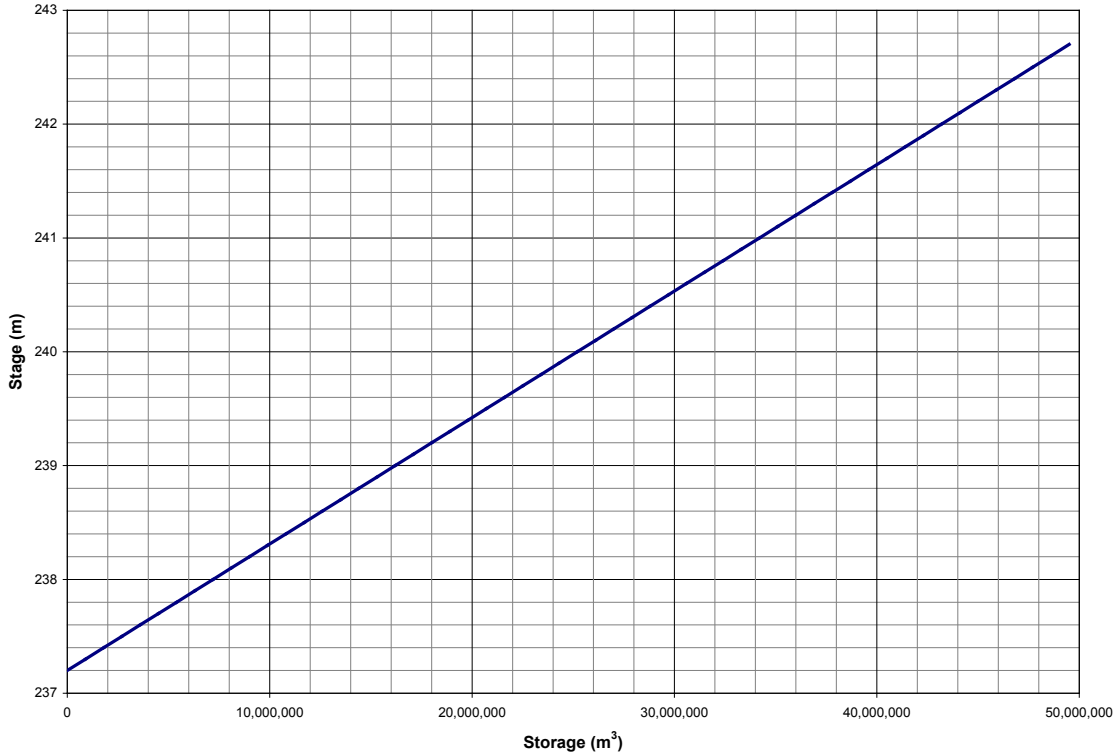
Water level data for Black Lake were estimated from the rating curve and flow rates provided by WSC for gauge 07LE002 for 1963 to 2011. The rating curve was converted to geodetic using a corresponding survey point delineated in 2005.

2.3 Middle Lake Storage Area

A stage-storage curve for Middle Lake was developed based on the surface area of the lake with assumed vertical side walls. This approach is considered preliminary and further studies are recommended to provide a more accurate stage-storage relationship. The surface area of Middle Lake was estimated to be approximately 9

square kilometres (km^2) based on 1:50,000 scale topographic maps. The estimated stage-storage relationship for Middle Lake is shown in Figure 1.

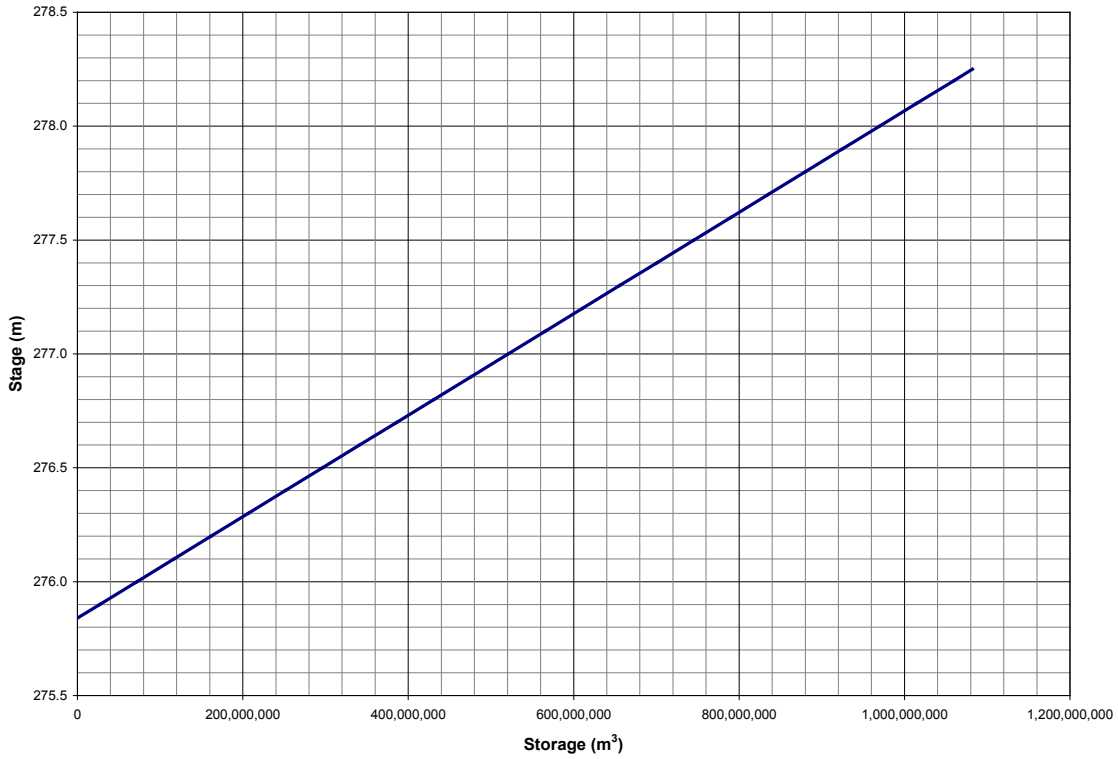
Figure 1: Middle Lake Stage-Storage Relationship



2.4 Black Lake Storage Area

The model controls the storage of Black Lake with the use of a stage-storage relationship. A stage-storage relationship for Black Lake was developed based on the surface area of the lake with assumed vertical side walls. This approach is considered appropriate for Black Lake as the surface area is quite large and a change in depth affects the lake storage much more than a change in surface area for this lake. The surface area of Black Lake was estimated to be approximately 449 km^2 based on 1:50,000 scale topographic maps. The estimated stage-storage relationship for Black Lake is shown in Figure 2.

Figure 2: Black Lake Stage-Storage Relationship

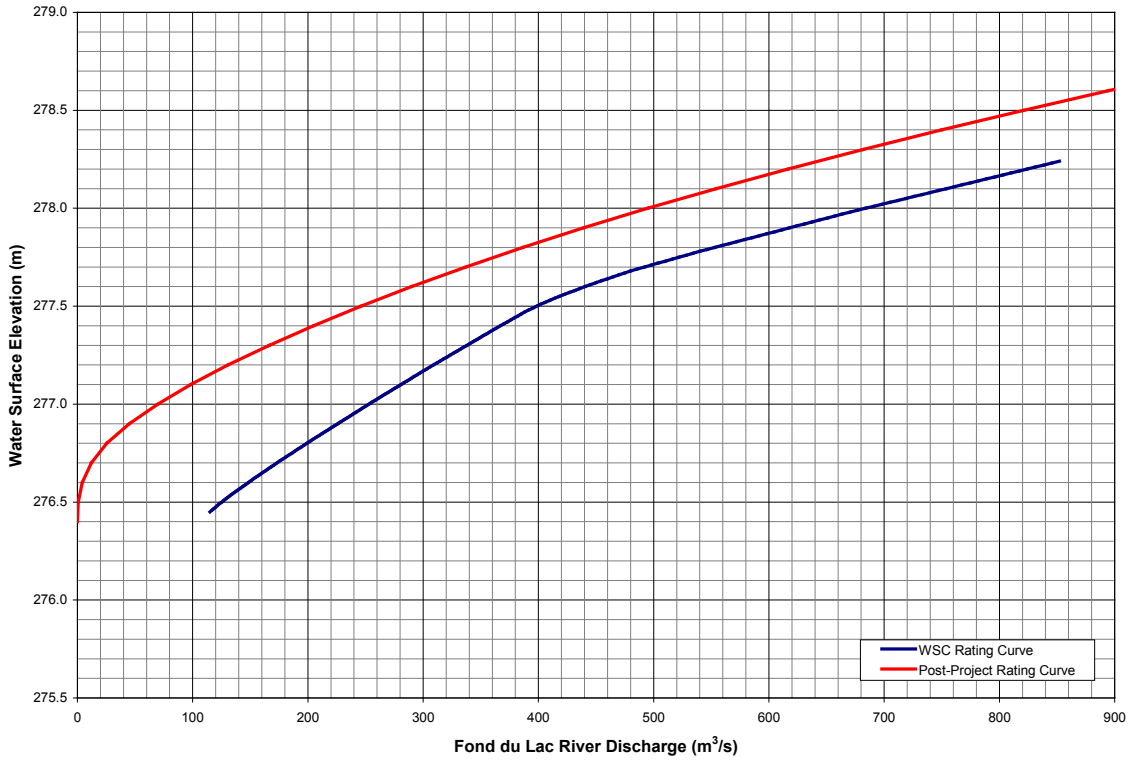


2.5 Black Lake Stage-Discharge Relationship

In the model, outflow from Black Lake is controlled by a stage-discharge relationship. Because the construction of the proposed submerged weir at the outflow of Black Lake will change the stage-discharge relationship during operations, two stage-discharge relationships are used for the purposes of this model, one for baseline conditions, and one for during operations after the weir is constructed.

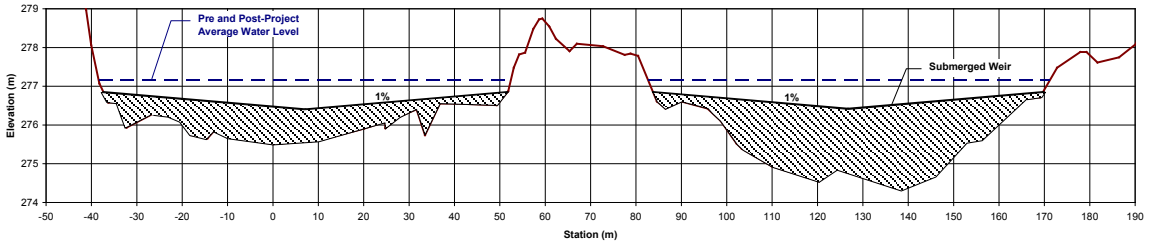
The stage-discharge relationship used for natural/baseline conditions was developed based on corresponding water level measurements and flow rates provided by WSC at the outflow of Black Lake (gauge 07LE002) for 1963 to 2011. The rating curve was converted to geodetic using a corresponding survey point that was delineated in 2005 and is presented in Figure 3 (WSC rating curve).

Figure 3: Black Lake Stage-Discharge Relationship during Baseline Conditions



During operations, when a weir is constructed across the Fond du Lac River near Grayling Island to maintain water levels within the historic range in Black Lake, the stage-discharge relationship will be governed by the characteristics of the weir. A preliminary design of this weir has been completed to minimize the change in Black Lake water level from the natural conditions during powerhouse discharge at a maximum rate of 190 cubic metres per second (m^3/s). The preliminary design includes a broad-crested rock weir with a triangular cross section with the deepest section (El. 275.749 m in the centre of the left channel and El. 275.728 m in the right channel) with a 2% slope up towards each shoreline. A triangular weir section was selected, as opposed to a flat horizontal crest, to provide greater flow depths at lower flows for improved fish passage across the weir. The downstream slope of the weir is set to be 20H:1V with an upstream slope of 5H:1V, also included for improved fish passage. The stage-discharge relationship for this weir is presented in Figure 3 (Post-Project Rating Curve) and a cross section of the proposed submerged weir is shown in Figure 4.

Figure 4: Cross Section of the Proposed Submerged Weir

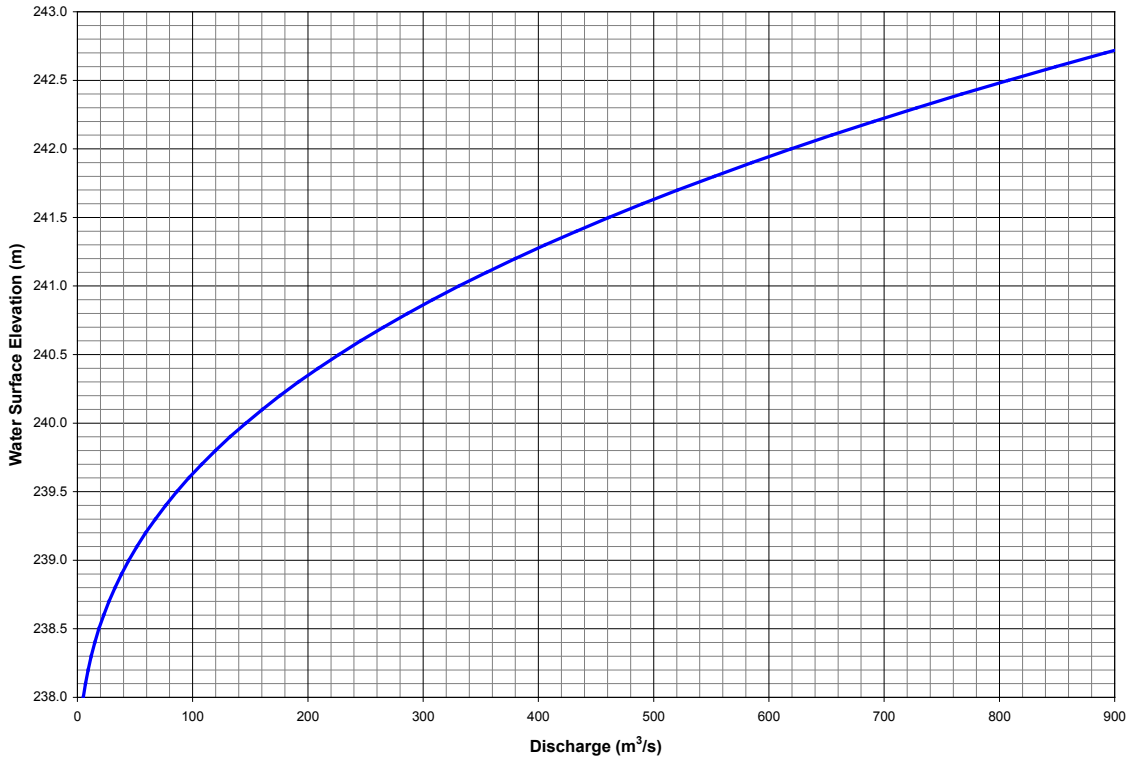


2.6 Middle Lake Stage-Discharge Relationship

Due to local ice build-up at the entrance of Middle Lake during winter, two stage-discharge relationships were applied to Middle Lake, one for the open water season (May 1 to October 31) and one for the winter season (November 1 to April 30). The open water stage-discharge equation was estimated using a regression analysis of stage and discharge measurements.

The winter stage-discharge relationship was estimated using the open-water stage-discharge equation with a 1 m allowance for local ice build-up at the entrance to Middle Lake between November 1 and April 30. This 1 m allowance is considered a conservative assumption for the purposes of this assessment as field observations, air photos, and local knowledge suggest that much of Middle Lake remains open throughout the winter. The stage-discharge relationship for Middle Lake during the open water period is presented in Figure 5.

Figure 5: Middle Lake Stage-Discharge Relationships



2.7 Powerhouse Discharge Capacity

For the purposes of this assessment, a maximum powerhouse discharge rate of 190 m^3/s was applied. However, the powerhouse discharge can be adjusted to any rate between 0 and 190 m^3/s, depending on hydrologic conditions or powerhouse operations.

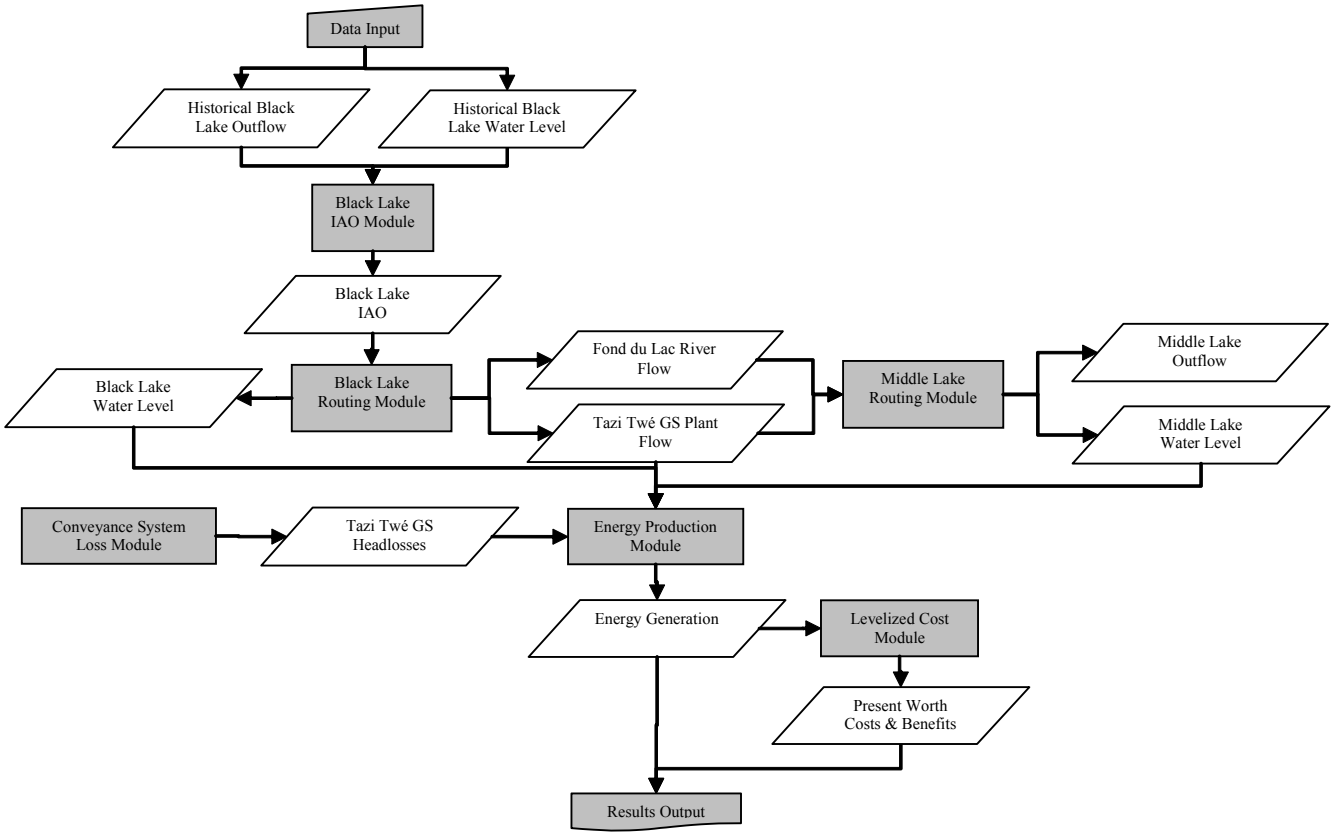
2.8 Instream Flow Requirements

The Project aims to maintain a minimum instream flow requirement (IFR) in the Fond du Lac River. This flow rate is maintained by the submerged weir design and water management strategies. For this Project, an IFR of 40 m^3/s is applied from July 1 to April 30 and an IFR of 70 m^3/s is applied during May 1 to June 30. The higher spring IFR is applied to support Arctic grayling spawning during this period.

3.0 MODEL COMPUTATIONAL METHODOLOGY

This section describes the computational steps each module in the model follows for the calculation of inflow available for outflow (IAO), routing and energy production. Unless otherwise stated, all formulas are computed on a daily basis. Figure 6 describes the model methodology in a graphical flow chart.

Figure 6: Model Methodology Flow Chart



3.1 Black Lake Inflow Available for Outflow (IAO) Module

To estimate the flow available for energy production, a daily storage volume is calculated using the Black Lake storage equation. The IAO is then computed using the continuity equation for the Black Lake flows. To help dampen the effects of wind and other anomalies in the source data, a 5 day moving average IAO is used through the model. Black Lake IAO is calculated on a daily basis according to the following equation:

$$Q_{IAO} = Q_{Black} - \Delta S$$

Where Q_{IAO} is the inflow available for outflow (m^3/day), Q_{Black} is the discharge from Black Lake (m^3/day) and ΔS is the change in storage in Black Lake (m^3/day).

3.2 Black Lake Routing Module

Once the IAO has been calculated from the previous module, outflow must be discharged through the Fond du Lac River, the Tazi Twé Generating Station or a combination of the two. The intent is to adjust the operation of the plant to pass at least the minimum riparian flow every day. This is achieved by lowering plant flows to the

point where there is sufficient storage available to fulfill the IFR. Actual riparian flows are governed by the calculated Black Lake water level. Plant flows are constrained between the minimum shutoff and maximum plant flow inputs.

3.3 Middle Lake Routine Module

The Fond du Lac River and the Tazi Twé Generating Station rejoin at their confluence downstream of the Project and upstream of Middle Lake. Since there are no other significant flows in between, the total inflow to Middle Lake is the sum of the Fond du Lac River and plant flows. Lake water level is calculated using the estimated Middle Lake storage equation. Outflow from Middle Lake is governed by the applicable stage-discharge rating curve, depending on the time of year.

Due to Middle Lake's relatively small surface area, its water level is much more susceptible to fluctuating inflows than is Black Lake. Therefore to avoid model instability, the daily Middle Lake routing computation was divided into two calculations, resulting in a time step of 0.5 day. The outflow from Middle Lake is defined according to the following equation:

$$Q_{Middle} = Q_{River} + Q_{Plant} - \Delta S$$

Where Q_{Middle} is the outflow from Middle Lake (m^3/12 hours) $Q_{River}$is the flow rate in the Fond du Lac River (m^3/12 hours), Q_{Plant} is the discharge though the powerhouse (m^3/12 hours), and ΔS is the change in storage in Middle Lake (m^3/12 hours)

4.0 RESULTS

4.1 Black Lake

Annual water level statistics for Black Lake under natural conditions and during operations are presented in Table 1 and Figure 7. While the submerged weir will be designed to maintain the mean water level near that of natural conditions, the variability in water levels will be reduced during operations. The most notable changes are predicted to occur during low water periods, for example during droughts or in the late winter when the weir restricts Blake Lake water levels from dropping. During these periods, low water levels may be elevated by up to approximately 0.5 m, however changes in water level of more than 0.1 m are predicted to occur less than 15% of the time.

Table 1: Natural and Predicted Water Levels in Black Lake

Water Level	Natural (m)	Operations (m)	Change (m)
Minimum	276.485	276.922	0.437
10th percentile	276.788	276.922	0.134
25th percentile	276.908	276.940	0.032
50th percentile	277.122	277.118	-0.004
Mean	277.159	277.171	0.012
75th percentile	277.380	277.326	-0.054
90th percentile	277.578	277.509	-0.069
Maximum	278.250	278.262	0.012

m = metre

Note: Statistics are derived from 1963-2011 and are processed at a daily resolution.

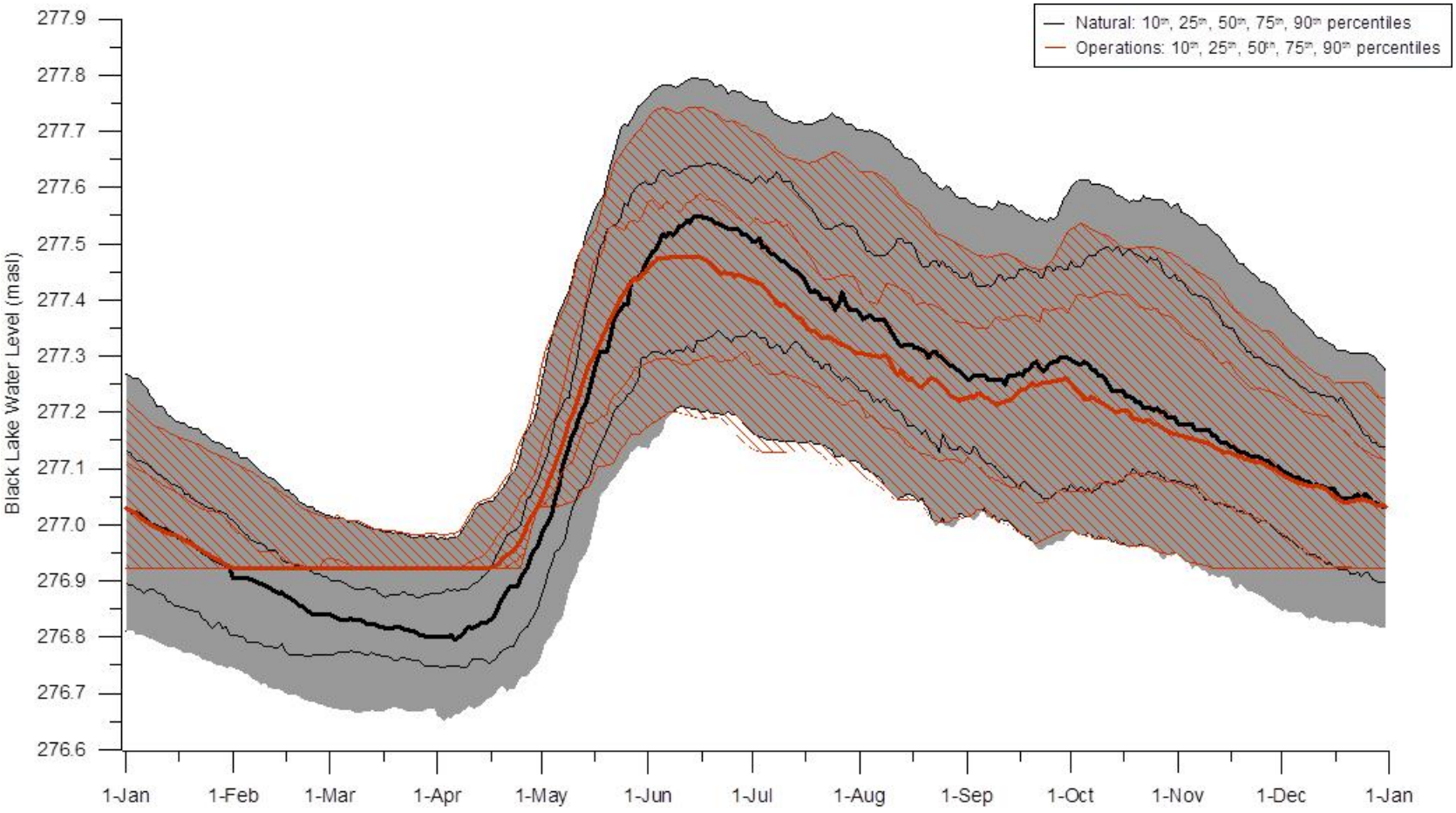


Figure 7: Predicted Changes in Daily Water Level in Black Lake

Note: Statistics are derived from 1963-2011 and are processed at a daily resolution.

4.2 Fond du Lac River

A statistical representation of the annual hydrograph for the bypassed section of the Fond du Lac River under natural conditions and Project operations is presented in Table 2 and Figure 8. While the hydrograph characteristics during operations follow similar patterns to those observed during natural conditions, the daily range of potential flow rates is reduced, and the magnitude of flow rates are reduced throughout the hydrograph.

The distribution of flow rates in the bypassed section of the Fond du Lac River lies below those recorded during baseline conditions; minimum flow rates are reduced from 122 to 40 m^3/s, mean flow rates are less than half of those naturally observed, and maximum flow rates are reduced from 860 m^3/s to 665 m^3/s.

During the lowest flow period of the year, approximately February to mid-April, discharge is predicted to be the most consistent, and the mean flow rate during this time is estimated to be 40 m^3/s. Like natural conditions, discharge increases in the spring, and displays considerable variability between years but is generally reduced by about 190 m^3/s. During the fall and early winter, as natural discharge decreases, the distribution of flows under operations becomes increasingly skewed towards lower flows.

Table 2: Predicted Discharge Rates in the Fond du Lac River

Discharge	Natural (m^3/s)	Operations (m^3/s)	Change (m^3/s)
Minimum	122	40	-82
10th percentile	196	40	-156
25th percentile	228	45	-183
50th percentile	287	97	-190
Mean	304	124	-180
75th percentile	361	173	-188
90th percentile	430	249	-182
Maximum	860	665	-195

m^3/s = cubic metres per second
Note: Statistics are derived from 1963-2011 and are processed at a daily resolution.

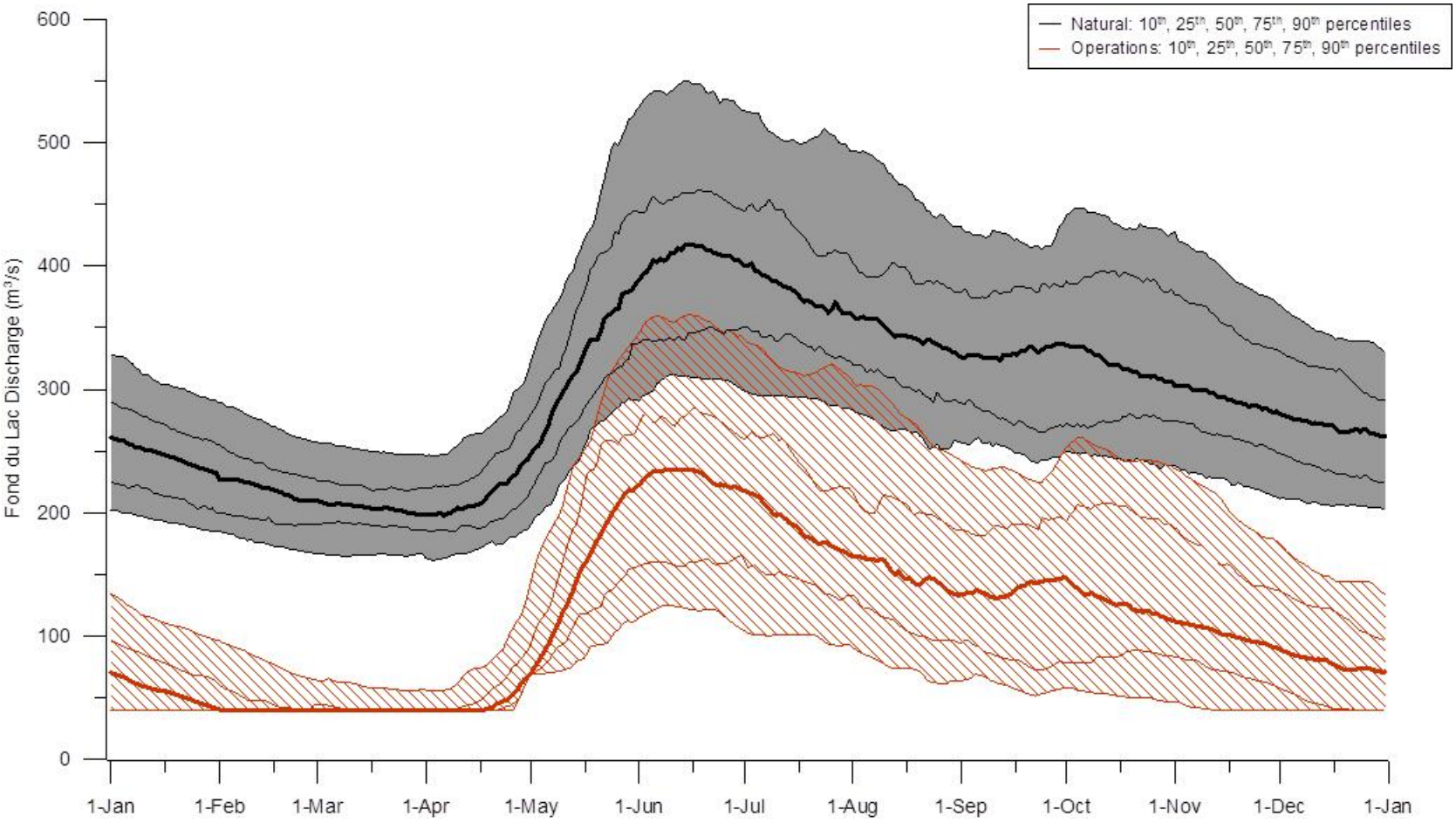


Figure 8: Predicted Changes in Daily Discharge in the Bypassed Section of the Fond du Lac River

Note: Statistics are derived from 1963-2010 and are presented at a daily resolution.

4.3 Middle Lake

During natural conditions Middle Lake receives inflow from the Fond du Lac River while during operations it receives inflow from the Fond du Lac River and the tailrace channel. A statistical representation of the annual hydrograph for Middle Lake discharge under natural conditions and Project operations is presented in Table 3 and Figure 9. Discharge is predicted to remain within 10 m^3/s of its natural rate, except for during extreme low flow when flow in the bypass section of the Fond du Lac River is at the minimum IFR (40 m^3/s) and water through the power tunnel is reduced to less than 50 m^3/s to maintain water level in Black Lake and the IFR in the Fond du Lac River. During these periods, flow from Middle Lake may be reduced by up to 50%. However, a reduction in Middle Lake outflow of more than 10% is only predicted to occur less than 3% of the time.

Table 3: Predicted Discharge Rates from Middle Lake

Discharge	Natural (m^3/s)	Operations (m^3/s)	Change (m^3/s)
Minimum	122	82	-40
10^{th} percentile	196	191	-5
25^{th} percentile	228	232	4
50^{th} percentile	287	287	0
Mean	304	304	0
75^{th} percentile	361	363	2
90^{th} percentile	430	439	8
Maximum	860	854	-6

m^3/s = cubic metres per second

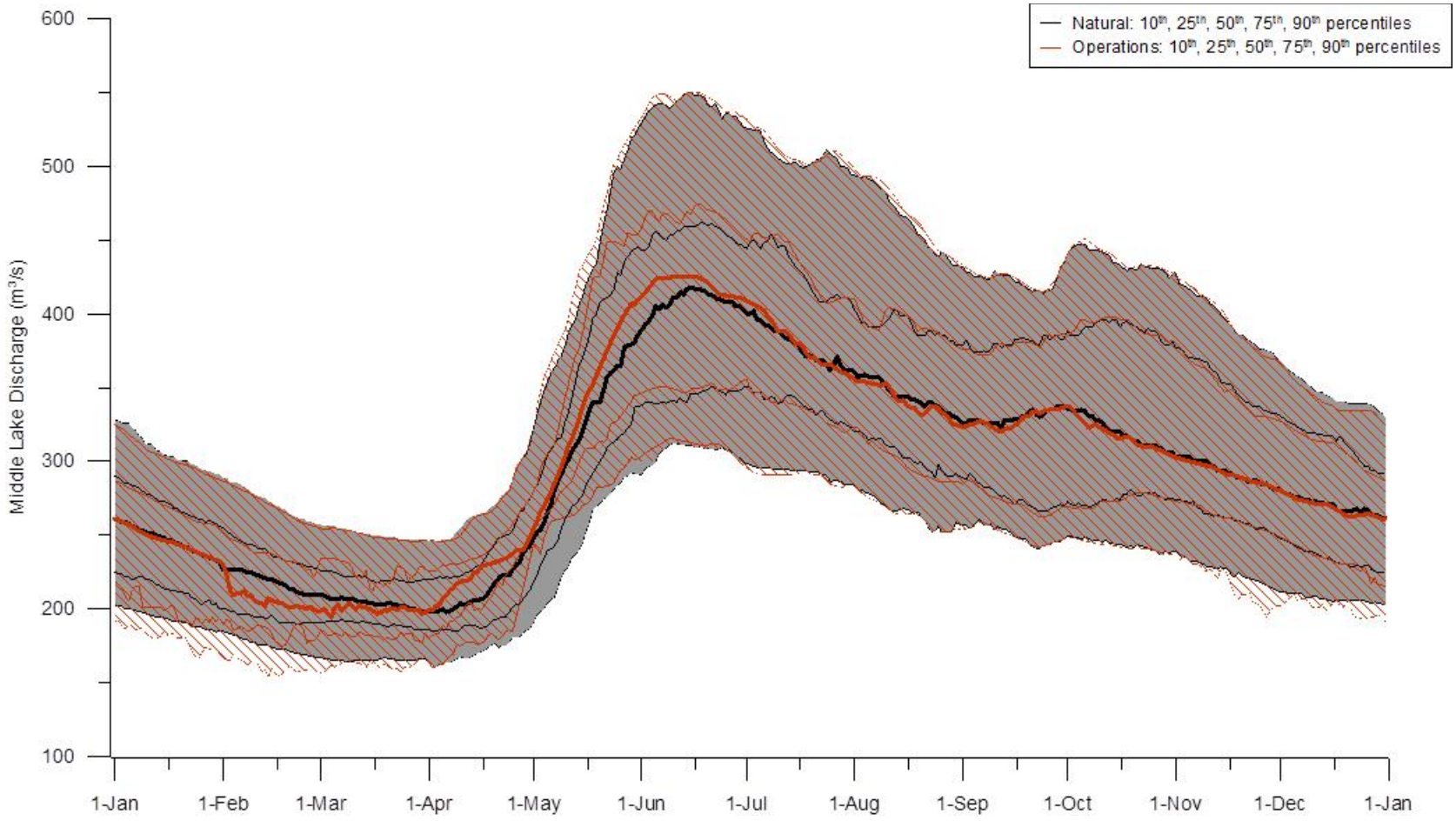


Figure 9:Predicted Changes in Discharge in Middle Lake

Note: Statistics are derived from 1963-2011 and are processed at a daily resolution.

5.0 UNCERTAINTIES AND RECOMMENDATIONS

Though the modeling completed in this study is considered sufficiently accurate and representative for the purposes of this assessment, a number of uncertainties and recommendations have been proposed to more accurately and fully represent the local hydrology and more accurately predict Project effects to hydrology.

- Water levels should be surveyed on Middle Lake during the winter conditions to confirm the amount of ice staging that occurs and to validate the winter stage-discharge relationships for Middle Lake.
- Discharge rates and corresponding water levels should be competed under a variety of hydrological conditions at the outflow of Middle Lake to more accurately describe the stage-discharge relationship for Middle Lake.
- A stage-storage curve for Middle Lake was developed based on the surface area of the lake with assumed vertical side walls. This approach is considered preliminary and further studies are recommended to provide a more accurate stage-storage relationship.

APPENDIX 10.2

River 2D

February 2014
Report No. 10-1365-0004/DCN-171

1.0 INTRODUCTION

The Tazi Twé Hydroelectric Project (Project) is a proposed water diversion type hydroelectric generation station located in Northern Saskatchewan on the Fond du Lac River between Black Lake and Middle Lake. The Project proposes to withdraw water from Black Lake, divert it through a power tunnel and turbines, and discharge it into the Fond du Lac River immediately upstream of Middle Lake. The withdrawal of water from Black Lake, the diversion of this water around the Fond du Lac River, and its temporal characteristics has potential to change local hydrological conditions. To reduce environmental effects and to minimize changes to Black Lake and downstream water levels, the proponent proposes the installation of a submerged weir at the outflow of Black Lake and the implementation of water management strategies.

The Proponent plans to design the Project such that power generation is maximized and environmental effects minimized to the extent possible. Although various project designs have been considered throughout the planning stages, a preferred option has been considered and assessed in detail. This option includes the following characteristics:

- A maximum water withdrawal rate from Black Lake of 190 cubic metres per second (m^3/s). This water is diverted from Black Lake through the power tunnel and discharged into the Fond du Lac River just upstream of Middle Lake through the tailrace channel.
- A minimum target riparian flow rate of 70 m^3/s during the spring (May 1 to June 30) and a minimum target riparian flow rate of 40 m^3/s during the summer, fall and winter (July 1 to April 30).
- A submerged weir at the outflow of Black Lake that is designed to maintain a near natural mean water level in Black Lake.

The diversion of water around the Fond du Lac River under the project operation has potential to change the riverine hydraulic habitat in the Fond du Lac River reach between the Black Lake and Middle Lake. To determine the river shoreline and hydraulics under specific flow rates that are predicted to occur during Project operations, a specialized hydraulic model was used. Results from the modeling are used to determine potential corresponding effects to fish and fish habitat.

2.0 METHOD

River2D is a two-dimensional, depth averaged finite element hydrodynamic model. The River2D model provides an appropriate platform for this project as it is 1) intended for use on natural streams and rivers, 2) has features designed to accommodate supercritical and subcritical flow transitions and variations in wetted area, 3) it is a transient model but allows for convergence to steady-state conditions, and 4) includes a number of options to aid the user in visualizing the progression and/or final results of the hydrodynamic computations including colour maps, contour maps and velocity vector fields.

2.1 Model Inputs

The River2D model requires a digital elevation model (DEM) of the bathymetric surface including adjacent shoreline and floodplain topography, substrate characteristics, and water level and discharge information as described below.

2.1.1 Digital Elevation Model (DEM)

Bathymetric data along the bypassed section of the Fond du Lac River (Annex III) were merged with light direction and ranging (LiDAR) data and real time kinematics (RTK) geodetic surveys to create a DEM of the study area. All data were screened for quality assurance and quality control to create an accurate and representative DEM and datasets were merged to a common elevation datum using overlapping measurements. Small areas of missing bathymetric data were interpolated with gradual gradients similar to that of the water surface. Because bathymetric data could not be obtained for all sections of the study area due to safety concerns, the river was divided into three segments for analyses, as presented in Figure 1. Segment 1 extends from Black Lake to approximately 3 kilometres (km) downstream, Segment 2 extends from near the end of Segment 1 to approximately 1 km downstream, and Segment 3 extends from approximately 500 metres (m) upstream of the proposed tailrace outflow to Middle Lake.

2.1.2 Substrate Characteristics

Substrate characteristics along each segment of the Fond du Lac River were collected during field observations in 2010, 2011, and 2012. These observations included descriptions of vegetation, soil, and river bed materials. The river bed material in these reaches is mainly boulders and cobbles, while finer material (gravel and sand) was observed in ponding prone areas, low velocity areas and infilling the interstitial spaces of coarser material. There is a large variation in substrate diameter ranging from fine gravel (0.04 m) to boulders (0.5 m). For this assessment the bed medium particle size D_{50} is estimated to be 0.15 m (mostly cobble). A typical Manning coefficient is about 0.035 and the roughness height is estimated to be from 0.1 to 0.2 m.

The vegetation cover on the floodplain consists mainly of dense tall trees, with occasional patches of grass. Vegetated areas are typically assigned a roughness height of greater than 0.3 m; however due to the channel characteristics (high gradients combined with riffles, cascades and good bank control) and the lower discharges evaluated, no flooding above the bankfull levels was modeled .

2.1.3 Water Level and Discharge Relationships

For modelling purposes, discharge is assigned as the upstream hydraulic boundary condition and water level is assigned as the downstream hydraulic boundary condition for each segment. As such, stage-discharge information is required for each segment; these data were derived from field surveys (RTK and LiDAR) and the Environment Canada continuous discharge record, and are presented in Table 1.

Table 1: Water Level and Discharge Data

Discharge (m^3/s)	Water Elevation (m ASL) at the Downstream end of:		
	Segment 1	Segment 2	Segment 3
220	266.769	258.531	240.453
245	266.988	258.700	240.600
312	267.182	259.371	240.920
383	267.670	259.970	241.230

m^3/s = cubic metres per second; m ASL = metres above sea level

2.2 Data Processing

2.2.1 Bed Topography

Bed topography data were processed with the R2D_Bed component. During this process, the bed is improved, to avoid misrepresentation after interpolations. Field survey data and the shoreline edge available from LiDAR were used as a reference when required. The outliers were removed following visual checks against LiDAR mapping and Ortho imagery.

The computation exterior boundary is based on the following factors:

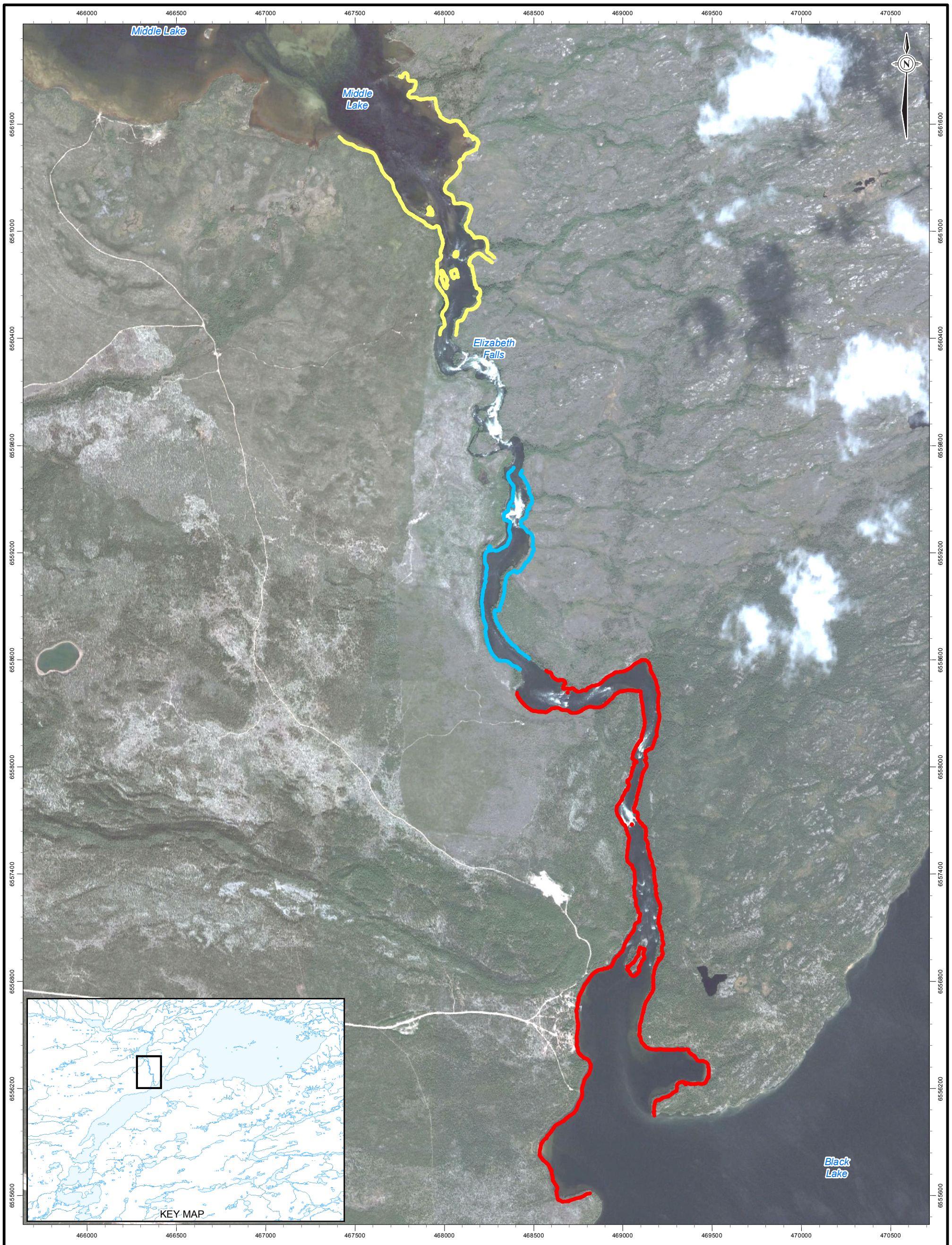
- study area of interest;
- the water level elevation recorded at the Environment Canada hydrometric station for the maximum discharge to be simulated;
- the water level elevation and measured discharges from field surveys;
- computational time (i.e., larger domains have longer run times), (i.e., the computational domain was reduced as much as possible); and
- flow conditions.

The resulting refined bed topography was used to develop a computational mesh in R2D_Mesh.

2.2.2 Mesh Generation

An appropriate mesh system is required to ensure numerical stability and accuracy in the modeling process. River2D uses a mesh system with triangular finite elements, which were generated for the River2D modelling of Fond du Lac River hydraulics using the R2D_Mesh component. To generate the mesh the following features were considered:

- A computational domain was defined by the exterior boundary determined in R2D_Bed.
- The mesh grid size was set initially to a reasonable size, (e.g., to 20 m for the flood plain and 10 m for the main channel). During the calibration process, the mesh was refined based on high velocity results and complexity of the bathymetry.
- The mesh systems were optimized through adjustments to the nodes and grid connections to improve the mesh quality until a satisfactory quality index (QI) value was obtained. According to the model references, a QI value of greater than 0.15 is considered to be acceptable for River2D modelling.



LEGEND

- SEGMENT 1
- SEGMENT 2
- SEGMENT 3

500 0 500

SCALE 1:20,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODELED SEGMENTS ALONG THE FOND DU LAC RIVER

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	11/11/13	FIGURE: 1	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		

2.3 Model Calibration

Model calibration was completed using the water level profile obtained during LiDAR data collection and the corresponding flow rate (245 m^3/s). Adjustments were made to bed roughness factors (K_s) to obtain agreement between simulated and observed conditions, as well as measured and simulated velocity profiles along the study reach.

Table 2 and Figure 2 provide a summary of measured and simulated water levels along each segment after calibration. Simulations indicate that the model generally simulated the actual water level within 0.2 m, however discrepancies up to 0.5 m were observed in areas of high topographic variation.

Table 2: Calibration Results

	Distance from Black Lake outlet (m)	Bed Elevation (m ASL)	Surveyed Water Level (m ASL)	Simulated Water Level (m ASL)	Water Level Difference (Simulated-Surveyed) (m)
Segment 1	0	262.5	277.0	277.0	0.0
	227	264.3	277.0	277.0	0.0
	524	268.2	277.1	277.0	-0.1
	755	264.4	277.1	277.0	-0.1
	1,004	266.6	277.0	277.0	0.0
	1,262	275.0	276.8	276.9	0.1
	1,490	274.3	275.6	275.6	0.0
	1,750	272.7	274.6	274.5	-0.1
	2,023	270.8	274.4	274.2	-0.2
	2,260	270.3	271.9	272.0	0.1
	2,507	269.6	271.4	271.3	-0.1
	2,727	263.5	270.3	269.8	-0.5
	3,045	257.6	270.1	269.9	-0.2
	3,255	267.1	268.8	269.0	0.3
	3,497	266.7	268.0	267.8	-0.2
Segment 2	3,850	263	266	266	-0.2
	3,940	263	266	266	0.0
	4,076	262	265	265	0.1
	4,208	261	265	265	0.1
	4,299	264	265	265	0.3
	4,433	262	264	264	0.2
	4,550	262	264	264	0.3
	4,657	259	263	263	-0.2
	4,733	261	263	263	0.2

Table 2: Calibration Results (continued)

	Distance from Black Lake outlet (m)	Bed Elevation (m ASL)	Surveyed Water Level (m ASL)	Simulated Water Level (m ASL)	Water Level Difference (Simulated-Surveyed) (m)
Segment 3	3,850	263	266	266	-0.2
	3,940	263	266	266	0.0
	4,076	262	265	265	0.1
	4,208	261	265	265	0.1
	4,299	264	265	265	0.3
	4,433	262	264	264	0.2
	4,550	262	264	264	0.3
	4,657	259	263	263	-0.2
	4,733	261	263	263	0.2

m = metre; m ASL = metres above sea level

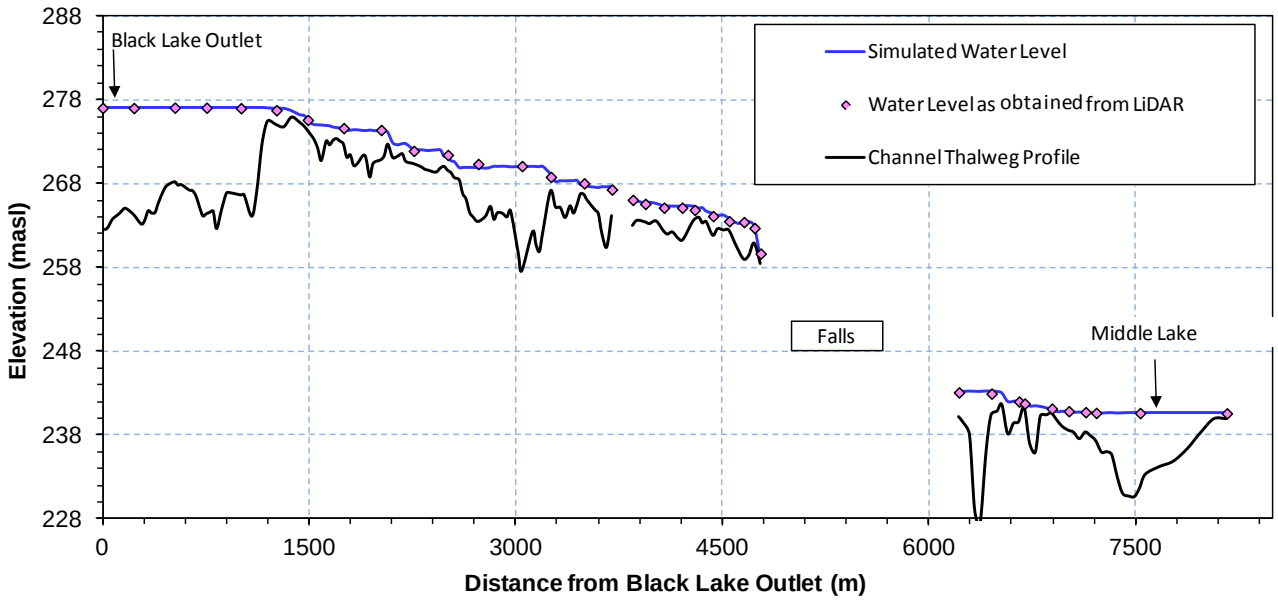


Figure 2: Model Calibration - Simulated and Measured Water Level at 245 m^3/s along the Fond du Lac River

2.4 Model Validation

The calibrated River2D model was further validated using water edges and velocities measured during field surveys. Simulated velocities were compared to the measured velocities to qualitatively assess similarity in magnitude and distribution. Simulated velocities are reasonably close to the measured velocities at the calibration discharge. Increasing biases were found in areas with riffles and rapids, however these discrepancies can be expected due to high turbulence.

2.5 Model Results

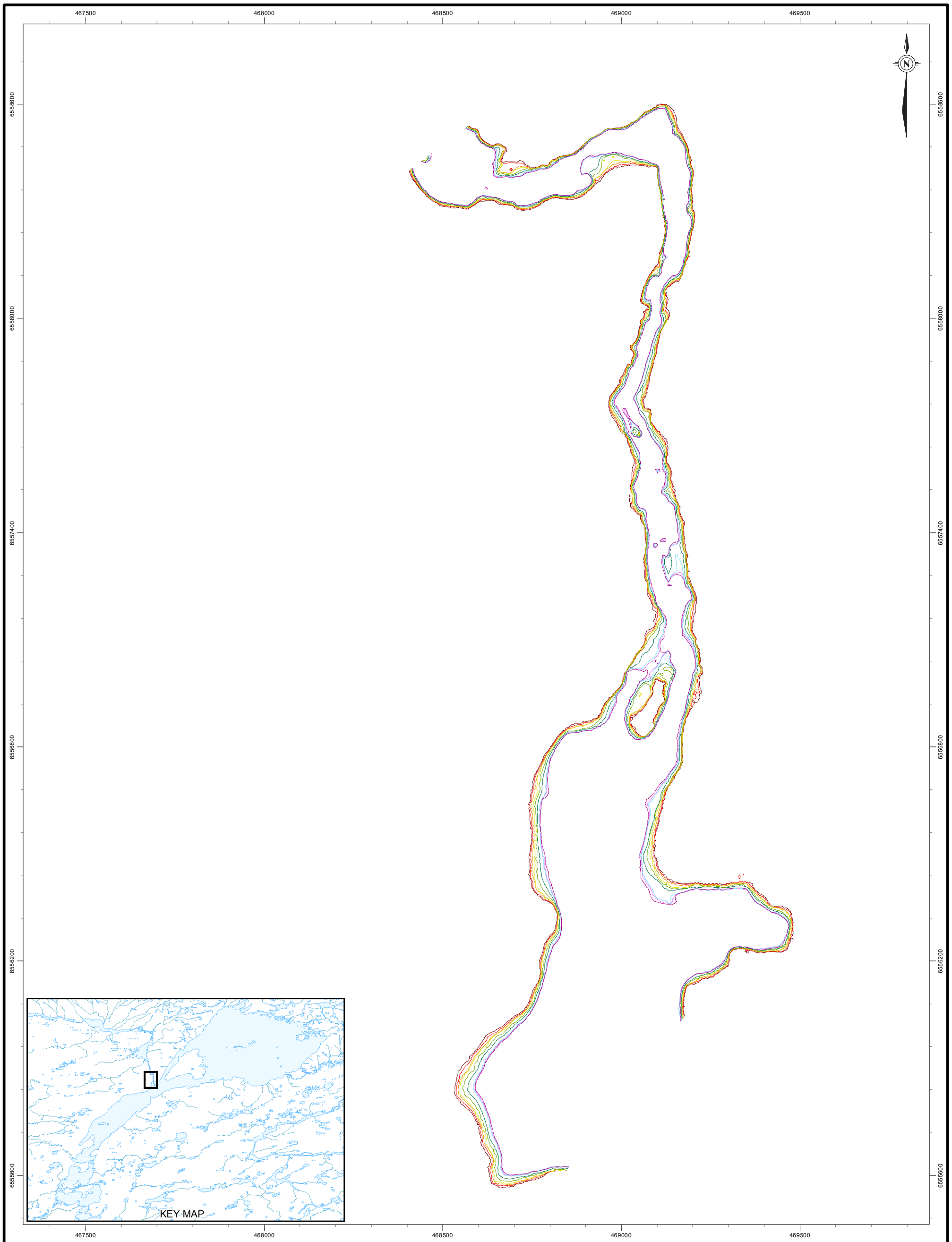
The calibrated River2D model was used to simulate steady-state conditions for a variety of flow scenarios. The water's edge under each flow rate is included in Figure 3, Figure 4, and Figure 5 and the depth profiles for each flow scenario are included in Figures 6 to 33, as indicated in Table 3.

Table 3: Model Simulations

Riparian Flow Rate (m^3/s)	Relevance	Segment 1	Segment 2	Segment 3	
				Plus 0 m^3/s tailrace flow	Plus 190 m^3/s tailrace flow
30	Below IFR during operations	Figure 6	Figure 15		Figure 28
40	Summer/fall/winter IFR during operations	Figure 7	Figure 16		Figure 29
50	Above spring summer/fall/winter IFR during operations	Figure 8	Figure 17		Figure 30
112	1:10 low spring flow during operations	Figure 9	Figure 18		Figure 31
210	Average spring flow during operations; Average winter low flow during natural conditions	Figure 10	Figure 19	Figure 24	Figure 32
302	1:10 low spring flow during natural conditions	Figure 11	Figure 20	Figure 25	
320	1:10 high spring flow during operations	Figure 12	Figure 21		Figure 33
400	Average spring flow during natural conditions	Figure 13	Figure 22	Figure 26	
510	1:10 high spring flow during natural conditions	Figure 14	Figure 23	Figure 27	

m^3/s = cubic metres per second, IFR = Instream Flow Requirement

This report provides the methods and results for the River2D model that was developed for the Fond du Lac River to assess the spatial distribution and hydraulic conditions for a range of flows within the river channel between Black Lake and Middle Lake. Corresponding flow depths and velocities were also used to evaluate potential effects to fish and fish habitat.



LEGEND

- WATER'S EDGE AT 510 m³/s
- WATER'S EDGE AT 400 m³/s
- WATER'S EDGE AT 320 m³/s
- WATER'S EDGE AT 302 m³/s
- WATER'S EDGE AT 210 m³/s
- WATER'S EDGE AT 112 m³/s
- WATER'S EDGE AT 50 m³/s
- WATER'S EDGE AT 40 m³/s
- WATER'S EDGE AT 30 m³/s

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
NAD83 UTM ZONE 13
NTS MAPSHEETS: 73P

250 0 250
SCALE 1:10,000 METRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

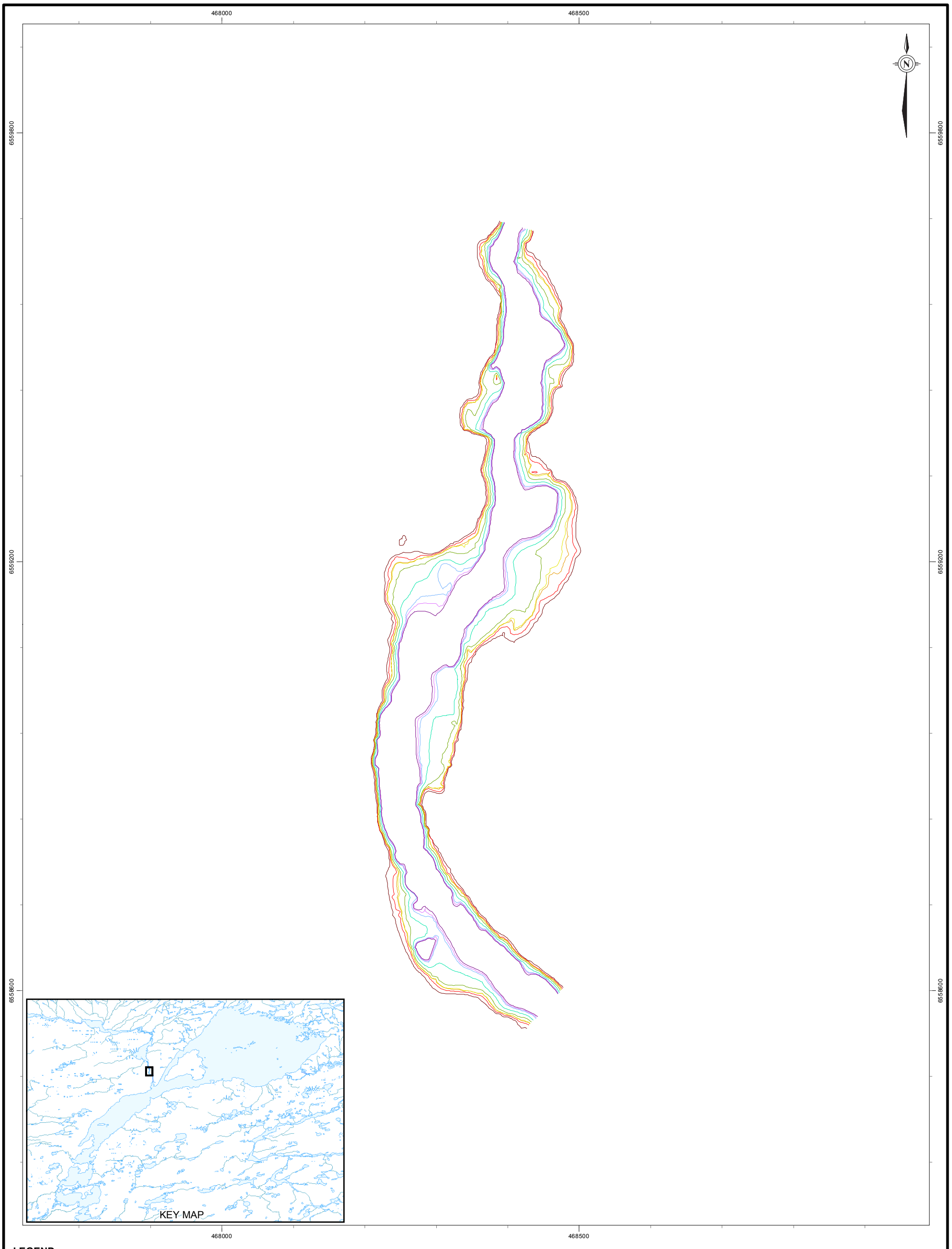
TITLE

WATER'S EDGE FOR MODELED FLOW SCENARIOS IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	11/11/13		
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		

FIGURE: 3



LEGEND

- WATER'S EDGE AT 510 m³/s
- WATER'S EDGE AT 400 m³/s
- WATER'S EDGE AT 320 m³/s
- WATER'S EDGE AT 302 m³/s
- WATER'S EDGE AT 210 m³/s
- WATER'S EDGE AT 112 m³/s
- WATER'S EDGE AT 50 m³/s
- WATER'S EDGE AT 40 m³/s
- WATER'S EDGE AT 30 m³/s

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
NAD83 UTM ZONE 13
NTS MAPSHEETS: 73P

125 0 125
SCALE 1:5,000 METRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

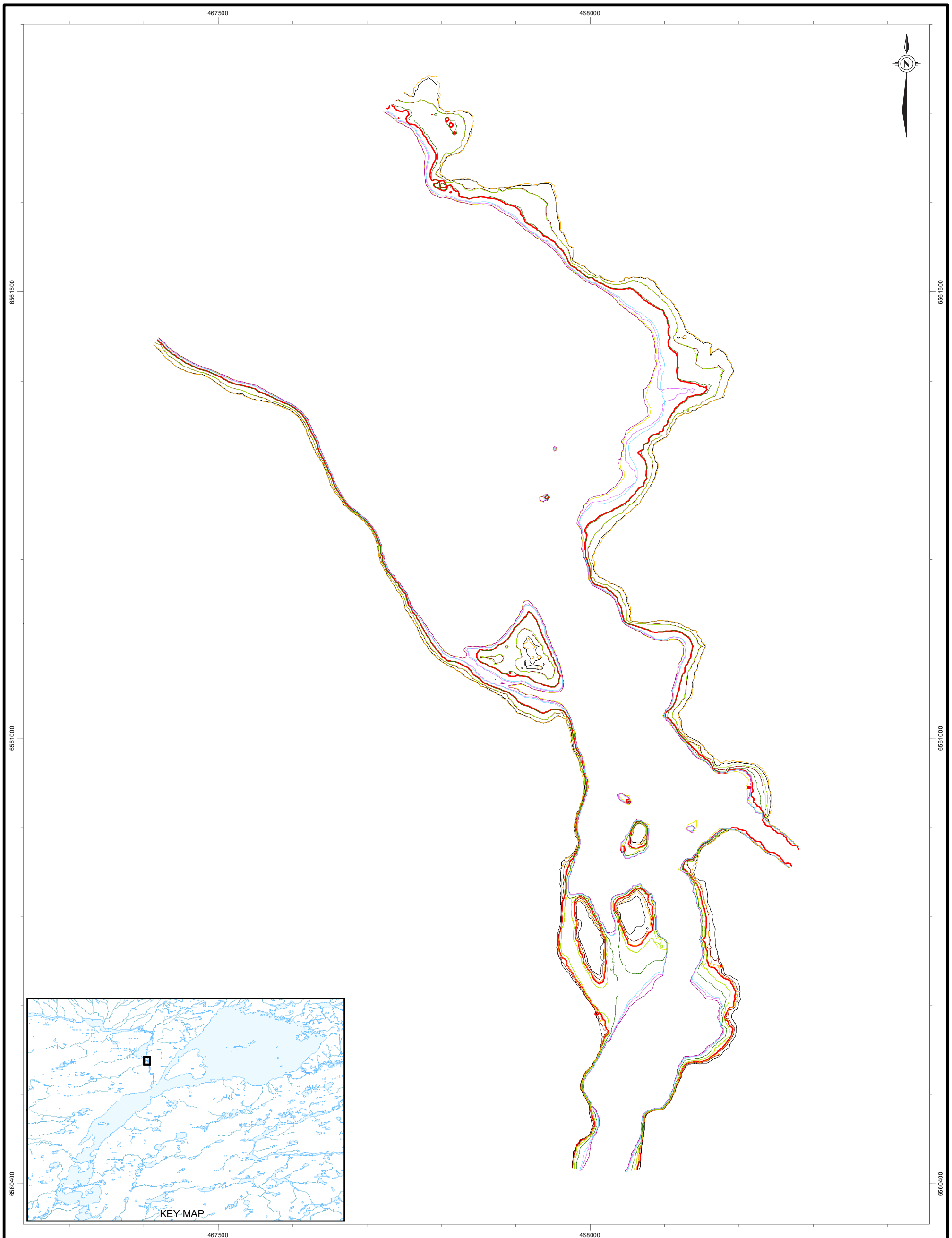
TITLE

WATER'S EDGE FOR MODELED FLOW SCENARIOS IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	07/11/13		
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		

FIGURE: 4



LEGEND

- WATER'S EDGE AT 510 m³/s RIPARIAN AND 0 m³/s TAILRACE
- WATER'S EDGE AT 400 m³/s RIPARIAN AND 0 m³/s TAILRACE
- WATER'S EDGE AT 302 m³/s RIPARIAN AND 0 m³/s TAILRACE
- WATER'S EDGE AT 210 m³/s RIPARIAN AND 0 m³/s TAILRACE
- WATER'S EDGE AT 320 m³/s RIPARIAN AND 190 m³/s TAILRACE
- WATER'S EDGE AT 210 m³/s RIPARIAN AND 190 m³/s TAILRACE
- WATER'S EDGE AT 112 m³/s RIPARIAN AND 190 m³/s TAILRACE
- WATER'S EDGE AT 50 m³/s RIPARIAN AND 190 m³/s TAILRACE
- WATER'S EDGE AT 40 m³/s RIPARIAN AND 190 m³/s TAILRACE
- WATER'S EDGE AT 30 m³/s RIPARIAN AND 190 m³/s TAILRACE

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
NAD83 UTM ZONE 13
NTS MAPSHEETS: 73P

125 0 125
SCALE 1:4,802 METRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

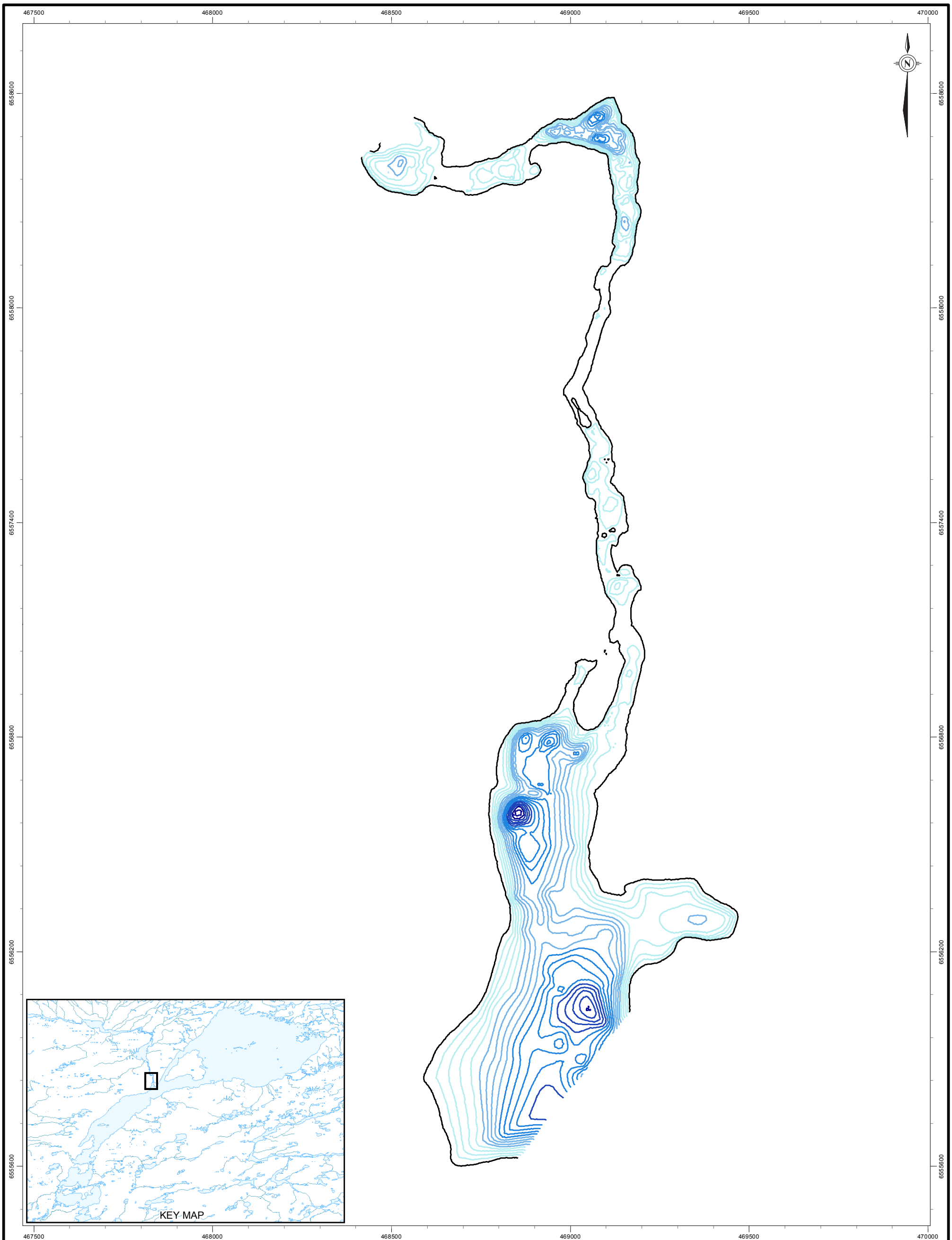
TITLE

WATER'S EDGE FOR MODELED FLOW SCENARIOS IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	11/11/13		
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		

FIGURE: 5



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

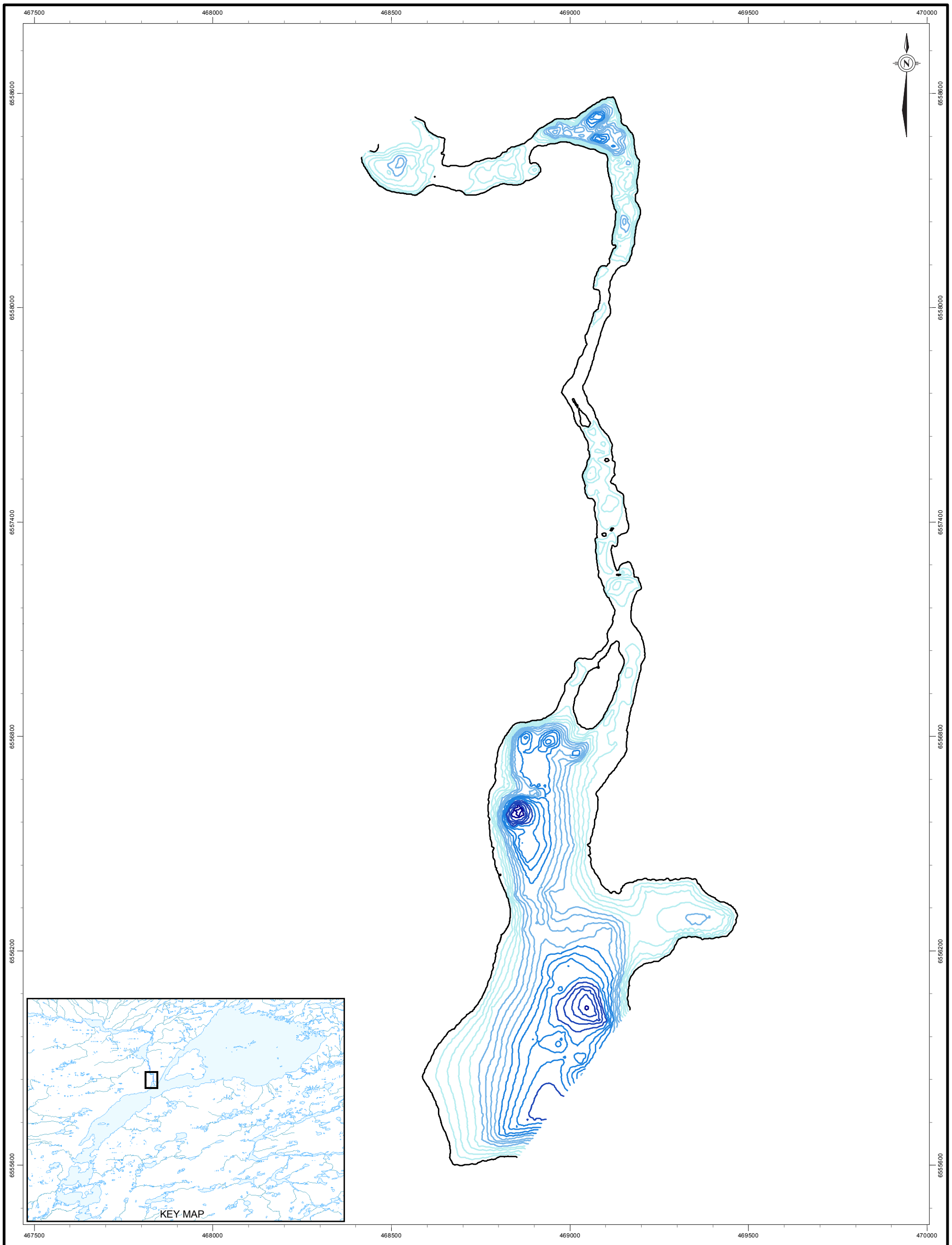
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 30 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	04/11/13	FIGURE: 6	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

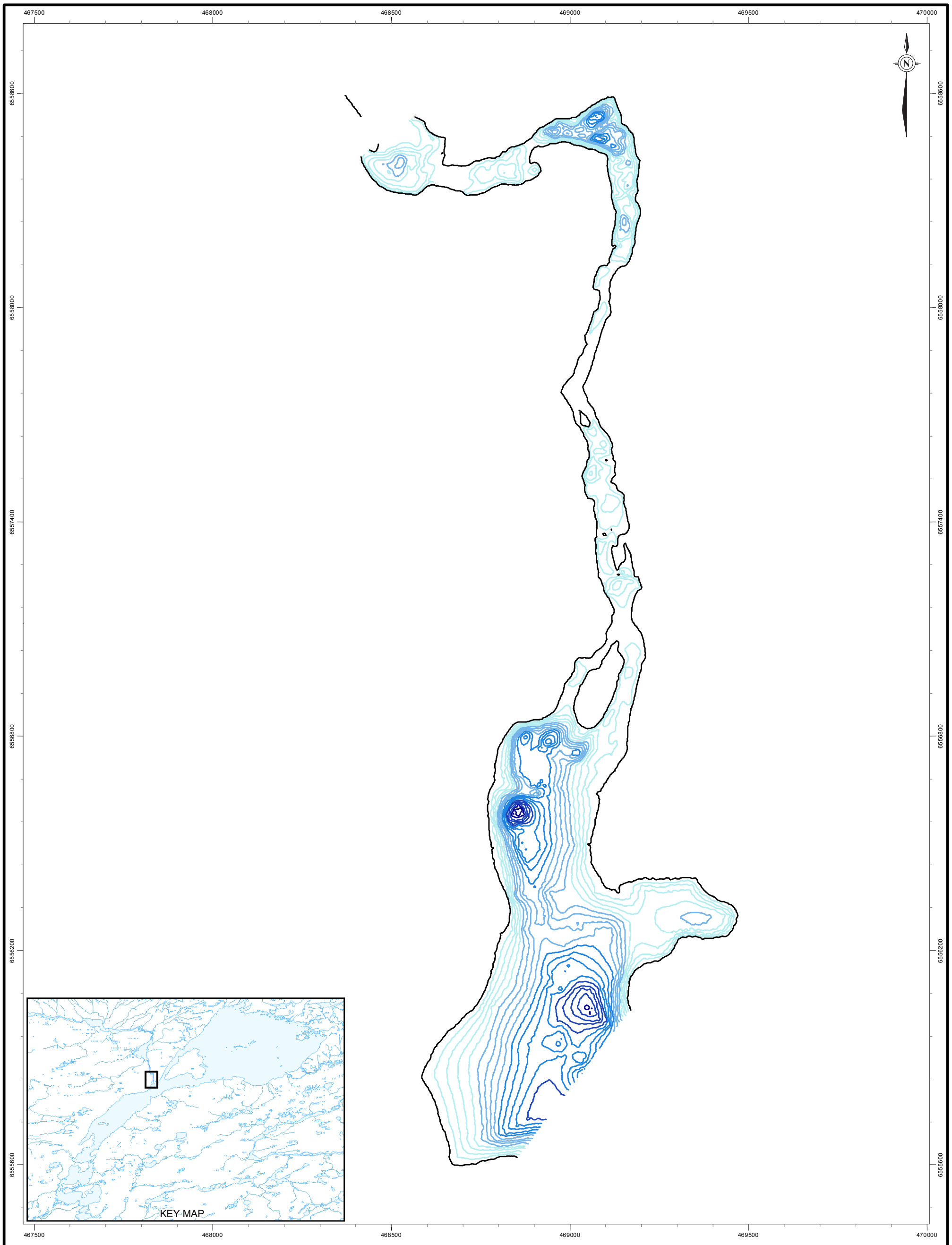
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 40 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 7	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

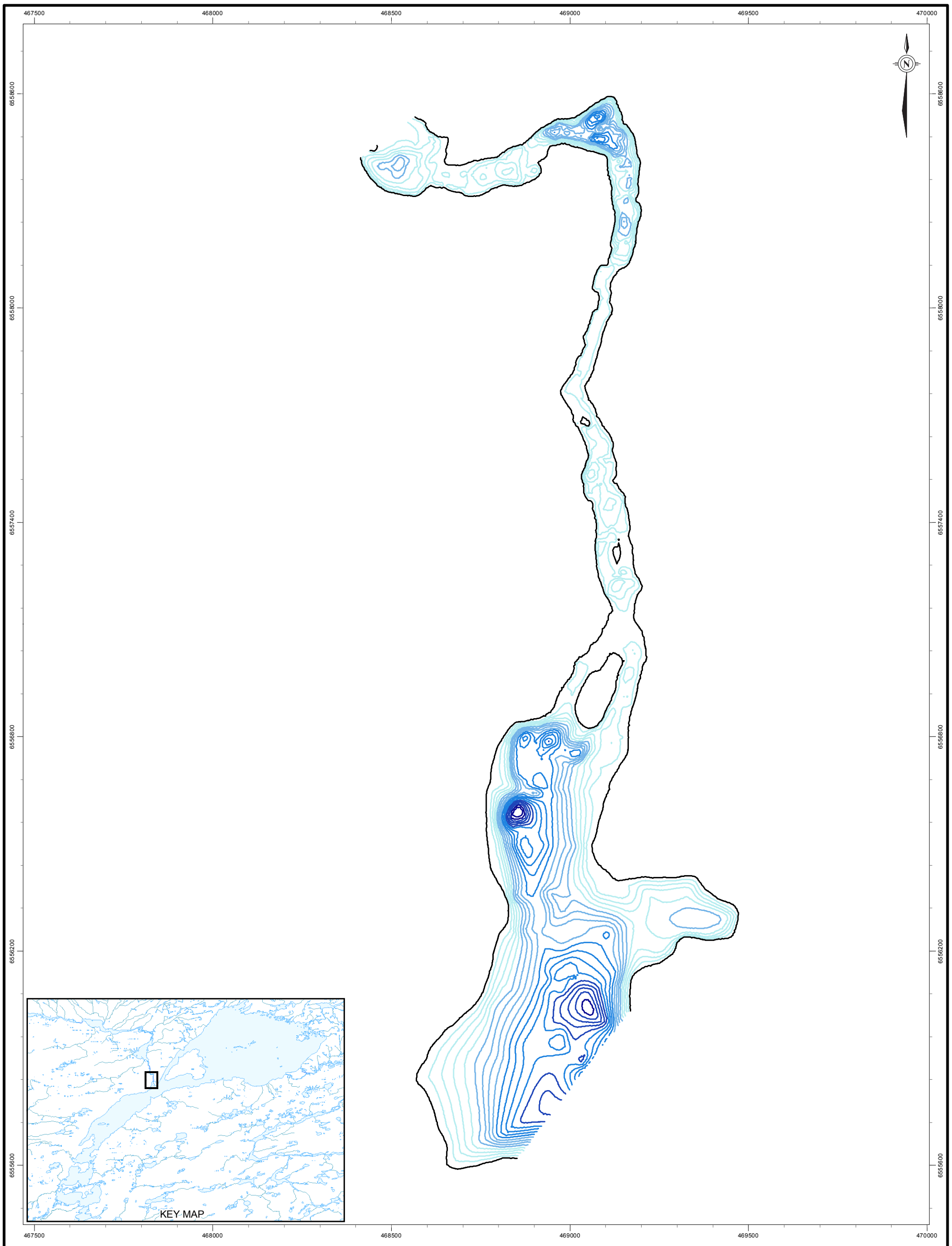
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 50 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 8	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

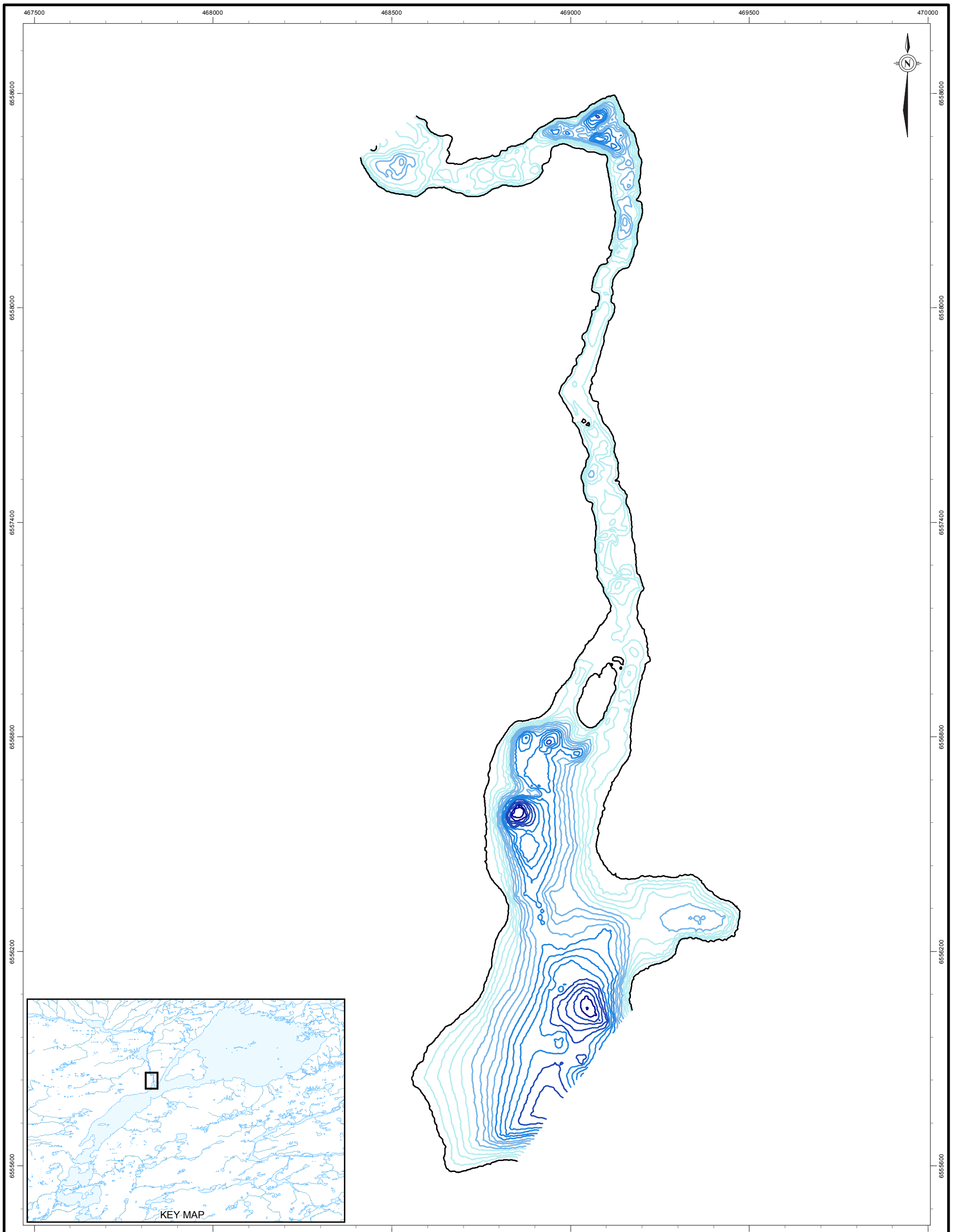
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 112 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 9	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

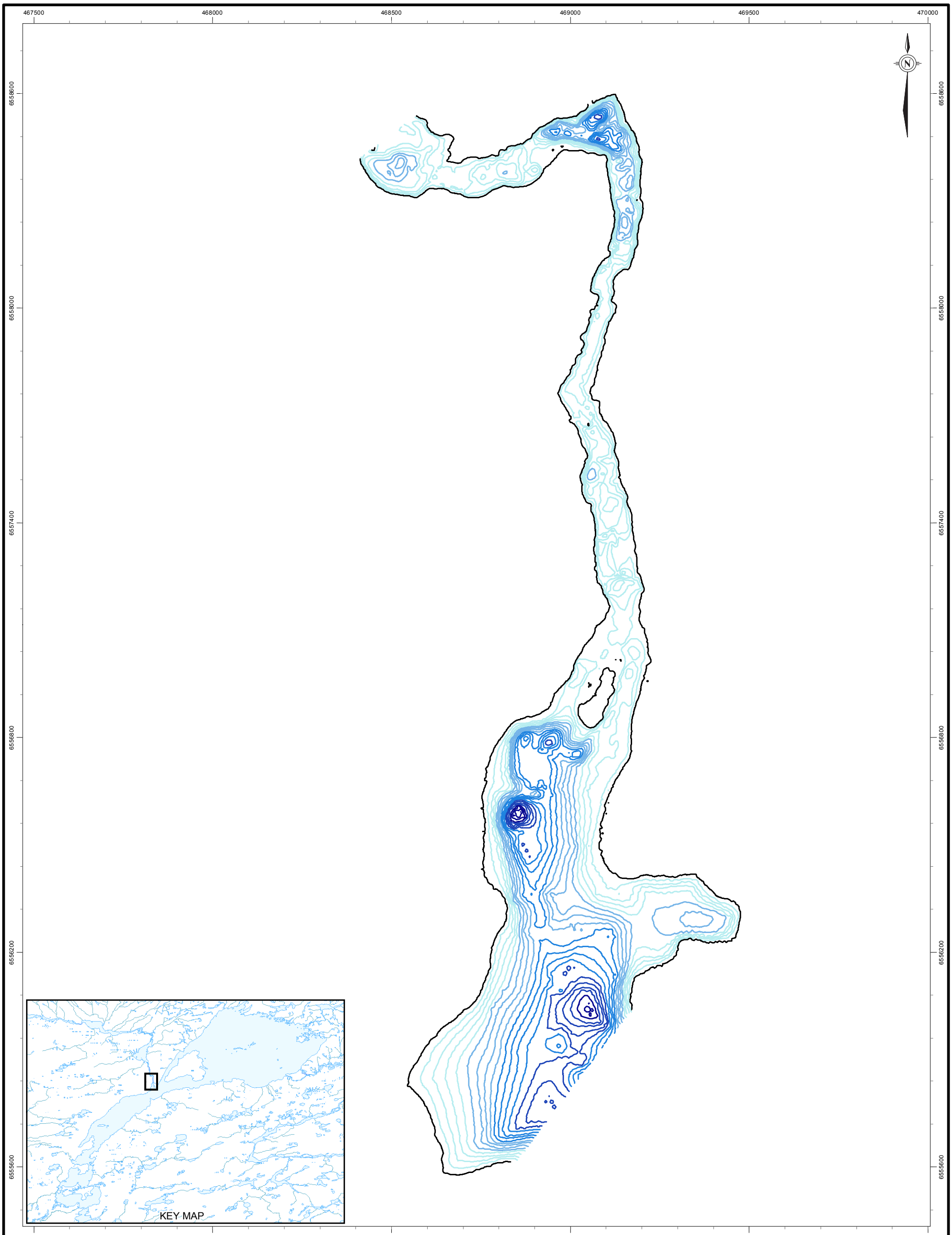
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 210 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 10	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 0 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 20

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

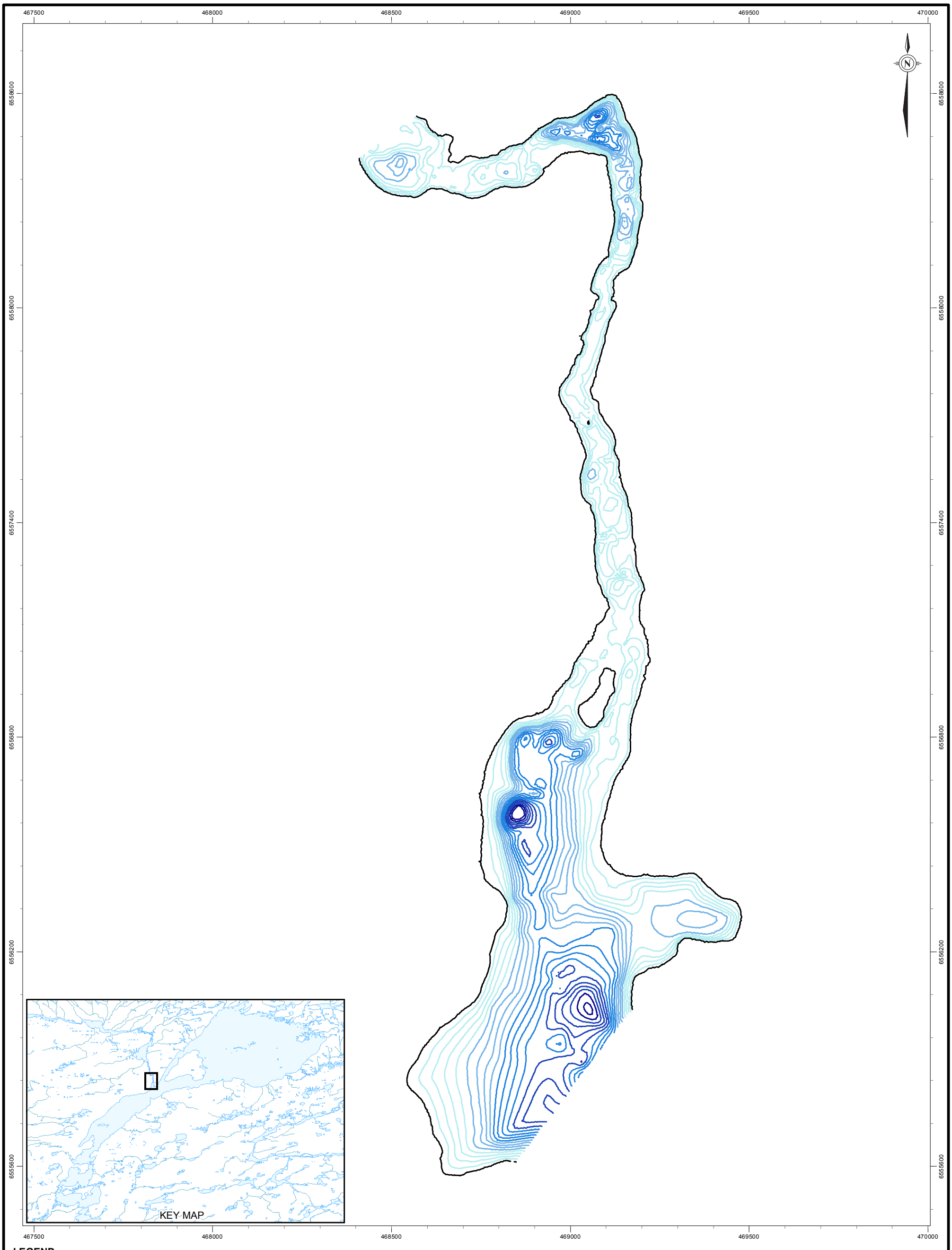
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 302 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 11	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

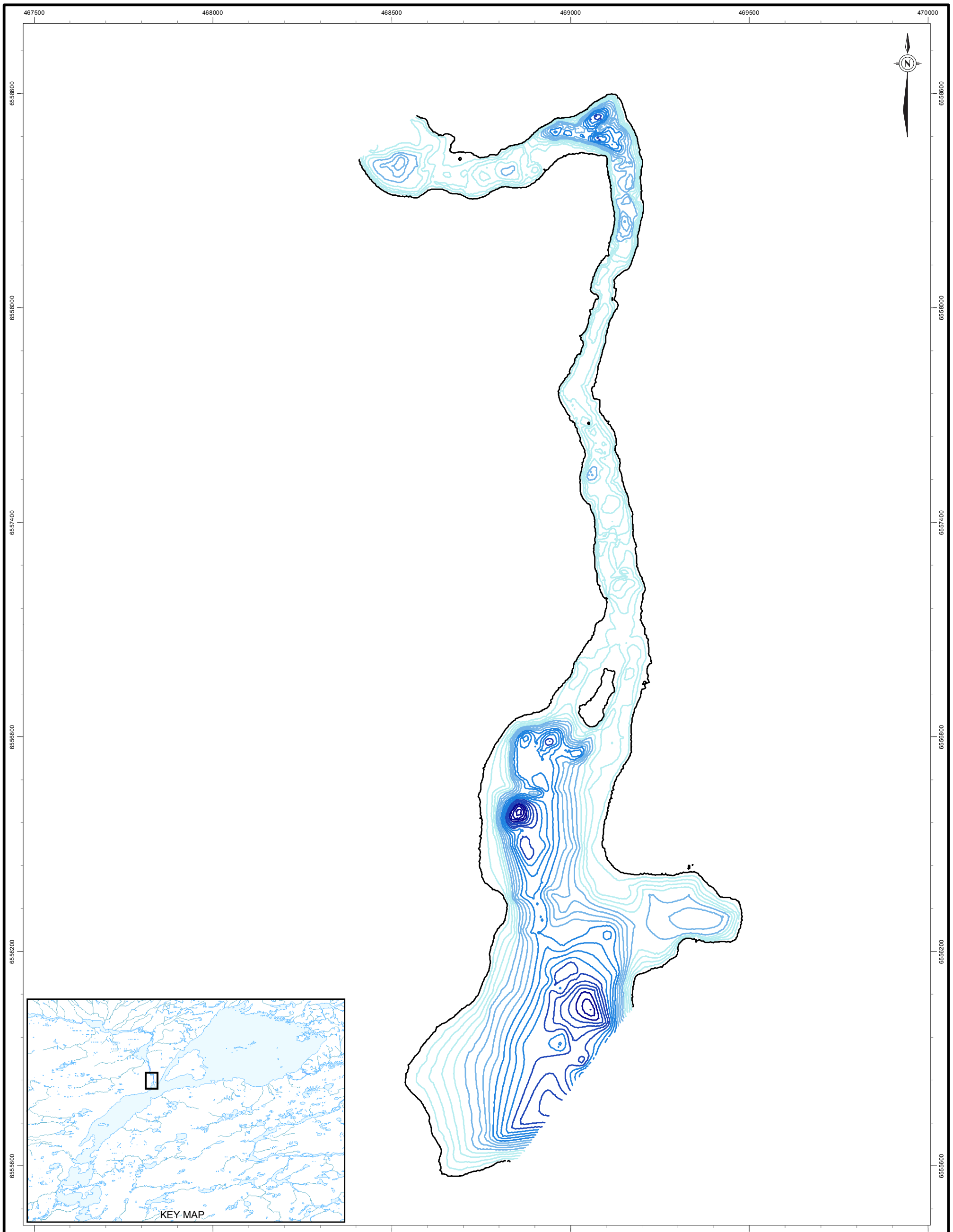
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 320 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 12	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 20

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

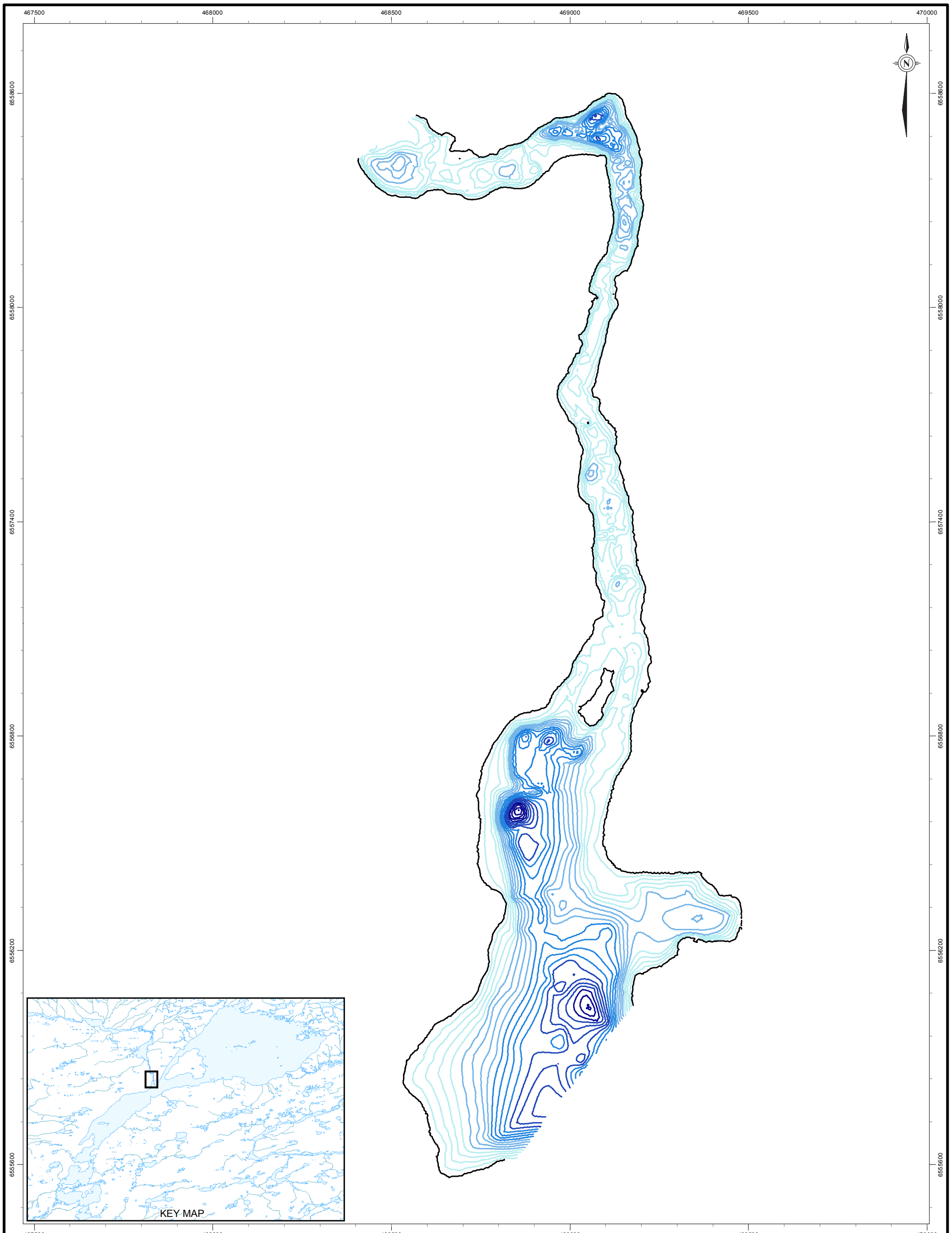
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 400 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 13	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 21

WATER'S EDGE

250 0 250

SCALE 1:10,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

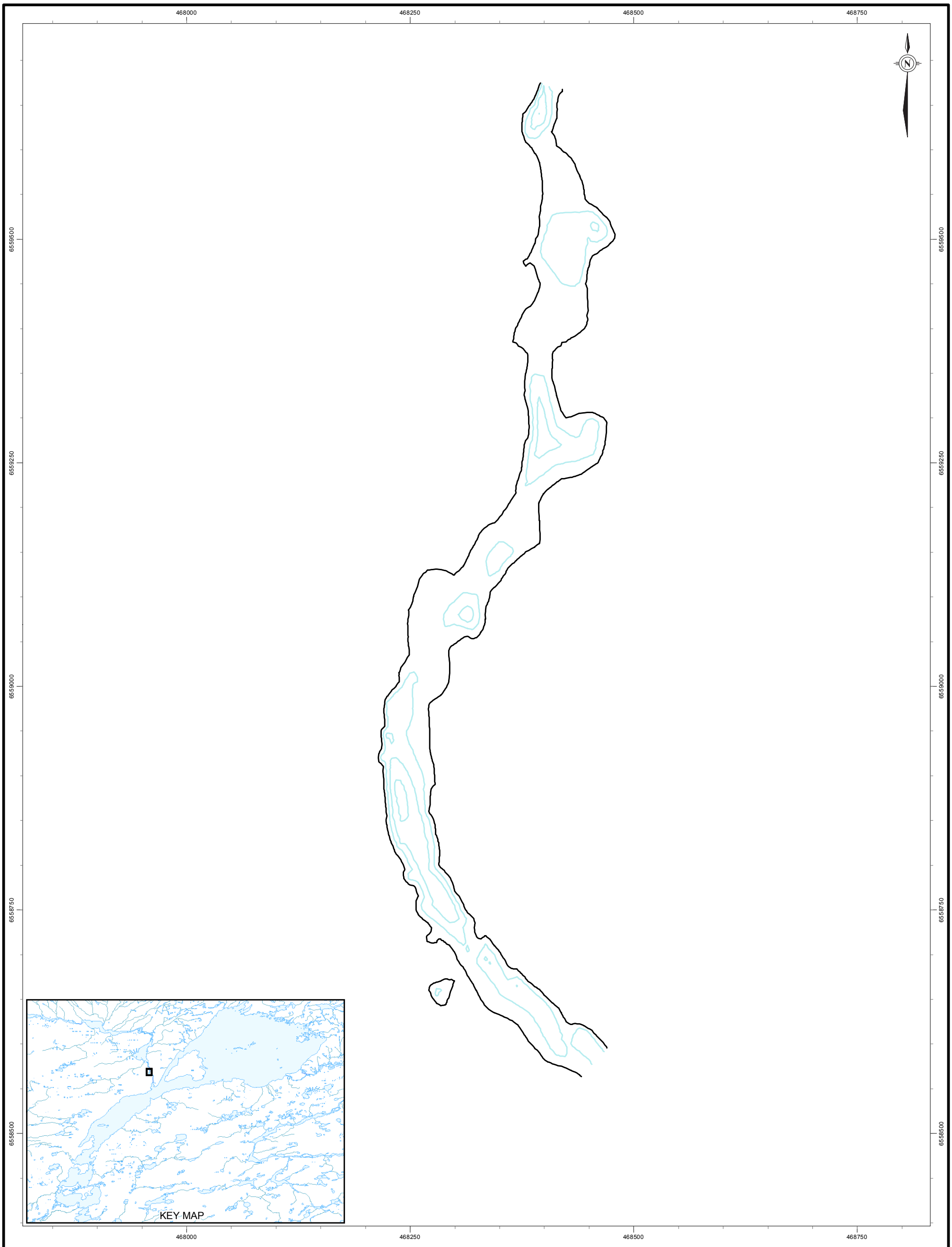
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 510 m^3/s IN SEGMENT 1

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 14	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

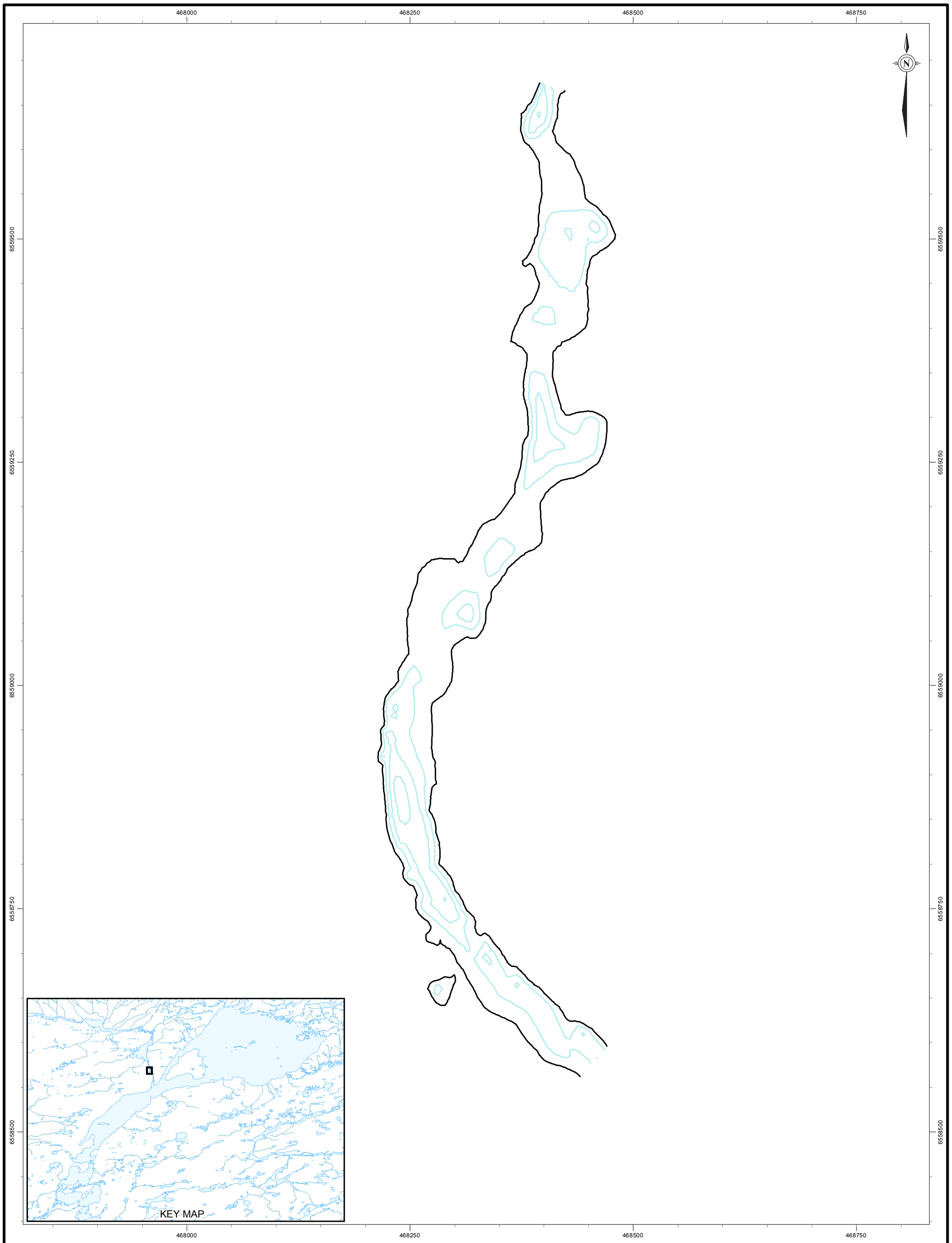
HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 30 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 15	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

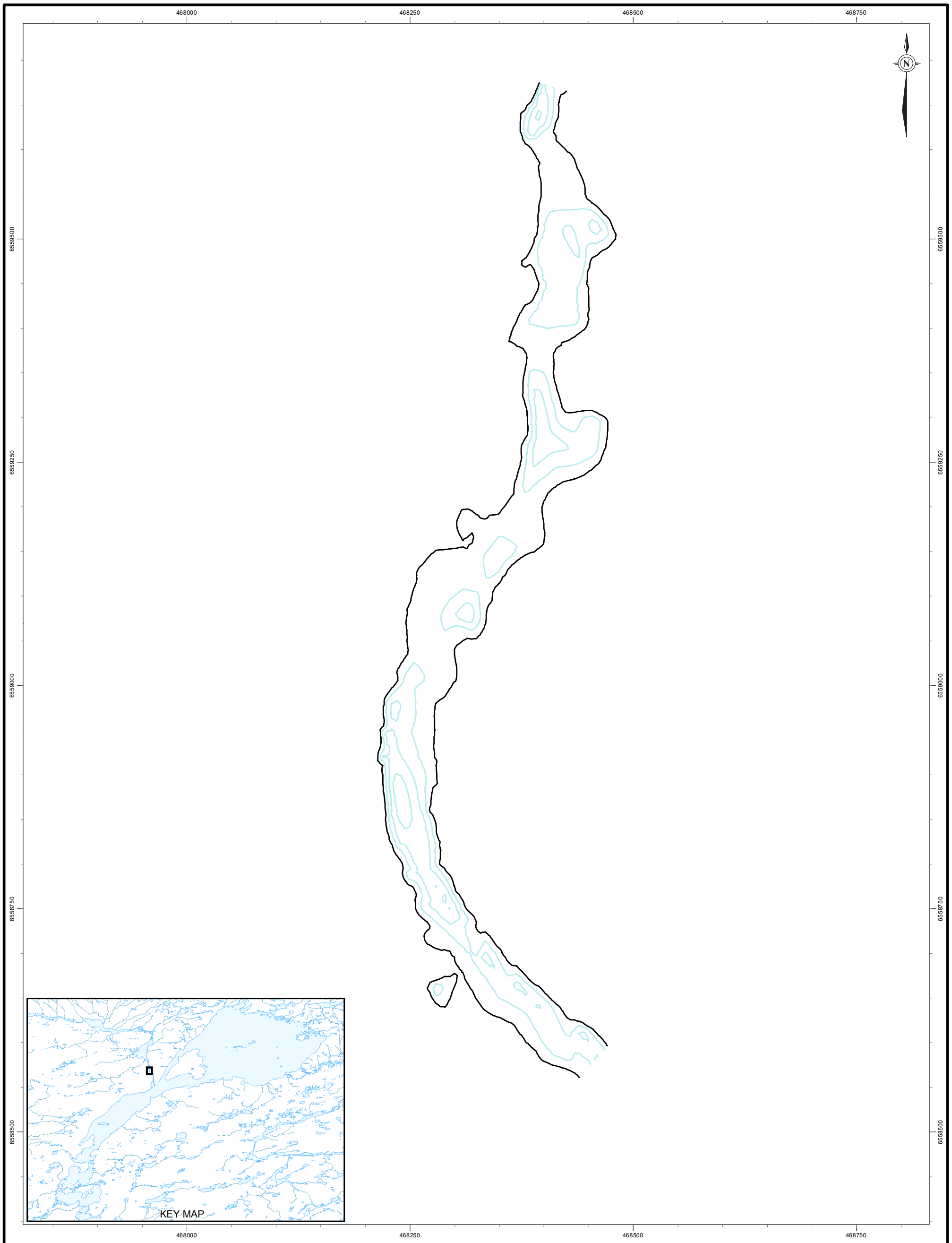
HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 40 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 16	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

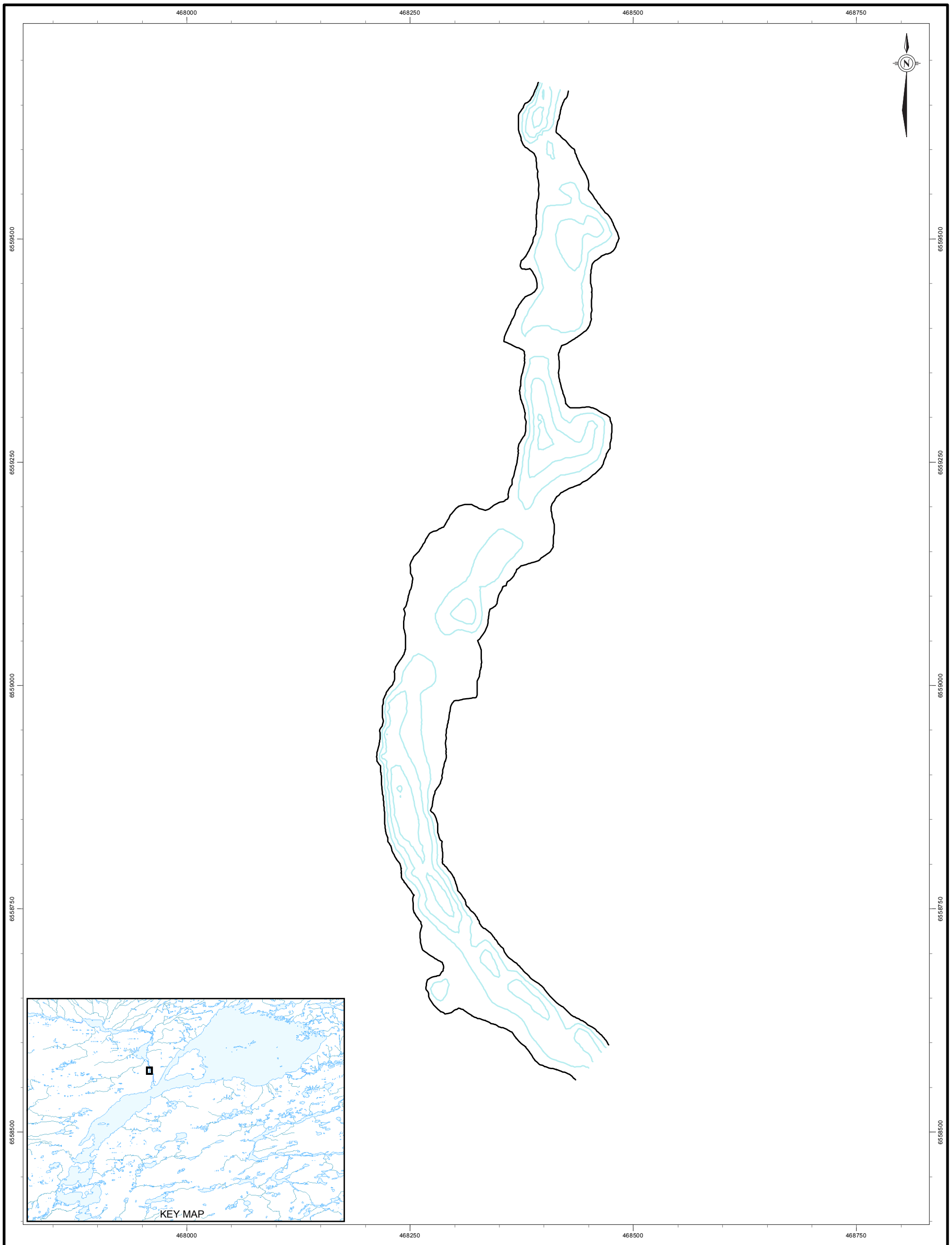
HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 50 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 17	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

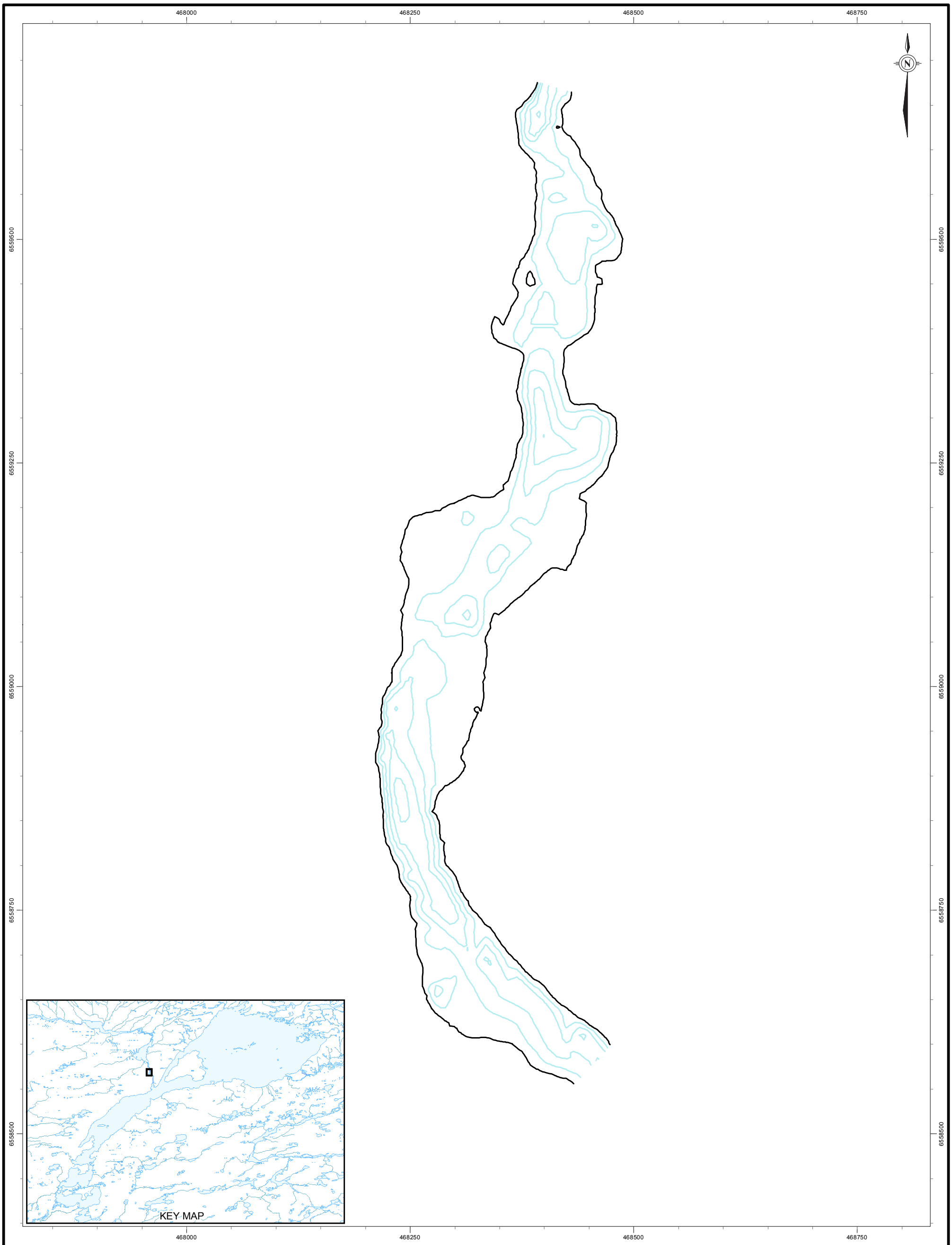
HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 112 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	**FIGURE: 18**	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

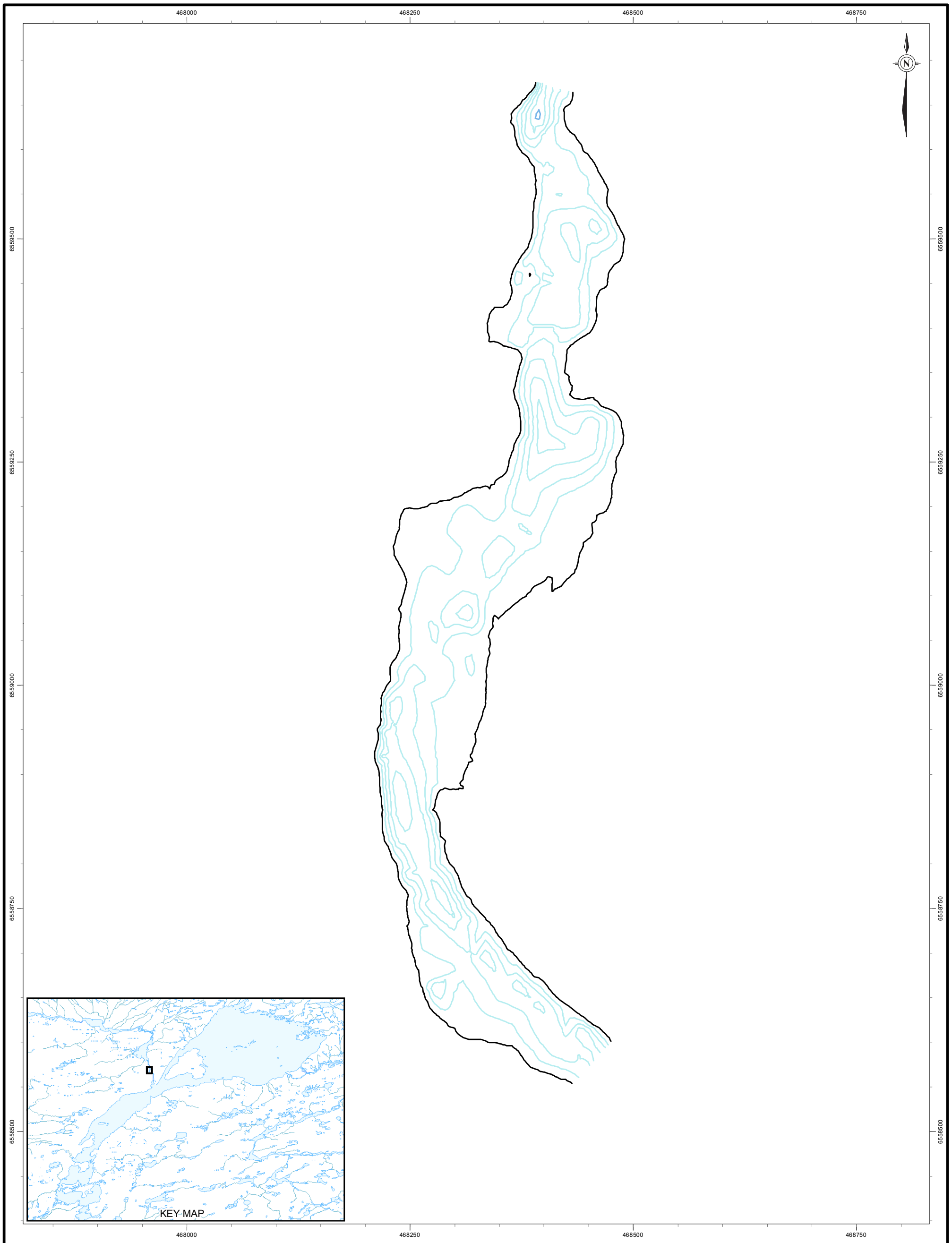
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 210 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 19	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

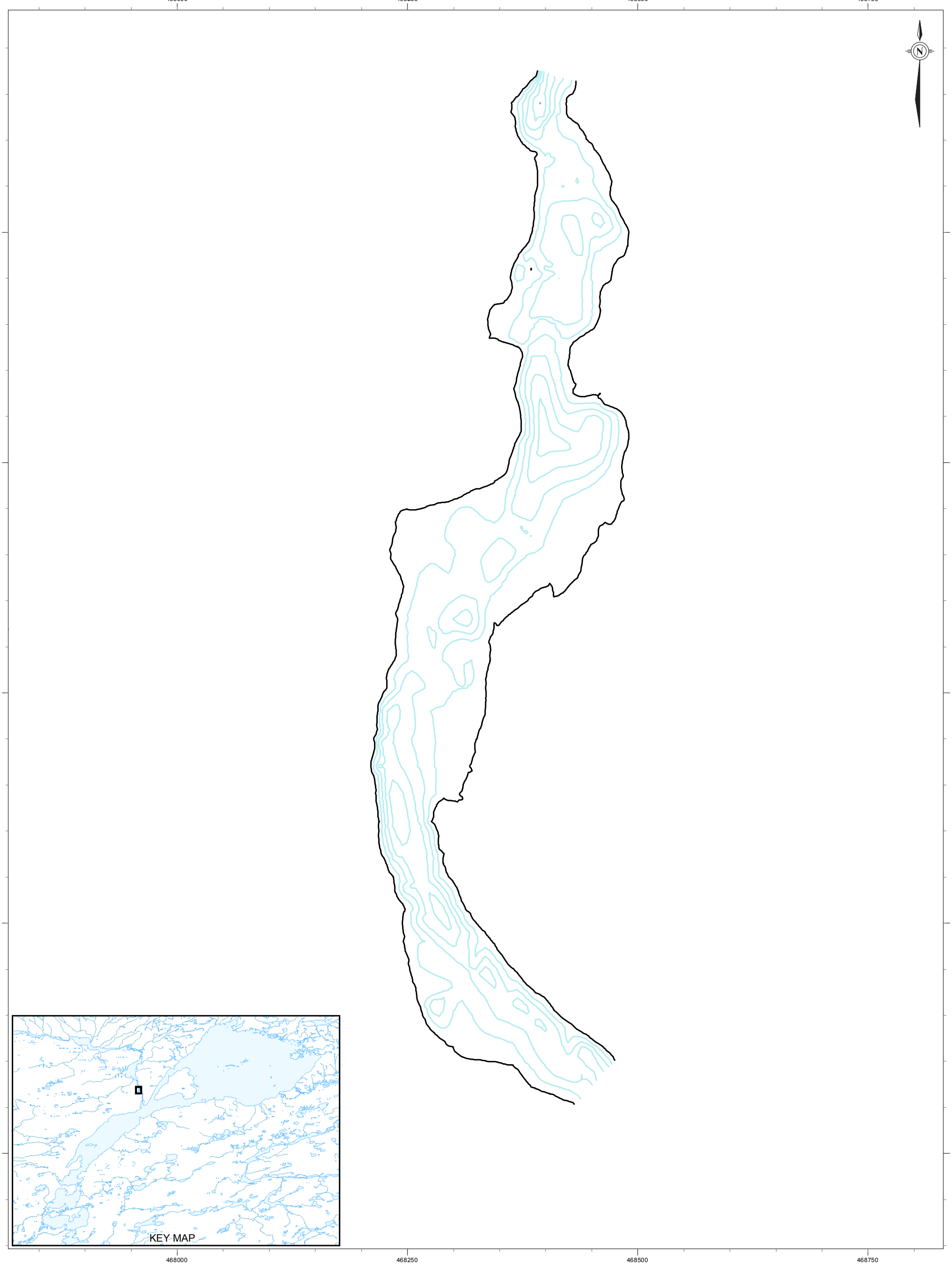
DEPTH FOR 302 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 20	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		

468000 468250 468500 468750

6559500 6559250 6559000 6558750 6558500



KEY MAP

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 320 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 21	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

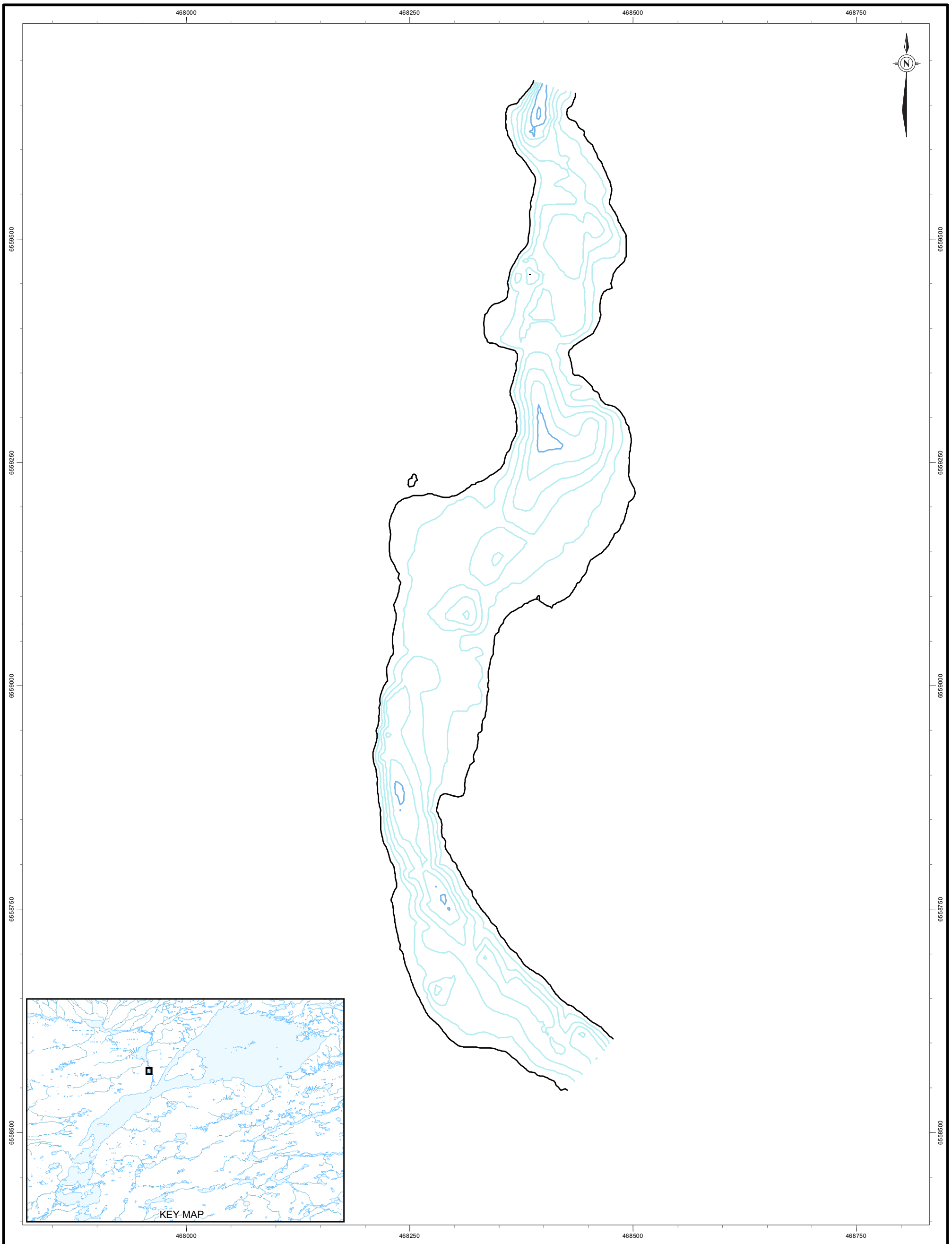
HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 400 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 22	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 510 m^3/s IN SEGMENT 2

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 23	
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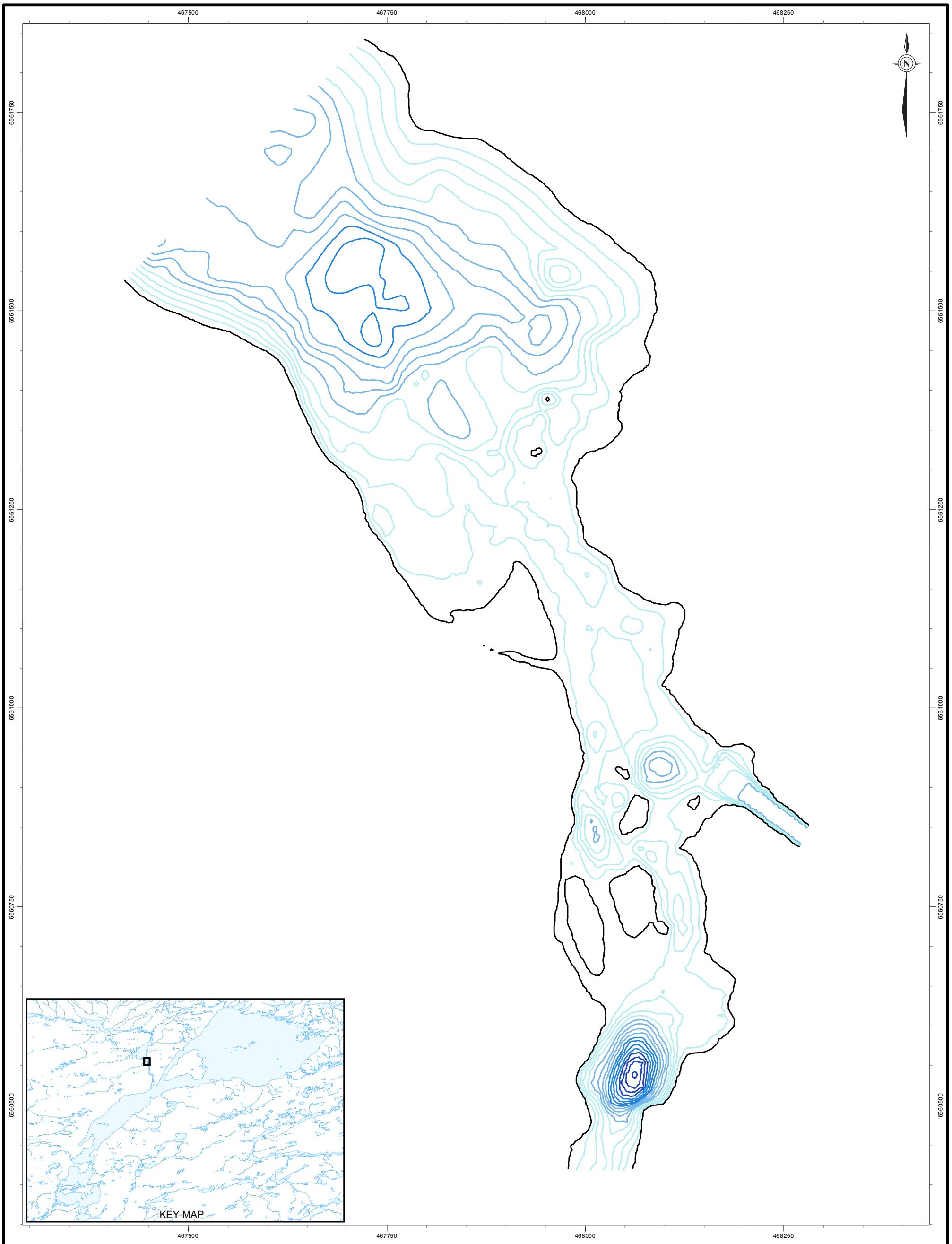

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 210 m^3/s RIPARIAN AND 0 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
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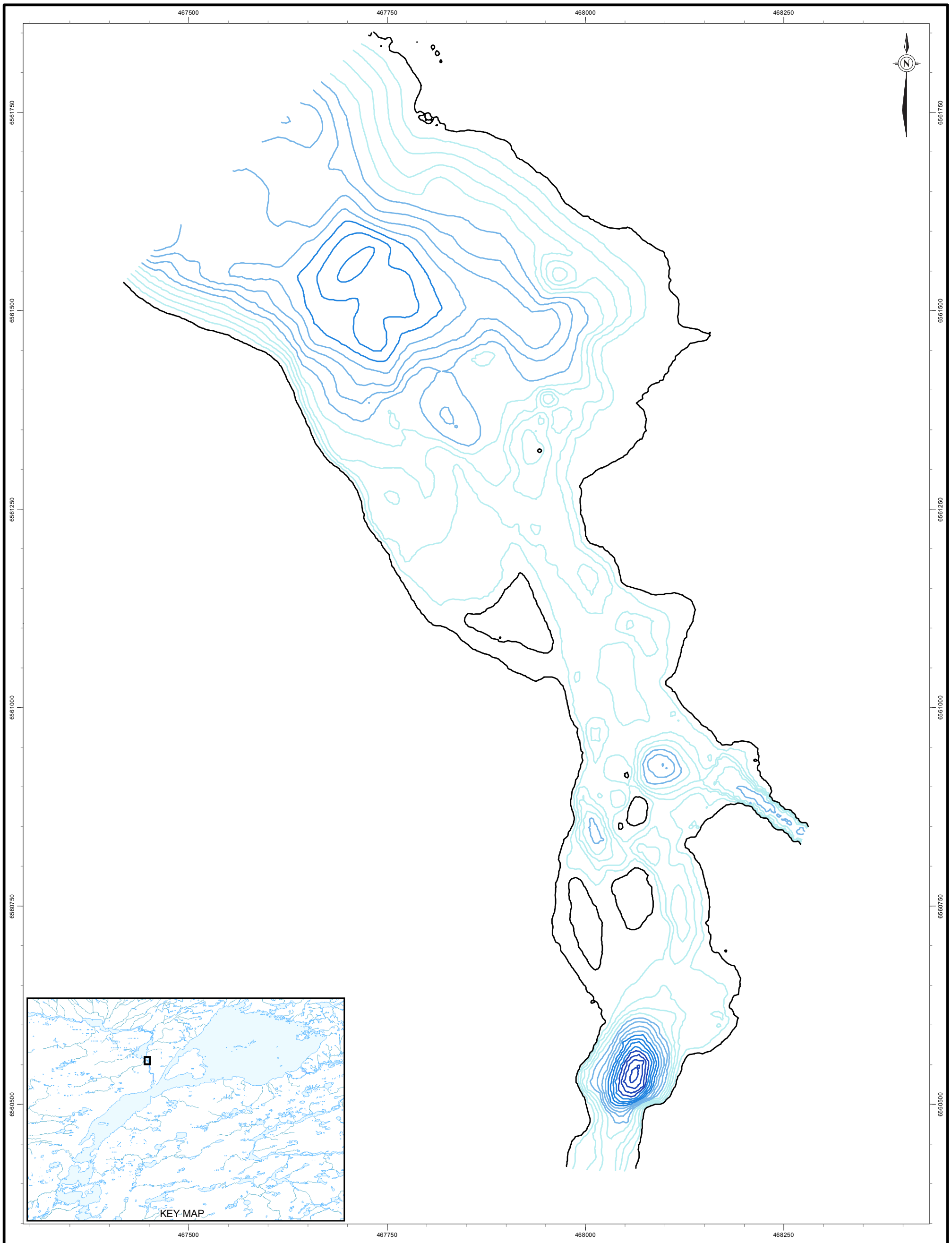

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 302 m^3/s RIPARIAN AND 0 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
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CHECK	AD	15/11/13		
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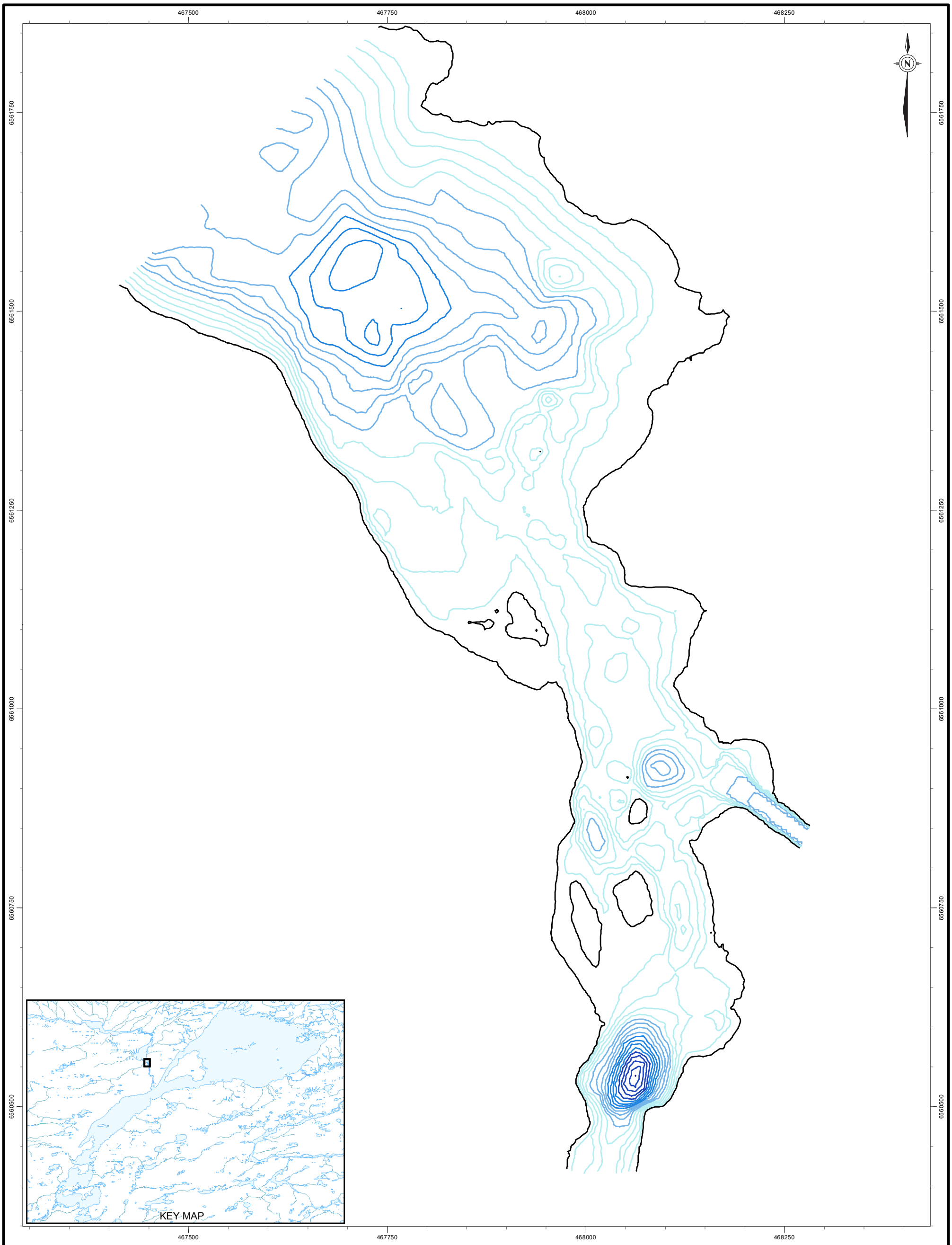

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 400 m^3/s RIPARIAN AND 0 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
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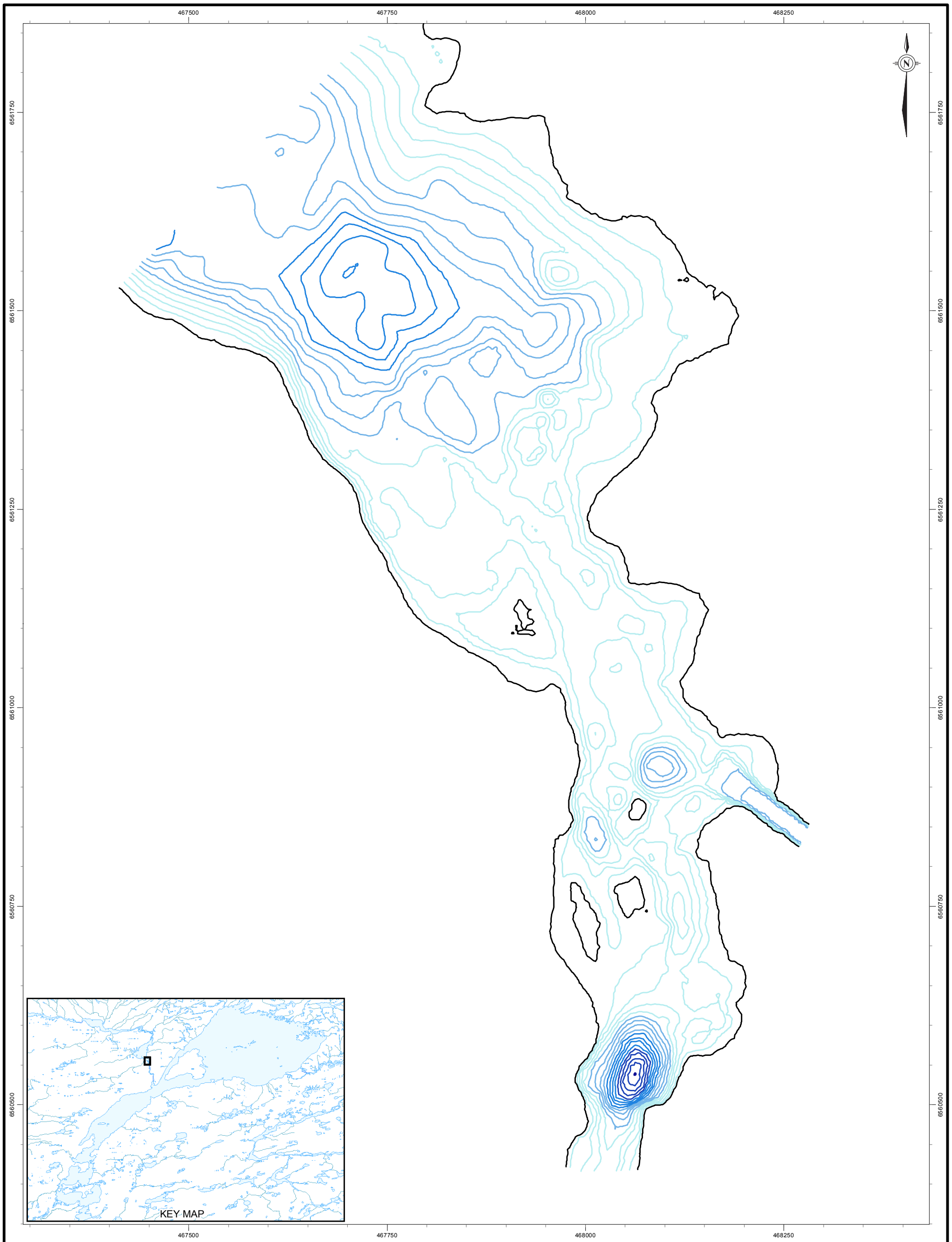

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 510 m^3/s RIPARIAN AND 0 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
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CHECK	AD	15/11/13		
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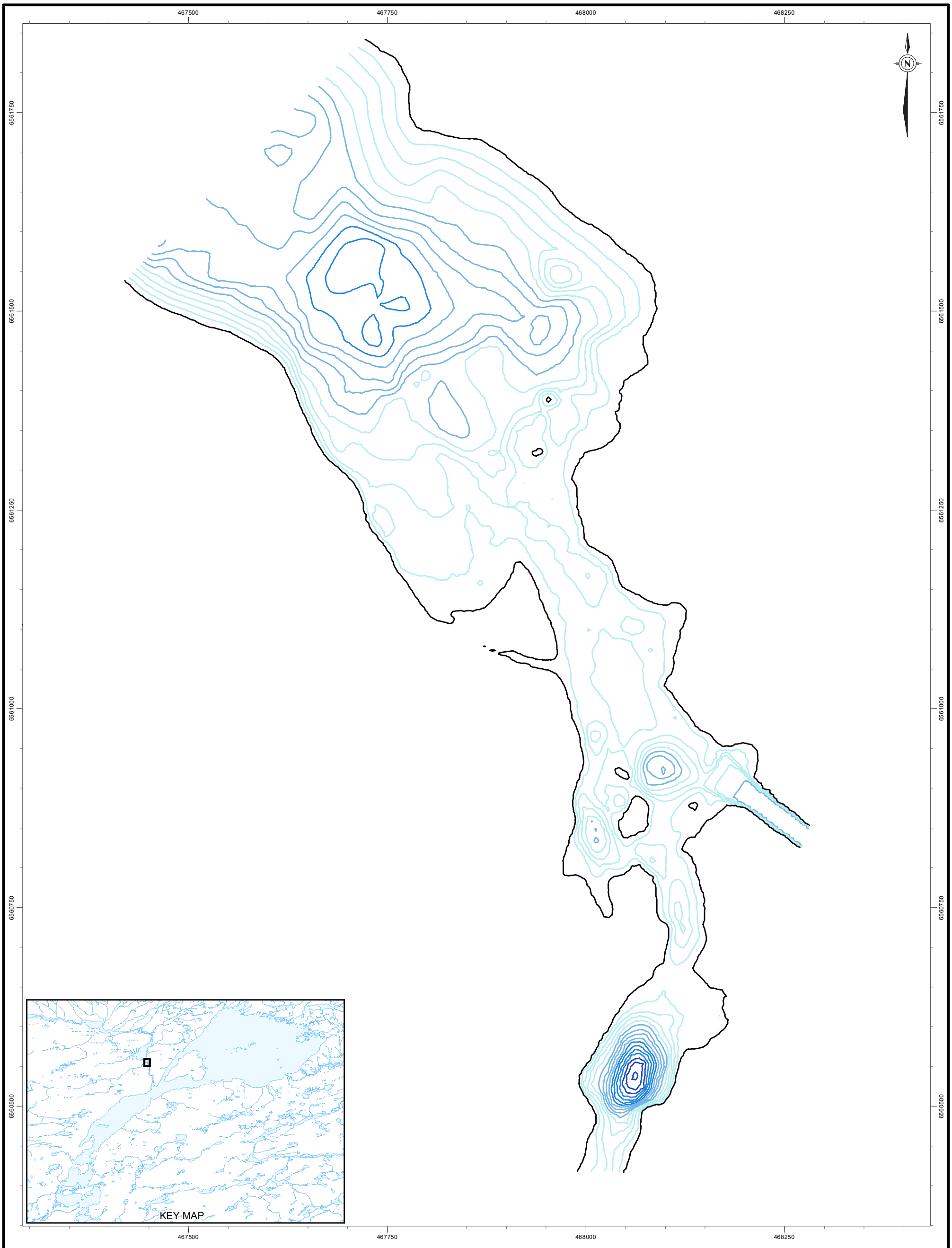

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100

SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 30 m^3/s RIPARIAN AND 190 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
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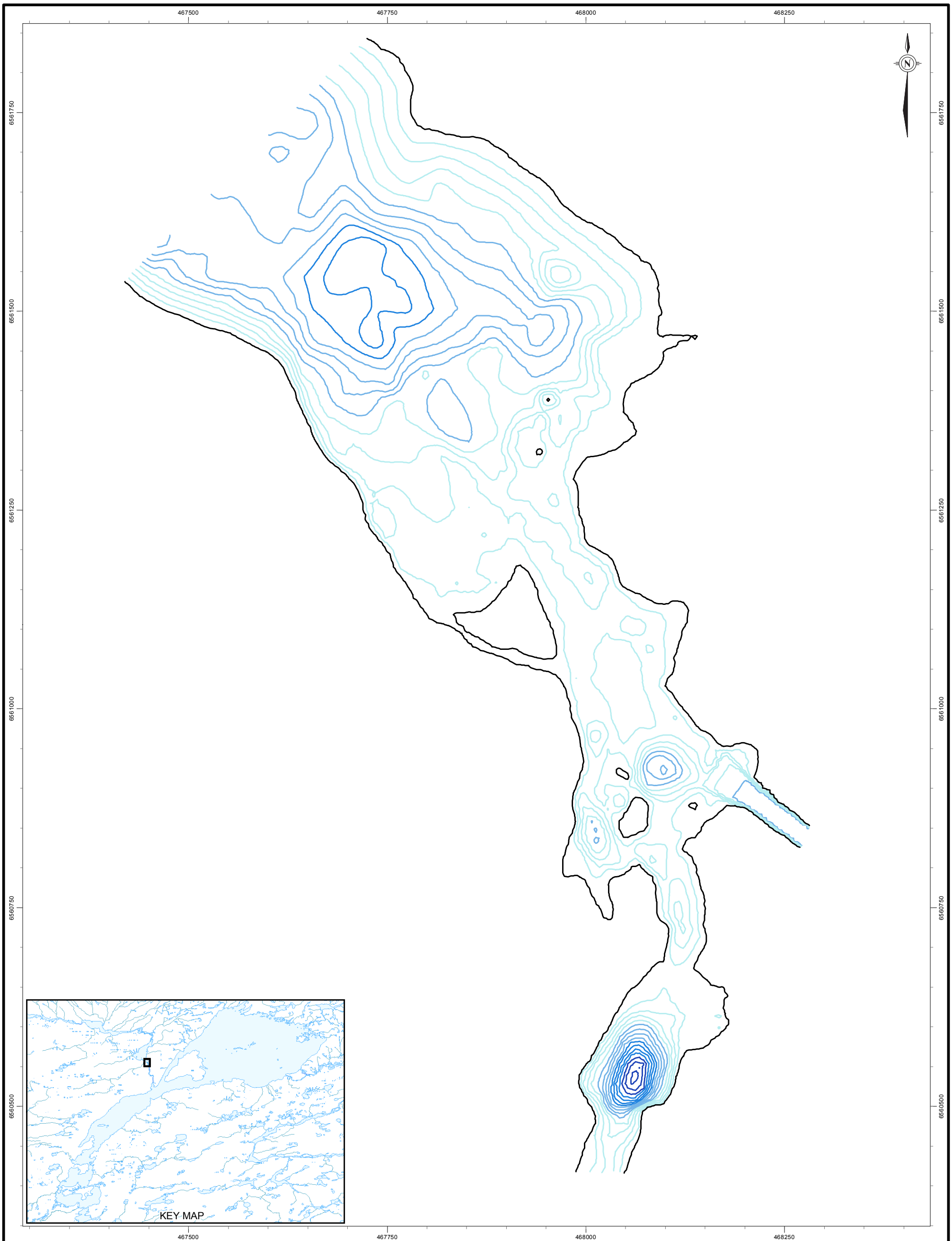

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 40 m^3/s RIPARIAN AND 190 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 29	
CHECK	AD	15/11/13		
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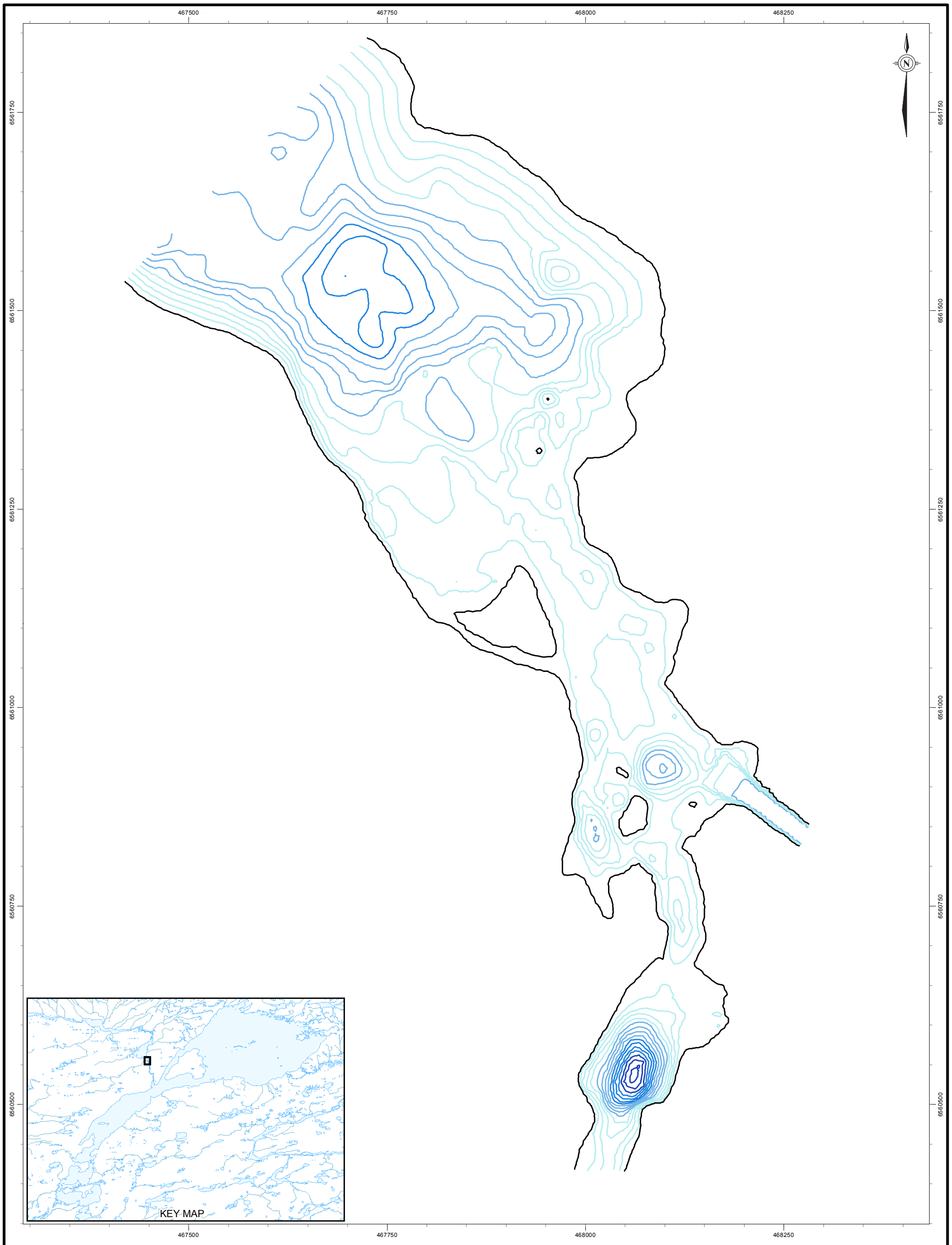

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100

SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 50 m^3/s RIPARIAN AND 190 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 30	
CHECK	AD	15/11/13		
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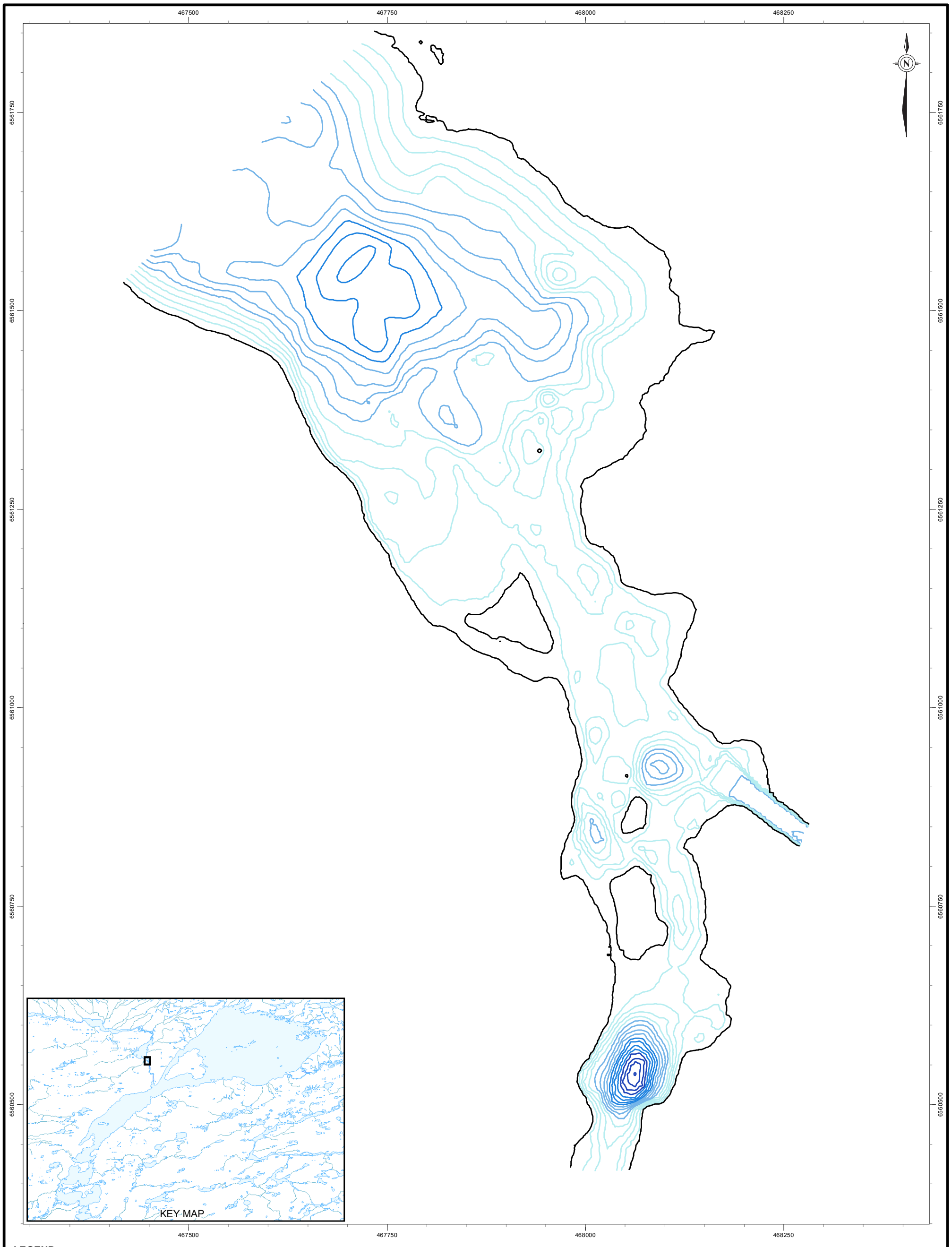

LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100

SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DEPTH FOR 112 m^3/s RIPARIAN AND 190 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
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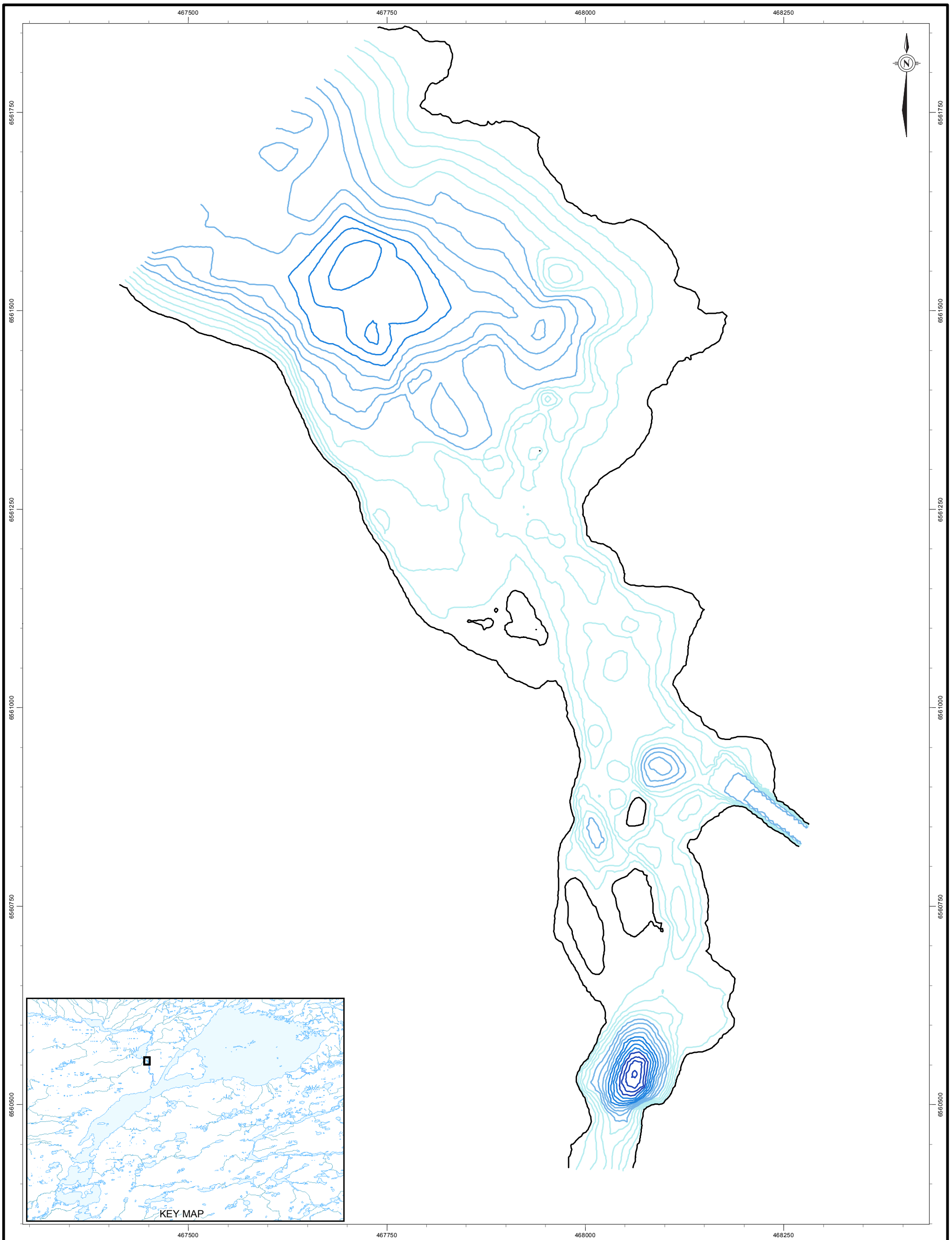


LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,500 METRES

REFERENCE

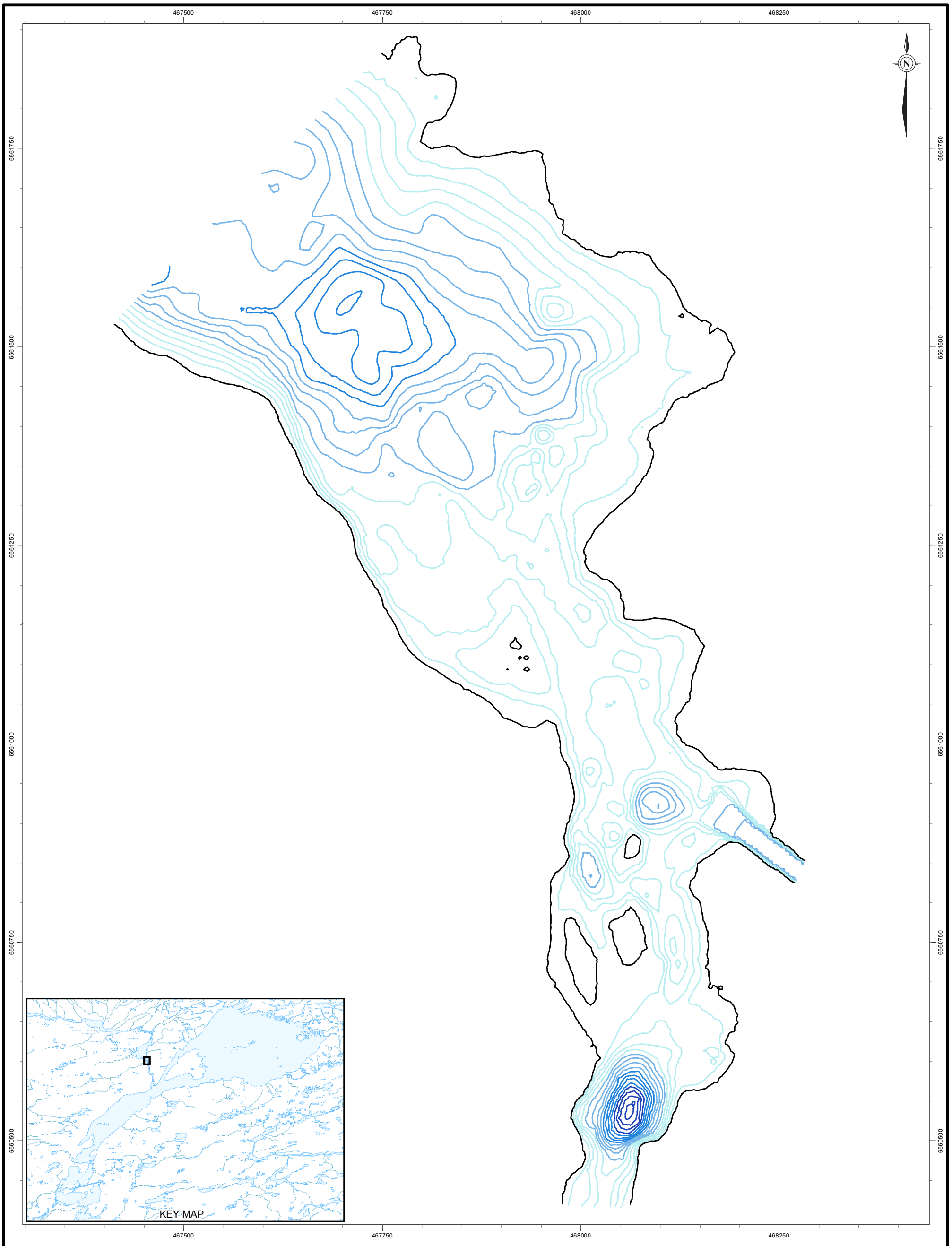
HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 210 m^3/s RIPARIAN AND 190 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 32	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		



LEGEND

WATER DEPTH (m)

- 1 - 4
- 5 - 8
- 9 - 12
- 13 - 16
- 17 - 18

WATER'S EDGE

100 0 100
SCALE 1:4,500 METRES

REFERENCE

HYDROLOGIC DATA © GOLDER, 2013
DATUM: NAD83 PROJECTION: UTM ZONE 13
NTS MAPSHEETS: 73P

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
DEPTH FOR 320 m^3/s RIPARIAN AND 190 m^3/s TAILRACE FLOW IN SEGMENT 3

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/ANK	22/01/14	FIGURE: 33	
CHECK	AD	15/11/13		
REVIEW	BT	15/11/13		

APPENDIX 10.3

Ramping Study

February 2014
Report No. 10-1365-0004/DCN-171

1.0 BACKGROUND

Hydroelectric developments typically have the capability of affecting water levels downstream of the power generation facilities and the rate of water level change is referred to as the ramping rate or ramping. Ramping down the river flow can potentially strand fish in areas of low gradient or in side channels. This Appendix evaluates the effect of ramping on water levels for the purpose of project design and the environmental assessment associated with the proposed Tazi Twé hydroelectric development on the Fond du Lac River between Black Lake and Middle Lake. In particular, this Appendix provides an assessment of potential impacts associated with water level changes in Middle Lake in response to ramping. This analysis focuses on the predicted rate for the short-term lake level changes due to the ramping flow transitions and compares the results to generally accepted criteria which are likely to protect fish in Middle Lake from becoming stranded when ramping occurs. While there are no specific regulatory guidelines, it is believed that a maximum water level reduction rate of 5 to 10 centimetres (cm) per hour would protect fish in Middle Lake from being stranded when water levels recede.

2.0 SCOPE

The scope of this assessment is to evaluate the Middle Lake drawdown rate following flow decreases in the Fond du Lac River immediately upstream of the lake. Specifically, the assessment considers a range of drawdown scenarios which could occur when inflow to the powerplant ceases under operational conditions such as damaged powerlines or transformers.

For assessment purposes, total discharges to Middle Lake via the Fond du Lac River are considered to range from 200 to 400 cubic metres per second (m^3/s). From this total discharge, the powerplant is assumed to contribute 190 m^3/s for a river discharge equal to or exceeding 250 m^3/s and 150 m^3/s for a river discharge of 200 m^3/s. Four by-pass flow scenarios following an outage were selected for the analysis. Table 1 summarizes the combinations of river and plant discharges and the four by-pass scenarios.

Table 1: Discharges and By-pass Scenarios for the Middle Lake Drawdown Analysis

Discharge (m^3/s)			By-pass Discharge in % of Powerplant Design Discharge			
Total	**River**	**Powerplant**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
400	210	190	0	30	50	70
350	160	190	0	30	50	70
300	110	190	0	30	50	70
250	60	190	0	30	50	70
200	50	150	0	30	50	70

m^3/s = cubic metres per second; % = percentage

3.0 METHOD

To estimate the drawdown rate at Middle Lake, it is assumed that after the powerplant is shutdown, the discharge to Middle Lake will be decreased by the amount equal to the powerplant discharge minus the discharge by-pass, (i.e., during the drawdown period, any effects from the resulting water level rise-up that would follow in Black lake are ignored. This is an acceptable assumption due to Black Lake's size).

A mass continuity equation is used to estimate the drawdown rate for Middle Lake to change from the steady state condition prior to the powerplant outage to the new steady state condition after the outage. After the bypass condition is initiated, the decrease in discharge will result in a decrease in Middle Lake surface water level. The rationale is that immediately after the outage and until the new steady state condition is reached, the water volume moving downstream of Middle Lake in a period of time (∂t) is equal to the water volume that remains entering the lake from upstream, plus the water volume that the lake loses when the surface elevation drops (∂h), (i.e., in a time ∂t the level in the lake falls ∂h). This can be expressed using the following equation:

$$Q_o * \partial t = A * \partial h + Q_i * \partial t \quad or \quad (Q_o - Q_i) * \partial t = A * \partial h$$

Where Q_o (m³/s) represents the discharge from Middle Lake; Q_i (m³/s) represents the remaining discharge to Middle Lake after the outage; A (square metres [m²]) represents the Middle Lake water surface at the elevation where the level decreases ∂h; ∂t is expressed in seconds and ∂h in metres. Consequently, following this expression, the time for water levels to decrease from the initial elevation h_1 to the final elevation h_2 can be estimated as:

$$T = \int_{h_1}^{h_2} \frac{A[h]}{Q[h]} * \partial h$$

Where T is time (sec), A[h] (m²) is the Middle Lake water surface area as a function of h (m) and Q[h] (m³/s) is the discharge from Middle Lake minus the remaining inflow discharge to Middle Lake as a function of h (m).

The estimated stage-discharge rating for Middle Lake outlet was developed and is as follows:

$$Q_o = 9.25\, h^{2.68} \quad and \quad h = H - 237.2$$

Where Q_o is the Middle Lake discharge in m³/s; *H* is the Middle Lake water elevation in metres above mean sea level. This expression is valid for H larger than or equal to 237.2 metres above sea level (masl). Consequently

$$Q[h] = (9.25\, h^{2.68} - Q_i) \quad and \quad h = H - 237.2$$

Q_i , the remaining inflow discharge to Middle Lake, is known and assumed constant. The equation for estimating the time has physical meaning while $Q_o \geq Q_i$; when $Q_o = Q_i$ the steady state is reached.

The estimated water surface area for Middle Lake is developed based on the lake bathymetry and can be expressed using the following expression:

$$A = 1 * 10^6 * h + 3 * 10^6 \quad and \quad h = H - 237.2$$

Where A is the Middle Lake water surface area in m²; *H* is the Middle Lake water elevation in metres above mean sea level. This expression is valid for 237.25 masl ≤ H ≤ 241.28 masl.

Finally, by using these functions, the time for the level to fall from the elevation h_1 to the elevation h_2 can be estimated numerically evaluating the expression that follows:

$$T = \sum_{i=h_1}^{h_2} \left(\frac{10^6 * \left(\frac{h_i + h_{i+1}}{2}\right) + 3 * 10^6}{9.25 * \left(\frac{h_i + h_{i+1}}{2}\right)^{2.68} - Q_i} \right) * (h_i - h_{i+1})$$

Where T is in seconds and h is metres and Q_i (m³/s) represents the remaining discharge to the Middle Lake after the outage. The expression above solves the integral equations when $(h_i - h_{i+1})$ tends to zero.

4.0 RESULTS

The equation for time (T) is solved following a discretization such as $(h_i - h_{i+1}) = 0.01\ m$ and the drawdown rate in Middle Lake is calculated for the adjusted discharges according to each by-pass scenarios following an outage as shown in Table 1.

Detailed results for water levels and discharges to Middle Lake before and after the powerplant shutdown for an initial discharge of 400, 350, 300, 250, and 200 m³/s for each by-pass scenario are presented in Table 2; the predicted drawdown rate for each by-pass scenario and flow rate are presented in Figure 1 to Figure 5. As expected the maximum drawdown rates occurs for zero flow by-pass. Results indicate that under all scenarios, total drawdown will remain below 1.41 metres (m) and maximum drawdown rate will remain below 10.59 centimetres per hour (cm/hr).

Table 2: Discharges and By-pass Scenarios for the Middle Lake Drawdown Analysis

Initial Discharge (m^3/s)	By-Pass Scenario	Conditions Before Powerplant Shutdown		Conditions After Powerplant Shutdown			
		Flow input (m³/s)	Water level (masl)	Flow input (m³/s)	Water level (m ASL)	Total drawdown (m)	Maximum Drawdown rate (cm/hr)
400	0%	400	241.28	210	240.41	0.87	9.63
	30%	400	241.28	267	240.71	0.57	6.73
	50%	400	241.28	305	240.89	0.39	4.80
	70%	400	241.28	343	241.05	0.23	2.86
350	0%	350	241.08	160	240.1	0.98	9.89
	30%	350	241.08	217	240.45	0.63	6.91
	50%	350	241.08	255	240.65	0.43	4.92
	70%	350	241.08	293	240.83	0.25	2.93
300	0%	300	240.87	110	239.72	1.15	10.29
	30%	300	240.87	167	240.14	0.73	7.21
	50%	300	240.87	205	240.38	0.49	5.16
	70%	300	240.87	243	240.59	0.28	3.11
250	0%	250	240.62	60	239.21	1.41	10.59
	30%	250	240.62	117	239.78	0.84	7.39
	50%	250	240.62	155	240.06	0.56	5.26
	70%	250	240.62	193	240.31	0.31	3.12
200	0%	200	240.35	50	239.08	1.27	8.75
	30%	200	240.35	95	239.58	0.77	6.12
	50%	200	240.35	125	239.84	0.51	4.36
	70%	200	240.35	155	240.06	0.29	2.60

m³/s = cubic metres per second; % = percentage; m ASL = metres above sea level; cm/hr = centimetres per hour

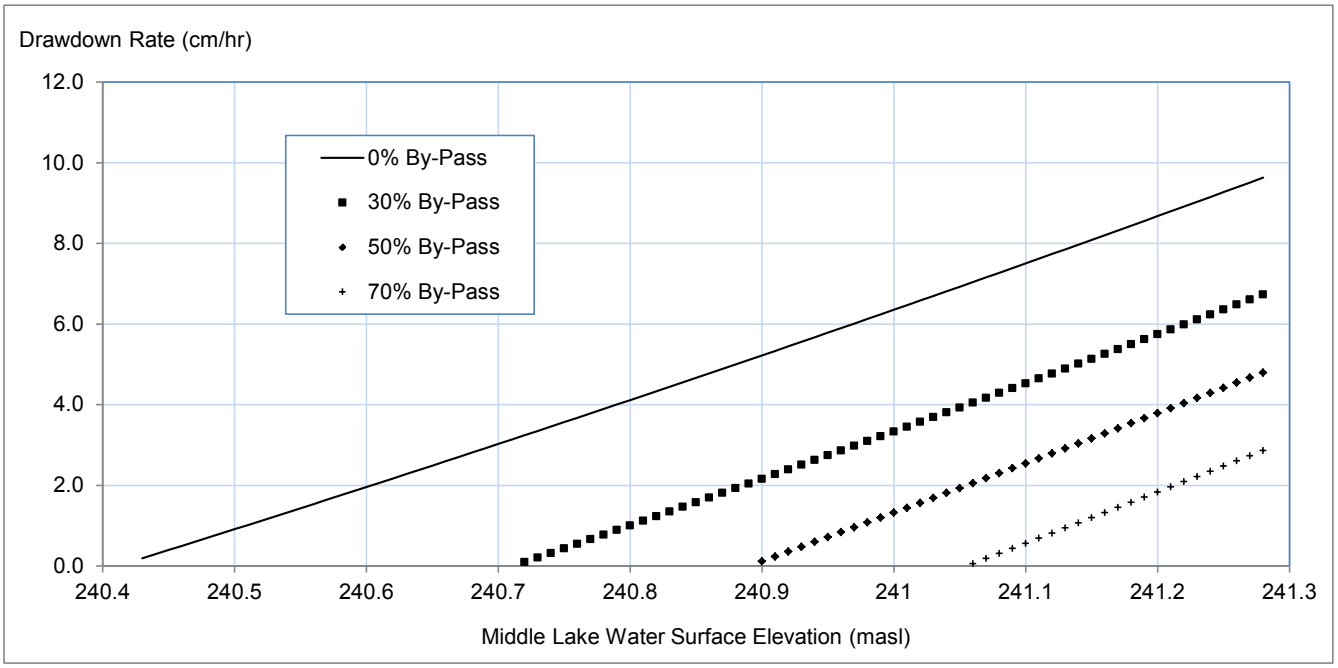


Figure 1: Drawdown rate for an initial discharge condition of 400 m³/s

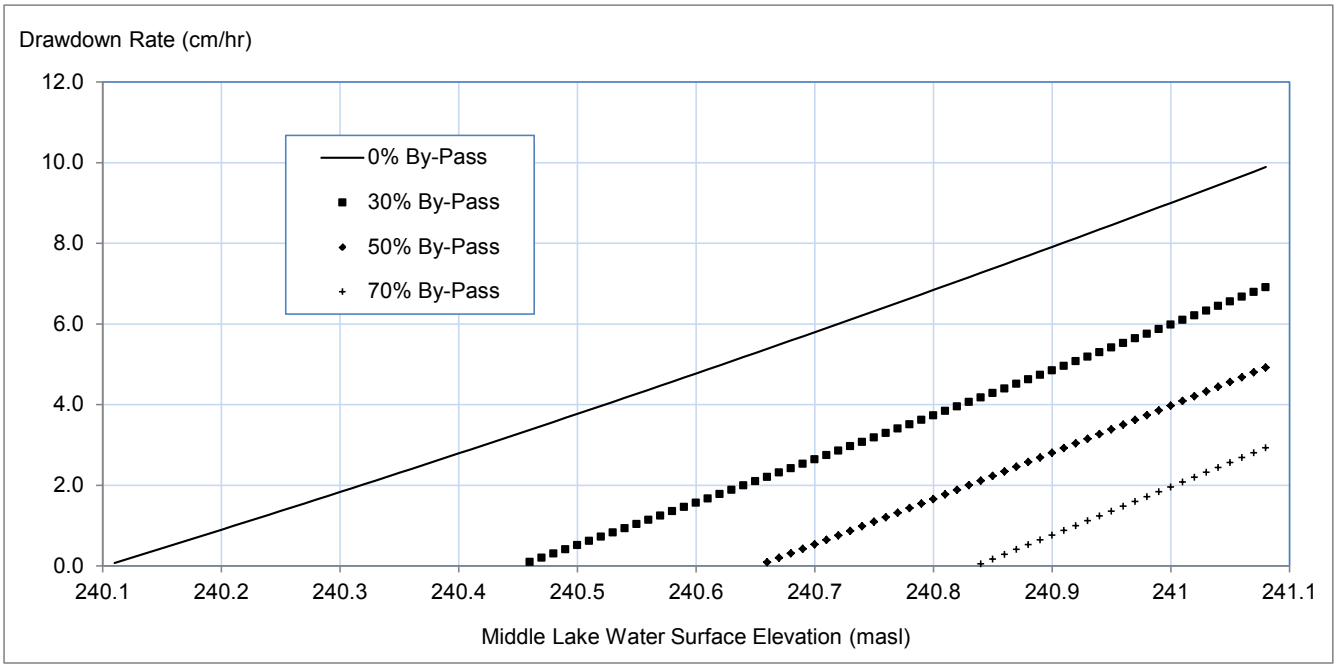


Figure 2: Drawdown rate for an initial discharge condition of 350 m³/s

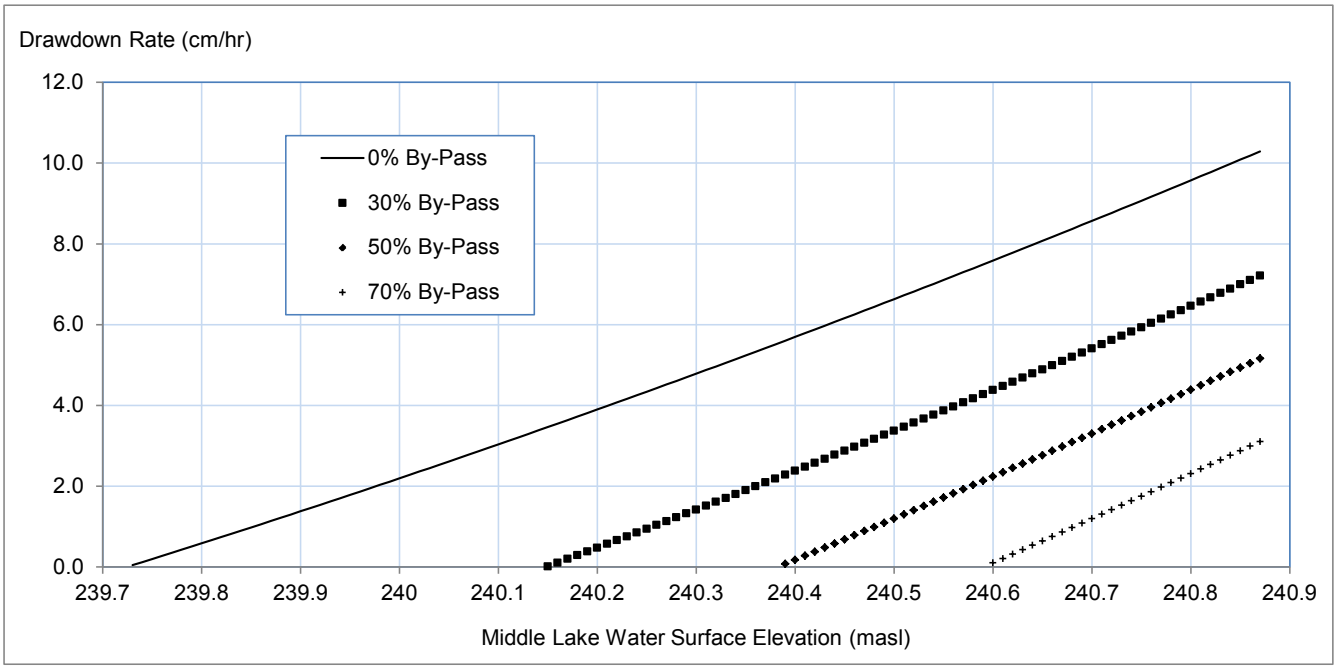


Figure 3: Drawdown rate for an initial discharge condition of 300 m³/s

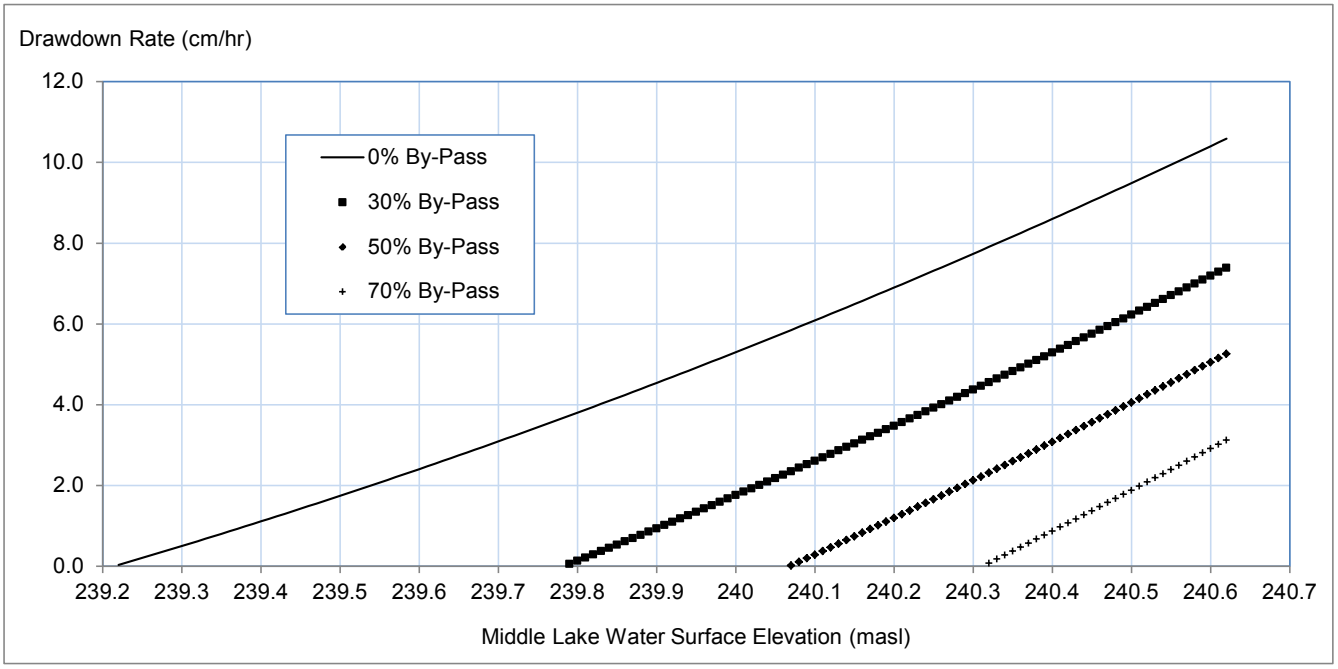


Figure 4: Drawdown rate for an initial discharge condition of 250 m³/s

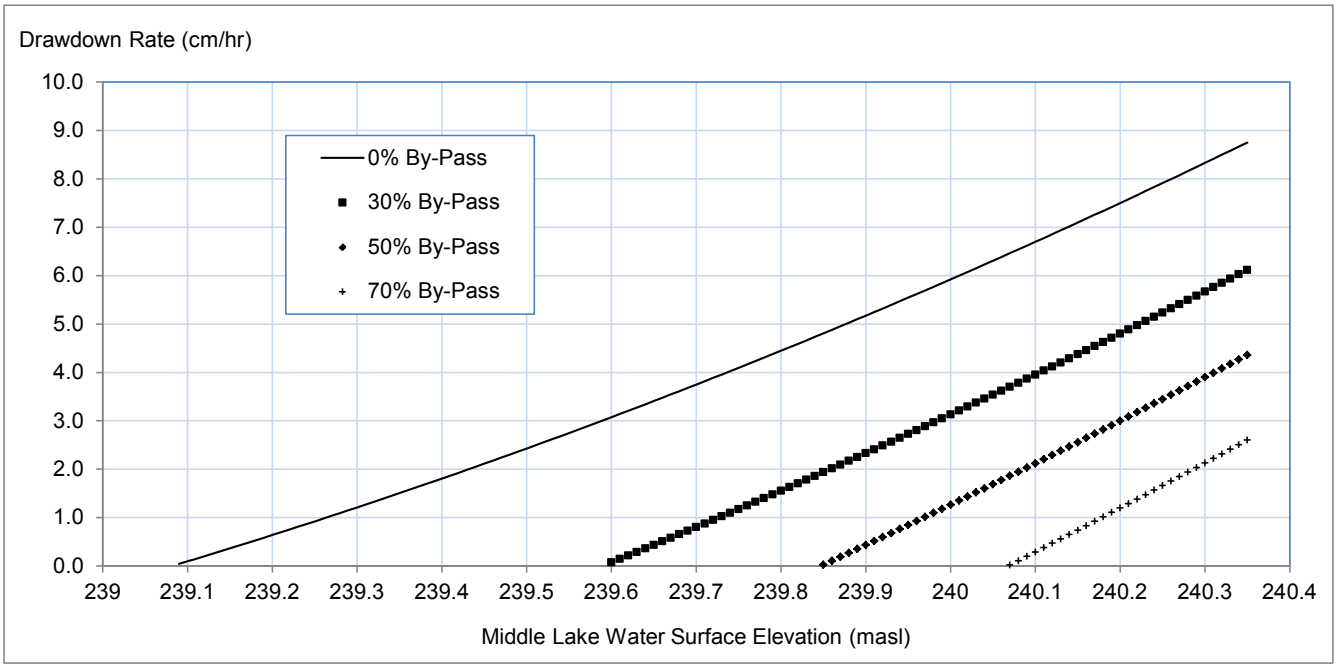


Figure 5: Drawdown rate for an initial discharge condition of 200 m³/s.

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APPENDIX 11.1

Surface Water Quality Modelling

February 2014
Report No. 10-1365-0004/DCN-171

1.0 BACKGROUND

1.1 General

The Black Lake First Nation (BLFN) together with Saskatchewan Power Corporation (SaskPower) has proposed to construct and operate the Tazi Twé Hydroelectric Project (Project) between Black Lake and Middle Lake, Saskatchewan, near the Fond du Lac River. Construction of this facility will generate Project-affected water at the Project site that will need to be managed. Two main types of water will be generated or affected by construction of the Project:

- pumped groundwater from the dewatering processes relating to power tunnel and tailrace channel construction and seepage water collected from sumps and/or dewatering wells within these excavated areas; and
- diverted runoff from the waste rock piles.

These Project-affected waters will be collected in three settling ponds, and subsequently discharged into the Fond du Lac River at two potential discharge locations. Water within the settling ponds will be tested and treated, if required, before release, in accordance with applicable regulations and licence requirements.

This document presents the modelling conducted in support of the surface water quality component of the Environmental Impact Statement (EIS) to assess potential effects on water quality in the Fond du Lac River due to settling pond discharges. More specifically, this analysis was completed to evaluate whether there will be parameters of potential concern (POPC) from the modelled parameters in the settling pond discharge, and whether additional treatment or mitigation would be required.

1.2 Scope

The objective of this study was to use modelling to assess the potential change in water quality of the Fond Du Lac River during the construction phase due to discharge of water from the settling ponds. The focus of this study was on site water management during the construction phase. Construction represents the period of peak discharge from the settling ponds, primarily due to the anticipated volume of groundwater inflow into the power tunnel and tailrace channel at that time (maximum upper-bound estimate of 4,700 cubic metres per day [m^3/d]). In comparison, the volume of groundwater inflow is expected to be 680 m^3/d during operations, which is approximately 15 percent (%) of the maximum groundwater inflow during construction. The groundwater inflows will represent a very small proportion of the total operational flows through the tunnel (i.e., 0.004% of the flow through the tunnel) which is estimated at approximately 16.4 million m^3/d (i.e., 185 to 190 cubic metres per second [m^3/s]) for a 50 megawatt (MW) facility. Since the groundwater inflow during operations is negligible compared to the flow in the Fond du Lac River, modelling the operational phase is not necessary.

Tasks performed to meet the study objective included:

- input data compilation and water quality guideline review;
- characterization of natural surface waters (i.e., quality and flows of the Fond du Lac River) and potential loading sources (e.g., groundwater flows; waste rock runoff);
- mass-balance modelling to predict water quality in the receiving environment; and
- comparison of predicted water quality within the Fond du Lac River to appropriate water quality objectives (WQO).

The assessment conducted herein involved comparing various WQO to predicted concentrations in the Fond du Lac River, under fully mixed conditions and within a 1.2 km mixing zone (see Section 3 for further details). The WQO used were:

- Canadian Water Quality Guidelines (CWQG) for the protection of aquatic life (long-term values) from the Canadian Council of Ministers of the Environment (CCME 1999 plus updates);
- Saskatchewan Surface Water Quality Objectives for the protection of aquatic life (SSWQO; Saskatchewan Environment 2006);
- Canadian Drinking Water Guidelines (Health Canada 2012); and
- Saskatchewan Drinking Water Standards and Objectives (Saskatchewan Environment 2002).

Guidelines from other provinces (e.g., British Columbia and Ontario) were included if CWQG or SSWQO for the protection of aquatic life were not available.

Effluent discharges rarely mix instantaneously with a receiving stream (AEP 1995). Mixing zones for initial dilution of the effluent plume are a practical necessity. These limited exceedance areas are established to ensure protection of the waterbody as a whole (chronic) and to limit acute lethality to organisms passing through the effluent plume (acute) (AEP 1995). Within this analysis, the quality of water within the receiving environment was believed to be protective of aquatic life if WQO were met under fully mixed conditions and at the edge of the mixing zone. If the WQO were not met under fully mixed conditions or at the edge of the mixing zone for a given parameter, then the reason for the exceedence was investigated and, if appropriate, the parameter was listed as a POPC.

Effluent quality criteria (EQC) for POPCs can be established as regulatory requirements during the permitting process for a given discharge from a proposed facility. These criteria represent the concentration of a parameter that has to be met prior to discharge (i.e., end-of-pipe concentration). In the case of the Project, the EQC would apply to the quality of water in the settling ponds prior to discharge. Development of EQC was determined to be beyond the scope of the analysis conducted here.

Currently, two potential locations are being considered for the discharge of water from the settling ponds into the Fond du Lac River (Figure 1). Assessment of the hydraulic characteristics of the river sections at these locations shows that the current speed at the northern location (Discharge Location 2) will be higher than at Discharge Location 1. Additionally the discharge will be subject to enhanced mixing due to bathymetric configuration of this location. Therefore, to be conservative, the southern location (Discharge Location 1) with less favorable mixing conditions was considered in the modelling exercise. Modelling using one discharge location is also conservative because the total mass load enters the river at a single location, rather than being split into two smaller discharge loads. The model involves continuous discharge from a single settling pond, with the assumption that incoming water is held within the pond long enough to allow suspended sediments to settle out (see related assumptions in Section 2).

LEGEND

DISTANCE CHAIN (0.5 KM INTERVAL)

400 0 400

SCALE 1:20,000 METRES

REFERENCE

GOOGLE EARTH IMAGE © 2010 DIGITAL GLOBE
NAD 83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

TWO POTENTIAL LOCATIONS OF SETTLING POND DISCHARGE TO THE FOND DU LAC RIVER

Golder Associates
Saskatoon, Saskatchewan

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	LMR	21/10/13	FIGURE: 1	
CHECK	LT	25/10/13		
REVIEW	BC	25/10/13		

2.0 ASSUMPTIONS

The approach for addressing areas of uncertainty in this study was to make conservative assumptions. For example, natural surface runoff into the settling ponds, which would dilute the two sources (i.e., groundwater inflows and waste rock runoff), was not considered. Furthermore, the model assumes one settling pond would receive both the waste rock runoff and the groundwater collected from the tunnel instead of three different settling ponds; this simplifies the model and also provides a more conservative approach to the predicted water quality. Other key assumptions that support a conservative approach include:

- an upper-bound value of 4,700 m^3/d for groundwater inflow into the tunnel, as predicted by the groundwater model sensitivity analysis (Golder 2013a);
- the use of maximum parameter values from the site-specific groundwater chemistry data and expected waste rock runoff chemistry data; and
- the use of low river flows such as the 7Q10, which is the lowest average discharge over a period of one week with a recurrence interval of 10 years.

Groundwater will start to flow into the tunnel as soon as the tunnel construction begins, but the flow rate will not reach its peak until after the full construction of the tunnel. However, the estimated peak groundwater flow rate into the tunnel was conservatively adopted for the modelling.

A number of additional assumptions were made for the modelling exercise by considering the design details and data available at this stage of the Project.

- Contaminant loading to surface runoff from contractor laydown or construction activities, other than the tunnel development, is assumed to be negligible or locally treated and, therefore, not considered for modelling. Similarly, flow from outside the waste rock pile, but within the same watershed where the Project site is located, will not be collected in the settling pond.
- The settling pond will effectively remove suspended sediments from wastewaters through sedimentation prior to discharge to receiving surface waters; therefore, release of suspended sediment was not considered in this study.
- Notwithstanding the above, it was assumed that total metals concentrations would not be attenuated in the settling pond.
- No decay or chemical reactions were considered for modelling; the total mass of each parameter is conserved throughout the modelling process.
- Groundwater seepage directly into the settling pond was considered negligible compared to other sources.
- Groundwater flow and waste rock drainage would be fully mixed prior to discharge of water from the settling pond.
- Both ammonium nitrate/fuel oil (ANFO) and water resistant emulsion explosives will be used for tunnel construction. Drainage that comes into contact with the waste rock in the disposal areas will receive nitrogen inputs (i.e., ammonia and nitrate) from explosive residue. The groundwater inflows to the tunnel may also receive nitrogen ammonia and nitrate input from the explosives, due to potential leaching from ANFO that is placed in wet conditions, prior to blasting. However, best practices, as outlined in the Blasting

Plan for the Project, will be applied to blasting activities to minimize any potential for enhanced loading due to the placement and use of ANFO during construction. Therefore, nitrogen residues in groundwater inflows were not included.

- Of the proposed 1,075,000 kilograms (kg) of total explosives to be used for construction of the Project, it is currently expected that 860,000 kg will be ANFO and 215,000 kg will be bulk emulsion. Potential loadings of ammonia and nitrate from the ANFO/emulsion explosives to the waste rock drainage were determined using the following assumed input values:
  - powder factor: 2.1 kilograms per cubic metre (kg/m^3);
  - fraction of residues: 5%;
  - fraction of ammonium nitrate (NH_4NO_3) in ANFO explosives: 94%;
  - fraction of fuel oil in ANFO explosives: 6%;
  - fraction of $NaNO_3$ in emulsion explosives: 18%;
  - fraction of NH_4NO_3 in emulsion explosives: 63%;
  - fraction of fuel oil in emulsion explosives: 6%;
  - fraction of H_2O in emulsion explosives: 9%; and
  - glass microballoons in emulsion explosives: 4%.
- The powder factor provided above is highly conservative (the powder factor can be as low as 1 kg/m^3).
- The potential effect of dust deposition to nearby waterbodies is not evaluated in this model, but was considered as a separate component of the overall assessment in the EIS of the potential effects to surface water quality by the Project.

3.0 METHODS

3.1 Model

A mass-balance modelling platform, GoldSim™, developed by GoldSim™ Technology Group (GTG 2010), was applied for the water quality modelling for the discharges into the Fond du Lac River. GoldSim™ is a graphical program for carrying out dynamic, probabilistic simulations to support decision-making. GoldSim™ has been widely used throughout Canada and around the world in a wide variety of applications including:

- simulation of water balances and contaminant transport in surface water systems;
- food web, bioaccumulation, and population modelling of aquatic and terrestrial ecosystems; and
- support of environmental compliance and permitting and for evaluation of the development, expansion, remediation, and closure of mining projects.

The GoldSim™ water quality model was configured to simulate parameter concentrations downstream of the discharge point in the Fond du Lac River. The model included key loading sources potentially affected by the Project (i.e., groundwater from the tunnel and waste rock runoff, both collected in the modelled single settling

pond). To take into account the most critical receiving water quality conditions, the modelling was performed under a low river flow condition.

The water quality predictions were calculated by estimating mass loads from each inflow source and mixing them in their corresponding flow and with other site water sources. Water quality was evaluated in the Fond du Lac River as follows:

- The total mass load (milligrams per day [mg/d]) from the runoff and tunnel dewatering process was calculated within the settling pond.
- The total mass from the settling pond was released into Fond du lac River and allowed to mix with background loadings.

An illustration demonstrating the logic included in the model calculations is presented in Figure 2.

When effluent is released into a river or stream, the substance concentration changes with time and distance until the effluent is fully mixed with the background flow. For the assessment of potential effects due to a discharge, it is necessary to examine the water quality for a fully mixed condition as well as at the boundary of the mixing zone. A reach of the river that is 10 times the river width from the discharge point is considered as an appropriate mixing zone (AEP 1995). Typically, where the lateral variation of parameter concentration is within 5% of the mean value, the condition is considered as fully mixed; the mean value is equal to the average of the lateral concentrations at 1.2 km downstream of the point of discharge (i.e., the edge of the defined mixing zone). The following sub-sections describe the methods used herein for estimating parameter concentrations in the river water under fully-mixed condition and within a selected river section considered as the mixing zone. It was assumed that the discharge will be released at the centre of the river.

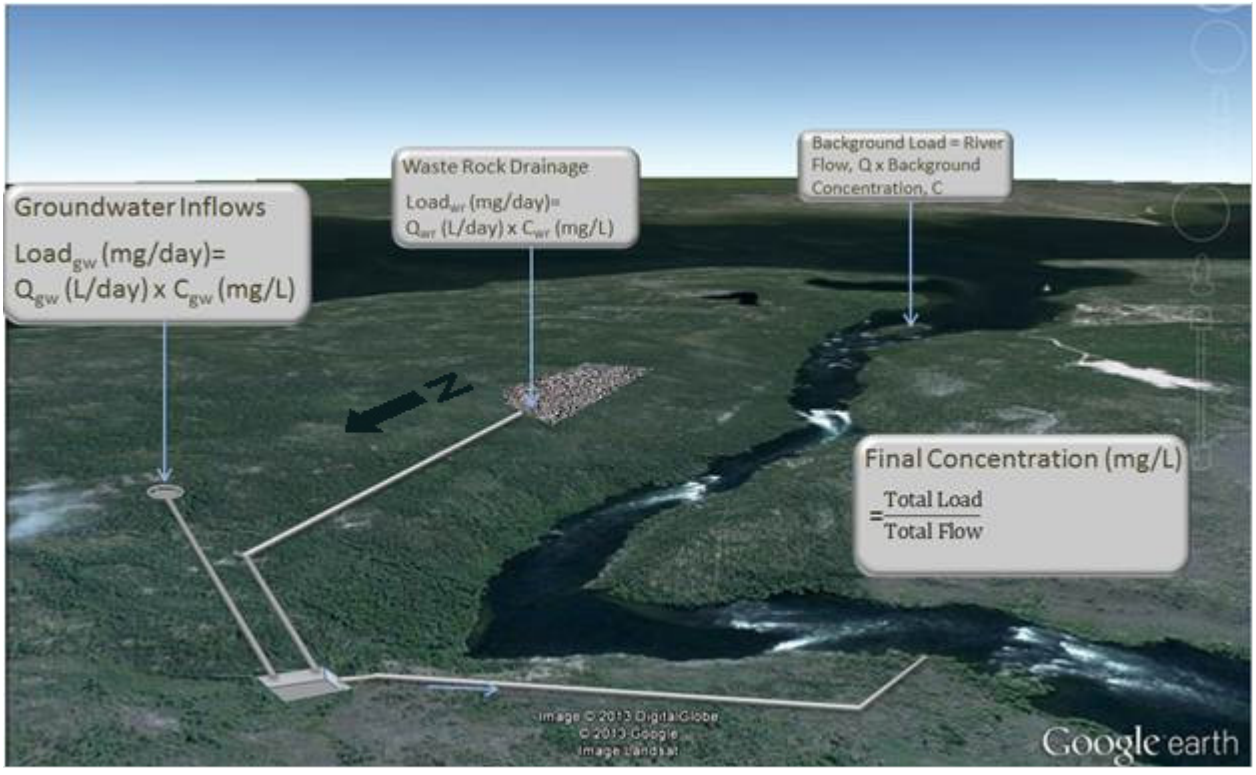


Figure 2: Conceptual Site Water Quality Model

Notes:
The settling pond is shown as one single settling pond in the conceptual instead of the proposed three ponds in reality; the single settling pond supports the conservative approach.
mg/day = milligrams per day; mg/L = milligrams per litre, L/day = litre per day

3.1.1 Fully Mixed Condition

As mentioned above, a two-step mixing process was assumed in the GoldSim™ model for estimating the parameter concentrations. First, groundwater was mixed with waste rock drainage in the settling pond, and then discharge from the settling pond was mixed with the Fond du Lac River.

Water quality downstream of the discharge point was calculated by considering full mixing of the flows and associated constituent loads. At a given modelled location (or node), parameter concentrations were predicted by adding all upstream loads and dividing by the total flow using the following equation:

$$C_x = \frac{\sum_{i=1}^{n} c_i \cdot q_i}{\sum_{i=1}^{n} q_i} \quad (1)$$

where:

C_x = predicted concentration of parameter 'x' at a given location;

c_i = concentration of parameter 'x' in inflow 'i' discharging to a given location;

q_i = flow rate of inflow 'i'; and

n = number of inflows to the location in question.

The sources considered in the mass balance equation include:

- background flows in the Fond du Lac River;
- waste rock runoff; and
- groundwater inflow into the tunnel.

3.1.2 Plume Dispersion Condition Within the Mixing Zone

The two proposed discharge locations are shown in Figure 1. As outlined in Section 1.2, the focus of this modelling exercise was Discharge Location 1, because that location would result in the lowest mixing potential and hence most conservative predictions for assessment.

An effluent plume will travel a certain distance before it mixes fully across the river flow. A concentration gradient will exist within the zone between the discharge point and the location where full mixing is achieved. A reach of the river that is 10 times the river width from the discharge point is considered as an appropriate mixing zone (AEP 1995); for the Fond du Lac River this represents a distance of 1.2 km from the discharge point. For estimating the parameter concentrations of the dispersing plume within this mixing zone, an analytical approach was used.

For a single, point-source load with negligible flow, the following equation describes the concentration at any location downstream of the source (Fischer et al. 1979):

$$C(x,\eta) = C_{BK} + \frac{Me^{-k(x-x_i)/u}}{udW_0\xi\sqrt{\pi}} \sum_{j=-Nr}^{j=Nr} \left\{ \exp\left[-\frac{(\eta - 2j - \eta_0)^2}{\xi^2} \right] + \exp\left[-\frac{(\eta - 2j + \eta_0)^2}{\xi^2} \right] \right\} \quad (2)$$

where:

$C(x,\eta)$ = concentration in Fond du Lac River (mg/L)

C_{BK} = background concentrations in Fond du Lac River, (mg/L)

M = load of substance from the source release (kg/d)

K = decay rate of substance (s^{-1})

X = longitudinal distance downstream from the upstream boundary of the reach (m)

x_i = longitudinal distance of source downstream from the upstream boundary of the reach (m)

u = velocity of Fond du Lac River at the upstream boundary of the reach (m/s)

d = depth of Fond du Lac River at the upstream boundary of the reach (m)

W_0 = river width at the upstream boundary of the modelled reach (m)

ξ = the normalized transverse mixing coefficient (dimensionless)

J = the j'th reflection

N_r = the number of river bank reflections, which depends on the rate of transverse mixing across the river and the distance downstream; an N_r = 2 was applied

η = the normalized location across the river (normalized by fraction of river flow) (dimensionless)

η_o = the normalized location across the river of the centre of the source (normalized by fraction of river flow) (dimensionless)

The normalized transverse mixing coefficient (ξ) is:

$$\xi = \frac{2d\sqrt{E_t xu}}{Q_{(0)}} \quad (3)$$

where:

E_t = transverse mixing coefficient of the reach (m^2/s)

$Q_{(0)}$ = river flow at the upstream boundary of each reach (m^3/s)

In natural systems, estimates of mixing and dispersion coefficients rely on accurate estimate of the hydraulic properties of the river flow. The mixing is related to turbulent shear (i.e., vertical mixing is induced by bottom friction and lateral mixing is generated by bottom roughness). The transverse mixing coefficient in the model is included as a function of shear velocity, as expressed below:

$$E_t = C_m\sqrt{gRS} \quad (4)$$

where,

C_m = mixing constant for meandering river, 0.6 (Fischer 1979)

g = gravitational acceleration, 9.81 m/s^2

R = hydraulic radius of the river section

S = average river slope

3.2 Model Inputs

3.2.1 Groundwater Loading

Groundwater inflows to the tunnel during excavation were estimated by evaluating the hydrogeologic parameters on the basis of borehole data from the Project site (Golder 2013a). An upper-bound inflow of 4,700 m^3/d was predicted by considering constant head and contribution from the overburden.

To characterize the quality of groundwater reporting to the settling pond, site-specific groundwater chemistry data were obtained from the groundwater quality sampling program was used (Golder 2013b). Site-specific groundwater chemistry data are presented in Table 1. To maintain a conservative approach, the maximum parameter concentrations associated with the site-specific groundwater chemistry data were used as input data to the surface water quality model (Table 1).

Table 1: Summary of Site-specific Groundwater Input Water Quality

Parameter	Units	BH13-01	BH13-02	BH13-03	WP13-01	WP13-04	Site-Specific Maximum[a]
Conventional							
Total Alkalinity	mg/L as $CaCO_3$	102	140	69	40	59	140
Total Hardness	mg/L	75	41	50	41	79	79
Total Dissolved Solids	mg/L	134	207	130	171	229	229
Nutrients							
Ammonia as N	mg/L as N	0.08	--	--	--	--	0.08
Nitrate (calculated)	mg/L as NO_3	<0.40	<0.18	<0.18	<0.18	<0.18	<0.40[c]
Major Ions							
Calcium	mg/L	16	8.4	10	8.6	12	16
Chloride	mg/L	1.5	24	2.4	0.2	1.4	24
Magnesium	mg/L	7.2	3.2	3.8	4.6	12	12
Potassium	mg/L	3.3	2.0	1.5	3.0	12	12
Sodium	mg/L	16	57	16	1.3	6.1	57
Sulphate	mg/L	10	2.4	12	1.3	5.4	12
Metals							
Aluminum	mg/L	0.016	0.025	0.023	0.95	--	0.95
Antimony	mg/L	0.0055	0.0076	0.0086	<0.002	--	0.0086
Arsenic	mg/L	0.020	0.022	0.092	0.001	--	0.092
Barium	mg/L	0.0077	0.0031	0.0011	0.033	--	0.033
Beryllium	mg/L	<0.0001	<0.0001	<0.0001	<0.001	--	<0.001[c]
Boron	mg/L	0.12	0.48	0.10	0.1		0.48
Cadmium	mg/L	0.00001	<0.00001	<0.00001	0.0001	--	0.0001
Copper	mg/L	0.0008	<0.0002	0.0002	0.004	--	0.004
Chromium	mg/L	0.0006	<0.0005	<0.0005	0.010	--	0.010
Iron	mg/L	0.29	0.021	0.010	5.8	--	5.8
Lead	mg/L	0.0005	0.0001	<0.0001	0.001	--	0.001
Manganese	mg/L	0.0033	0.0049	0.0052	0.12	--	0.12
Mercury	mg/L	0.00007	<0.00002	<0.00002	<0.00002	--	0.00007
Molybdenum	mg/L	0.0051	0.0053	0.013	0.002	--	0.013
Nickel	mg/L	0.0009	0.0038	0.0013	0.016	--	0.016
Selenium	mg/L	0.0060	0.0001	0.0024	<0.001	--	0.0060
Silver	mg/L	<0.00005	<0.00005	0.00005	<0.0005	--	<0.0005[c]
Thallium	mg/L	<0.0002	<0.0002	<0.0002	<0.002	--	<0.002[c]
Uranium	mg/L	0.302[b]	0.0054	0.0078	<0.001	--	0.302[b]
Vanadium	mg/L	0.015	0.0020	0.0017	0.012	--	0.015
Zinc	mg/L	0.0046	0.0025	0.0022	0.051	--	0.051

[a] Maximum concentrations were used as input chemistry for the model. As recommended in Golder (2013c), data from sample BH13-05 (not shown in Table 1) were not included because the sample was thought to be contaminated by grout in the monitoring well.
[b] Possible outlier value but used as the upper bound case as a conservative measure.
[c] Less than detection limit; half the detection limit was used as input chemistry for the model.
mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; NO_3 = nitrate; N = nitrogen; '--' = no data available.

BH13-01 was installed within the Black Lake Shear Zone (mylonitic gneiss) and intersected two major faults (approximately 0.5 m). Given the fact that known localized uranium deposits have been identified in the shear zone, and that uranium readily dissolves when exposed to water, the elevated uranium concentration at this location is likely not indicative of uranium concentrations in groundwater across the site. This is further supported by the low uranium concentrations at BH13-02 and BH13-03, installed along the tunnel alignment to the northwest. However, the uranium concentration at this location (0.302 mg/L) was conservatively used in the water quality model.

3.2.2 Waste Rock Loading and Explosive Residue Input

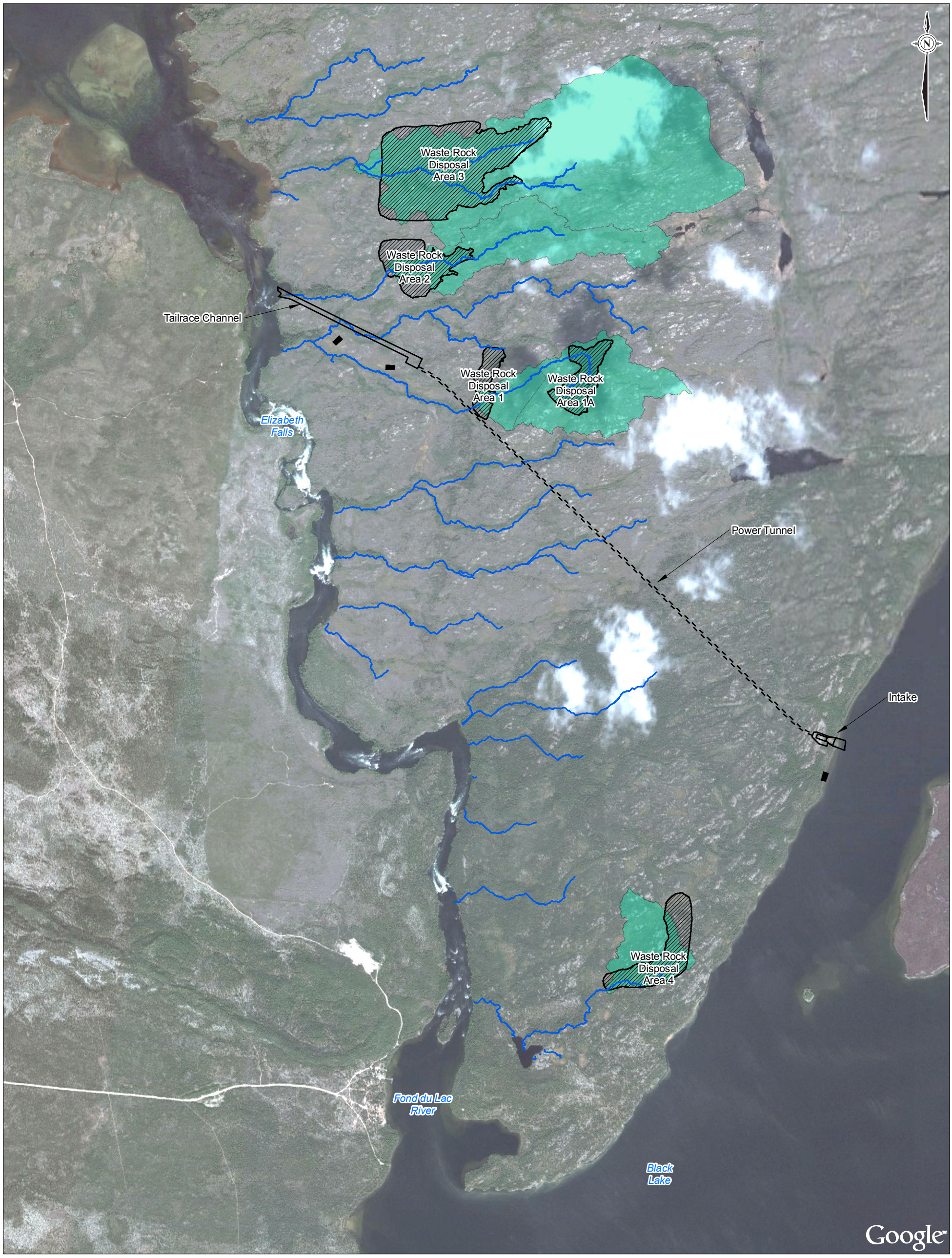
The drainage areas associated with four potential waste rock disposal areas are illustrated in Figure 3 The expected annual volume of water reporting to each disposal area was estimated using a runoff rate production equal to 0.0056 cubic metres per second per square kilometre ($m^3/s/km^2$) (Golder 2013d).

For the small drainage of the disposal areas and due to the lack of perennial streams, the largest drainage contribution in a year is that associated with stored snow, with the highest runoff occurring at the beginning of the spring season during freshet. Therefore, it was assumed that the volumes of precipitation estimated from December to May would be accumulated to drain as runoff in May and June. The annual water volume of each disposal area was distributed monthly based on the observed monthly variation in the historical record at the Thyme Hill River below Mackenzie Lake (ST 06DB003). The expected monthly water volumes associated with each waste rock disposal area are reported in Table 2.

Table 2: Expected Monthly Water Volume into the Disposal Areas

Item	Station 06DB003 (m^3/s)	Distribution Factor (on per unit)	Disposal Area 1 (m^3/Mon)	Disposal Area 1A (m^3/Mon)	Disposal Area 2 (m^3/Mon)	Disposal Area 3 (m^3/Mon)	Disposal Area 4 (m^3/Mon)
January	4.092	0.04	574	1,907	2,283	7,445	1,181
February	3.169	0.03	444	1,477	1,768	5,765	915
March	2.730	0.02	383	1,272	1,523	4,968	788
April	3.237	0.03	454	1,508	1,806	5,889	934
May	20.922	0.18	2,932	9,750	11,671	38,063	6,040
June	19.933	0.18	2,794	9,289	11,119	36,264	5,755
July	12.776	0.11	1,791	5,954	7,127	23,244	3,689
August	9.955	0.09	1,395	4,639	5,553	18,112	2,874
September	11.511	0.10	1,613	5,364	6,421	20,942	3,323
October	10.627	0.09	1,489	4,952	5,928	19,333	3,068
November	8.388	0.07	1,176	3,909	4,679	15,260	2,422
December	5.935	0.05	832	2,766	3,311	10,797	1,713

Source: Elizabeth Falls – Disposal Areas Drainage (Golder 2013d)
Note: Volumes of water estimated from December to May are assumed to accumulate as snow to finally drain in late May and or early June.
m^3/s = cubic metres per second; m^3/Mon = cubic metres per month



LEGEND

- EXISTING WATERCOURSE
- WASTE ROCK DISPOSAL AREA
- DRAINAGE AREA
- SETTLING POND

400 0 400

SCALE 1:20,000 METRES

REFERENCE

GOOGLE EARTH IMAGE © 2010 DIGITAL GLOBE
NAD 83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

DRAINAGE AREAS ASSOCIATED WITH THE WASTE ROCK DISPOSAL AREAS

Golder Associates
Saskatoon, Saskatchewan

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	LMR	31/10/13	FIGURE: 3	
CHECK	LT	31/10/13		
REVIEW	BC	31/10/13		

The runoff from the waste rock disposal areas was assumed to be characteristic of the waste rock to which it will be exposed. The water chemistry of the runoff was therefore assigned on the basis of geochemical testing results (e.g., metals and other leachable geochemical sources) (Golder 2013e). Potential concentrations of the parameters used as model input for runoff are presented in Table 3.

It was also assumed that the residue of the explosives used at the construction site would be dissolved in the waste rock runoff. The ammonia and nitrate loadings due to the explosives residues were calculated on an annual mass basis based on the input assumptions stated in Section 2; the annual loadings contributed by the explosive residue during construction were estimated to be 5.8 tonnes (t) for ammonia and 20 t for nitrate. Annual loadings were then converted into monthly loadings. Based on the monthly loadings and the estimated monthly waste rock run off volume (Table 2), monthly concentrations of ammonia and nitrate were calculated. The maximum concentration for the waste rock runoff was then applied in the model as a constant value, regardless of the month, since the rest of the parameters of waste rock runoff water quality were not differentiated month to month (Table 3).

Table 3: Waste Rock Runoff Input Water Quality

Parameter	Units	Estimated Waste Rock Loading Concentration
Conventional Parameters		
Total Alkalinity	mg/L as $CaCO_3$	78
Total Hardness	mg/L as $CaCO_3$	48
Total Dissolved Solids	mg/L	440
Nutrients		
Total Ammonia	mg/L as N	44
Nitrate	mg/L as NO_3	187
Major Ions		
Calcium	mg/L	13.5
Chloride	mg/L	7.7
Magnesium	mg/L	3.4
Potassium	mg/L	34.8
Sodium	mg/L	38.6
Sulphate	mg/L	42.0
Total Metals		
Aluminum	mg/L	2.63
Antimony	mg/L	0.0059
Arsenic	mg/L	0.0148
Barium	mg/L	0.0244
Berylium	mg/L	0.0001
Boron	mg/L	0.9
Cadmium	mg/L	0.00002
Copper	mg/L	0.06
Chromium	mg/L	0.01
Iron	mg/L	2.12

Table 3: Waste Rock Runoff Input Water Quality (continued)

Total Metals		
Lead	mg/L	0.0019
Manganese	mg/L	0.0184
Mercury[(a)]	mg/L	<0.0001
Molybdenum	mg/L	0.0193
Nickel	mg/L	0.0081
Selenium	mg/L	0.003
Silver	mg/L	0.0043
Thallium[(a)]	mg/L	<0.00002
Uranium	mg/L	0.0039
Vanadium	mg/L	0.0512
Zinc	mg/L	0.003

Source: Tazi Twé Hydroelectric Project – Geochemical Characterization Report (Golder 2013e), except for total ammonia and nitrate. Total ammonia and nitrate were calculated separately from explosives residue loadings and expected runoff flow.

Notes: mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; mg/L as N = milligrams per litre as nitrogen; mg/L as NO_3 = milligrams per litre as nitrate.

[(a)] Less than detection limit; half the detection limit was used as input chemistry for the model.

3.2.3 River Flow and Background Water Quality

River flows were estimated using the Water Survey Canada's historical records at the Environment Canada hydrometric station (07LE002) located at the outflow of Black Lake for the period 1961 to 2003. The flow data were analysed to estimate the 7-day low flow of 10 years recurrence (i.e., 7Q10) (Golder 2013f). The current velocity at the selected locations was estimated by River 2D, a 2D hydrodynamic model (Golder 2013f). A relationship between the discharge and modelled current speed was derived and used for this study.

Available water quality data from Black Lake were used to characterize the background water quality in the Fond du Lac River (Golder 2013g). Seasonal water quality data from a number of locations in Black Lake were averaged and interpolated to derive the monthly variation of the parameter concentrations (Table 4). When baseline sample concentrations were less than the analytical detection limit, half the detection limit value was used in the interpolation, which is a standard Golder practice.

Table 4: Monthly Background Water Quality Parameter Concentrations at Black Lake

Parameter[a]	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Conventional Parameters													
Total Alkalinity	mg/L as $CaCO_3$	20	22	20	19	17	17	17	17	13	15	17	18
Total Hardness	mg/L as $CaCO_3$	15	16	14	13	12	12	12	13	13	14	14	15
Total Dissolved Solids	mg/L	33	35	33	30	28	29	29	29	27	29	30	32
Nutrients													
Total Ammonia[b]	mg/L as N	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Nitrate[b]	mg/L as NO_3	0.08	0.09	0.10	0.11	0.12	0.08	0.05	0.02	0.02	0.03	0.05	0.06
Major Ions													
Calcium	mg/L	3.6	3.7	3.5	3.2	3.0	3.0	3.1	3.2	3.2	3.3	3.4	3.5
Chloride	mg/L	5.0	5.1	4.2	3.2	2.3	2.3	2.3	2.3	4.7	4.8	4.8	4.9
Magnesium	mg/L	1.5	1.5	1.4	1.2	1.1	1.1	1.1	1.1	1.2	1.3	1.4	1.4
Potassium	mg/L	0.8	0.9	0.8	0.7	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8
Sodium	mg/L	2.0	2.1	1.9	1.7	1.5	1.5	1.6	1.6	1.6	1.7	1.8	1.9
Sulfate	mg/L	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.4
Total Metals													
Aluminum	mg/L	0.0036	0.0038	0.0034	0.003	0.0026	0.0029	0.0031	0.0034	0.003	0.0032	0.0033	0.0035
Antimony[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Arsenic[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Barium	mg/L	0.0044	0.0045	0.0044	0.0043	0.0042	0.0044	0.0045	0.0046	0.0042	0.0043	0.0043	0.0044
Beryllium[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Boron[b]	mg/L	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cadmium[b]	mg/L	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Chromium[b]	mg/L	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
Copper[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Iron	mg/L	0.0283	0.0300	0.0408	0.0516	0.0623	0.0483	0.0343	0.0203	0.0217	0.0233	0.0250	0.0267
Lead[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Manganese	mg/L	0.0070	0.0049	0.0008	0.0127	0.0166	0.0170	0.0173	0.0177	0.0154	0.0133	0.0112	0.0091
Mercury[b]	mg/L	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Molybdenum[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Nickel[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Selenium[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Silver[b]	mg/L	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001
Thallium[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Uranium[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Vanadium[b]	mg/L	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Zinc[b]	mg/L	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0004	0.0003	0.0003	0.0003

Source: Baseline Report Annex III Surface Water Environment – Tazi Twé Hydroelectric Project Environmental Impact Statement

[a] Seasonal water quality data from a number of locations in Black Lake were averaged and interpolated to derive the monthly variation of the parameter concentrations.

[b] These are the parameters with some or all samples below detection limit. In those cases, half the detection limit was used in the interpolation.

Notes: mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; mg/L as N = milligrams per litre as nitrogen; mg/L as NO_3 = milligrams per litre as nitrate.

3.3 Modelling Scenarios

To assess the periods of minimum dilution for the river and maximum loading from the sources, the simulation was performed for annual and seasonal 7Q10 flows. The seasonal scenarios (i.e., Winterand Spring) were modelled to investigate the effect of changing waste rock runoff volumes (Table 5). The Annual scenario using background water quality data from February was included because February was the month with the maximum concentrations for most of the parameters.

The discharge rate used in the model for the settling pond was considered to be the sum of the groundwater inflows and waste rock runoff (Equation 1; Table 5).

Table 5: Modelling Scenarios

Scenario	River flows (m^3/s)	Background Condition	Groundwater Inflows (m^3/d)	Waste Rock Runoff[(a)] (m^3/d)	Discharge rate from the Settling Pond (m^3/d)[(b)]
Annual	160.8 (Annual 7Q10)	February water quality data	4,700	370	5,100
Winter	156.2 (Winter 7Q10)	March water quality data	4,700	290	5,000
Spring	250.4 (Spring 7Q10)	May water quality data	4,700	2,210	6,900

(a) Based on precipitation and snowmelt data, rounded to the nearest 10
(b) Rounded to the nearest 100

Notes: m^3 = cubic metres; 7Q10 = 7 day low flow with recurrence period of 10 years

Based on the chemistry and flow rates for the groundwater inflow and waste rock runoff described in Sections 3.2.1 and 3.2.2, Table 6 provides the predicted maximum concentrations of parameters in the water of the settling pond, under fully-mixed conditions. The three scenarios of predicted concentrations represent settling pond concentrations at different times of the year (February, March and May), as outlined above.

Table 6: Predicted Maximum Concentrations of Parameters in the Water of the Settling Pond

Parameters	Units	Predicted Settling Pond Concentrations		
		Annual	Winter	Spring
Conventional Parameters				
Alkalinity, as $CaCO_3$	mg/L	136	136	120
Hardness	mg/L as $CaCO_3$	77	77	69
Total Dissolved Solids	mg/L	243	241	297
Anions and Nutrients				
Total Ammonia (NH_3/NH_4)	mg/L as N	3.08	2.69	14.46
Nitrate	mg/L as NO_3	12.81	11.17	60.58

Table 6: Predicted Maximum Concentrations of Parameters in the Water of the Settling Pond (continued)

Parameters	Units	Predicted Settling Pond Concentrations		
		Annual	Winter	Spring
Major Ions				
Calcium	mg/L	15.8	15.9	15.2
Chloride	mg/L	22.9	23.0	18.7
Magnesium	mg/L	11.4	11.5	9.2
Potassium	mg/L	13.5	13.3	19.4
Sodium	mg/L	55.8	55.9	51.0
Sulphate	mg/L	14.0	13.8	21.7
Total Metals				
Aluminum	mg/L	1.0635	1.0488	1.4937
Antimony	mg/L	0.00842	0.00844	0.00773
Arsenic	mg/L	0.0868	0.0875	0.067
Barium	mg/L	0.0324	0.0325	0.0302
Beryllium	mg/L	0.0005	0.0005	0.0004
Boron	mg/L	0.51	0.50	0.62
Cadmium	mg/L	0.00009	0.00010	0.00007
Chromium	mg/L	0.0100	0.0100	0.0100
Copper	mg/L	0.0078	0.0073	0.0221
Iron	mg/L	5.551	5.584	4.609
Lead	mg/L	0.0011	0.0011	0.0013
Manganese	mg/L	0.113	0.114	0.087
Mercury	mg/L	0.00007	0.00007	0.00006
Molybdenum	mg/L	0.0134	0.0134	0.0150
Nickel	mg/L	0.0155	0.0155	0.0134
Selenium	mg/L	0.0058	0.0058	0.0050
Silver	mg/L	0.00052	0.00049	0.00156
Thallium	mg/L	0.0009	0.0009	0.0007
Uranium	mg/L	0.2819	0.2845	0.2055
Vanadium	mg/L	0.0174	0.0171	0.0267
Zinc	mg/L	0.0478	0.0482	0.0355

mg/L = milligrams per litre; mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; NO_3 = nitrate; N = nitrogen.

3.4 Water Quality Objectives

The following water quality objectives were used for the assessment of the modelled water quality in the Fond du Lac River:

- SSWQO (Saskatchewan Environment 2006);
- CWQG for the protection of aquatic life - freshwater long-term (CWQG; CCME 1999);
- Canadian Drinking Water Guidelines (Health Canada 2012);
- Saskatchewan Drinking Water Standards and Objectives (SDWO; Saskatchewan Environment 2002);
- British Columbia Ministry of Environment (BCMOE 2013) for the protection of aquatic life; and
- Ontario Ministry of Energy and Environment (OMEE 1994) for the protection of aquatic life.

The water quality objectives for the parameters considered in the model are presented together with the mass balance modelling results in Section 4 below.

4.0 RESULTS AND DISCUSSION

The modelled parameter concentrations in the Fond du Lac River downstream of the discharge from the settling pond are presented in Table 7. Results are presented for the annual 7Q10, winter 7Q10 and spring 7Q10 flow conditions. Results of the mass balance analysis represent a fully mixed condition. Applicable guidelines are also presented in the table for comparative assessment.

The results of the modelling exercise indicated that only minor, short-term changes would occur to the water chemistry of the Fond du Lac River during the construction phase because of discharge from the settling pond. For example, predicted concentrations of various parameters under fully mixed conditions are within the range of baseline concentrations measured in 2010 and 2011 (Table 7). The one exception is uranium, where predicted concentrations in the river (i.e., 0.0001 to 0.0002 mg/L) were estimated to be slightly above the baseline value (<0.0001 mg/L). These results take into consideration a very conservative maximum uranium concentration in the groundwater inflows (see Section 3.2.1).

All of the modelled parameter concentrations were lower than guideline values when the discharge was assumed to be fully mixed with river flow, with the exception of cadmium. Both baseline and predicted (under fully mixed conditions) concentrations of cadmium exceeded the current CWQG for protection of aquatic life (0.006 micrograms per litre [µg/L]) because the method detection limit (0.01 µg/L) also exceeds the guideline (CCME 1999). This highly conservative guideline for cadmium is currently under review, with the future guideline value likely to be higher than the current guideline value.

Under the assumed conditions, parameters expected to have elevated concentrations in the settling pond (i.e., prior to discharge) were identified as being effectively dispersed and predicted to meet applicable guidelines within 30 m of the discharge point under the annual 7Q10 and sooner under other flow conditions.

Aluminum was selected for illustrative purposes to show the plume dispersion and the distance required to meet the guideline. Total ammonia and nitrate were also selected to be part of the assessment within the mixing zone as they are the key parameters from the explosives residues associated with the waste rock runoff. The predicted parameter concentrations downstream of the discharge point are presented in Figure 4. The concentrations were estimated over a 1.2 km downstream reach from the discharge point, which represents the limit of a typical mixing zone covering 10 times the river width along the river (AEP 1995). All three selected parameters were predicted as being less than guideline values well before the edge of the mixing zone for the considered 7Q10 flow and upper bound of the groundwater flows and chemistry.

Based on assessment of the mass-balance results and the mixing zone evaluation, it is predicted that all modelled parameters would meet applicable WQO for the single point discharge from the settling pond at the edge of the 1.2 km mixing zone, and within a near-field zone of 30 m. The primary reason for parameters remaining in baseline ranges and not exceeding guidelines given the settling pond discharge is the relatively small rate of discharge from the settling pond compared to the flow rate of the Fond du Lac River. For example, the rate of discharge from the settling pond used in the model ranged from 0.058 to 0.080 cubic metres per second (m^3/s), while the river flows used in the model were much larger at 156 to 250 m^3/s. The use of a diffuser is, therefore, not anticipated to be required for achieving compliance with WQO in the Fond du Lac River.

As illustrated in Figure 4, given the assumed condition of discharge occurring in the middle of the Fond du Lac River and because of the large volume of the natural river flow relative to the small volume of effluent discharge, the effluent should be entrained by the river flow almost immediately and carried over the falls where turbulent mixing will occur. The plume would likely then move downstream near the centre of the river. The extending (i.e. lengthening) and diluting plume would not be expected to reach the shoreline areas for some distance (likely several hundred metres) downstream of the diffuser location, if at all.

Fish habitat information was evaluated within the mixing zone of 1.2 km for both potential discharge locations (see Section 12 of the Environmental Impact Statement for details). In general, no sensitive fish habitat (e.g., overwintering, spawning) is located within the mixing zone of Discharge Location 2 (see Figure 1 for discharge locations). For Discharge Location 1, which is the location considered in this modeling exercise, the following conditions were determined regarding overwintering and spawning habitat in the 1.2 km mixing zone.

- Several small zones of suitable and moderately suitable adult Arctic grayling overwintering habitat exist at the diffuser location and along the west shoreline in the 1.2 km downstream of the diffuser. However, these zones are not likely to be critical as much larger areas of suitable habitat occur upstream of the diffuser and downstream of the plume (i.e., greater than 1.2 km downstream of the diffuser).
- Some overwintering habitat for juvenile Arctic grayling occurs on the west shore at the diffuser location (immediately upstream of the falls). Larger areas of suitable overwintering habitat are accessible upstream and much further downstream of the discharge location
- Several small zones of potentially moderately suitable or suitable Arctic grayling spawning habitat occur along the shore at the diffuser location and nearby falls. Fish above the falls have access to much larger areas of suitable habitat upstream.

Table 7: Baseline And Modelled Fond Du Lac River Water Chemistry Given Settling Pond Discharge

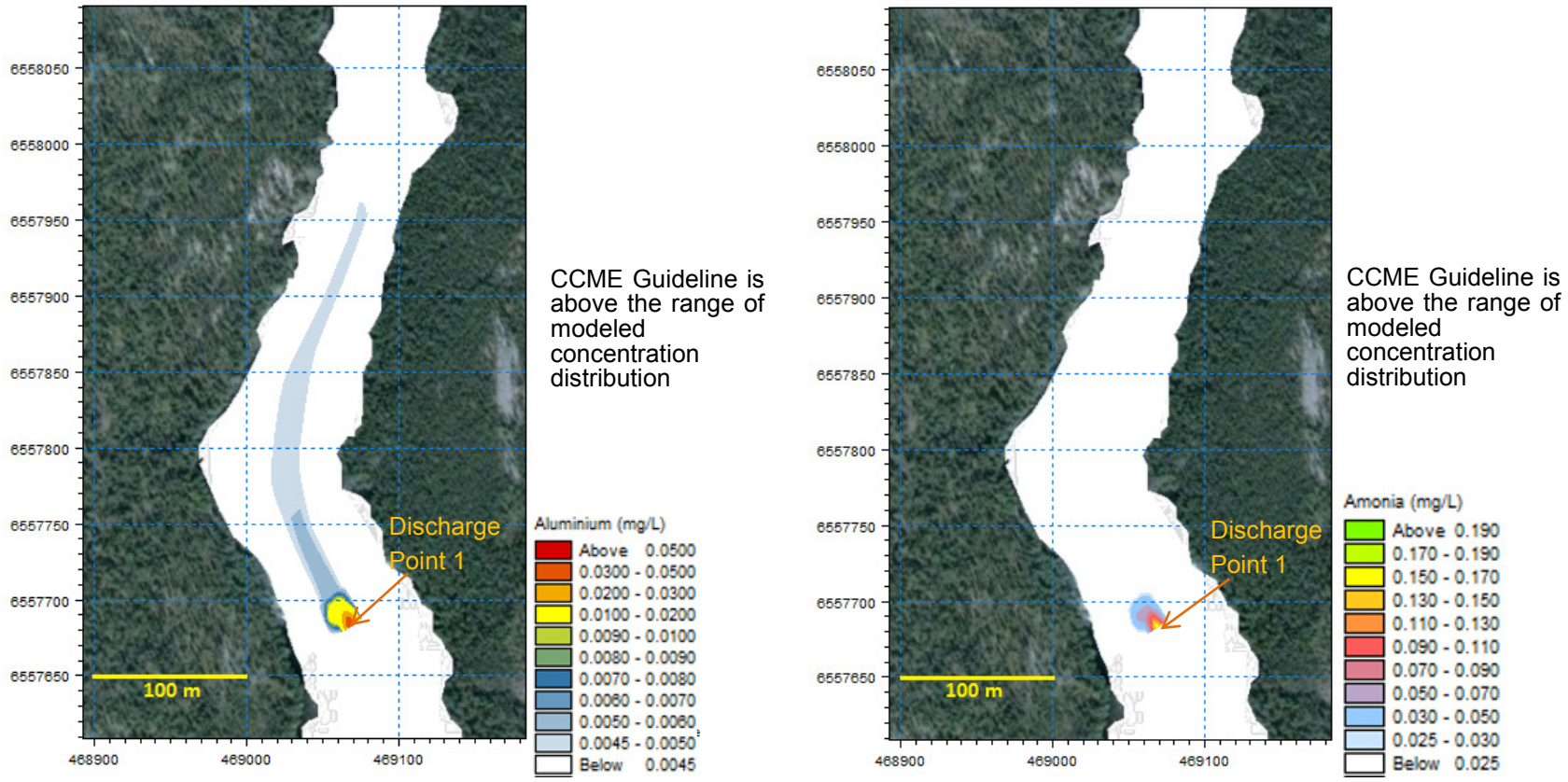
Parameters	Units	Water Quality Objectives					Baseline Concentrations[n]	Predicted River Concentrations (Fully Mixed Conditions)		
		SSWQO[a]	CWQG[b]	CDWG[c]	SDWO[d]	Other		Annual	Winter	Spring
Conventional Parameters										
Total Alkalinity	mg/L as $CaCO_3$	-	-	-	500 (AO)	-	11 to 24	22	20	17
Total Hardness	mg/L as $CaCO_3$	-	-	-	800 (AO)	-	11 to 17	16	14	12
Total Dissolved Solids	mg/L	-	-	≤ 500 (AO)	1500 (AO)	-	24 to 43	35	33	28
Nutrients						-				
Total Ammonia	mg/L as N	0.88[e]	0.88[e]	-	-	-	<0.01 to 0.05	0.02	0.02	0.01
Nitrate	mg/L as NO_3	-	13	-	45	-	< 0.04 to 0.13	0.10	0.11	0.14
Major Ions										
Calcium	mg/L	-	-	-	-	-	2.9 to 4	3.7	3.5	3.0
Chloride	mg/L	-	120	≤ 250 (AO)	250 (AO)	-	0.8 to 7	5.1	4.2	2.3
Magnesium	mg/L	-	-	-	200 (AO)	-	1 to 1.7	1.5	1.4	1.1
Potassium	mg/L	-	-	-	-	-	0.5 to 0.9	0.9	0.8	0.6
Sodium	mg/L	-	-	≤ 200 (AO)	300 (AO)	-	1.2 to 2.4	2.1	1.9	1.5
Sulphate	mg/L	-	-	≤ 500 (AO)	500 (AO)	128[o]	1.1 to 1.5	1.4	1.4	1.3
Total Metals										
Aluminum	mg/L	0.1[f]	0.1[f]	-	-	-	0.0017 to 0.0054	0.0042	0.0038	0.0031
Antimony	mg/L	-	-	-	-	0.02[p]	<0.0002	0.0001	0.0001	0.0001
Arsenic	mg/L	0.005	0.005	0.01	0.025	-	<0.0001 to 0.0002	0.0002	0.0002	0.0002
Barium	mg/L	-	-	1	1	1[q]	0.0040 to 0.0048	0.0045	0.0044	0.0042
Beryllium	mg/L	-	-	-	-	0.0053[q]	<0.0001	0.0001	0.0001	0.0001
Boron	mg/L	-	1.5	5	5	-	<0.01 - 0.02	0.02	0.01	0.01
Cadmium[l,m]	mg/L	0.000017[g]	0.000006[g]	0.005	0.005	-	<0.00001 to 0.00001	0.00001	0.00001	0.00001
Chromium	mg/L	0.001	0.001	0.05	0.05	-	<0.0005	0.0003	0.0003	0.0003
Copper	mg/L	0.002[h]	0.002[h]	≤ 1 (AO)	1	-	<0.0002	0.0001	0.0001	0.0001
Iron	mg/L	0.3	0.3	≤ 0.3 (AO)	0.3 (AO)	-	0.01 to 0.086	0.032	0.043	0.064
Lead	mg/L	0.001[i]	0.001[i]	0.01	0.01	-	<0.0001	0.0001	0.0001	0.0001
Manganese	mg/L	-	-	≤ 0.05 (AO)	0.05 (AO)	0.8[o]	0.004 to 0.034	0.005	0.009	0.017
Mercury	mg/L	0.000026	0.000026	0.001	0.001	-	<0.00001	0.00001	0.00001	0.00001
Molybdenum	mg/L	-	0.073	-	-	-	<0.0001 to 0.0002	0.0001	0.0001	0.0002
Nickel	mg/L	0.025[i]	0.025[j]	-	-	-	<0.0001 to 0.0001	0.0001	0.0001	0.0001

Table 7: Baseline And Modelled Fond Du Lac River Water Chemistry Given Settling Pond Discharge (continued)

Parameters	Units	Water Quality Objectives					Baseline Concentrations[n]	Predicted River Concentrations (Fully Mixed Conditions)		
		SSWQO[a]	CWQG[b]	CDWG[c]	SDWO[d]	Other		Annual	Winter	Spring
Selenium	mg/L	0.001[k]	0.001[k]	0.01	0.01	-	<0.0001 to 0.0002	0.0001	0.0001	0.0001
Silver	mg/L	0.0001	0.0001	-	-	-	<0.00001	0.00001	0.00001	0.00001
Thallium	mg/L	-	0.0008	-	-	-	<0.0002	0.0001	0.0001	0.0001
Uranium	mg/L	0.015	0.015	0.02	0.02	-	<0.0001	0.0002	0.0002	0.0001
Vanadium	mg/L	-	-	-	-	0.006[p]	<0.0001	0.0001	0.0001	0.0001
Zinc	mg/L	0.03	0.03	≤ 5 (AO)	5 (AO)	-	<0.0005 to 0.0006	0.0003	0.0003	0.0003

[a] Saskatchewan Surface Water Quality Objectives (SSWQO) (Saskatchewan Environment's 2006).
[b] Canadian water quality guidelines (CWQG) for the protection of aquatic life - freshwater (CCME 1999).
[c] Canadian drinking water guidelines (Health Canada 2012); unless stated, the guideline concentrations are Maximum Acceptable Concentrations (MAC).
[d] Saskatchewan Drinking Water Standards and Objectives (SDWO) (Saskatchewan Environment 2002).
[e] The guidelines for total ammonia are dependent on temperature and pH . Total ammonia is the sum of ammonia (NH_3) and ammonium (NH_4^+) concentrations and is expressed as 'total ammonia-nitrogen' due to the slightly different relative molecular masses. The conservative guideline value chosen was based on a maximum pH of 7.8 and temperature of 15.58°C for Black Lake.
[f] The guidelines for aluminum are pH-dependent. Based on the mean baseline pH value (7.1) for Black Lake, the guideline is 0.1 mg/L.
[g] The SSWQO for cadmium is hardness-dependent; for hardness ranging from 0 to 48.5 mg/L as $CaCO_3$, the guideline is 0.017 µg/L. The CWQG is also hardness dependent; this guideline was calculated using the equation ($10^{0.86 \times [\log10(\text{hardness})] - 3.2}$); based on a mean hardness of 13.3 mg/L for Black Lake, the guideline is 0.006 µg/L.
[h] The guidelines for copper are hardness-dependent. The mean baseline hardness for Black Lake was 13.3 mg/L $CaCO_3$. For hardness ranging from 0 to 120 mg/L as $CaCO_3$, the SSWQO is 0.002 mg/L. The CWQG is determined based on a specific equation; however, the minimum guideline of 0.002 mg/L applies in this case.
[i] The guidelines for lead are hardness-dependent. The mean baseline hardness for Black Lake was 13.3 mg/L $CaCO_3$. For hardness ranging from 0 to 60 mg/L as $CaCO_3$, the SSWQO is 0.001 mg/L. The CWQG is determined based on a specific equation; however, the minimum guideline of 0.001 mg/L applies in this case.
[j] The guidelines for nickel are hardness-dependent; The mean baseline hardness for Black Lake was 13.3 mg/L $CaCO_3$. For hardness ranging from 0 to 60 mg/L as $CaCO_3$, the SSWQO is 0.025 mg/L. The CWQG is determined based on a specific equation; however, the minimum guideline of 0.025 mg/L applies in this case.
[k] The selenium guideline is based on waterborne exposure. However, selenium has a bioaccumulation pathway similar to mercury.
[l] Since the detection limit of cadmium is 0.00001 mg/L, it is indeterminate if the predicted values are above the SSWQO guideline.
[m] Since the detection limit of cadmium is 0.00001 mg/L, baseline detection limit and predicted concentrations equal to that value are above the CWQG (0.000006 mg/L).
[n] Baseline Report Annex III Surface Water Environment – Tazi Twé Hydroelectric Project EIS. Report 10-1365-004/DCN-072
[o] Guideline was obtained from British Columbia Ministry of Environment (BCMOE 2013) for the protection of aquatic life. Guideline is hardness-dependent. Black Lake mean baseline hardness of 13.3 mg/L $CaCO_3$ used in determining guideline value.
[p] Guideline was obtained from Ontario Ministry of Energy and Environment (OMEE 1994) for the protection of aquatic life.
[q] Draft guideline under review by BCMOE (2013) for the protection of aquatic life.

Notes: mg/L = milligrams per litre; mg $CaCO_3$/L = milligrams of calcium carbonate per litre; ≤ less than or equal to; - = not applicable; N = nitrogen; NO_3 = nitrate; AO = Aesthetic objectives.



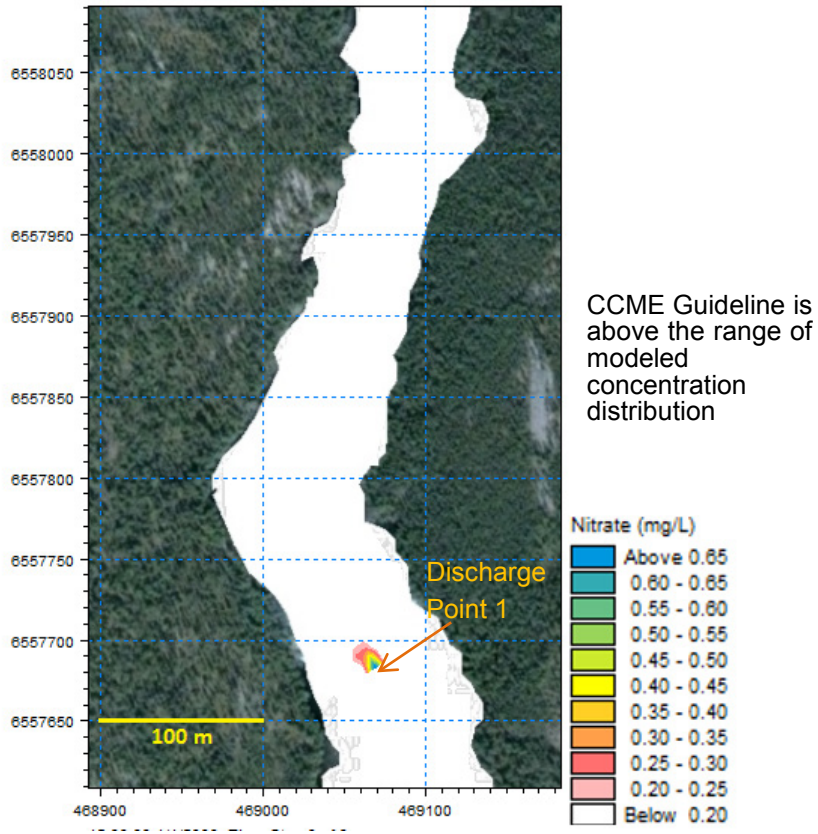
(A) Aluminum

(B) Total Ammonia

Figure 4: Modelled concentration distribution of A) Aluminum, (B) Total Ammonia and (C) Nitrate Within the Mixing Zone for Annual 7Q10 Flow

Notes:
mg/L = milligrams per litre, µg/L = micrograms per litre.

The upper bound CCME guideline for aluminium was applied (0.1 mg/L) as the mean baseline pH for Black Lake (= 7.1) is above 6.5.



(C) Nitrate

Figure 4: (cont'd) Modelled concentration distribution of (A) Aluminum, (B) Total Ammonia and (C) Nitrate Within the Mixing Zone for Annual 7Q10 Flow

Notes:
mg/L = milligrams per litre, µg/L = micrograms per litre.

4.1 Model Limitations and Uncertainty

Given the current status of the Project design, various assumptions were made to complete this assessment. As outlined in Section 2, uncertainty in the model inputs was addressed by adopting conservative assumptions, such as using input values in the modelling that represented conditions at the upper limits of those expected.

The model used an analytical approach for delineating the discharge plume distribution and therefore secondary river mixing (i.e., across the river channel section) was not taken into consideration. More enhanced mixing can be represented if a numerical modelling approach is adopted by employing a discretized model domain and incorporating relevant dynamics that are typically excluded from the analytical approach. A numerical model was not required because parameters met guidelines relatively quickly under very conservative assumptions for input rates and chemistry.

It was assumed that the Fond du Lac River will be subject to natural flow during the period between the completion of the tunnel and commencement of operation. If construction of the proposed weir is completed during this period, the resulting reduced river flow may be lower than the 7Q10. If water is discharged from the settling ponds during this period, instream parameter concentration in the plume may be higher than the modelled values and re-modelling should take place when additional information for this scenario is more likely to be available.

The factual data, interpretations, suggestions, recommendations and opinions expressed in this document pertain to the specific project, site conditions, design objective, development and purpose described to Golder by SaskPower for the Project, and are not applicable to any other project or site location. Specifically, the predictions provided in this report are solely to present the expected water quality in the Fond du Lac River for the model scenarios outlined in Section 3.

5.0 CONCLUSIONS

The objective of the modeling described herein was to assess the potential change in water quality of the Fond Du Lac River during the construction phase due to discharge of water from the settling pond for the Project and identify POPC. Using conservative assumptions, the modelling results suggest that while increases in the concentration of parameters are expected to occur within the Fond du Lac River at Discharge Location 1 as a result of the settling pond discharge, these changes will primarily be within the range represented in baseline data. The one exception was uranium, where the predicted river concentration (0.0001 to 0.0002 mg/L) was marginally above baseline (<0.0001 mg/L), because of the use of a very conservative uranium concentration for the groundwater inflows.

Given the Project details and assumptions at the current time, WQO for the protection of aquatic life and drinking water are not expected to be exceeded under fully mixed conditions and at the edge of the 1.2 km mixing zone, The one exception was cadmium, but this was due to the detection limit being greater than the conservative guideline, currently under review. As such, no POPC have been identified within this assessment.

Although TSS and pH have not been modelled herein, it is anticipated that EQCs will be established for these parameters within the permitting processes, as these parameters often have regulatory limits. It is also anticipated that acute toxicity testing of the settling pond discharge will be another regulatory requirement.

6.0 REFERENCES

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APPENDIX 12.1

Overwintering and Spawning Habitat Suitability Index (HSI) Assessments

February 2014
Report No. 10-1365-0004/DCN-171

1.0 INTRODUCTION

Construction and operation of the Tazi Twé Hydroelectric Project (Project) will result in reduced water flows in the Fond du Lac River between Black Lake and Middle Lake. It is anticipated that reduced flows and associated reductions in water surface area and volume will result in the loss of fish habitat and/or changes to the quality of available fish habitat. Some side channel areas or pools may become isolated during reduced flows and potentially prevent fish movement back into the main river channel. Reduced velocities in some areas of the river may make some habitats more accessible and/or more suitable for fish.

The objective of the overwintering and spawning Habitat Suitability Index (HSI) assessment was to evaluate the habitat available to Arctic grayling (*Thymallus arcticus*), longnose sucker (*Catostomus catostomus*), and white sucker (*Catostomus commersonii*) during the lowest annual flow period (winter) and the spring spawning season. Suitability Index (SI) curves were developed over the ranges of depths and velocities that may be encountered by fish that overwinter (age-0/juvenile and adult fish) and/or spawn in areas between Black Lake and Middle Lake. The quantity and quality of available overwintering habitats were evaluated for the following riparian flow scenarios in the Fond du Lac River:

- 210 cubic metres per second [m^3/s]) (historical average normal low winter flow with a power tunnel and tailrace outlet flow of 0 m^3/s);
- 50 m^3/s (with a power tunnel and tailrace outlet flow of 190 m^3/s);
- 40 m^3/s (with a power tunnel and tailrace outlet flow of 190 m^3/s); and
- 30 m^3/s (with a power tunnel and tailrace outlet flow of 190 m^3/s).

The 210 m^3/s historical average normal low winter flow value was determined based on flow measurements collected from the Fond du Lac River between 1963 and 2011. Flows were measured at Environment Canada gauging stations. The 210 m^3/s flow value was estimated based on data for the month with the lowest average discharge in the historical records (i.e., March).

The following flow scenarios were assessed for the spring spawning season:

- 302 m^3/s (historical average Q10 low spring flow with a power tunnel and tailrace outlet flow of 0 m^3/s);
- 112 m^3/s (average Q10 low spring flow [i.e., 302 m^3/s] with a power tunnel and tailrace outlet flow of 190 m^3/s);
- 400 m^3/s historical average spring flow (with a power tunnel and tailrace outlet flow of 0 m^3/s);
- 210 m^3/s (average spring flow [i.e., 400 m^3/s] with a power tunnel and tailrace outlet flow of 190 m^3/s);
- 510 m^3/s average Q90 high spring flow (with a power tunnel and tailrace outlet flow of 0 m^3/s); and
- 320 m^3/s (average Q90 high spring flow [i.e., 510 m^3/s] with a power tunnel and tailrace outlet flow of 190 m^3/s).

Historical spring flow scenarios (i.e., 302 m^3/s, 400 m^3/s, and 510 m^3/s) were determined based on flow measurements completed at Environment Canada gauging stations in the Fond du Lac River. Flow values were

calculated for the spring spawning period (i.e., from mid-May to end of June) based on data collected between 1963 and 2011.

2.0 METHODS

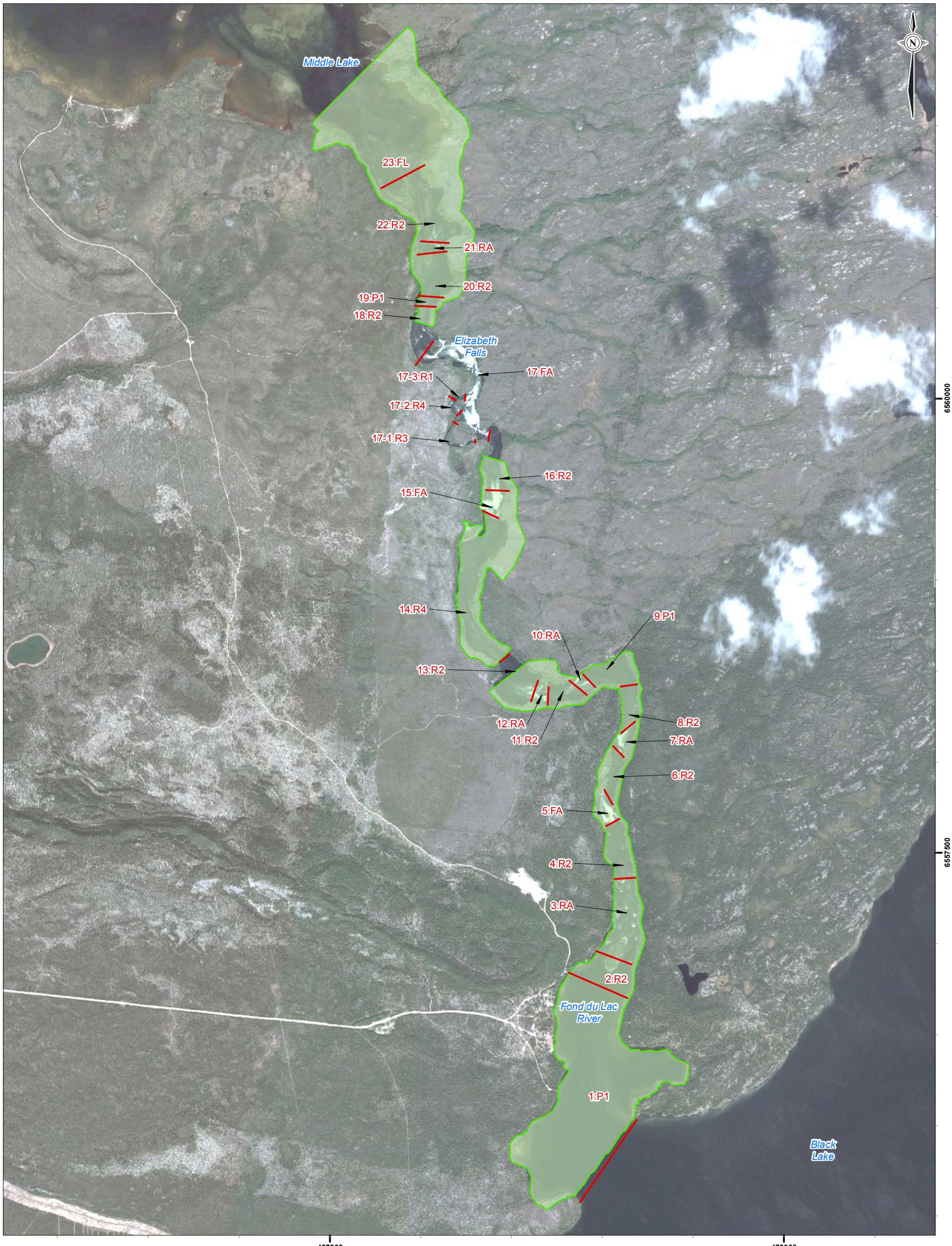
2.1 Hydrodynamic Simulations

Due to the complex bathymetry and shoreline topography of the Fond du Lac River channel between Black Lake and Middle Lake, three separate segments from this section of river were simulated using the River2D hydrodynamic model (Figure 1). River2D modelling segment 1 contains the Fond du Lac River reaches labelled 1 through 13. Segment 2 is comprised of reaches 14 through 16. The furthest downstream segment contains reaches 18 through 23. Reach 17 was not included in the simulations due to the hydrodynamic complexity of the falls, as well as safety concerns for field personnel in obtaining channel bathymetric data for use in the River2D model. A map showing the reaches of the Fond du Lac River between Black Lake and Middle Lake can be found in Figure 2.

Discharge data for the Fond du Lac River was obtained from the Environment Canada hydrometric station (07LE002) located at the outflow of Black Lake and is based on daily discharge data recorded between 1963 and 2011. Water levels recorded in Light Detection and Ranging (LiDAR) data obtained on October 20, 2010 were used to calibrate the hydrodynamic model. River flows on the date of the LiDAR survey were 245 m^3/s. The difference between surveyed and simulated water levels following model calibration was generally less than 0.1 metre (m).

The winter low reference flow of 210 m^3/s was determined from the Environment Canada hydrometric data. This flow scenario represents the average stream flow for the month (i.e., March) with the lowest average discharge in the historical record (1963 to 2011). Construction and operation of the Project is expected to reduce riparian flows to as low as 40 m^3/s in winter, depending on power generation requirements. A total of four flow scenarios were simulated for use in the overwintering fish habitat assessments; these included the historically normal average low winter flow of 210 m^3/s, as well as 50 m^3/s, 40 m^3/s, and 30 m^3/s alternative minimum riparian flows. The power tunnel and tailrace outlet flow (i.e., 190 m^3/s) under consideration for the Project was assessed for each of the 50 m^3/s, 40 m^3/s, and 30 m^3/s minimum riparian flows.

The average spring Q10 low flow reference of 302 m^3/s, the historical average spring riparian flow (i.e., 400 m^3/s) and the average spring Q90 high flow (i.e., 510 m^3/s) were determined from the Environment Canada hydrometric data for the May 15 to June 1 spawning and rearing period. Construction and operation of the Project is expected to reduce the historical average Q10 low flow (302 m^3/s) to 112 m^3/s during the spring spawning period, assuming that 190 m^3/s is required for maximum power generation. It is anticipated that historically normal average riparian flows (i.e., 400 m^3/s) and average Q90 high flows (i.e., 510 m^3/s) will be reduced to 210 m^3/s and 320 m^3/s, respectively, when the Project is operating at 190 m^3/s capacity. A total of six spring flow scenarios were assessed.



LEGEND

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- MODEL EXTENT

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SCALE 1:20,000 METRES

REFERENCE

GOLDER ASSOCIATES © 2012
GOOGLE EARTH IMAGE © 2010 DIGITAL GLOBE
NAD 83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

SEGMENTS OF THE FOND DU LAC RIVER BETWEEN BLACK LAKE AND MIDDLE LAKE THAT WERE SIMULATED USING THE RIVER 2D HYDRODYNAMIC MODEL

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
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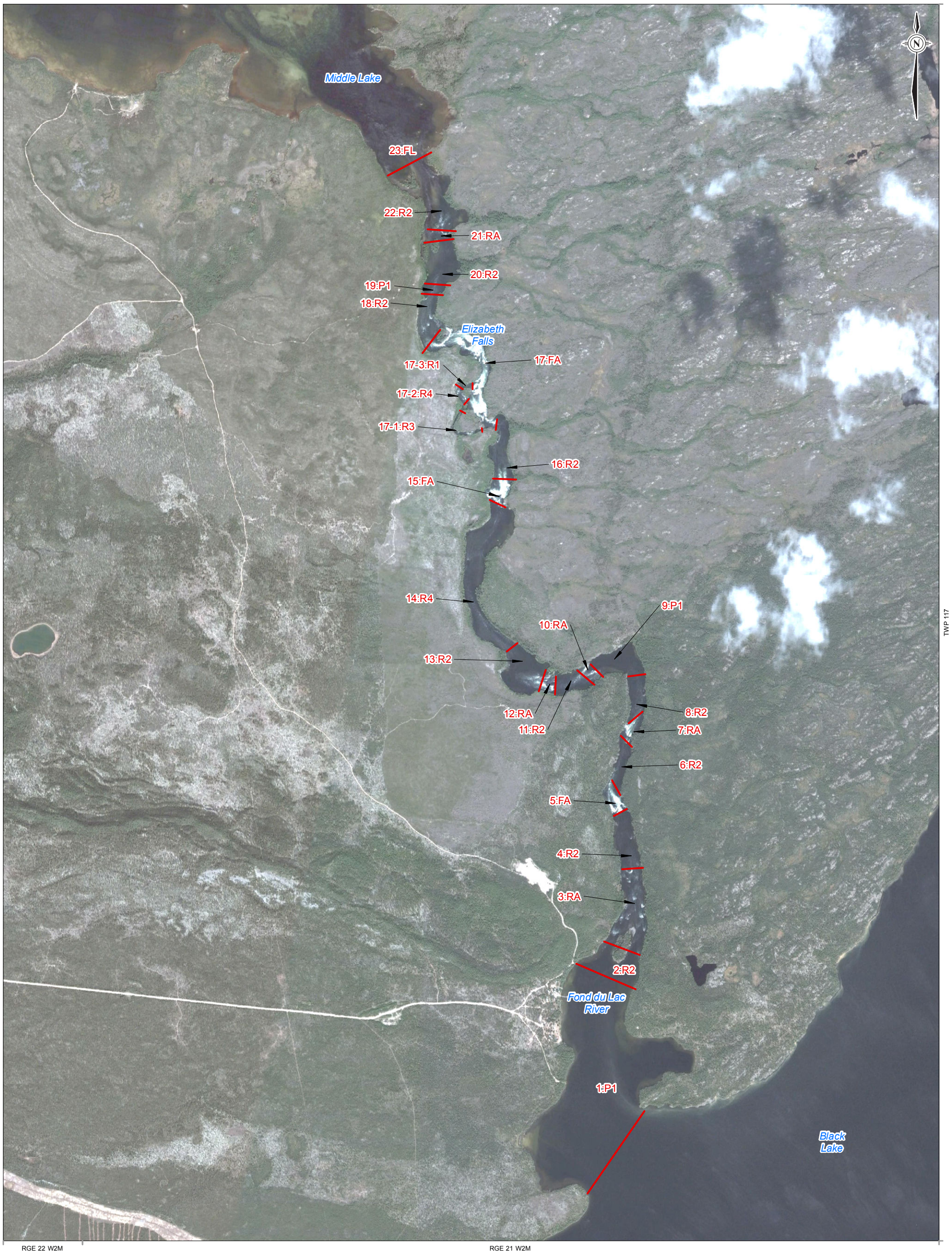
GIS	SM/LR	25/06/13		
CHECK	BC	18/11/13		
REVIEW	BC	18/11/13		

FIGURE: 1



LEGEND

PRIMARY CLASSIFICATION (REACH NUMBER : CLASSIFICATION)

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SCALE 1:20,000 METRES

REFERENCE

GOLDER ASSOCIATES © 2012
GOOGLE EARTH IMAGE © 2010 DIGITAL GLOBE
NAD 83 UTM ZONE 13

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
RIVER REACHES OF THE FOND DU LAC RIVER BETWEEN BLACK LAKE AND MIDDLE LAKE

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	JRC	26/04/13	**FIGURE: 2**	
CHECK	BC	18/11/13		
REVIEW	BC	18/11/13		

2.1.1 Preparation of Hydrodynamic Data

The hydrodynamic datasets modelled for each of the winter (n = 4) and spring (n = 6) flow scenarios were exported from River2D to an ArcInfo Geographical Information Systems (GIS) platform. This was possible because each modelled data point (i.e., each depth and velocity pair) was geo-referenced to a location within the simulated section of the Fond du Lac River (Figure 1). Each geo-referenced data point was assigned a water surface area in ArcInfo based on its Thiessen polygon size (i.e., the size of a polygon placed around a sampling point so that any location inside the polygon is closer to the bounded point than any other nearby data point). Depth, velocity, and water surface area data were then exported to Microsoft Excel; data values were reviewed and then prepared for use in the fish habitat assessments. Data points representing locations outside the wetted channel were removed from the datasets. Points having suspicious depths and/or velocities were identified and reviewed by Golder Associates Ltd. (Golder) hydrologists; anomalous points were removed. Data for a number of modelled river reaches and/or flow scenarios were also removed as follows:

- **Reach 1.** This reach was removed from all ten flow scenarios because it is located entirely upstream of the proposed submerged weir structure. This reach is actually the outlet portion of Black Lake; it is anticipated that water levels within this reach will not be affected by reduced riparian flows.
- **Reach 2.** For the four winter flow scenarios, only the 210 m^3/s flow scenario data (existing average low winter flows) was included for Reach 2. The rationale for eliminating the Reach 2 data for the proposed minimum riparian flow scenarios was that water levels within this reach are unlikely to be affected by reduced flows during winter because the deepest portion of the reach is located upstream of the proposed weir structure. Reach 2 data for each of the spring flow scenarios (i.e., 302, 112, 400, 210, 510, and 320 m^3/s) was retained as-is because changing water levels are expected to have a greater effect on shallow-water spawning areas than on deep-water overwintering habitat in Reach 2.
- **Reaches 15, 16 and 18.** These reaches were removed from all ten flow scenarios. These reaches included falls and severe rapids, and were excluded from the fish habitat assessments because the underlying bathymetric data for these reaches was created manually by Golder during the River2D hydrodynamic model calibration process to align modelled water levels with actual observed water levels for these reaches. High water velocities and the presence of numerous rapids and falls in this section of the river prohibited the safe collection of field bathymetric data to support the River2D model. For these reasons, SI values could not be confidently assigned to the depths in these reaches.
- **Reach 22.** For the historical reference flows (i.e., 210 m^3/s in winter and 510, 400, and 302 m^3/s in spring), tailrace channel outlet flows were assumed to be equal to 0 m^3/s and data points representing the proposed tailrace outlet bay area were removed from the analyzed datasets. Based on the proposed tailrace location, water diverted for the Project will be released back into the Fond du Lac River at Reach 22. It is anticipated that most hydraulic and hydrologic processes will return to pre-diversion conditions at this location. Therefore, each of the hydrodynamic models assessed for Reach 22 based on winter operating conditions include predicted minimum riparian flows of 50, 40 and 30 m^3/s, as well as a 190 m^3/s tailrace outlet flow component. Similarly, hydrodynamic models for Project operation during the spring spawning period include 112, 210, and 320 m^3/s riparian flows with 190 m^3/s tailrace outlet flow components in Reach 22.

- **Reach 23.** This Reach was removed from each of the ten flow scenario datasets because it is predominantly located within Middle Lake, rather than the Fond du Lac River, and is therefore more representative of the aquatic environment in Middle Lake. Also, because this reach is located downstream of the proposed tailrace, it is expected to receive relatively normal riparian flows throughout Project operation.

2.2 Habitat Assessment

2.2.1 Habitat Variables and Suitability Indices

Suitability indices can be used to rate the "suitability" of a habitat variable (e.g., depth, velocity, substrate, temperature, cover) for a particular species or life stage (e.g., is there sufficient depth for fish to overwinter?) (Golder 2005). Habitat variables included in the evaluation of overwintering and spawning habitats in the Fond du Lac River for Arctic grayling and sucker species were depth (metre [m]) and velocity (metres per second [m/s]). Substrate could not be included as a habitat variable in the HSI models for spawning. Substrate information could not be collected at a number of locations in the Fond du Lac River due to hazardous conditions for field personnel; therefore, the spatial extent of ground-truthed substrate data is limited. Because the distributions of various substrate types in the river cannot be described with confidence, it is anticipated that the inclusion of "substrate" as a habitat variable in the HSI models along with depth and velocity would render the models less robust. Instead, areas of potentially suitable or unsuitable spawning substrates for Arctic grayling were predicted based on critical velocities of various substrate size classes (e.g., gravel, cobble) and water velocities modelled for the Fond du Lac River.

2.2.1.1 *Overwintering Habitat*

A literature review was conducted in order to identify published SI values and overwintering habitat preference data for the species of interest. To the greatest extent possible, the review focussed on riverine environments in Canada's northern temperate region and Alaska. A summary of references reviewed for the species, life stages, and habitat variables of interest is provided in Table 1.

Table 1: Literature Reviewed for Overwintering Habitat Preference and Suitability Index (SI) Data

Species	Age Group	References
Arctic grayling (*Thymallus arcticus*)	Age-0/Juvenile	Dahlke 1983 DenBeste and McCart 1984 Falk et al. 1980 Ford et al. 1995 Golder 2013a Hubert et al. 1985 Jones and Tonn 2004 Lee 1985 Low and Read 1987 Vascotto 1970
	Adult[(a)]	Alaska Department of Fish and Game 1984 Ford et al. 1995 Golder 2005 Hubert et al. 1985

Table 1: Literature Reviewed for Overwintering Habitat Preference and Suitability Index (SI) Data (continued)

Species	Age Group	References
Suckers (*Catostomus* sp.)[(b)]	Age-0/Juvenile	Becker 1983 Bond and Machniak 1979 Hatfield et al. 1972 Walton 1980
	Adult	Becker 1983 Cunjak 1996 Hatfield et al. 1972 Stewart and Watkinson 2004

[(a)] Golder's site-specific field data was selected for use over values found in the literature.
[(b)] Longnose sucker (*Catostomus catostomus*) and white sucker (*Catostomus commersonii*) were not considered separately because these species are not expected to exhibit habitat segregation in this river system during winter.

The SI values used to create the suitability curves in Sections 2.2.1.1.1 and 2.2.1.1.2 are based primarily on references having the most complete habitat data and/or SI curve data; this data was modified based on habitat data collected from the Fond du Lac River during Golder field surveys in 2010 and 2012 and/or the expert opinion of senior environmental staff. Secondary references were used as guidelines for comparison (e.g., do the SI curves developed for the Project differ drastically from those reported in other studies?). See Appendix 12.1-A for a summary of the SI values used for the species and life stages of interest.

2.2.1.1.1 Overwintering Suitability Curves: Arctic Grayling

Suitability index (SI) curves for overwintering depth and velocity preferences of age-0/juvenile Arctic grayling (Figures 3 and 4) were created based on resource selection curves for young-of-the-year fish inhabiting a natural Barrenland stream in the Canadian Arctic (Jones and Tonn 2004). Jones and Tonn (2004) was selected as a primary reference because it provided robust resource selection curves (i.e., SI curves) that could be easily modified based on site-specific data and expert opinion. These curves were modified to incorporate the results of Arctic grayling fry surveys that were conducted in the Fond du Lac River in 2012 (Golder 2013a). Golder field staff documented fry using areas of Reach 9 with depths of 0.18 to 0.75 m (average = 0.36 m) and an average velocity of 0.15 m/s. Fry were also documented in Reach 22 at locations having water depths ranging from 0.15 to 0.36 m (average = 0.22 m) and an average velocity of 0.12 m/s. It is also anticipated that because piscivorous predators (e.g., walleye [*Sander vitreus*]) are likely to overwinter in areas with depths greater than approximately 1 m, smaller Arctic grayling would be more likely to avoid these areas as a defense against potential predation.

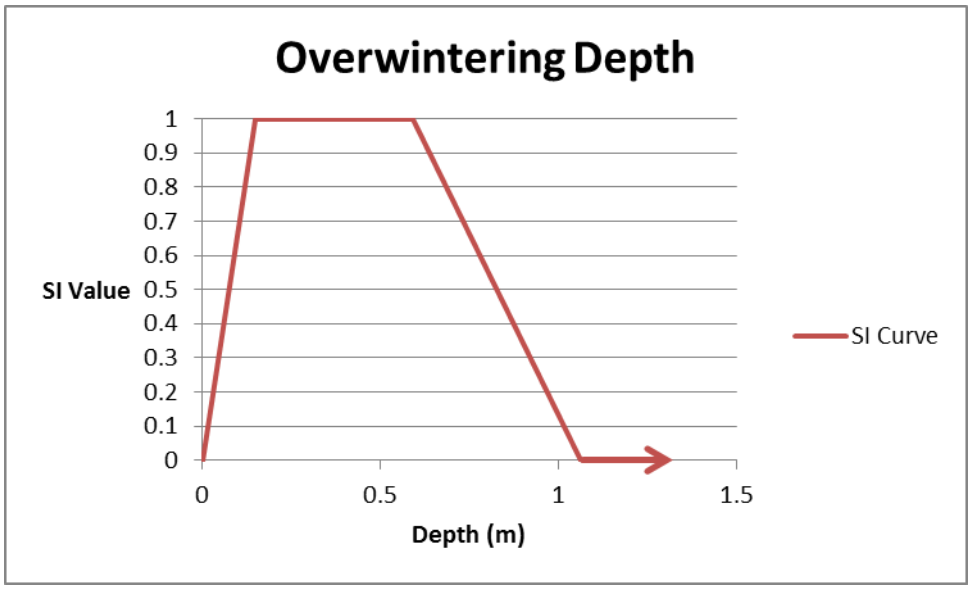


Figure 3: Suitability Index (SI) Curve for Depths Preferred by Overwintering Age-0/Juvenile Arctic Grayling

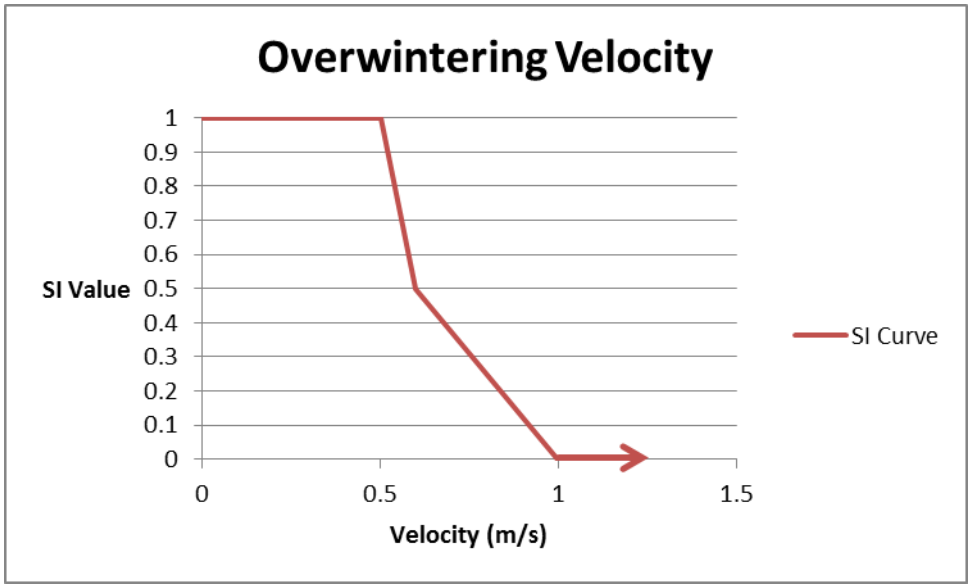


Figure 4: Suitability Index (SI) Curve for Velocities Preferred by Overwintering Age-0/Juvenile Arctic Grayling

The SI curve for depth preferences of adult Arctic grayling was developed based on data collected by Golder personnel during fish surveys on the Fond du Lac River (Figure 5). Because the velocities measured in the Fond du Lac River at locations where adult Arctic grayling were captured were similar to values reported by Ford et al. 1995, the SI data from the literature was used to construct the velocity SI curve (Figure 6).

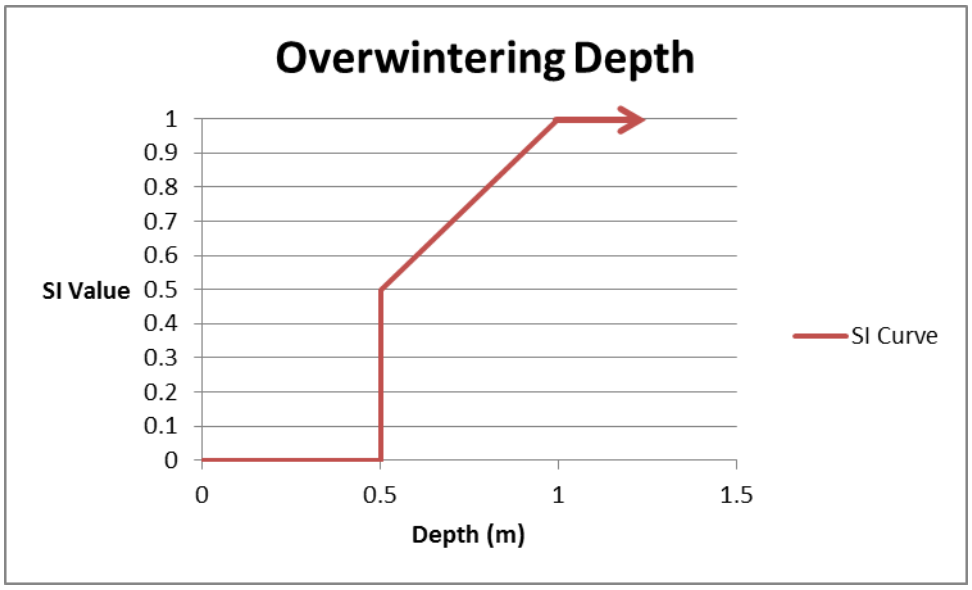


Figure 5: Suitability Index (SI) Curve for Depths Preferred by Overwintering Adult Arctic Grayling

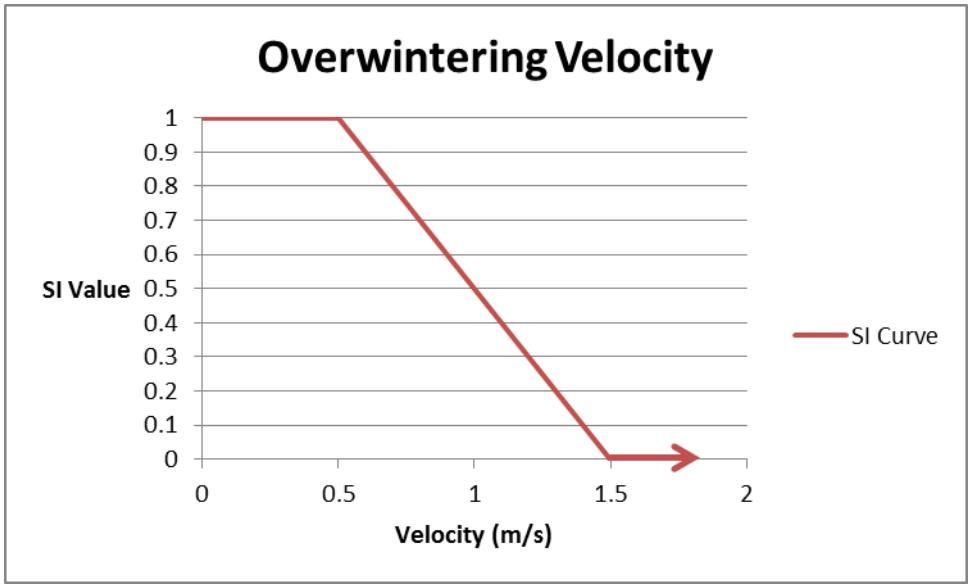


Figure 6: Suitability Index (SI) Curve for Velocities Preferred by Overwintering Adult Arctic Grayling

2.2.1.1.2 Overwintering Suitability Curves: Sucker Species

Depth preference data for age-0 sucker species were modified from Becker 1983 and Walton 1980 (Figure 7). The upper end of the depth SI curve (greater than or equal to [≥] 0.6 m depth) was modified to provide a smooth decline in suitability with increasing depth, rather than a sharp threshold (i.e., so that 0.61 m no longer had an SI = 0 when 0.60 m had an SI = 1). It was also assumed that smaller suckers would avoid areas having depths greater than approximately 1 m because these areas are likely to provide overwintering habitat for larger predatory piscivores, such as walleye. The SI curve for velocity was constructed using values from Hatfield et al. 1972 and Walton 1980 (Figure 8).

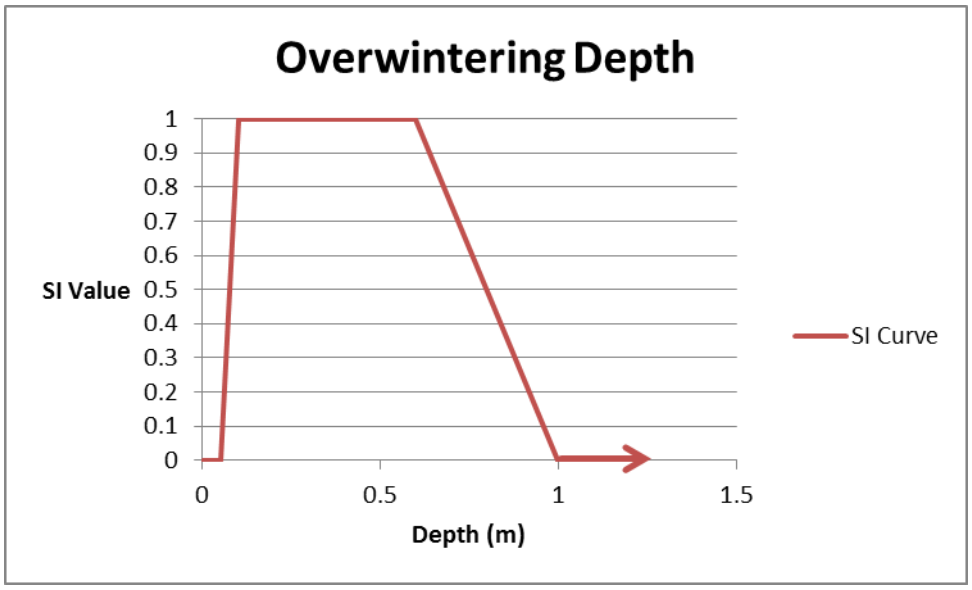


Figure 7: Suitability Index (SI) Curve for Depths Preferred by Overwintering Age-0/Juvenile Sucker Species

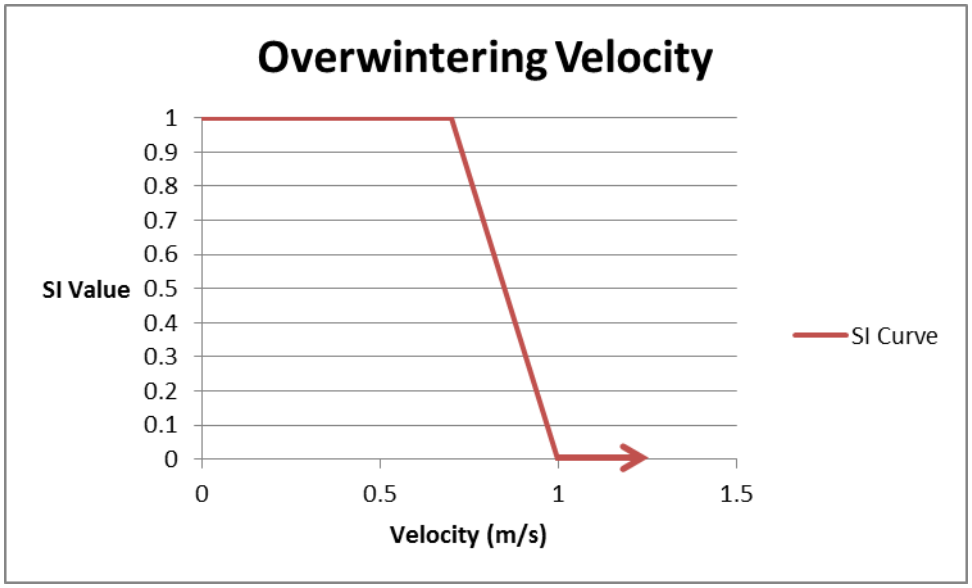


Figure 8: Suitability Index (SI) Curve for Velocities Preferred by Overwintering Age-0/Juvenile Sucker Species

Depth and velocity preference data for adult longnose and white suckers were also obtained from Hatfield et al. 1972 and Walton 1980 (Figures 9 and 10). The depth SI data was modified slightly to create a gradual increase in habitat suitability as depth increased above a minimum.

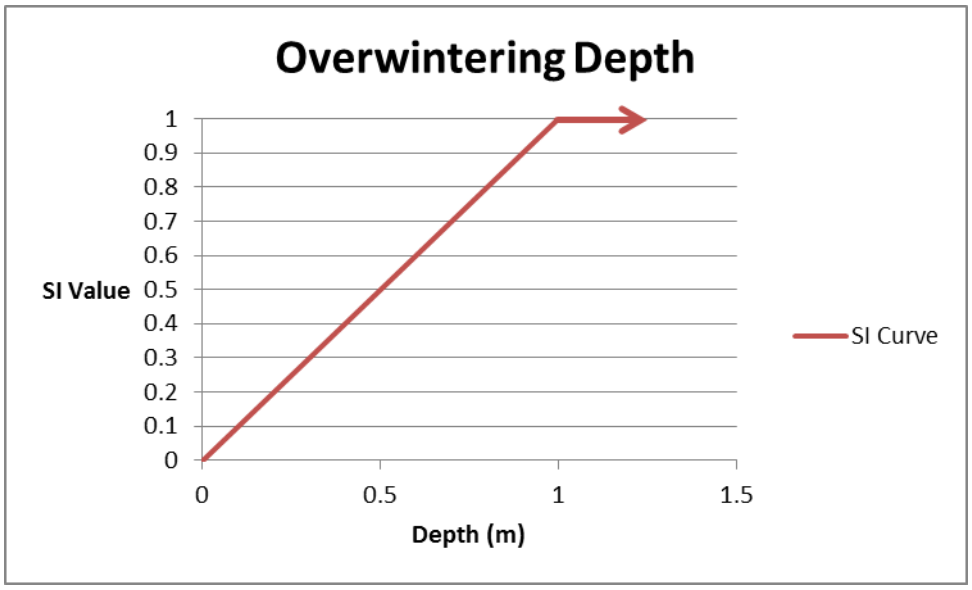


Figure 9: Suitability Index (SI) Curve for Depths Preferred by Overwintering Adult Sucker Species

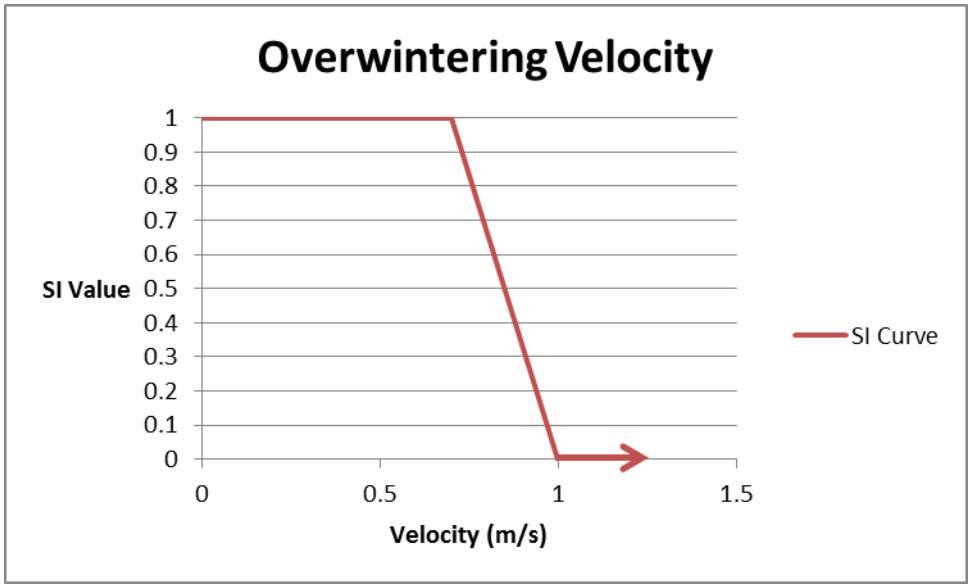


Figure 10: Suitability Index (SI) Curve for Depths Preferred by Overwintering Adult Sucker Species

2.2.1.2 *Spawning Habitat*

A literature review was conducted in order to identify published SI values and spawning habitat preference data for the species of interest. The review focussed on riverine environments in Canada's northern temperate region and Alaska. A summary of references reviewed for the species and habitat variables of interest is provided in Table 2.

Table 2: Literature Reviewed for Spawning Habitat Preference and Suitability Index (SI) Data

Species	Age Group	References
Arctic grayling (*Thymallus arcticus*)	Adult	Ford et al. 1995 Golder 2013b Hubert et al. 1985 Krueger 1981 Machniak et al. 1980
Longnose sucker (*Catostomus catostomus*)	Adult	Bradbury et al. 1999 Edwards 1983 Geen et al. 1966 McPhail 2007 Nelson and Paetz 1992 Scott and Crossman 1973 Stewart and Watkinson 2004 Walton 1980
White sucker (*Catostomus commersonii*)	Adult	Curry 1979 Nelson 1968 Scott and Crossman 1973 Schneberger 1972 Stewart and Watkinson 2004 Symons 1976 Twomey et al. 1984

The SI values used to create the suitability curves in Sections 2.2.1.2.1, 2.2.1.2.2, and 2.2.1.2.3 are based on references having the most complete habitat data and/or SI curve data; literature data was modified using habitat data collected from the Fond du Lac River during Golder field surveys and/or the expert opinion of senior environmental staff. Secondary references were used as guidelines for comparison (e.g., do the SI curves developed for the Project differ drastically from those used in other studies?). See Appendix 12.1-B for a summary of the SI values used for the species of interest.

2.2.1.2.1 Spawning Suitability Curves: Arctic Grayling

Suitability index (SI) curves for spawning depth and velocity preferences of Arctic grayling (Figures 11 and 12) were developed based on Hubert et al. (1985). Hubert et al. (1985) stated that Arctic grayling are known to spawn at depths between approximately 0.15 and 0.91 m; however, in developing SI models for riverine populations, assumed that depths greater than the minimum threshold value of 0.30 m (i.e., 1.0 foot [ft]) were not limiting, and therefore considered ideal (SI = 1) for spawning. Although the assumption of Hubert et al. (1985) may be true for some systems or populations, there is a preference for using site-specific data where it is available. Therefore, the curves were modified to incorporate the results of Arctic grayling egg searches that were conducted in the Fond du Lac River in 2010 and 2012 (Golder 2013b). Egg counts were completed in areas where spawning Arctic grayling were captured, or where conditions suggested Arctic grayling spawning might have occurred. Egg counts were completed along transects extending from shore and perpendicular to flow. Counting activities along each transect ended when water depth and/or flow velocity could no longer be safely waded; the maximum depth at which egg count data could be collected was 0.91 m.

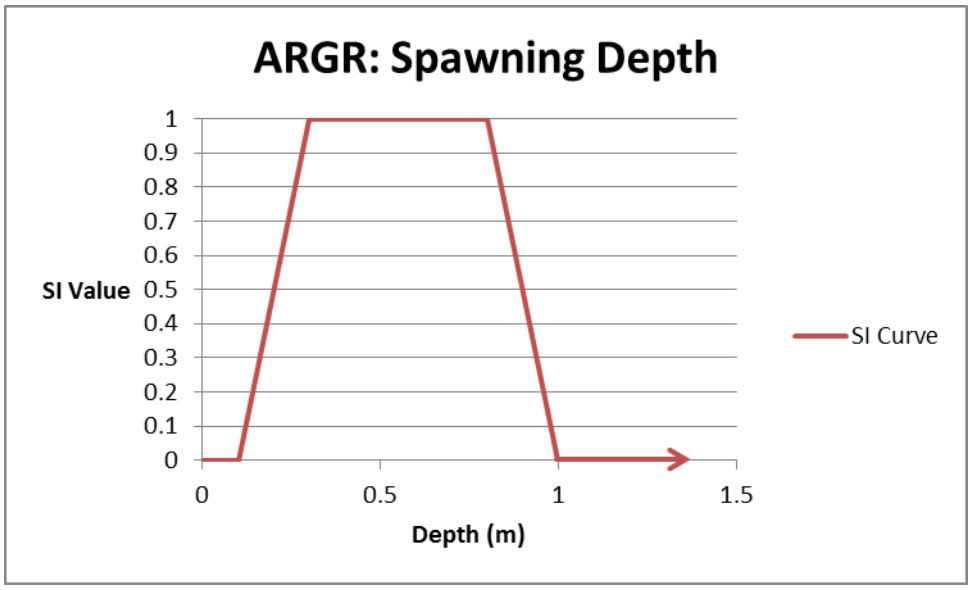


Figure 11: Suitability Index (SI) Curve for Depths Preferred by Spawning Arctic Grayling

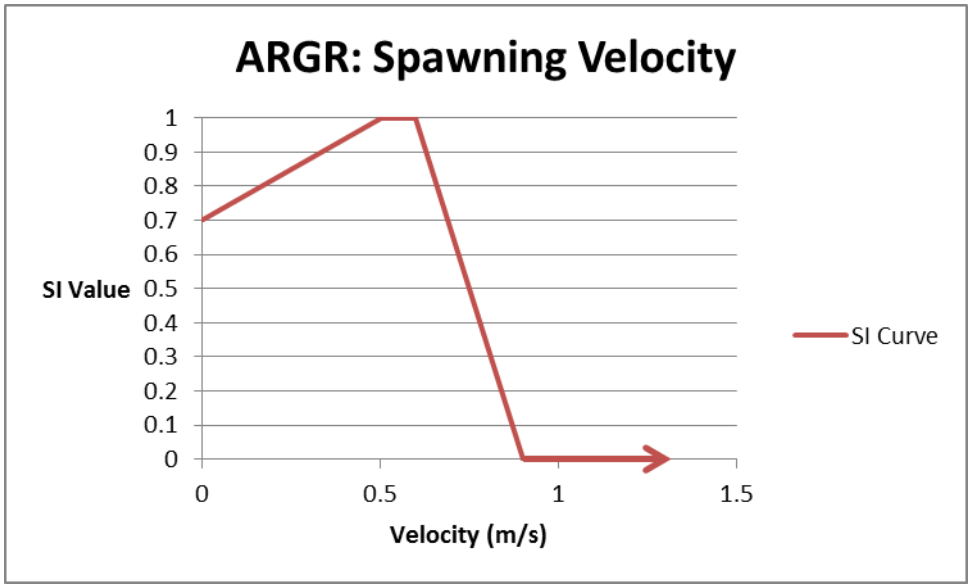


Figure 12: Suitability Index (SI) Curve for Velocities Preferred by Spawning Arctic Grayling

The numbers of efforts expended at various sampling depths in the Fond du Lac River are presented in Figure 13. Because fewer egg search efforts could be completed at deeper depths due to safety concerns for field personnel, a comparison of the depth and velocity values at egg search locations was completed to determine if deeper depths were in fact a limiting factor for spawning Arctic grayling. The depth and velocity comparison is shown in Figure 14.

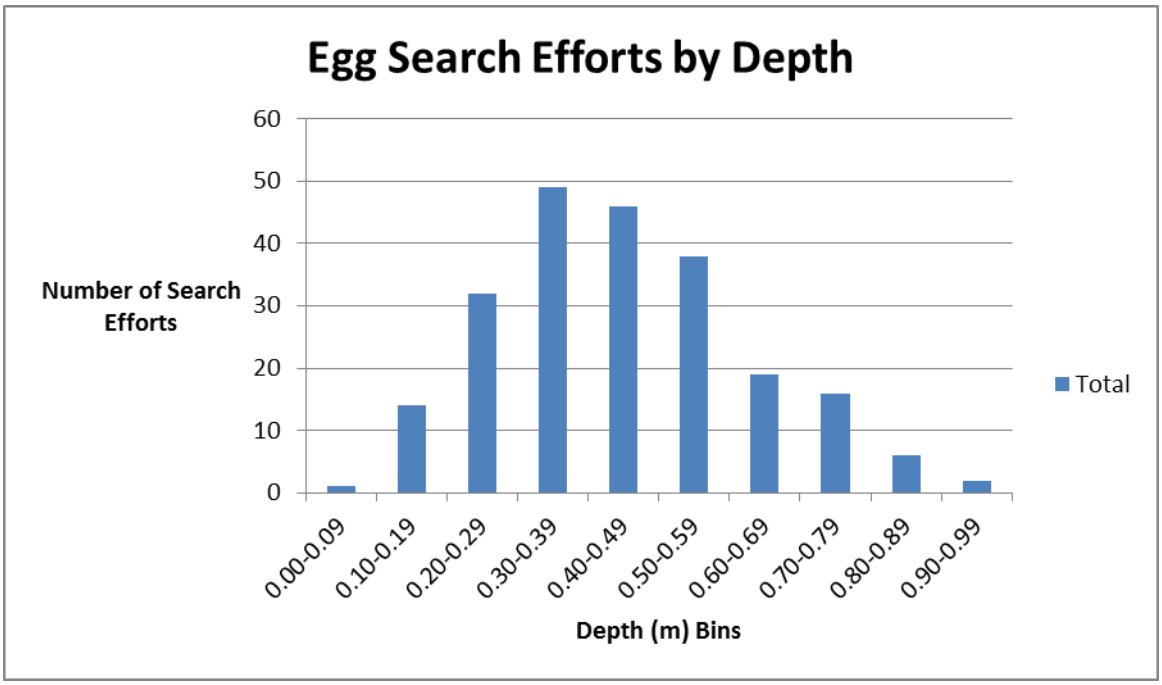


Figure 13: Number of Egg Searches Completed at Varying Water Depths within the Fond du Lac River

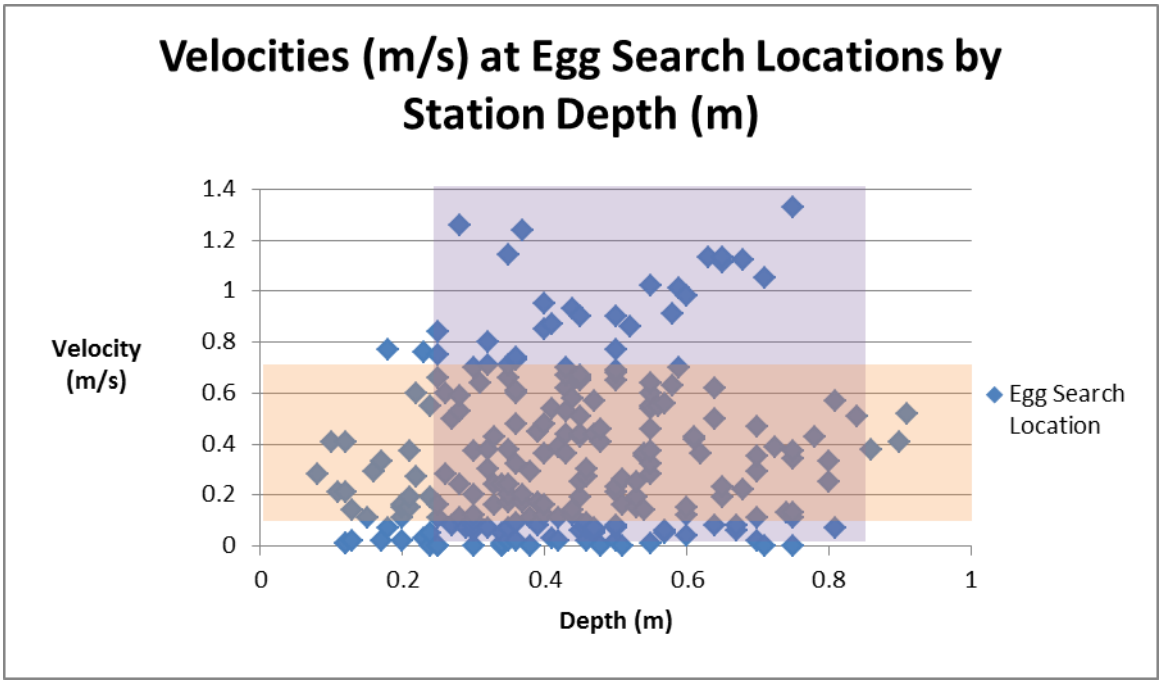


Figure 14: Velocities Measured at Egg Survey Locations the Fond du Lac River based on Depth.

The blue shaded area in Figure 14 represents all depths with SI values greater than 0.75 and the red shaded area represents all velocities with SI values greater than 0.75; These areas are shaded based on the assumption that the SI curves presented in Figures 11 and 12 were developed based on the most accurate and

applicable data for the Fond du Lac River. Predictions of Arctic grayling spawning areas will have the most certainty when there is corroborating evidence based on depth, velocity, and the presence of eggs. For the stations having depths greater than approximately 0.85 m, there is little supporting evidence to suggest successful spawning of Arctic grayling, despite the presence of little field data for those depths. Very few eggs were found at deeper stations; however, Figure 14 shows that velocities at these stations were highly suitable for Arctic grayling to spawn in. The other limiting factor at these stations must therefore be depth.

The numbers of Arctic grayling eggs collected from the surveyed areas were classified into bins based on the depth at which they were collected; this data is presented in Figure 15.

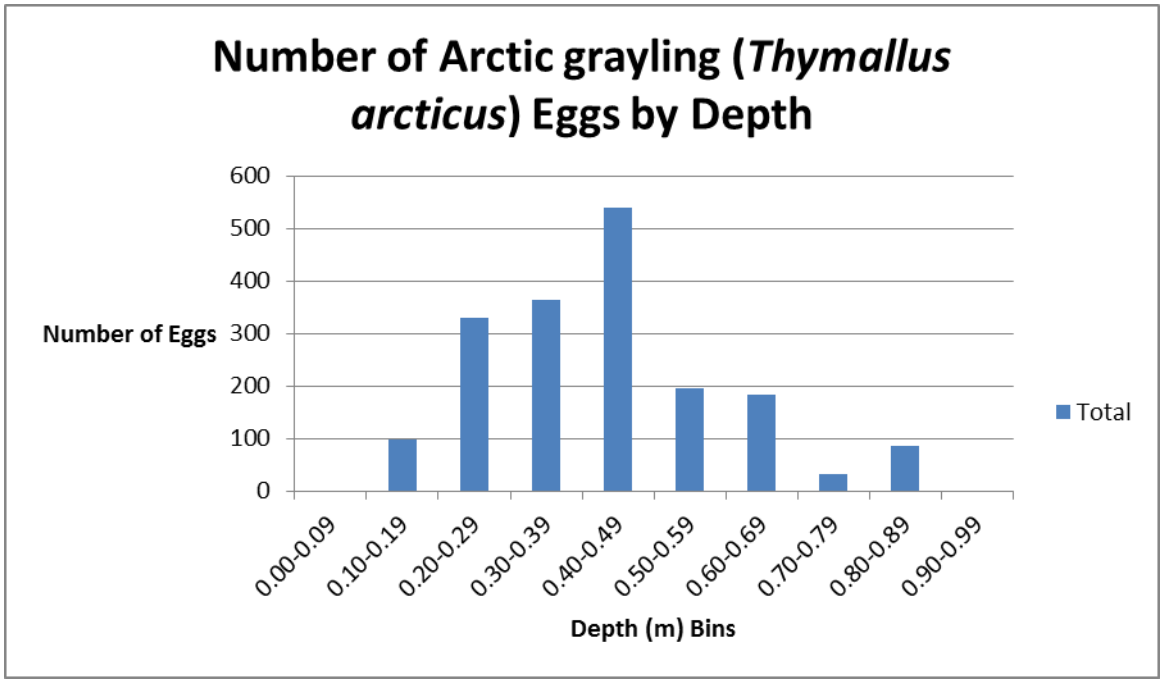


Figure 15: Number of Arctic Grayling (Thymallus arcticus) Eggs Collected at Varying Water Depths within the Fond du Lac River

The largest relative proportion of Arctic grayling eggs was collected from water depths in the 0.40 to 0.49 m range (n = 541). No eggs were collected at depths ≥ 0.90 m. Only 5 percent (%) of the total number of eggs counted from the Fond du Lac River during the spring spawning surveys were collected from areas having depths greater than 0.70 m (i.e., between 0.70 and 0.91 m). Although egg count data for depths greater than 0.91 m is not currently available for the Fond du Lac River between Black Lake and Middle Lake, the scatterplot in Figure 14 and the shape of the curve in Figure 15 suggest that very few eggs are likely to be collected from areas with depths of approximately 1.0 m or greater. The range of suitable spawning depths identified for the Fond du Lac River based on egg count data (Figure 15) is similar to the ranges reported for two Alaskan streams. Preferred spawning depths reported for Arctic grayling in an outlet stream of Mineral Lake, Alaska were between 0.18 and 0.73 m deep (mean = 0.30 m) (Krueger 1981). Arctic grayling in a large tributary stream of Tyee Lake, Alaska are reported to spawn at depths between 0.15 and 0.91 m (Krueger 1981).

Because few eggs are likely to be found in areas deeper than approximately 1.0 m, it is anticipated that spawning is not likely to occur, or is not likely to be successful, at these river depths. Therefore, the upper end of the SI curve from Hubert et al. (1985) was modified to include a 1 m threshold which was used to delineate "suitable/moderately suitable/poor" versus "unsuitable" depths. The highest mean egg counts documented by Golder staff occurred in areas with velocities between 0.5 and 0.6 m/s; therefore, these velocities were assigned SI = 1 (Figure 12). Because a large number of eggs were also collected at velocities below 0.50 m/s, the left side of the velocity SI curve was revised so that the intercept with the y-axis was equivalent to SI = 0.7. No eggs were found at high velocity flows (e.g., 1.2 m/s).

The presence or absence of certain substrate types (e.g., cobble, boulder, gravel) may be an important factor (i.e., habitat variable) in determining where Arctic grayling may or may not prefer to spawn. However, a three-parameter (i.e., depth, velocity, and substrate) HSI model could not be evaluated for Arctic grayling under the various proposed flow conditions because substrate data could not be collected or modelled at the same level of detail or spatial scale as the depth and velocity data.

The distribution of potentially suitable and unsuitable spawning substrates within the modelled sections of the Fond du Lac River was predicted based on substrate particle sizes and water velocities in the channel. A modified Wentworth classification system (Golder 2013c) was used to group substrates based on their size (i.e., particle diameter) (Table 3). Upper and lower critical velocities (i.e., velocities for incipient motion) were then calculated based on the upper and lower particle diameters included within each substrate type classification (Gordon et al. 2004). Based on this system, locations having velocities less than 0.22 m/s are expected to have substrates consisting of clay, silt and/or sand; locations having velocities greater than 2.48 m/s are expected to have predominantly boulder substrates. Substrate types in Table 3 were further classified as suitable or unsuitable based on the preferences of spawning Arctic grayling (Golder 2013b,c; Fish and Fish Habitat Section 12.3.3.1).

Table 3: Classification of Substrate Types by Size and Critical Velocity

Substrate Type	Lower Size	Upper Size	Lower Velocity	Upper Velocity	Spawning Habitat Classification
	mm	mm	m/s	m/s	
Clay/silt	-	<0.059	-	<0.22	Suitable[(a)]
Sand	0.06	1	-	<0.22	
Gravel	2	15	0.22	0.62	
Pebble	16	63	0.62	1.24	
Cobble	64	256	1.24	2.48	
Boulder	>256	-	>2.48	-	Unsuitable

[(a)] The lower boundary of the "suitable" habitat classification could not be limited exclude clay, sand and gravel because larger substrate sizes are also expected to be present at velocities <0.22 m/s; site-specific data indicates that fine substrates are generally flushed from the system during high-flow events (Golder 2013c).

mm = millimetres; m/s = metres per second; <= less than; >= greater than; - = not applicable.

Areas of suitable and unsuitable spawning habitat in the Fond du Lac River were mapped based on the classification system presented in Table 3 and flow data modelled in River2D. This was possible because the flow rate in a river channel determines what the water velocities will be, and whether those velocities are sufficiently large to move substrate particles of various sizes (Robison 2007). Because channel features are

formed at extreme high flows (Knighton 1998), substrate suitabilities were assigned to each data point (i.e., each depth and velocity pair) modelled for the 510 m^3/s Q90 average high spring flow. Because each River2D data point was geo-referenced to a location within the modelled sections of the Fond du Lac River (i.e., reaches 2 through 14 and 19 through 22), it was possible to import the substrate suitability classifications into a GIS platform. A substrate distribution map was created for the river; the map was then overlain with areas of moderately suitable and suitable Arctic grayling spawning habitat predicted for the 112 m^3/s spring flow scenario Q10 low spring flow with the Project in place). It was assumed that under higher spring flows (i.e., ≥ 112 m^3/s) larger areas of suitable substrates would be wetted and would have suitable depths and/or velocities. Locations that were classified as moderately suitable or suitable at the 112 m^3/s flow based on their depths and velocities were re-classified as unsuitable whenever the substrate at that location was predicted to be unsuitable for spawning. It is recommended that these predictions be confirmed during follow-up field programs.

2.2.1.2.2 Spawning Suitability Curves: Longnose Sucker

Depth and velocity preference data for spawning longnose sucker were obtained from Edwards 1983 (Figures 16 and 17). Because Edwards' (1983) HSI model framework was developed for the entire native range of longnose sucker in North America, we believe that the model and its components (i.e., the depth SI curve data) are appropriate for the Fond du Lac River. However, the depth SI data was modified slightly to create a gradual decrease in habitat suitability as depth increased from 0.21 to 1.2 m. The velocity SI curve was modified to include an SI = 0 at 1 m/s because it is anticipated that longnose sucker in the Fond du Lac River are not able to spawn in water with velocities greater than 1.0 m/s. For the purposes of this assessment, it is assumed that suitable gravel substrates are available for longnose sucker spawning in the Fond du Lac River.

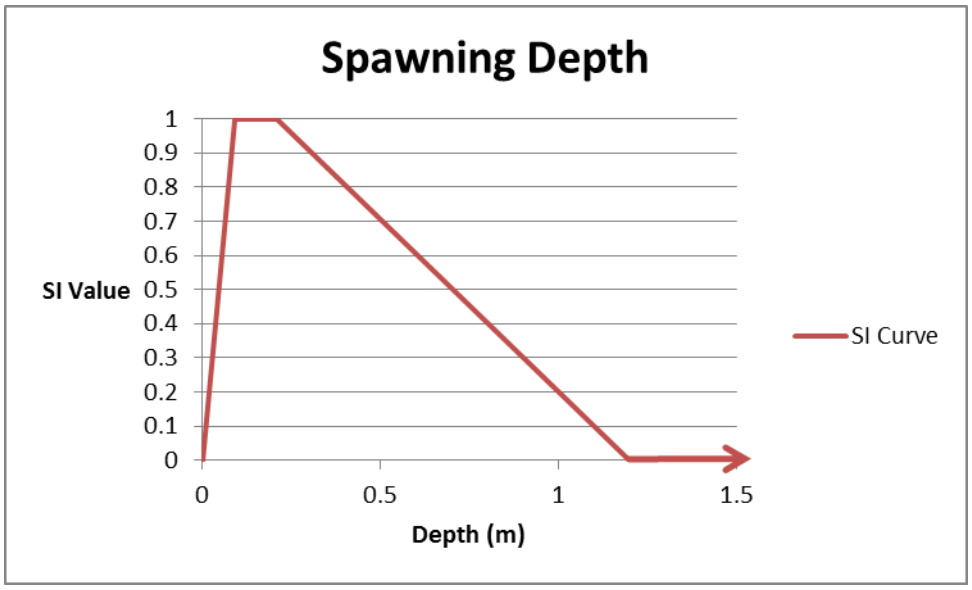


Figure 16: Suitability Index (SI) Curve for Depths Preferred by Spawning Longnose Sucker

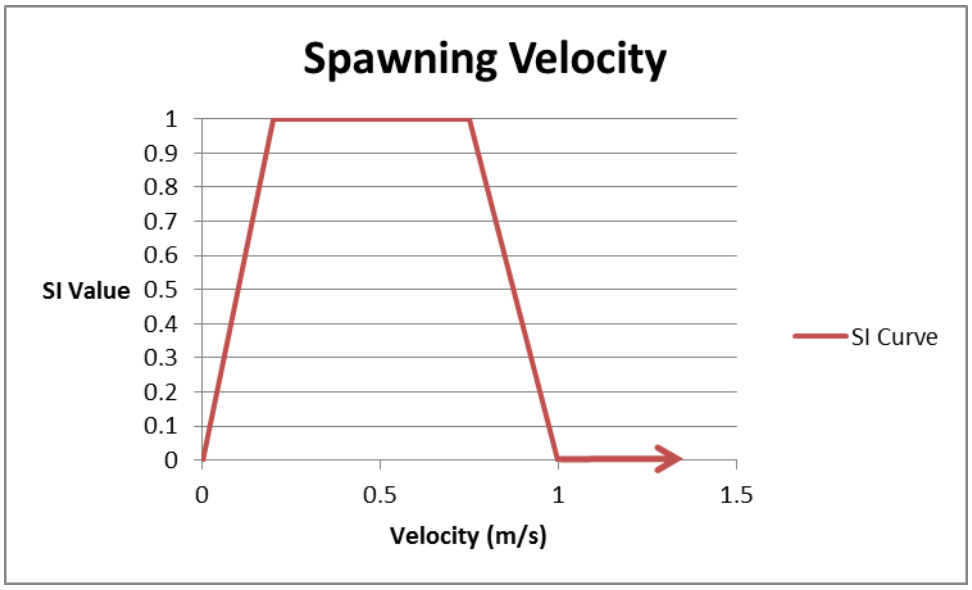


Figure 17: Suitability Index (SI) Curve for Velocities Preferred by Spawning Longnose Sucker

2.2.1.2.3 Spawning Suitability Curves: White Sucker

Depth and velocity preference data for white sucker were taken directly from Twomey et al. 1984 (Figures 18 and 19). Because the HSI model framework of Twomey et al. (1984) was developed for the entire native range of white sucker in North America, we believe that the model and its components (i.e., the depth SI curve data) are appropriate for the Fond du Lac River. For the purposes of this assessment, it is assumed that suitable gravel substrates are available to white sucker spawning in the Fond du Lac River.

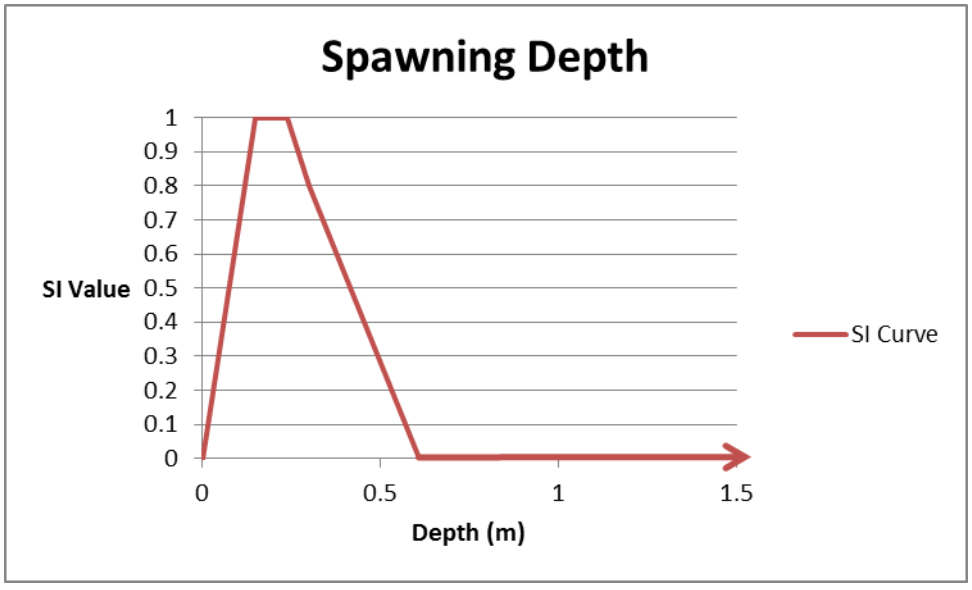


Figure 18: Suitability Index (SI) Curve for Depths Preferred by Spawning White Sucker

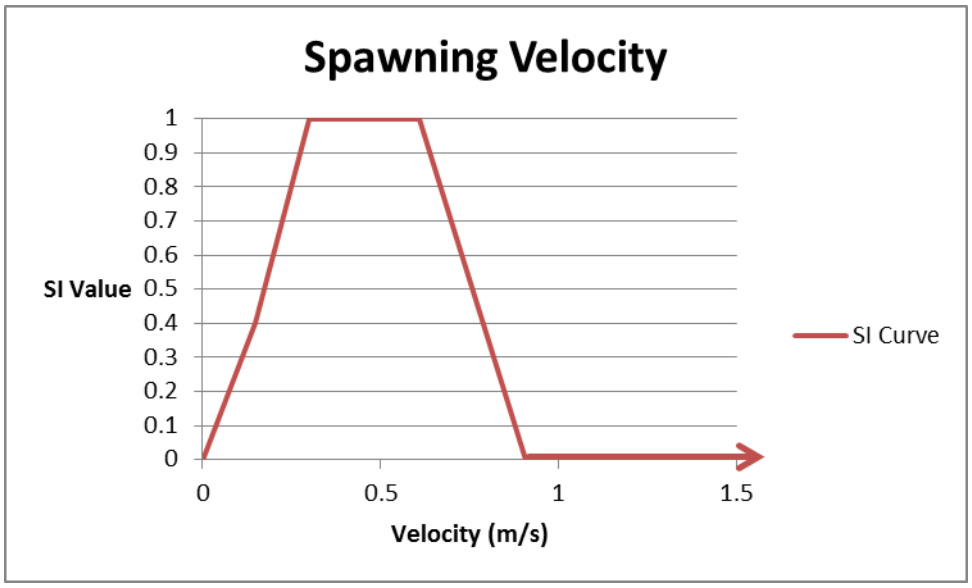


Figure 19: Suitability Index (SI) Curve for Velocities Preferred by Spawning White Sucker

2.2.2 Habitat Suitability Indices

Habitat Suitability Indices (HSIs) can be used to rank available habitats and determine whether a particular combination of habitat variables is "suitable" for the species, life stage or activity (i.e., spawning) of interest. Habitat Suitability Index (HSI) values typically range from zero (0; "unsuitable habitat") to one (1; "suitable habitat"), and may be derived based on expert opinion, literature reviews, and/or habitat data collected in the field (Jones and Tonn 2004).

The SI curves presented in Section 2.2.1 have been used to develop HSIs for the species, lifestages, activities (i.e., overwintering and/or spawning), and flow scenarios (i.e., normal versus reduced flows resulting from Project operation) of interest. For this study, the HSI value for a particular species or life stage was considered to be equal to the minimum value of the suitability indices (SI1 and SI2) that corresponded to the habitat variables V1 (depth) and V2 (velocity), respectively (Golder 2005; Golder 2008; Hubert et al. 1985). The calculated HSI values were assigned to four groups and classified as follows:

HSI = 0.0000 to 0.2500: unsuitable habitat;

HSI = 0.2501 to 0.5000: poor habitat;

HSI = 0.5001 to 0.7500: moderately suitable habitat; and

HSI = 0.7501 to 1.0000: suitable habitat.

Because the surface area associated with each River2D model output data point (i.e., each depth and velocity pair) could be determined based on its Thiessen polygon size, it was possible to quantify the amount of habitat assigned to each of the four HSI groupings under various flow scenarios. The amount of overall habitat potentially lost due to construction and operation of the Project was also determined for the simulated sections of river. The HSI values derived from the depth and velocity pairs were imported into a GIS platform; each River2D data point was geo-referenced to a location within the simulated sections of the Fond du Lac River (Figure 1).

Areas of suitable and moderately suitable habitat were then mapped and compared among the flow scenarios assessed.

2.2.3 Sensitivity Analysis

Because the SI curves for depth and velocity preferences of fish are based on site-specific data, professional knowledge, and values reported in the literature, there is expected to be some inherent uncertainty in the curves themselves and in the HSI model results. A sensitivity analysis was completed for a subset of the Arctic grayling spawning data to determine how sensitive the HSI model outputs are to small changes in the depth and velocity SI curves. The results of the sensitivity analysis therefore describe the accuracy of the model output data.

The sensitivity analysis was completed for spawning habitats available to Arctic grayling in Fond du Lac River reaches 2 through 13 (i.e., Segment 1 of the modelled River2D data) during 400 m^3/s average spring flows. The depth and velocity components of the spawning HSI values for Arctic grayling were changed one at a time to determine the overall influence of each component on the HSI results. Four total scenarios were assessed; these included:

- Scenario 1: depth curve shifted to the left by 10% with the velocity curve unchanged;
- Scenario 2: depth curve shifted to the right by 10% with the velocity curve unchanged;
- Scenario 3: depth curve unchanged with the velocity curve shifted to the left by 10%; and
- Scenario 4: depth curve unchanged with the velocity curve shifted to the right by 10%.

The values used to construct the curves for the sensitivity analysis are summarized in Appendix 12.1-C, Tables C1 and C2. HSI values based on data for the four scenarios listed above were calculated according to the methods described in Section 2.2.2.

3.0 RESULTS

3.1 Overwintering

3.1.1 Overwintering Habitat Variables

3.1.1.1 *Depth*

The maximum depths reported in each reach are presented in Figure 20 and Table 4 for the normal low flow scenario (210 m^3/s), as well as for the 50 m^3/s, 40 m^3/s and 30 m^3/s riparian flow options. Percent deviation from the normal winter low flow (210 m^3/s) scenario is also included for each of the minimum riparian flow options that are being assessed for the Project. In Figure 20 and all subsequent similar figures, “cms” is used to abbreviate “cubic metres per second” instead of “m^3/s”.

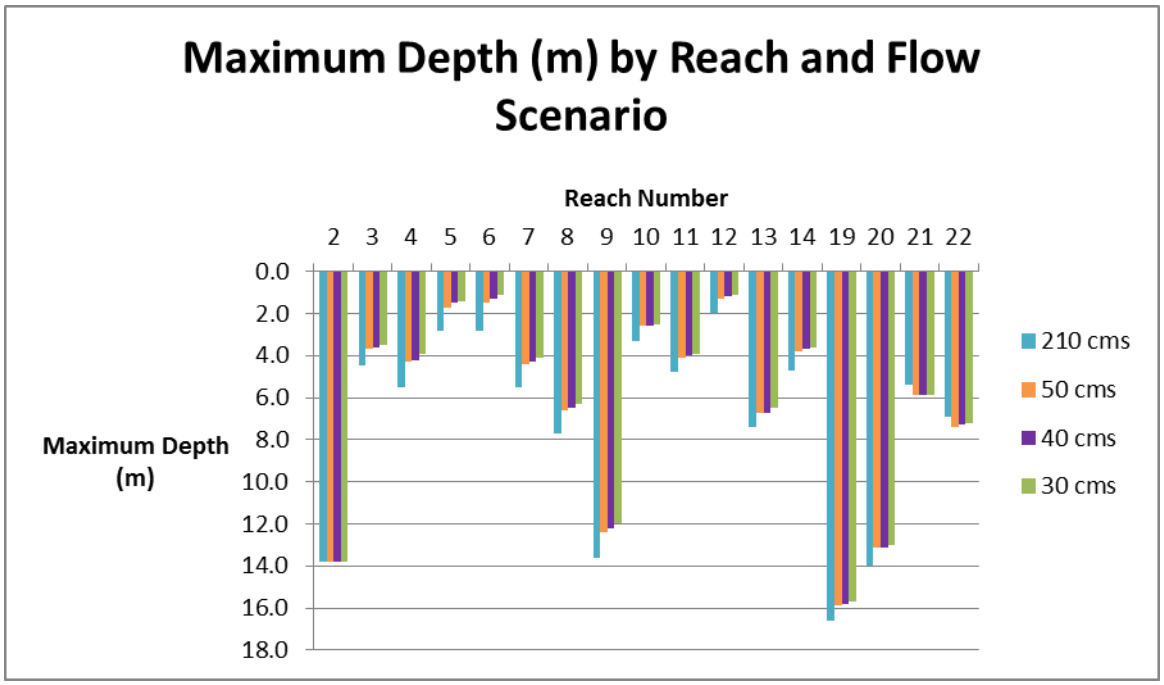


Figure 20: Maximum Depths of River Reaches between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Table 4: Maximum Depth (m) by Reach and Flow Scenario

Reach	Reach Class[a]	Maximum Depth (m)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Max (m)	Max (m)	% Change	Max (m)	% Change	Max (m)	% Change
2	R2[b]	13.8	13.8	0.0	13.8	0.0	13.8	0.0
3	RA	4.5	3.7	-17.8	3.6	-20.0	3.5	-22.2
4	R2	5.5	4.3	-21.8	4.2	-23.6	3.9	-29.1
5	FA	2.8	1.7	-39.3	1.5	-46.4	1.4	-50.0
6	R2	2.8	1.5	-46.4	1.3	-53.6	1.1	-60.7
7	RA	5.5	4.4	-20.0	4.3	-21.8	4.1	-25.5
8	R2	7.7	6.6	-14.3	6.5	-15.6	6.3	-18.2
9	P1	13.6	12.4	-8.8	12.2	-10.3	12.0	-11.8
10	RA	3.3	2.6	-21.2	2.6	-21.2	2.5	-24.2
11	R2	4.8	4.1	-14.6	4.0	-16.7	3.9	-18.8
12	RA	2.0	1.3	-35.0	1.2	-40.0	1.1	-45.0
13	R2	7.4	6.7	-9.5	6.7	-9.5	6.5	-12.2

Table 4: Maximum Depth (m) by Reach and Flow Scenario (continued)

Reach	Reach Class[a]	Maximum Depth (m)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Max (m)	Max (m)	% Change	Max (m)	% Change	Max (m)	% Change
14	R4[c]	4.7	3.8	-19.1	3.7	-21.3	3.6	-23.4
19	P1	16.6	15.9	-4.2	15.8	-4.8	15.7	-5.4
20	R2	14.0	13.1	-6.4	13.1	-6.4	13.0	-7.1
21	RA	5.4	5.9	9.3	5.9	9.3	5.9	9.3
22	R2	6.9	7.4	7.2	7.3	5.8	7.2	4.3

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m = metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

Because Reach 2 is located upstream of the proposed submerged weir structure, the amount of water and therefore maximum water depths in this reach are not expected to deviate from normal conditions when the Project is operating during winter. The percent change in maximum depth for this reach is expected to be equal to zero during winter (Table 4). Under each of the reduced flow scenarios (50, 40 and 30 m^3/s), Reach 6 (run) exhibited the greatest predicted decreases in maximum depth relative to the 210 m^3/s flow (Figure 20, Table 4). The maximum depth of Reach 19 (pool) decreased the least when flows were reduced; maximum depths in reaches 20 (run) and 9 (pool) also decreased very little relative to other reaches. Decreases in maximum depth with decreasing flows were similar among reaches containing rapids (i.e., reaches 3, 7, and 10). Reaches 21 and 22 were the only reaches where predicted maximum depths were greater than normal historical values whenever flows were reduced (i.e., the only reaches where a positive percent change in maximum depth was observed) (Table 4). These reaches are likely affected by backwater effects caused by the inflow of 190 m^3/s from the tailrace channel outlet in Reach 22.

The mean depths reported in each reach for the four winter flow scenarios are presented in Figure 21 and Table 5. Percent deviation from the historical average winter flow (210 m^3/s) is included in Table 5 for the 50 , 40 and 30 m^3/s minimum riparian flow options that are being considered for the Project.

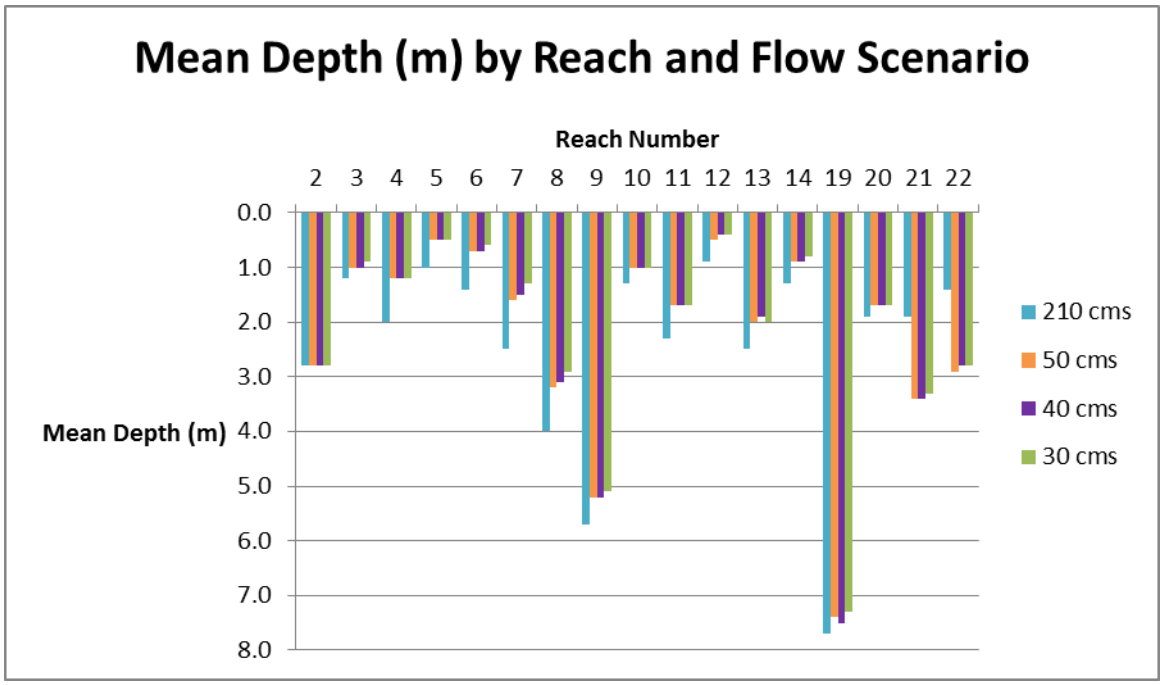


Figure 21: Mean Depths of River Reaches between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Table 5: Mean Depth (m) by Reach and Flow Scenario

Reach	Reach Class[a]	Mean Depth (m)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Mean (m)	Mean (m)	% Change	Mean (m)	% Change	Mean (m)	% Change
2	R2[b]	2.8	2.8	0.0	2.8	0.0	2.8	0.0
3	RA	1.2	1.0	-16.7	1.0	-16.7	0.9	-25.0
4	R2	2.0	1.2	-40.0	1.2	-40.0	1.2	-40.0
5	FA	1.0	0.5	-50.0	0.5	-50.0	0.5	-50.0
6	R2	1.4	0.7	-50.0	0.7	-50.0	0.6	-57.1
7	RA	2.5	1.6	-36.0	1.5	-40.0	1.3	-48.0
8	R2	4.0	3.2	-20.0	3.1	-22.5	2.9	-27.5
9	P1	5.7	5.2	-8.8	5.2	-8.8	5.1	-10.5
10	RA	1.3	1.0	-23.1	1.0	-23.1	1.0	-23.1
11	R2	2.3	1.7	-26.1	1.7	-26.1	1.7	-26.1
12	RA	0.9	0.5	-44.4	0.4	-55.6	0.4	-55.6
13	R2	2.5	2.0	-20.0	1.9	-24.0	2.0	-20.0

Table 5: Mean Depth (m) by Reach and Flow Scenario (continued)

Reach	Reach Class[a]	Mean Depth (m)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Mean (m)	Mean (m)	% Change	Mean (m)	% Change	Mean (m)	% Change
14	R4[c]	1.3	0.9	-30.8	0.9	-30.8	0.8	-38.5
19	P1	7.7	7.4	-3.9	7.5	-2.6	7.3	-5.2
20	R2	1.9	1.7	-10.5	1.7	-10.5	1.7	-10.5
21	RA	1.9	3.4	78.9	3.4	78.9	3.3	73.7
22	R2	1.4	2.9	107.1	2.8	100.0	2.8	100.0

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m = metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

It is anticipated that the proposed submerged weir structure will maintain the amount of water, and therefore mean water depths, in Reach 2 when the Project is operating during winter. The percent change in maximum depth for this reach is expected to be equal to zero during winter (Figure 21 Table 5). When modelled flows were reduced from 210 m^3/s to one of the reduced flow scenarios (50, 40 and 30 m^3/s), the greatest decreases in mean depth occurred in reaches 5 (falls), 6 (run) and 12 (rapids). The slowest-moving reaches (i.e., the pool habitats in reaches 9 and 19) exhibited the smallest decreases in mean depth whenever modelled flows were reduced from 210 m^3/s; mean depths in Reach 19 decreased by 3.9%, 2.6% and 5.2% when flows were reduced to 50 m^3/s, 40 m^3/s and 30 m^3/s, respectively. Reaches 21 and 22 were the only reaches where predicted mean depths were greater than normal historical values whenever flows were reduced. Mean depths in Reach 21 are expected to increase by approximately 75% to 80% when the Project is operating during winter; mean depths in Reach 22 are expected to double (Figure 21, Table 5).

The overall distribution of depths that were modelled for the Fond du Lac River reaches 2 through 14 and 19 through 22 is presented in Figure 22. Depth values were classified into groups of approximately 1 m (e.g., the first group contains depths between 0 and 0.9999 m). The depth distribution comparison is based on the sum of river area (square metres [m^2]) associated with each depth classification group.

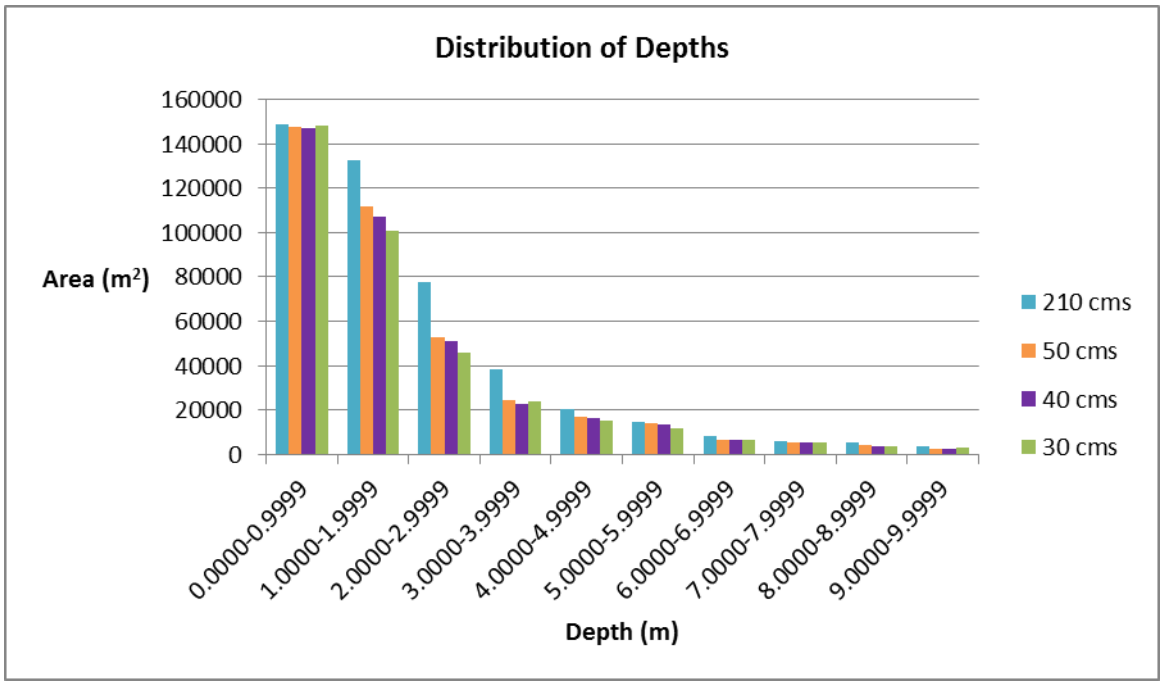


Figure 22: Distribution of River Surface Area by Depth in River Reaches between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Shallow-water areas predominated under each of the four flow scenarios. For each of the 210, 50, 40, and 30 m^3/s flows, the largest proportion of river area had depths within the 0.0000 to 0.9999 m range, representing approximately 32%, 38%, 38% and 40% of the distributions, respectively. The graph is truncated at a depth of approximately 10 m to improve presentation of the data; areas with depths greater than 10 m represented 1.8%, 1.4%, 1.3%, and 1.3% of the total river areas under each of the 210, 50, 40, and 30 m^3/s flows, respectively.

3.1.1.2 *Velocity*

The mean water velocities modelled for reaches 2 through 14 and 19 through 22 are presented in Figure 23 and Table 6. Mean velocities expected in each reach during 50, 40, and 30 m^3/s flows were compared to the mean velocities calculated for the 210 m^3/s historical low flow reference. Percent changes in reach velocity are shown in Table 6 along with the means.

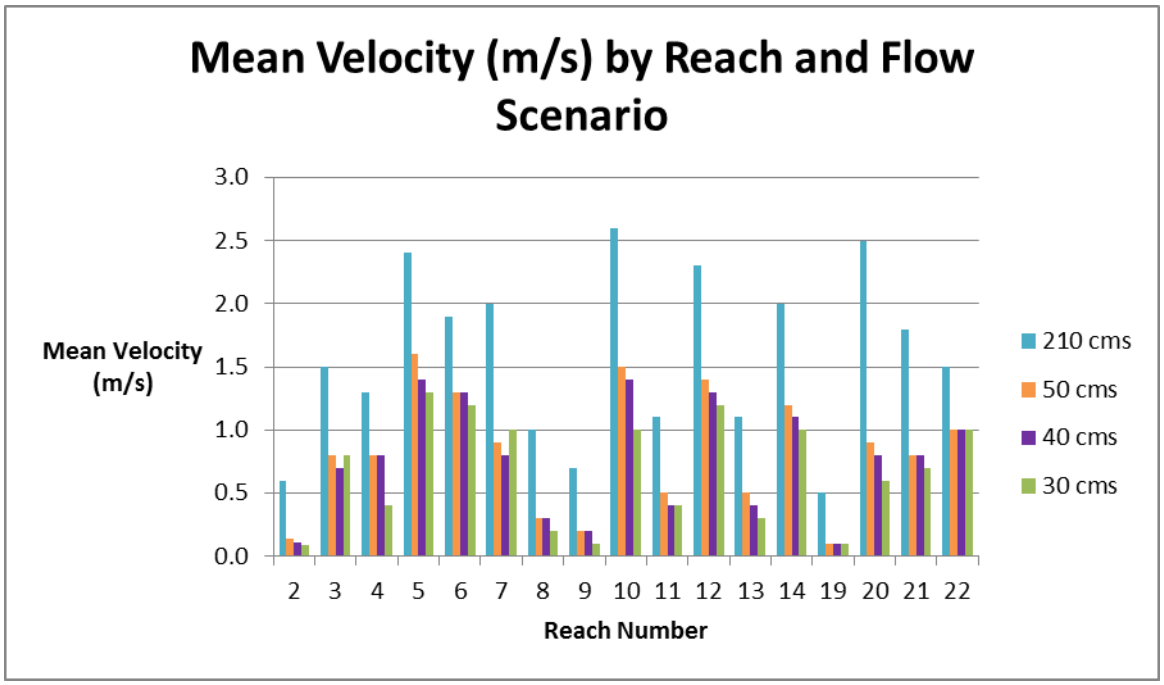


Figure 23: Mean Water Velocities of River Reaches between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Table 6: Mean Water Velocity (m/s) by Reach and Flow Scenario

Reach	Reach Class[a]	Mean Velocity (m/s)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Mean (m/s)	Mean (m/s)	% Change	Mean (m/s)	% Change	Mean (m/s)	% Change
2	R2[b]	0.6	0.14	-76.7	0.11	-81.7	0.09	-85.7
3	RA	1.5	0.8	-46.7	0.7	-53.3	0.8	-46.7
4	R2	1.3	0.8	-38.5	0.8	-38.5	0.4	-69.2
5	FA	2.4	1.6	-33.3	1.4	-41.7	1.3	-45.8
6	R2	1.9	1.3	-31.6	1.3	-31.6	1.2	-36.8
7	RA	2.0	0.9	-55.0	0.8	-60.0	1.0	-50.0
8	R2	1.0	0.3	-70.0	0.3	-70.0	0.2	-80.0
9	P1	0.7	0.2	-71.4	0.2	-71.4	0.1	-85.7
10	RA	2.6	1.5	-42.3	1.4	-46.2	1.0	-61.5
11	R2	1.1	0.5	-54.5	0.4	-63.6	0.4	-63.6
12	RA	2.3	1.4	-39.1	1.3	-43.5	1.2	-47.8
13	R2	1.1	0.5	-54.5	0.4	-63.6	0.3	-72.7

Table 6: Mean Water Velocity (m/s) by Reach and Flow Scenario (continued)

Reach	Reach Class[a]	Mean Velocity (m/s)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Mean (m/s)	Mean (m/s)	% Change	Mean (m/s)	% Change	Mean (m/s)	% Change
14	R4[c]	2.0	1.2	-40.0	1.1	-45.0	1.0	-50.0
19	P1	0.5	0.1	-80.0	0.1	-80.0	0.1	-80.0
20	R2	2.5	0.9	-64.0	0.8	-68.0	0.6	-76.0
21	RA	1.8	0.8	-55.6	0.8	-55.6	0.7	-61.1
22	R2	1.5	1.0	-33.3	1.0	-33.3	1.0	-33.3

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m/s = metres per second; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

Because a submerged weir will be constructed at the Black Lake outflow to the Fond du Lac River, it is anticipated that Project operation will not alter flow depths in Reach 2; however reductions in flow volumes, and therefore flow velocities, are predicted for Reach 2. As in all other reaches that were assessed, the mean velocities were lower at the 50, 40 and 30 m^3/s flows than at the 210 m^3/s historically normal low winter flow. In Reach 2 (located above the proposed submerged weir), mean velocities are expected to be lower than those associated with the historical normal low winter flow by 76.7%, 81.7% and 85.7% for modelled Project winter flows of 50, 40, and 30 m^3/s, respectively (Figure 23, Table 6). In reaches 9 (pool) and 22 (run), modelled mean velocities decreased as flows were reduced from 210 to 50 m^3/s, but remained stable at the 50, 40, and 30 m^3/s flows (Figure 23, Table 6). Overall, mean velocities are expected to decrease the most in pool habitats (i.e., reaches 9 and 19) and above the submerged weir (Reach 2) when the Project is operating and winter riparian flows are reduced. The smallest decreases in mean velocity with decreasing riparian flows are expected to occur in reaches 6 (run) and 22 (run); the mean velocities in these reaches will decrease by approximately one-third (Table 6).

The overall distribution of velocities that were modelled for the Fond du Lac River reaches 2 through 14 and 19 through 22 is presented in Figure 24. Groupings of approximately 0.1 m/s were used to demonstrate the distribution of the velocity data (e.g., the first group contains velocities between 0 and 0.0999 m/s). Comparisons are based on the sum of river area (m^2) associated with each velocity classification group.

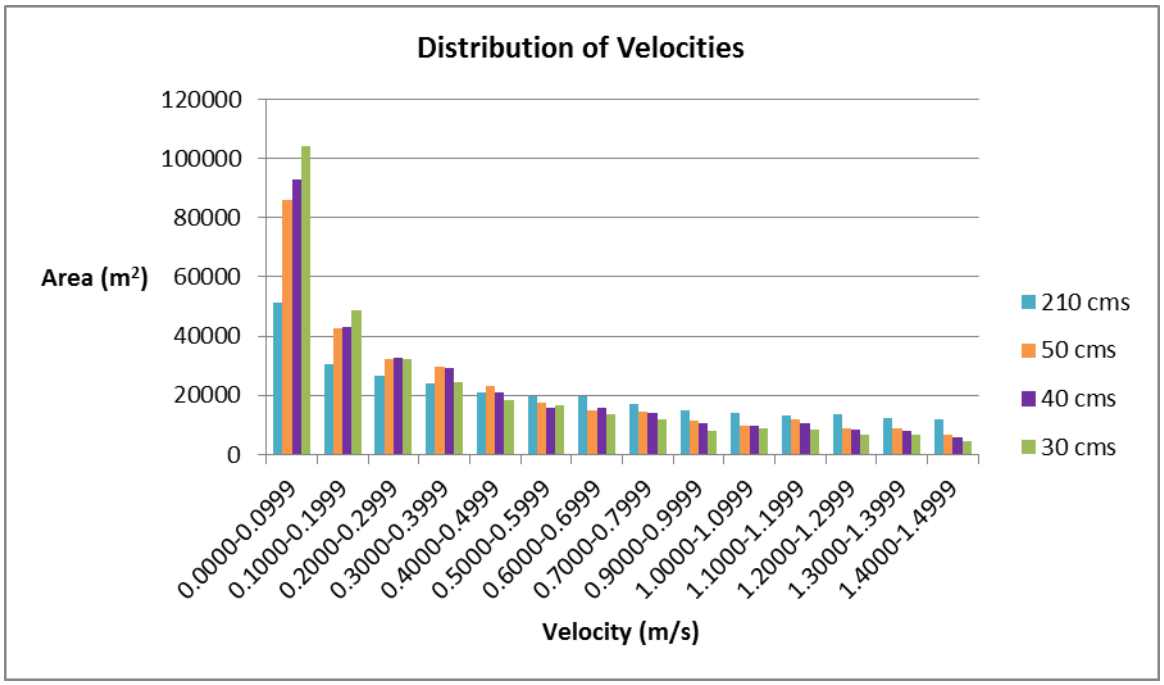


Figure 24: Distribution of River Surface Area by Velocity Values in River Reaches between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

The areas modelled for the 210 m^3/s reference low flow scenario have velocities that are more widely distributed amongst the velocity groups than those associated with the three lower flow scenarios. The velocity distributions shown for the 50, 40, and 30 m^3/s flows demonstrate a general trend toward decreased velocities with decreased flow rates (Figure 24). For example, the group containing the lowest velocities (0.0000 to 0.0999 m/s) represents 11%, 22%, 24%, and 28% of the total wetted surface area in the Fond du Lac River for the 210 m^3/s, 50 m^3/s, 40 m^3/s, and 30 m^3/s flow scenarios, respectively. Bins for velocities greater than 1.4999 m/s were not presented in Figure 24 because velocities above this value were considered to be above velocity tolerances of principle fish species. Areas with velocities greater than 1.4999 m/s represented approximately 34%, 16%, 14%, 13%, and 20% of the total river areas under each of the 210, 50, 40, and 30 m^3/s flows, respectively.

3.1.1.3 *Area*

The total areas of Reaches 2 through 14 and 19 through 22 are presented in Figure 25 and Table 7. Total reach areas for the 50, 40, and 30 m^3/s flow scenarios were compared to those calculated for the 210 m^3/s historical low flow reference. Percent gains or losses in total reach area are shown in Table 7.

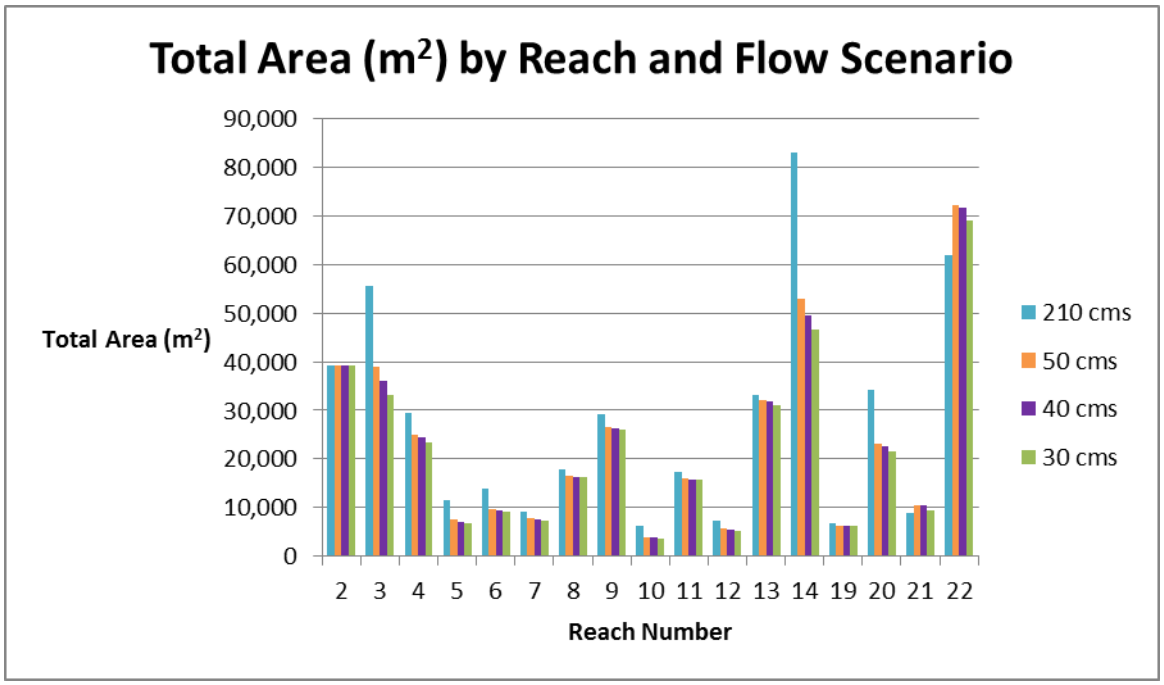


Figure 25: Total Wetted Surface Areas of River Reaches between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Table 7: Total Area (m^2) by Reach and Flow Scenario

Reach	Reach Class[(a)]	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
2	R2[(b)]	39,166	39,166	0.0	39,166	0.0	39,166	0.0
3	RA	55,608	38,950	-30.0	36,182	-34.9	33,196	-40.3
4	R2	29,339	24,979	-14.9	24,350	-17.0	23,424	-20.2
5	FA	11,454	7,530	-34.3	7,073	-38.2	6,746	-41.1
6	R2	13,880	9,642	-30.5	9,289	-33.1	9,245	-33.4
7	RA	9,255	7,739	-16.4	7,587	-18.0	7,356	-20.5
8	R2	17,913	16,406	-8.4	16,191	-9.6	16,341	-8.8
9	P1	29,260	26,463	-9.6	26,180	-10.5	26,148	-10.6
10	RA	6,347	3,859	-39.2	3,819	-39.8	3,549	-44.1
11	R2	17,431	15,932	-8.6	15,671	-10.1	15,783	-9.5
12	RA	7,301	5,585	-23.5	5,328	-27.0	5,072	-30.5
13	R2	33,053	32,114	-2.8	31,959	-3.3	31,135	-5.8

Table 7: Total Area (m^2) by Reach and Flow Scenario (continued)

Reach	Reach Class[a]	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
14	R4[c]	83,108	52,922	-36.3	49,525	-40.4	46,736	-43.8
19	P1	6,635	6,268	-5.5	6,174	-6.9	6,174	-6.9
20	R2	34,175	23,095	-32.4	22,725	-33.5	21,587	-36.8
21	RA	8,795	10,415	18.4	10,365	17.9	9,305	5.8
22	R2	61,904	72,184	16.6	71,643	15.7	69,012	11.5

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m^2 = square metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

The water surface area in Reach 2 was not anticipated to deviate from normal conditions during Project operation due to pre-Project water levels being maintained by the submerged weir; as a result no percent deviation calculations were completed for this reach. The greatest percent decreases in total reach area are expected to occur in Reach 10 (pool habitat) when winter riparian flows are reduced to 50 m^3/s (39.2% decrease) or 30 m^3/s (43.8% decrease) and in Reach 14 (shallow, fast run) when flows are reduced to 40 m^3/s (40.4% decrease) (Table 7). The smallest percent decreases in total reach area occurred in Reach 13 (deep to moderately deep run) when flows were reduced from 210 m^3/s; percent decreases in this reach were equal to 2.8%, 3.3% and 5.8% for the 50, 40, and 30 m^3/s flows. Total areas of reaches 8 (deep to moderately deep run) and 19 (pool) also decreased by less than 10% whenever modelled flows were reduced below 210 m^3/s. Reaches 21 and 22 differed from all other reaches in that the total wetted surface areas of these reaches increased when modelled flows were reduced to less than 210 m^3/s. This predicted increase in reaches 21 and 22 may be attributed to changes in flow patterns and bottom characteristics (e.g., contours of the tailrace outlet bay) that might be expected to occur within this section of the river as a result of tailrace outlet construction and operation.

3.1.1.4 *Volume*

The volume of water contained in the river reaches may limit how much space and resources are available to resident fish. For this reason, total reach volumes were calculated for each of the four winter flow scenarios, and volumes for the proposed riparian flows of 50, 40, and 30 m^3/s were compared to the low flow reference (210 m^3/s). Total reach volumes are presented in Figure 26 and Table 8. Percent reductions in total reach volume are shown in Table 8.

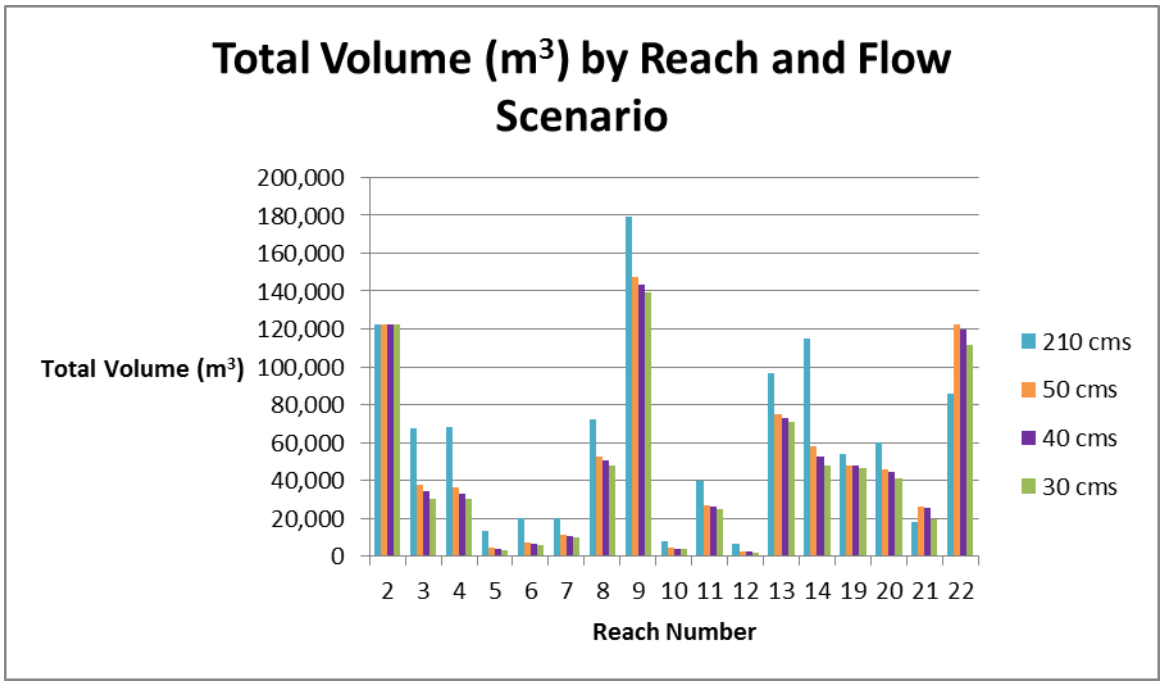


Figure 26: Total Water Volumes in River Reaches between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River

Table 8: Total Volume (m^3) by Reach and Flow Scenario

Reach	Reach Class[(a)]	Total Volume (m^3)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Volume (m^3)	Volume (m^3)	% Change	Volume (m^3)	% Change	Volume (m^3)	% Change
2	R2[(b)]	122,633	122,633	0.0	122,633	0.0	122,633	0.0
3	RA	67,533	37,450	-44.5	34,580	-48.8	30,273	-55.2
4	R2	68,104	36,481	-46.4	33,276	-51.1	30,153	-55.7
5	FA	12,982	4,168	-67.9	3,566	-72.5	3,123	-75.9
6	R2	20,246	7,524	-62.8	6,489	-67.9	5,678	-72.0
7	RA	20,344	11,357	-44.2	10,417	-48.8	9,639	-52.6
8	R2	72,050	52,676	-26.9	50,262	-30.2	47,705	-33.8
9	P1	179,331	147,248	-17.9	143,367	-20.1	139,187	-22.4
10	RA	8,021	4,340	-45.9	4,071	-49.2	3,712	-53.7
11	R2	39,751	27,117	-31.8	25,989	-34.6	25,144	-36.7
12	RA	6,711	2,600	-61.3	2,253	-66.4	1,917	-71.4
13	R2	96,562	74,991	-22.3	72,686	-24.7	70,807	-26.7

Table 8: Total Volume (m^3) by Reach and Flow Scenario (continued)

Reach	Reach Class[a]	Total Volume (m^3)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Volume (m^3)	Volume (m^3)	% Change	Volume (m^3)	% Change	Volume (m^3)	% Change
14	R4[c]	114,869	57,784	-49.7	52,921	-53.9	47,851	-58.3
19	P1	53,788	48,133	-10.5	47,545	-11.6	46,189	-14.1
20	R2	59,932	45,687	-23.8	44,134	-26.4	41,010	-31.6
21	RA	18,108	25,983	43.5	25,706	42.0	19,645	8.5
22	R2	86,135	122,440	42.1	119,563	38.8	111,667	29.6

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m^3 = cubic metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

Because Project operation is not expected to reduce water levels in Reach 2 because of the presence of the submerged weir, no changes in total volume were predicted for this reach. For reaches 21 and 22, the total reach volumes increased when riparian flows were reduced below 210 m^3/s. The biggest predicted increases occurred under the 50 m^3/s riparian flow conditions, followed by the 40 m^3/s, then 30 m^3/s. This is because the 50 m^3/s riparian flow plus the modelled (i.e., 190 m^3/s) tailrace outlet flow will amount to a greater volume of water entering Reach 22 than either of the 40 m^3/s or 30 m^3/s flows plus the tailrace outlet flow. Total reach volumes in all other reaches decreased with decreasing riparian flows (Table 8). Total volume predicted for the falls in Reach 5 exhibited the greatest percent decrease from normal when flows were reduced; percent decreases of 67.9%, 72.5% and 75.9% were predicted based on the 50, 40, and 30 m^3/s flows. Large decreases in total volume were also predicted for reaches 6 and 12. Reach 6 is a deep to moderately deep run; Reach 12 represents a set of rapids. The smallest decreases in total volume were observed for pool habitats in reaches 9 and 19. Reach 19 had the smallest percent decreases in total volume relative to the other reaches for the 50 m^3/s (10.5% decrease), 40 m^3/s (11.6% decrease), and 30 m^3/s (14.1% decrease) flow scenarios. With the exception of reaches 21 and 22, the lowest total volumes for all reaches occurred under 30 m^3/s flows (Figure 26, Table 8).

3.1.2 Overwintering Habitat Assessment

3.1.2.1 *Arctic grayling*

3.1.2.1.1 Age-0/Juveniles

The quantity of unsuitable, poor, moderately suitable, and suitable overwintering habitat available to age-0 and juvenile Arctic grayling in the Fond du Lac River reaches between Black Lake and Middle Lake is summarized in Table 9. Reaches 2 through 14 and 19 through 22 are represented in the table. Habitat suitability indices (HSIs) are based on the lowest of either the depth SI value or the velocity SI value for age-0/juvenile Arctic grayling.

Table 9: Total Areas (m^2) Associated with Unsuitable, Poor, Moderately Suitable, or Suitable Habitat for Age-0 and Juvenile Arctic Grayling (*Thymallus arcticus*) Overwintering in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
0.0000-0.2500	Unsuitable	388,164	305,512	-21.3	295,512	-23.9	277,116	-28.6
0.2501-0.5000	Poor	19,183	22,043	14.9	21,153	10.3	23,235	21.1
0.5001-0.7500	Moderately Suitable	13,610	16,070	18.1	14,159	4.0	15,376	13.0
0.7501-1.0000	Suitable	43,666	49,625	13.6	52,401	20.0	54,247	24.2

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

Under all four winter flow scenarios, the largest proportion of river area falls within the category of unsuitable habitat, followed by suitable, poor, and then moderately suitable habitat. Based on the data in Table 9, the amount of suitable habitat available to age-0 and juvenile Arctic grayling is anticipated to increase with each subsequent decrease in flow rate (i.e., at the 50, 40, and 30 m^3/s steps). Areas of moderately suitable overwintering habitat are also expected to increase whenever riparian flows are reduced as a result of Project operation; however, such increases are not expected to occur in a stepwise manner (i.e., the smallest percent increase occurs at 40 m^3/s). The areas for each of the habitat classification types are presented in Figure 27 for the base low flow condition (210 m^3/s) and the three reduced riparian flow scenarios (i.e., 50, 40, and 30 m^3/s).

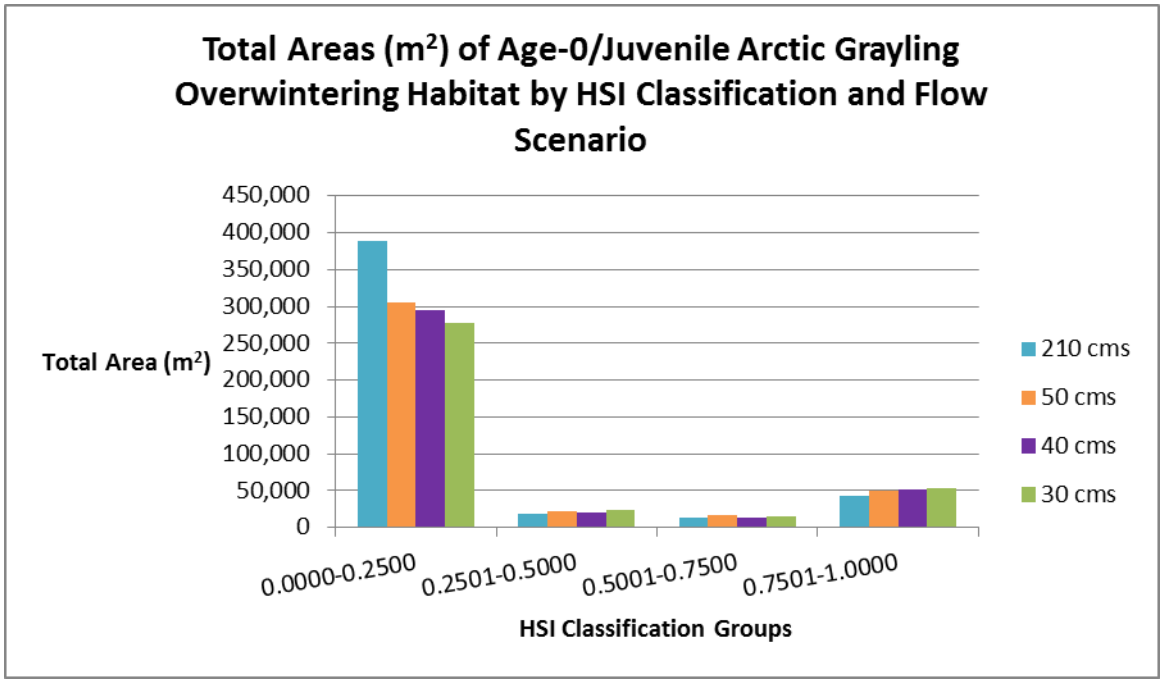


Figure 27: Total Areas of Overwintering Habitat for Age-0 and Juvenile Arctic Grayling in Fond du Lac River Reaches between Black Lake and Middle Lake by HSI Value and Flow Scenario

Based on Table 9 and Figure 27, unsuitable habitats will be lost, and all other habitat types will be gained when flows are decreased as a result of Project operation during winter. Areas of suitable habitat are expected to increase by 13.6%, 20.0%, and 24.2% as flows decrease from 210 m^3/s to 50 m^3/s, 40 m^3/s and 30 m^3/s, respectively. The predicted increases in total areas of suitable and moderately suitable habitats for overwintering age-0 and juvenile Arctic grayling is attributed to decreases in average velocities and depths observed for the reduced flow scenarios.

The quantity of unsuitable, poor, moderately suitable and suitable overwintering habitat available to age-0 and juvenile Arctic grayling in the Fond du Lac River was also determined for individual reaches. Tables and figures for reaches 2 through 14 and 19 through 22 are presented in Appendix 12.1-D, Table D1 and Figures D1 to D17. The largest gains in overwintering habitat are expected to occur in Reach 13 (deep to moderately deep run) when flows are decreased to 50 m^3/s (349.7% gain), 40 m^3/s (466.9% gain) or 30 m^3/s (439.4%). Areas of suitable overwintering habitat for age-0 and juvenile Arctic grayling in reaches 10 (rapids) and 21 (rapids) are also anticipated to increase by more than double when flows are reduced. Maps depicting likely areas of moderately suitable and suitable overwintering habitat for age-0/juvenile Arctic grayling in reaches 2 through 14 and 19 through 22 of the Fond du Lac River are presented in Appendix 12.1-F (Figures F1 to F12).

3.1.2.1.2 Adults

The quantity of unsuitable, poor, moderately suitable, and suitable overwintering habitat available to adult Arctic grayling in the Fond du Lac River reaches between Black Lake and Middle Lake is summarized in Table 10. Reaches 2 through 14 and 19 through 22 are represented in the table. Habitat suitability indices (HSIs) are based on the lowest of either the depth SI value or the velocity SI value for adult Arctic grayling.

Table 10: Total Areas (m^2) Associated with Unsuitable, Poor, Moderately Suitable, or Suitable Habitat for Adult Arctic Grayling (*Thymallus arcticus*) Overwintering in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
0.0000-0.2500	Unsuitable	250,657	143,274	-42.8	134,144	-46.5	123,932	-50.6
0.2501-0.5000	Poor	30,803	24,269	-21.2	22,005	-28.6	18,704	-39.3
0.5001-0.7500	Moderately Suitable	51,573	48,172	-6.6	46,779	-9.3	42,479	-17.6
0.7501-1.0000	Suitable	131,589	177,536	34.9	180,297	37.0	184,859	40.5

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

For the 210 m^3/s flow scenario, the largest proportion of river area falls within the category of unsuitable overwintering habitat, followed by suitable, moderately suitable, and then poor habitat. For the three low flow scenarios however, the largest proportion of river area was classified as suitable overwintering habitat for adult Arctic grayling (Table 10); the remaining river area was predominantly classified as unsuitable, then moderately suitable, and then poor. Based on data presented in Table 10, the amount of suitable overwintering habitat available to adult Arctic grayling is anticipated to increase with each subsequent decrease in flow rate (i.e., at the 50, 40, and 30 m^3/s steps) due to associated decreases in average flow velocities. Areas lost and gained within each of the habitat classification types as a result of changes in riparian flow are presented in Figure 28.

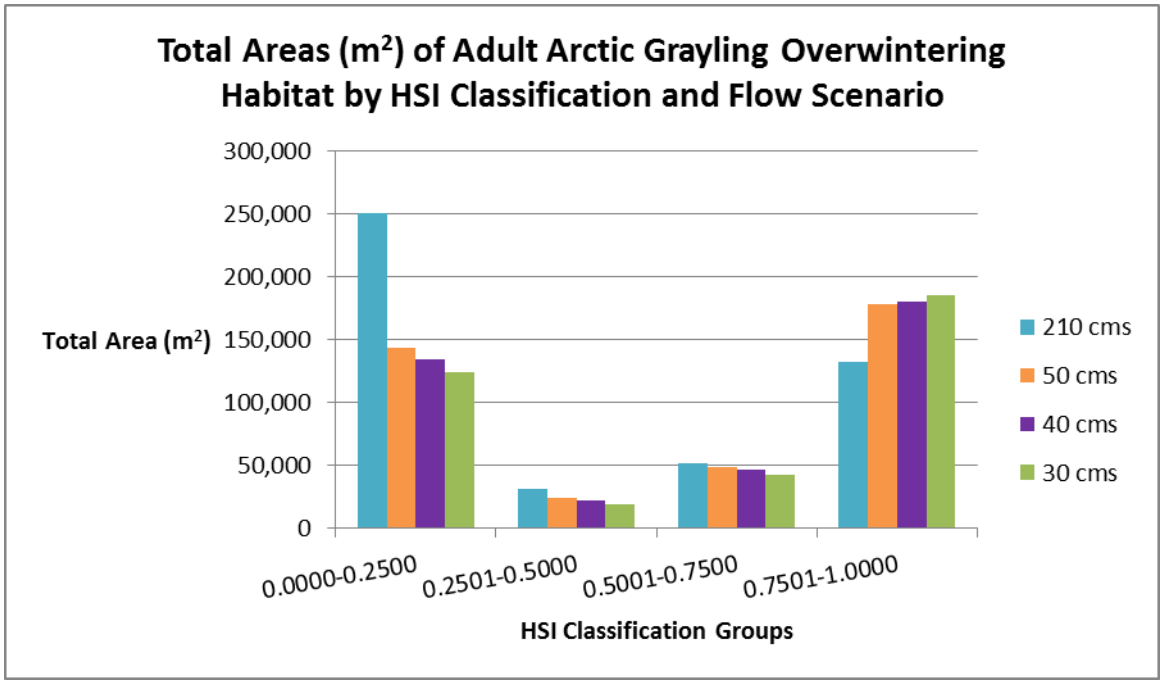


Figure 28: Total Areas of Overwintering Habitat for Adult Arctic Grayling in Fond du Lac River Reaches between Black Lake and Middle Lake by HSI Value and Flow Scenario.

Based on the data presented in Table 10 and Figure 28, the largest loss of total area will occur to unsuitable habitat while suitable habitat will increase with each subsequent decrease in flow rate (i.e., at the 50, 40, and 30 m^3/s steps). Poor and moderately suitable habitat will also decrease with each decrease in flow rate. The increase in suitable habitat is attributed to decreases in average flow velocities under the reduced flow scenarios.

The quantity of unsuitable, poor, moderately suitable and suitable overwintering habitat available to adult Arctic grayling in the Fond du Lac River was also determined by reach. Tables and figures for individual reaches are presented in Appendix 12.1-D, Table D2 and Figures D18 to D34. The largest gains in suitable overwintering habitat for adult Arctic grayling are expected to occur in reaches 3 (rapids) and 21 (rapids) when flows are reduced as a result of Project operation during winter. Unsuitable habitat will be lost from all reaches, except reaches 2 and 22, when flows in the bypassed section of the river are reduced and tailrace outlet flows in Reach 22 are equivalent to 190 m^3/s. Maps depicting likely areas of moderately suitable and suitable overwintering habitat for age-0/juvenile Arctic grayling in reaches 2 through 14 and 19 through 22 of the Fond du Lac River are presented in Appendix 12.1-F (Figures F13 to F24).

3.1.2.2 *Sucker Species*

3.1.2.2.1 Age-0/Juveniles

The quantity of unsuitable, poor, moderately suitable, and suitable overwintering habitat available to age-0 and juvenile sucker species in the Fond du Lac River reaches between Black Lake and Middle Lake is summarized in Table 11. Reaches 2 through 14 and 19 through 22 are represented in the table. Habitat suitability indices (HSIs) are based on the lowest of either the depth SI value or the velocity SI value for age-0/juvenile sucker species.

Table 11: Total Areas (m^2) Associated with Unsuitable, Poor, Moderately Suitable, or Suitable Habitat for Age-0 and Juvenile Suckers (*Catostomus* species) Overwintering in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
0.0000-0.2500	Unsuitable	388,882	308,790	-20.6	298,587	-23.2	279,876	-28.0
0.2501-0.5000	Poor	10,261	11,806	15.1	11,276	9.9	14,609	42.4
0.5001-0.7500	Moderately Suitable	9,555	11,676	22.2	11,361	18.9	10,826	13.3
0.7501-1.0000	Suitable	55,925	60,978	9.0	62,000	10.9	64,664	15.6

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

Under all four flow scenarios, the largest portion of river area falls within the category of unsuitable habitat, followed by suitable habitat. Areas of poor and moderately suitable habitat were predicted to be fairly similar within each of the four winter flow scenarios. Based on the data presented in Table 11, the amount of suitable habitat available to age-0 and juvenile sucker species is anticipated to increase with each subsequent decrease in flow rate (i.e., at the 50, 40, and 30 m^3/s steps). Areas of moderately suitable habitat are also predicted to be more prevalent at 50 m^3/s (11,676 m^2), 40 m^3/s (11,361 m^2) and 30 m^3/s (10, 826 m^2) flows than under normal low winter flow conditions (210 m^3/s; 9,555 m^2). The areas for each of the habitat classification types are presented in Figure 29 for the base condition (210 m^3/s) and the three reduced riparian flow scenarios (i.e., 50, 40, and 30 m^3/s).

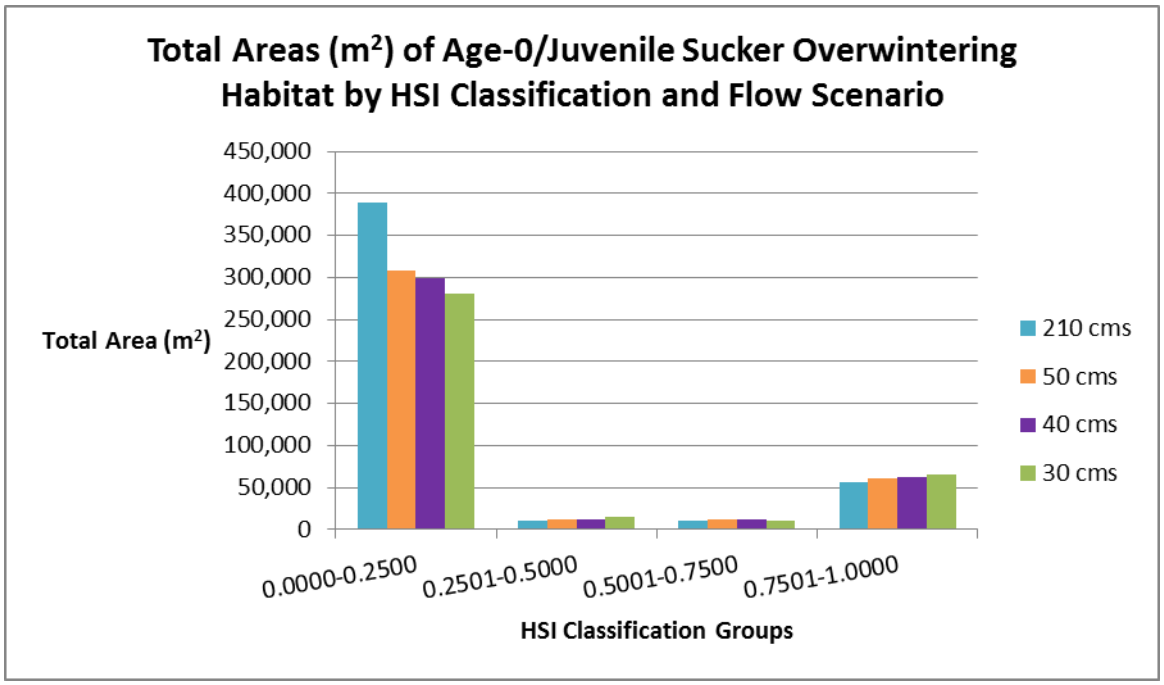


Figure 29: Total Areas of Overwintering Habitat for Age-0 and Juvenile Suckers in Fond du Lac River Reaches between Black Lake and Middle Lake by HSI Value and Flow Scenario.

Based on the data presented in Table 11 and Figure 29, unsuitable overwintering habitats will be lost and areas of poor, moderately suitable and suitable habitat will be gained whenever flows are reduced as a result of Project operation during winter. Suitable overwintering habitat for age-0 and juvenile suckers is predicted to increase by 9.0%, 10.9% and 15.6% when winter riparian flows are decreased from 210 m^3/s to 50 m^3/s, 40 m^3/s and 30 m^3/s, respectively.

The quantity of unsuitable, poor, moderately suitable and suitable overwintering habitat available to age-0 and juvenile sucker species in the Fond du Lac River was also determined by reach. Tables and figures for individual reaches are presented in Appendix 12.1-D, Table D3 and Figures D35 to D51. In some reaches, such as Reach 12 (rapid) and Reach 14 (shallow, fast run), areas of suitable habitat are expected to decrease in size (m^2) when riparian flows are decreased from 210 m^3/s to between 50, 40, or 30 m^3/s. However, these losses may be considered minor relative the major gains in suitable habitat observed in other reaches. For example, suitable habitat is expected to increase by 569.7%, 632.9%, and 548.3% in Reach 13 (deep to moderately deep run) when flows are reduced to 50 m^3/s, 40 m^3/s and 30 m^3/s, respectively.

3.1.2.2.2 Adults

The quantity of unsuitable, poor, moderately suitable, and suitable overwintering habitat available to adult sucker species in the Fond du Lac River reaches between Black Lake and Middle Lake is summarized in Table 12. Reaches 2 through 14 and 19 through 22 are represented in the table. Habitat suitability indices (HSIs) are based on the lowest of either the depth SI value or the velocity SI value for adult sucker species.

Table 12: Total Areas (m^2) Associated with Unsuitable, Poor, Moderately Suitable, or Suitable Habitat for Adult Suckers (*Catostomus* species) Overwintering in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
0.0000-0.2500	Unsuitable	267,783	148,938	-44.4	136,501	-49.0	120,138	-55.1
0.2501-0.5000	Poor	34,811	34,856	0.1	34,731	-0.2	34,301	-1.5
0.5001-0.7500	Moderately Suitable	26,756	29,400	9.9	28,864	7.9	28,781	7.6
0.7501-1.0000	Suitable	135,273	180,056	33.1	183,129	35.4	186,754	38.1

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

Under the 210 m^3/s flow scenario, the largest proportion of river area falls within the category of unsuitable habitat, followed by suitable, poor, and then moderately suitable habitat. For each of the 50, 40, and 30 m^3/s flow scenarios however, the largest proportion of river area is classified as suitable, followed by unsuitable, poor, and then moderately suitable. The amount of suitable overwintering habitat available to adult sucker species is anticipated to increase by approximately 33.1% when flows are reduced to 50 m^3/s; gains in suitable habitat are expected to be greater yet when average normal flows are reduced to 40 m^3/s or 30 m^3/s (Table 12). Areas lost or gained in each of the habitat classification groups are presented in Figure 30.

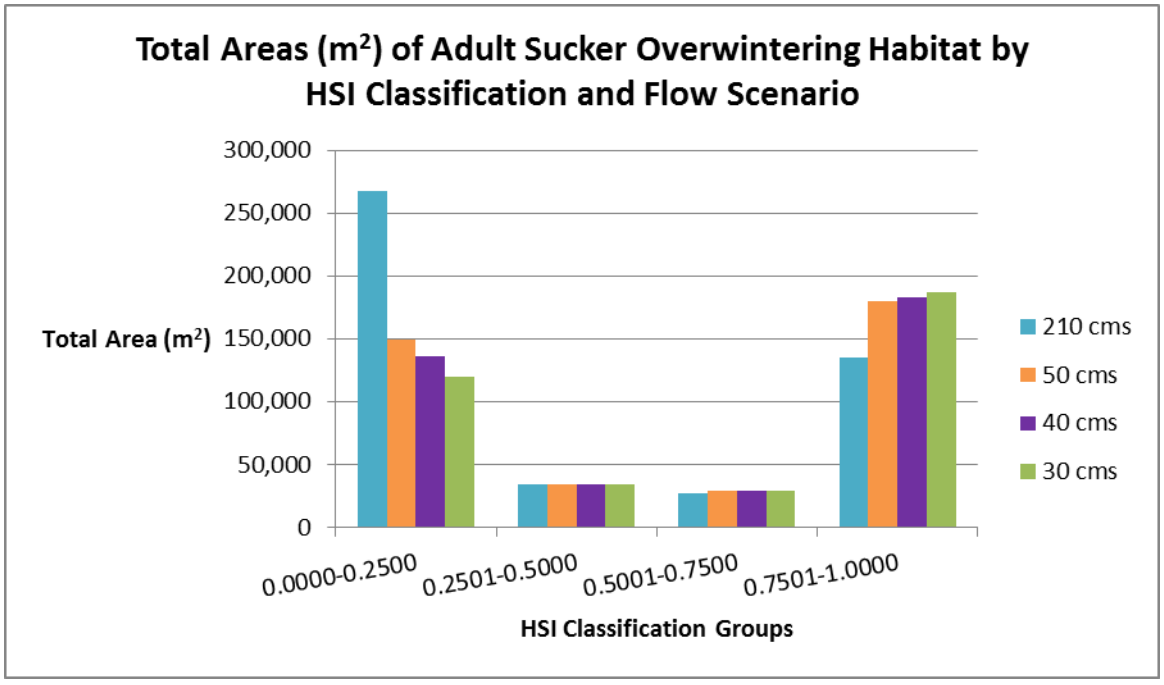


Figure 30: Total Areas of Overwintering Habitat for Adult Suckers in Fond du Lac River Reaches between Black Lake and Middle Lake by HSI Value and Flow Scenario.

Based on the data presented in Table 12 and Figure 30, the largest loss of total area will occur to unsuitable habitat; areas of suitable habitat will be greater under reduced flow conditions (i.e., at the 50, 40, and 30 m^3/s

steps) than under normal historical low flow conditions (210 m^3/s). Any losses or gains in poor habitat are expected to be minor (i.e., ≤ 1.5%) when flows are reduced. The overall increase in suitable and moderately suitable overwintering habitat for adult longnose sucker and white sucker is attributed to the associated decreases in average flow velocities and the prevalence of deep-water habitats in the Fond du Lac River between Black Lake and Middle Lake.

The quantity of unsuitable, poor, moderately suitable and suitable overwintering habitat available to adult sucker species in the Fond du Lac River was also determined by reach. Tables and figures for individual reaches are presented in Appendix 12.1-D, Table D4 and Figures D52 to D68. Areas of suitable overwintering habitat for adult suckers are expected to increase in the majority of modelled reaches; the exceptions include reaches 5 (falls), 6 (run) and 20 (run). Areas of suitable habitat in Reach 21 are expected to expand the most as a result of Project operation.

3.2 Spawning

3.2.1 Spawning Habitat Variables

3.2.1.1 *Depth*

The maximum depths reported in each reach for the six spring flow scenarios that were assessed are presented in Table 13, as well as Figures 31, 32 and 33. Percent deviation from the historical Q10 average low spring flow (302 m^3/s) is included in Table 13 for the 112 m^3/s riparian flow scenario. Percent deviation from the historical average spring flow (400 m^3/s) and Q90 average high spring flow (510 m^3/s) are also included for the 210 m^3/s and 320 m^3/s riparian flow scenarios, respectively.

Table 13: Maximum Depth (m) by Reach and Flow Scenario

Reach	Reach Class[(a)]	Maximum Depth (m)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Max (m)	Max (m)	% Change	Max (m)	Max (m)	% Change	Max (m)	Max (m)	% Change
2	R2[(b)]	14.1	13.2	-6.4	14.4	13.8	-4.2	14.4	13.9	-3.5
3	RA	4.8	4.0	-16.7	5.1	4.5	-11.8	5.2	4.7	-9.6
4	R2	6.0	4.8	-20.0	6.3	5.5	-12.7	6.5	5.8	-10.8
5	FA	3.2	2.2	-31.3	3.6	2.8	-22.2	3.9	3.2	-17.9
6	R2	3.3	2.0	-39.4	3.7	2.8	-24.3	4.0	3.2	-20.0
7	RA	5.8	5.0	-13.8	6.1	5.5	-9.8	6.6	6.0	-9.1
8	R2	8.1	7.1	-12.3	8.4	7.7	-8.3	8.7	8.1	-6.9
9	P1	14.0	12.9	-7.9	14.3	13.6	-4.9	14.6	13.9	-4.8
10	RA	3.7	3.0	-18.9	3.9	3.3	-15.4	4.2	3.7	-11.9
11	R2	5.2	4.4	-15.4	5.5	4.8	-12.7	5.9	5.2	-11.9

Reach	Reach Class[a]	Maximum Depth (m)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Max (m)	Max (m)	% Change	Max (m)	Max (m)	% Change	Max (m)	Max (m)	% Change
12	RA	2.4	1.6	-33.3	2.7	2.0	-25.9	2.8	2.3	-17.9
13	R2	7.7	6.9	-10.4	8.0	7.4	-7.5	8.1	7.6	-6.2
14	R4[c]	4.9	4.3	-12.2	5.2	4.7	-9.6	5.6	5.0	-10.7
19	P1	16.9	16.3	-3.6	17.1	16.6	-2.9	17.3	16.9	-2.3
20	R2	14.1	13.6	-3.5	14.4	14.0	-2.8	14.6	14.2	-2.7
21	RA	5.6	6.1	8.9	5.9	6.3	6.8	6.2	6.5	4.8
22	R2	7.2	7.6	5.6	7.6	7.8	2.6	8.0	8.2	2.5

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m = metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

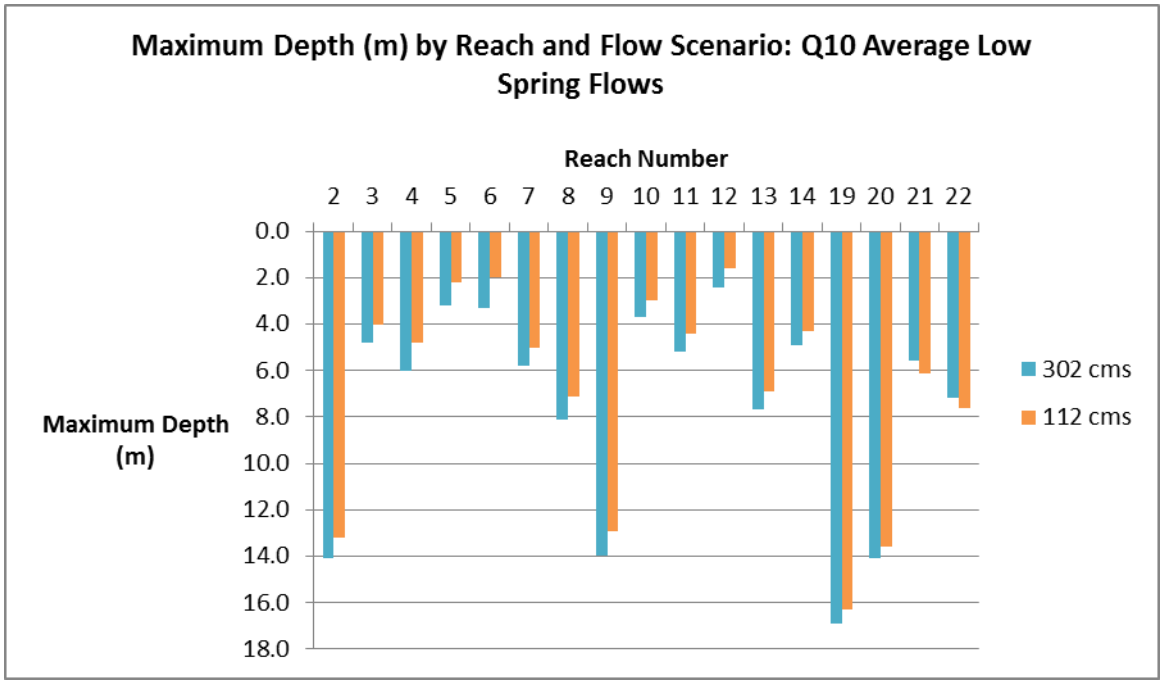


Figure 31: Maximum Depths of River Reaches between Black Lake and Middle Lake for the 302 m^3/s and 112 m^3/s Spring Flow Scenarios in the Fond du Lac River.

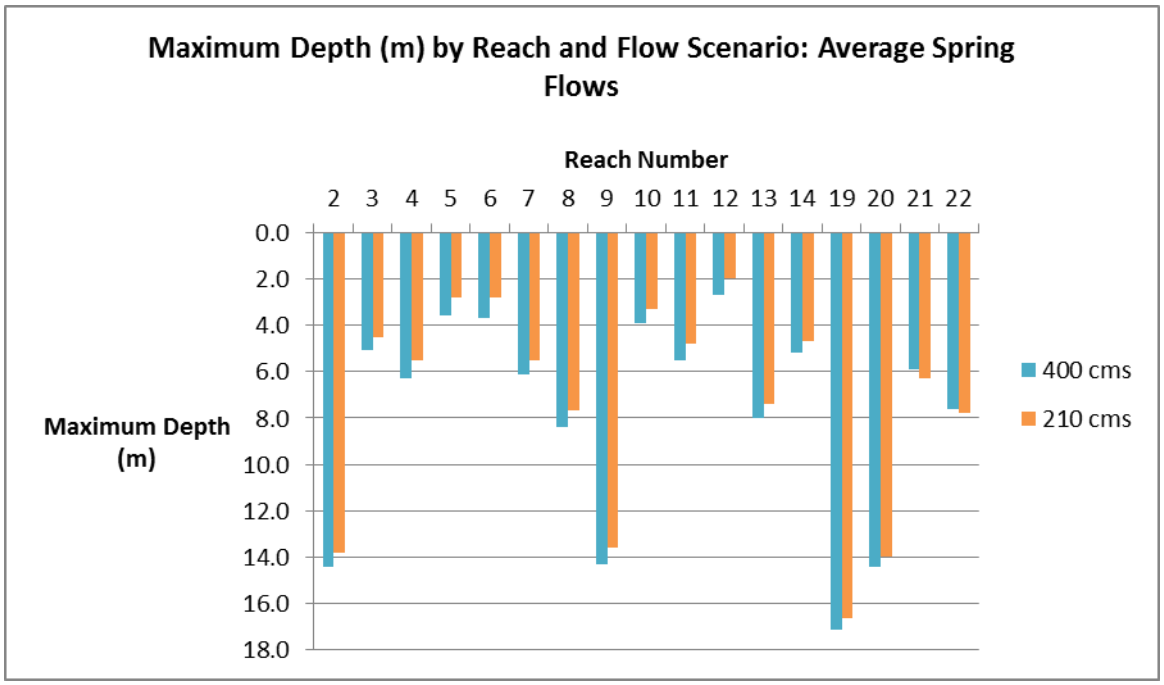


Figure 32: Maximum Depths of River Reaches between Black Lake and Middle Lake for the 400 m^3/s and 210 m^3/s Spring Flow Scenarios in the Fond du Lac River.

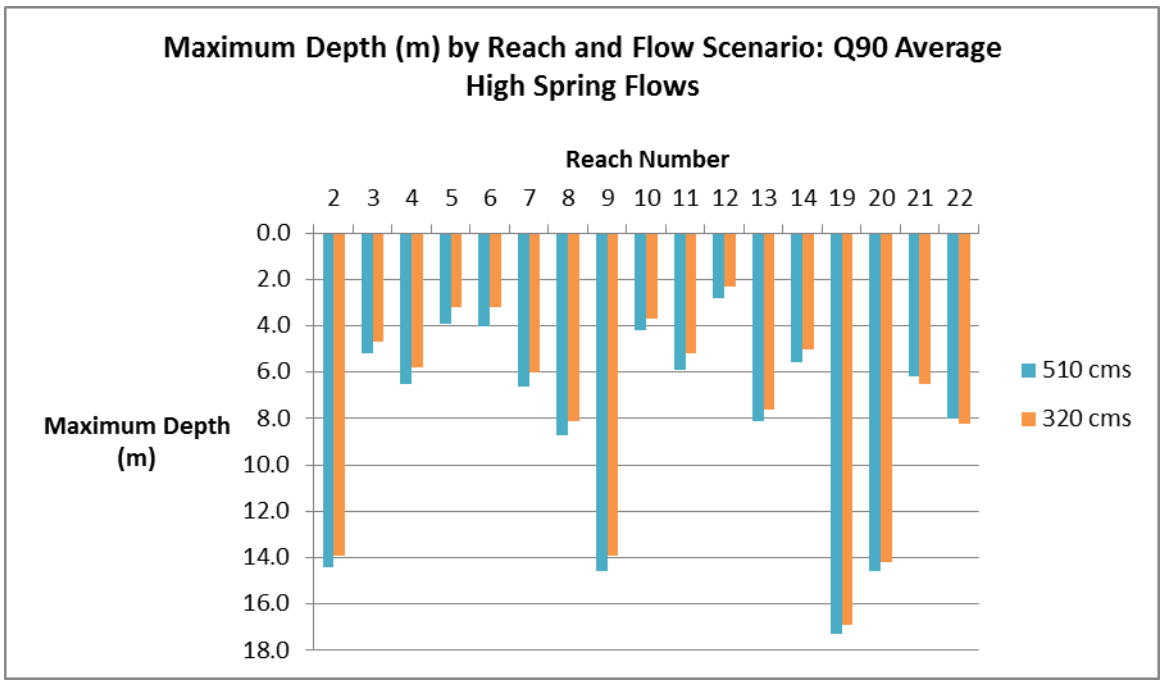


Figure 33: Maximum Depths of River Reaches between Black Lake and Middle Lake for the 510 m^3/s and 320 m^3/s Spring Flow Scenarios in the Fond du Lac River

When historically normal flows (i.e., 302, 400, and 510 m^3/s) are reduced based on power tunnel flows of 190 m^3/s, the maximum depths in all reaches except reaches 21 and 22 are expected to decrease. The increased maximum depths in reaches 21 and 2 are attributed to mixing of riparian flows with flows entering the river via the tailrace outlet, as well as changes to the channel and river bottom (e.g., changes to the contours of the tailrace outlet bay as a result of construction, development of backflow areas). Maximum depths in Reach 2 (i.e., in the vicinity of the proposed submerged rockfill weir) changed by ≤ 6.4% whenever modelled flows were reduced based on a 190 m^3/s flow through the powerhouse (Table 13). Reaches 6 (deep to moderately deep run) and 12 (rapids) are expected to exhibit the greatest percent decreases in maximum depth when the Project is operating. Whenever modelled flows were reduced below historically normal values (i.e., from 302 m^3/s, 400 m^3/s and 510 m^3/s to 112 m^3/s, 210 m^3/s and 320 m^3/s, respectively), the maximum depths of reaches 19 (pool) and 20 (deep to moderately deep run) changed the least (Figures 31, 32 and 33). In general, the maximum depths of pool habitats in reaches 9 and 19 changed very little (≤ 7.9% reduction) when flows were reduced as a result of Project operation.

Operation of the Project at a 190 m^3/s flow capacity is expected to elicit the largest percent changes in maximum depth at low spring flows (i.e., when flows are decreased from 302 m^3/s to 112 m^3/s), followed by average, then high flows for all reaches assessed (i.e., reaches 2 through 14 and 19 through 22) (Table 13). This suggests that depths in the Fond du Lac River are more sensitive to changes in flow at low spring flows, and less sensitive to water withdrawal at average and high spring flows.

The mean depths reported in each reach for the six spring flow scenarios are presented in Table 14, as well as Figures 34, 35 and 36. Percent deviation from the historical Q10 average low spring flow (302 m^3/s) is included in Table 14 for the 112 m^3/s riparian flow options that are being considered for the Project. Percent deviation from the historical average spring flow (400 m^3/s) and Q90 average high spring flow (510 m^3/s) are also included for the 210 m^3/s riparian flow scenario and the 320 m^3/s flow scenario, respectively.

Table 14: Mean Depth (m) by Reach and Flow Scenario

Reach	Reach Class[a]	Mean Depth (m)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Mean (m)	Mean (m)	% Change	Mean (m)	Mean (m)	% Change	Mean (m)	Mean (m)	% Change
2	R2[b]	2.9	3.0	3.4	3.0	2.8	-6.7	3.5	3.3	-5.7
3	RA	1.4	1.0	-28.6	1.3	1.2	-7.7	1.8	1.4	-22.2
4	R2	2.3	1.8	-21.7	1.8	2.0	11.1	2.8	2.4	-14.3
5	FA	1.3	0.8	-38.5	1.8	1.0	-44.4	2.0	1.5	-25.0
6	R2	1.7	1.2	-29.4	2.3	1.4	-39.1	2.6	2.0	-23.1
7	RA	2.8	1.9	-32.1	2.5	2.5	0.0	3.0	2.7	-10.0
8	R2	4.1	3.7	-9.8	4.3	4.0	-7.0	4.7	4.4	-6.4
9	P1	5.7	5.6	-1.8	5.6	5.7	1.8	5.6	5.4	-3.6
10	RA	1.6	1.0	-37.5	1.3	1.3	0.0	1.7	1.4	-17.6
11	R2	2.6	2.1	-19.2	2.7	2.3	-14.8	3.1	2.8	-9.7
12	RA	1.2	0.7	-41.7	1.4	0.9	-35.7	1.6	1.3	-18.8
13	R2	2.8	2.3	-17.9	2.6	2.5	-3.8	3.2	2.9	-9.4
14	R4[c]	1.5	1.1	-26.7	1.7	1.3	-23.5	1.9	1.5	-21.1
19	P1	7.9	7.7	-2.5	7.9	7.7	-2.5	8.3	7.8	-6.0
20	R2	1.9	1.8	-5.3	2.2	2.0	-9.1	2.7	2.1	-22.2
21	RA	1.9	3.5	84.2	2.2	2.9	31.8	2.5	3.9	56.0
22	R2	1.6	2.9	81.3	1.9	2.4	26.3	2.2	3.2	45.5

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m = metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

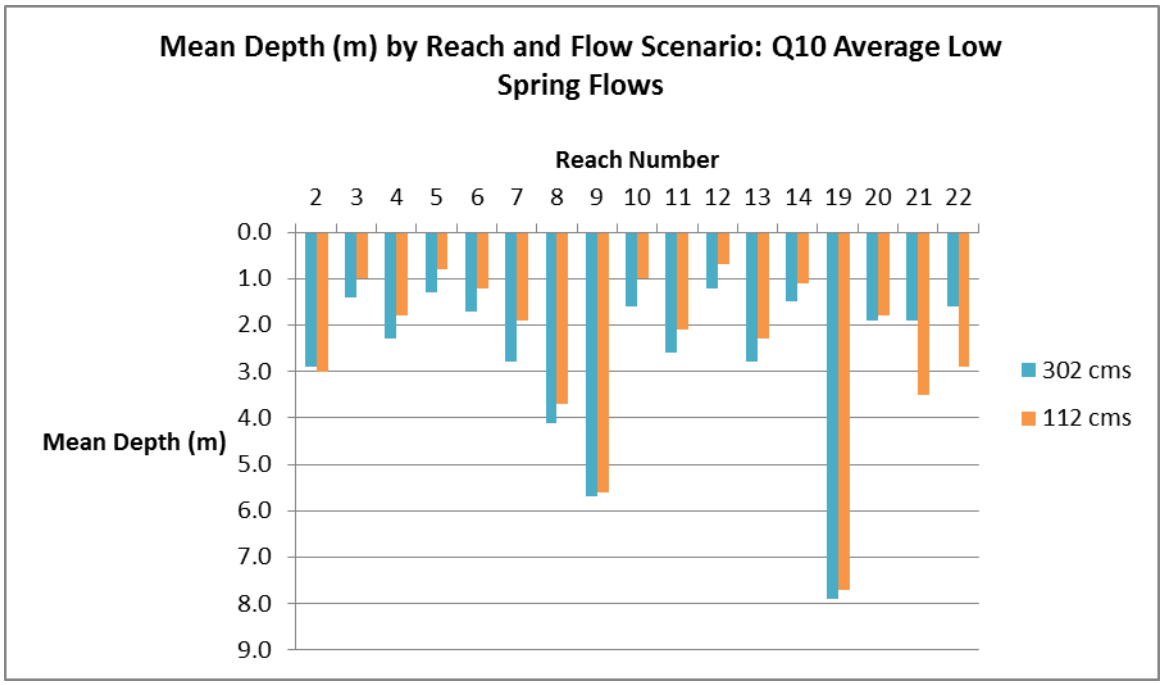


Figure 34: Mean Depths of River Reaches between Black Lake and Middle Lake for the 302 m^3/s and 112 m^3/s Spring Flow Scenarios in the Fond du Lac River

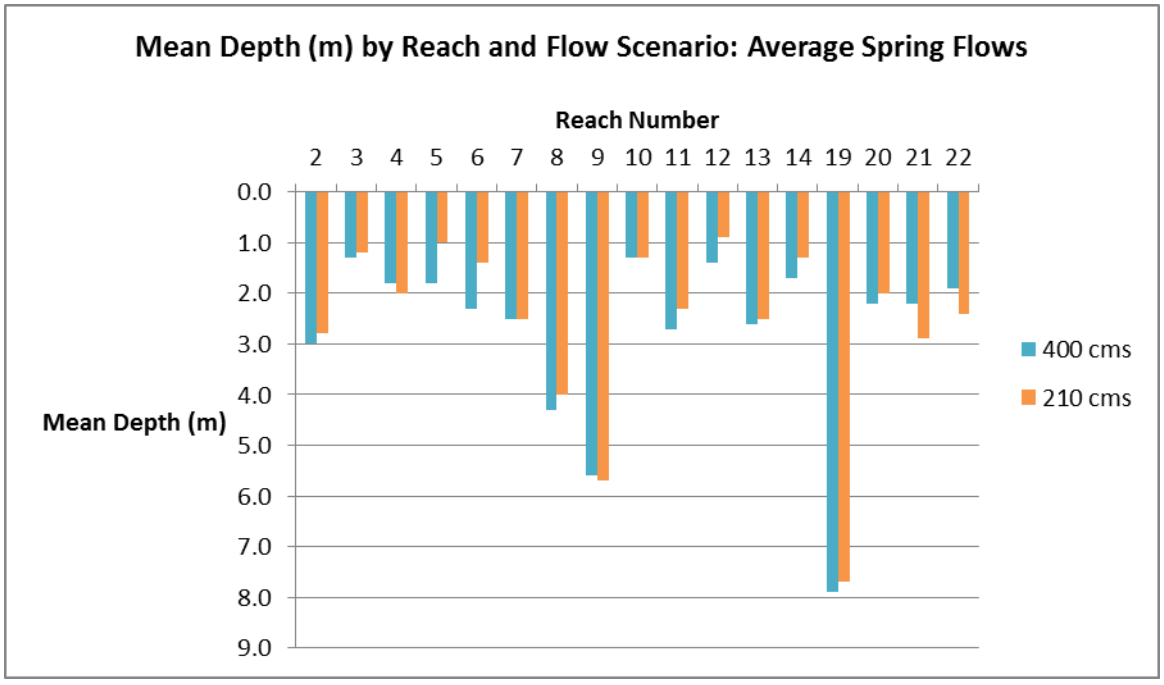


Figure 35: Mean Depths of River Reaches between Black Lake and Middle Lake for the 400 m^3/s and 210 m^3/s Spring Flow Scenarios in the Fond du Lac River

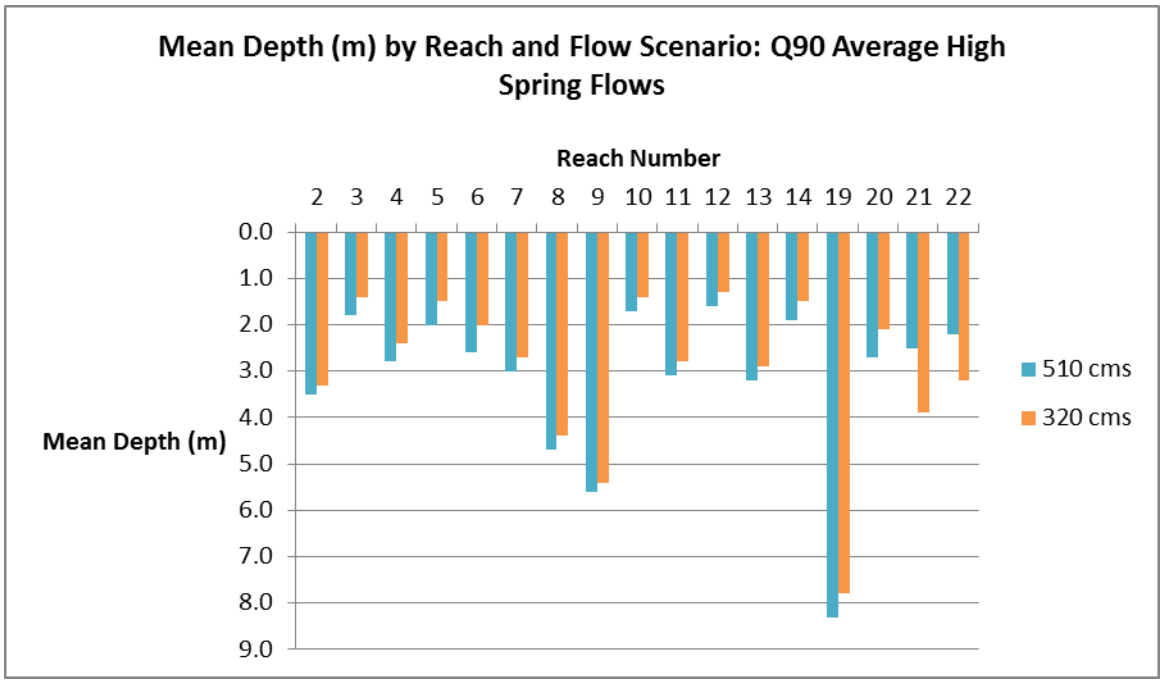


Figure 36: Mean Depths of River Reaches between Black Lake and Middle Lake for the 510 m^3/s and 320 m^3/s Spring Flow Scenarios in the Fond du Lac River

In general, mean depths of pool habitats in reaches 9 and 19 changed very little (≤ 6.0%) whenever flows were reduced as a result of Project operation (Table 14). Mean depths in Reach 2 also remained relatively stable (≤ 6.7% change) due to the submerged rockfill weir. Under normal low spring flow conditions (i.e., 302 m^3/s), operation of the Project is expected to reduce the mean depths in most reaches; the largest reductions are predicted for fast-moving areas such as Reach 5 (falls), Reach 7 (rapids), Reach 10 (rapids) and Reach 12 (rapids) (Table 14, Figure 34). However, the largest percent changes to mean depth are expected to occur in reaches 21 (84.2% increase) and 22 (81.3% increase) when riparian flows are reduced from 302 m^3/s to 112 m^3/s. Under average spring flow conditions and with the Project in place (i.e., at 210 m^3/s riparian flows), the largest change in mean depth is expected to occur in Reach 5 (falls) (Table 14). At high (i.e., Q90) flows, operation of the Project is expected to have the greatest effect on mean depths in reaches 21 and 22.

The overall distribution of depths that were modelled for the Fond du Lac River reaches 2 through 14 and 19 through 22 are presented in Figures 37, 38 and 39. These figures have been truncated at 9.9999 m for display purposes. Distributions were compared within the Q10 average low spring flow (i.e., 302 m^3/s and 112 m^3/s), average spring flow (i.e., 400 m^3/s and 210 m^3/s), and Q90 average high spring flow (i.e., 510 m^3/s and 320 m^3/s) groupings. River areas were classified into bins of approximately 1 m (e.g., the first group contains depths between 0.0000 and 0.9999 m) based on their associated depths. The depth distribution comparisons are therefore based on the sum of river area (m^2) associated with each depth classification group.

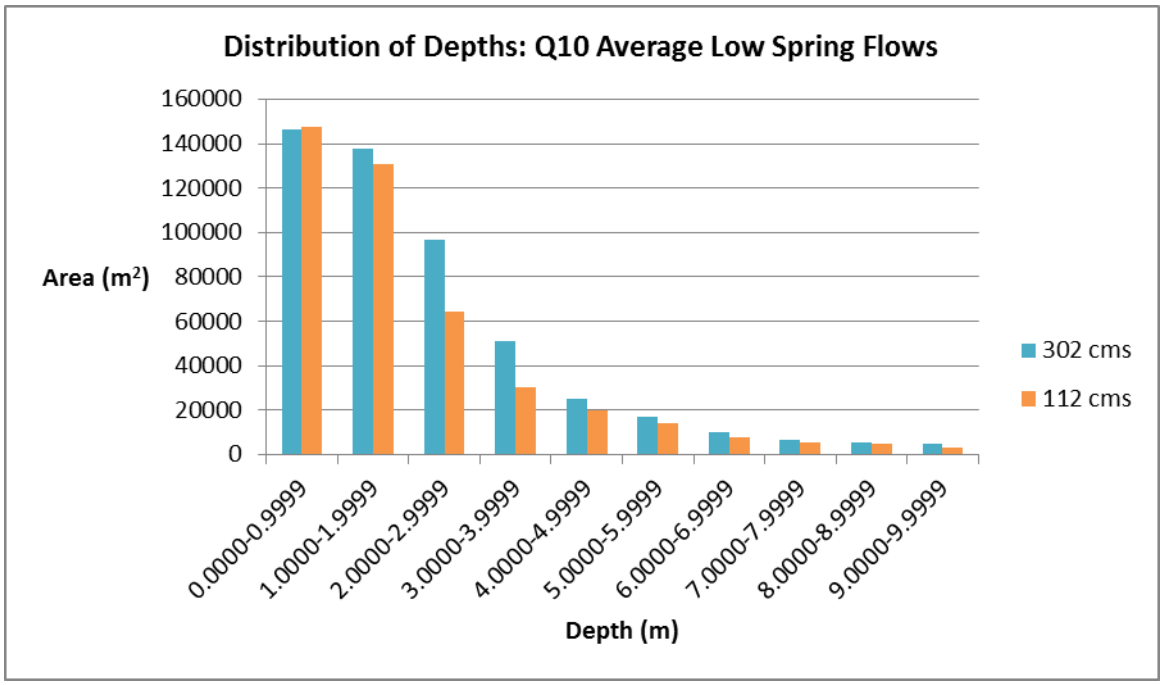


Figure 37: Distribution of River Surface Area by Depth in River Reaches between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

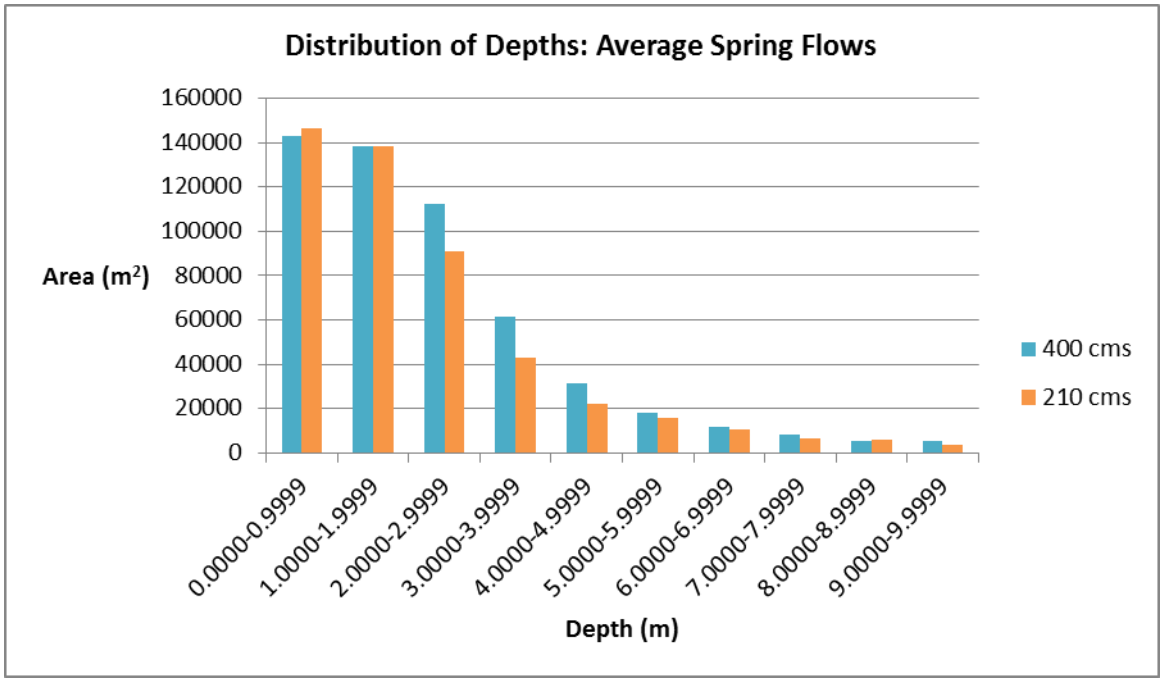


Figure 38: Distribution of River Surface Area by Depth in River Reaches between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

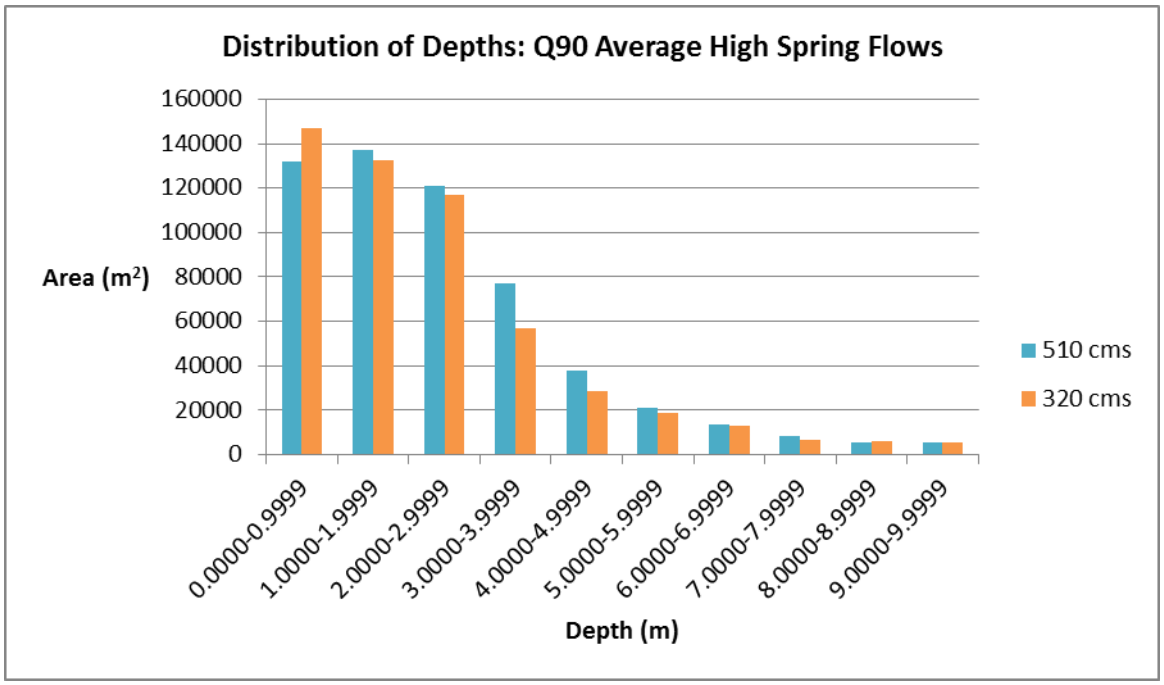


Figure 39: Distribution of River Surface Area by Depth in River Reaches between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

Based on Figures 37, 38 and 39, areas of the Fond du Lac River having depths less than approximately 3 m were most prevalent for each of the six (302, 112, 400, 210, 510, and 320 m^3/s) flow scenarios assessed. For the historical flows of 302 m^3/s and 400 m^3/s, the largest proportion of river area is expected to have depth values occurring within the 0.0000 to 0.9999 m bin; the majority of depths fall within the 1.0000 to 1.9999 m range for the 510 m^3/s historical flow. For all of the Project-related flows that were assessed (i.e., 112, 210, and 320 m^3/s), the largest proportion of river area is expected to have depths that fall within the 0.0000 to 0.9999 m bin. The largest gain in 0.0000 to 0.9999 m depths is expected to occur when normally high (i.e., 510 m^3/s) flows are reduced as a result of 190 m^3/s being diverted through the power tunnel (Figure 39). Only about 1.9%, 1.4%, 2.1%, 1.7%, 2.4%, and 1.9% of the river surface areas for the 302, 112, 400, 210, 510, and 320 m^3/s flow scenarios have depths of 10.0000 m or greater.

3.2.1.2 *Velocity*

The mean spring water velocities modelled for reaches 2 through 14 and 19 through 22 are presented in Table 15 and Figures 40, 41 and 42. Mean velocities anticipated in each reach for the 112 m^3/s flow scenario were compared to the mean velocities predicted for the 302 m^3/s historical Q10 low flow. Mean velocities for the 210 m^3/s flow were compared to mean velocities calculated for the 400 m^3/s historical average spring flow. The proposed spring Project flow of 320 m^3/s was compared to the Q90 average high spring flow (i.e., 510 m^3/s). Percent changes are shown in Table 15 along with the mean velocities.

Table 15: Mean Water Velocity (m/s) by Reach and Flow Scenario

Reach	Reach Class[a]	Mean Velocity (m/s)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Mean (m/s)	Mean (m/s)	% Change	Mean (m/s)	Mean (m/s)	% Change	Mean (m/s)	Mean (m/s)	% Change
2	R2[b]	0.6	0.3	-50.0	0.8	0.6	-25.0	0.8	0.6	-25.0
3	RA	1.8	1.4	-22.2	3.0	1.5	-50.0	2.4	2.1	-12.5
4	R2	1.5	0.9	-40.0	2.8	1.3	-53.6	1.5	1.3	-13.3
5	FA	2.7	2.2	-18.5	4.1	2.4	-41.5	3.3	3.0	-9.1
6	R2	2.1	2.0	-4.8	3.5	1.9	-45.7	3.1	2.7	-12.9
7	RA	2.3	1.7	-26.1	4.4	2.0	-54.5	3.5	2.9	-17.1
8	R2	1.1	0.5	-54.5	1.3	1.0	-23.1	2.0	1.5	-25.0
9	P1	0.9	0.3	-66.7	1.0	0.7	-30.0	1.5	1.1	-26.7
10	RA	2.9	1.7	-41.4	4.5	2.6	-42.2	3.6	2.9	-19.4
11	R2	1.3	0.9	-30.8	1.7	1.1	-35.3	1.8	1.5	-16.7
12	RA	2.4	2.1	-12.5	3.7	2.3	-37.8	3.1	2.7	-12.9
13	R2	1.1	0.8	-27.3	1.8	1.1	-38.9	1.7	1.3	-23.5
14	R4[c]	2.3	1.6	-30.4	2.6	2.0	-23.1	2.6	2.3	-11.5
19	P1	0.8	0.3	-62.5	0.8	0.5	-37.5	1.0	0.8	-20.0
20	R2	2.2	1.5	-31.8	2.5	2.0	-20.0	2.7	2.0	-25.9
21	RA	2.0	1.0	-50.0	2.3	1.4	-39.1	2.7	1.3	-51.9
22	R2	1.5	1.1	-26.7	1.8	1.3	-27.8	1.9	1.1	-42.1

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m/s = metres per second; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

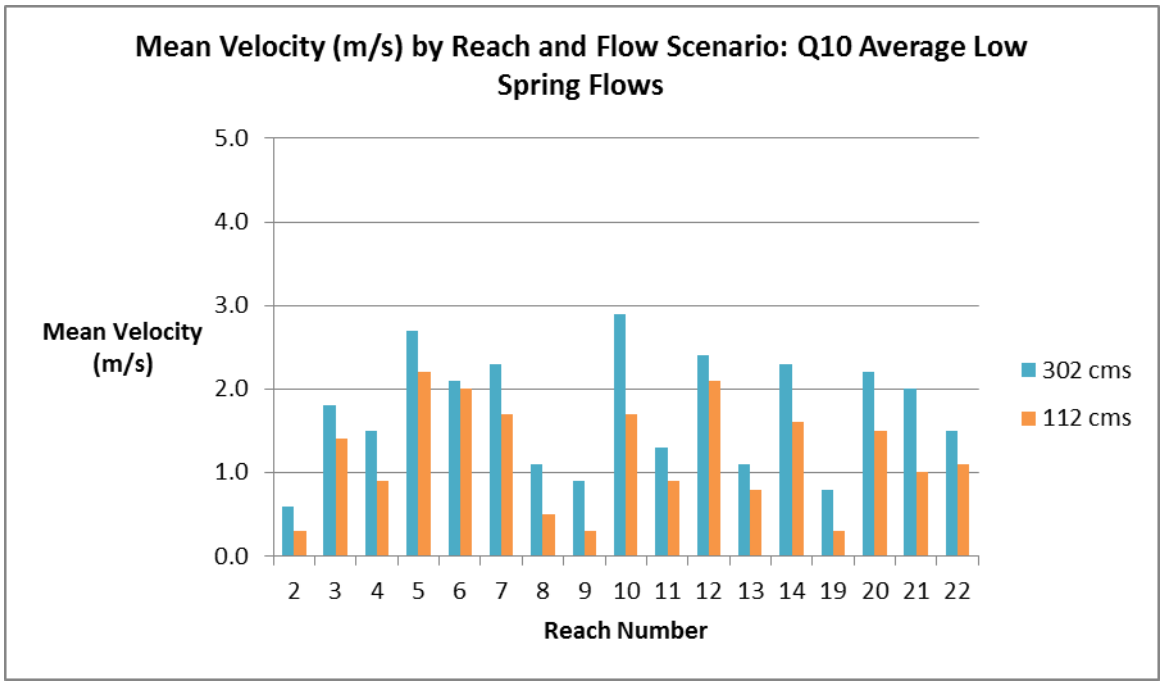


Figure 40: Mean Water Velocities of River Reaches between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

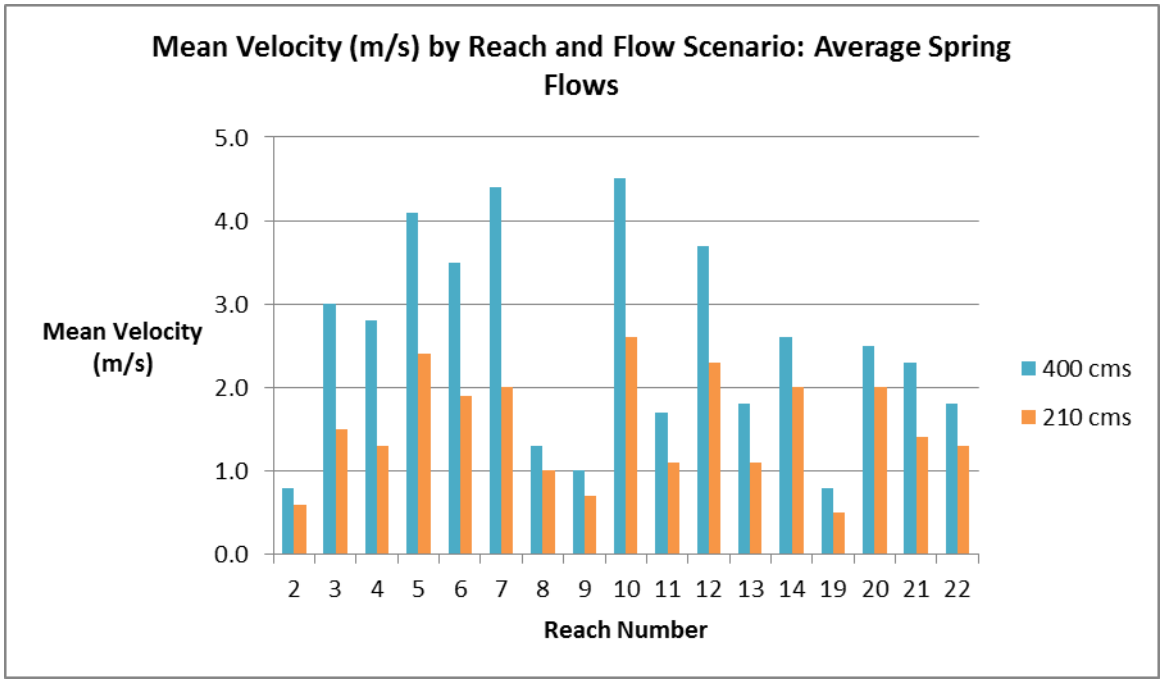


Figure 41: Mean Water Velocities of River Reaches between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

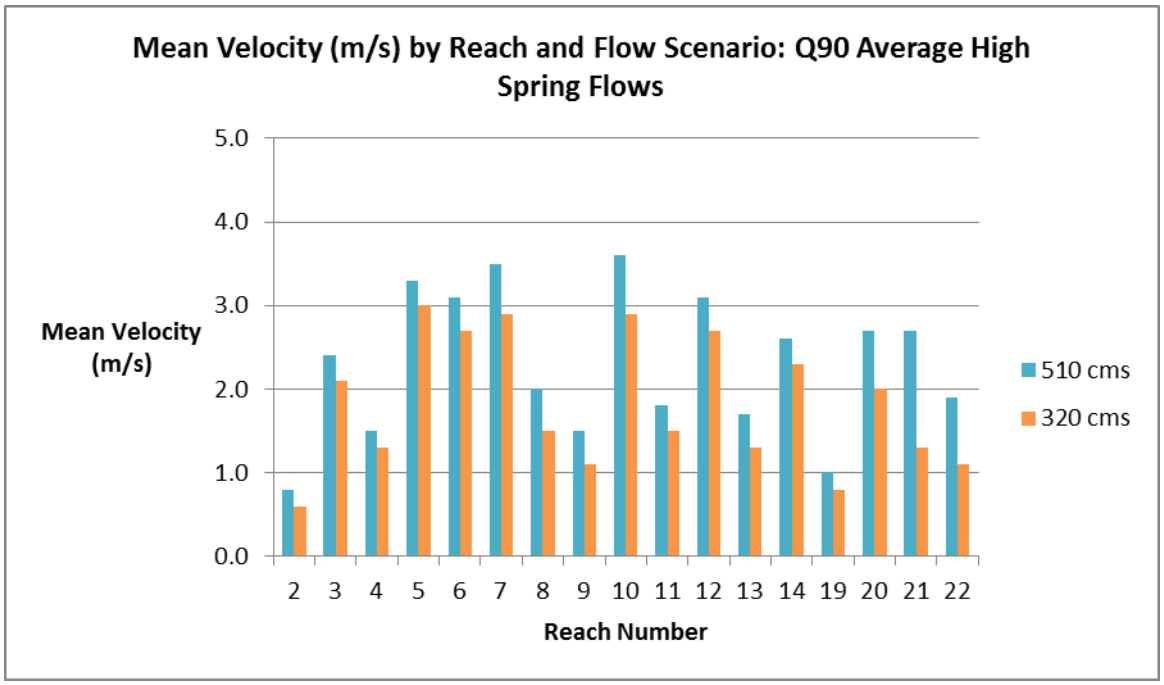


Figure 42: Mean Water Velocities of River Reaches between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

For all river reaches that were assessed, mean velocities decreased whenever modelled flows were reduced below their respective historically normal values (i.e., below 302, 400, or 510 m^3/s). Under Q10 low flow conditions, Project operation would have the greatest effect on mean velocities in pool habitats within reaches 9 (66.7% decrease) and 19 (62.5% decrease) (Table 15 and Figure 40). Mean velocities are expected to decrease the least in Reach 6 (run) when riparian flows are decreased from 302 m^3/s to 112 m^3/s. The mean velocities of reaches 4 (run) and 7 (rapids) are expected to change the most (53.6% and 54.5%, respectively) when flows are reduced from 400 m^3/s to 210 m^3/s. When 190 m^3/s of water is diverted through the powerhouse under historically normal flow conditions (i.e., 400 m^3/s), the mean velocity in Reach 20 (run) is expected to change the least (20.0% decrease (Table 15, Figure 41). At historically normal Q90 high flow levels (i.e., 510 m^3/s), diversion of water through the power tunnel is expected to cause the largest percent decreases in water velocities for reaches 21 and 22; velocities in Reach 5 (falls) will change the least (Table 15, Figure 42).

Predicted mean velocities for reaches 2 through 14 and 19 through 22 were greatest for the 400 m^3/s and 510 m^3/s flow scenarios, depending on reach class type (e.g., falls, pools). For pools (reaches 9 and 19) and approximately half of the deep to moderately deep runs, the greatest mean velocities are expected to occur during 510 m^3/s flow conditions. For areas containing swift, shallow runs or numerous falls and rapids (i.e., reaches 3 to 7, inclusive, Reach 10, and reaches 12 to 14, inclusive), the greatest mean velocities are expected to occur during the 400 m^3/s flows. Reaches 3 through 7, Reach 10, and reaches 12 through 14 are anticipated to have greater maximum depths and/or larger wetted surface areas under the 510 m^3/s flow scenario than under 400 m^3/s flow conditions. The slower average velocities in these reaches during 510 m^3/s flows are attributed to the slightly deeper depths and increased wetted surface areas (i.e., increased channel widths) that are expected to occur. Mean velocities are expected to be slowest when spring flows are naturally low (i.e., at approximately 302 m^3/s) and the Project is operating at 190 m^3/s capacity.

Wetted river areas were classified based on their modelled velocity value; the associated distribution for Fond du Lac River reaches 2 through 14 and 19 through 22 are presented in Figures 43, 44 and 45. Bin sizes of approximately 0.1 m/s were used to demonstrate the distribution of the data (e.g., the first group contains the sum area having velocities between 0.0000 and 0.0999 m/s). Bins for velocities greater than 1.4999 m/s were not presented in Figures 43, 44 and 45 because velocities above this value were considered to be above velocity tolerances of principal fish species. River areas having velocities greater than 1.4999 m/s represented approximately 39%, 20%, 47%, 32%, 54%, and 41% of the total river areas under the 302, 400, 210, 510 and 320 m^3/s flow scenarios, respectively.

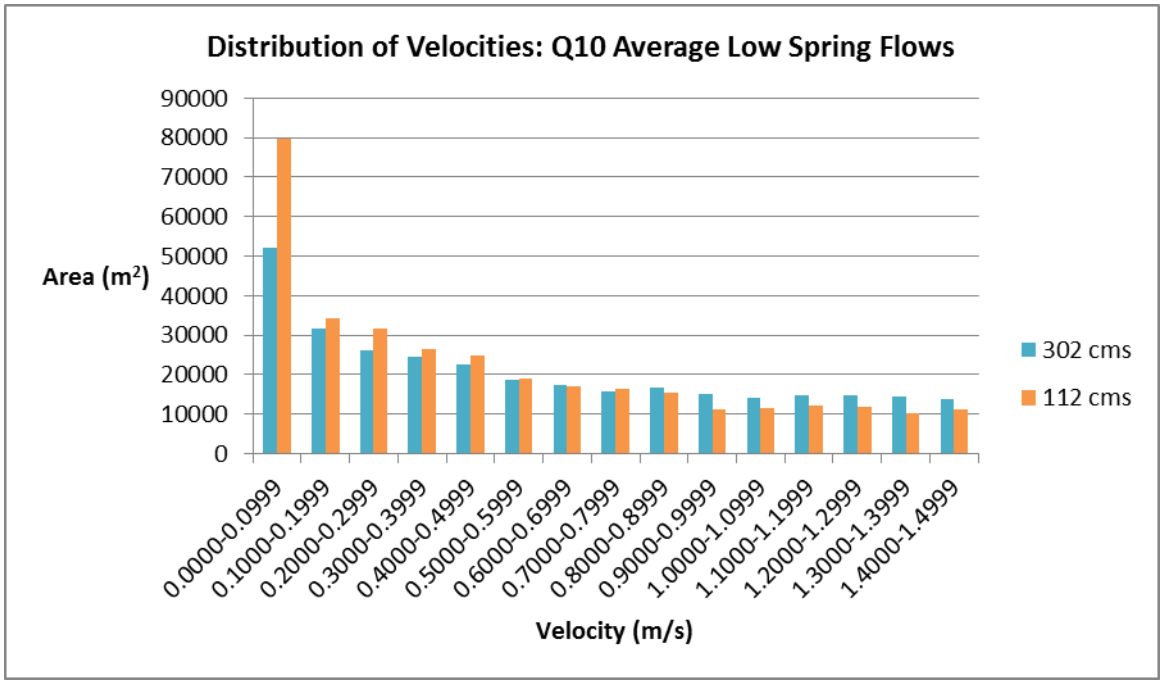


Figure 43: Distribution of River Surface Area by Velocity in River Reaches between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

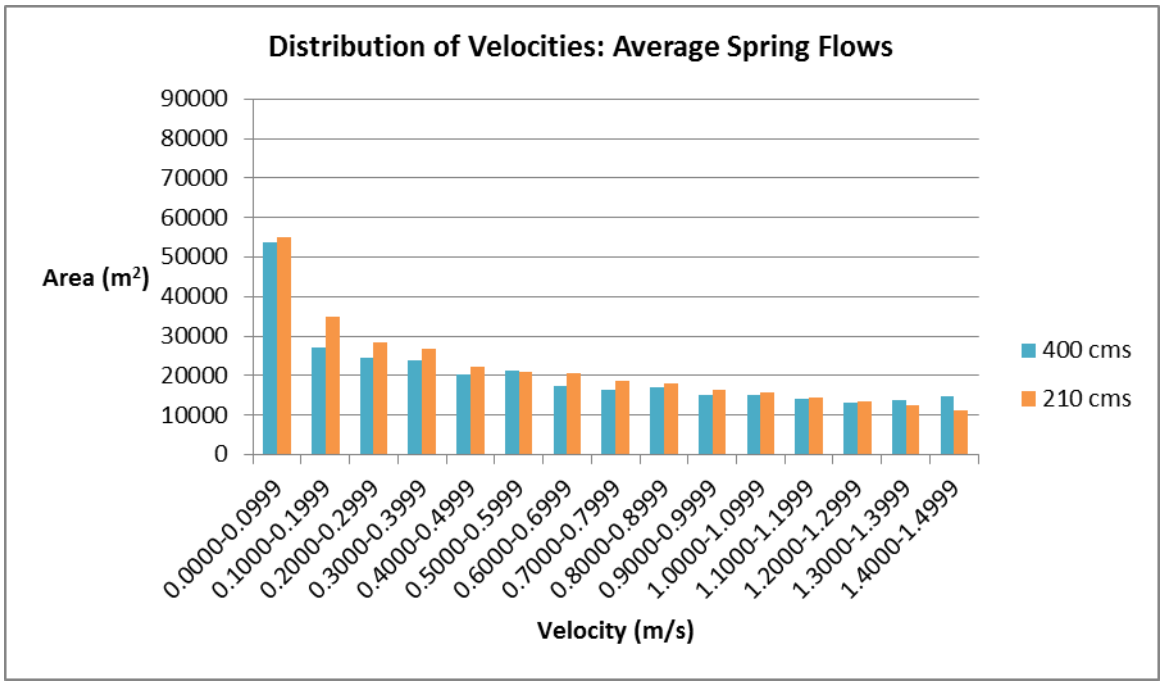


Figure 44: Distribution of River Surface Area by Velocity in River Reaches between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

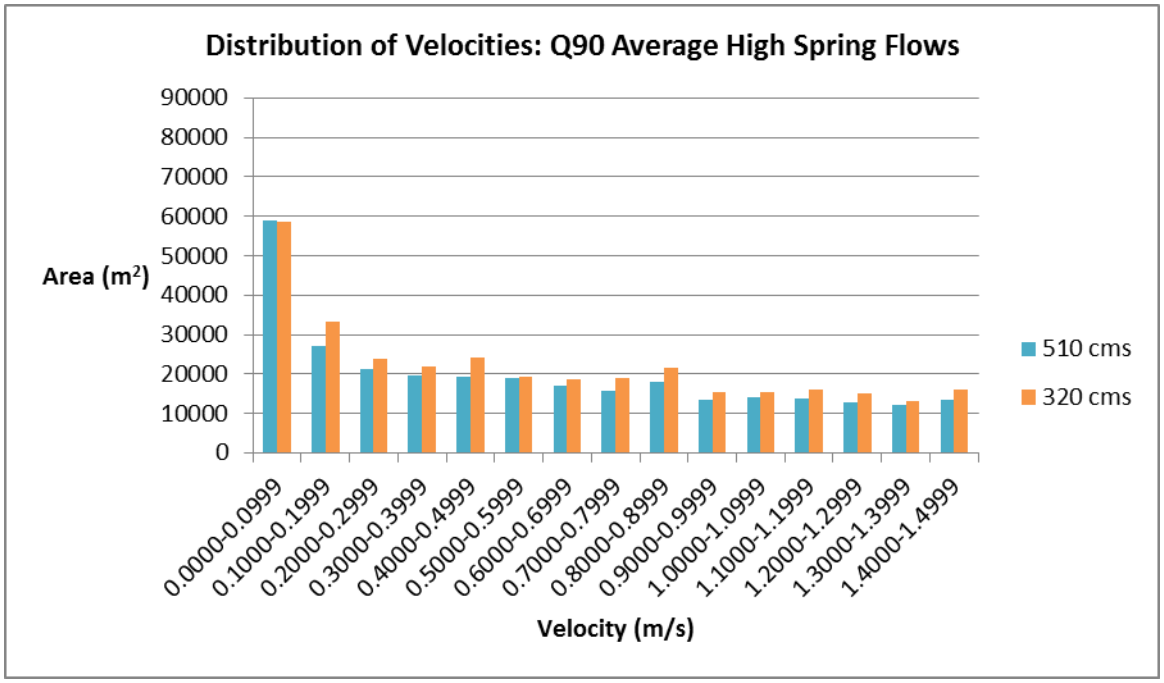


Figure 45: Distribution of River Surface Area by Velocity in River Reaches between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

For the Q10 average low spring flow scenarios (i.e., 302 m^3/s and 112 m^3/s) (Figure 43), the average spring flows scenarios (i.e., 400 m^3/s and 210 m^3/s) (Figure 44), and the Q90 average high spring flow scenarios (i.e., 510 m^3/s and 320 m^3/s) (Figure 45), the largest proportion of river surface area is expected to have velocities that are within the 0.0000 to 0.0999 m/s range. Among the flow scenarios in Figure 43, the riparian flow of 112 m^3/s is expected to have the largest proportion of velocities less than 0.1000 m/s. In Figure 44, areas having velocities less than 0.1000 m/s are slightly larger when normal average riparian flows are reduced to 210 m^3/s; at Q90 high flows, the proportion of river area having velocities less than 0.1000 m/s is expected to remain relatively stable when flows are reduced from 510 m^3/s to 320 m^3/s (Figure 45).

3.2.1.3 *Area*

The total areas of Reaches 2 through 14 and 19 through 22 are presented in Table 16 and Figures 46, 47 and 48. Total reach areas anticipated for the 112 m^3/s flow scenario were compared to the total reach areas predicted for the 302 m^3/s historical Q10 average low spring flow; total reach areas for the 210 m^3/s flow scenario were compared to those calculated for the 400 m^3/s historical average spring flow; and total reach areas for the 320 m^3/s flow scenario were compared to those calculated for the 510 m^3/s historical Q90 average high spring flow. Percent changes in total area for each reach are shown in Table 16 along with the total reach areas.

Table 16: Total Area (m^2) by Reach and Flow Scenario

Reach	Reach Class[a]	Total Area (m^2)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
2	R2[b]	42,914	35,901	-16.3	44,117	39,166	-11.2	44,889	42,635	-5.0
3	RA	61,100	48,065	-21.3	64,761	55,608	-14.1	67,916	61,719	-9.1
4	R2	31,517	27,153	-13.8	34,318	29,339	-14.5	36,019	32,025	-11.1
5	FA	12,392	9,324	-24.8	13,374	11,454	-14.4	13,967	12,423	-11.1
6	R2	15,483	11,403	-26.4	16,924	13,880	-18.0	17,645	16,026	-9.2
7	RA	10,132	8,544	-15.7	10,819	9,255	-14.5	11,819	9,915	-16.1
8	R2	18,864	17,182	-8.9	19,563	17,913	-8.4	20,079	18,983	-5.5
9	P1	31,891	27,934	-12.4	34,126	29,260	-14.3	35,084	32,977	-6.0
10	RA	6,898	5,474	-20.6	7,477	6,347	-15.1	7,599	6,931	-8.8
11	R2	18,216	16,808	-7.7	19,260	17,431	-9.5	20,337	18,586	-8.6
12	RA	7,923	6,505	-17.9	9,395	7,301	-22.3	9,826	8,042	-18.2
13	R2	33,765	32,223	-4.6	34,562	33,053	-4.4	34,487	33,622	-2.5

Table 16: Total Area (m^2) by Reach and Flow Scenario (continued)

Reach	Reach Class[a]	Total Area (m^2)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
14	R4[c]	91,936	66,679	-27.5	99,321	83,108	-16.3	105,328	93,669	-11.1
19	P1	6,630	6,359	-4.1	6,777	6,542	-3.5	6,820	6,776	-0.6
20	R2	38,570	27,698	-28.2	41,204	35,329	-14.3	44,233	40,696	-8.0
21	RA	9,706	9,757	0.5	10,310	10,312	0.0	10,800	11,429	5.8
22	R2	71,675	78,561	9.6	78,818	86,709	10.0	84,508	93,673	10.8

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m^2 = square metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

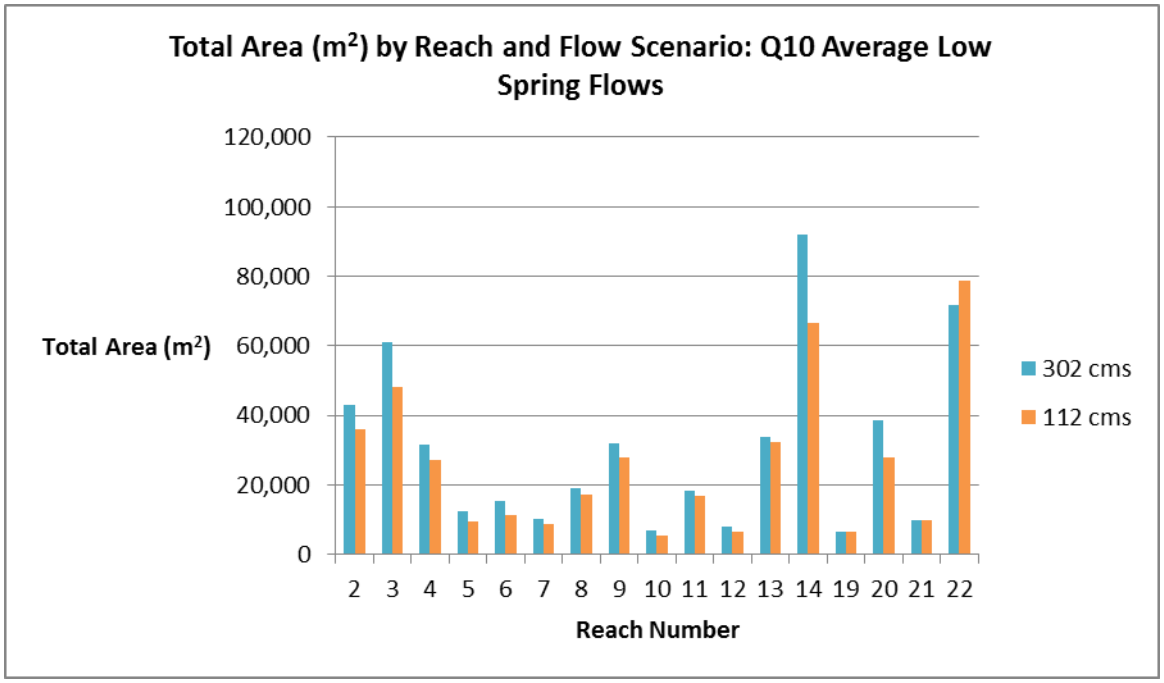


Figure 46: Total Wetted Surface Areas of River Reaches between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

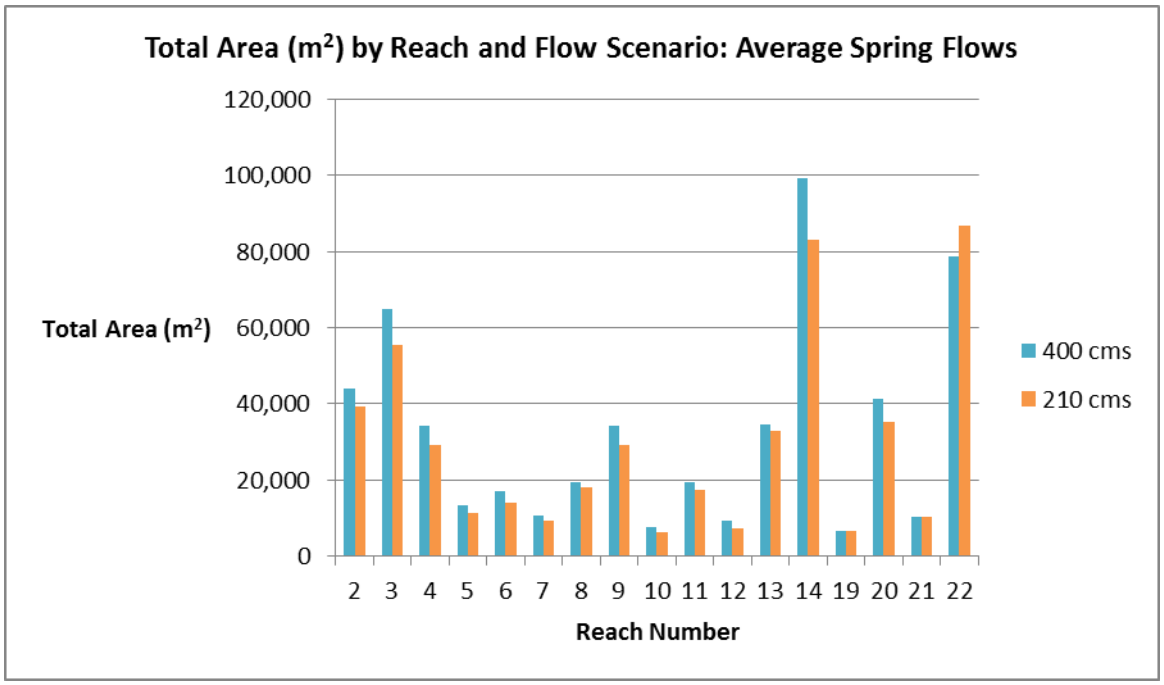


Figure 47: Total Wetted Surface Areas of River Reaches between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

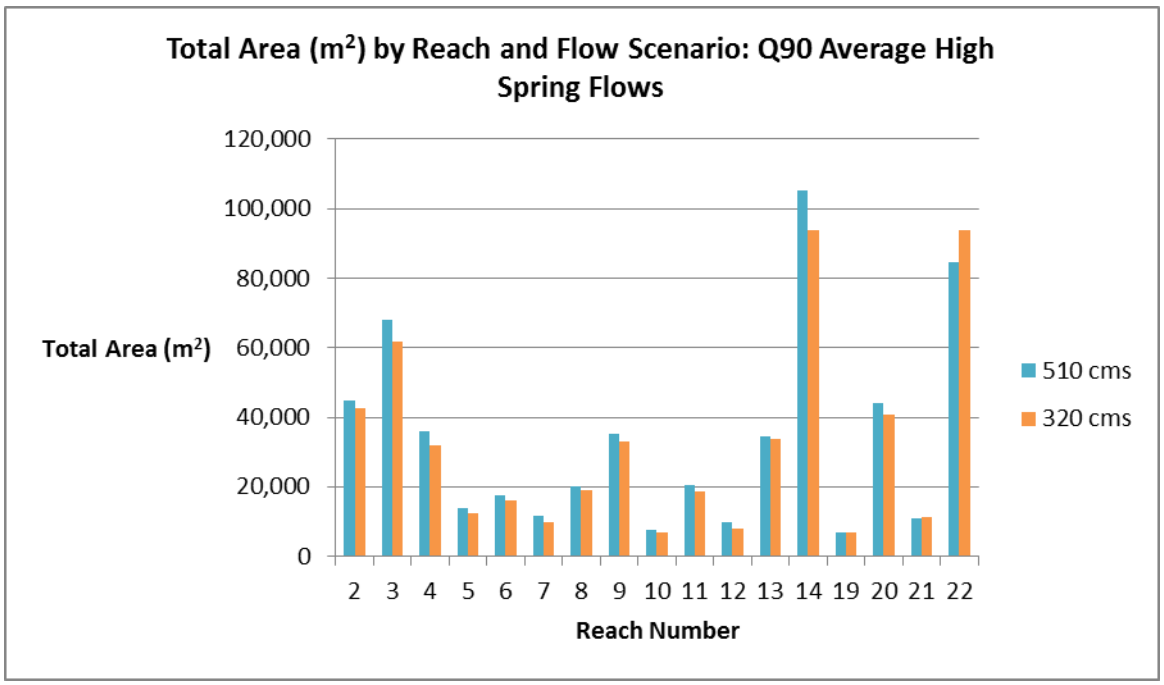


Figure 48: Total Wetted Surface Areas of River Reaches between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

Total areas of reaches 2 through 14, 19, and 20 are expected to decrease as spring flows are reduced from 302 m^3/s to 112 m^3/s, from 400 m^3/s to 210 m^3/s, and from 510 m^3/s to 320 m^3/s (Table 16). Negligible to small increases in the total areas of reaches 21 (0.0% to 5.8% change) and 22 (≤ 10.8% change) are expected to occur whenever 190 m^3/s of water is diverted for Project operation during spring. The small increases in total area predicted for reaches 21 and 22 may be attributed to changes in flow patterns and bottom characteristics (e.g., contours of the tailrace outlet bay) resulting from tailrace construction and operation, as well as tailrace discharges.

When modelled flows were reduced from 302, 400, or 510 m^3/s based on a Project operation flow of190 m^3/s, the smallest percent decreases in total area were observed for Reach 13 (deep to moderately deep run; ≤ 4.6% decrease) and Reach 19 (pool; ≤ 4.1% decrease). During conditions of historically normal low spring flows (i.e., at 302 m^3/s), water withdrawal for power generation is expected to result in relatively large percent reductions in the total areas of Reach 14 (shallow, fast run) and Reach 20 (deep to moderately deep run) (Table 16, Figure 46). When flows are reduced at historically normal average (400 m^3/s) and high (510 m^3/s) flows, it is anticipated that the total area of Reach 12 (rapids) will decrease the most.

3.2.1.4 *Volume*

The volume of water contained in the river reaches may limit how much space and resources are available to resident fish. For this reason, total reach volumes were calculated for each of the six spring flow scenarios assessed for the Project. Reach volumes for the proposed 112 m^3/s riparian flow scenario were compared to those predicted for the 302 m^3/s historical average Q10 low spring flow; reach volumes anticipated for 210 m^3/s flow were compared to the historical average spring flow (400 m^3/s); the proposed riparian flow of 320 m^3/s was compared to the 510 m^3/s historical average Q90 high spring flow. Total reach volumes are presented in Table 17 and Figures 49, 50 and 51. Percent reductions in total reach volume are shown in Table 17.

Table 17: Total Volume (m^3) by Reach and Flow Scenario

Reach	Reach Class[(a)]	Total Volume (m^3)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Volume (m^3)	Volume (m^3)	% Change	Volume (m^3)	Volume (m^3)	% Change	Volume (m^3)	Volume (m^3)	% Change
2	R2[(b)]	136,423	109,046	-20.1	147,239	122,633	-16.7	158,308	138,954	-12.2
3	RA	84,193	49,747	-40.9	98,361	67,533	-31.3	112,413	85,252	-24.2
4	R2	80,972	51,523	-36.4	92,476	68,104	-26.4	103,485	81,741	-21.0
5	FA	17,520	7,797	-55.5	22,298	12,982	-41.8	27,512	18,400	-33.1
6	R2	26,851	13,227	-50.7	33,754	20,246	-40.0	41,273	28,494	-31.0
7	RA	24,766	15,784	-36.3	28,438	20,344	-28.5	32,003	25,547	-20.2
8	R2	79,603	62,872	-21.0	85,815	72,050	-16.0	91,915	81,031	-11.8

Table 17: Total Volume (m^3) by Reach and Flow Scenario (continued)

Reach	Reach Class[a]	Total Volume (m^3)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Volume (m^3)	Volume (m^3)	% Change	Volume (m^3)	Volume (m^3)	% Change	Volume (m^3)	Volume (m^3)	% Change
9	P1	191,607	164,033	-14.4	201,513	179,331	-11.0	210,953	192,582	-8.7
10	RA	10,019	5,957	-40.5	11,637	8,021	-31.1	12,938	10,144	-21.6
11	R2	46,918	33,339	-28.9	52,606	39,751	-24.4	58,298	48,543	-16.7
12	RA	9,314	4,394	-52.8	11,403	6,711	-41.1	13,493	9,535	-29.3
13	R2	106,305	85,702	-19.4	114,925	96,562	-16.0	120,374	106,433	-11.6
14	R4[c]	143,154	81,928	-42.8	171,234	114,869	-32.9	203,519	147,462	-27.5
19	P1	54,979	50,735	-7.7	55,901	53,084	-5.0	58,581	55,626	-5.0
20	R2	70,319	52,519	-25.3	79,053	63,909	-19.2	89,399	75,291	-15.8
21	RA	20,787	22,312	7.3	23,429	25,066	7.0	26,077	28,921	10.9
22	R2	112,809	136,888	21.3	137,638	164,781	19.7	164,820	197,970	20.1

[a] Reach class definitions are based on Golder's Aquatic and Hydrology Technical Procedures: Watercourse Habitat Mapping System (unpublished protocol).
[b] R2: a run that is generally deep/fast or moderately deep/slow (0.75-1.0 m deep).
[c] R4: a run that is generally shallow (0.5-0.75 m deep) with high velocities.
m^3 = cubic metres; m^3/s = cubic metres per second; % = percent; R = run; RA = rapids; FA = falls; P = pool.

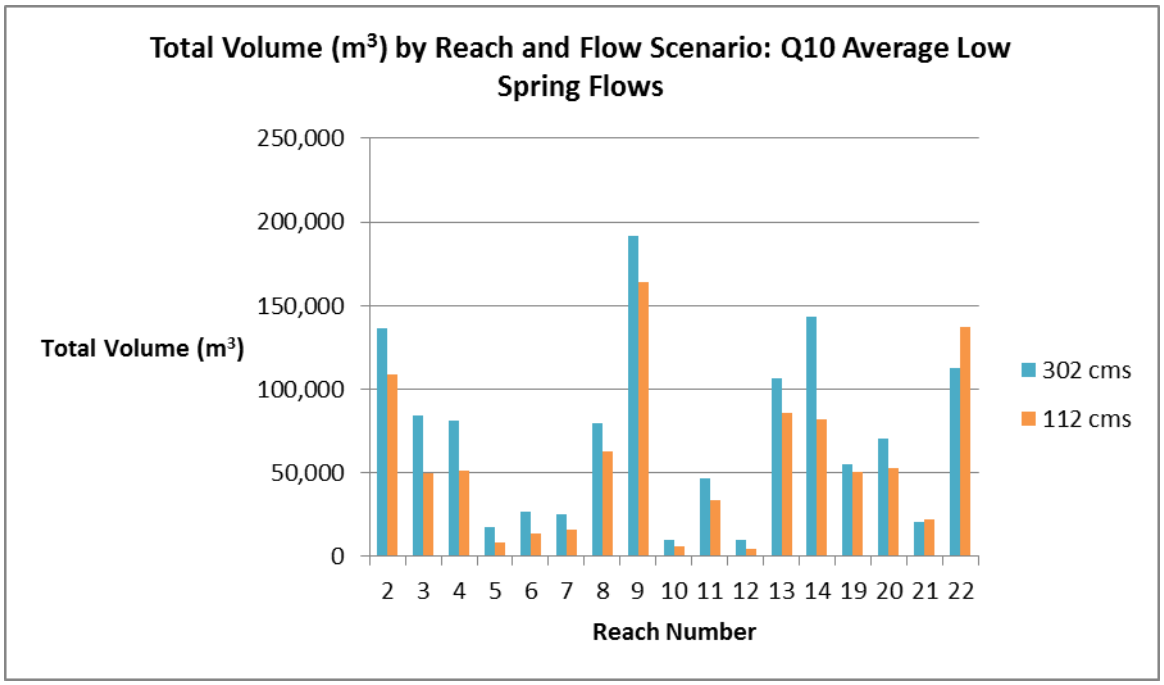


Figure 49: Total Water Volumes in River Reaches between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

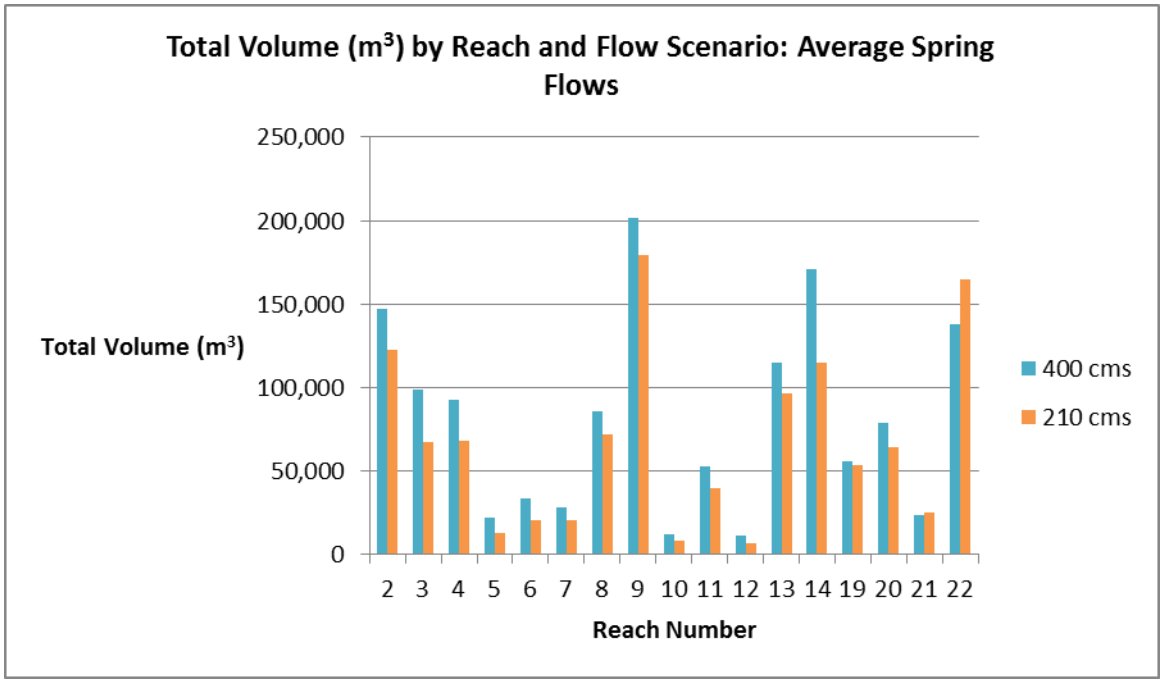


Figure 50: Total Water Volumes in River Reaches between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

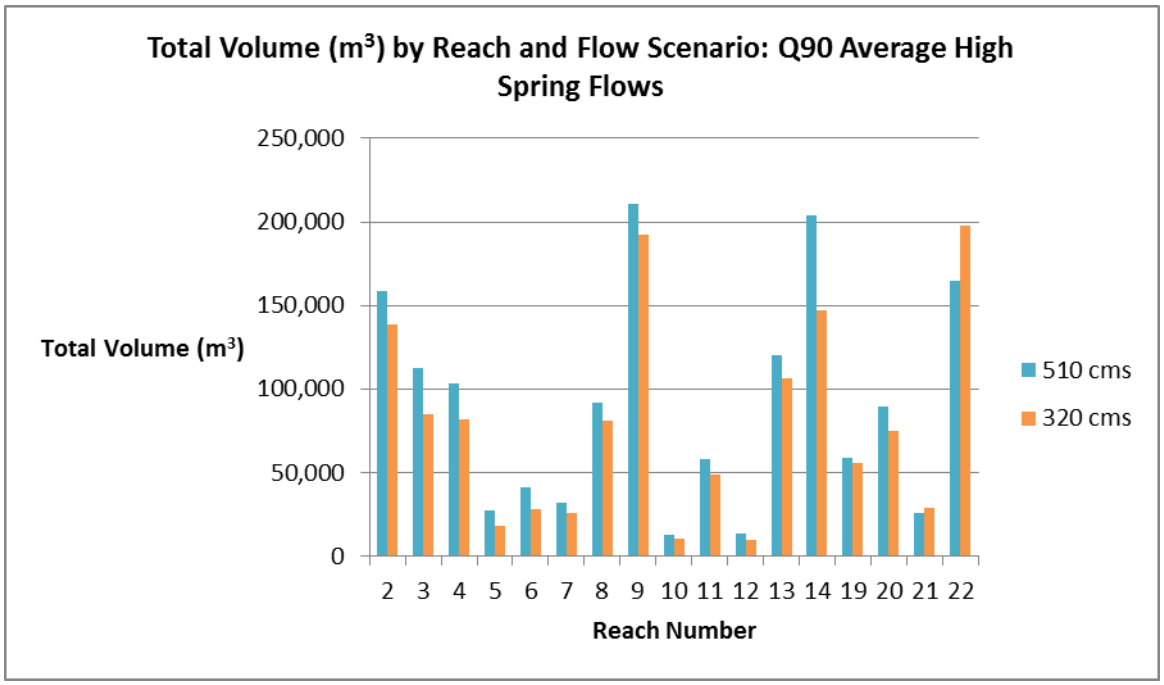


Figure 51: Total Water Volumes in River Reaches between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

Total reach volume decreased in all reaches except reaches 21 and 22 when modelled Fond du Lac River flows were reduced from historically normal values (i.e., 302, 400, and 510 m^3/s) based on a Project operational flow of 190 m^3/s) (Table 17). Volumes of reaches 21 and 22 are expected to increase by 7.0% to 10.9% and 19.7% to 21.3%, respectively, whenever 190 m^3/s of water is diverted through the power tunnel and tailrace. The falls in Reach 5 consistently exhibited the greatest percent decrease in total reach volume when modelled riparian flows were reduced from 302 m^3/s to 112 m^3/s (55.5% decrease) (Table 17, Figure 49), 400 m^3/s to 210 m^3/s (41.8% decrease) (Table 17, Figure 50), and 510 m^3/s to 320 m^3/s (33.1% decrease (Table 17, Figure 51). Large percent decreases are also expected to occur in Reach 12 (rapids) whenever the Project is operating at 190 m^3/s capacity. Reductions in reach volumes resulting from water diversion and power generation are expected to have the smallest effect on pool habitat in Reach 19 (Table 17); the volume of the pool habitat in Reach 9 is also expected to be relatively resistant to reductions in flow.

3.2.2 Spawning Habitat Assessment

3.2.2.1 *Arctic Grayling*

The quantity of unsuitable, poor, moderately suitable, and suitable spawning habitat available to Arctic grayling in the Fond du Lac River reaches between Black Lake and Middle Lake is summarized in Table 18. Reaches 2 through 14 and 19 through 22 are represented in the table. Habitat suitability indices (HSIs) are based on the lowest of either the depth SI value or the velocity SI value for spawning Arctic grayling.

Table 18: Total Areas (m^2) Associated with Unsuitable, poor, Moderately Suitable, or Suitable Habitat for Arctic Grayling (*Thymallus arcticus*) Spawning in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Group	HSI Classification Title	Total Area (m^2)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
0.0000-0.2500	Unsuitable	442,958	369,026	-16.7	469,567	424,730	-9.5	498,940	466,446	-6.5
0.2501-0.5000	Poor	11,422	12,456	9.1	12,015	12,442	3.6	8,746	13,996	60.0
0.5001-0.7500	Moderately Suitable	24,300	28,376	16.8	28,131	25,166	-10.5	33,217	26,672	-19.7
0.7501-1.0000	Suitable	30,932	25,713	-16.9	35,410	29,668	-16.2	30,453	33,012	8.4

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

Under all six of the spring flow scenarios assessed, the largest proportion of the river area falls within the category of unsuitable habitat. For all but the 112 m^3/s and 510 m^3/s flow scenarios, the remaining habitat area that is not "unsuitable" is classified as primarily suitable habitat, followed by moderately suitable, then poor (Table 18). Under Q10 average low spring flow conditions (302 m^3/s), a reduction in riparian flow resulting from Project operation is expected to result in a 16.9% decrease in suitable spawning habitat for Arctic grayling (Table 18, Figure 52). Suitable Arctic grayling spawning habitat will also be lost when average Fond du Lac River spring flows (i.e., 400 m^3/s) are reduced to 210 m^3/s (16.2% decrease) (Table 18, Figure 53). During spring spawning seasons when average Q90 high flows might occur in the Fond du Lac River, water withdrawal for power generation is expected to result in a slight increase (i.e., 8.4%) in suitable habitat area for spawning Arctic grayling (Table 18, Figure 54). Areas of moderately suitable Arctic grayling spawning habitat in the Fond du Lac River will be reduced when flows are in the average to high range and the Project is operating; however, operation of the Project at low flows will result in a net percent gain in moderately suitable habitat (Table 18). It is anticipated that the suitable habitat "lost" as a result of Project operation at low flows will in fact be re-classified as moderately suitable habitat.

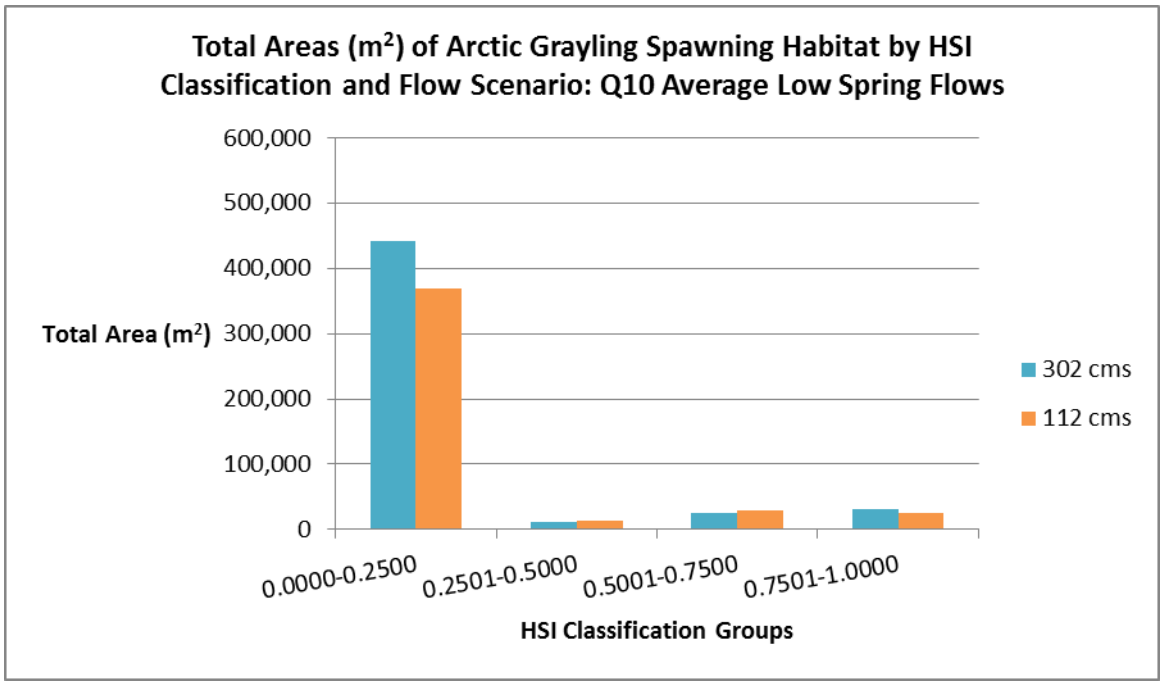


Figure 52: Total Areas of Spawning Habitat for Arctic Grayling in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (302 m^3/s and 112 m^3/s).

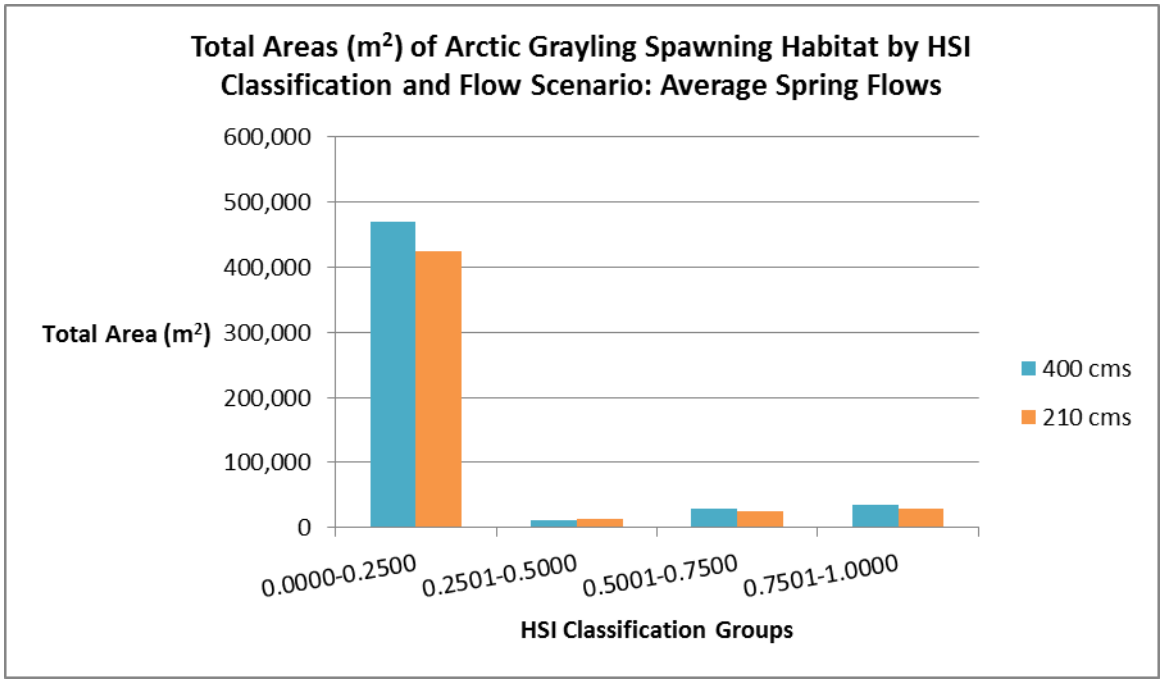


Figure 53: Total Areas of Spawning Habitat for Arctic Grayling in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (400 m^3/s and 210 m^3/s).

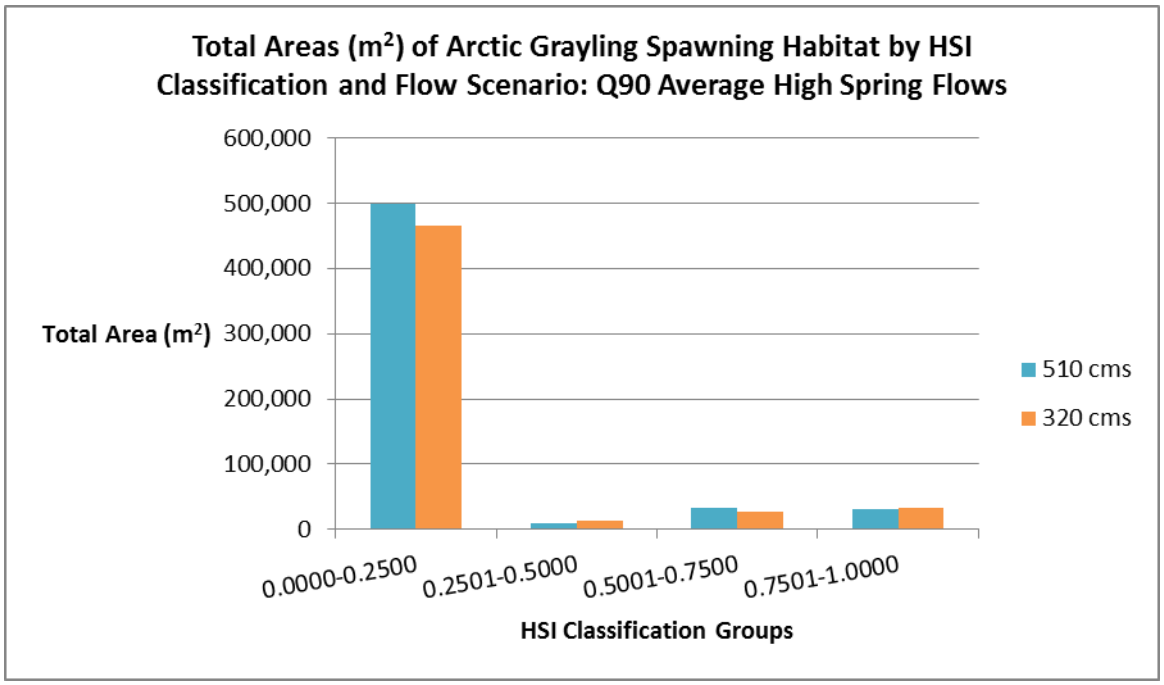


Figure 54: Total Areas of Spawning Habitat for Arctic Grayling in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (510 m^3/s and 320 m^3/s).

Reductions in suitable habitat types available to Arctic grayling under average to low flows are likely attributable to decreased surface areas in each of the river reaches and the drying of some near-shore spawning locations. Gains in suitable spawning habitat when natural flow conditions are high (i.e., 510 m^3/s) and water is being diverted for power generation are expected to result from general decreases in flow velocity and flooding of areas that may have suitable substrates, but are dry most (i.e., 90 out of 100) years.

The quantity of unsuitable, poor, moderately suitable and suitable spawning habitat available to Arctic grayling in the Fond du Lac River was also determined by reach. Tables and figures for individual reaches are presented in Appendix 12.2-E, Table E1 and Figures E1 to E51. The data presented in Appendix 12.1-E, Table E1 suggests that Arctic grayling spawning habitat will improve in every set of rapids (i.e., reaches 3, 7, 10, 12, and 21) and in a number of deep to moderately deep runs (i.e., reaches 2, 6, 20, and 22) whenever Q90 high flows (510 m^3/s) are reduced to 320 m^3/s riparian flows. It is anticipated that velocities will be reduced to preferred levels for spawning when flows are reduced from 510 m^3/s. Based on the modelled flow scenarios, areas of suitable habitat will consistently be lost in reaches 4 (run) 5 (falls), 8 (run), 9 (pool) and 19 (pool) when the Project is operating; suitable habitat is likely to be gained in reaches 2 (run), 12 (rapid), 21 (rapid) and 22 (run), regardless of what the riparian flow would be without the Project in place. Maps depicting likely areas of moderately suitable and suitable Arctic grayling spawning habitat in reaches 2 through 14 and 19 through 22 of the Fond du Lac River are presented in Appendix 12.1-G.

Because substrate type (e.g., cobble, boulder, gravel) may be an important factor in determining where Arctic grayling prefer to spawn, the distribution of potentially suitable and unsuitable substrates within the modelled sections of the Fond du Lac River was predicted based on substrate particle sizes and water velocities. Locations that are expected to have suitable spawning substrates for Arctic grayling are shown in Figures 55, 56, and 57 for the different modelling segments in the Fond du Lac River; areas of suitable and moderately suitable habitat predicted for the 112 m^3/s flow scenario based on the two-parameter (i.e., depth and velocity) HSIs are also shown. Narrow margins (i.e., around shorelines) or single, isolated Thiessen polygons identified as being moderately suitable or suitable habitat were evaluated and removed from the maps (Figures 55, 56 and 57) on the basis that these areas are not likely to be of sufficient size for fish to congregate and spawn successfully. The total areas of suitable and moderately suitable Arctic grayling spawning habitat from Figures 55, 56 and 57 that are predicted to have potentially suitable spawning substrates are provided in Table 19. Total areas of suitable and moderately suitable habitat predicted based on a riparian flow of 112 m^3/s and the two-parameter HSI model are also provided for comparison.

Table 19: Total Areas (m^2) Associated with Suitable Spawning Substrates, Depths and Velocities for Arctic Grayling (*Thymallus arcticus*) Spawning in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Title	Total Area (m^2) at 112 m^3/s		
	Two-Parameter HSI (Depth and Velocity)[(a)]	Depth, Velocity and Potentially Suitable Substrate	
	Area (m^2)	Area (m^2)	% Change
Moderately Suitable	12,929	11,492	-9.3
Suitable	15,672	14,216	-11.0

[(a)] Narrow fringe habitats along the edges of islands and shorelines were not included in the predicted spawning areas shown in Figures 55, 56 and 57 or Table 19; these areas are not anticipated to provide sufficient area for fish to congregate and spawn successfully.

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

LEGEND

HABITAT
- MODERATELY SUITABLE
- SUITABLE

SUBSTRATE
- SUITABLE
- UNSUITABLE

150 0 150
SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

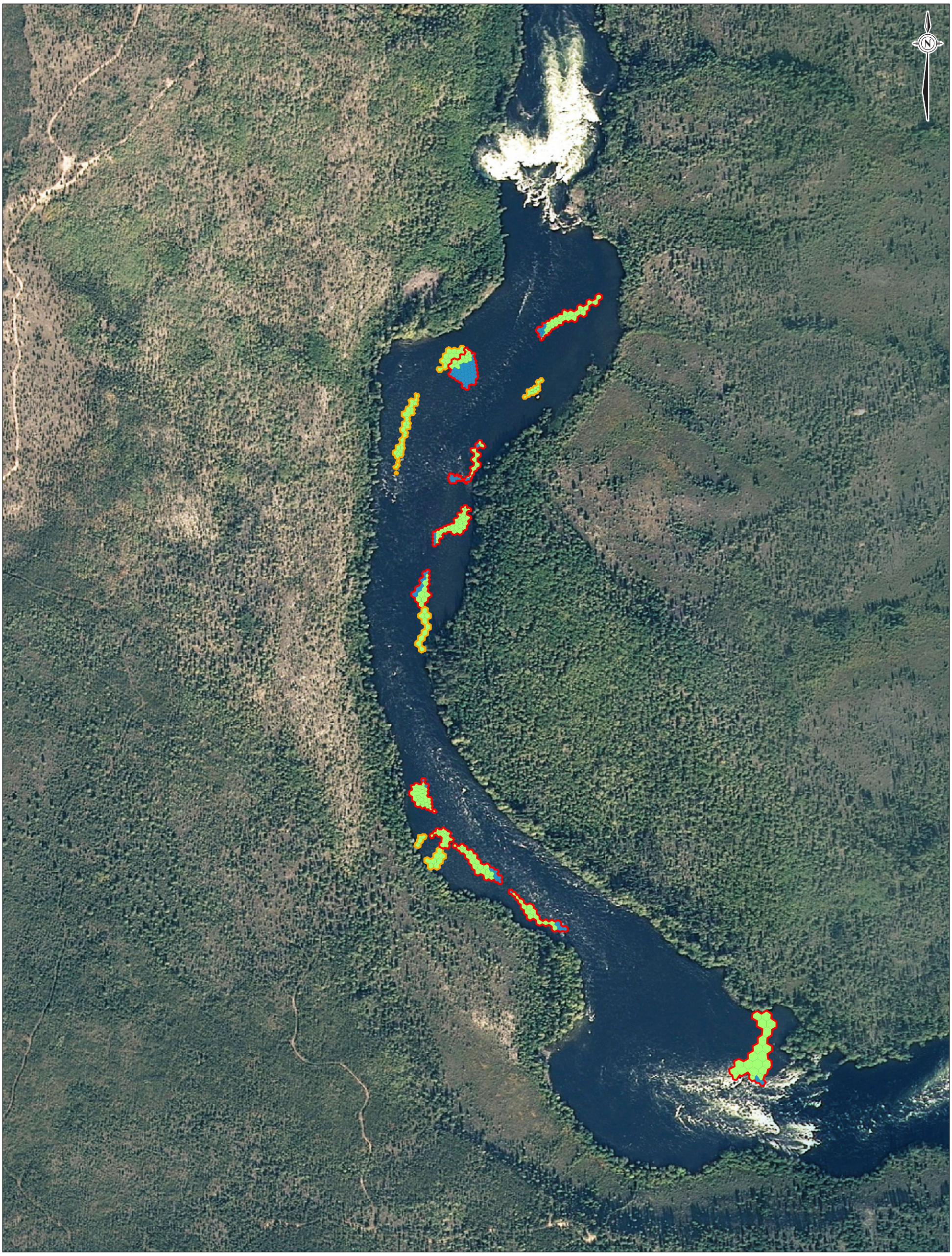
PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
PREDICTED ARCTIC GRAYLING SPAWNING AREAS AT 112 m³/s

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13		
CHECK	AO	02/11/13		
REVIEW	BC	02/11/13		

FIGURE: 55



LEGEND

HABITAT

- MODERATELY SUITABLE
- SUITABLE

SUBSTRATE

- SUITABLE
- UNSUITABLE

100 0 100

SCALE 1:4,000 METRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

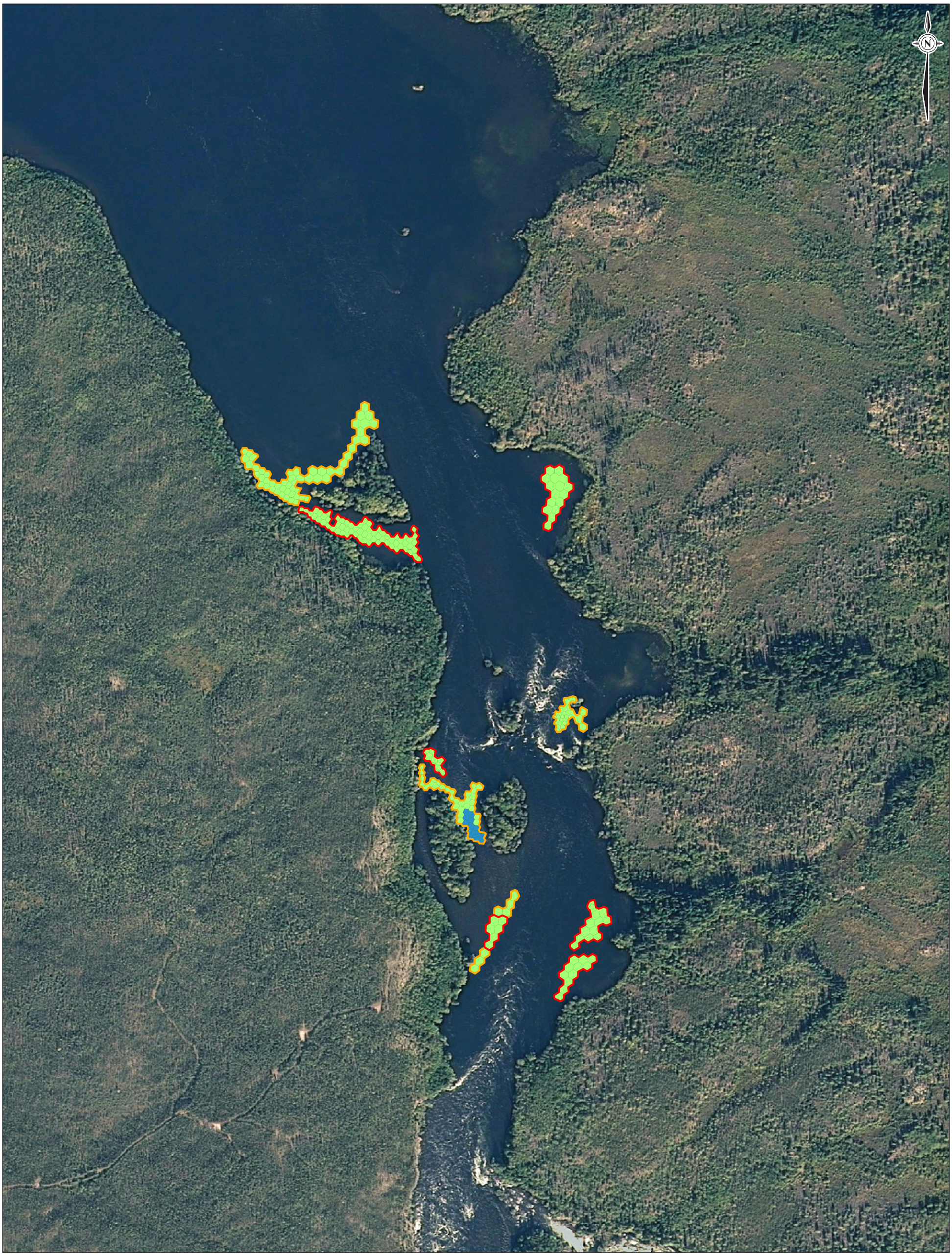
PREDICTED ARCTIC GRAYLING SPAWNING AREAS AT 112 m³/s

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: 56	
CHECK	AO	01/11/13		
REVIEW	BC	01/11/13		



LEGEND

HABITAT
- MODERATELY SUITABLE
- SUITABLE

SUBSTRATE
- SUITABLE
- UNSUITABLE

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

100 0 100
SCALE 1:4,000 METRES

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
PREDICTED ARCTIC GRAYLING SPAWNING AREAS AT 112 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: 57	
CHECK	AO	01/11/13		
REVIEW	BC	01/11/13		

The areas of suitable and moderately suitable Arctic grayling spawning habitat predicted in Figures 55, 56 and 57 for the 112 m^3/s flow scenario are expected to have predominantly suitable substrates. An approximately 10% decrease (i.e., 9.3% for moderately suitable habitat and 11.0% for suitable habitat) in predicted suitable habitat area occurred when modelled substrate data were included in the predictions of suitable and moderately suitable habitat. It is anticipated that areas of suitable and moderately suitable habitat predicted for riparian spawning season flows greater than 112 m^3/s will have greater relative proportions of suitable substrate.

3.2.2.1.1 Sensitivity Analysis

A sensitivity analysis was completed for a subset of the Arctic grayling spawning data to investigate how sensitive the HSI model outputs are to small changes in the depth and velocity SI curves. The results of the sensitivity analyses are presented in Tables 20 and 21. The sensitivity analysis provides a measure of how sensitive the model outputs are to variations in the SI variables (i.e., depth, velocity values).

Table 20: Changes in Total Areas (m) of Arctic Grayling (*Thymallus arcticus*) Spawning Habitat Based on 10% Changes in the Depth Suitability Index (SI) Curves

HSI Classification Group	HSI Classification Title	Total Area (m^2) at 400 m^3/s				
		Assessed	SI Curve 10% Shift Left	% Change	SI Curve 10% Shift Right	% Change
0.0000-0.2500	Unsuitable	276,104	277,849	0.6	274,975	-0.4
0.2501-0.5000	Poor	5,272	4,596	-14.7	5,335	1.2
0.5001-0.7500	Moderately Suitable	11,893	11,845	-0.4	12,229	2.7
0.7501-1.0000	Suitable	15,427	14,405	-7.1	16,156	4.5

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; SI = Suitability Index; % = percent.

Changing the depth SI curve for spawning Arctic grayling by 10% resulted in an average change of HSI classification of 5.7% (left shift) and only 2.2% (right shift). Individual classification changes ranged from -14.7% to 4.5% (average plus or minus [±] 4.0%) of total areas associated with each of the HSI habitat classification bins under the 400 m^3/s flow scenario. These results indicate that the depth SI curve for Arctic grayling spawning habitat is quite robust and that HSI modelling results are not likely to change with minor changes or uncertainties in the shape of the depth SI curves.

Table 21: Changes in Total Areas (m) of Arctic Grayling (*Thymallus arcticus*) Spawning Habitat Based on 10% Changes in the Velocity Suitability Index (SI) Curves

HSI Classification Group	HSI Classification Title	Percent (%) Deviation from Normal Total Area (m^2) at 400 m^3/s				
		Assessed	10% Shift Left	% Change	10% Shift Right	% Change
0.0000-0.2500	Unsuitable	276,104	277,356	0.5	274,791	-0.5
0.2501-0.5000	Poor	5,272	5,091	-3.5	5,468	3.6
0.5001-0.7500	Moderately Suitable	11,893	11,601	-2.5	12,336	3.6
0.7501-1.0000	Suitable	15,427	14,647	-5.3	16,099	4.2

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; SI = Suitability Index; % = percent.

Percent changes in the total areas of each HSI classification group resulting from shifting the velocity SI curves 10% left or right are smaller than those resulting from similar changes to the depth SI curves. Shifting the

velocity SI curve left or right by 10% resulted in an average change of ± 3.0% in the total areas associated with each of the HSI habitat classification bins under the 400 m^3/s flow scenario. Individual classification changes ranged from -5.3% to 4.2%. These results indicate that the velocity SI curve for Arctic grayling spawning habitat is robust, and that HSI modelling results are not likely to change with minor changes or uncertainties in the data underlying the velocity curve.

3.2.2.2 *Longnose Sucker*

The quantity of unsuitable, poor, moderately suitable, and suitable spawning habitat available to longnose sucker in the Fond du Lac River reaches between Black Lake and Middle Lake is summarized in Table 22. Reaches 2 through 14 and 19 through 22 are represented in the table. Habitat suitability indices (HSIs) are based on the lowest of either the depth SI value or the velocity SI value for spawning longnose sucker.

Table 22: Total Areas (m^2) Associated with Unsuitable, Poor, Moderately Suitable, or Suitable Habitat for Longnose Sucker (*Catostomus catostomus*) Spawning in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Group	HSI Classification Title	Total Area (m^2)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
0.0000-0.2500	Unsuitable	444,328	377,331	-15.1	477,223	425,255	-10.9	512,658	472,056	-7.9
0.2501-0.5000	Poor	25,786	26,984	4.6	27,470	25,417	-7.5	28,265	29,816	5.5
0.5001-0.7500	Moderately Suitable	20,842	17,340	-16.8	23,623	20,335	-13.9	19,307	21,955	13.7
0.7501-1.0000	Suitable	18,656	13,914	-25.4	16,808	20,999	24.9	11,127	16,299	46.5

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

For the modelled 302, 112, 400, 510, and 320 m^3/s spring flow scenarios, the largest proportions of river area were classified as unsuitable, followed by poor, moderately suitable, and then suitable (Table 22, Figures 58, 59 and 60). For the 210 m^3/s spring flow scenario, the largest proportion of river area were also classified as unsuitable; however, the remaining areas were classified as predominantly poor, then suitable, and then moderately suitable (Table 22, Figure 59).

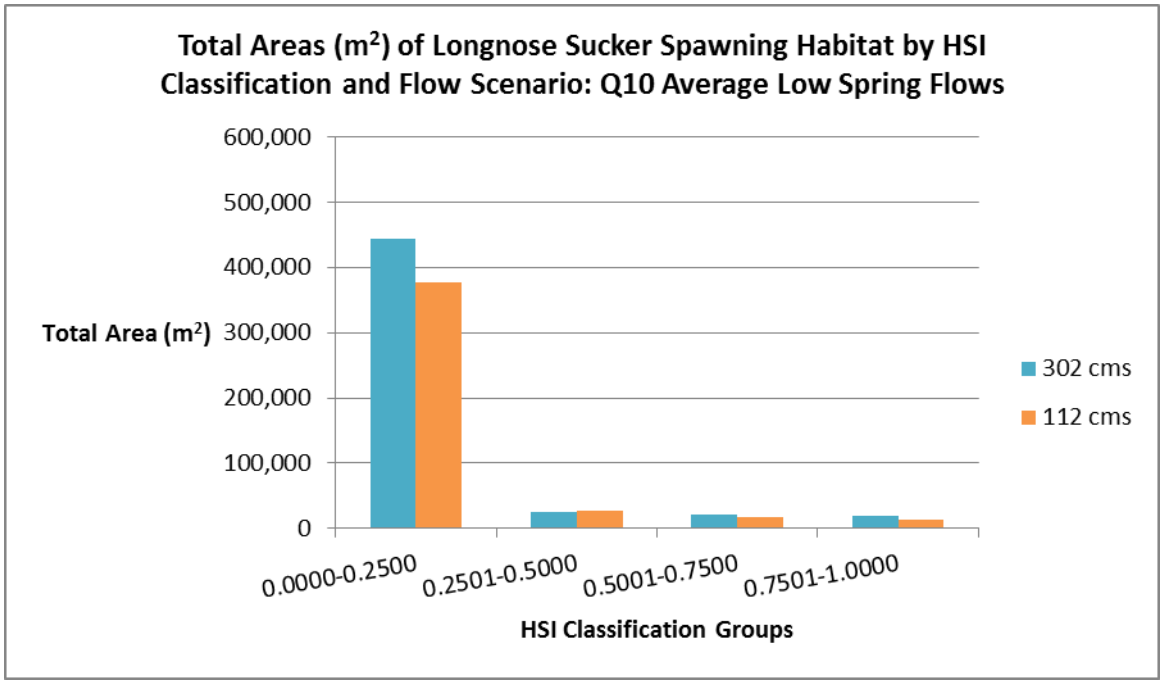


Figure 58: Total Areas of Spawning Habitat for Longnose Sucker in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (302 m^3/s and 112 m^3/s).

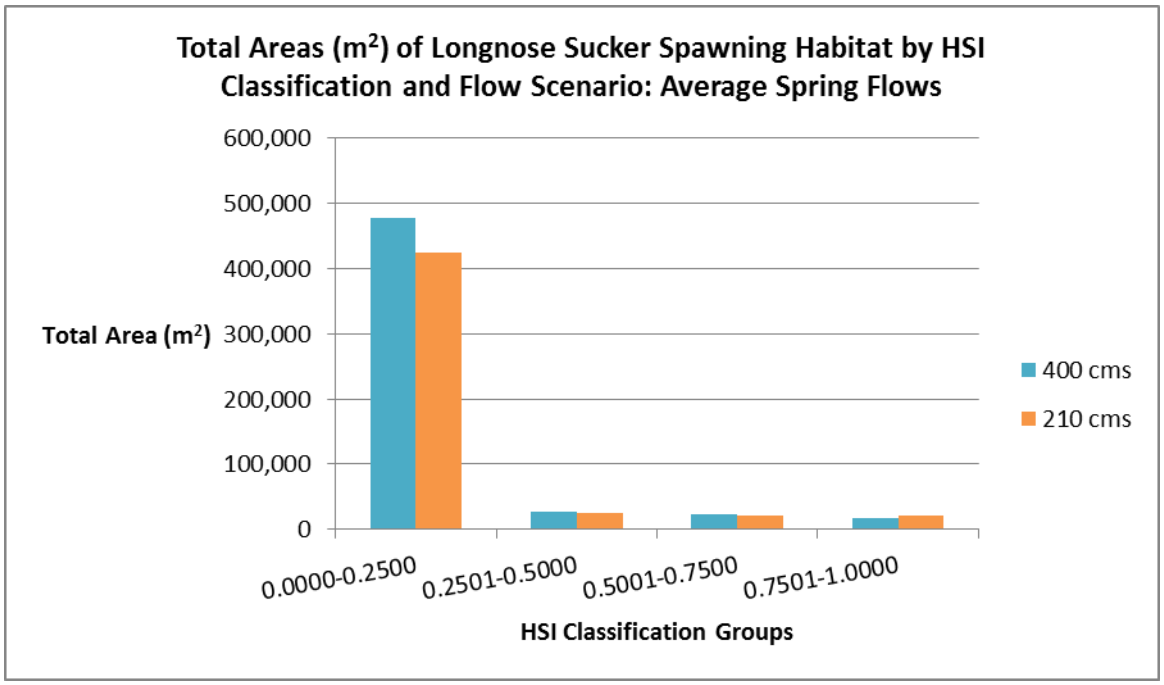


Figure 59: Total Areas of Spawning Habitat for Longnose Sucker in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (400 m^3/s and 210 m^3/s).

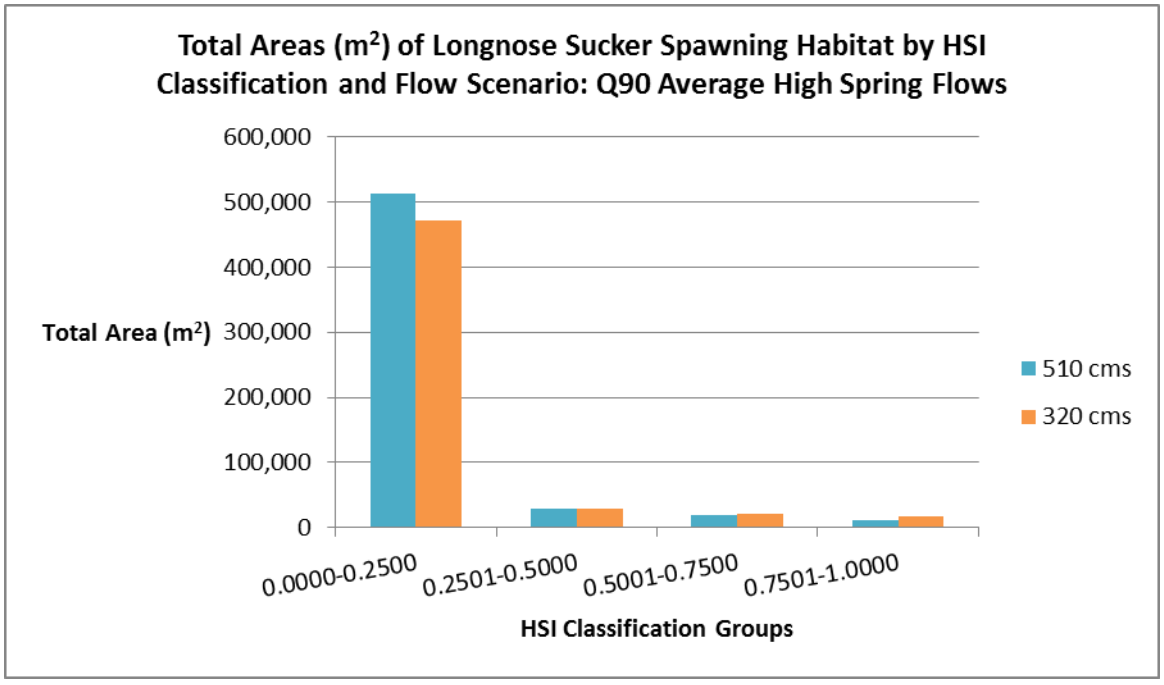


Figure 60: Total Areas of Spawning Habitat for Longnose Sucker in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (510 m^3/s and 320 m^3/s).

Of the six spring flow scenarios assessed, the 510 m^3/s average Q90 high spring flow scenario had the largest amount of unsuitable spawning habitat and the smallest amount of suitable spawning habitat, by area (m^2). The 112 m^3/s flow scenario had the smallest amount of unsuitable habitat, but also had less suitable habitat than most of the other flow scenarios assessed (Table 22). When the Q10 average low flow (i.e., 302 m^3/s) is reduced to 112 m^3/s as a result of Project operation, areas of moderately suitable and suitable habitat are expected to decrease by 16.8% and 25.4%, respectively. Areas of suitable spawning habitat for longnose sucker are expected to increase when average flows (i.e., 400 m^3/s) and Q90 average high flows (i.e., 510 m^3/s) in the Fond du Lac River are reduced as a result of Project operation (Table 22, Figures 59 and 60). Unsuitable longnose sucker spawning habitat will be lost whenever historically normal flows (i.e., 302, 400, and 510 m^3/s) are reduced as a result of Project operation (assuming flow through the plant is equal to 190 m^3/s).

The quantity of unsuitable, poor, moderately suitable and suitable spawning habitat available to longnose sucker in the Fond du Lac River was also determined by reach. Tables and figures for individual reaches are presented in Appendix 12.1-E, Table E2 and Figures E52 to E102. With the exception of reaches 21 and 22, unsuitable habitat will be lost in all reaches whenever historically normal Fond du Lac River flows are reduced to levels proposed for the Project. Based on the modelled scenarios, total area of suitable longnose sucker spawning habitat in Reach 19 (pool) will remain fairly stable (i.e., near zero), regardless of riparian flows in the Fond du Lac River. Relatively large gains (103.9% to 793.3%) in suitable longnose sucker spawning habitat are expected for reaches 2 (deep to moderately deep run), 3 (rapids), 6 (deep to moderately deep run), 10 (rapids) and 14 (shallow, fast run) when the Project is operating and flow conditions within the river are high (i.e., when riparian flows are 320 m^3/s and 190 m^3/s is being diverted through the power tunnel).

3.2.2.3 *White Sucker*

The quantity of unsuitable, poor, moderately suitable, and suitable spawning habitat available to white sucker in the Fond du Lac River reaches between Black Lake and Middle Lake is summarized in Table 23. Reaches 2 through 14 and 19 through 22 are represented in the table. Habitat suitability indices (HSIs) are based on the lowest of either the depth SI value or the velocity SI value for spawning white sucker.

Table 23: Total Areas (m^2) Associated with Unsuitable, Poor, Moderately Suitable, or Suitable Habitat for White Sucker (*Catostomus commersonii*) Spawning in the Fond du Lac River between Black Lake and Middle Lake

HSI Classification Group	HSI Classification Title	Total Area (m^2)								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
0.0000-0.2500	Unsuitable	479,895	413,683	-13.8	518,414	460,531	-11.2	552,418	512,846	-7.2
0.2501-0.5000	Poor	16,086	11,364	-29.4	14,098	14,616	3.7	10,956	14,896	36.0
0.5001-0.7500	Moderately Suitable	7,780	5,991	-23.0	7,296	8,653	18.6	5,119	6,868	34.2
0.7501-1.0000	Suitable	5,851	4,533	-22.5	5,316	8,206	54.4	2,864	5,516	92.6

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

For the six spring flows that were assessed, the largest proportion of river area available to spawning white sucker falls within the category of unsuitable habitat, followed by poor, moderately suitable, and then suitable habitat (Table 23, Figures 61, 62 and 63).

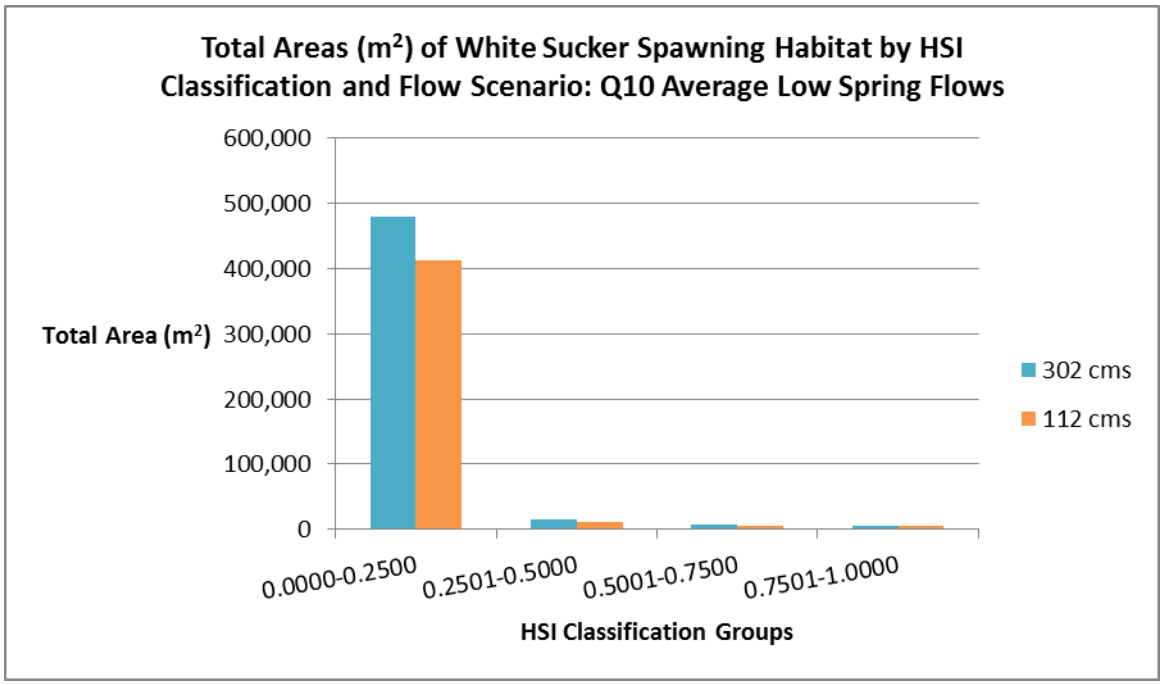


Figure 61: Total Areas of Spawning Habitat for White Sucker in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (302 m^3/s and 112 m^3/s).

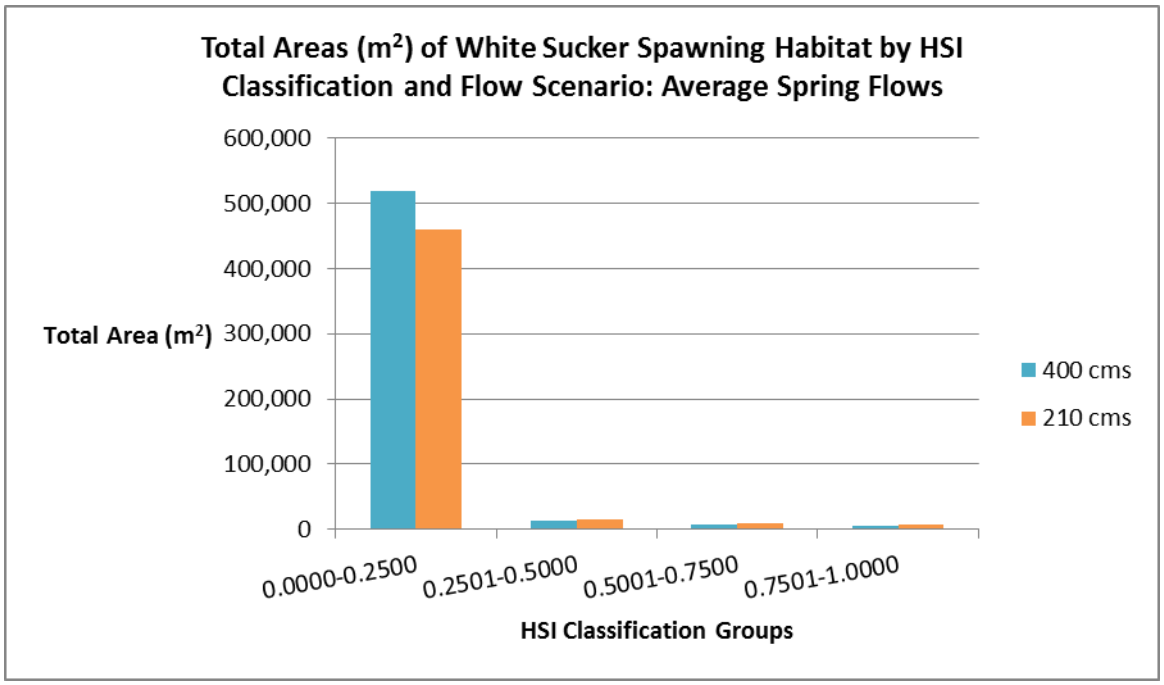


Figure 62: Total Areas of Spawning Habitat for White Sucker in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (400 m^3/s and 210 m^3/s).

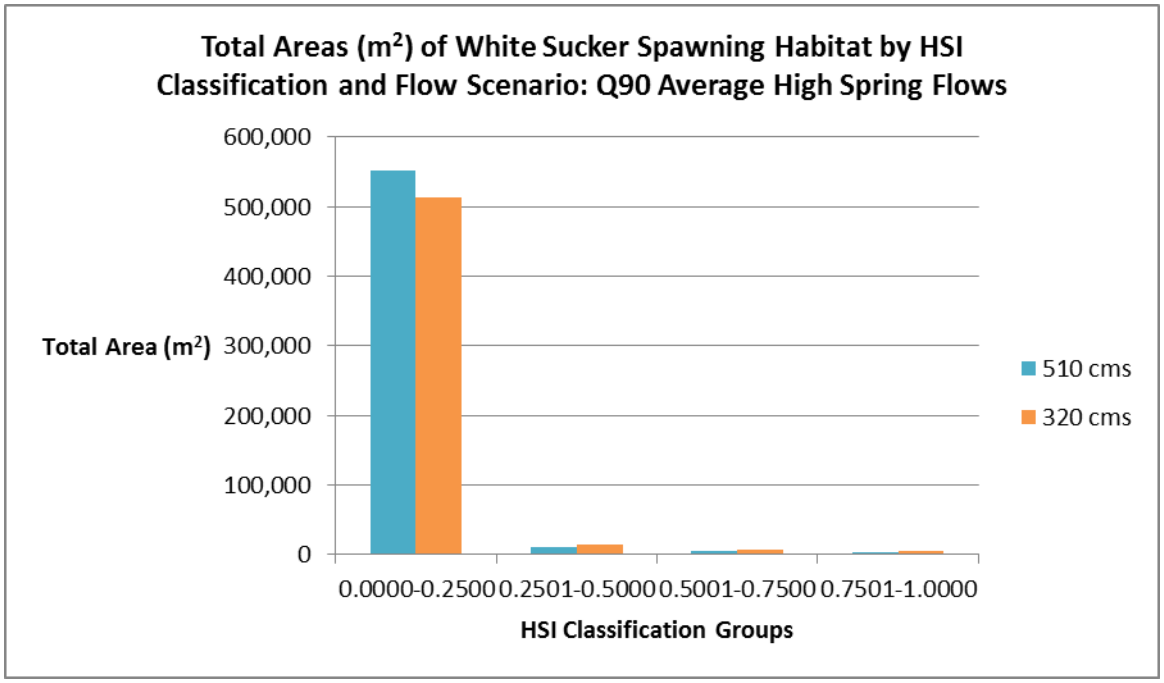


Figure 63: Total Areas of Spawning Habitat for Longnose Sucker in the Fond du Lac River between Black Lake and Middle Lake by HSI Value and Flow Scenario (510 m^3/s and 320 m^3/s).

Unsuitable white sucker spawning habitat will be lost whenever the Project is operating at 190 m^3/s and riparian flows are reduced accordingly (Table 23, Figures 61, 62 and 63). The amount of suitable spawning habitat for white sucker is also expected to decrease when Fond du Lac River flows are naturally low (i.e., 302 m^3/s) and the Project is operating at 190 m^3/s capacity. Moderately suitable and suitable habitats are predicted to decrease by 23.0% and 22.5%, respectively, when spring riparian flows are decreased from 302 m^3/s to 112 m^3/s (Table 23, Figure 61). At normal average to normal high spring flows, water withdrawal for power generation is expected to result in an overall improvement in white sucker spawning habitat. The amount of suitable habitat is expected to increase by 54.4% and 92.6% when riparian flows are reduced from 400 m^3/s and 510 m^3/s, respectively (Table 23, Figures 62 and 63). Moderately suitable spawning habitat for white sucker will also be gained when average to high riparian flows (i.e., 400 m^3/s or 510 m^3/s) are reduced by 190 m^3/s.

The quantity of unsuitable, poor, moderately suitable, and suitable spawning habitat available to white sucker in the Fond du Lac River was also determined by reach. Tables and figures for individual reaches are presented in Appendix 12.1-E, Table E3 and Figures E103 to E153. No suitable spawning habitat for white sucker was identified for reaches 2 (run), 4 (run), 5 (falls), 6 (run), 10 (rapids), 11 (run), 12 (rapid) and 19 (pool) based on the modelled average Q90 high flow (i.e., 510 m^3/s); suitable spawning habitat was also absent from reaches 4, 5, 6, 7 (rapids) and 19 when the modelled flows were reduced to 320 m^3/s. This may suggest that high flow years are less conducive to successful spawning for white sucker in the Fond du Lac River between Black Lake and Middle Lake relative to low flow years. This assumption is corroborated by the relatively large gains in white sucker habitat that are expected to occur when flows are reduced as a result of Project operation.

Based on the modelled values, Project operation will result in a consistent improvement to white sucker spawning habitat in Reach 14 (shallow, fast run) and Reach 22 (deep to moderately deep run); this is likely attributed to reduced velocities at these locations. Reduced velocities in Reach 5 (falls) resulting from Project operation are also expected to make this location more suitable for spawning white sucker, especially at low to average flows (i.e., at 112 m^3/s or 210 m^3/s).

4.0 SUMMARY

Results of the River2D hydrodynamic modelling enabled us to predict the effects that the reduced flow scenarios may have on several habitat variables, and what those changes may mean to fish species that overwinter and/or spawn in the Fond du Lac River.

4.1 Overwintering

As riparian flows decrease, so will the maximum depths in most river reaches between the submerged weir and the tailrace outlet. Slight (i.e., <10%) increases in maximum depths are expected to occur in Reach 21 (immediately upstream of the tailrace outlet reach) and Reach 22 (reach containing the tailrace outlet). Deep pools in reaches 9 and 19, as well as the deep to moderately deep run habitat in Reach 20 are expected to undergo relatively small percent decreases in maximum depth during Project operation. Mean velocities will decrease in all river reaches as flows decrease, with the exception of reaches 21 and 22. Pool habitats (reaches 9 and 19), and above the submerged weir (Reach 2) will undergo the greatest percent reduction in velocities; velocities will change the least in the deep to moderately deep run habitat of Reach 6 when flows are reduced to 50 m^3/s or 40 m^3/s. The mean velocity in Reach 22 is expected to decrease by one-third whenever the historically normal average winter low flow (i.e., 210 m^3/s) is reduced as a result of Project operation. Total wetted area and reach volumes are expected to decrease in all reaches between the submerged weir and

Reach 20, inclusive; increases in wetted area and reach volume are expected for reaches 21 and 22 when winter flow conditions are reduced below the normal historical average (i.e., below 210 m^3/s).

Habitat variables included in the evaluation of overwintering habitat in the Fond du Lac River for Arctic grayling and sucker species were depth (m) and velocity (m/s). Changes to the modelled depth and velocity variables resulted in changes to the habitat suitability indices for adult and age-0/juvenile Arctic grayling and sucker species.

Under the reduced flow conditions, the total area classified as unsuitable for age-0 and juvenile Arctic grayling habitat is predicted to decrease, while the poor, moderately suitable, and suitable habitat areas are expected to increase. .For adult Arctic grayling, it is anticipated that the total areas of unsuitable, poor, and moderately suitable habitat will decrease during Project operation and the total area of suitable overwintering habitat will increase.

Results were similar for sucker species. Under reduced flow scenarios the total area classified as unsuitable for age-0 and juvenile suckers is expected to decrease, while the poor, moderately suitable, and suitable habitat areas are expected to increase. For adult longnose sucker and white sucker, the total areas of unsuitable habitat are expected to decrease with decreasing winter flows; areas of moderately suitable and suitable habitat are expected to increase with decreasing riparian flows.

Habitat suitability indices for Arctic grayling and sucker species were determined by the depth and velocity habitat variables, and in all cases it is anticipated that unsuitable habitat will be lost and suitable habitat will be gained. The Arctic grayling and sucker species suitability curves for depth and velocity suggest that lower velocities are of higher quality for both age-0/juvenile and adult fish while the shallower depths are better for age-0/juvenile fish. Adult Arctic grayling and sucker species require deeper water. Given that maximum depth and average velocity both decrease with reduced flow, and suitable habitat increases for both age-0/juvenile and adult fish, it can be determined that the decrease in average velocity throughout the river has a greater effect on the suitability of habitat than the decrease in maximum depth. The modelling results indicate that changes to depths and velocities resulting from decreased winter flows are likely to result in an overall increase in “suitable” habitat.

4.2 Spawning

Maximum depths decreased with decreasing flow for most river reaches assessed between Black Lake and Middle Lake. Reaches 21 and 22 were the exceptions; maximum depths in these reaches tended to be greater under Project flows than during historically natural flows. This phenomenon may be the result of changes to flow patterns (e.g., formation of backwater areas) and/or characteristics of the tailrace outlet channel and tailrace outlet bay (e.g., changes induced by re-contouring and excavation).

Predicted mean velocities were greatest for the 400 m^3/s and 510 m^3/s flow scenarios. For pools (reaches 9 and 19) and most deep to moderately deep runs, the greatest mean velocities occurred during 510 m^3/s flows; for swift runs, falls, and rapids, the greatest mean velocities occurred at 400 m^3/s flows. This is attributed to flow-induced changes to wetted width and depths in a number of reaches. For normal Q10 low (i.e., 302 m^3/s), normal average (i.e., 400 m^3/s) and normal Q90 high (i.e., 510 m^3/s) flows, water withdrawal for power generation is expected to result in an overall decrease in water velocities.

Total reach areas are generally expected to decrease as a result of Project operation. Small increases in total reach area are expected for reaches 21 and 22; these increases may be due to changes in flow patterns and river bottom morphology induced by the Project. Total reach volume is also expected to decrease with decreasing flow in all reaches except 21 and 22. The volumes of pool habitats (reaches 9 and 19), and Reach 2 above the submerged weir are expected to be fairly resistant to decreases in flow.

For Arctic grayling, the largest proportion of river area is expected to fall within the category of unsuitable spawning habitat, regardless of flow level. Suitable spawning habitats for Arctic grayling are expected to decrease in size (m^2) whenever natural flow conditions are in the normal (i.e., average) to low range and the Project is operating. Operation of the Project at historically normal high flows is expected to result in minor (i.e., 8.4%) increases in the total area of suitable habitat available for spawning. Because areas of suitable Arctic grayling spawning habitat are expected to be lowest at 112 m^3/s riparian flows based on the two-parameter (i.e., depth and velocity) HSI model, substrate types were assessed for this flow to estimate the minimum area of suitable depth, velocity and substrates that will be available to Arctic grayling that will spawn in the Fond du Lac River when the Project is operating. It is estimated that for 112 m^3/s flows, 11,492 m^2 of "moderately suitable" and 14,216 m^2 of "suitable" habitat will be located over substrates that are conducive to successful spawning for Arctic grayling.

For longnose sucker, unsuitable spawning habitat was the most common habitat type for each of the spring flow scenarios; however, the average Q90 high flow had the largest proportion of unsuitable spawning habitat and the smallest proportion of suitable spawning habitat. Suitable spawning habitat for longnose sucker is likely to be gained as a result of Project operation during average-to-high flows years. Suitable habitat will be lost as a result of Project operation during low flow years; however, the total area of suitable habitat will still be greater than that available during normal high flows without the Project in place (i.e., within the range of natural variability).

Under all flow scenarios assessed, the largest proportions of spawning habitat for white sucker falls within the category of unsuitable habitat, followed by poor, moderately suitable, and then suitable. In general, suitable habitat is expected to increase with decreasing riparian flow until the modelled flow of 112 m^3/s is reached. The greatest percent increase in suitable white sucker spawning habitat is expected to occur when Q90 average high flows (i.e., 510 m^3/s) are reduced to 320 m^3/s.

Spawning habitat suitability indices for Arctic grayling, longnose sucker, and white sucker were determined by the depth and velocity habitat variables; additional substrate data was also assessed for Arctic grayling. Overall, it is anticipated that no substantial losses to suitable habitat will occur as a result of reduced riparian flows associated with the Project. The Arctic grayling and sucker species suitability curves for depth and velocity suggest that low to moderate velocities and shallower depths are of higher quality for spawning. It is anticipated that the general decrease in average velocity throughout the river under reduced flow conditions has a large effect on suitability of spawning habitat within the river.

Because the amount of suitable spawning and overwintering habitat for white sucker is expected to increase during most periods of Project operation, it is possible that white sucker populations will increase. Predation of fish eggs by white sucker has been reported for other systems, although the accuracy of this data is considered equivocal (Holey et al. 1979; Scott and Crossman 1973). Scott and Crossman (1973) identified a study where no eggs were found in the stomach contents of 100 white sucker that were captured from a lake whitefish

(Cor*egonus clupeaformis*) spawning area during the spawning season. Similarly, Stewart (1926) reported that no eggs were found in the stomachs of over 200 white sucker that were captured over brook trout (*Salvelinus fontinalis*) redds. Holey et al. (1979) completed a review of the relevant literature, and determined that even in situations where white sucker have been known to consume eggs and fry of other species, predation was not of sufficient magnitude to cause effects to populations.

Young white suckers may compete with Arctic grayling in the event that food supplies in the river become scarce (Holey et al. 1979) as there is some overlap in preferred food items. Young Arctic grayling and white sucker fry feed within the water column; the former consumes zooplankton and immature insects and the latter depends on plankton and small invertebrates (Scott and Crossman 1973). However, because adult Arctic grayling tend to feed on food items found drifting in the water column (mostly plankton) and adult white sucker feed primarily at the bottom, there is expected to be only minor overlap in feeding strategies and therefore minimal opportunity for competition.

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Appendix 12.1-A

Values Used to Construct Overwintering Suitability Index (SI) Curves

February 2014
Project No. 10-1365-0004/DCN-171

Table A1: Values Used to Construct Depth and Velocity Suitability Index (SI) Curves for Arctic Grayling (*Thymallus arcticus*) Overwintering in the Fond du Lac River

Age Group	Depth (m)	Corresponding Depth SI Value	Velocity (m/s)	Corresponding Velocity SI Value
Age-0/Juvenile	Golder 2013a; Jones and Tonn 2004			
	0	0	0	1
	0.15	1	0.4999	1
	0.5899	1	0.6	0.5
	1.0643	0	1.0	0
	1.1	0	1.1	0
Adult	Golder 2013a; Ford et al. 1995			
	0	0	0	1
	0.49	0	0.5	1
	0.5	0.5	1.5	0
	1	1	2	0
	100	1	-	-

m = metre; SI = Suitability Index; m/s = metres per second; - = not applicable.

Table A2: Values Used to Construct Depth and Velocity Suitability Index (SI) Curves for Sucker (*Catostomus*) Species Overwintering in the Fond du Lac River

Age Group	Depth (m)	Corresponding Depth SI Value	Velocity (m/s)	Corresponding Velocity SI Value
Age-0/Juvenile	Becker 1983; Walton 1980		Hatfield et al. 1972; Walton 1980	
	0	0	0	1
	0.05	0	0.7	1
	0.1	1	0.85	0.5
	0.6	1	1	0
	1	0	2	0
	1.1	0	-	-
Adult	Hatfield et al. 1972; Walton 1980			
	0	0	0	1
	1	1	0.7	1
	1.1	1	0.85	0.5
	-	-	1	0
	-	-	2	0

m = metre; SI = Suitability Index; m/s = metres per second; - = not applicable.

Appendix 12.1-B

Values Used to Construct Spawning Suitability Index (SI) Curves

February 2014
Project No. 10-1365-0004/DCN-171

Table B1: Values used to Construct Depth and Velocity Suitability Index (SI) Curves for Arctic Grayling (*Thymallus arcticus*) Spawning in the Fond du Lac River

Age Group	Depth (m)	Corresponding Depth SI Value	Velocity (m/s)	Corresponding Velocity SI Value
Adult	Golder 2013b; Hubert et al. 1985			
	0	0	0	0.7
	0.1	0	0.5	1
	0.3	1	0.6	1
	0.8	1	0.9	0
	1	0	1.2	0

m = metre; SI = Suitability Index; m/s = metres per second.

Table B2: Values used to Construct Depth and Velocity Suitability Index (SI) curves for Longnose Sucker (*Catostomus catostomus*) Spawning in the Fond du Lac River

Age Group	Depth (m)	Corresponding Depth SI Value	Velocity (m/s)	Corresponding Velocity SI Value
Adult	Edwards 1983			
	0	0	0	0
	0.09	1	0.2	1
	0.21	1	0.75	1
	1.2	0	1	0

m = metre; SI = Suitability Index; m/s = metres per second.

Table B3: Values used to Construct Depth and Velocity Suitability Index (SI) Curves for White Sucker (*Catostomus commersonii*) Spawning in the Fond du Lac River

Age Group	Depth (m)	Corresponding Depth SI Value	Velocity (m/s)	Corresponding Velocity SI Value
Adult	Twomey et al. 1984			
	0	0	0	0
	0.15	1	0.15	0.4
	0.24	1	0.3	1
	0.3	0.8	0.61	1
	0.61	0	0.91	0
	100	0	100	0

m = metre; SI = Suitability Index; m/s = metres per second.

Appendix 12.1-C

Values Used to Construct Suitability Index (SI) Curves used in the Sensitivity Analysis

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Project No. 10-1365-0004/DCN-171

Table C1: Depth Values used to Construct Depth Suitability Index (SI) Curves used in the Sensitivity Analysis for Arctic Grayling (*Thymallus arcticus*) Spawning in the Fond du Lac River

Age Group	10% Shift Left		Depth (m)	Corresponding Velocity SI Value	10% Shift Right	
	Depth (m)	Corresponding Depth SI Value			Depth (m)	Corresponding Depth SI Value
Adult	Golder 2013b; Hubert et al. 1985					
	0	0	0	0	0	0
	0.09	0	0.1	0	0.11	0
	0.27	1	0.3	1	0.33	1
	0.72	1	0.8	1	0.88	1
	0.9	0	1	0	1.1	0

% = percent; m = metre; SI = Suitability Index; m/s = metres per second.

Table C2: Velocity Values used to Construct Velocity Suitability Index (SI) Curves used in the Sensitivity Analysis for Arctic Grayling (*Thymallus arcticus*) Spawning in the Fond du Lac River

Age Group	10% Shift Left		Velocity (m/s)	Corresponding Velocity SI Value	10% Shift Right	
	Velocity (m/s)	Corresponding Depth SI Value			Velocity (m/s)	Corresponding Velocity SI Value
Adult	Golder 2013b; Hubert et al. 1985					
	01	0.7	0	0.7	0	0.7
	0.45	1	0.5	1	0.55	1
	0.54	1	0.6	1	0.66	1
	0.8	0	0.9	0	0.99	0
	1.08	0	1.2	0	1.32	0

% = percent; m = metre; SI = Suitability Index; m/s = metres per second.

Appendix 12.1-D

Overwintering Habitat Suitability by Reach

February 2014
Project No. 10-1365-0004/DCN-171

Table D1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 2								
0.0000-0.2500	Unsuitable	33,343	33,343	0.0	33,343	0.0	33,343	0.0
0.2501-0.5000	Poor	1,578	1,578	0.0	1,578	0.0	1,578	0.0
0.5001-0.7500	Moderately Suitable	1,015	1,015	0.0	1,015	0.0	1,015	0.0
0.7501-1.0000	Suitable	3,229	3,229	0.0	3,229	0.0	3,229	0.0
Reach 3								
0.0000-0.2500	Unsuitable	45,811	25,772	-43.7	23,753	-48.2	21,222	-53.7
0.2501-0.5000	Poor	2,706	3,928	45.2	3,296	21.8	3,097	14.4
0.5001-0.7500	Moderately Suitable	1,551	2,273	46.6	2,198	41.7	1,620	4.4
0.7501-1.0000	Suitable	5,540	6,977	25.9	6,935	25.2	7,257	31.0
Reach 4								
0.0000-0.2500	Unsuitable	26,466	20,272	-23.4	19,029	-28.1	16,897	-36.2
0.2501-0.5000	Poor	626	1,178	88.2	1,578	152.1	1,751	179.7
0.5001-0.7500	Moderately Suitable	622	876	40.8	978	57.2	1,228	97.4
0.7501-1.0000	Suitable	1,625	2,653	63.3	2,765	70.2	3,548	118.3
Reach 5								
0.0000-0.2500	Unsuitable	9,784	5,024	-48.7	4,562	-53.4	3,596	-63.2
0.2501-0.5000	Poor	392	918	134.2	631	61.0	391	-0.3
0.5001-0.7500	Moderately Suitable	304	386	27.0	490	61.2	533	75.3
0.7501-1.0000	Suitable	974	1,203	23.5	1,390	42.7	2,226	128.5
Reach 6								
0.0000-0.2500	Unsuitable	11,295	7,613	-32.6	7,121	-37.0	5,941	-47.4
0.2501-0.5000	Poor	603	403	-33.2	550	-8.8	968	60.5
0.5001-0.7500	Moderately Suitable	619	255	-58.8	301	-51.4	492	-20.5
0.7501-1.0000	Suitable	1,363	1,370	0.5	1,317	-3.4	1,845	35.4

Table D1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 7								
0.0000-0.2500	Unsuitable	8,101	6,418	-20.8	6,221	-23.2	5,654	-30.2
0.2501-0.5000	Poor	176	237	34.7	288	63.6	473	168.8
0.5001-0.7500	Moderately Suitable	251	161	-35.9	222	-11.6	86	-65.7
0.7501-1.0000	Suitable	727	924	27.1	856	17.7	1,143	57.2
Reach 8								
0.0000-0.2500	Unsuitable	16,737	15,164	-9.4	14,982	-10.5	14,701	-12.2
0.2501-0.5000	Poor	208	157	-24.5	232	11.5	474	127.9
0.5001-0.7500	Moderately Suitable	90	191	112.2	171	90.0	257	185.6
0.7501-1.0000	Suitable	878	894	1.8	806	-8.2	910	3.6
Reach 9								
0.0000-0.2500	Unsuitable	27,283	25,061	-8.1	24,664	-9.6	23,961	-12.2
0.2501-0.5000	Poor	561	307	-45.3	350	-37.6	490	-12.7
0.5001-0.7500	Moderately Suitable	204	322	57.8	286	40.2	327	60.3
0.7501-1.0000	Suitable	1,211	773	-36.2	879	-27.4	1,369	13.0
Reach 10								
0.0000-0.2500	Unsuitable	5,828	2,951	-49.4	2,803	-51.9	2,512	-56.9
0.2501-0.5000	Poor	272	211	-22.4	222	-18.4	121	-55.5
0.5001-0.7500	Moderately Suitable	18	204	1033.3	178	888.9	227	1161.1
0.7501-1.0000	Suitable	228	493	116.2	615	169.7	689	202.2
Reach 11								
0.0000-0.2500	Unsuitable	15,864	12,804	-19.3	12,245	-22.8	11,780	-25.7
0.2501-0.5000	Poor	369	811	119.8	881	138.8	942	155.3
0.5001-0.7500	Moderately Suitable	215	599	178.6	677	214.9	1,068	396.7
0.7501-1.0000	Suitable	983	1,719	74.9	1,868	90.0	1,992	102.6

Table D1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 12								
0.0000-0.2500	Unsuitable	5,584	4,650	-16.7	4,165	-25.4	3,875	-30.6
0.2501-0.5000	Poor	242	129	-46.7	343	41.7	351	45.0
0.5001-0.7500	Moderately Suitable	147	190	29.3	35	-76.2	122	-17.0
0.7501-1.0000	Suitable	1,329	616	-53.6	784	-41.0	724	-45.5
Reach 13								
0.0000-0.2500	Unsuitable	31,642	25,041	-20.9	24,233	-23.4	23,958	-24.3
0.2501-0.5000	Poor	370	2,391	546.2	2,144	479.5	1,973	433.2
0.5001-0.7500	Moderately Suitable	280	1,256	348.6	1,261	350.4	1,094	290.7
0.7501-1.0000	Suitable	762	3,427	349.7	4,320	466.9	4,110	439.4
Reach 14								
0.0000-0.2500	Unsuitable	64,870	37,309	-42.5	35,068	-45.9	31,621	-51.3
0.2501-0.5000	Poor	5,069	4,310	-15.0	3,595	-29.1	4,224	-16.7
0.5001-0.7500	Moderately Suitable	3,412	2,926	-14.2	2,158	-36.8	2,512	-26.4
0.7501-1.0000	Suitable	9,757	8,377	-14.1	8,704	-10.8	8,378	-14.1
Reach 19								
0.0000-0.2500	Unsuitable	6,267	6,034	-3.7	5,939	-5.2	5,907	-5.7
0.2501-0.5000	Poor	0	128	100.0	0	0.0	33	100.0
0.5001-0.7500	Moderately Suitable	149	65	-56.4	193	29.5	0	-100.0
0.7501-1.0000	Suitable	219	42	-80.8	42	-80.8	235	7.3
Reach 20								
0.0000-0.2500	Unsuitable	24,751	14,108	-43.0	13,961	-43.6	12,953	-47.7
0.2501-0.5000	Poor	2,008	1,656	-17.5	1,202	-40.1	1,299	-35.3
0.5001-0.7500	Moderately Suitable	1,336	1,534	14.8	1,122	-16.0	1,351	1.1
0.7501-1.0000	Suitable	6,079	5,797	-4.6	6,439	5.9	5,984	-1.6

Table D1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 21								
0.0000-0.2500	Unsuitable	7,110	8,115	14.1	7,926	11.5	6,770	-4.8
0.2501-0.5000	Poor	640	439	-31.4	509	-20.5	604	-5.6
0.5001-0.7500	Moderately Suitable	447	441	-1.3	411	-8.1	493	10.3
0.7501-1.0000	Suitable	599	1,420	137.1	1,518	153.4	1,438	140.1
Reach 22								
0.0000-0.2500	Unsuitable	47,430	55,835	17.7	55,496	17.0	52,427	10.5
0.2501-0.5000	Poor	3,362	3,262	-3.0	3,754	11.7	4,468	32.9
0.5001-0.7500	Moderately Suitable	2,948	3,376	14.5	2,461	-16.5	2,949	0.0
0.7501-1.0000	Suitable	8,163	9,711	19.0	9,932	21.7	9,168	12.3

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

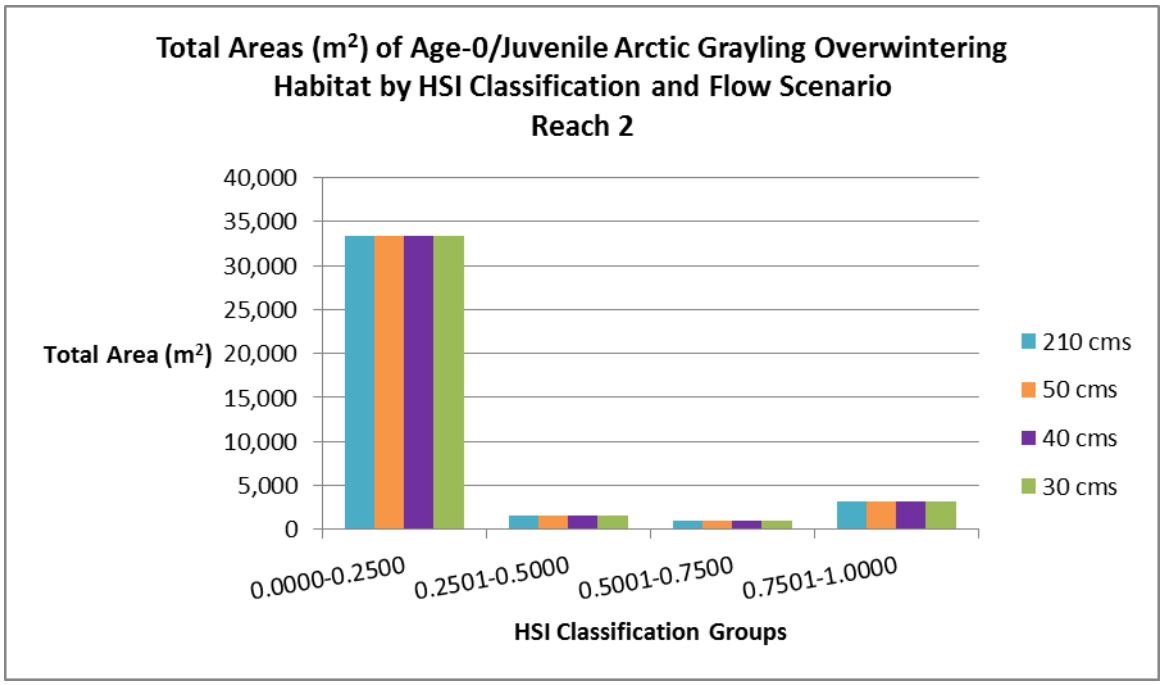


Figure D1: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 2 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

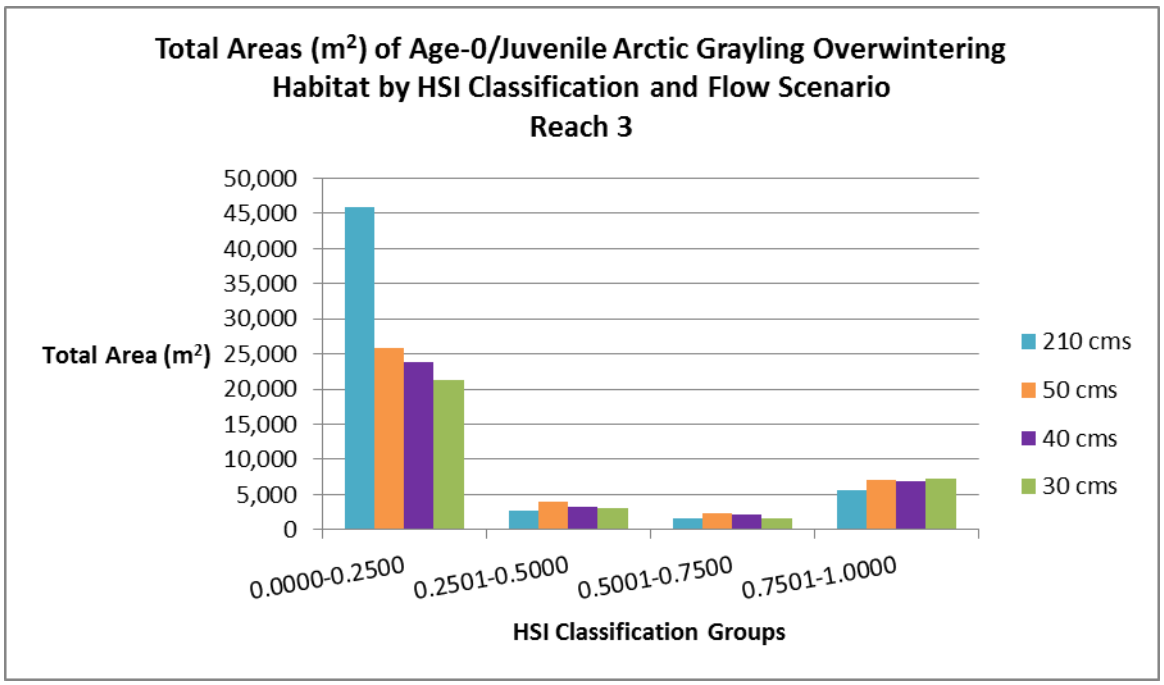


Figure D2: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 3 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

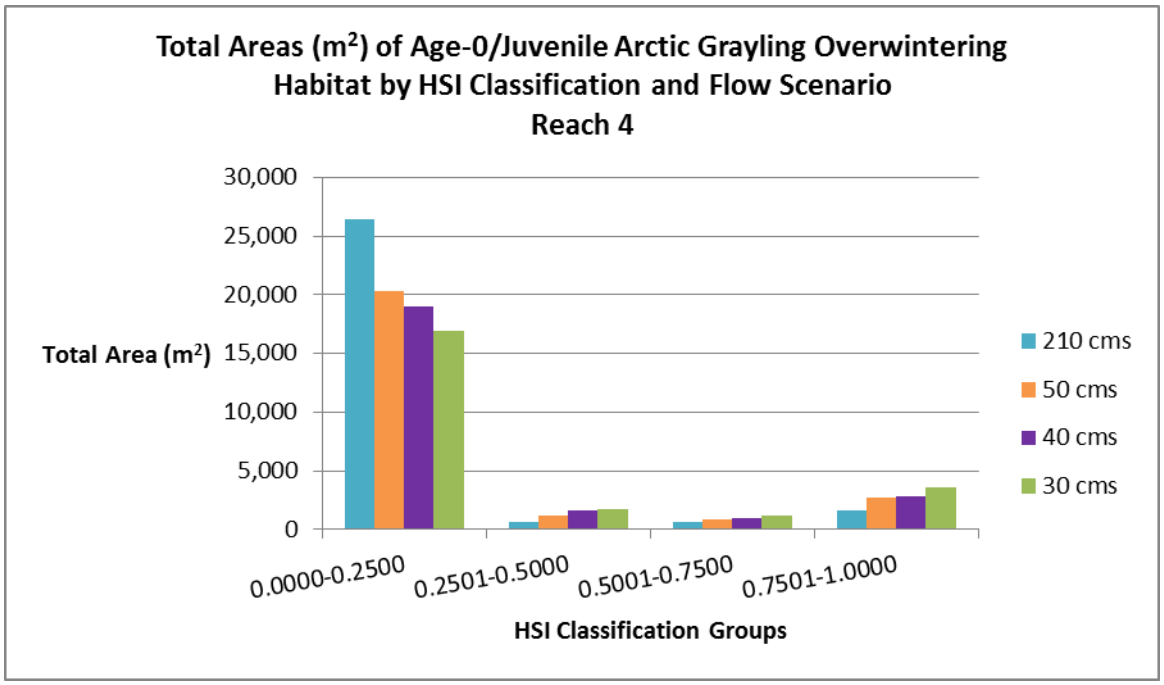


Figure D3: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 4 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

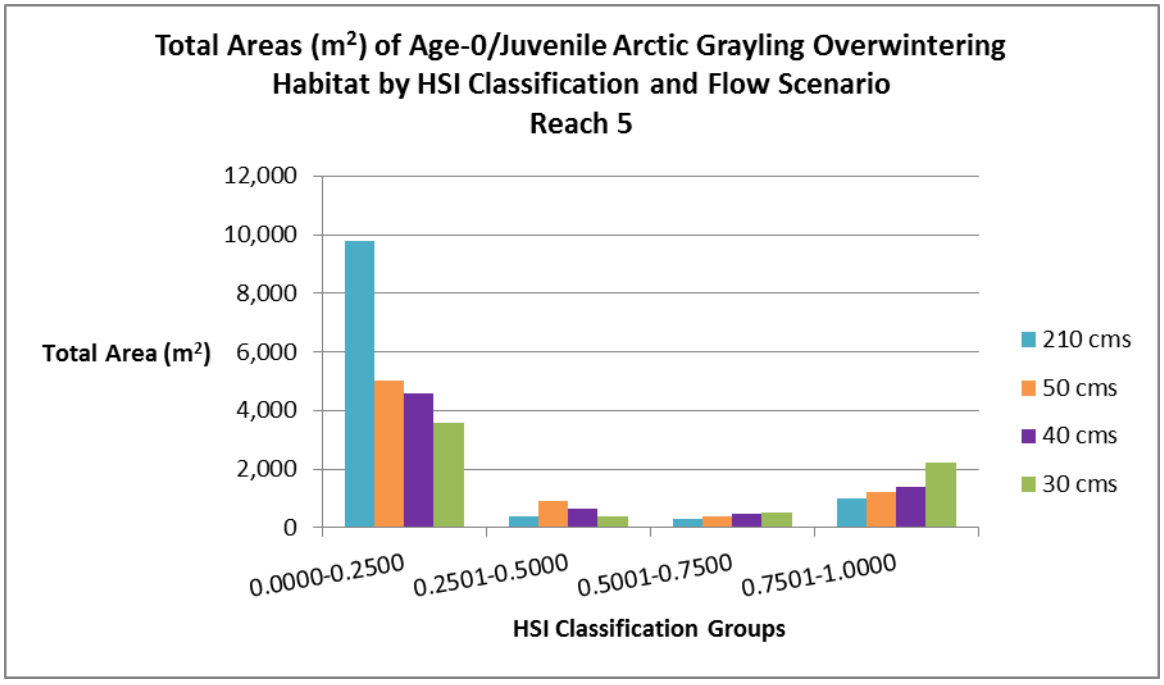


Figure D4: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 5 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

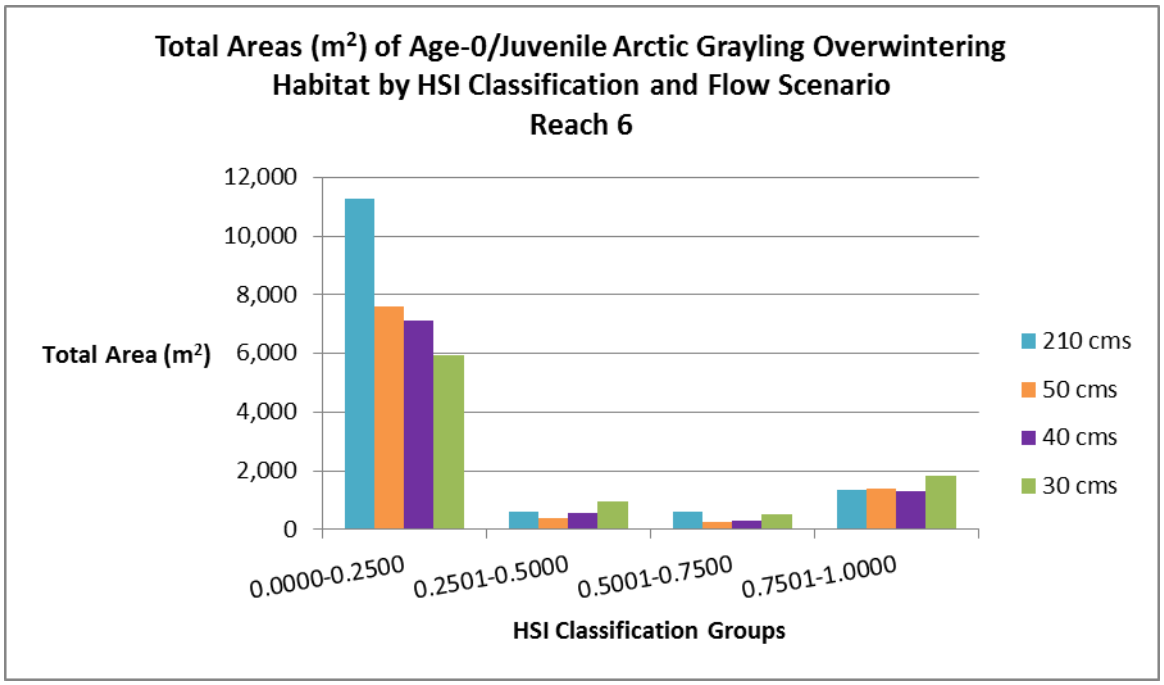


Figure D5: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 6 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

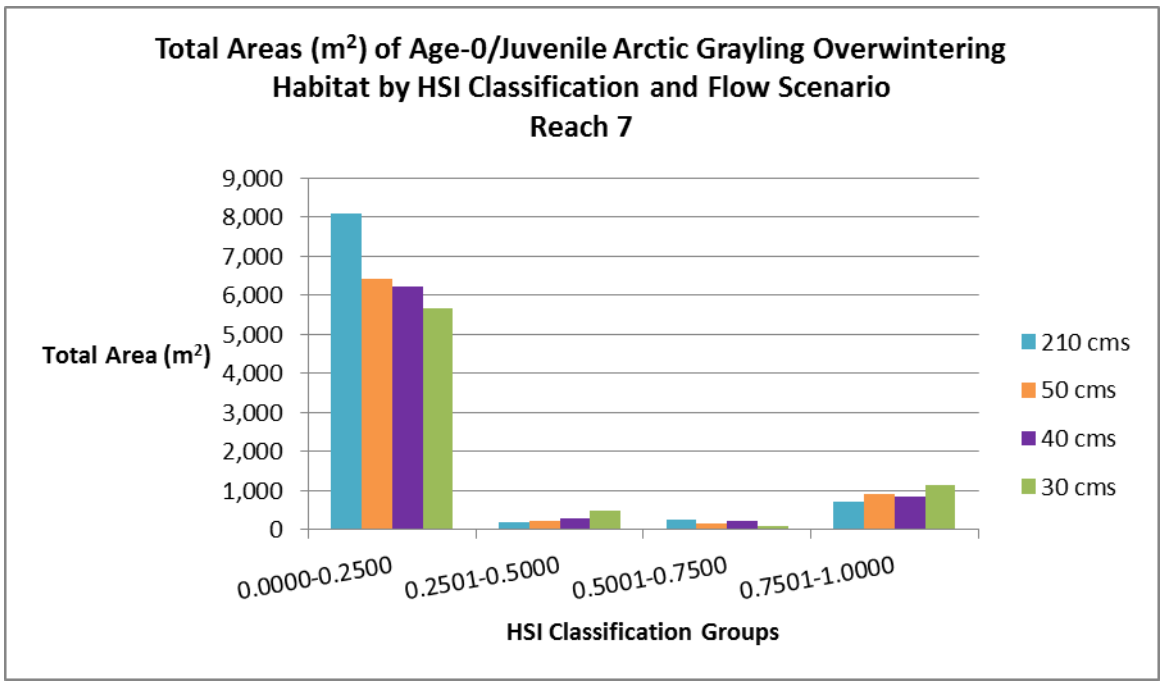


Figure D6: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 7 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

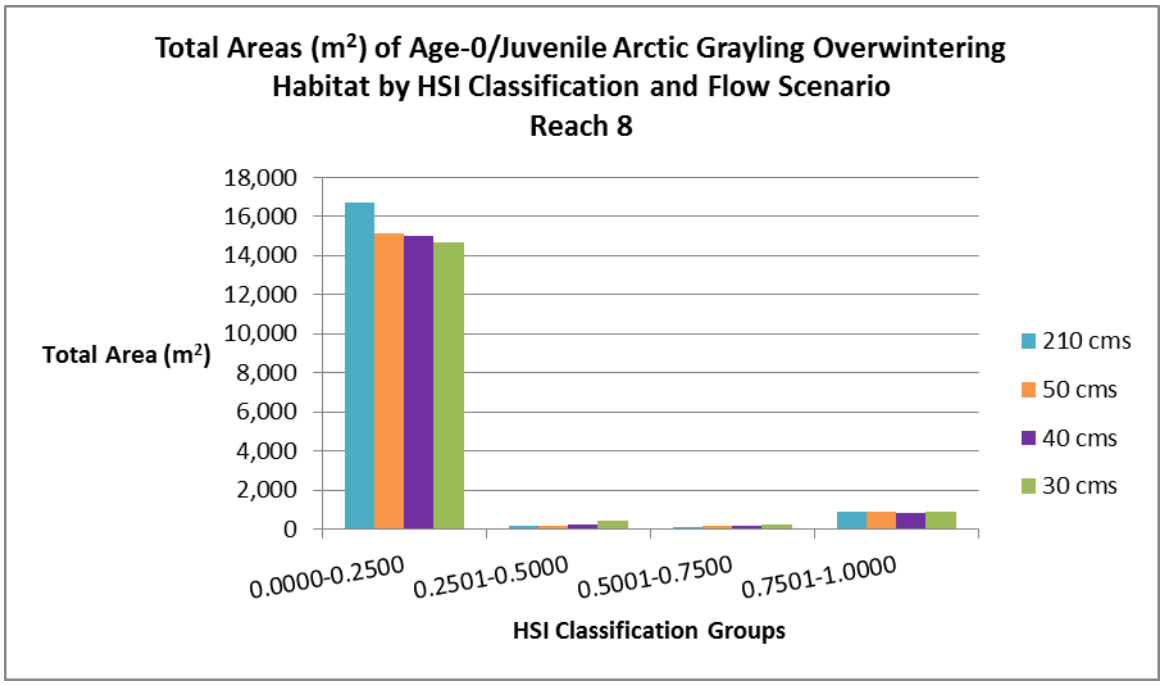


Figure D7: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 8 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

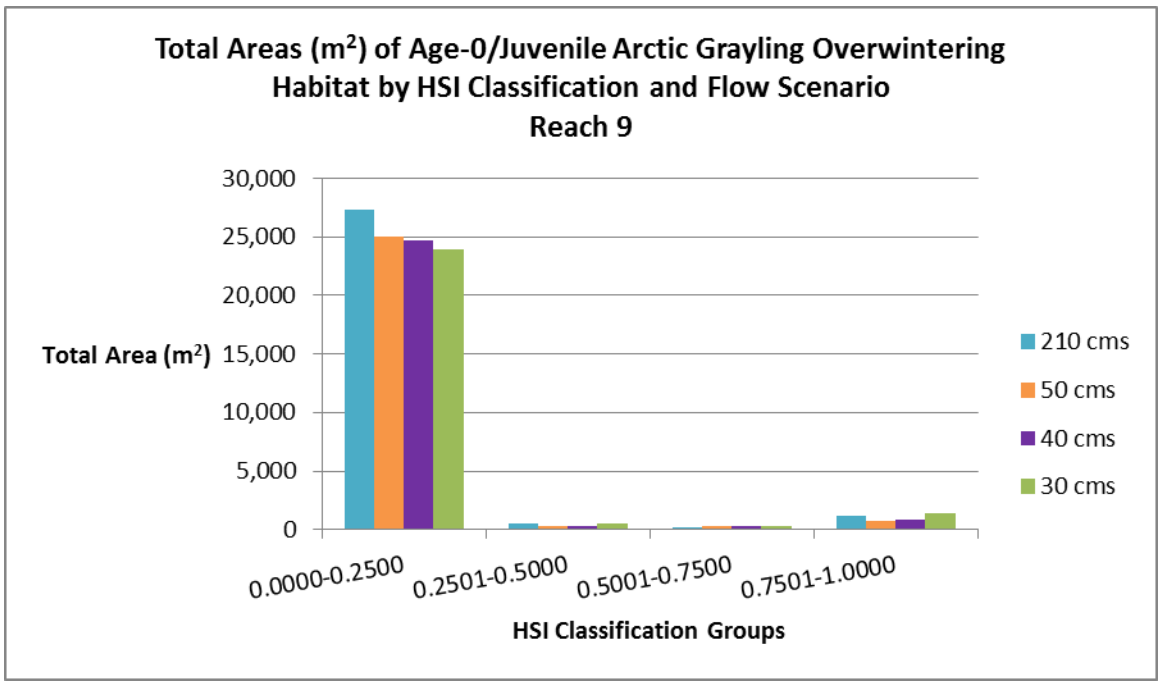


Figure D8: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 9 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

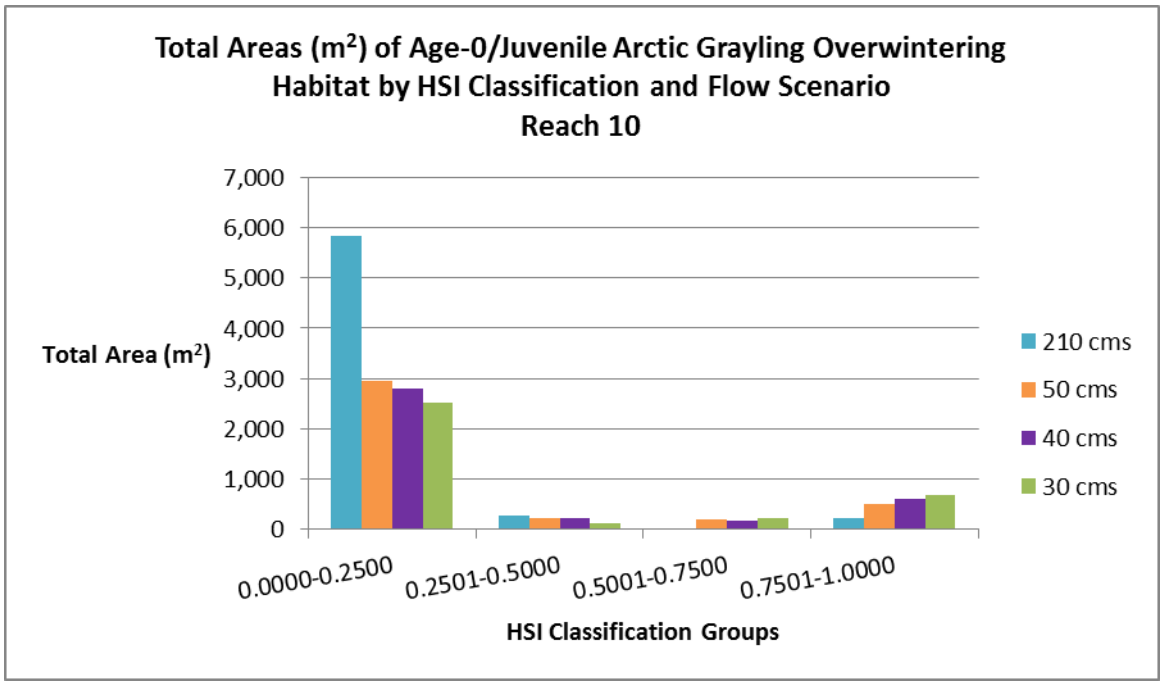


Figure D9: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 10 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

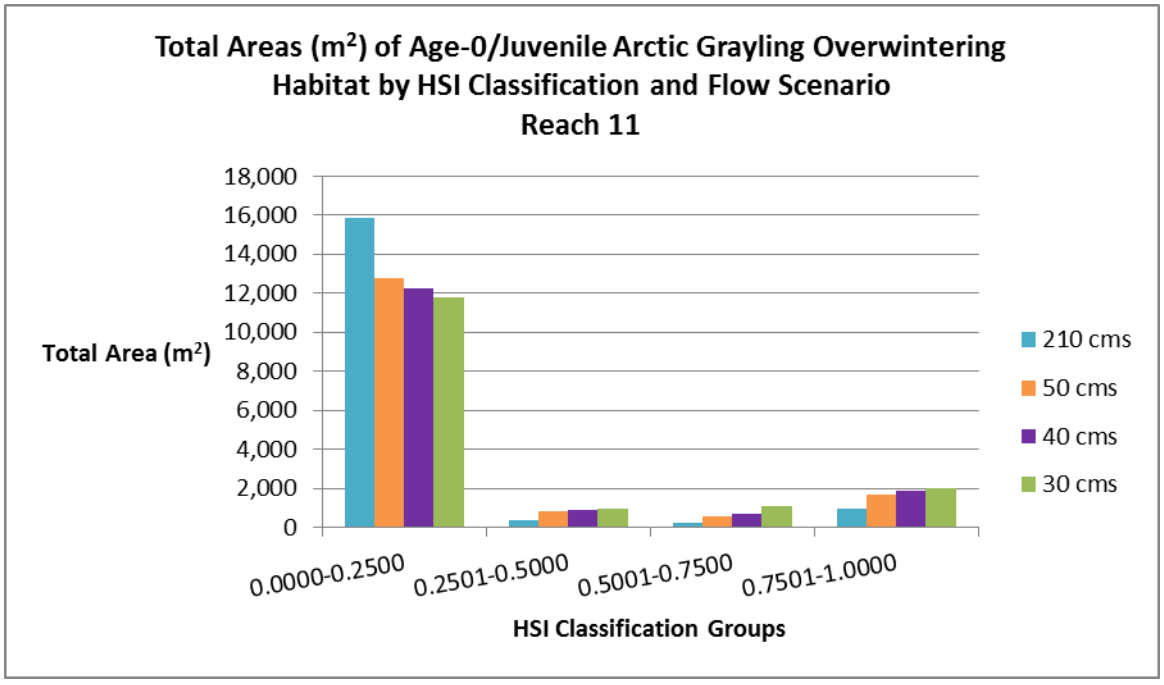


Figure D10: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 11 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

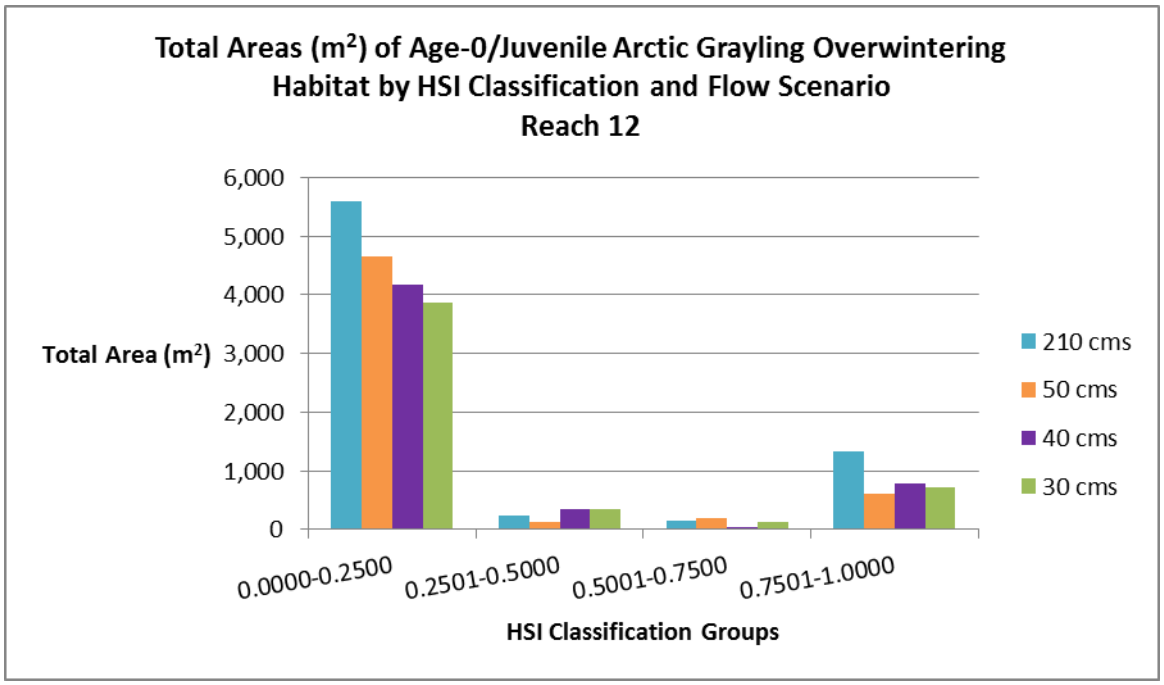


Figure D11: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 12 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

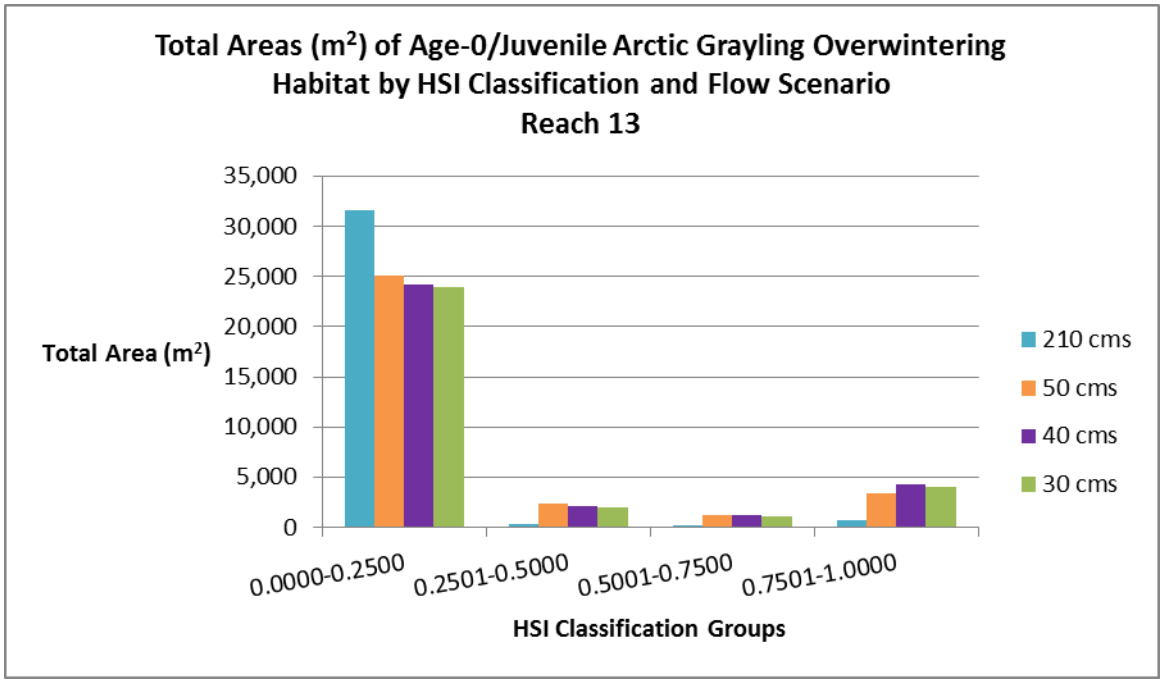


Figure D12: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 13 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

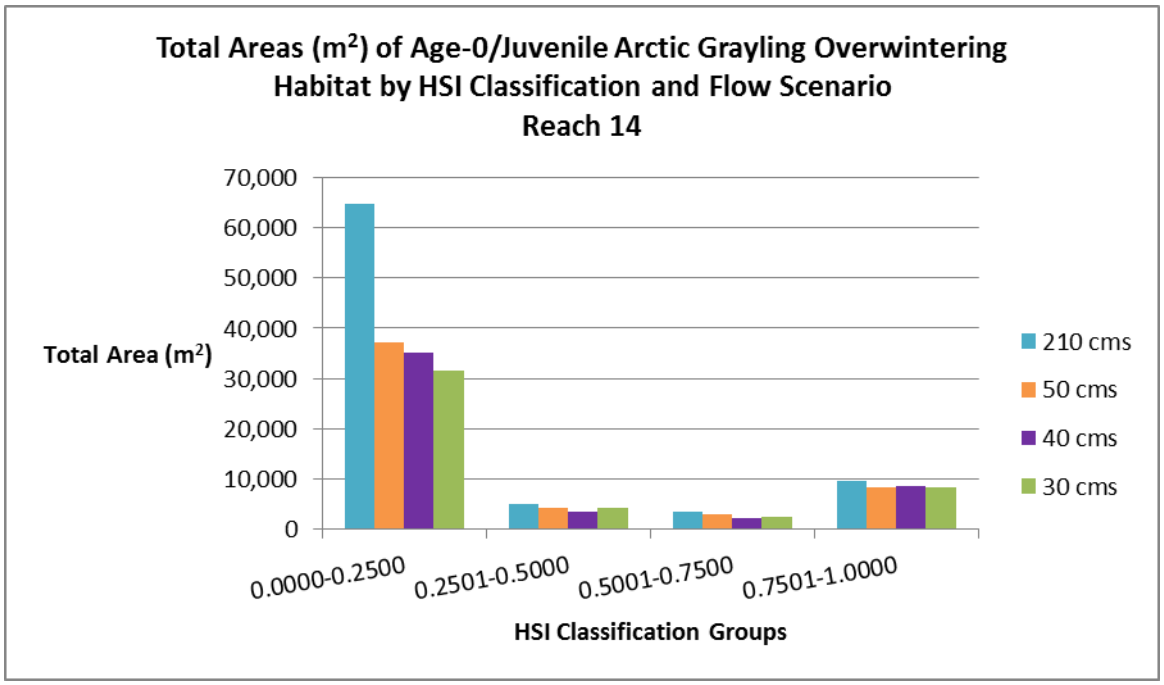


Figure D13: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 14 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

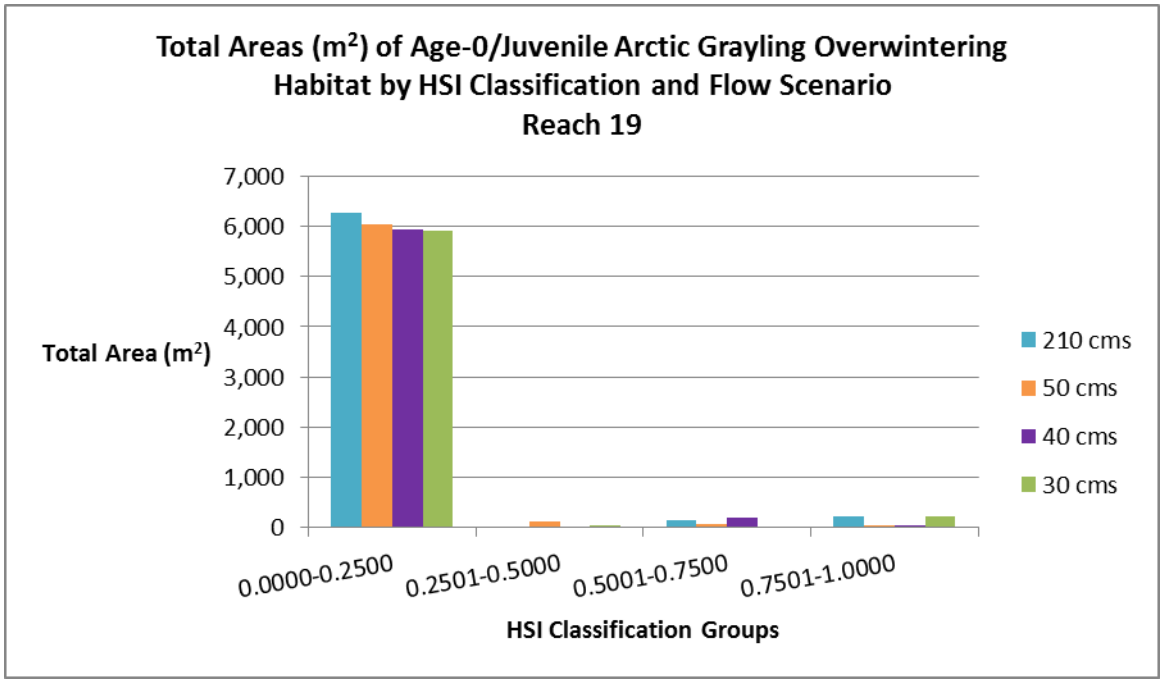


Figure D14: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 19 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

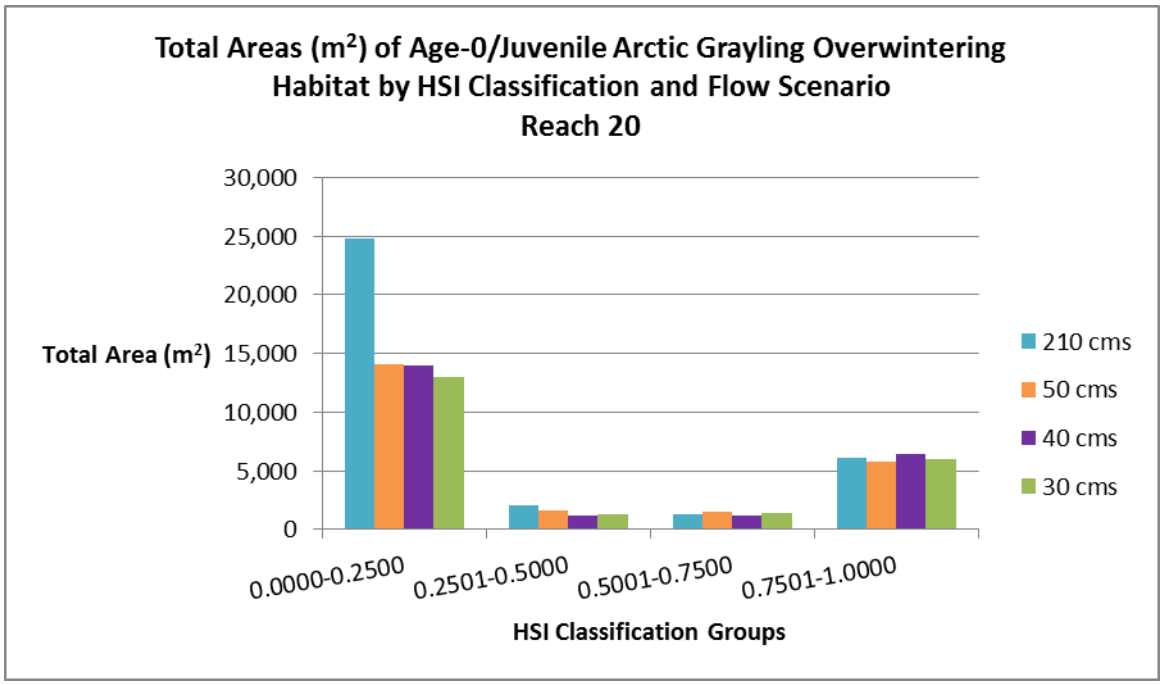


Figure D15: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 20 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

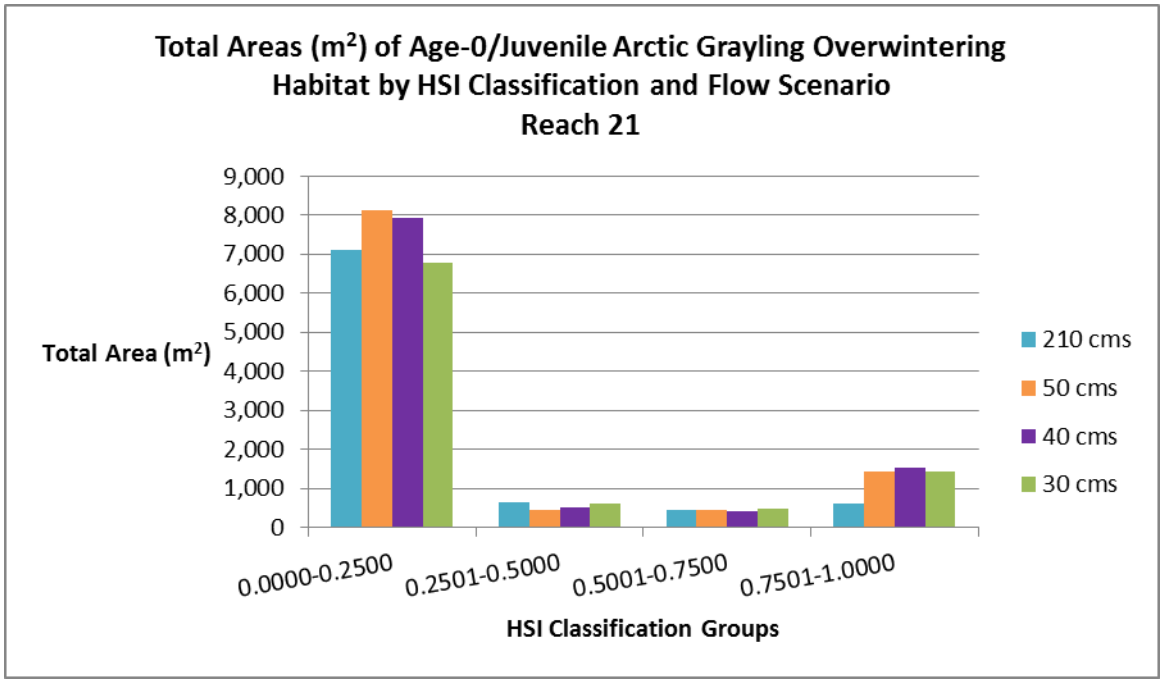


Figure D16: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 21 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

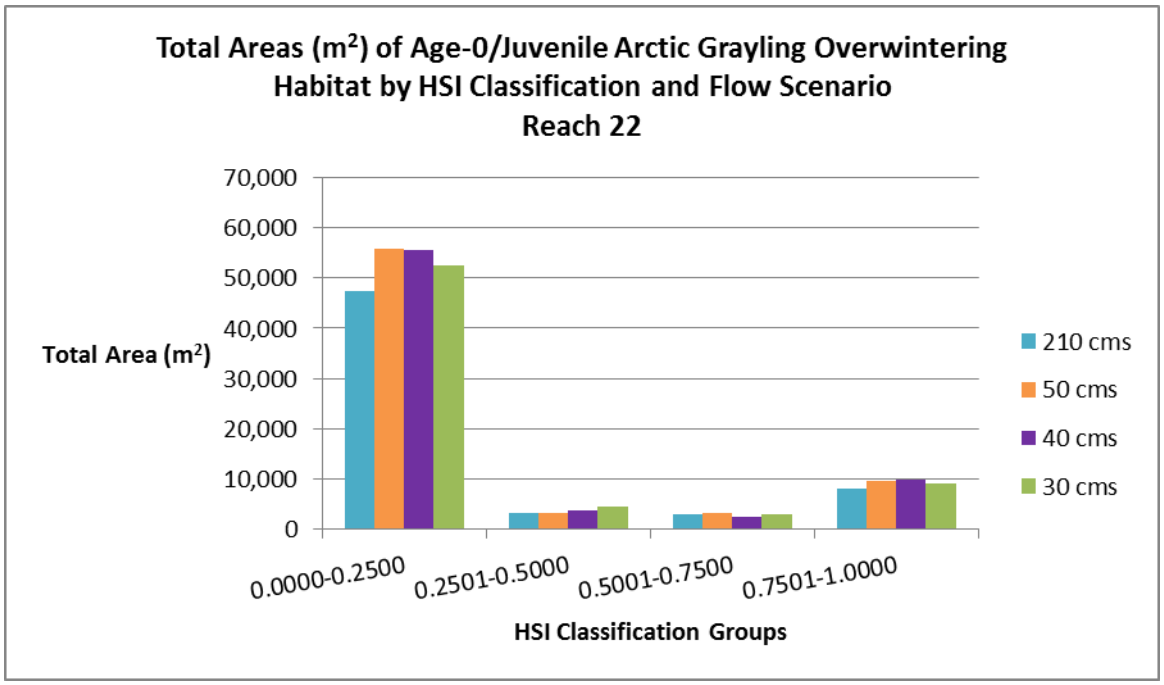


Figure D17: Total Areas of Age-0 and Juvenile Arctic Grayling Overwintering Habitat in River Reach 22 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Table D2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 2								
0.0000-0.2500	Unsuitable	6,711	6,711	0.0	6,711	0.0	6,711	0.0
0.2501-0.5000	Poor	3,553	3,553	0.0	3,553	0.0	3,553	0.0
0.5001-0.7500	Moderately Suitable	5,058	5,058	0.0	5,058	0.0	5,058	0.0
0.7501-1.0000	Suitable	23,844	23,844	0.0	23,844	0.0	23,844	0.0
Reach 3								
0.0000-0.2500	Unsuitable	41,291	18,646	-54.8	15,762	-61.8	14,305	-65.4
0.2501-0.5000	Poor	2,871	2,607	-9.2	2,034	-29.2	1,630	-43.2
0.5001-0.7500	Moderately Suitable	5,353	6,467	20.8	5,989	11.9	4,850	-9.4
0.7501-1.0000	Suitable	6,093	11,229	84.3	12,397	103.5	12,410	103.7
Reach 4								
0.0000-0.2500	Unsuitable	14,468	5,774	-60.1	5,348	-63.0	3,825	-73.6
0.2501-0.5000	Poor	2,856	2,014	-29.5	1,257	-56.0	958	-66.5
0.5001-0.7500	Moderately Suitable	2,654	5,084	91.6	4,960	86.9	4,039	52.2
0.7501-1.0000	Suitable	9,361	12,107	29.3	12,785	36.6	14,602	56.0
Reach 5								
0.0000-0.2500	Unsuitable	9,031	6,310	-30.1	6,143	-32.0	5,860	-35.1
0.2501-0.5000	Poor	260	188	-27.7	167	-35.8	196	-24.6
0.5001-0.7500	Moderately Suitable	613	684	11.6	572	-6.7	590	-3.8
0.7501-1.0000	Suitable	1,549	349	-77.5	191	-87.7	100	-93.5
Reach 6								
0.0000-0.2500	Unsuitable	11,199	7,827	-30.1	7,457	-33.4	6,820	-39.1
0.2501-0.5000	Poor	419	393	-6.2	522	24.6	580	38.4
0.5001-0.7500	Moderately Suitable	875	700	-20.0	771	-11.9	1,079	23.3
0.7501-1.0000	Suitable	1,388	722	-48.0	538	-61.2	765	-44.9

Table D2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 7								
0.0000-0.2500	Unsuitable	6,157	3,863	-37.3	3,768	-38.8	3,411	-44.6
0.2501-0.5000	Poor	243	230	-5.3	165	-32.1	224	-7.8
0.5001-0.7500	Moderately Suitable	582	533	-8.4	571	-1.9	711	22.2
0.7501-1.0000	Suitable	2,273	3,112	36.9	3,083	35.6	3,010	32.4
Reach 8								
0.0000-0.2500	Unsuitable	6,563	871	-86.7	764	-88.4	1,107	-83.1
0.2501-0.5000	Poor	1,275	302	-76.3	420	-67.1	0	-100.0
0.5001-0.7500	Moderately Suitable	1,563	1,232	-21.2	712	-54.4	329	-79.0
0.7501-1.0000	Suitable	8,512	14,001	64.5	14,295	67.9	14,904	75.1
Reach 9								
0.0000-0.2500	Unsuitable	4,375	793	-81.9	783	-82.1	1,132	-74.1
0.2501-0.5000	Poor	4,105	39	-99.0	25	-99.4	0	-100.0
0.5001-0.7500	Moderately Suitable	5,981	529	-91.2	512	-91.4	648	-89.2
0.7501-1.0000	Suitable	14,798	25,102	69.6	24,859	68.0	24,368	64.7
Reach 10								
0.0000-0.2500	Unsuitable	4,805	2,038	-57.6	2,002	-58.3	1,770	-63.2
0.2501-0.5000	Poor	110	138	25.5	85	-22.7	0	-100.0
0.5001-0.7500	Moderately Suitable	211	437	107.1	409	93.8	254	20.4
0.7501-1.0000	Suitable	1,222	1,247	2.0	1,322	8.2	1,525	24.8
Reach 11								
0.0000-0.2500	Unsuitable	6,797	3,061	-55.0	2,560	-62.3	2,439	-64.1
0.2501-0.5000	Poor	638	1,162	82.1	701	9.9	500	-21.6
0.5001-0.7500	Moderately Suitable	1,319	2,319	75.8	2,455	86.1	2,037	54.4
0.7501-1.0000	Suitable	8,677	9,390	8.2	9,956	14.7	10,807	24.5

Table D2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 12								
0.0000-0.2500	Unsuitable	6,484	5,112	-21.2	4,743	-26.9	4,401	-32.1
0.2501-0.5000	Poor	81	311	284.0	354	337.0	288	255.6
0.5001-0.7500	Moderately Suitable	531	162	-69.5	230	-56.7	384	-27.7
0.7501-1.0000	Suitable	206	0	-100.0	0	-100.0	0	-100.0
Reach 13								
0.0000-0.2500	Unsuitable	10,504	6,128	-41.7	6,236	-40.6	5,773	-45.0
0.2501-0.5000	Poor	2,090	817	-60.9	634	-69.7	527	-74.8
0.5001-0.7500	Moderately Suitable	4,594	3,034	-34.0	3,060	-33.4	1,949	-57.6
0.7501-1.0000	Suitable	15,864	22,135	39.5	22,028	38.9	22,886	44.3
Reach 14								
0.0000-0.2500	Unsuitable	61,553	28,312	-54.0	23,771	-61.4	20,288	-67.0
0.2501-0.5000	Poor	3,898	3,721	-4.5	4,048	3.8	4,063	4.2
0.5001-0.7500	Moderately Suitable	6,747	8,162	21.0	7,722	14.5	6,969	3.3
0.7501-1.0000	Suitable	10,909	12,727	16.7	13,983	28.2	15,416	41.3
Reach 19								
0.0000-0.2500	Unsuitable	618	136	-78.0	42	-93.2	42	-93.2
0.2501-0.5000	Poor	462	0	-100.0	0	-100.0	0	-100.0
0.5001-0.7500	Moderately Suitable	1,124	0	-100.0	142	-87.4	193	-82.8
0.7501-1.0000	Suitable	4,432	6,132	38.4	5,990	35.2	5,939	34.0
Reach 20								
0.0000-0.2500	Unsuitable	19,057	8,331	-56.3	8,303	-56.4	7,881	-58.6
0.2501-0.5000	Poor	1,986	1,241	-37.5	834	-58.0	490	-75.3
0.5001-0.7500	Moderately Suitable	4,719	3,162	-33.0	3,419	-27.5	2,674	-43.3
0.7501-1.0000	Suitable	8,413	10,361	23.2	10,169	20.9	10,542	25.3

Table D2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Arctic Grayling (*Thymallus arcticus*) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 21								
0.0000-0.2500	Unsuitable	4,337	1,224	-71.8	1,219	-71.9	1,208	-72.1
0.2501-0.5000	Poor	646	1,362	110.8	1,324	105.0	234	-63.8
0.5001-0.7500	Moderately Suitable	1,412	1,503	6.4	1,233	-12.7	1,129	-20.0
0.7501-1.0000	Suitable	2,401	6,326	163.5	6,590	174.5	6,733	180.4
Reach 22								
0.0000-0.2500	Unsuitable	36,707	38,136	3.9	38,530	5.0	36,958	0.7
0.2501-0.5000	Poor	5,309	6,191	16.6	5,882	10.8	5,461	2.9
0.5001-0.7500	Moderately Suitable	8,238	9,105	10.5	8,964	8.8	9,586	16.4
0.7501-1.0000	Suitable	11,650	18,752	61.0	18,266	56.8	17,007	46.0

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

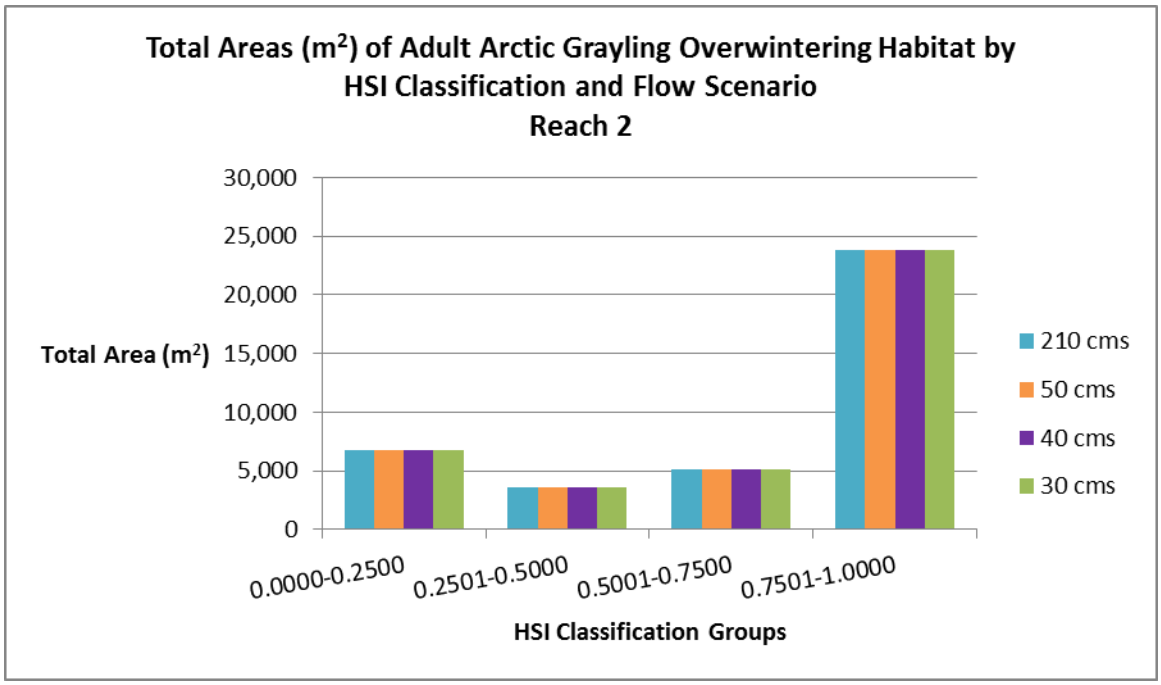


Figure D18: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 2 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

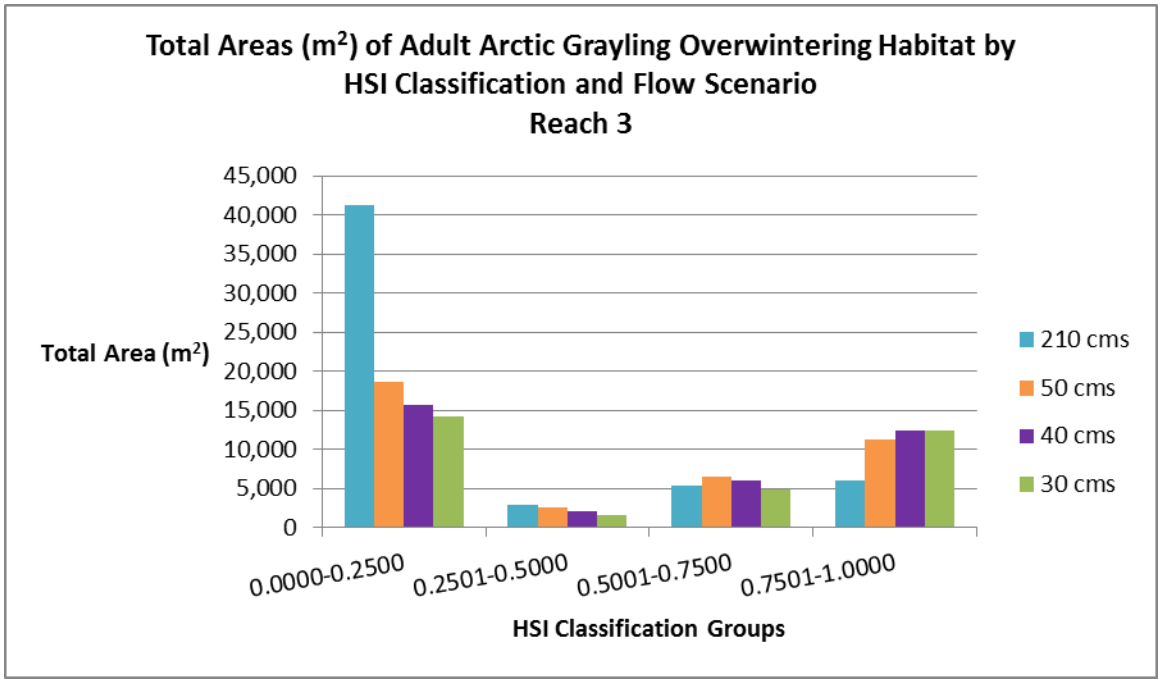


Figure D19: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 3 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

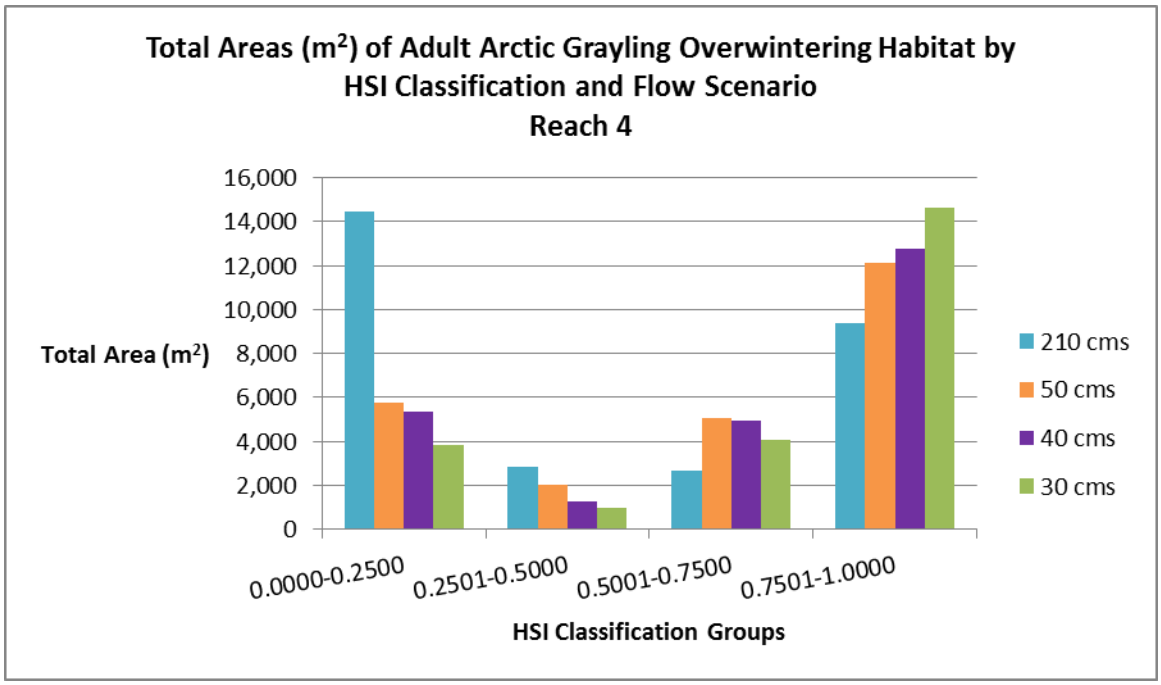


Figure D20: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 4 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

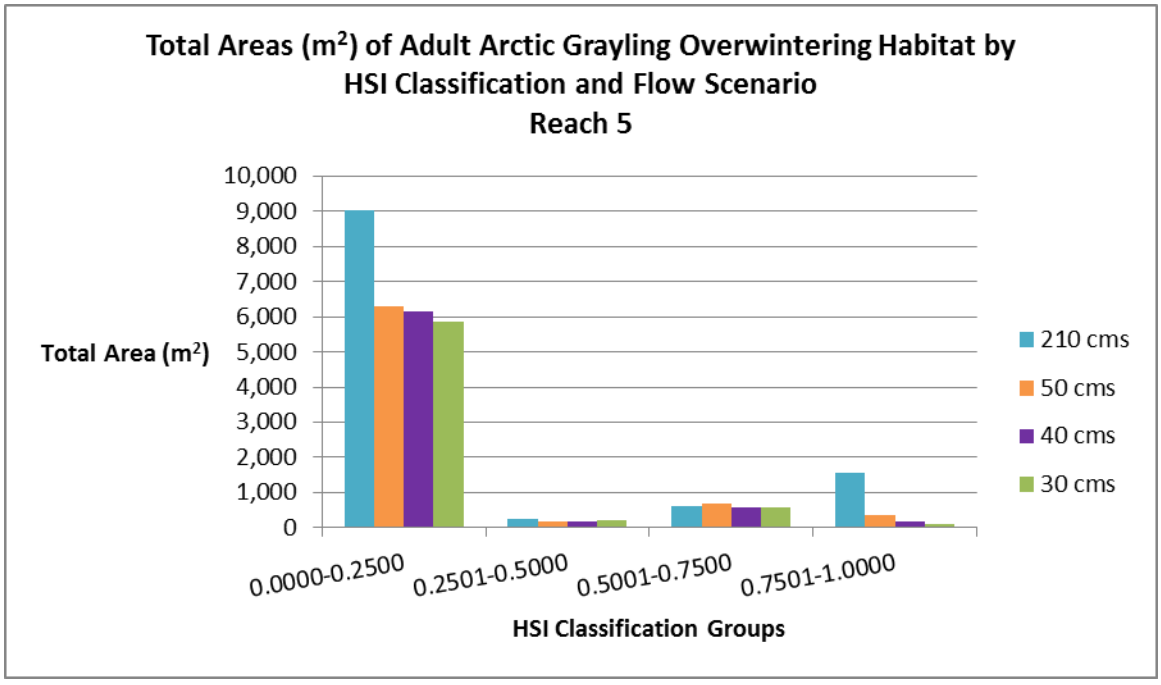


Figure D21: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 5 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

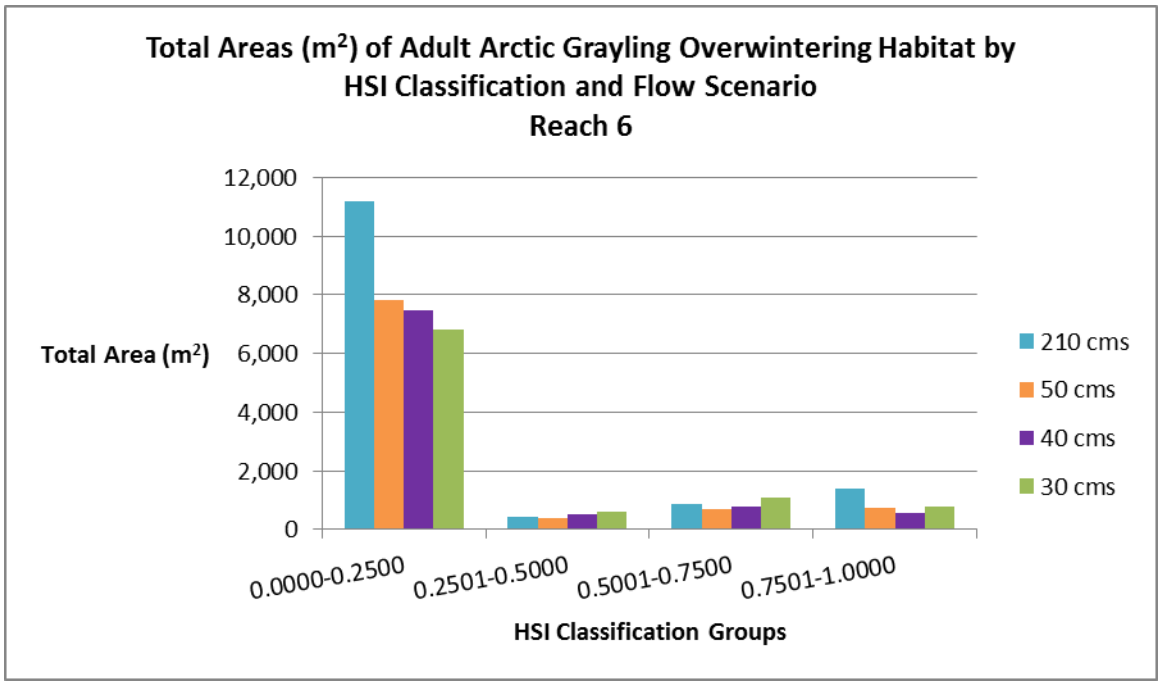


Figure D22: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 6 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

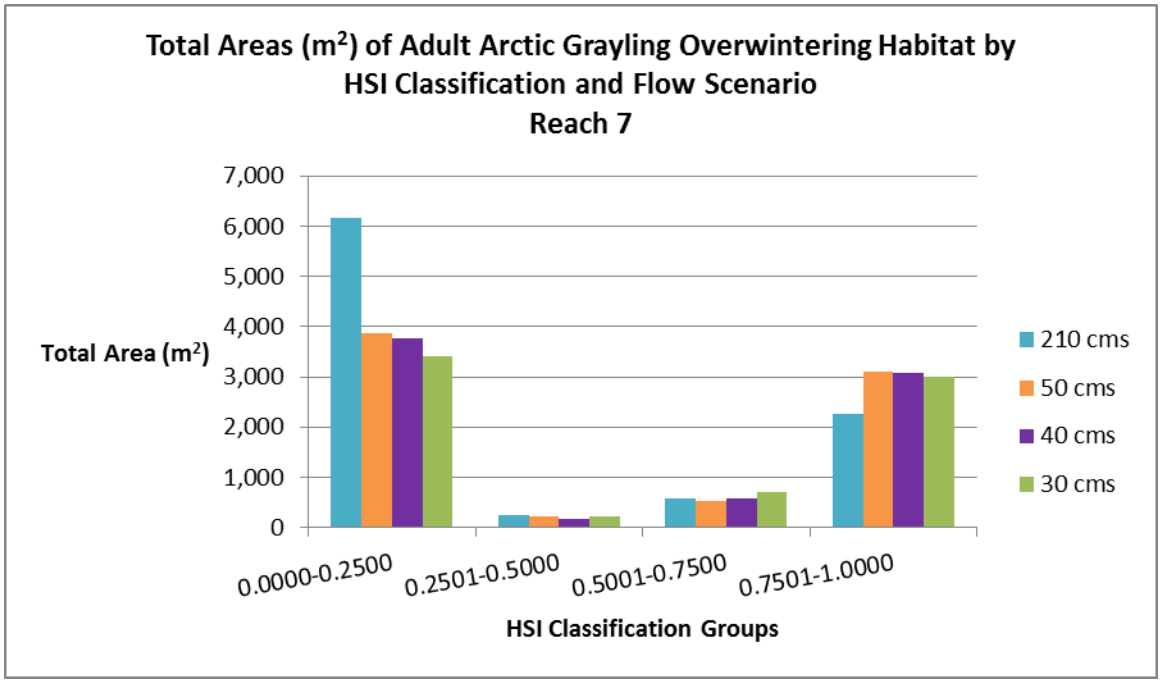


Figure D23: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 7 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

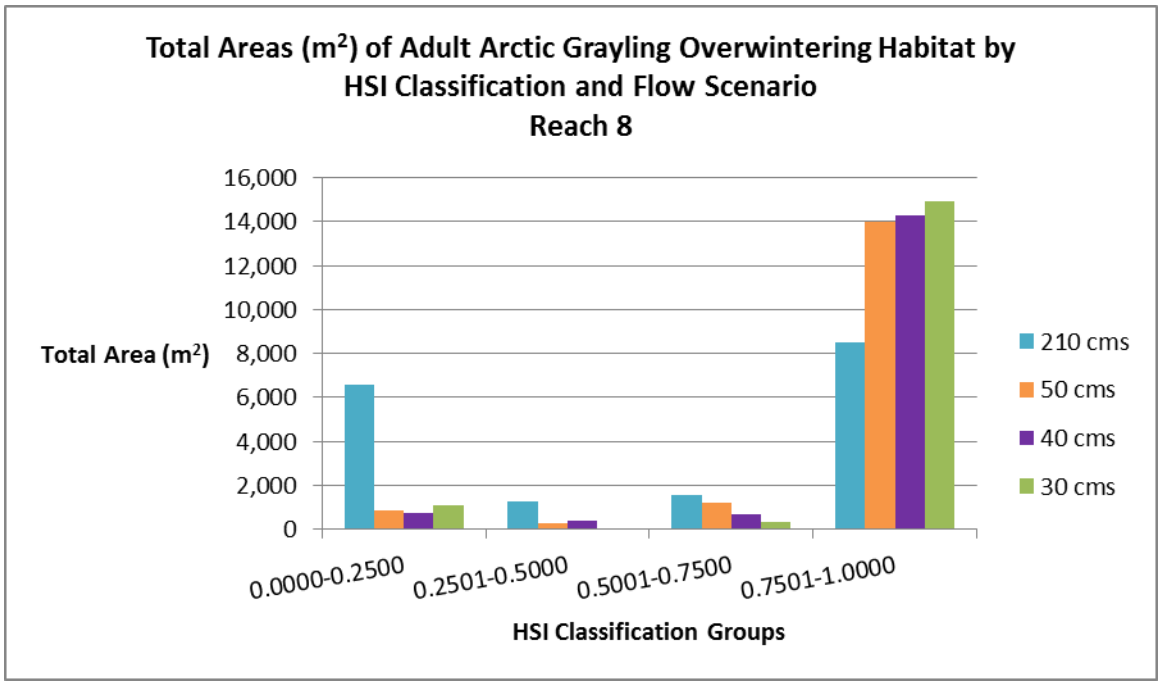


Figure D24: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 8 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

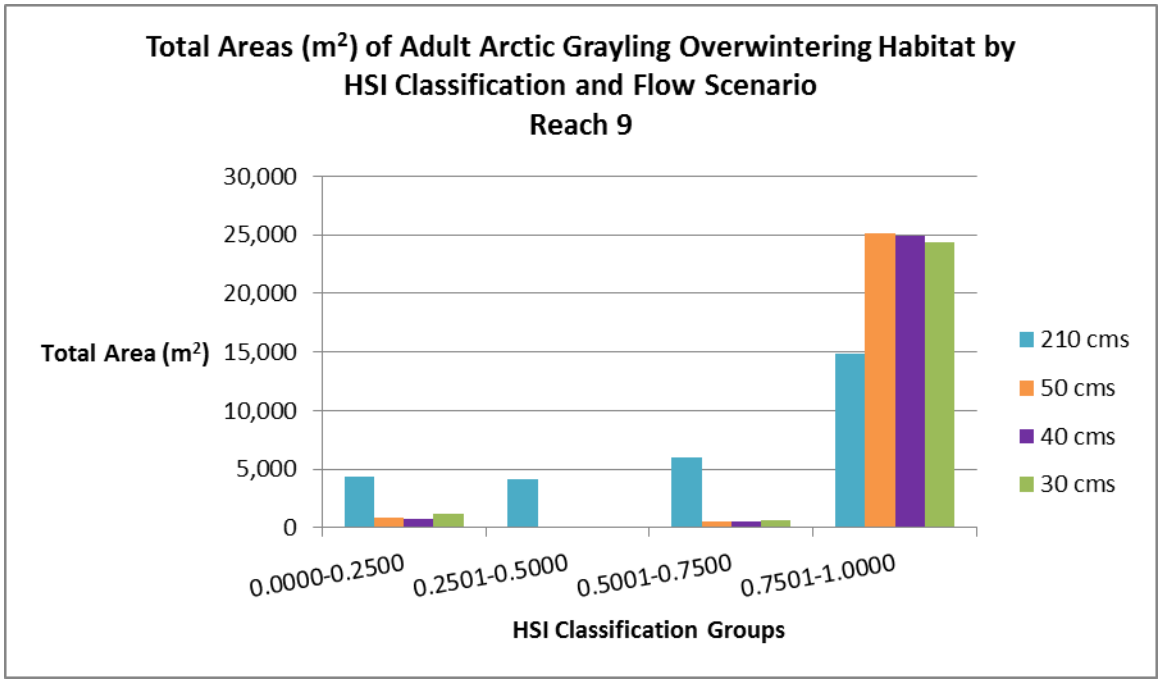


Figure D25: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 9 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

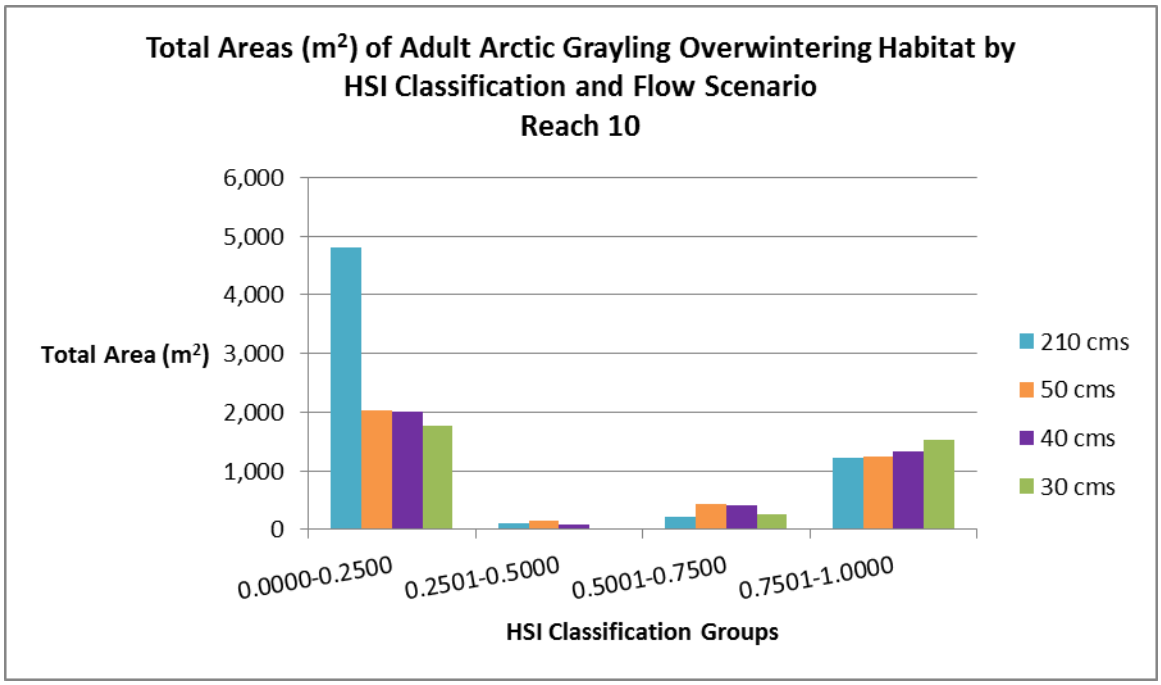


Figure D26: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 10 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

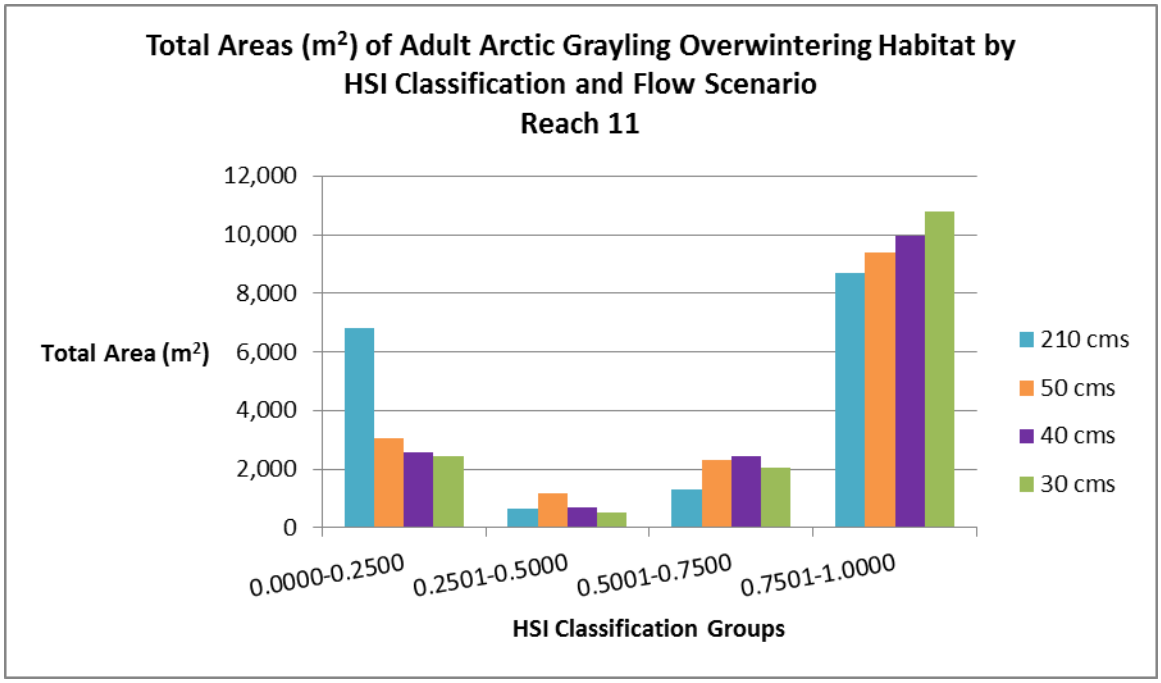


Figure D27: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 11 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

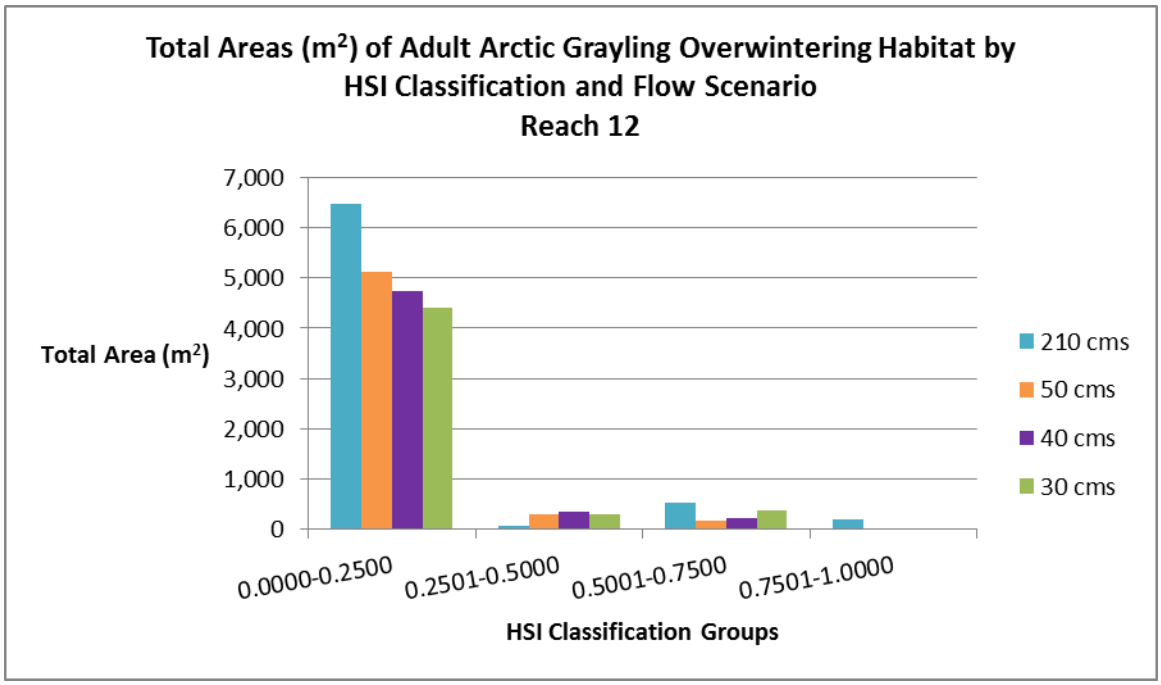


Figure D28: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 12 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

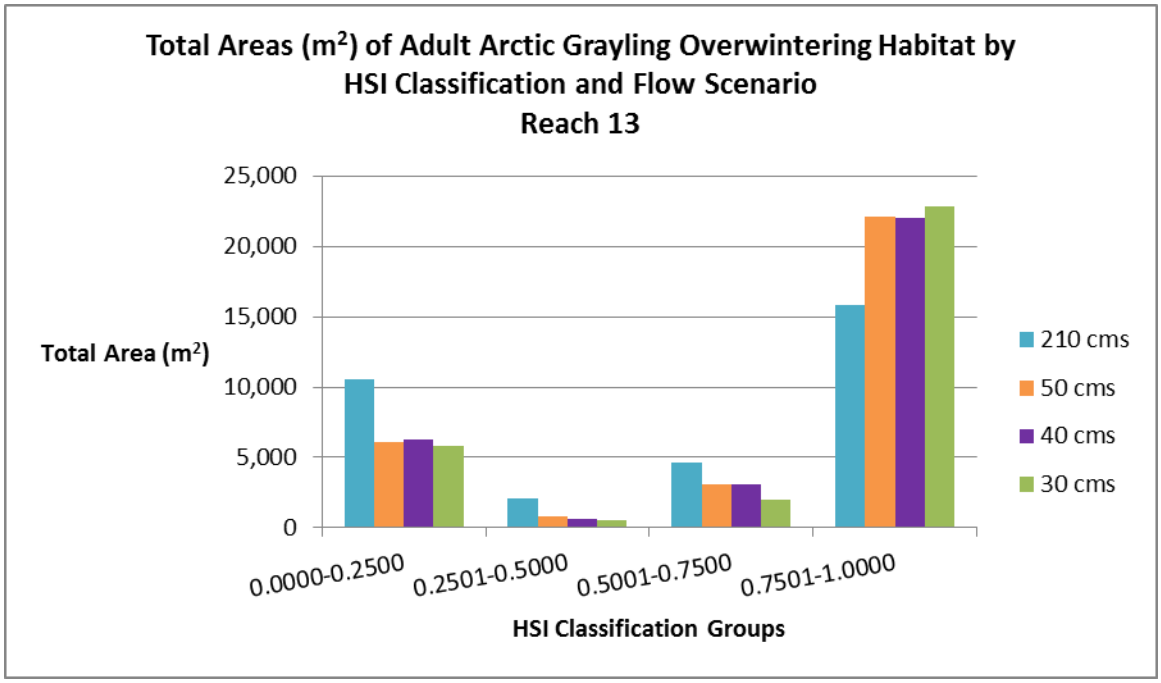


Figure D29: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 13 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

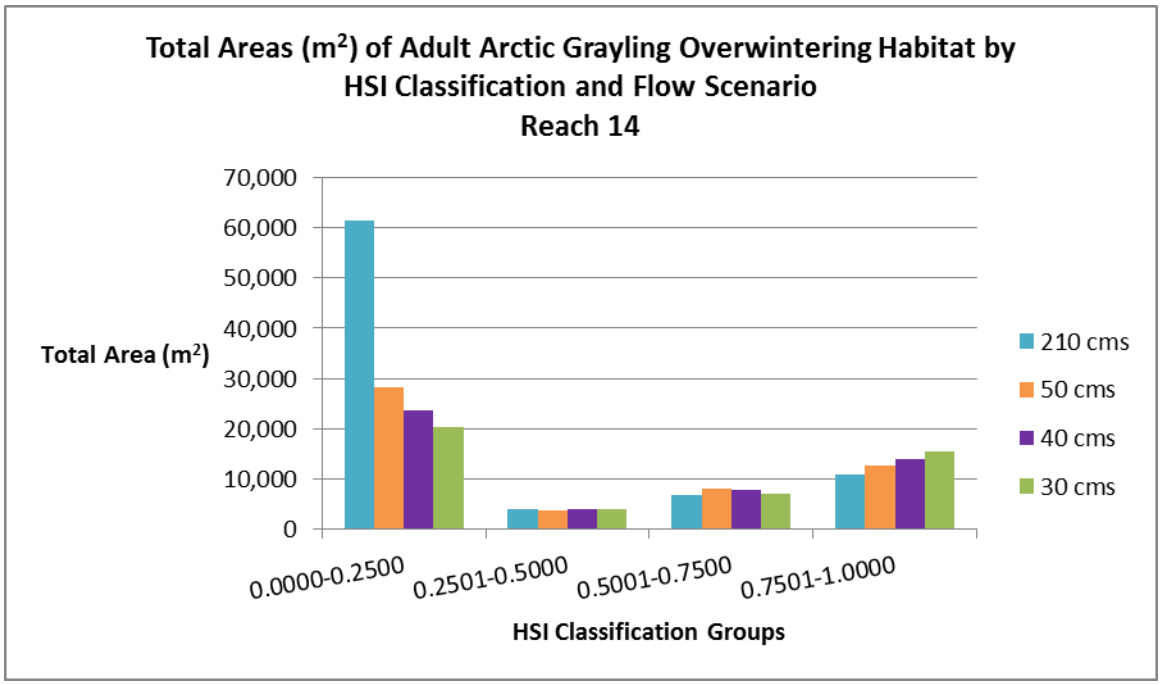


Figure D30: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 14 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

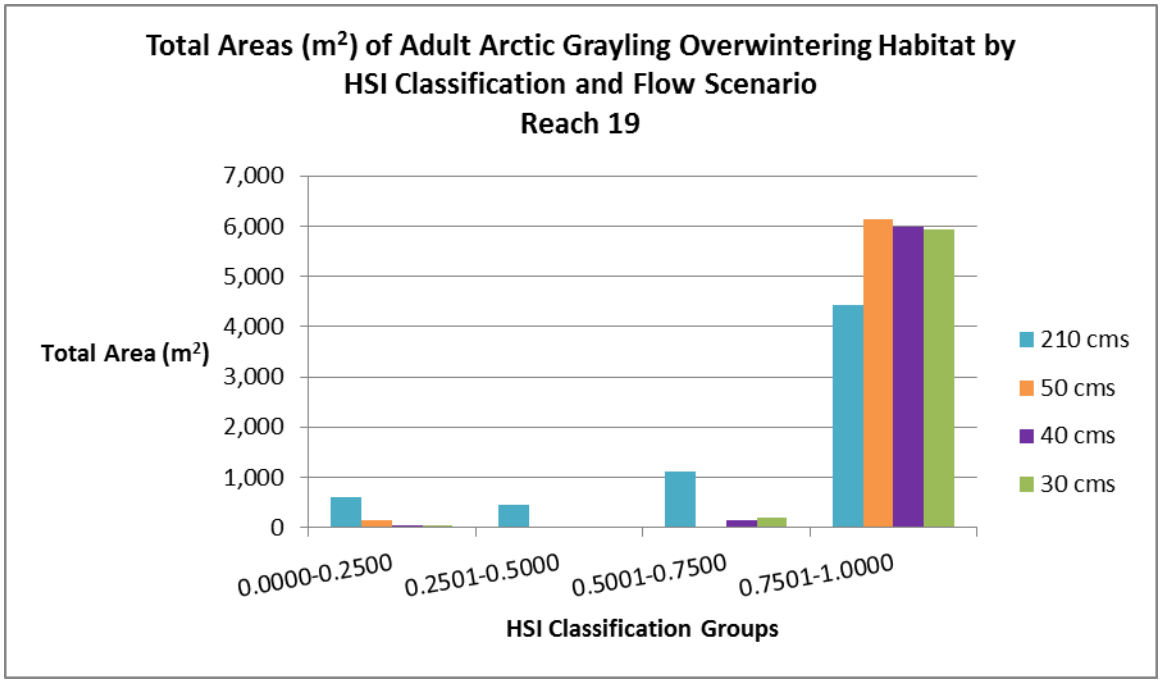


Figure D31: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 19 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

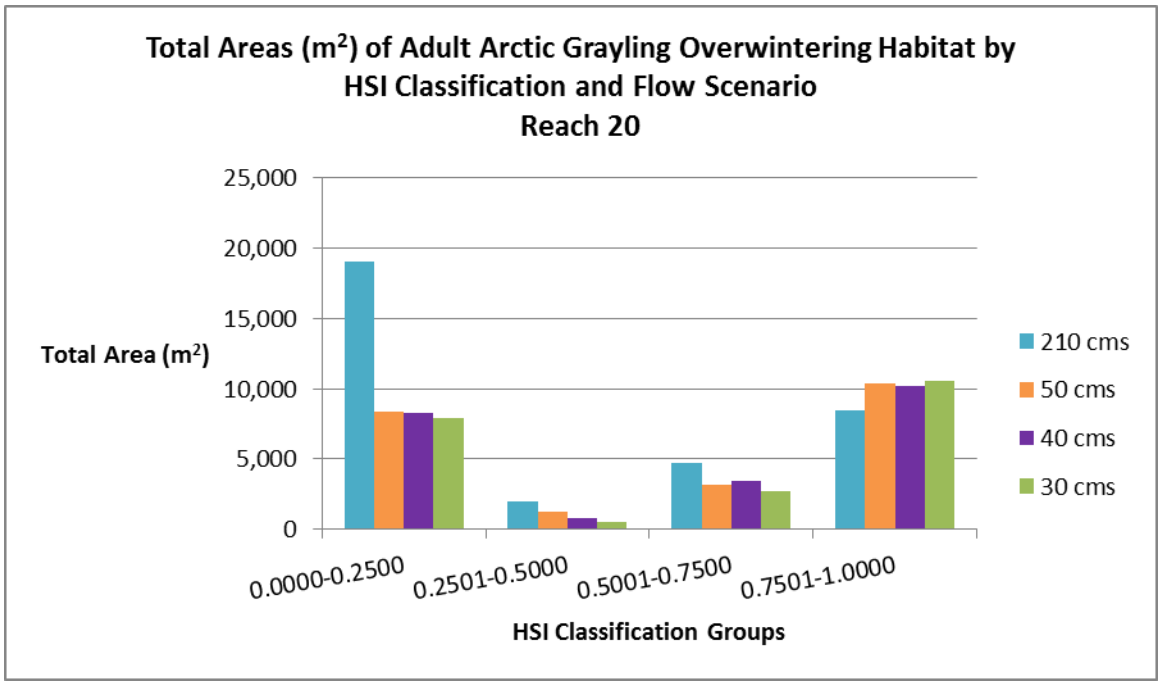


Figure D32: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 20 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

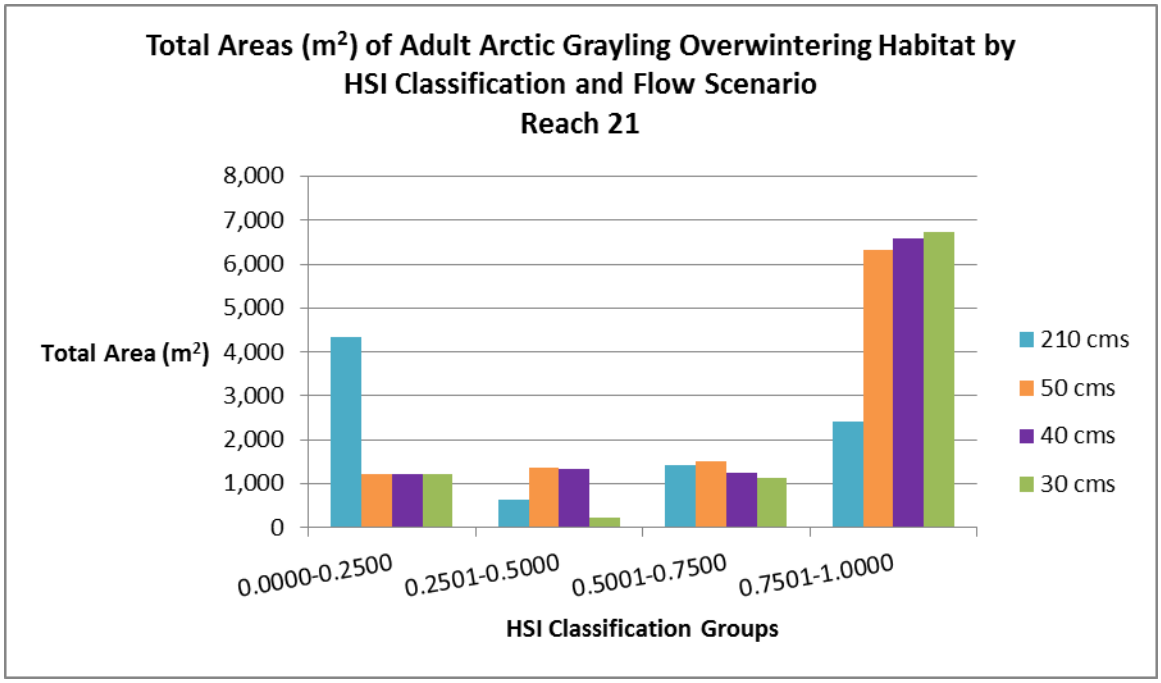


Figure D33: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 21 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

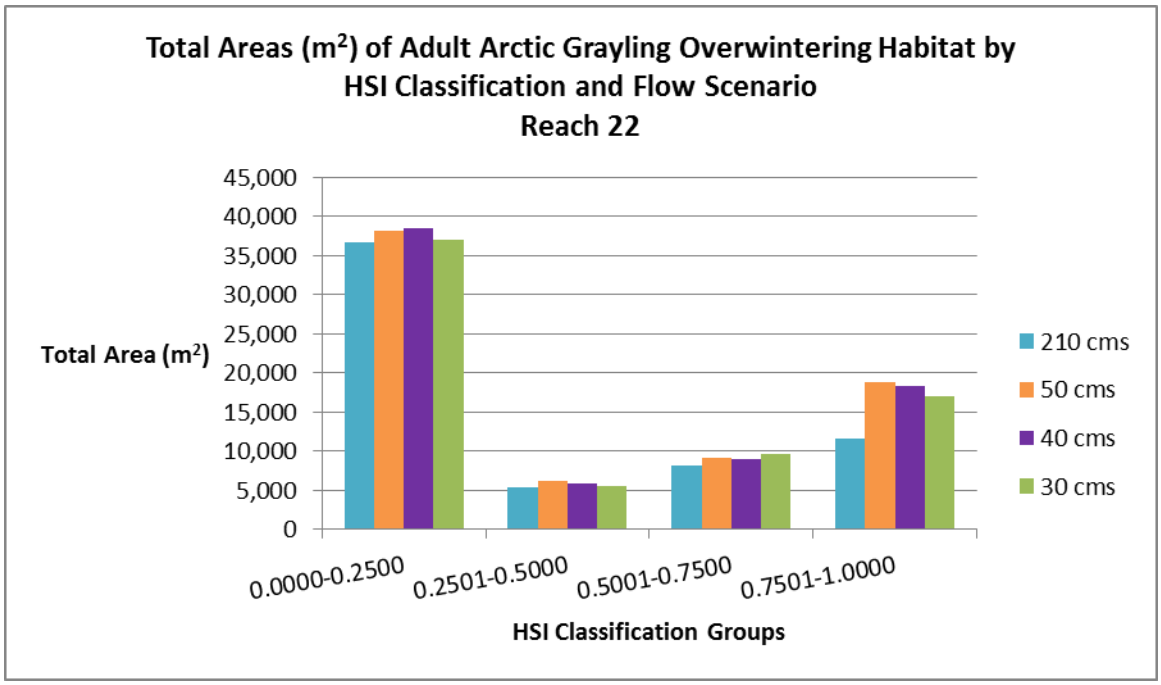


Figure D34: Total Areas of Adult Arctic Grayling Overwintering Habitat in River Reach 22 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Table D3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 2								
0.0000-0.2500	Unsuitable	33,585	33,585	0.0	33,585	0.0	33,585	0.0
0.2501-0.5000	Poor	765	765	0.0	765	0.0	765	0.0
0.5001-0.7500	Moderately Suitable	606	606	0.0	606	0.0	606	0.0
0.7501-1.0000	Suitable	4,209	4,209	0.0	4,209	0.0	4,209	0.0
Reach 3								
0.0000-0.2500	Unsuitable	45,541	26,823	-41.1	24,619	-45.9	21,737	-52.3
0.2501-0.5000	Poor	1,457	1,917	31.6	1,694	16.3	2,057	41.2
0.5001-0.7500	Moderately Suitable	1,211	1,833	51.4	1,611	33.0	1,157	-4.5
0.7501-1.0000	Suitable	7,399	8,377	13.2	8,257	11.6	8,246	11.4
Reach 4								
0.0000-0.2500	Unsuitable	26,583	20,483	-22.9	19,370	-27.1	17,192	-35.3
0.2501-0.5000	Poor	374	665	77.8	1,001	167.6	1,140	204.8
0.5001-0.7500	Moderately Suitable	382	813	112.8	647	69.4	866	126.7
0.7501-1.0000	Suitable	2,001	3,018	50.8	3,332	66.5	4,226	111.2
Reach 5								
0.0000-0.2500	Unsuitable	9,662	5,078	-47.4	4,520	-53.2	3,582	-62.9
0.2501-0.5000	Poor	229	426	86.0	162	-29.3	175	-23.6
0.5001-0.7500	Moderately Suitable	270	322	19.3	462	71.1	337	24.8
0.7501-1.0000	Suitable	1,292	1,704	31.9	1,929	49.3	2,652	105.3
Reach 6								
0.0000-0.2500	Unsuitable	11,375	7,506	-34.0	7,171	-37.0	6,118	-46.2
0.2501-0.5000	Poor	258	330	27.9	198	-23.3	520	101.6
0.5001-0.7500	Moderately Suitable	431	258	-40.1	378	-12.3	303	-29.7
0.7501-1.0000	Suitable	1,817	1,547	-14.9	1,541	-15.2	2,305	26.9

Table D3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 7								
0.0000-0.2500	Unsuitable	8,134	6,438	-20.9	6,223	-23.5	5,626	-30.8
0.2501-0.5000	Poor	102	126	23.5	190	86.3	356	249.0
0.5001-0.7500	Moderately Suitable	135	167	23.7	190	40.7	0	-100.0
0.7501-1.0000	Suitable	883	1,008	14.2	985	11.6	1,374	55.6
Reach 8								
0.0000-0.2500	Unsuitable	16,794	15,239	-9.3	15,027	-10.5	14,870	-11.5
0.2501-0.5000	Poor	116	120	3.4	182	56.9	331	185.3
0.5001-0.7500	Moderately Suitable	33	107	224.2	101	206.1	159	381.8
0.7501-1.0000	Suitable	970	940	-3.1	881	-9.2	982	1.2
Reach 9								
0.0000-0.2500	Unsuitable	27,436	25,205	-8.1	24,791	-9.6	24,152	-12.0
0.2501-0.5000	Poor	460	111	-75.9	222	-51.7	372	-19.1
0.5001-0.7500	Moderately Suitable	65	296	355.4	236	263.1	143	120.0
0.7501-1.0000	Suitable	1,299	850	-34.6	930	-28.4	1,480	13.9
Reach 10								
0.0000-0.2500	Unsuitable	5,888	2,960	-49.7	2,826	-52.0	2,578	-56.2
0.2501-0.5000	Poor	103	162	57.3	182	76.7	41	-60.2
0.5001-0.7500	Moderately Suitable	31	150	383.9	115	271.0	214	590.3
0.7501-1.0000	Suitable	326	588	80.4	696	113.5	715	119.3
Reach 11								
0.0000-0.2500	Unsuitable	15,937	12,973	-18.6	12,242	-23.2	11,829	-25.8
0.2501-0.5000	Poor	230	565	145.7	632	174.8	762	231.3
0.5001-0.7500	Moderately Suitable	193	498	158.0	735	280.8	880	356.0
0.7501-1.0000	Suitable	1,071	1,896	77.0	2,063	92.6	2,312	115.9

Table D3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 12								
0.0000-0.2500	Unsuitable	5,552	4,555	-18.0	4,113	-25.9	3,656	-34.1
0.2501-0.5000	Poor	223	64	-71.3	212	-4.9	219	-1.8
0.5001-0.7500	Moderately Suitable	101	65	-35.6	69	-31.7	239	136.6
0.7501-1.0000	Suitable	1,426	901	-36.8	934	-34.5	958	-32.8
Reach 13								
0.0000-0.2500	Unsuitable	31,769	24,701	-22.2	24,237	-23.7	23,965	-24.6
0.2501-0.5000	Poor	204	922	352.0	916	349.0	1,203	489.7
0.5001-0.7500	Moderately Suitable	275	1,100	300.0	906	229.5	748	172.0
0.7501-1.0000	Suitable	805	5,391	569.7	5,900	632.9	5,219	548.3
Reach 14								
0.0000-0.2500	Unsuitable	64,716	37,904	-41.4	35,273	-45.5	32,044	-50.5
0.2501-0.5000	Poor	1,983	2,226	12.3	1,941	-2.1	2,243	13.1
0.5001-0.7500	Moderately Suitable	2,426	1,947	-19.7	1,790	-26.2	1,780	-26.6
0.7501-1.0000	Suitable	13,984	10,845	-22.4	10,521	-24.8	10,668	-23.7
Reach 19								
0.0000-0.2500	Unsuitable	6,267	6,034	-3.7	5,939	-5.2	5,939	-5.2
0.2501-0.5000	Poor	0	193	100.0	0	0.0	0	0.0
0.5001-0.7500	Moderately Suitable	149	0	-100.0	193	29.5	0	-100.0
0.7501-1.0000	Suitable	219	42	-80.8	42	-80.8	235	7.3
Reach 20								
0.0000-0.2500	Unsuitable	24,209	14,331	-40.8	13,964	-42.3	13,038	-46.1
0.2501-0.5000	Poor	1,103	885	-19.8	692	-37.3	928	-15.9
0.5001-0.7500	Moderately Suitable	1,144	977	-14.6	924	-19.2	759	-33.7
0.7501-1.0000	Suitable	7,718	6,902	-10.6	7,145	-7.4	6,863	-11.1

Table D3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Age-0/Juvenile Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 21								
0.0000-0.2500	Unsuitable	7,110	8,345	17.4	8,238	15.9	6,886	-3.2
0.2501-0.5000	Poor	509	204	-59.9	292	-42.6	544	6.9
0.5001-0.7500	Moderately Suitable	347	355	2.3	190	-45.2	275	-20.7
0.7501-1.0000	Suitable	829	1,511	82.3	1,645	98.4	1,601	93.1
Reach 22								
0.0000-0.2500	Unsuitable	48,324	56,630	17.2	56,448	16.8	53,078	9.8
0.2501-0.5000	Poor	2,146	2,124	-1.0	1,997	-6.9	2,956	37.7
0.5001-0.7500	Moderately Suitable	1,756	2,181	24.2	2,208	25.7	2,359	34.3
0.7501-1.0000	Suitable	9,677	11,249	16.2	10,990	13.6	10,619	9.7

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

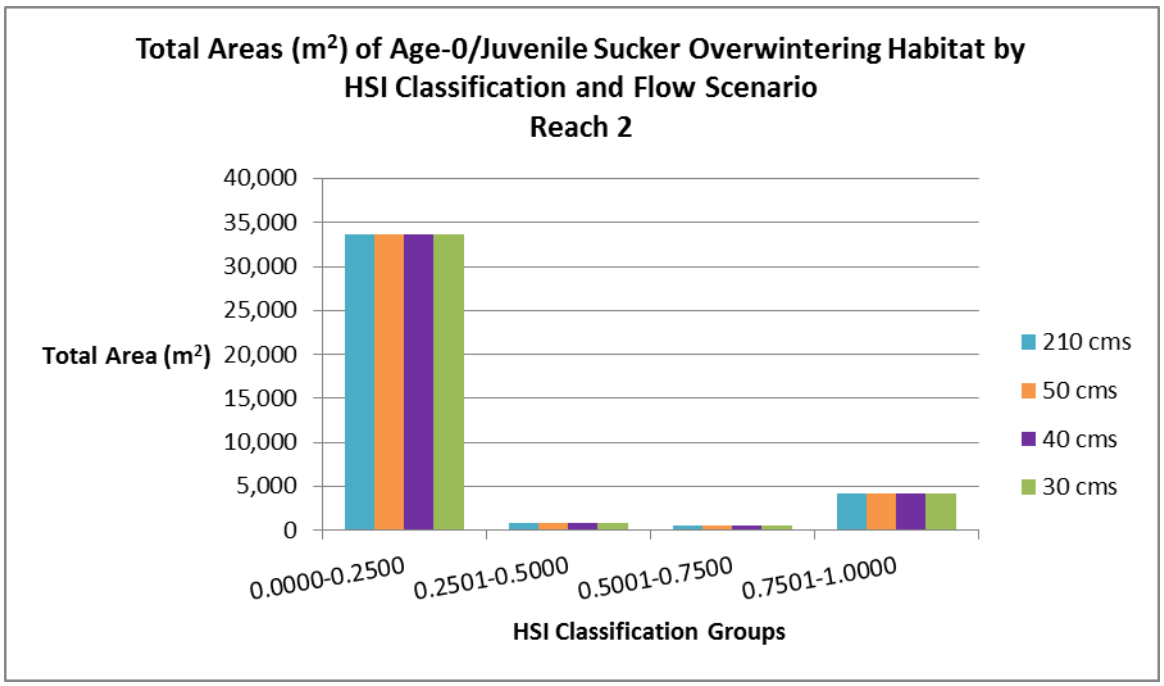


Figure D35: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 2 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

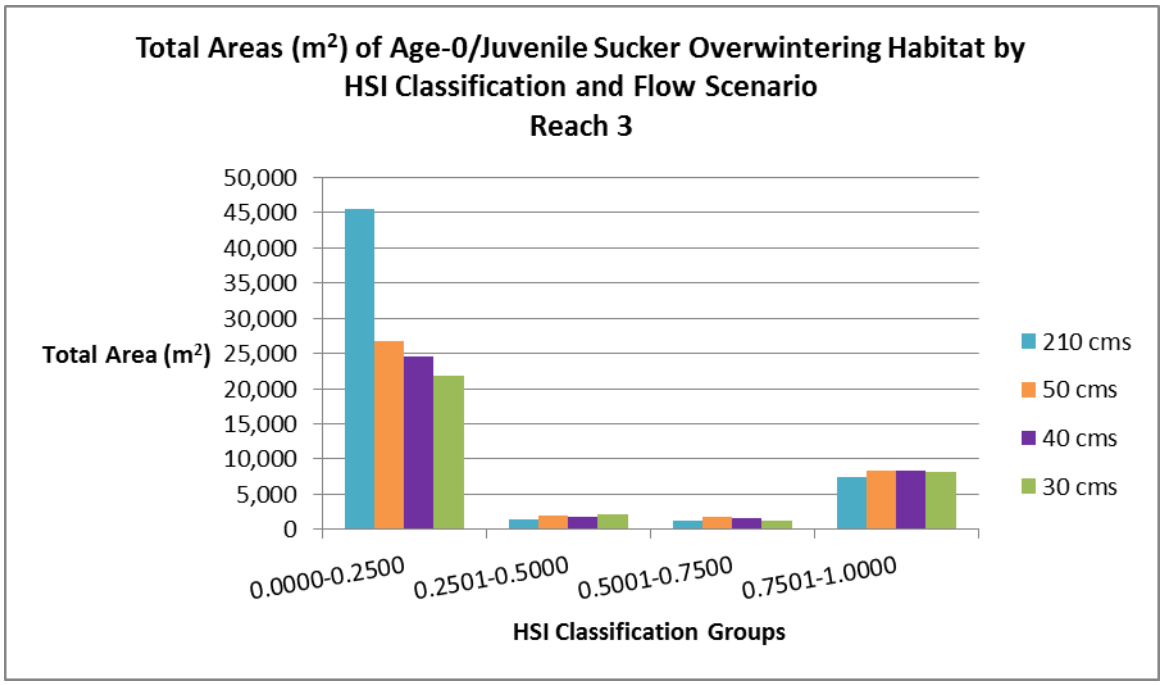


Figure D36: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 3 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

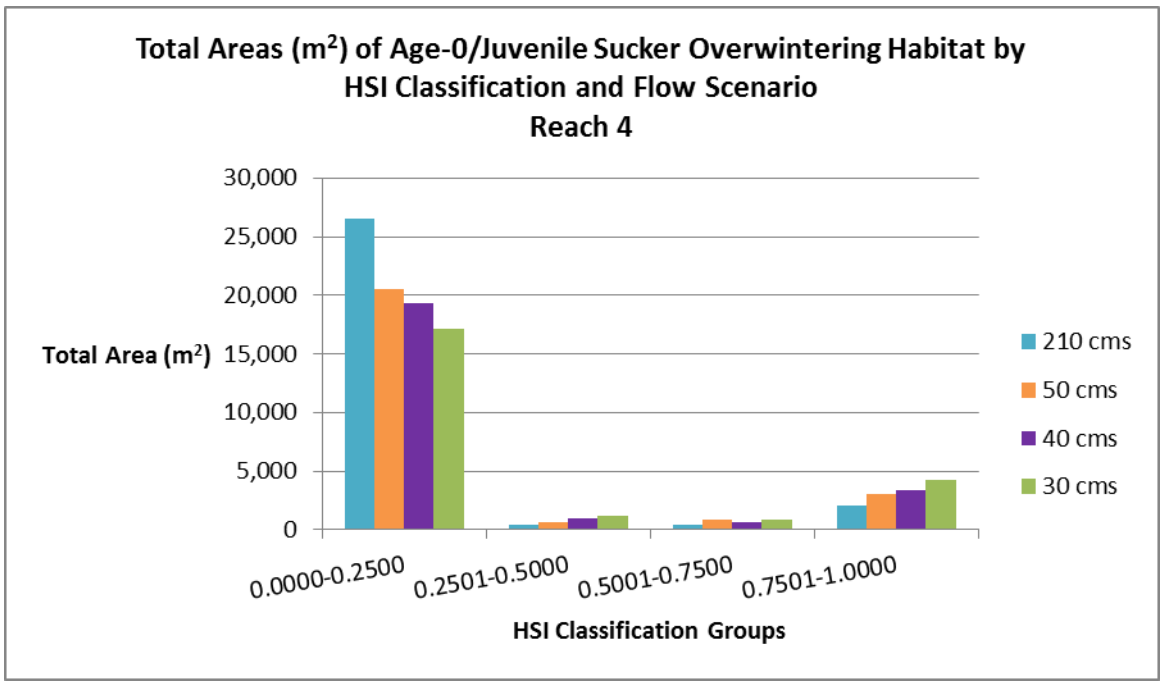


Figure D37: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 4 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

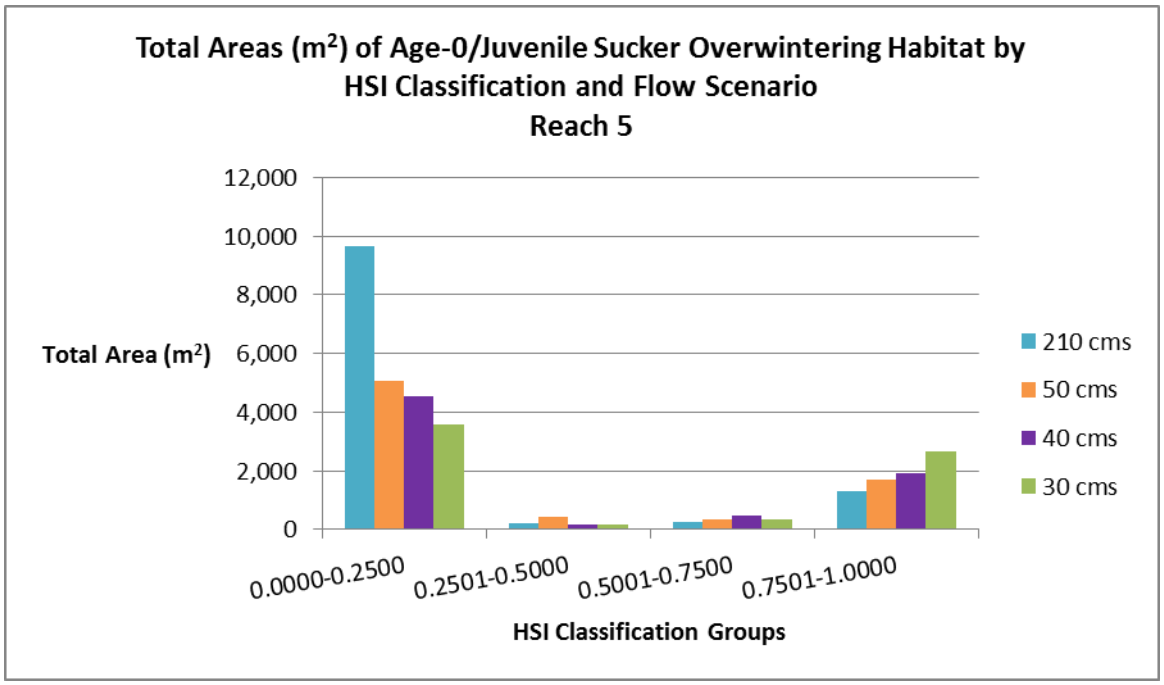


Figure D38: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 5 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

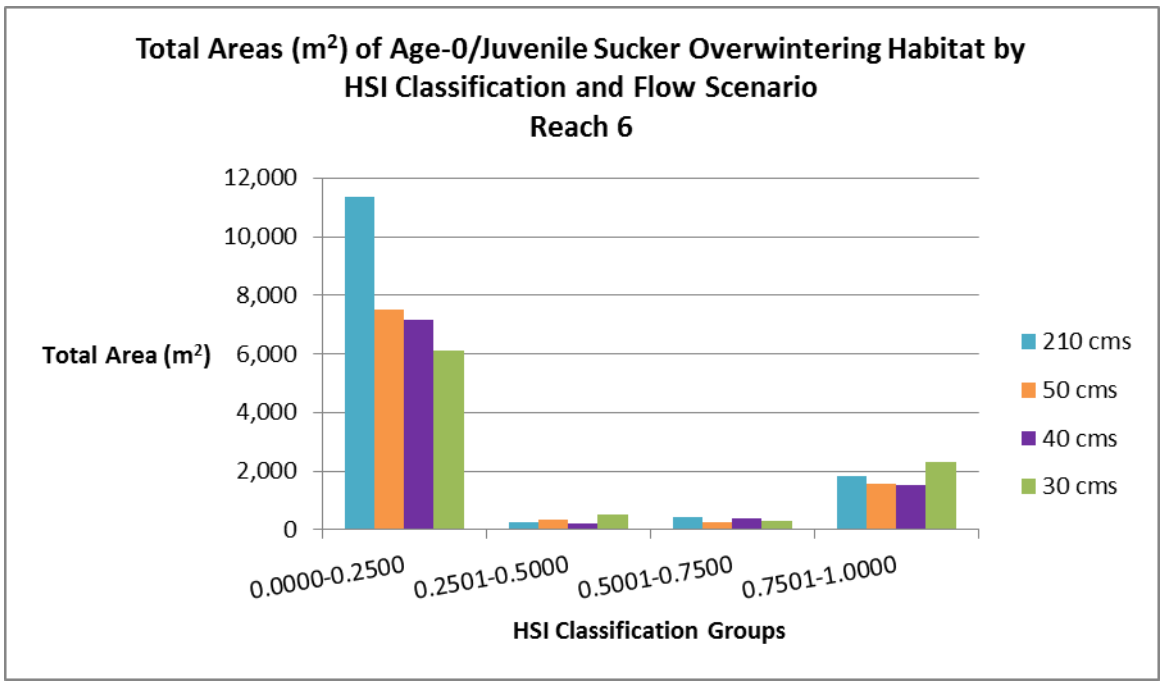


Figure D39: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 6 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

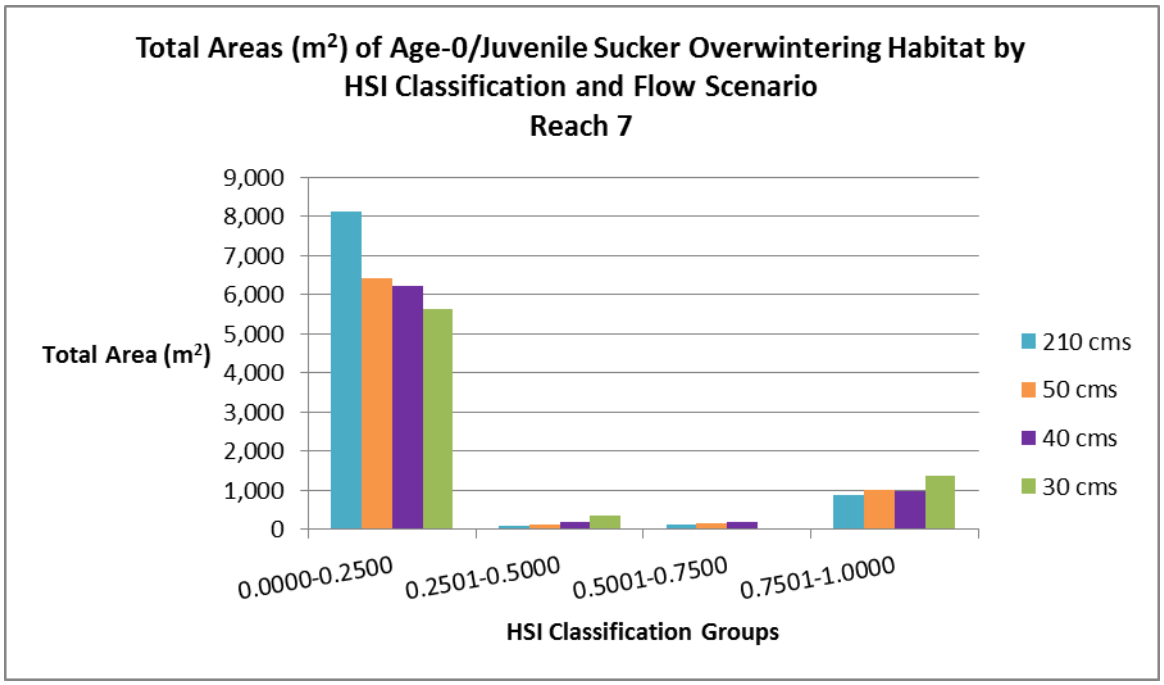


Figure D40: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 7 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

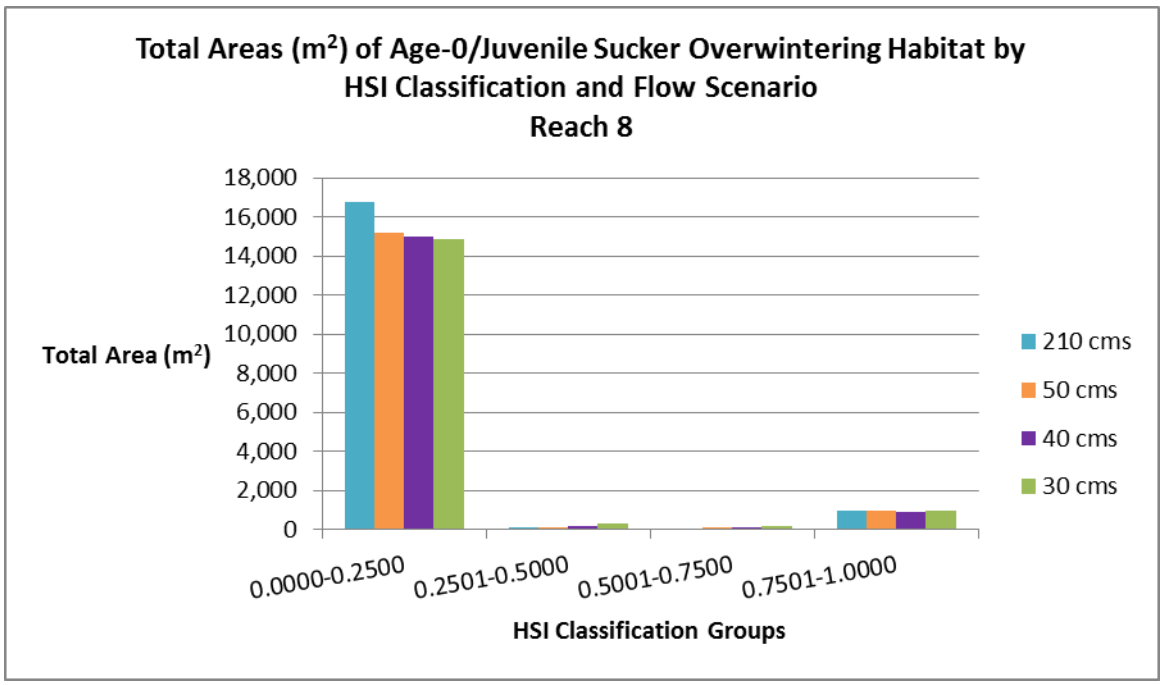


Figure D41: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 8 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

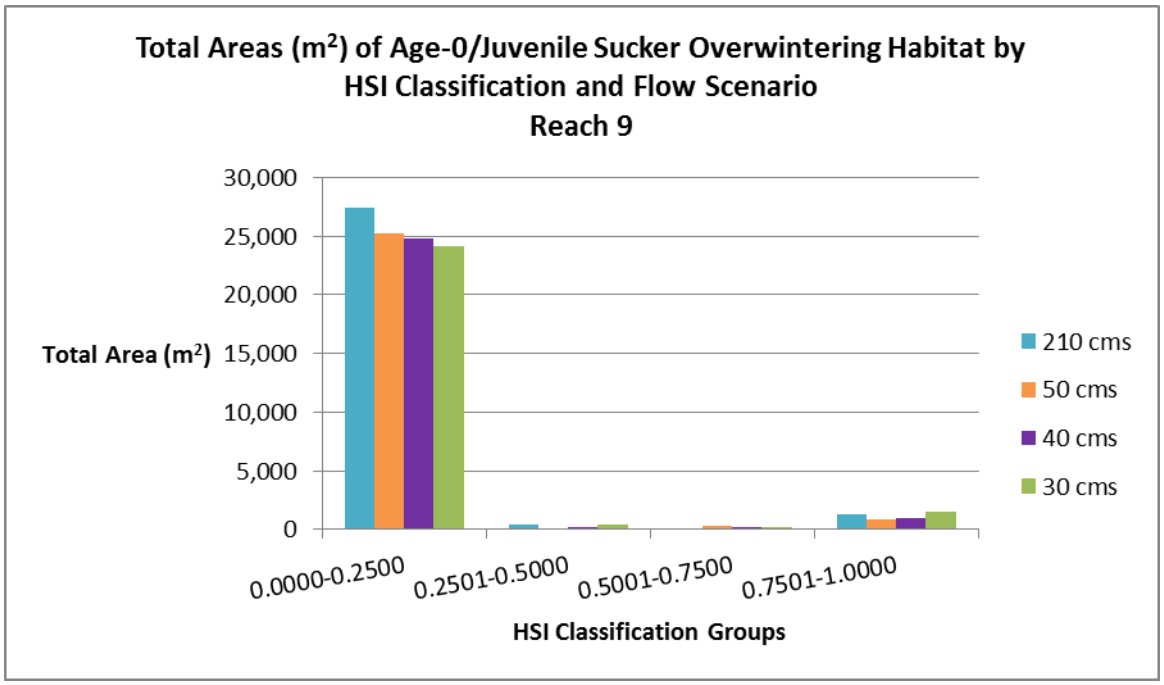


Figure D42: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 9 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

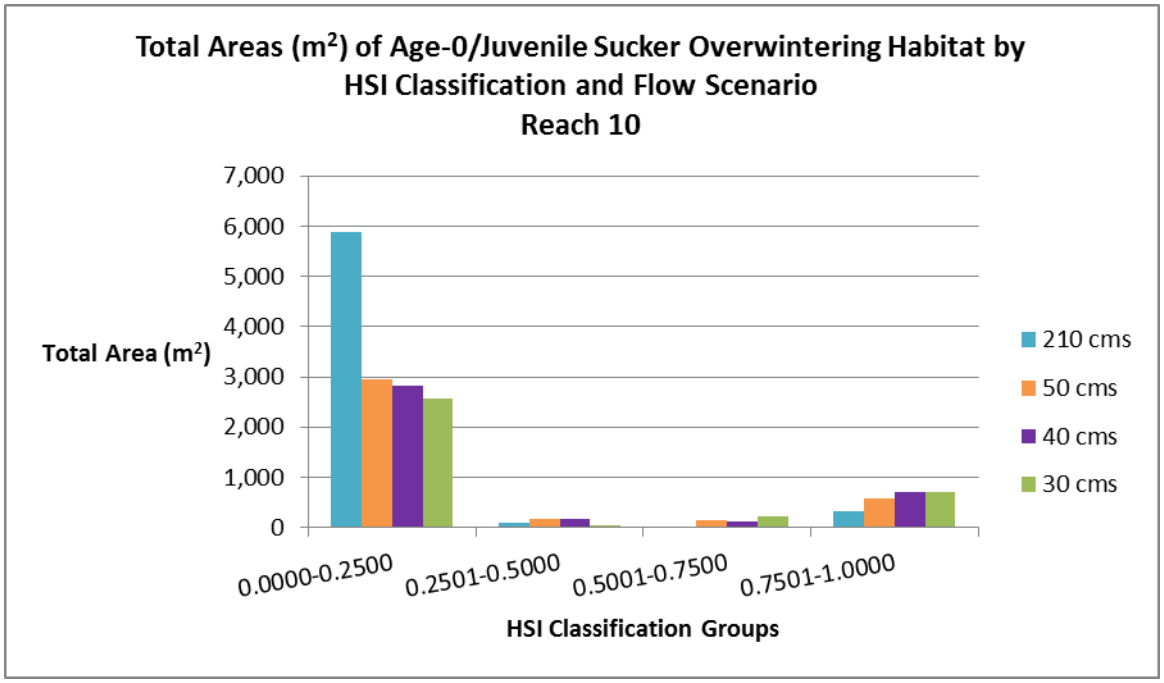


Figure D43: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 10 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

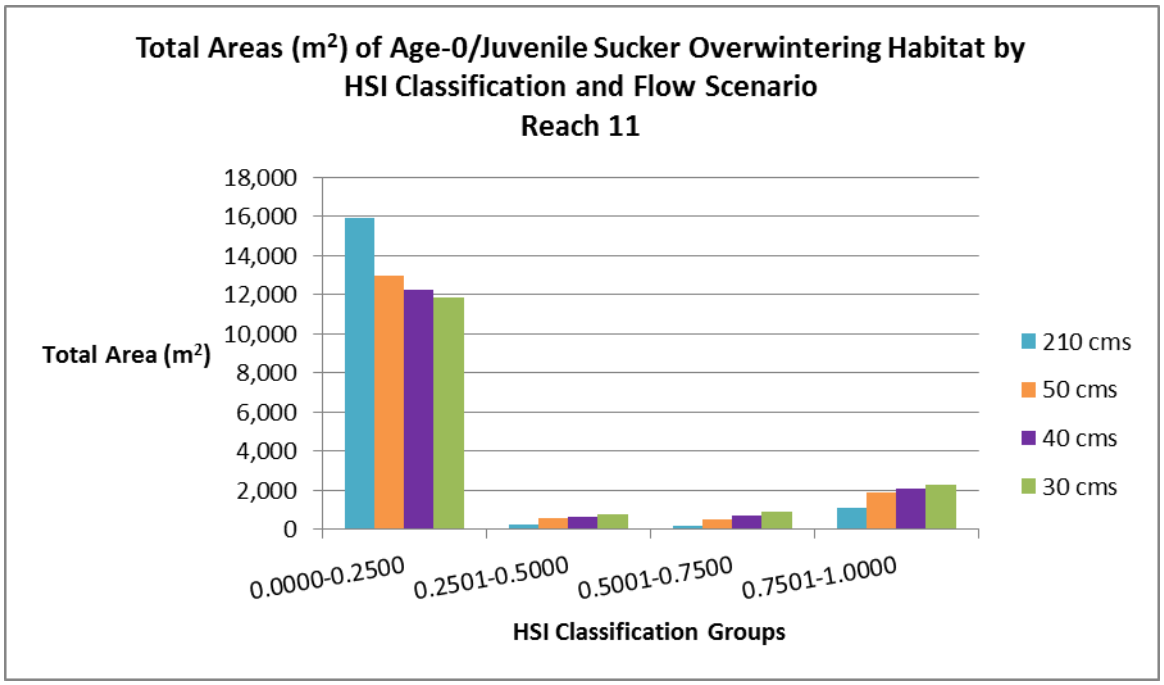


Figure D44: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 11 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

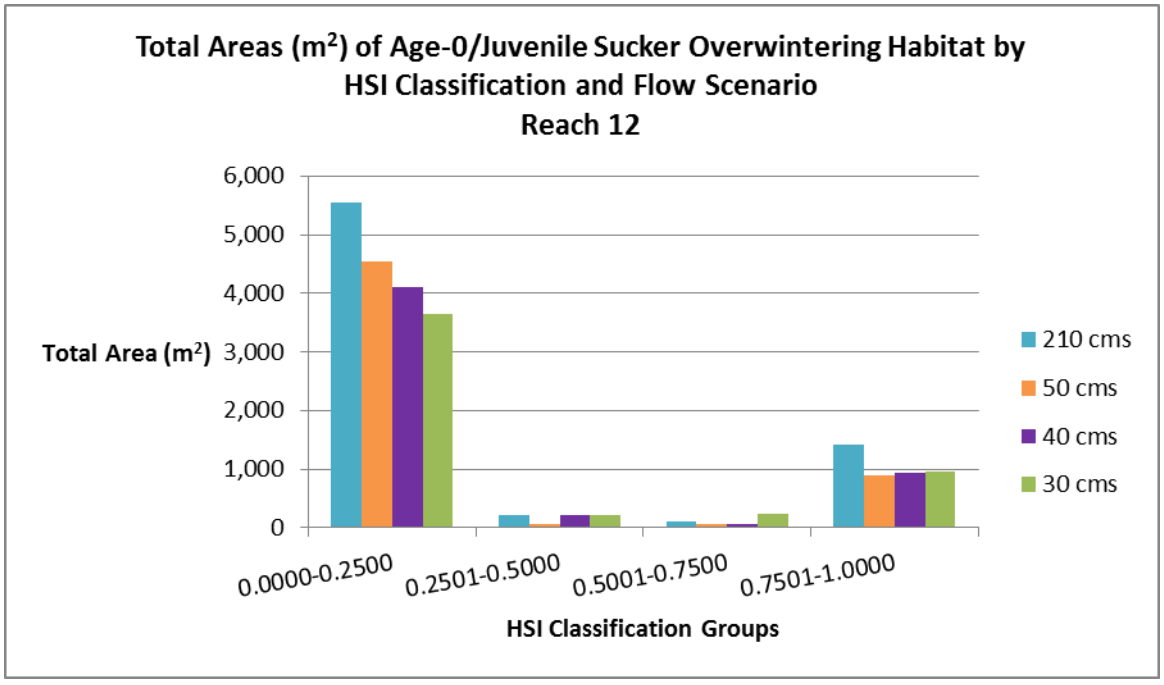


Figure D45: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 12 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

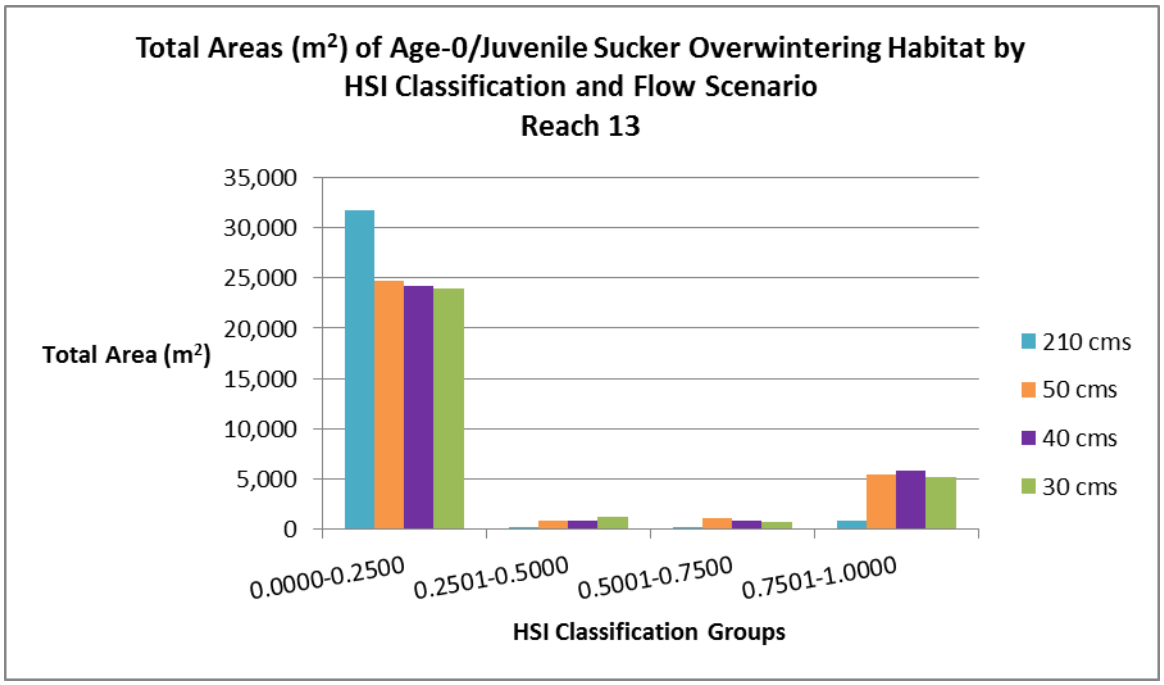


Figure D46: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 13 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

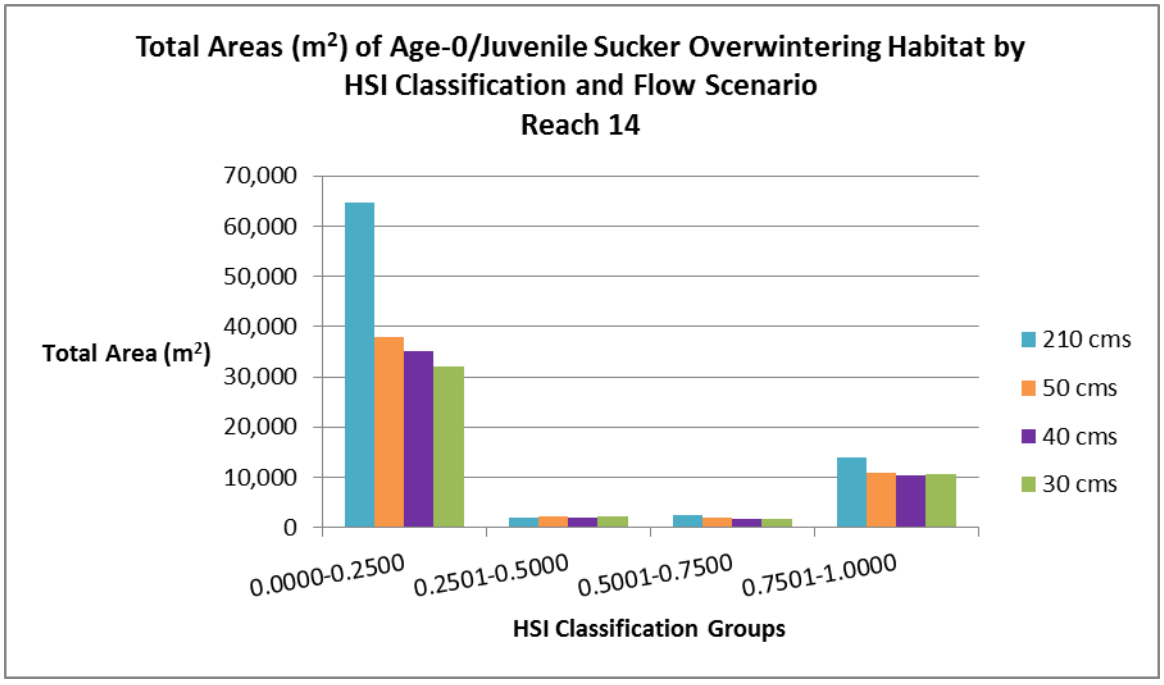


Figure D47: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 14 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

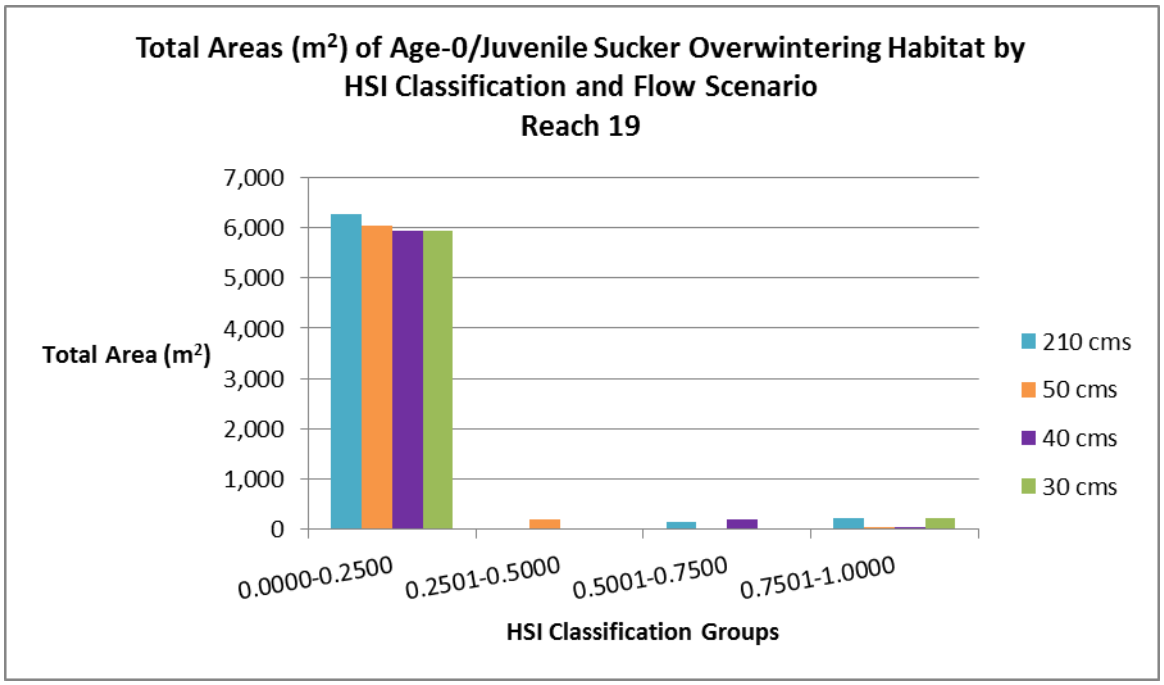


Figure D48: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 19 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

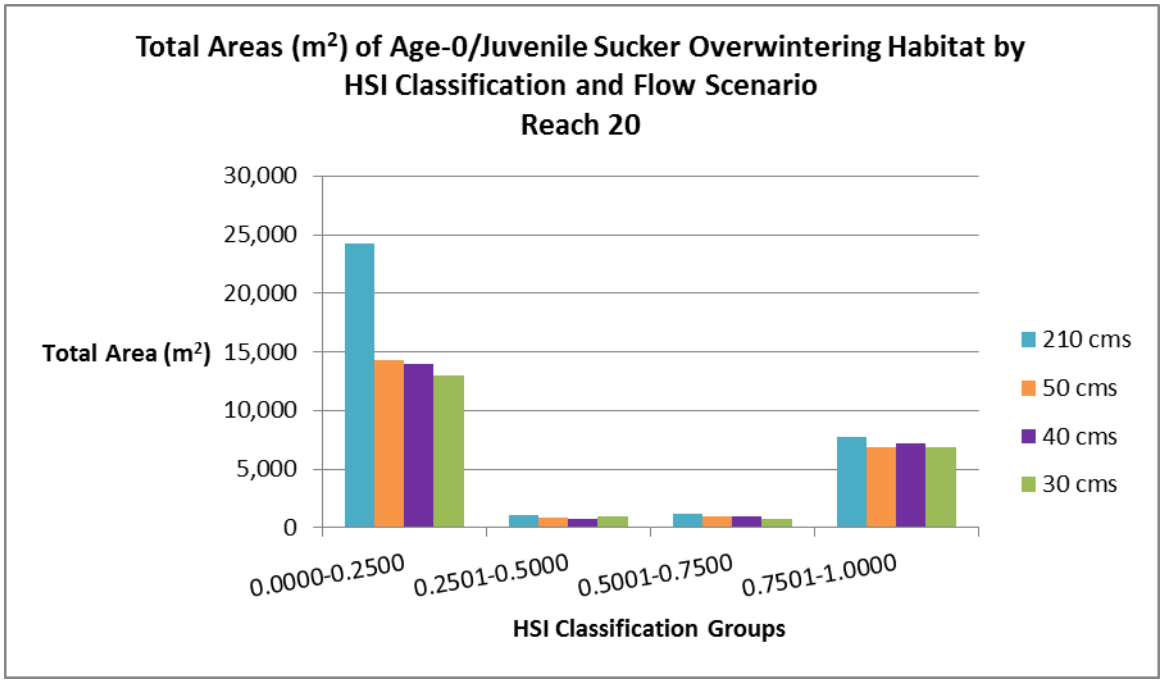


Figure D49: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 20 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

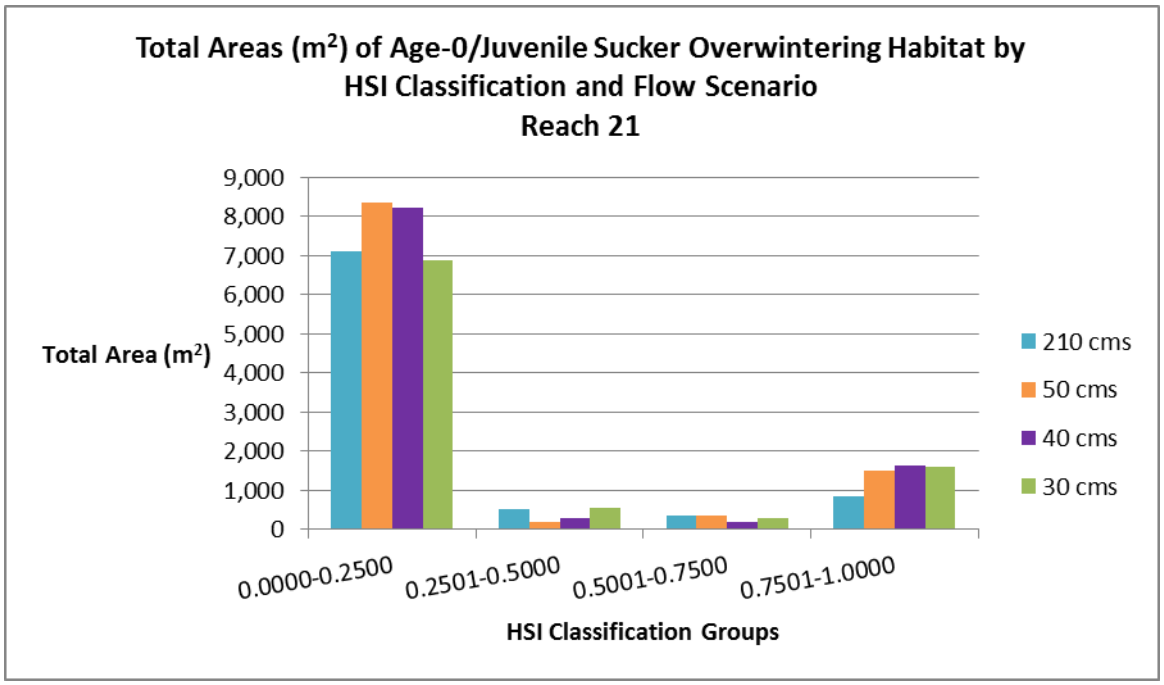


Figure D50: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 21 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

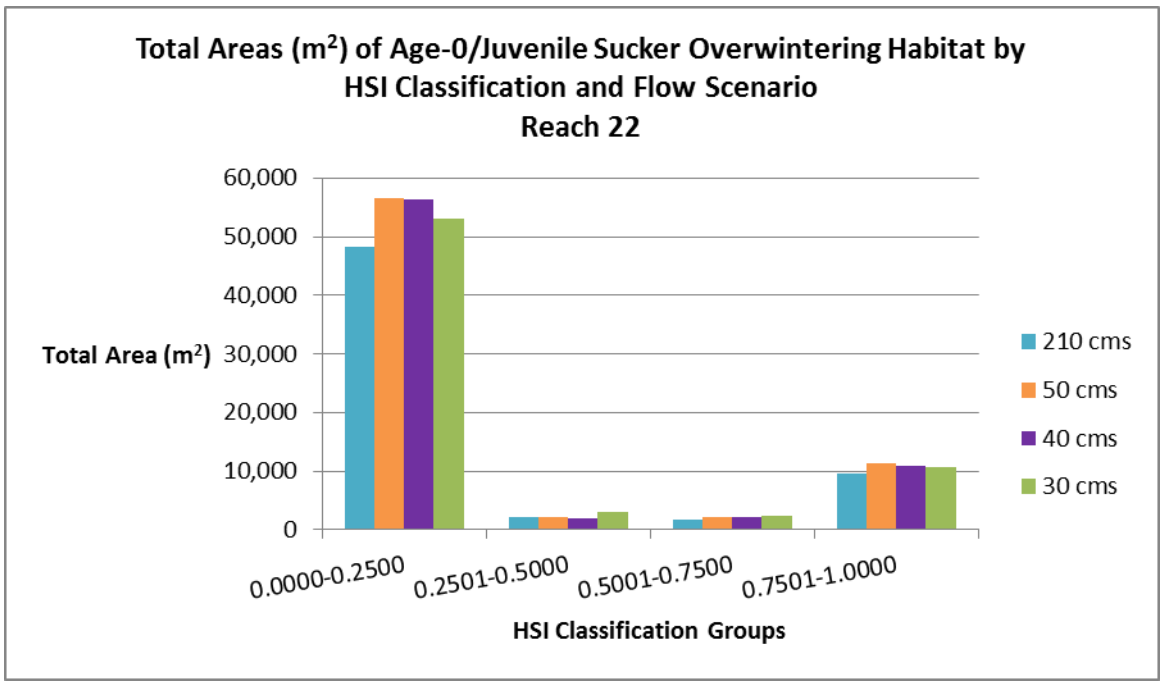


Figure D51: Total Areas of Age-0 and Juvenile Sucker Overwintering Habitat in River Reach 22 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Table D4: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 2								
0.0000-0.2500	Unsuitable	9,892	9,892	0.0	9,892	0.0	9,892	0.0
0.2501-0.5000	Poor	2,888	2,888	0.0	2,888	0.0	2,888	0.0
0.5001-0.7500	Moderately Suitable	2,242	2,242	0.0	2,242	0.0	2,242	0.0
0.7501-1.0000	Suitable	24,143	24,143	0.0	24,143	0.0	24,143	0.0
Reach 3								
0.0000-0.2500	Unsuitable	42,612	19,056	-55.3	15,469	-63.7	13,092	-69.3
0.2501-0.5000	Poor	4,079	4,329	6.1	4,382	7.4	3,880	-4.9
0.5001-0.7500	Moderately Suitable	2,629	4,020	52.9	3,595	36.7	3,471	32.0
0.7501-1.0000	Suitable	6,288	11,545	83.6	12,736	102.5	12,753	102.8
Reach 4								
0.0000-0.2500	Unsuitable	17,029	7,563	-55.6	6,280	-63.1	3,610	-78.8
0.2501-0.5000	Poor	1,438	2,532	76.1	2,272	58.0	1,719	19.5
0.5001-0.7500	Moderately Suitable	1,150	2,569	123.4	2,643	129.8	3,381	194.0
0.7501-1.0000	Suitable	9,722	12,316	26.7	13,156	35.3	14,713	51.3
Reach 5								
0.0000-0.2500	Unsuitable	8,816	5,949	-32.5	5,382	-39.0	4,795	-45.6
0.2501-0.5000	Poor	662	638	-3.6	1,029	55.4	1,318	99.1
0.5001-0.7500	Moderately Suitable	413	595	44.1	471	14.0	533	29.1
0.7501-1.0000	Suitable	1,562	349	-77.7	191	-87.8	100	-93.6
Reach 6								
0.0000-0.2500	Unsuitable	10,990	7,538	-31.4	7,240	-34.1	6,442	-41.4
0.2501-0.5000	Poor	881	888	0.8	935	6.1	1,163	32.0
0.5001-0.7500	Moderately Suitable	566	479	-15.4	558	-1.4	874	54.4
0.7501-1.0000	Suitable	1,443	738	-48.9	556	-61.5	765	-47.0

Table D4: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 7								
0.0000-0.2500	Unsuitable	5,980	3,696	-38.2	3,544	-40.7	3,076	-48.6
0.2501-0.5000	Poor	620	495	-20.2	473	-23.7	782	26.1
0.5001-0.7500	Moderately Suitable	307	404	31.6	457	48.9	446	45.3
0.7501-1.0000	Suitable	2,347	3,143	33.9	3,113	32.6	3,051	30.0
Reach 8								
0.0000-0.2500	Unsuitable	7,759	1,026	-86.8	801	-89.7	683	-91.2
0.2501-0.5000	Poor	905	604	-33.3	584	-35.5	491	-45.7
0.5001-0.7500	Moderately Suitable	587	680	15.8	439	-25.2	262	-55.4
0.7501-1.0000	Suitable	8,662	14,096	62.7	14,367	65.9	14,904	72.1
Reach 9								
0.0000-0.2500	Unsuitable	9,511	576	-93.9	465	-95.1	356	-96.3
0.2501-0.5000	Poor	2,003	301	-85.0	370	-81.5	848	-57.7
0.5001-0.7500	Moderately Suitable	2,319	483	-79.2	462	-80.1	576	-75.2
0.7501-1.0000	Suitable	15,428	25,102	62.7	24,882	61.3	24,368	57.9
Reach 10								
0.0000-0.2500	Unsuitable	4,767	1,840	-61.4	1,769	-62.9	1,430	-70.0
0.2501-0.5000	Poor	259	491	89.6	416	60.6	371	43.2
0.5001-0.7500	Moderately Suitable	84	265	215.5	281	234.5	223	165.5
0.7501-1.0000	Suitable	1,237	1,263	2.1	1,353	9.4	1,525	23.3
Reach 11								
0.0000-0.2500	Unsuitable	7,265	3,750	-48.4	2,823	-61.1	1,989	-72.6
0.2501-0.5000	Poor	721	1,268	75.9	1,113	54.4	1,274	76.7
0.5001-0.7500	Moderately Suitable	625	1,183	89.3	1,616	158.6	1,678	168.5
0.7501-1.0000	Suitable	8,820	9,731	10.3	10,119	14.7	10,843	22.9

Table D4: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 12								
0.0000-0.2500	Unsuitable	6,006	5,081	-15.4	4,778	-20.4	4,438	-26.1
0.2501-0.5000	Poor	591	428	-27.6	453	-23.4	457	-22.7
0.5001-0.7500	Moderately Suitable	498	76	-84.7	97	-80.5	177	-64.5
0.7501-1.0000	Suitable	206	0	-100.0	0	-100.0	0	-100.0
Reach 13								
0.0000-0.2500	Unsuitable	13,353	4,270	-68.0	4,332	-67.6	3,665	-72.6
0.2501-0.5000	Poor	1,519	3,417	125.0	3,237	113.1	3,132	106.2
0.5001-0.7500	Moderately Suitable	1,832	2,191	19.6	2,051	12.0	1,368	-25.3
0.7501-1.0000	Suitable	16,348	22,237	36.0	22,339	36.6	22,971	40.5
Reach 14								
0.0000-0.2500	Unsuitable	60,094	28,821	-52.0	24,734	-58.8	20,599	-65.7
0.2501-0.5000	Poor	7,582	5,873	-22.5	5,515	-27.3	5,977	-21.2
0.5001-0.7500	Moderately Suitable	4,242	5,086	19.9	4,859	14.5	4,316	1.7
0.7501-1.0000	Suitable	11,190	13,141	17.4	14,416	28.8	15,843	41.6
Reach 19								
0.0000-0.2500	Unsuitable	974	94	-90.3	42	-95.7	42	-95.7
0.2501-0.5000	Poor	189	42	-77.8	0	-100.0	0	-100.0
0.5001-0.7500	Moderately Suitable	835	0	-100.0	142	-83.0	193	-76.9
0.7501-1.0000	Suitable	4,637	6,132	32.2	5,990	29.2	5,939	28.1
Reach 20								
0.0000-0.2500	Unsuitable	18,699	6,227	-66.7	6,151	-67.1	5,884	-68.5
0.2501-0.5000	Poor	4,419	4,128	-6.6	3,877	-12.3	3,004	-32.0
0.5001-0.7500	Moderately Suitable	2,320	2,216	-4.5	2,433	4.9	2,119	-8.7
0.7501-1.0000	Suitable	8,737	10,524	20.5	10,263	17.5	10,580	21.1

Table D4: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Overwintering Habitat Available to Adult Suckers (*Catostomus* sp.) Relative to Normal Winter Flow Conditions (210 m^3/s) by Reach (continued)

HSI Classification Groups	HSI Classification Title	Total Area (m^2)						
		210 m^3/s	50 m^3/s		40 m^3/s		30 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	% Change	Area (m^2)	% Change
Reach 21								
0.0000-0.2500	Unsuitable	4,645	2,202	-52.6	2,101	-54.8	993	-78.6
0.2501-0.5000	Poor	961	660	-31.3	600	-37.6	586	-39.0
0.5001-0.7500	Moderately Suitable	736	1,166	58.4	1,033	40.4	968	31.5
0.7501-1.0000	Suitable	2,453	6,387	160.4	6,631	170.3	6,758	175.5
Reach 22								
0.0000-0.2500	Unsuitable	39,391	41,354	5.0	40,698	3.3	39,149	-0.6
0.2501-0.5000	Poor	5,092	5,874	15.4	6,587	29.4	6,408	25.8
0.5001-0.7500	Moderately Suitable	5,370	5,747	7.0	5,483	2.1	5,957	10.9
0.7501-1.0000	Suitable	12,050	19,209	59.4	18,874	56.6	17,499	45.2

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

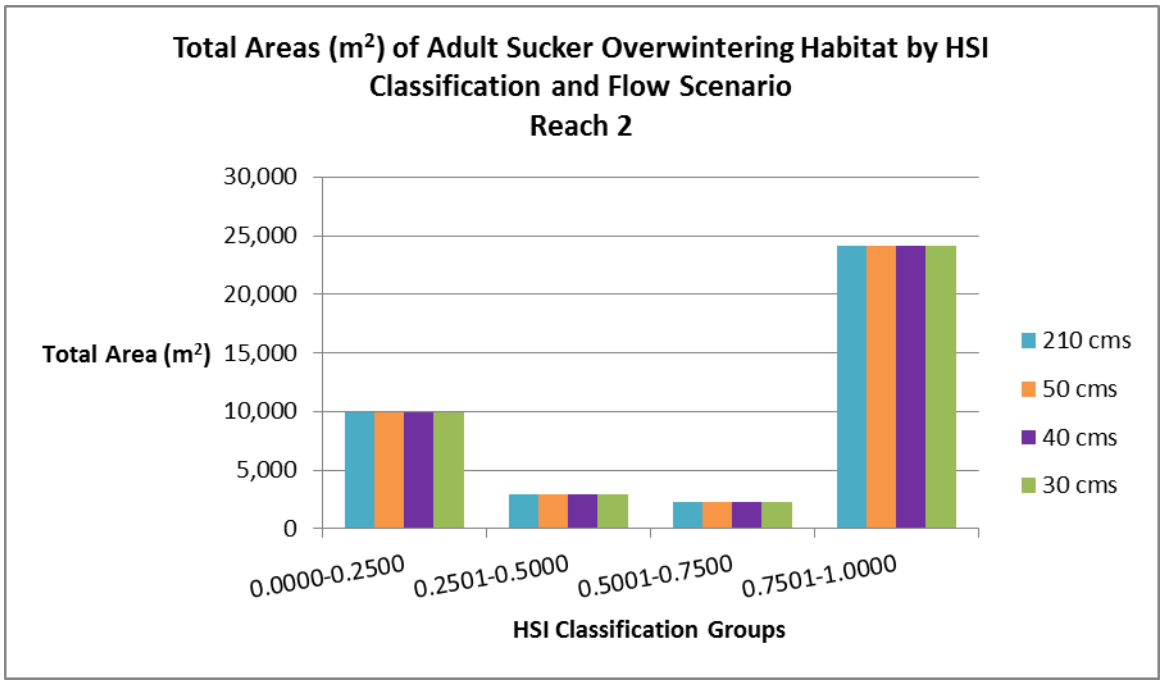


Figure D52: Total Areas of Adult Sucker Overwintering Habitat in River Reach 2 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

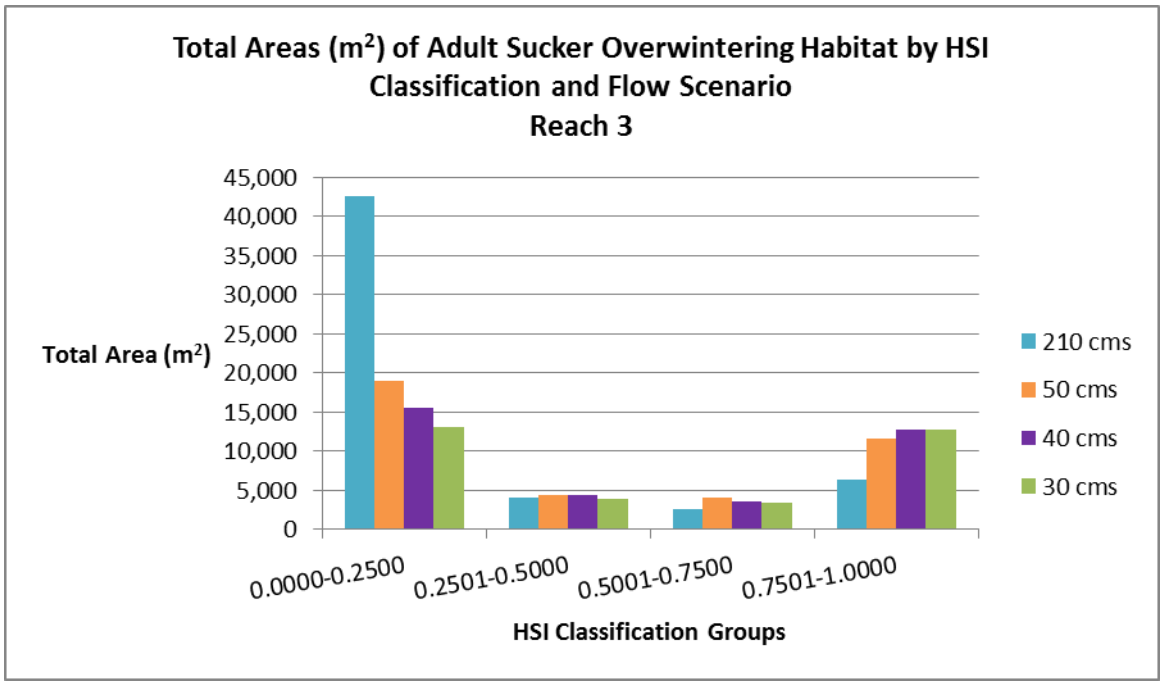


Figure D53: Total Areas of Adult Sucker Overwintering Habitat in River Reach 3 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

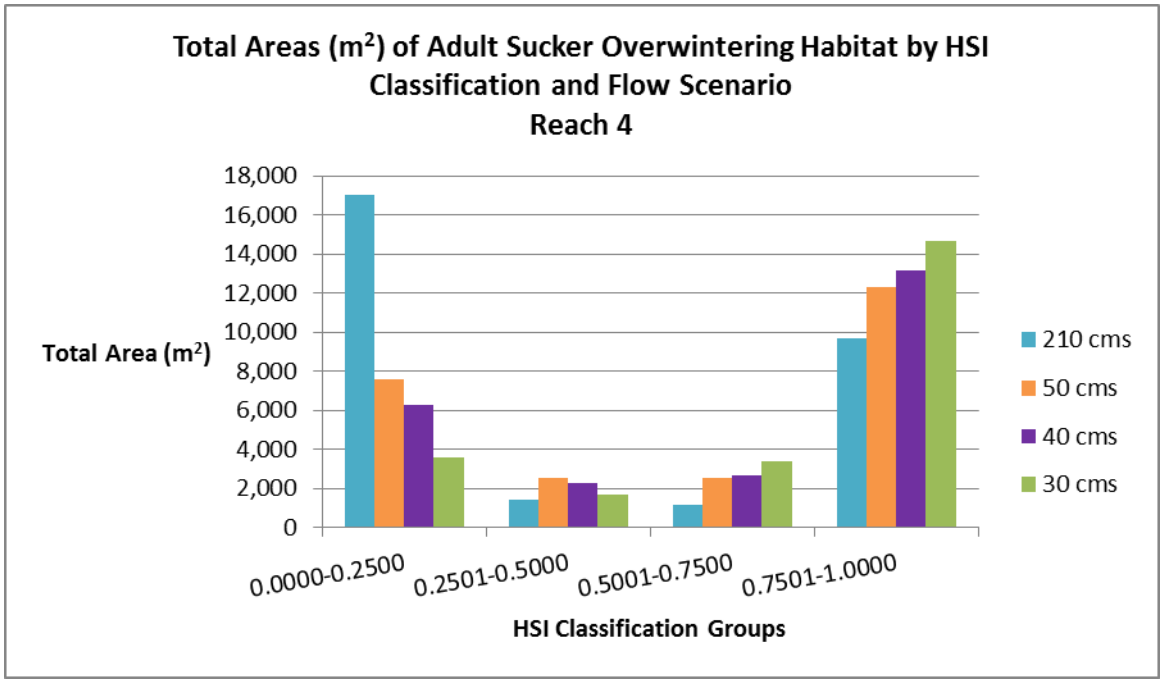


Figure D54: Total Areas of Adult Sucker Overwintering Habitat in River Reach 4 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

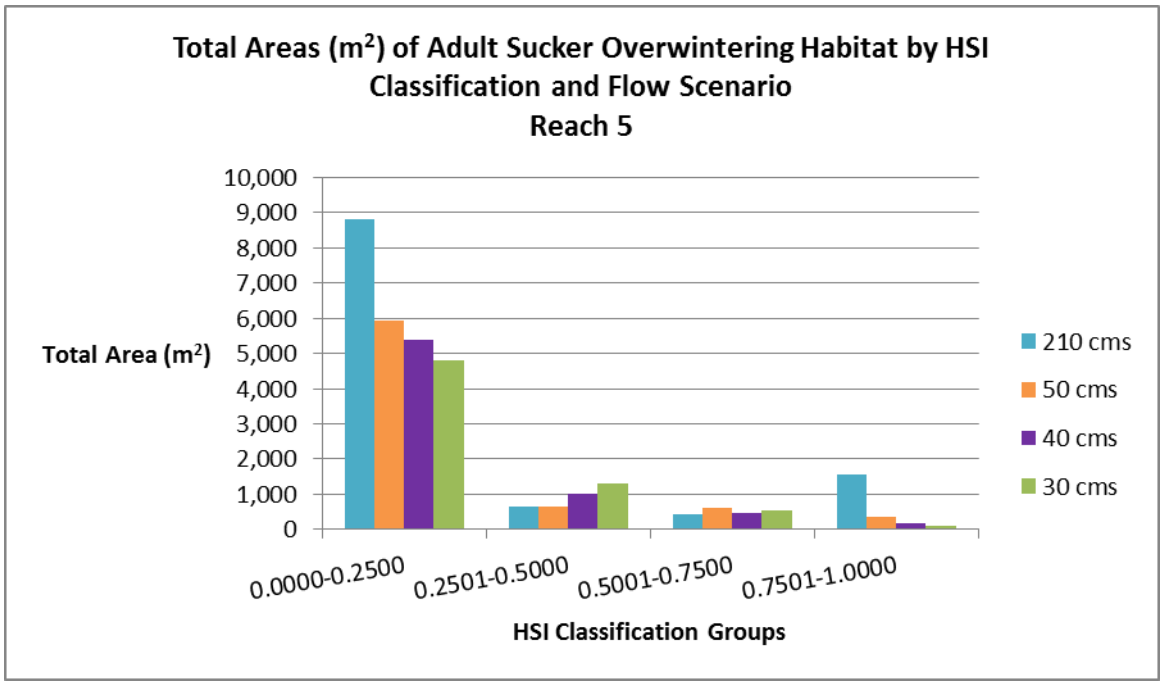


Figure D55: Total Areas of Adult Sucker Overwintering Habitat in River Reach 5 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

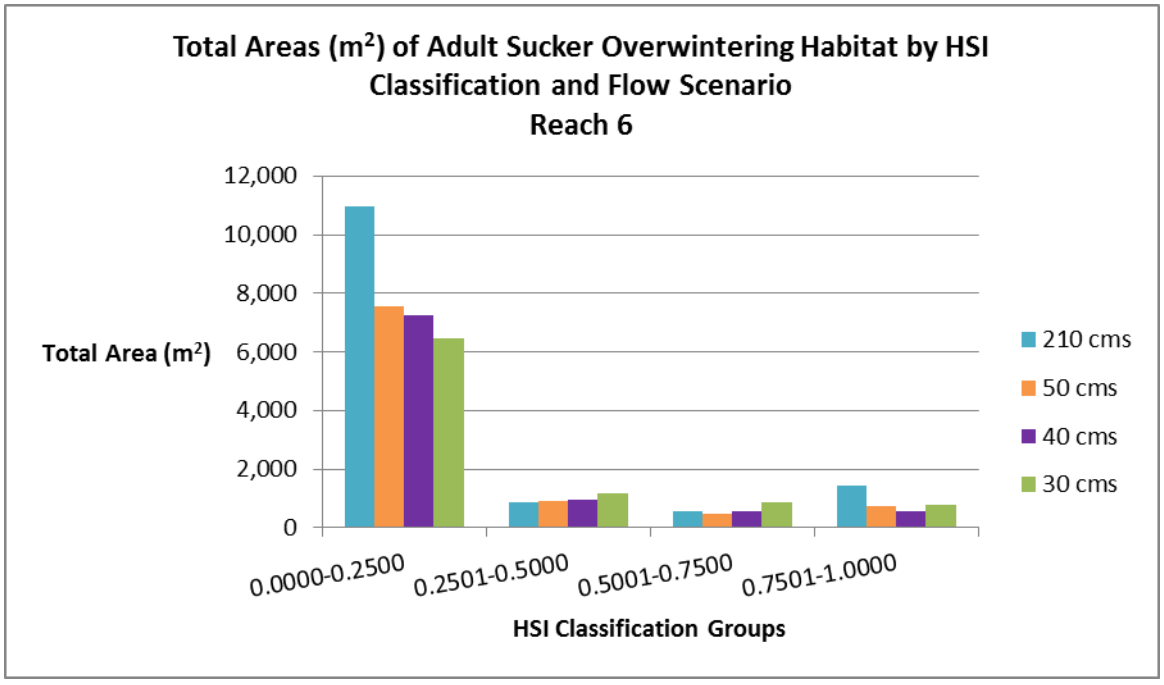


Figure D56: Total Areas of Adult Sucker Overwintering Habitat in River Reach 6 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

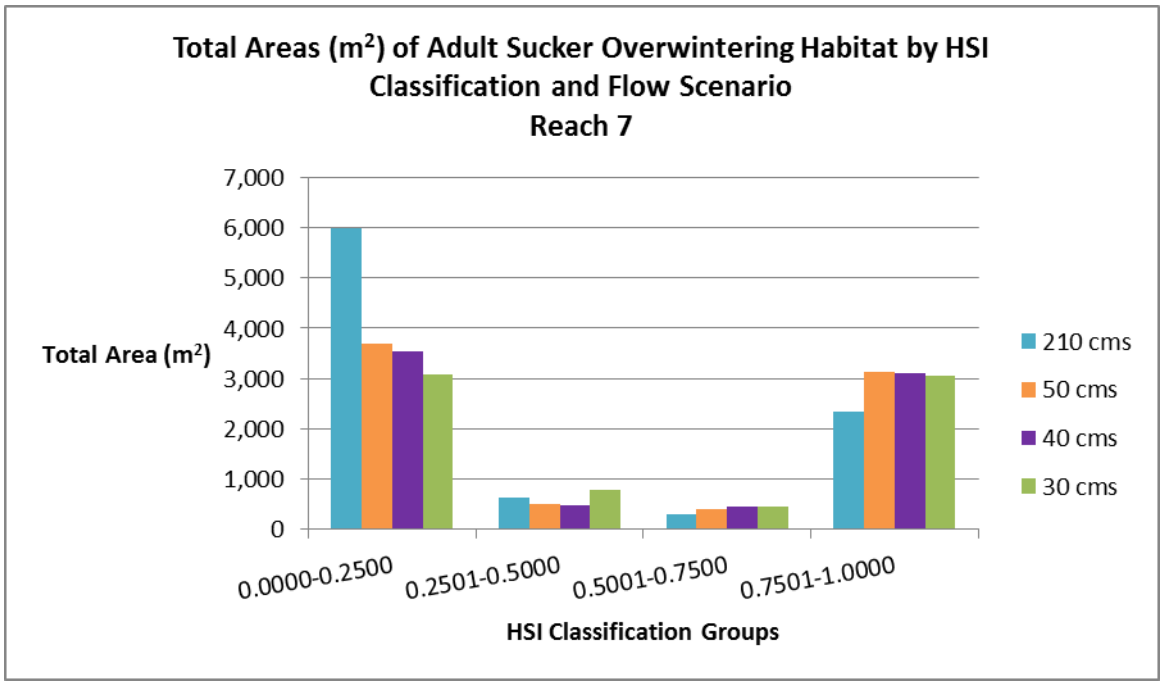


Figure D57: Total Areas of Adult Sucker Overwintering Habitat in River Reach 7 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

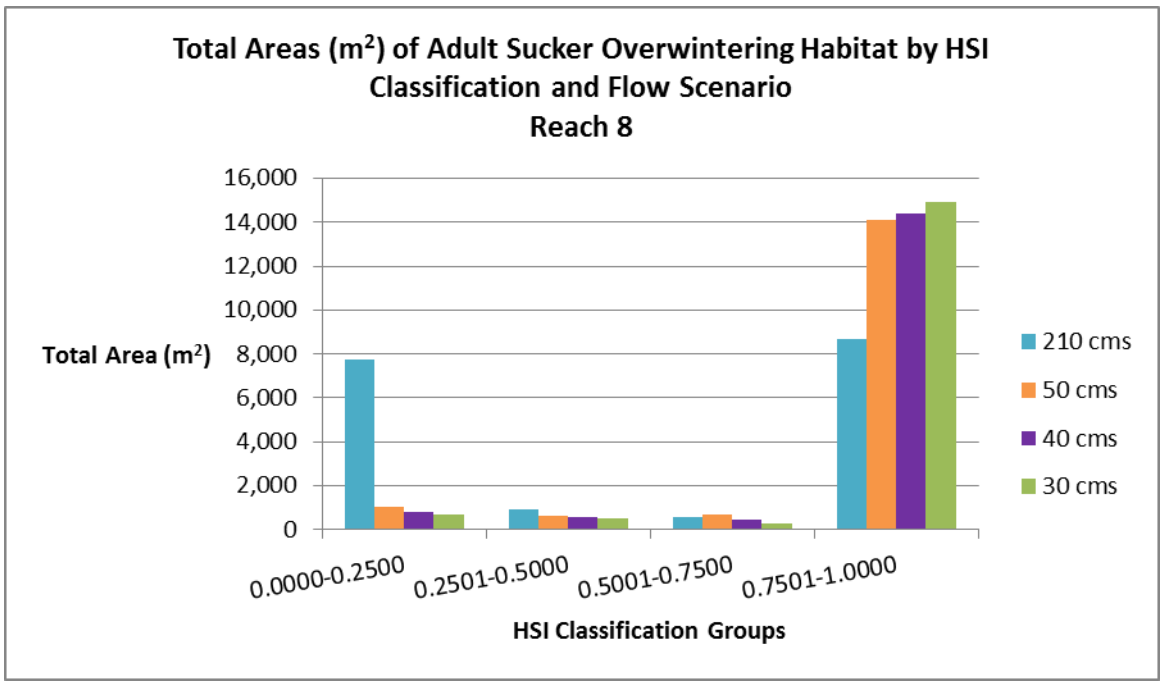


Figure D58: Total Areas of Adult Sucker Overwintering Habitat in River Reach 8 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

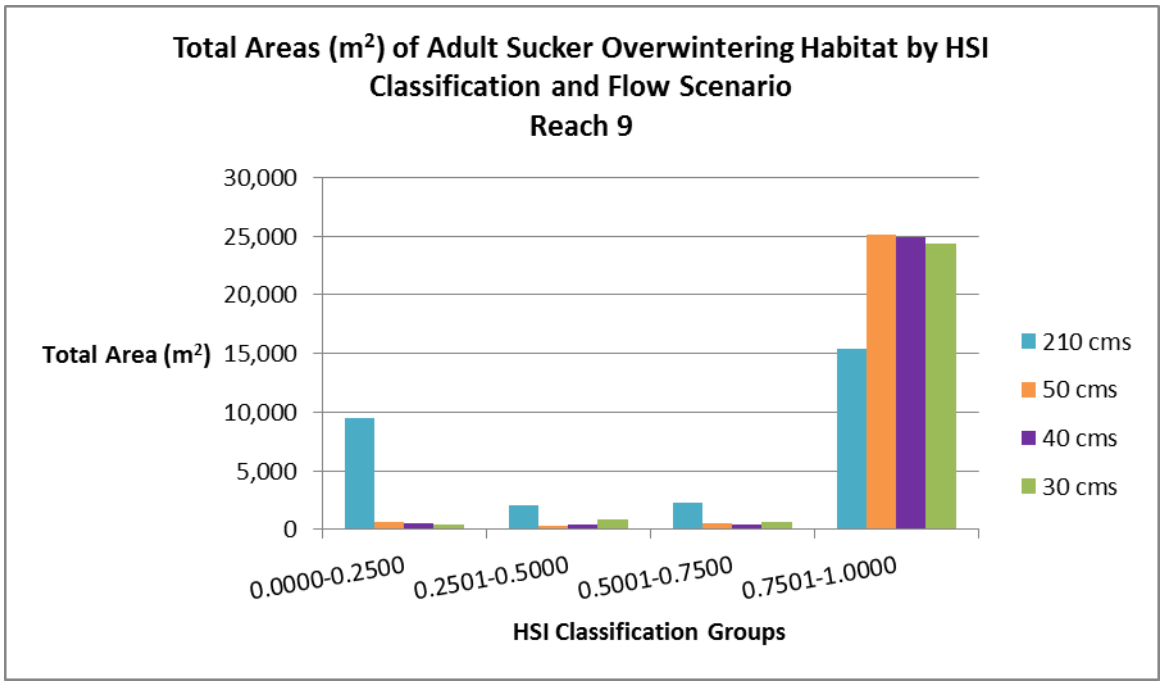


Figure D59: Total Areas of Adult Sucker Overwintering Habitat in River Reach 9 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

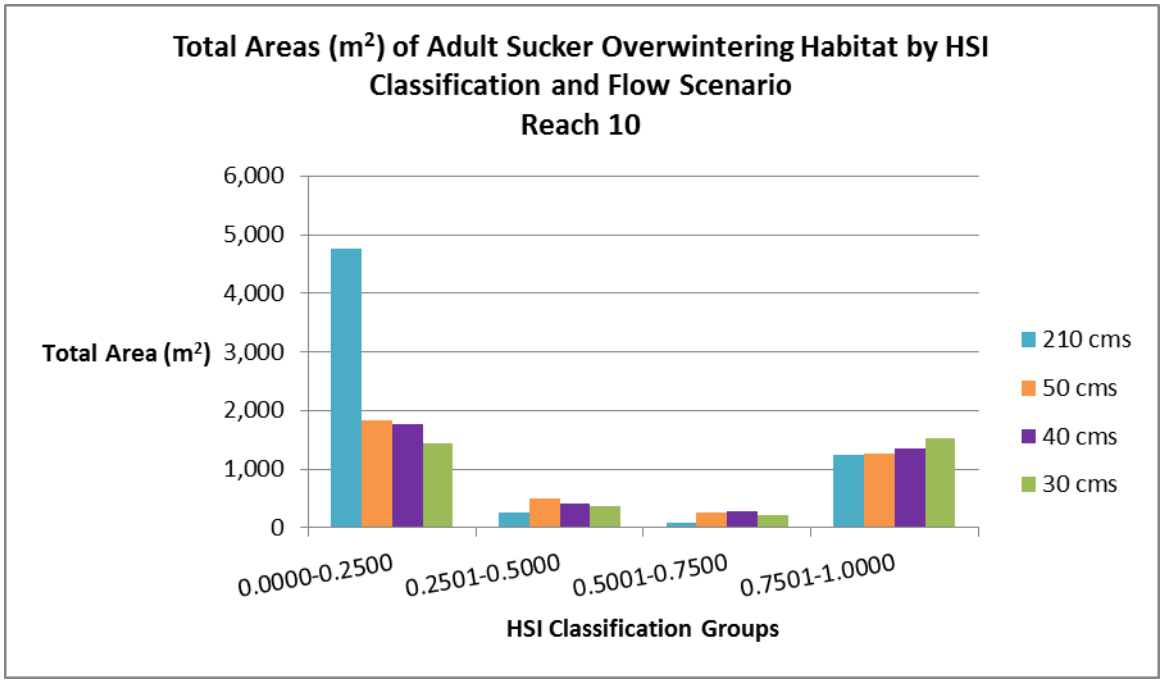


Figure D60: Total Areas of Adult Sucker Overwintering Habitat in River Reach 10 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

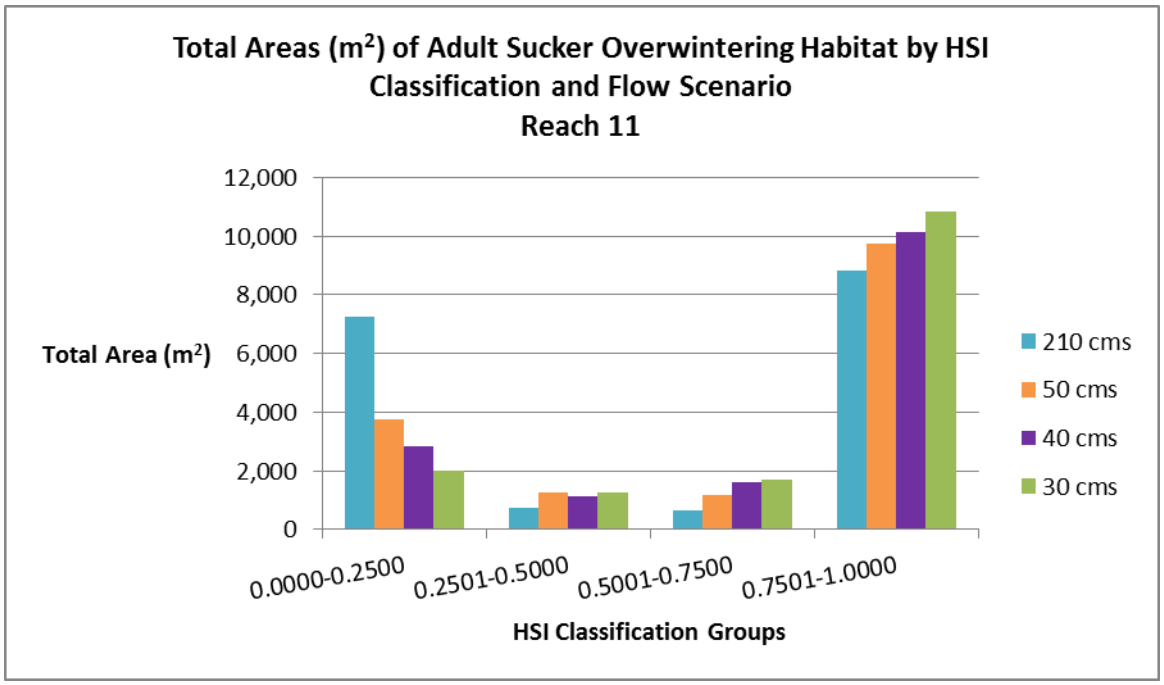


Figure D61: Total Areas of Adult Sucker Overwintering Habitat in River Reach 11 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

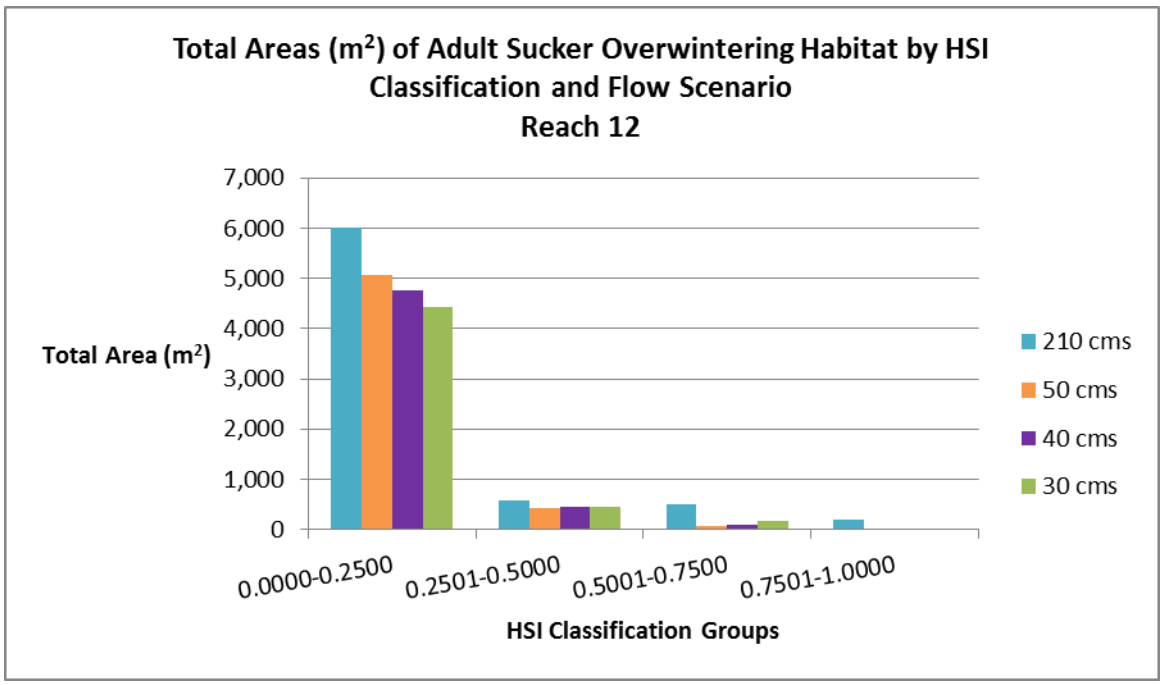


Figure D62: Total Areas of Adult Sucker Overwintering Habitat in River Reach 12 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

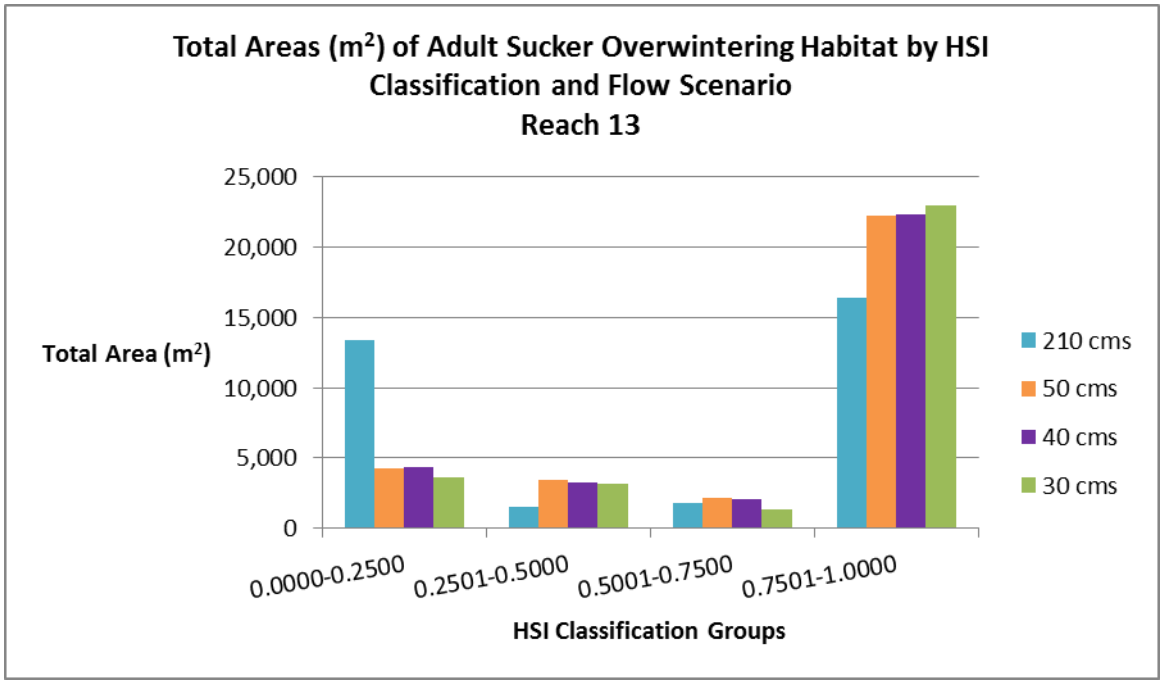


Figure D63: Total Areas of Adult Sucker Overwintering Habitat in River Reach 13 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

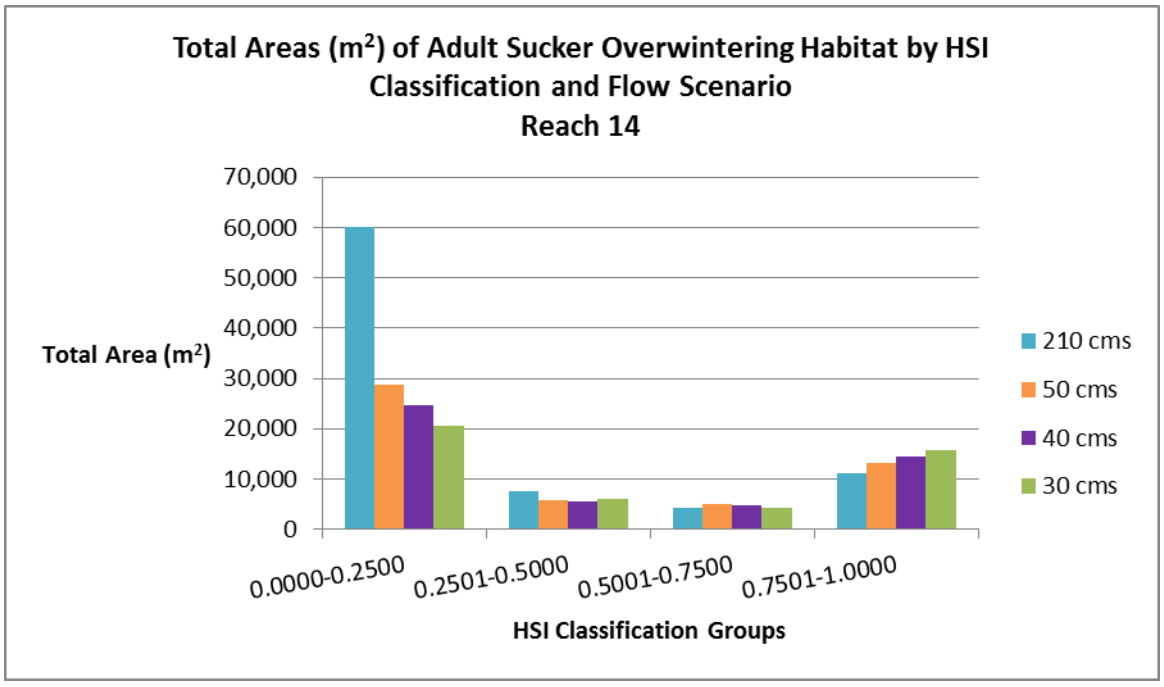


Figure D64: Total Areas of Adult Sucker Overwintering Habitat in River Reach 14 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

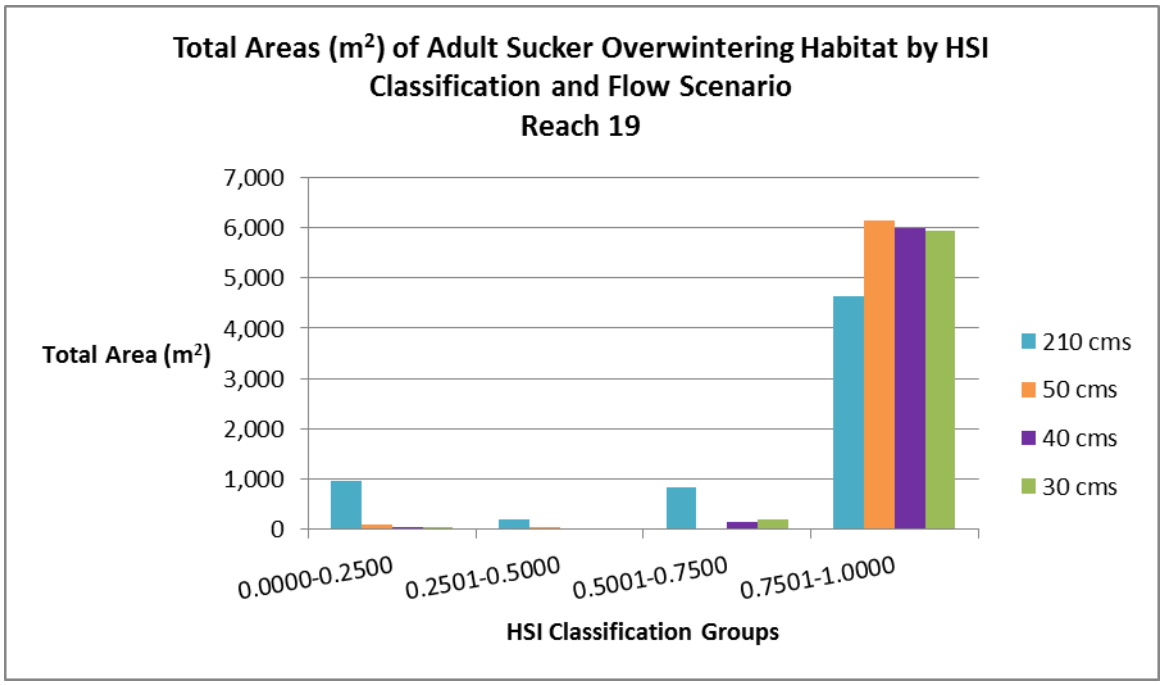


Figure D65: Total Areas of Adult Sucker Overwintering Habitat in River Reach 19 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

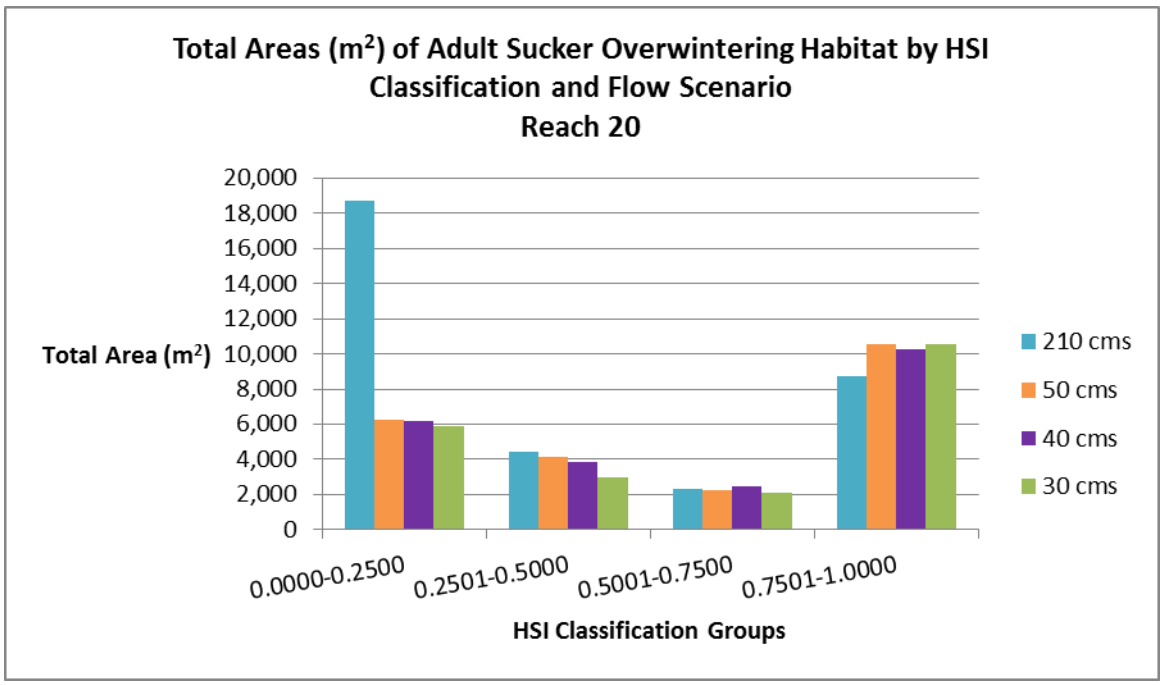


Figure D66: Total Areas of Adult Sucker Overwintering Habitat in River Reach 20 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

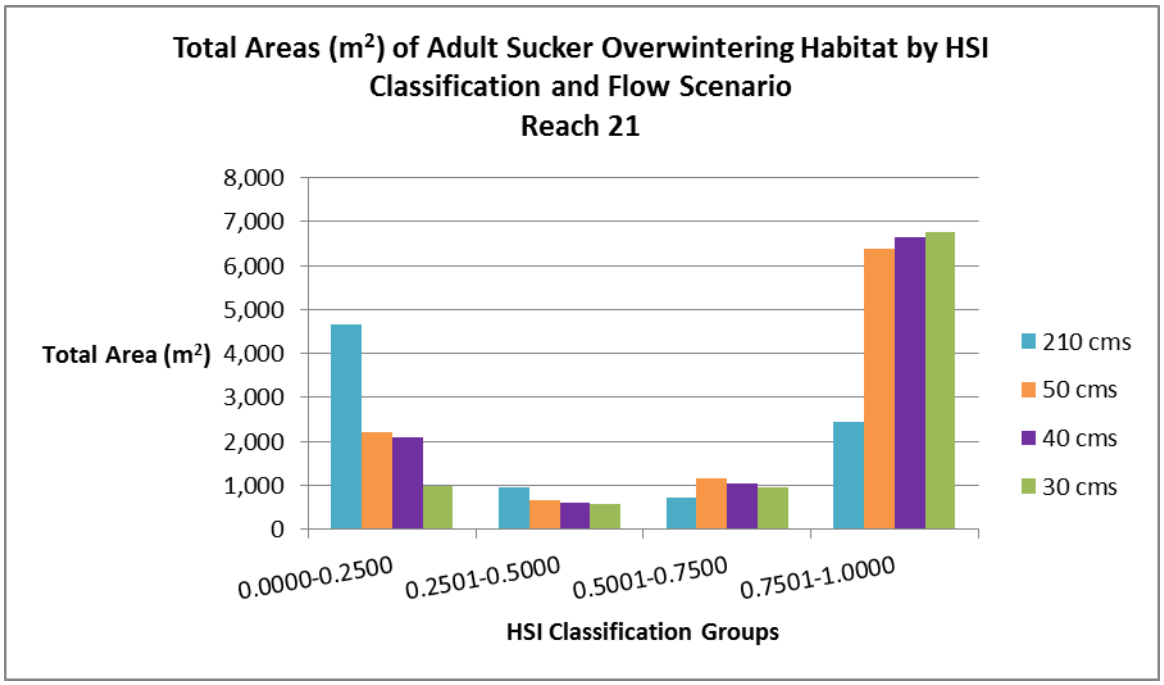


Figure D67: Total Areas of Adult Sucker Overwintering Habitat in River Reach 21 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

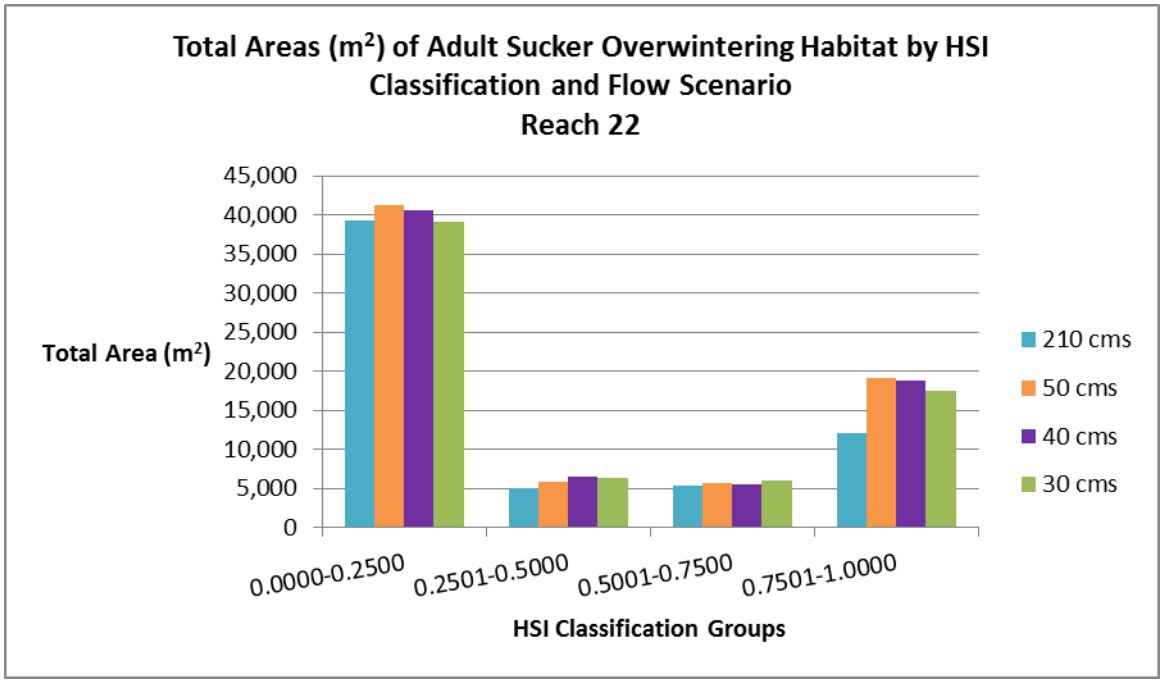


Figure D68: Total Areas of Adult Sucker Overwintering Habitat in River Reach 22 between Black Lake and Middle Lake for Four Flow Scenarios in the Fond du Lac River.

Appendix 12.1-E

Spawning Habitat Suitability by Reach

February 2014
Project No. 10-1365-0004/DCN-171

Table E1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Arctic Grayling (*Thymallus arcticus*) by Reach for Six Spring Flows

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 2										
0.0000-0.2500	Unsuitable	37,563	29,621	-21.1	37,893	34,480	-9.0	39,493	36,569	-7.4
0.2501-0.5000	Poor	1,043	1,407	34.9	826	955	15.6	390	1,134	190.8
0.5001-0.7500	Moderately Suitable	1,959	1,794	-8.4	2,846	1,149	-59.6	3,434	2,369	-31.0
0.7501-1.0000	Suitable	2,350	3,079	31.0	2,553	2,581	1.1	1,572	2,563	63.0
Reach 3										
0.0000-0.2500	Unsuitable	51,979	39,095	-24.8	55,743	48,474	-13.0	58,582	52,427	-10.5
0.2501-0.5000	Poor	1,459	2,084	42.8	1,645	1,818	10.5	1,053	1,792	70.2
0.5001-0.7500	Moderately Suitable	2,947	4,227	43.4	2,391	2,112	-11.7	4,284	3,453	-19.4
0.7501-1.0000	Suitable	4,714	2,659	-43.6	4,983	3,204	-35.7	3,998	4,048	1.3
Reach 4										
0.0000-0.2500	Unsuitable	29,097	23,858	-18.0	31,098	26,852	-13.7	31,889	29,226	-8.4
0.2501-0.5000	Poor	377	389	3.2	572	380	-33.6	412	451	9.5
0.5001-0.7500	Moderately Suitable	987	2,380	141.1	1,380	1,099	-20.4	1,989	1,085	-45.4
0.7501-1.0000	Suitable	1,056	526	-50.2	1,268	1,007	-20.6	1,730	1,263	-27.0

Table E1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Arctic Grayling (*Thymallus arcticus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 5										
0.0000-0.2500	Unsuitable	10,920	7,894	-27.7	12,183	10,053	-17.5	12,530	10,774	-14.0
0.2501-0.5000	Poor	256	214	-16.4	164	366	123.2	0	478	100.0
0.5001-0.7500	Moderately Suitable	420	798	90.0	474	506	6.8	453	364	-19.6
0.7501-1.0000	Suitable	796	418	-47.5	552	528	-4.3	984	807	-18.0
Reach 6										
0.0000-0.2500	Unsuitable	12,547	9,426	-24.9	14,174	11,857	-16.3	16,105	13,073	-18.8
0.2501-0.5000	Poor	445	237	-46.7	317	391	23.3	68	624	817.6
0.5001-0.7500	Moderately Suitable	1,086	1,035	-4.7	960	593	-38.2	901	1,360	50.9
0.7501-1.0000	Suitable	1,406	705	-49.9	1,473	1,039	-29.5	569	969	70.3
Reach 7										
0.0000-0.2500	Unsuitable	9,280	7,751	-16.5	9,885	8,267	-16.4	10,578	9,033	-14.6
0.2501-0.5000	Poor	160	195	21.9	170	116	-31.8	126	104	-17.5
0.5001-0.7500	Moderately Suitable	262	427	63.0	304	389	28.0	575	119	-79.3
0.7501-1.0000	Suitable	430	170	-60.5	460	483	5.0	540	660	22.2

Table E1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Arctic Grayling (*Thymallus arcticus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 8										
0.0000-0.2500	Unsuitable	17,706	16,551	-6.5	18,200	16,810	-7.6	18,579	17,600	-5.3
0.2501-0.5000	Poor	229	148	-35.4	85	133	56.5	321	268	-16.5
0.5001-0.7500	Moderately Suitable	599	383	-36.1	721	654	-9.3	768	925	20.4
0.7501-1.0000	Suitable	329	100	-69.6	556	316	-43.2	411	189	-54.0
Reach 9										
0.0000-0.2500	Unsuitable	30,134	26,668	-11.5	31,173	27,575	-11.5	31,686	31,060	-2.0
0.2501-0.5000	Poor	414	189	-54.3	570	147	-74.2	422	674	59.7
0.5001-0.7500	Moderately Suitable	617	878	42.3	1,070	1,063	-0.7	1,079	862	-20.1
0.7501-1.0000	Suitable	726	199	-72.6	1,313	475	-63.8	1,896	380	-80.0
Reach 10										
0.0000-0.2500	Unsuitable	6,545	4,799	-26.7	7,331	5,975	-18.5	7,259	6,355	-12.5
0.2501-0.5000	Poor	34	249	632.4	38	12	-68.4	0	133	100.0
0.5001-0.7500	Moderately Suitable	188	369	96.3	38	283	644.7	175	223	27.4
0.7501-1.0000	Suitable	131	57	-56.5	70	77	10.0	164	220	34.1

Table E1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Arctic Grayling (*Thymallus arcticus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 11										
0.0000-0.2500	Unsuitable	16,674	14,830	-11.1	17,405	16,066	-7.7	17,902	17,159	-4.2
0.2501-0.5000	Poor	151	420	178.1	264	236	-10.6	422	162	-61.6
0.5001-0.7500	Moderately Suitable	904	944	4.4	647	546	-15.6	1,172	847	-27.7
0.7501-1.0000	Suitable	487	613	25.9	944	583	-38.2	841	418	-50.3
Reach 12										
0.0000-0.2500	Unsuitable	6,475	5,200	-19.7	7,794	5,799	-25.6	8,194	6,611	-19.3
0.2501-0.5000	Poor	153	237	54.9	455	122	-73.2	281	235	-16.4
0.5001-0.7500	Moderately Suitable	906	599	-33.9	624	603	-3.4	871	635	-27.1
0.7501-1.0000	Suitable	389	470	20.8	522	777	48.9	480	561	16.9
Reach 13										
0.0000-0.2500	Unsuitable	32,469	29,939	-7.8	33,225	31,677	-4.7	33,324	32,353	-2.9
0.2501-0.5000	Poor	180	234	30.0	167	294	76.0	61	249	308.2
0.5001-0.7500	Moderately Suitable	690	1,206	74.8	437	491	12.4	650	879	35.2
0.7501-1.0000	Suitable	425	843	98.4	734	591	-19.5	453	141	-68.9

Table E1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Arctic Grayling (*Thymallus arcticus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 14										
0.0000-0.2500	Unsuitable	76,591	53,740	-29.8	80,570	69,112	-14.2	88,678	77,579	-12.5
0.2501-0.5000	Poor	2,603	2,706	4.0	2,543	2,820	10.9	1,982	3,319	67.5
0.5001-0.7500	Moderately Suitable	5,170	4,289	-17.0	6,645	4,269	-35.8	7,931	5,025	-36.6
0.7501-1.0000	Suitable	7,572	5,944	-21.5	9,563	6,907	-27.8	6,737	7,746	15.0
Reach 19										
0.0000-0.2500	Unsuitable	6,410	6,132	-4.3	6,427	6,281	-2.3	6,549	6,558	0.1
0.2501-0.5000	Poor	0	35	100.0	35	0	-100.0	36	35	-2.8
0.5001-0.7500	Moderately Suitable	184	192	4.3	253	262	3.6	141	182	29.1
0.7501-1.0000	Suitable	36	0	-100.0	61	0	-100.0	94	0	-100.0
Reach 20										
0.0000-0.2500	Unsuitable	30,778	20,707	-32.7	33,622	27,602	-17.9	37,173	32,417	-12.8
0.2501-0.5000	Poor	1,597	1,387	-13.1	1,824	1,593	-12.7	1,131	1,733	53.2
0.5001-0.7500	Moderately Suitable	2,463	2,810	14.1	2,841	2,783	-2.0	2,835	2,808	-1.0
0.7501-1.0000	Suitable	3,733	2,794	-25.2	2,918	3,351	14.8	3,093	3,738	20.9

Table E1: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Arctic Grayling (*Thymallus arcticus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 21										
0.0000-0.2500	Unsuitable	8,515	7,940	-6.8	9,245	9,186	-0.6	9,878	10,128	2.5
0.2501-0.5000	Poor	86	303	252.3	87	120	37.9	35	330	842.9
0.5001-0.7500	Moderately Suitable	537	806	50.1	411	390	-5.1	416	460	10.6
0.7501-1.0000	Suitable	569	708	24.4	567	617	8.8	472	511	8.3
Reach 22										
0.0000-0.2500	Unsuitable	59,276	64,875	9.4	63,600	68,663	8.0	70,539	77,524	9.9
0.2501-0.5000	Poor	2,234	2,022	-9.5	2,256	2,939	30.3	2,007	2,275	13.4
0.5001-0.7500	Moderately Suitable	4,382	5,238	19.5	6,088	7,975	31.0	5,543	5,077	-8.4
0.7501-1.0000	Suitable	5,784	6,426	11.1	6,874	7,132	3.8	6,420	8,798	37.0

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

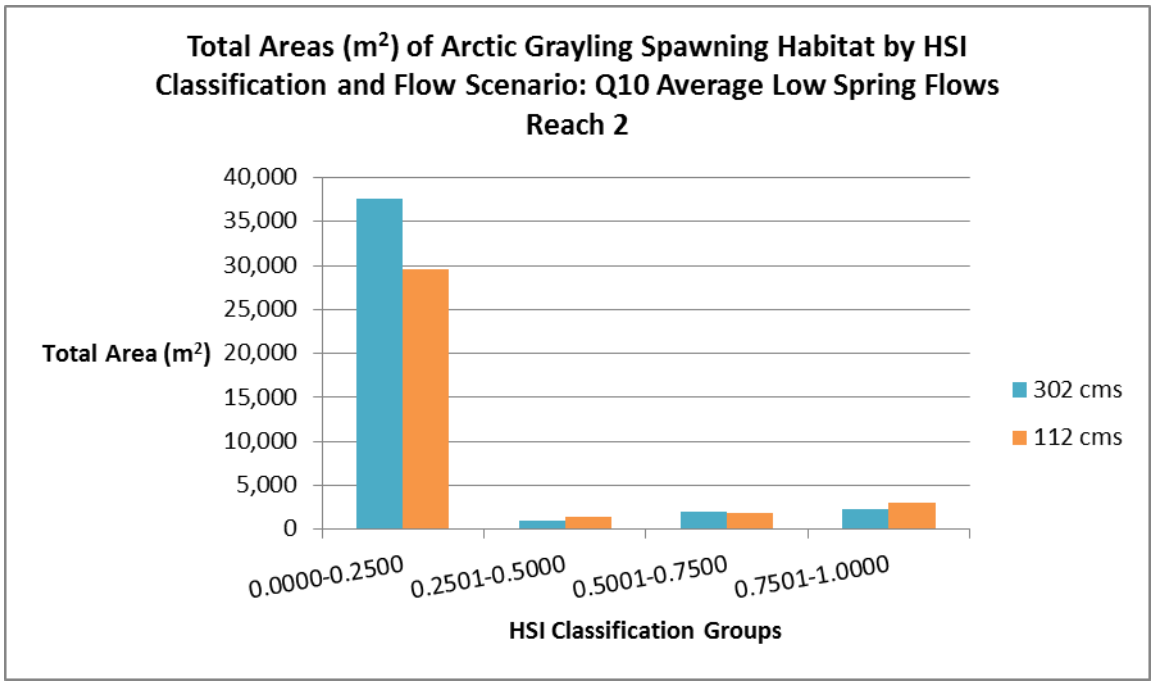


Figure E1: Total Areas of Arctic Grayling Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

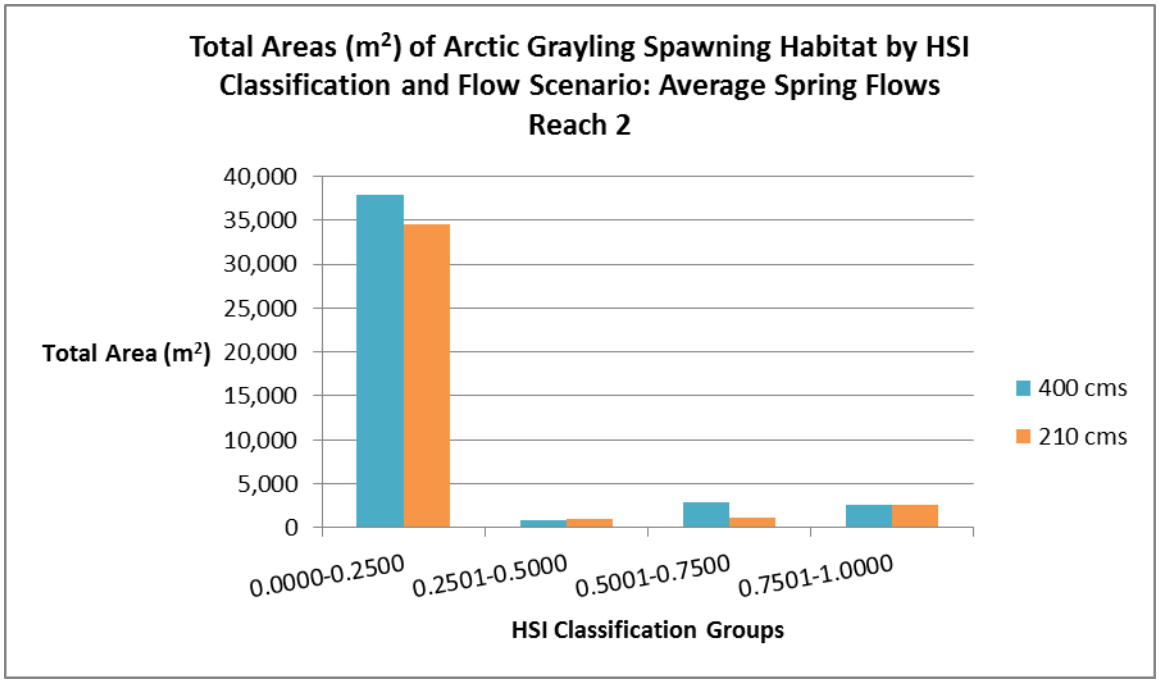


Figure E2: Total Areas of Arctic Grayling Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

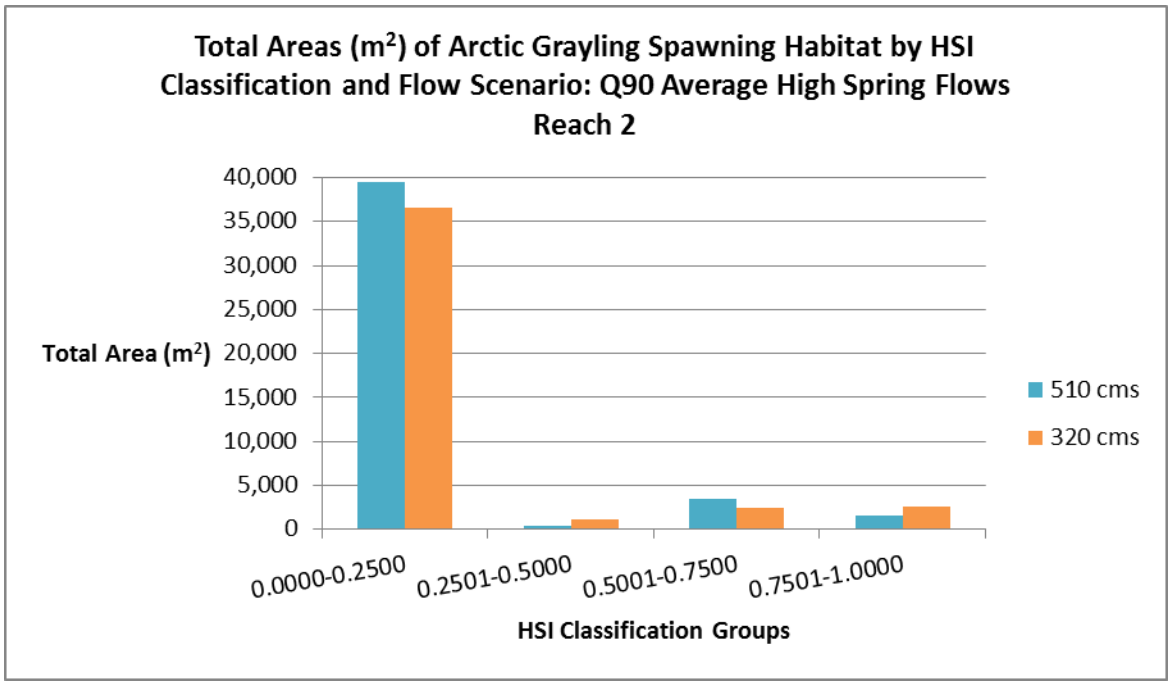


Figure E3: Total Areas of Arctic Grayling Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

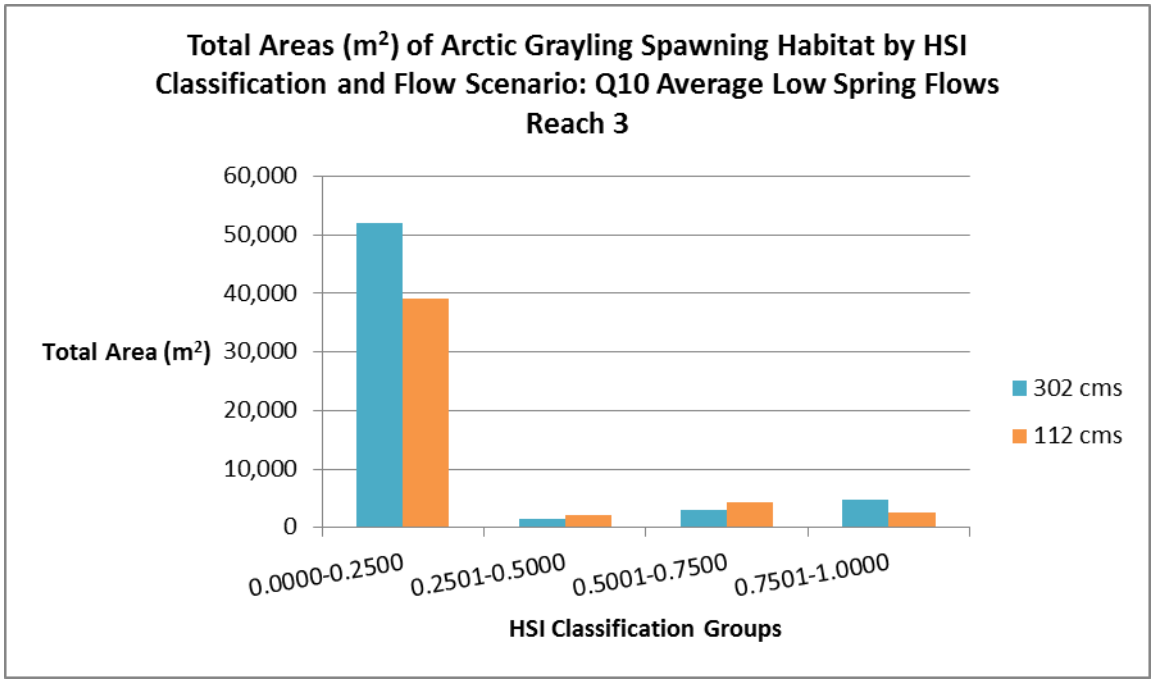


Figure E4: Total Areas of Arctic Grayling Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

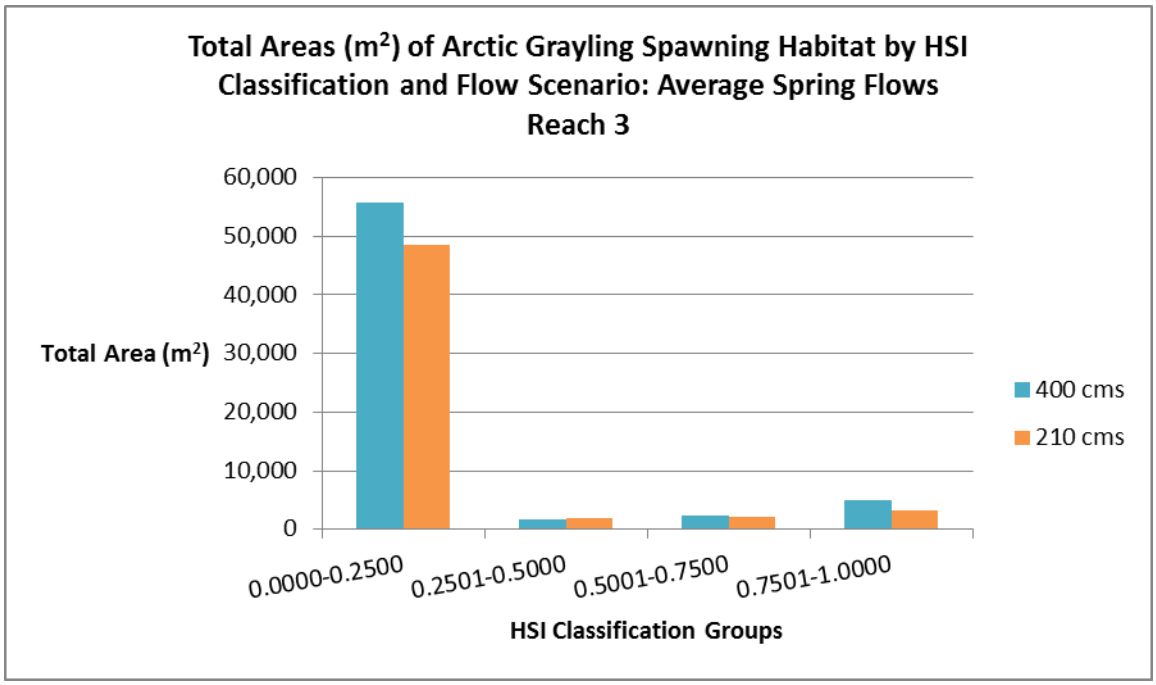


Figure E5: Total Areas of Arctic Grayling Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

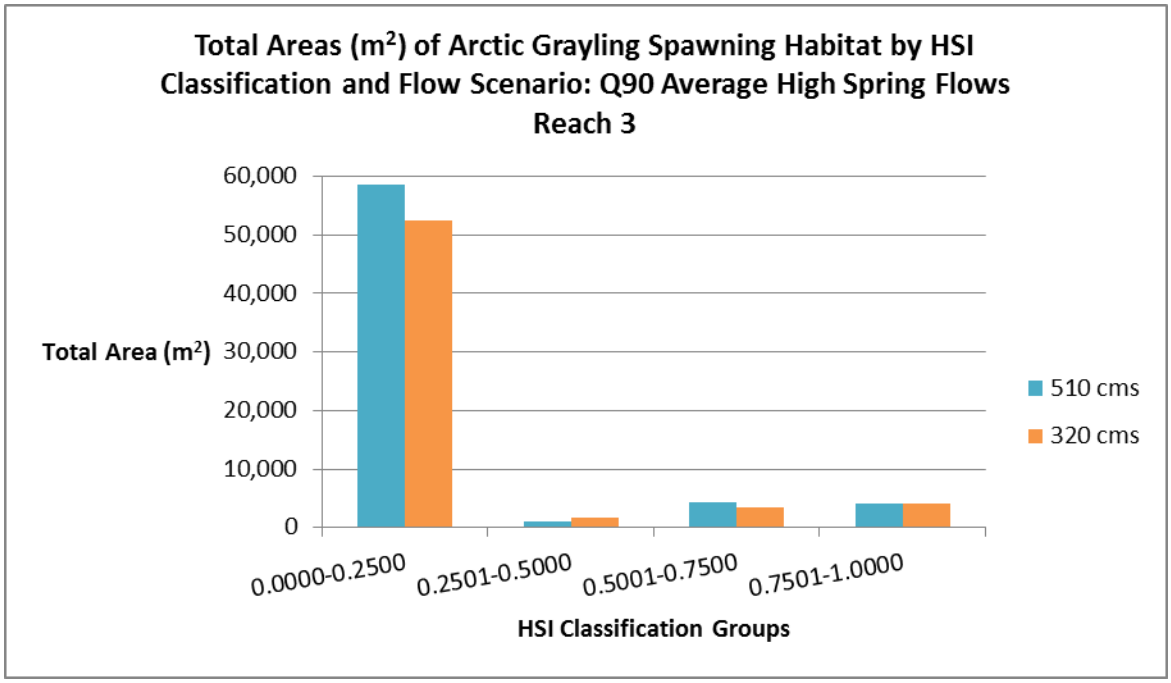


Figure E6: Total Areas of Arctic Grayling Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

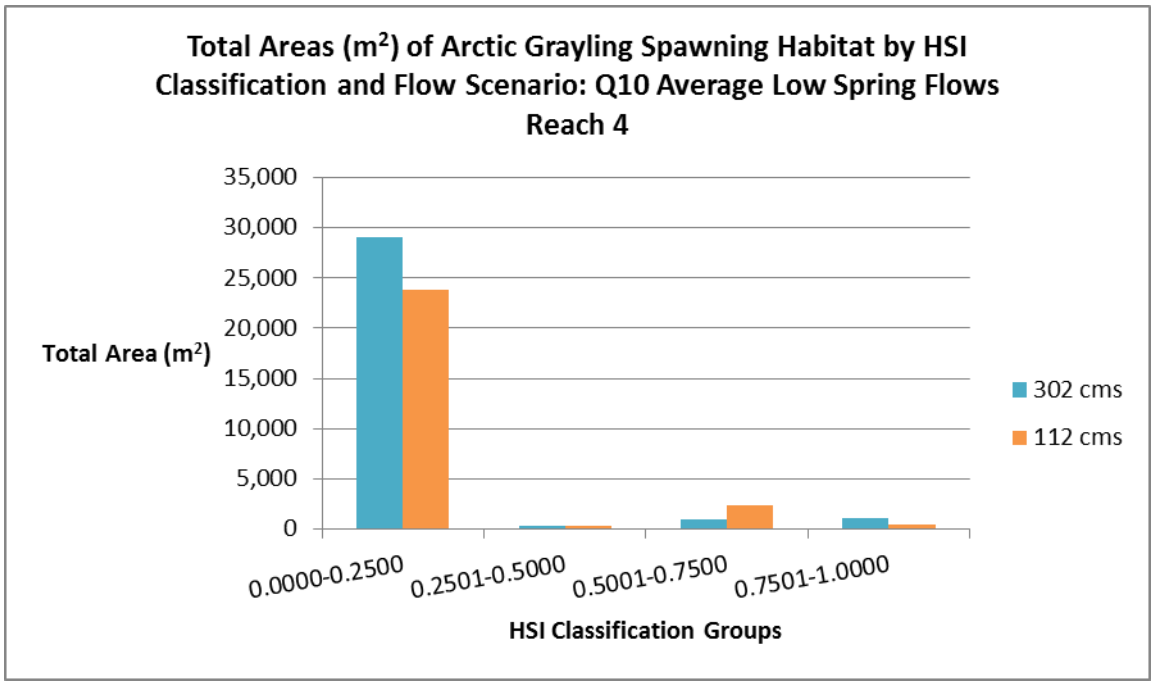


Figure E7: Total Areas of Arctic Grayling Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

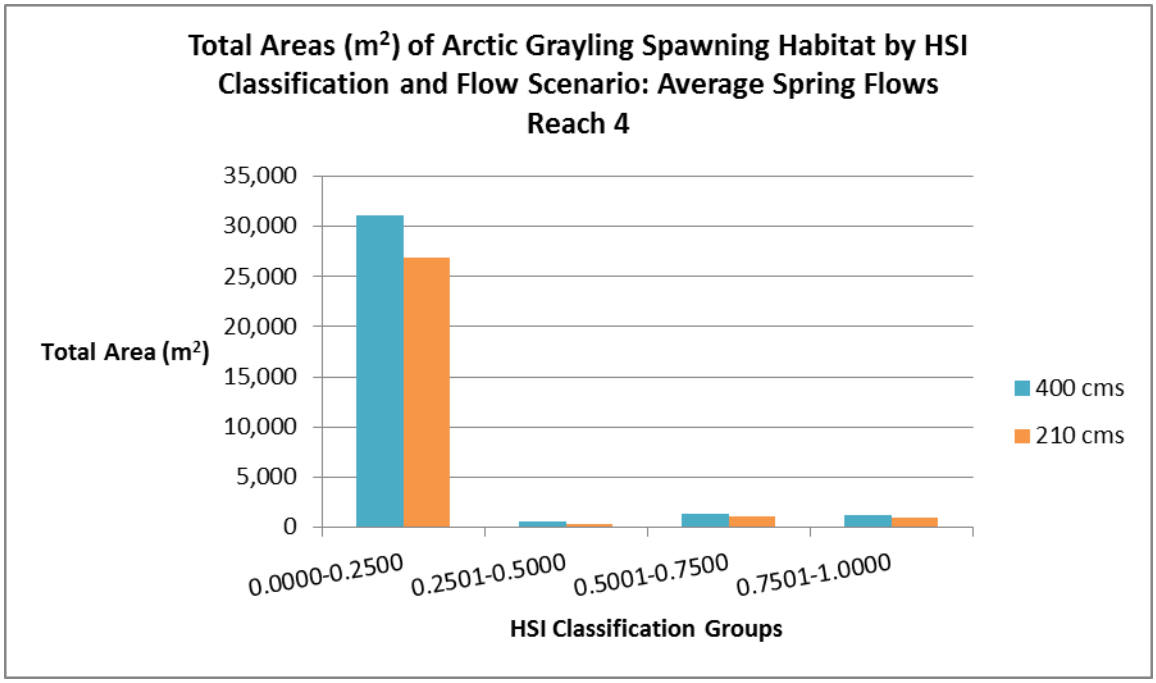


Figure E8: Total Areas of Arctic Grayling Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

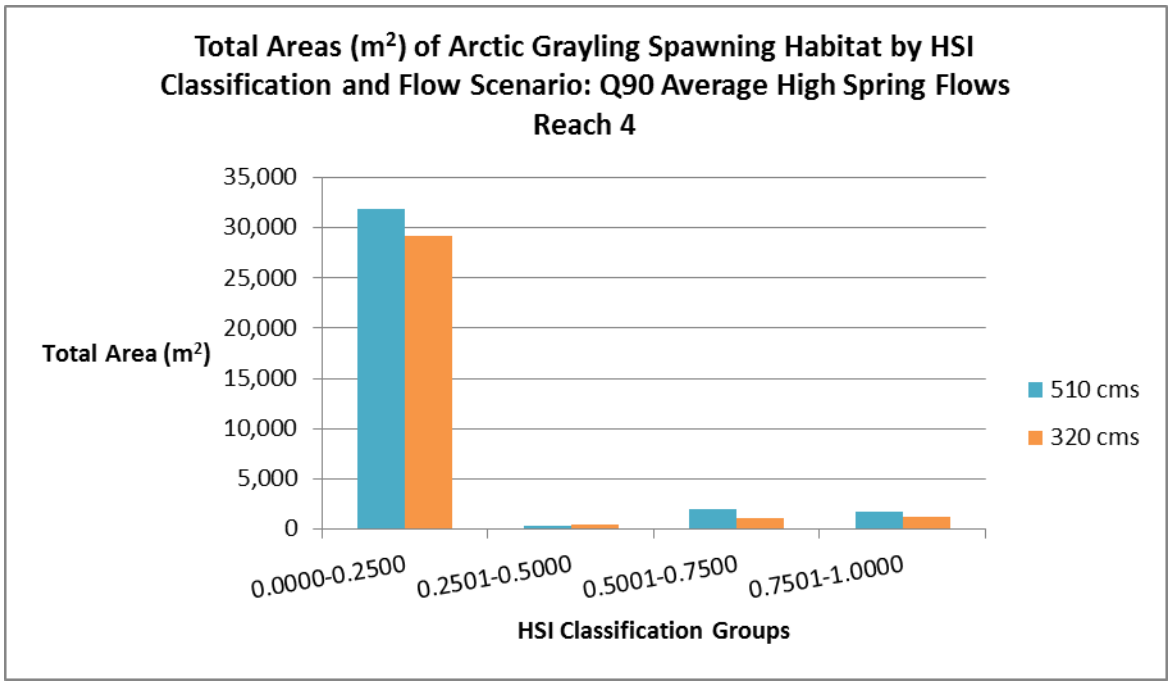


Figure E9: Total Areas of Arctic Grayling Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

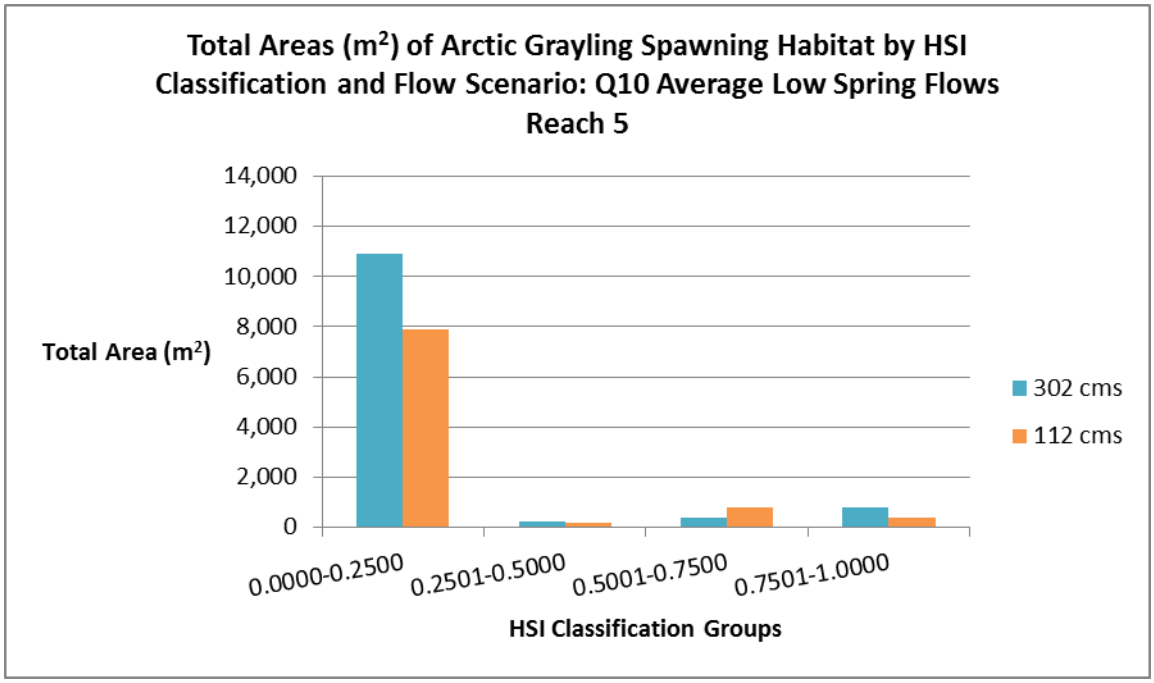


Figure E10: Total Areas of Arctic Grayling Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

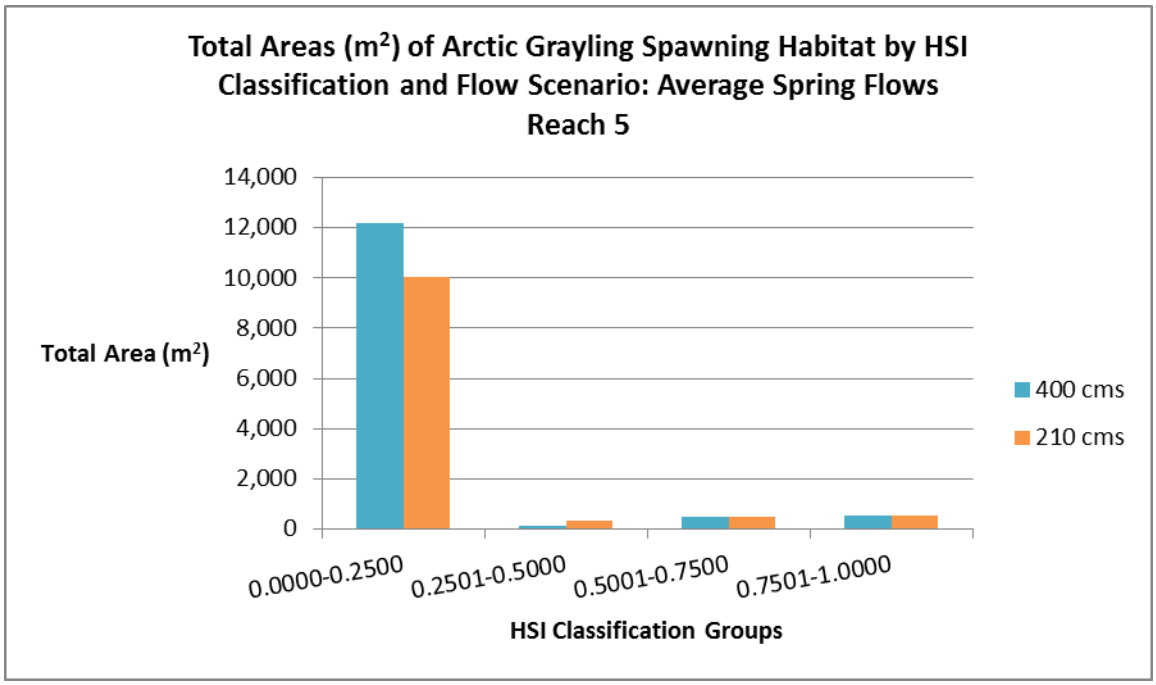


Figure E11: Total Areas of Arctic Grayling Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

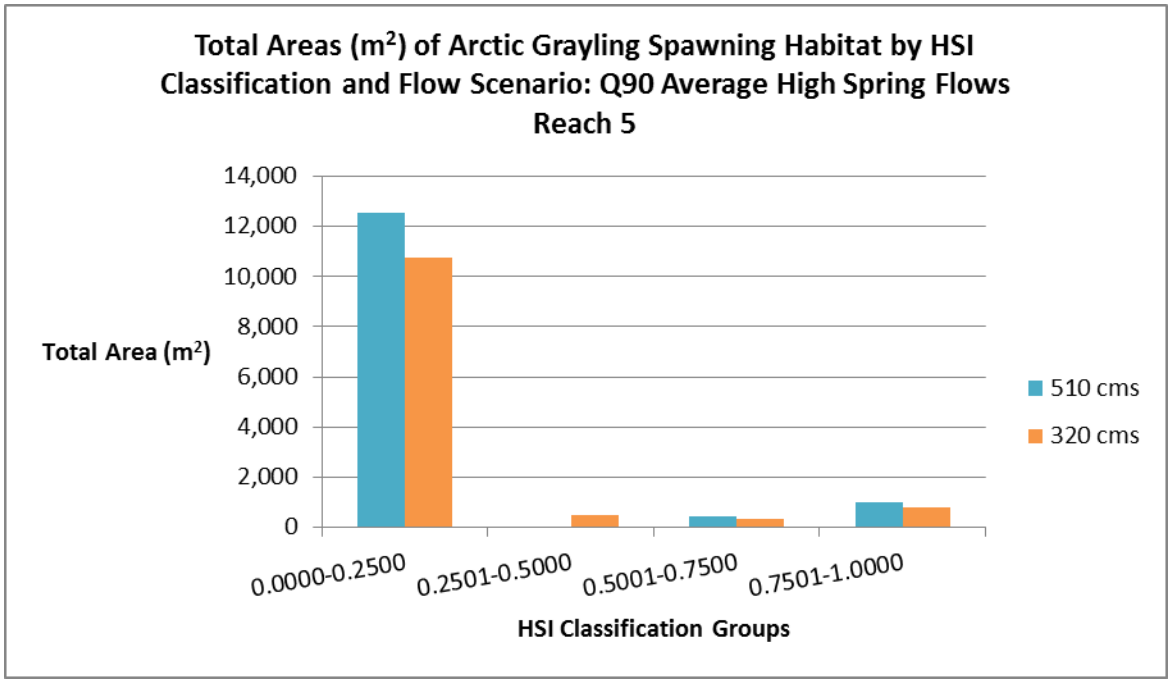


Figure E12: Total Areas of Arctic Grayling Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

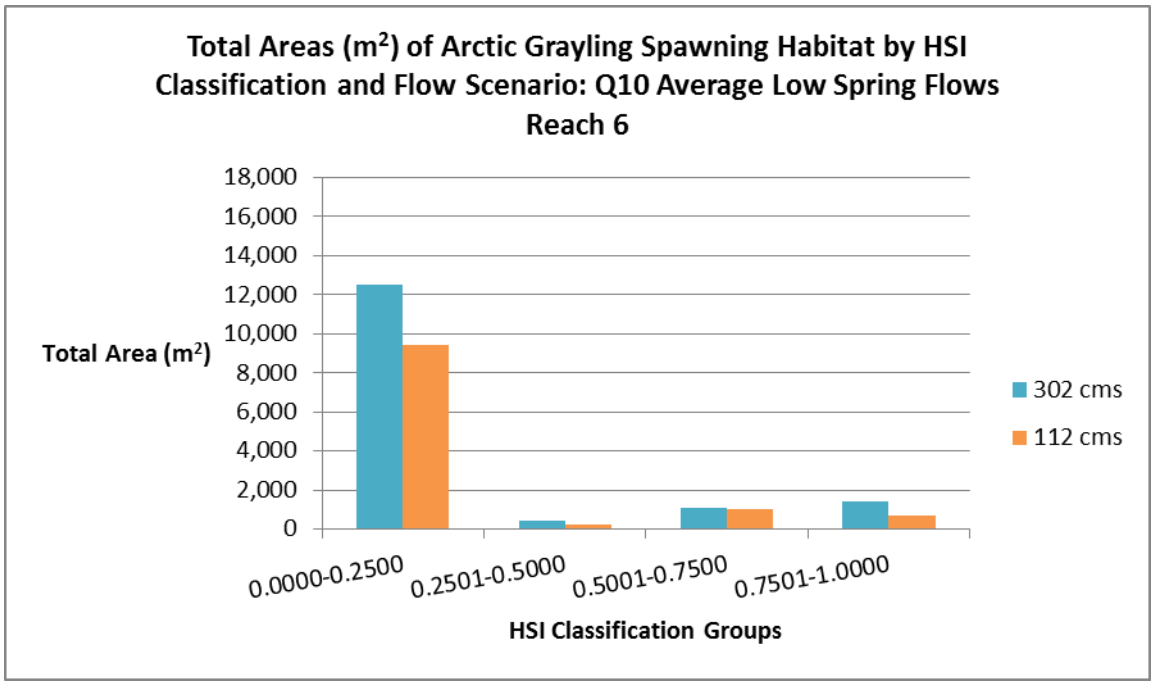


Figure E13: Total Areas of Arctic Grayling Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

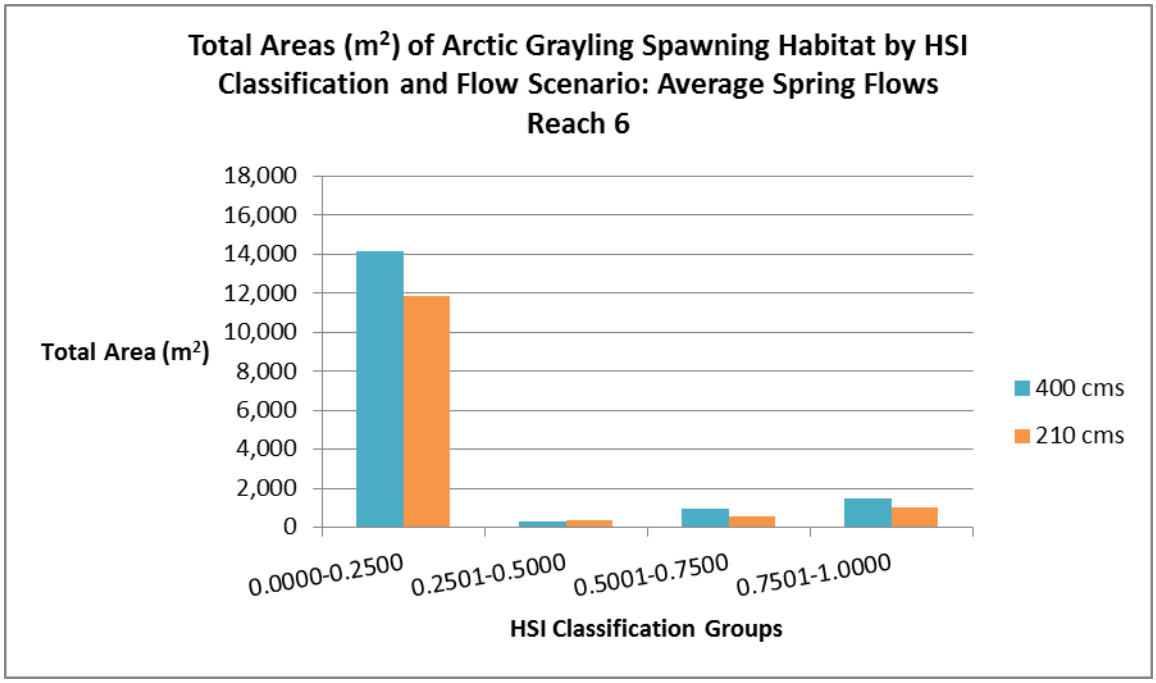


Figure E14: Total Areas of Arctic Grayling Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

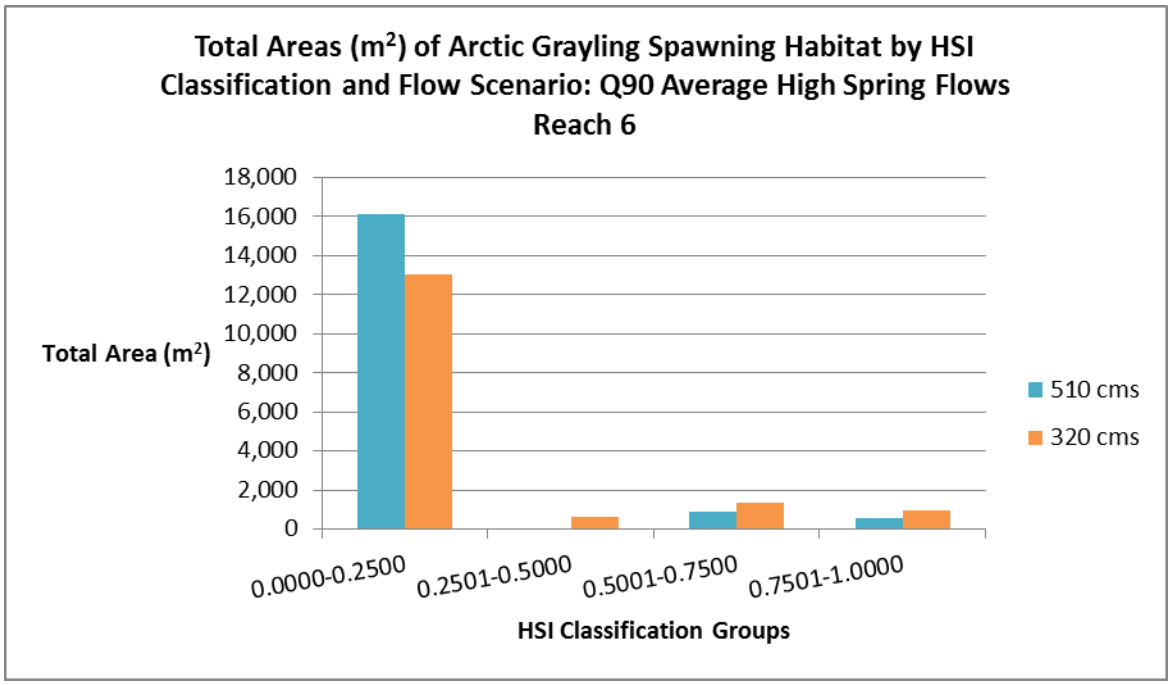


Figure E15: Total Areas of Arctic Grayling Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

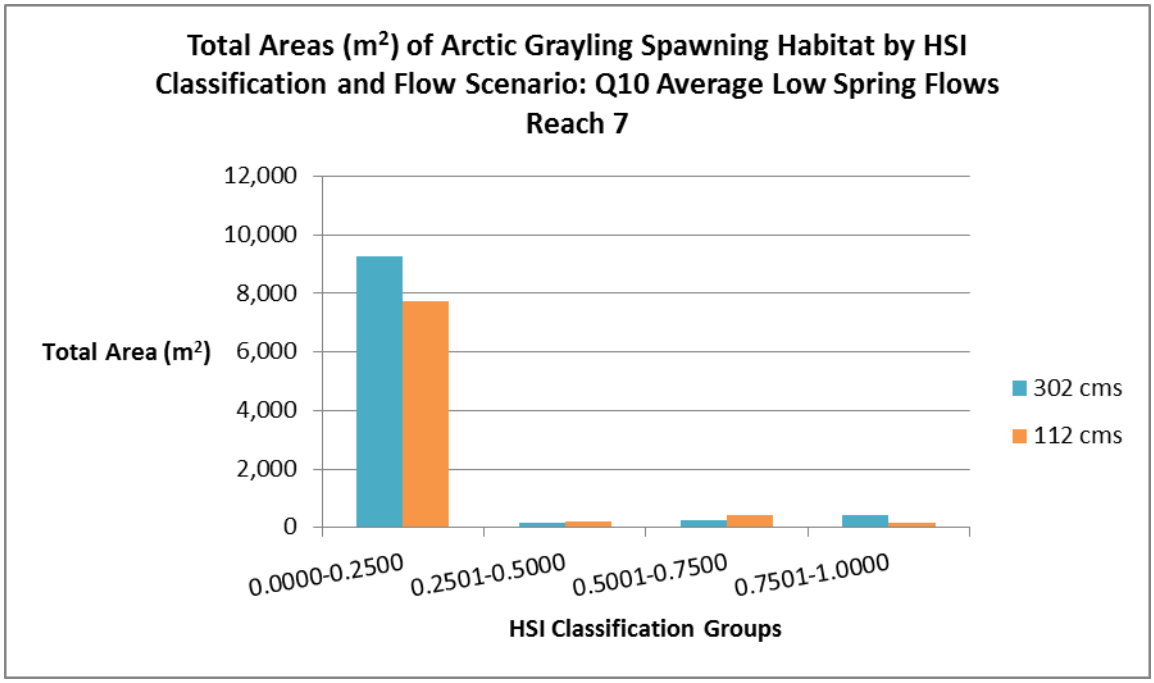


Figure E16: Total Areas of Arctic Grayling Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

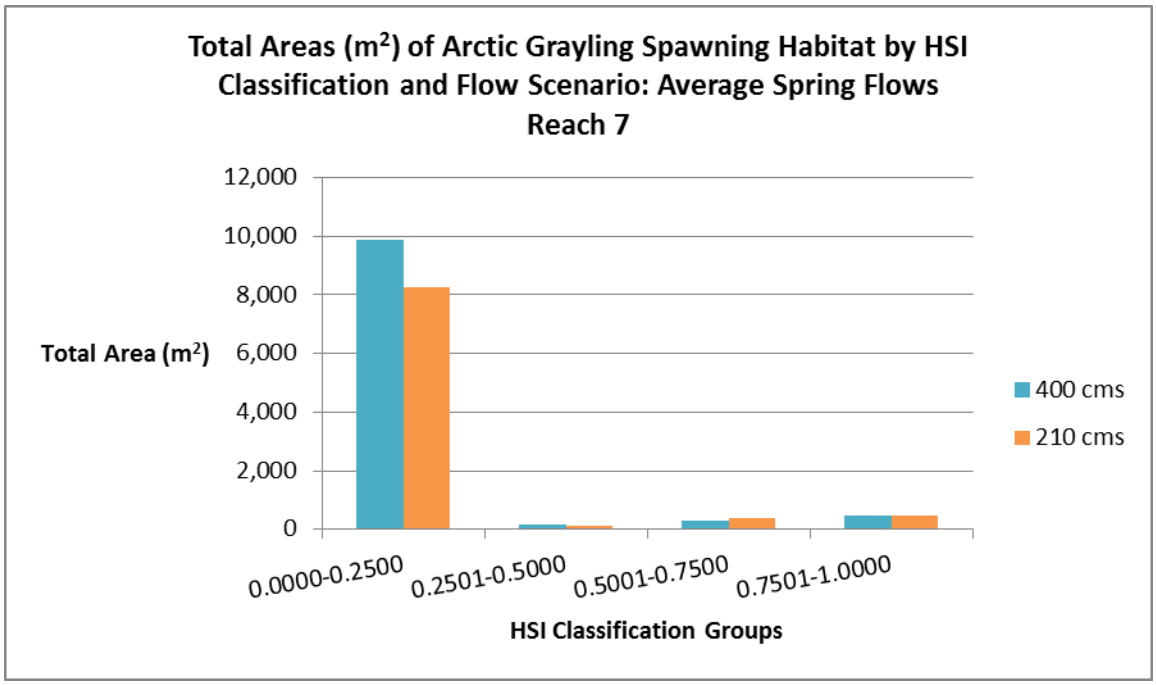


Figure E17: Total Areas of Arctic Grayling Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

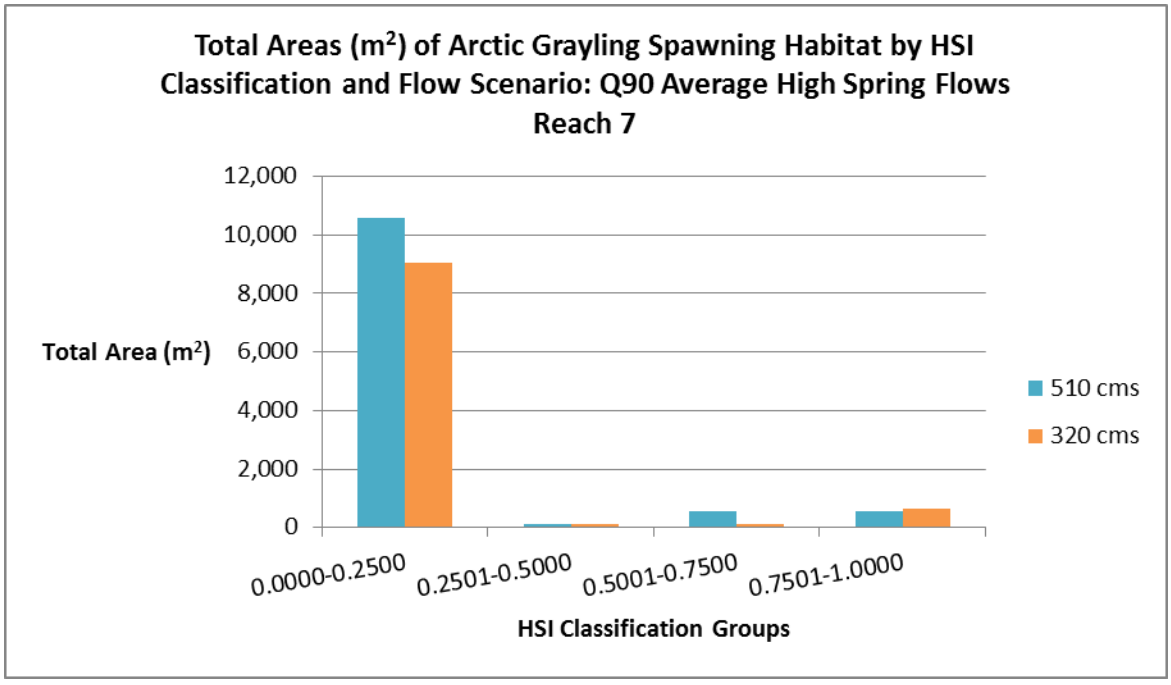


Figure E18: Total Areas of Arctic Grayling Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

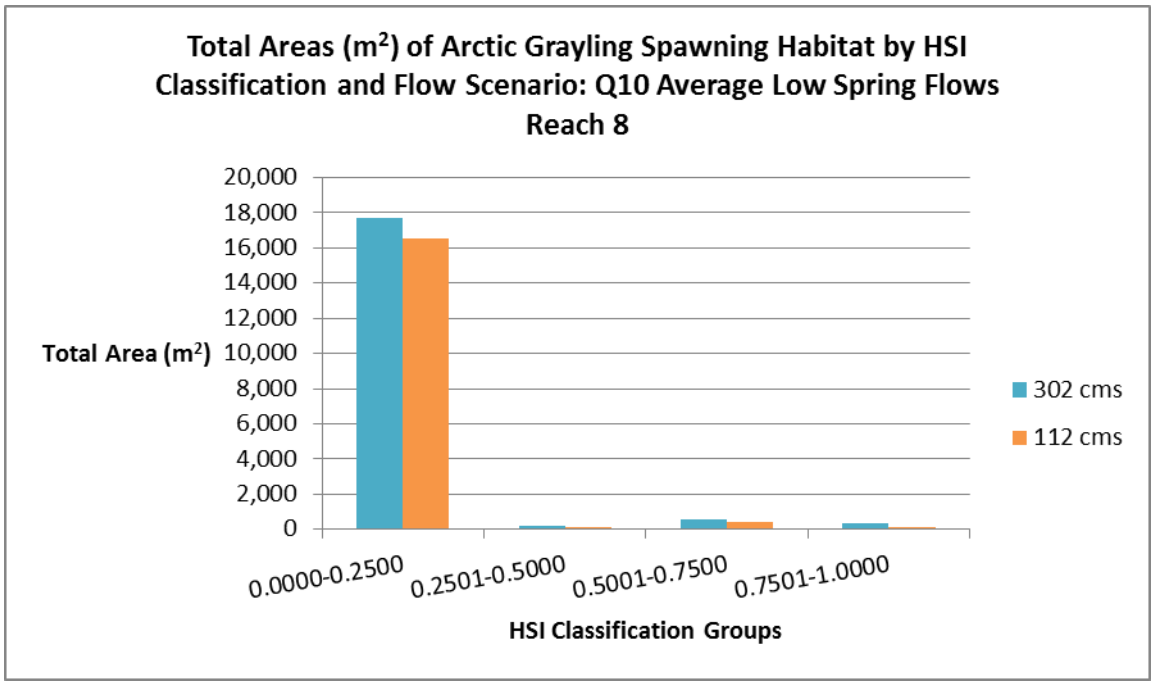


Figure E19: Total Areas of Arctic Grayling Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

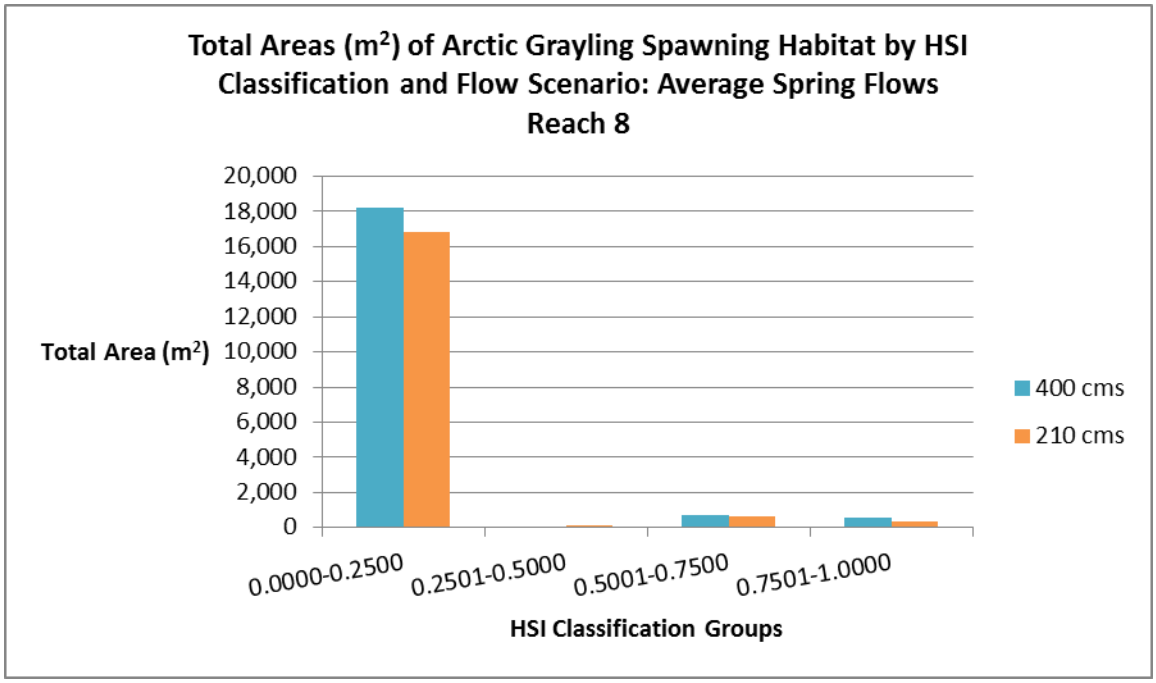


Figure E20: Total Areas of Arctic Grayling Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

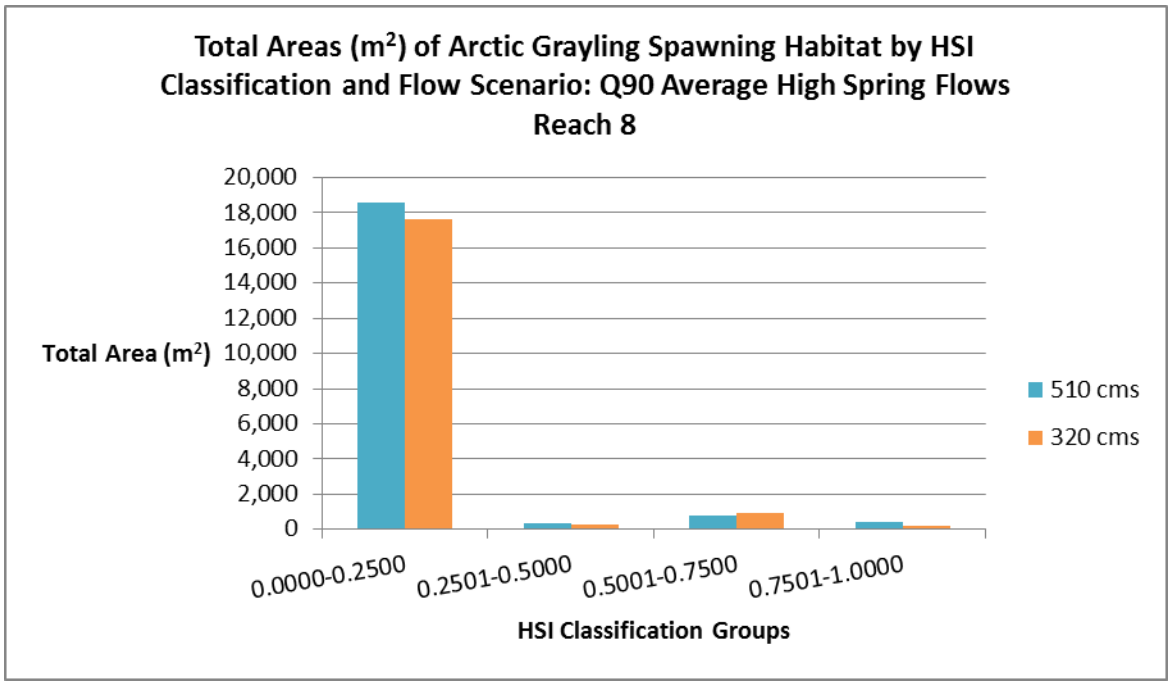


Figure E21: Total Areas of Arctic Grayling Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

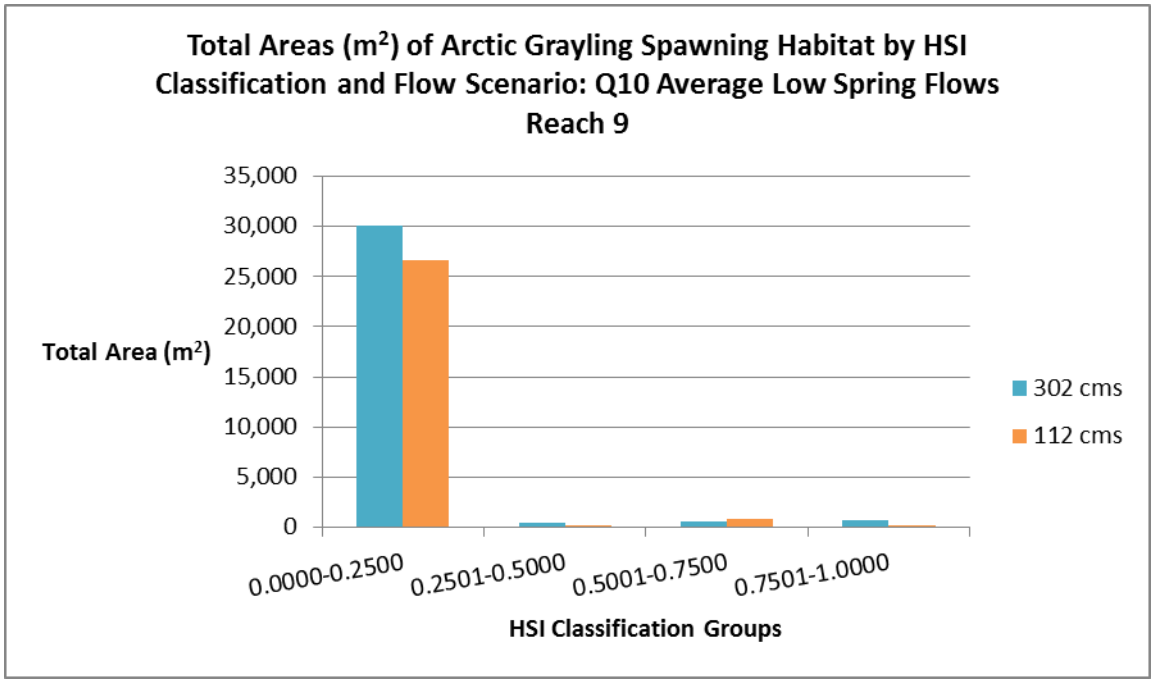


Figure E22: Total Areas of Arctic Grayling Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

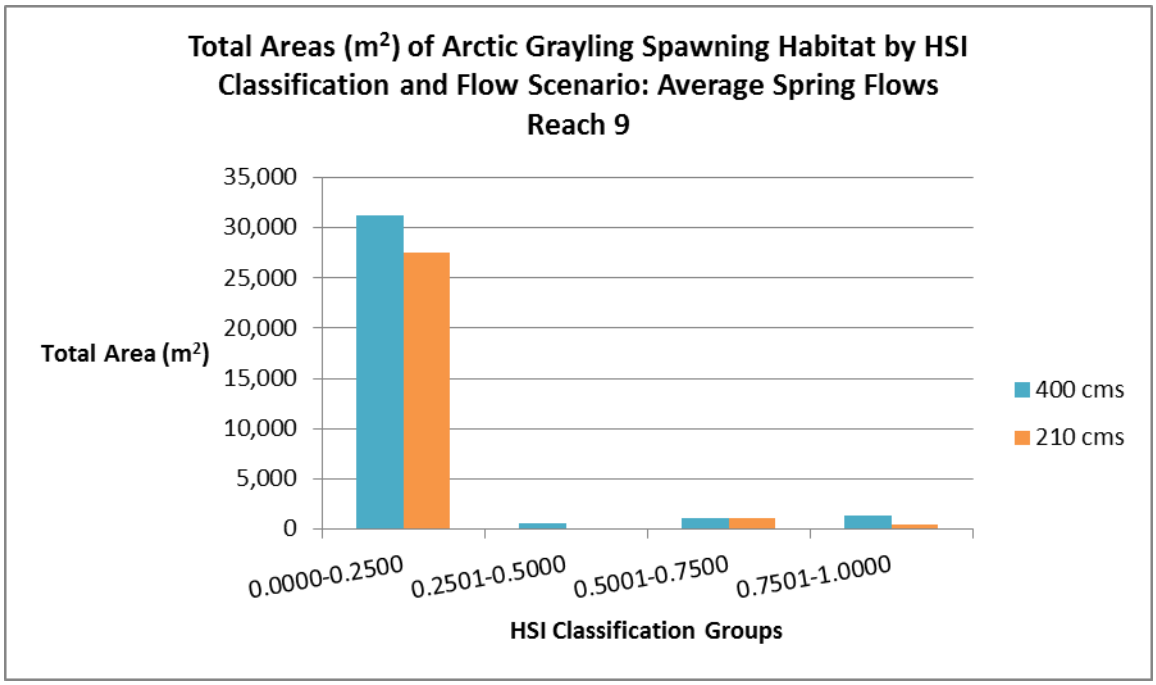


Figure E23: Total Areas of Arctic Grayling Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

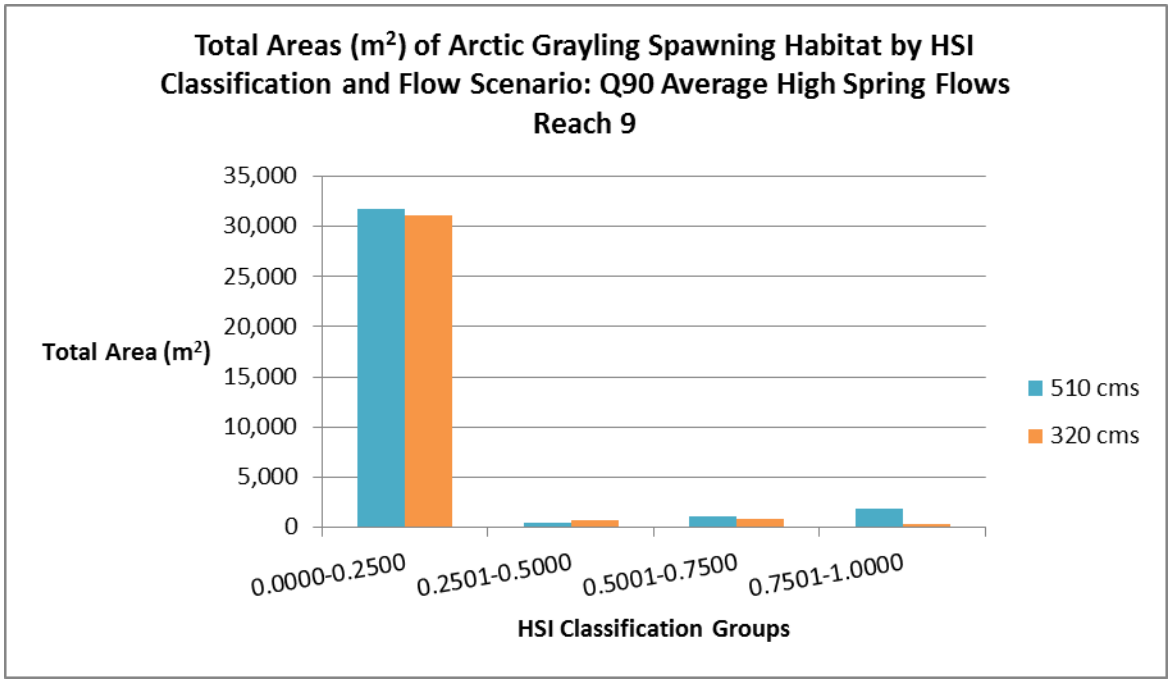


Figure E24: Total Areas of Arctic Grayling Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

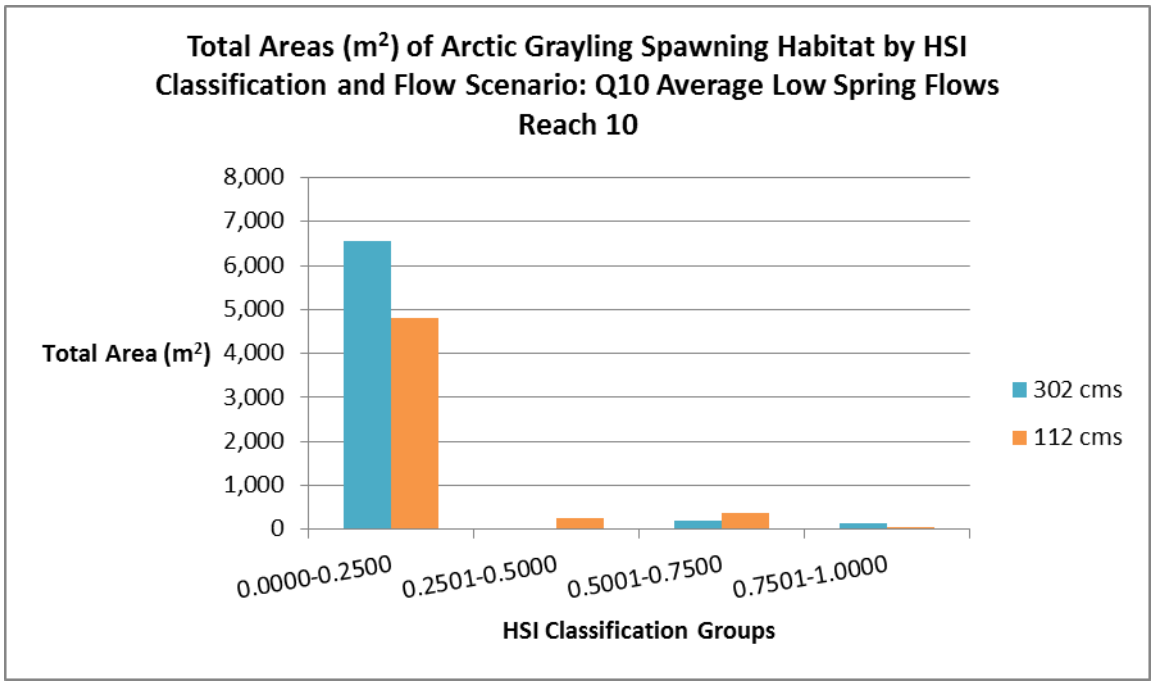


Figure E25: Total Areas of Arctic Grayling Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

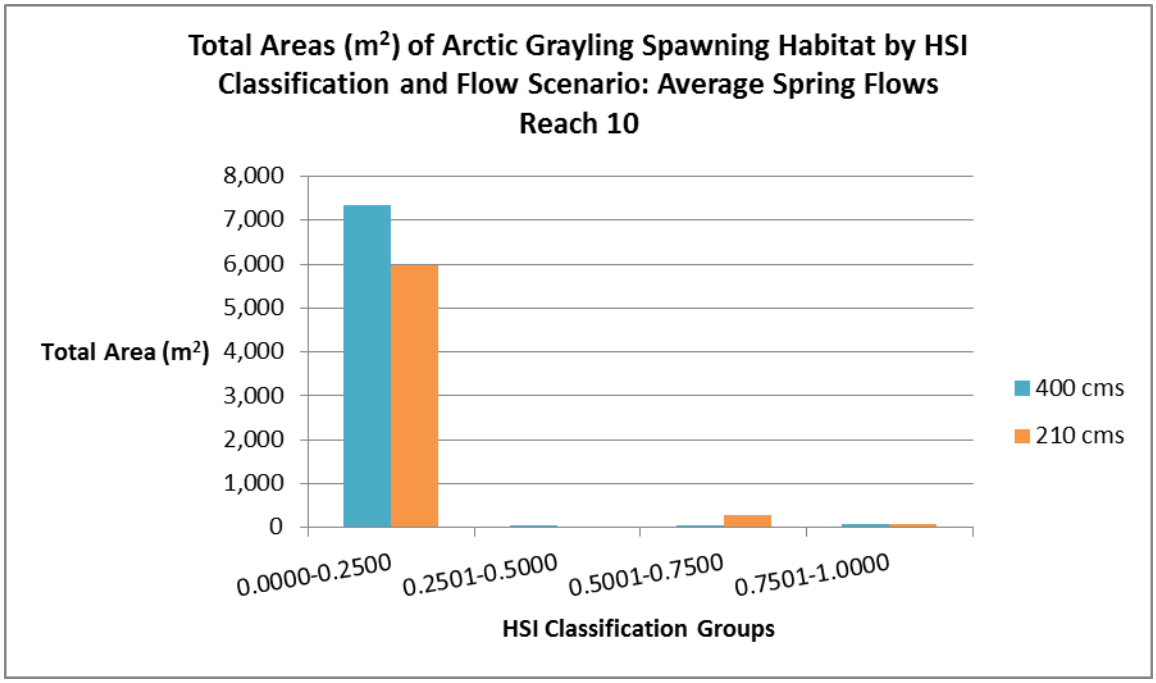


Figure E26: Total Areas of Arctic Grayling Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

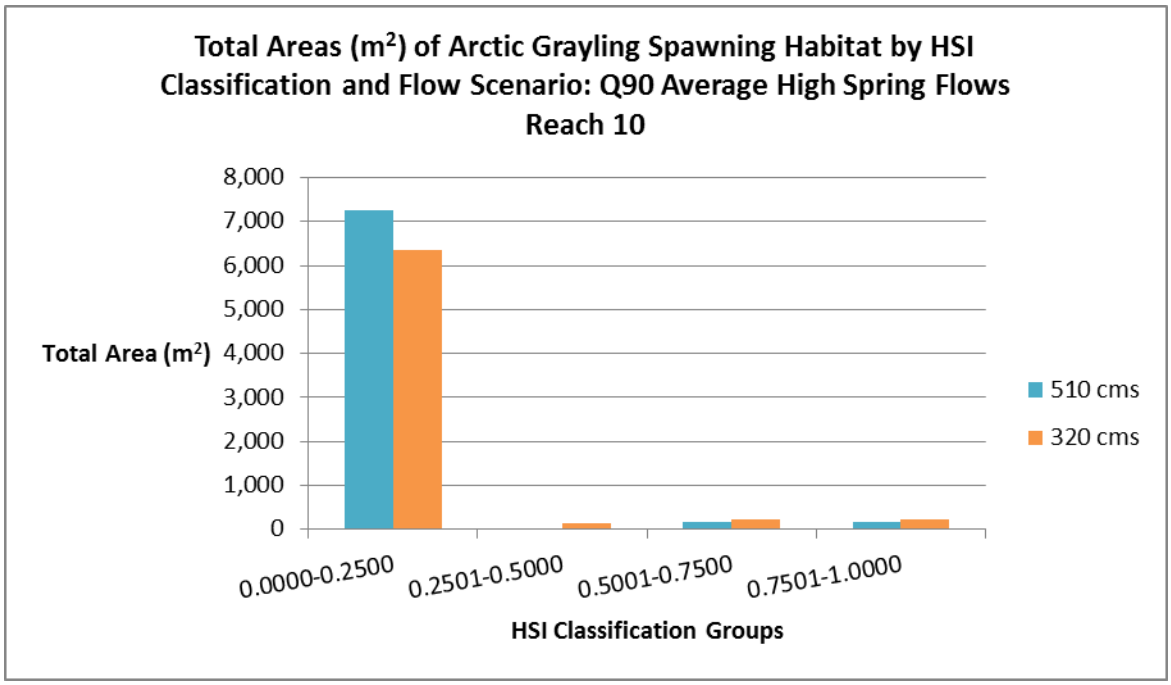


Figure E27: Total Areas of Arctic Grayling Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

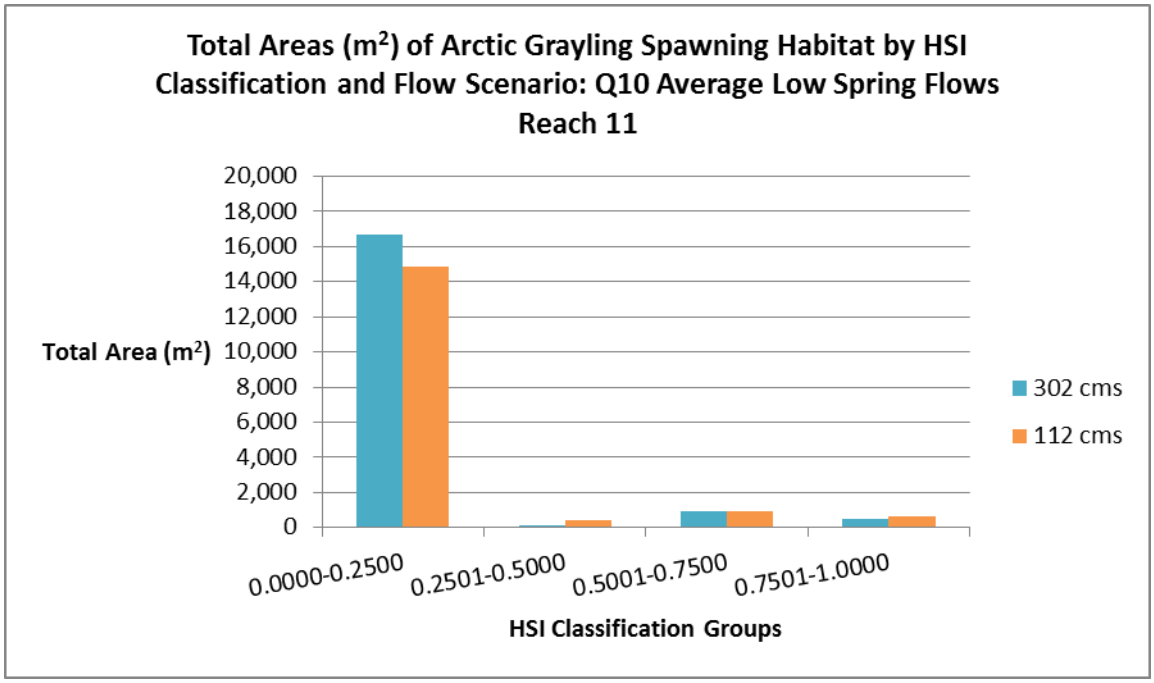


Figure E28: Total Areas of Arctic Grayling Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

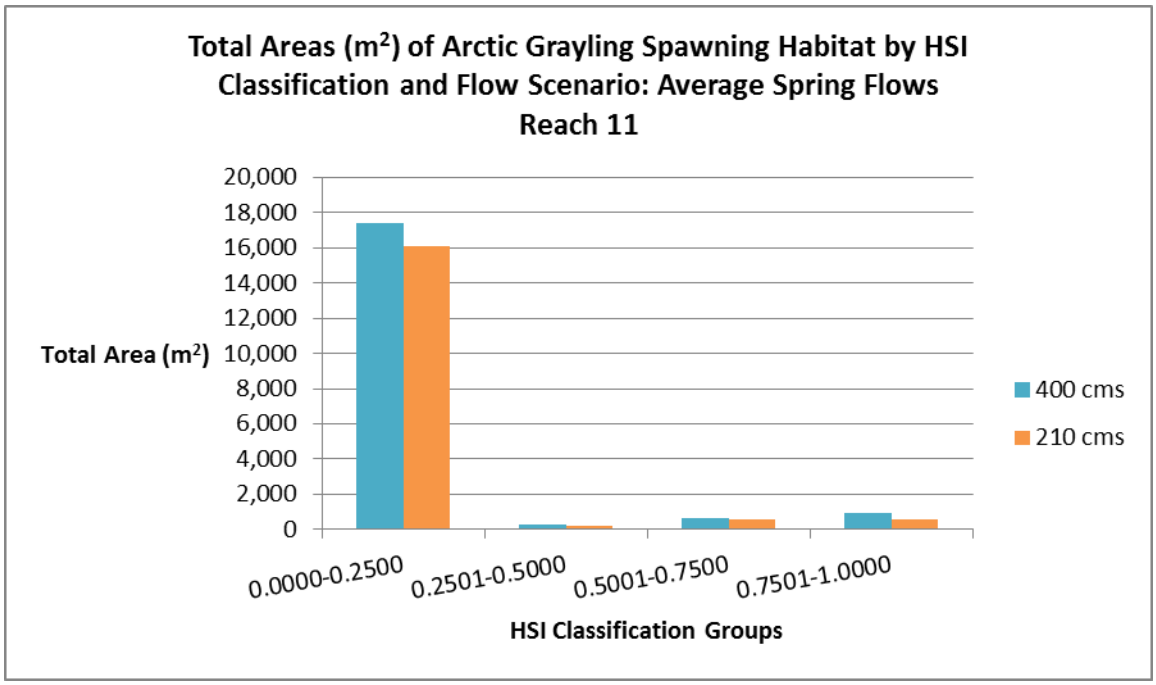


Figure E29: Total Areas of Arctic Grayling Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

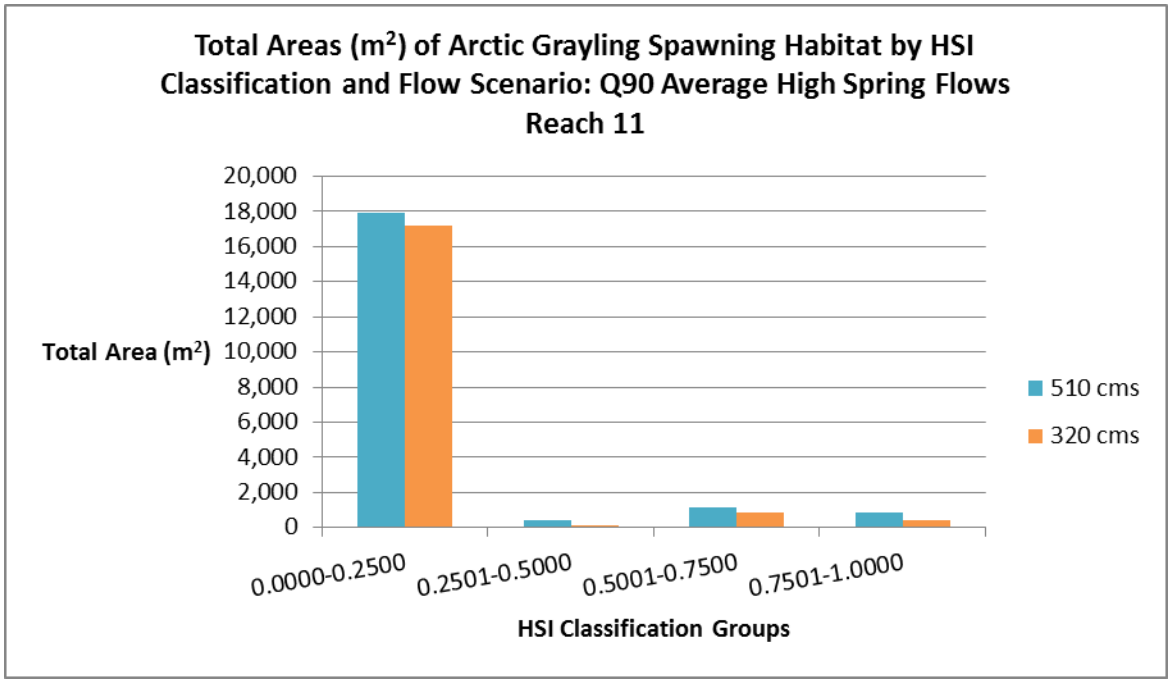


Figure E30: Total Areas of Arctic Grayling Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

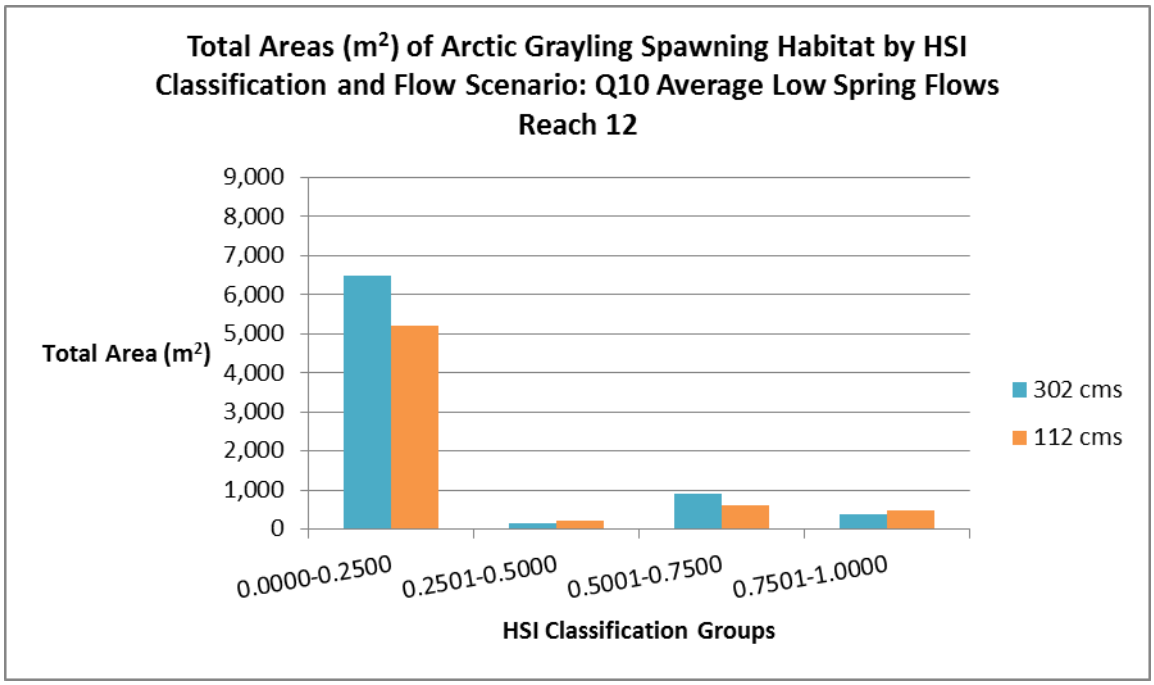


Figure E31: Total Areas of Arctic Grayling Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

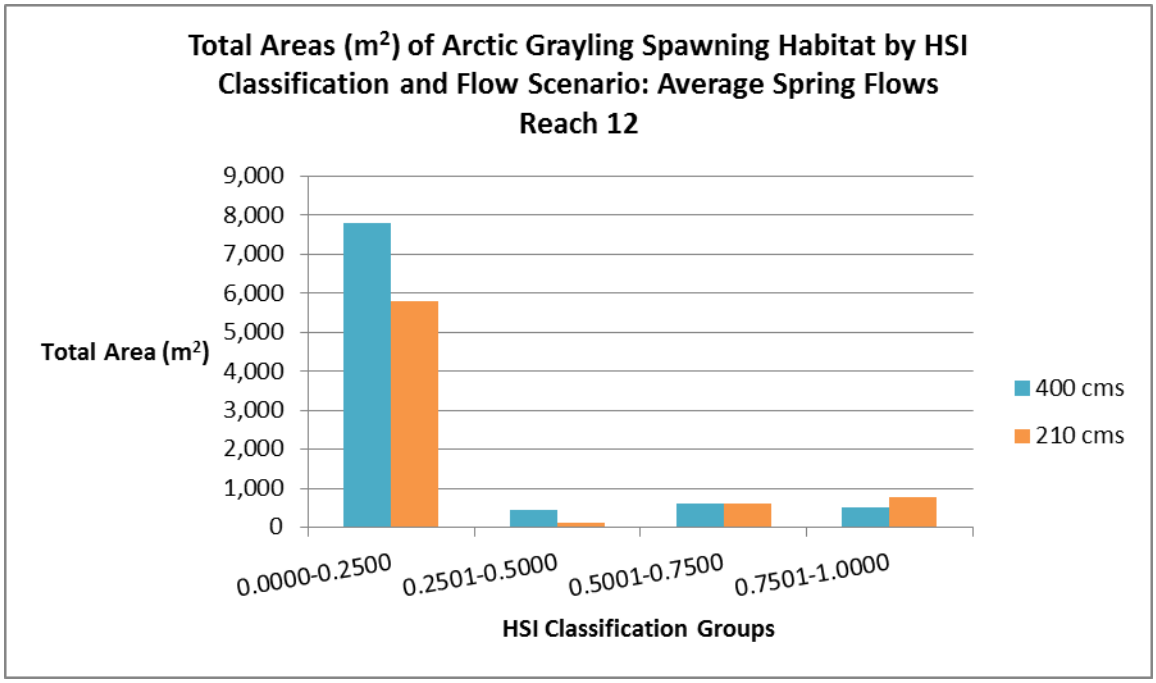


Figure E32: Total Areas of Arctic Grayling Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

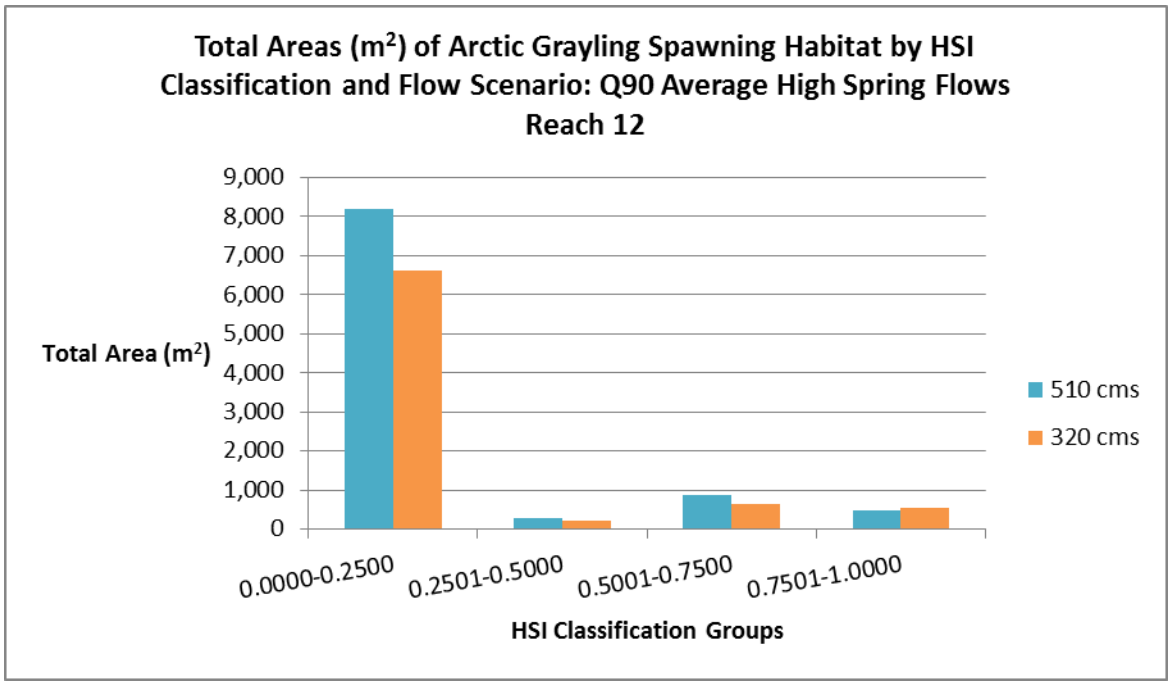


Figure E33: Total Areas of Arctic Grayling Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

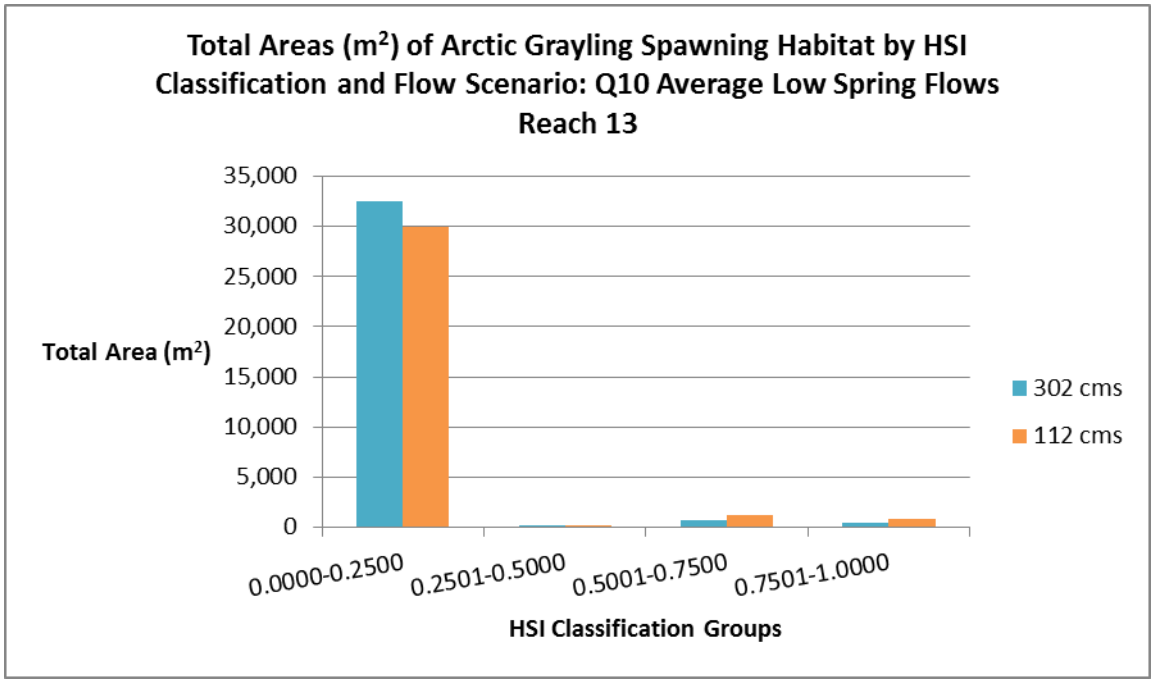


Figure E34: Total Areas of Arctic Grayling Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

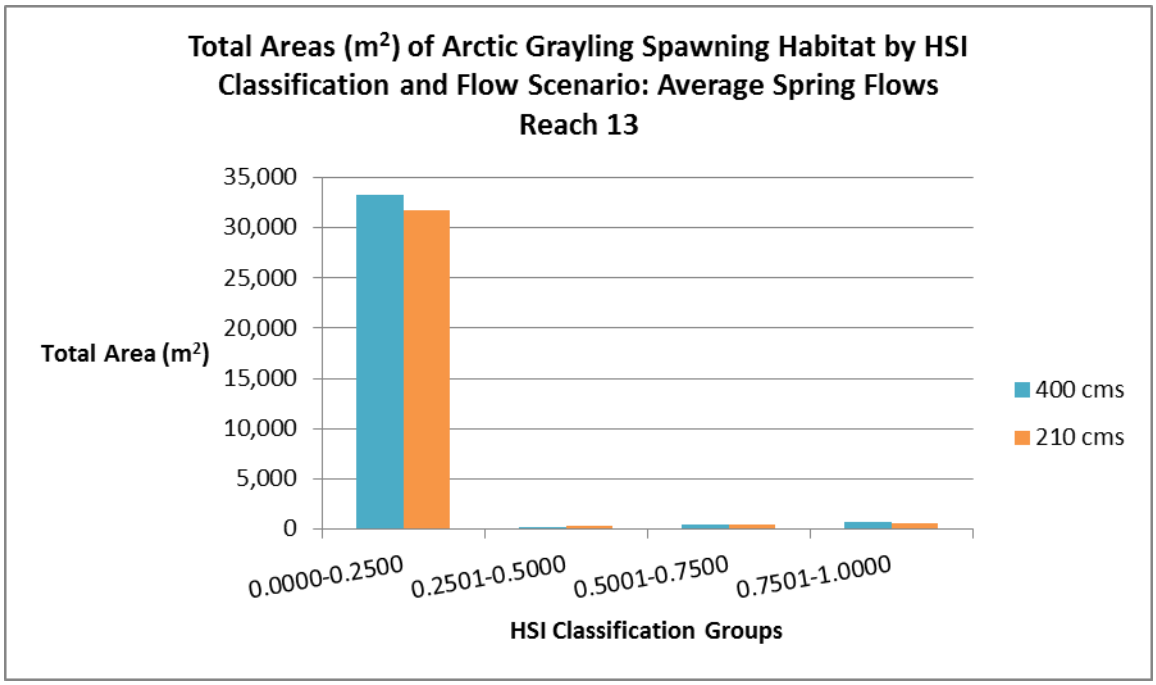


Figure E35: Total Areas of Arctic Grayling Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

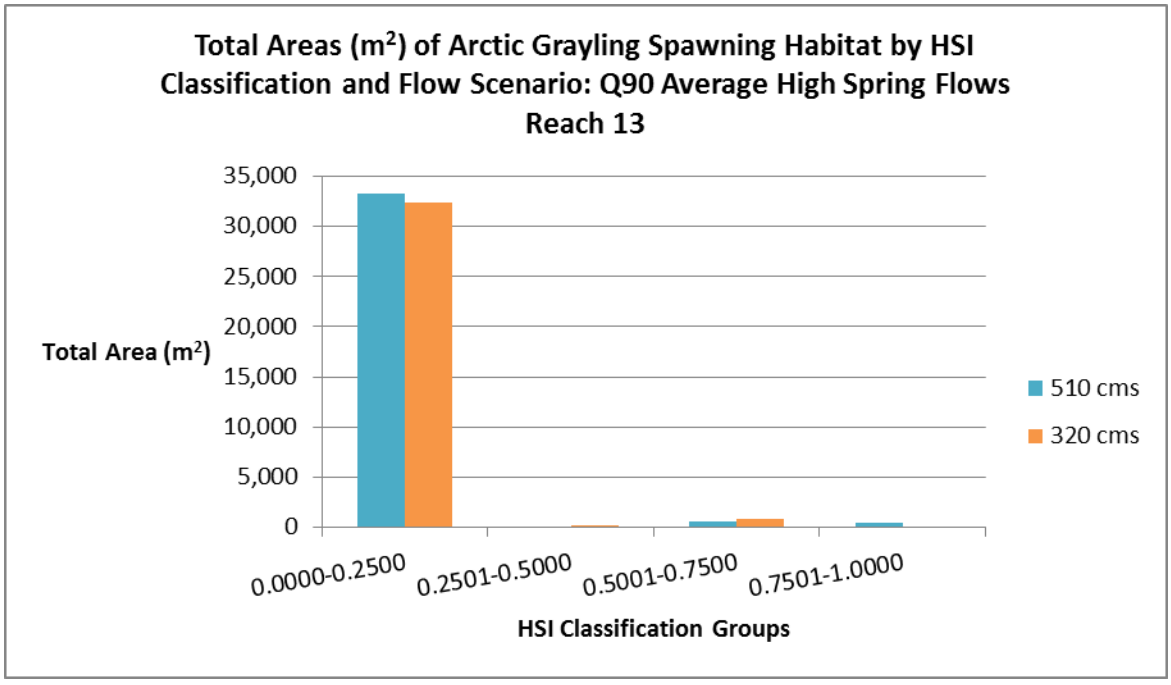


Figure E36: Total Areas of Arctic Grayling Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

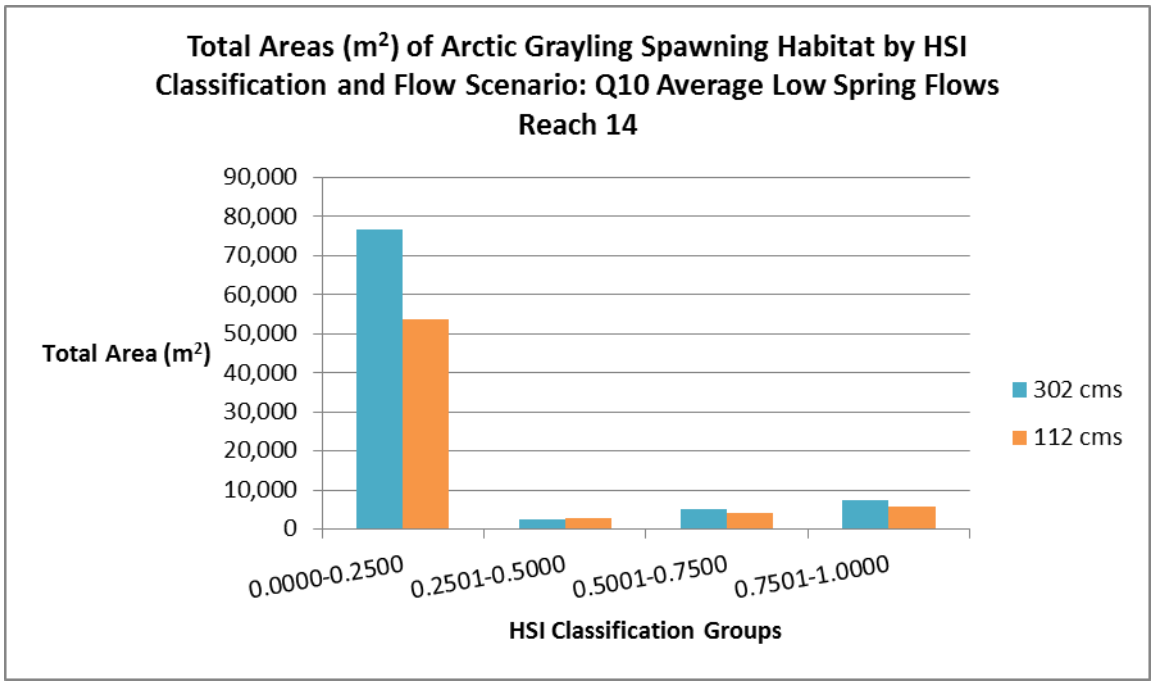


Figure E37: Total Areas of Arctic Grayling Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

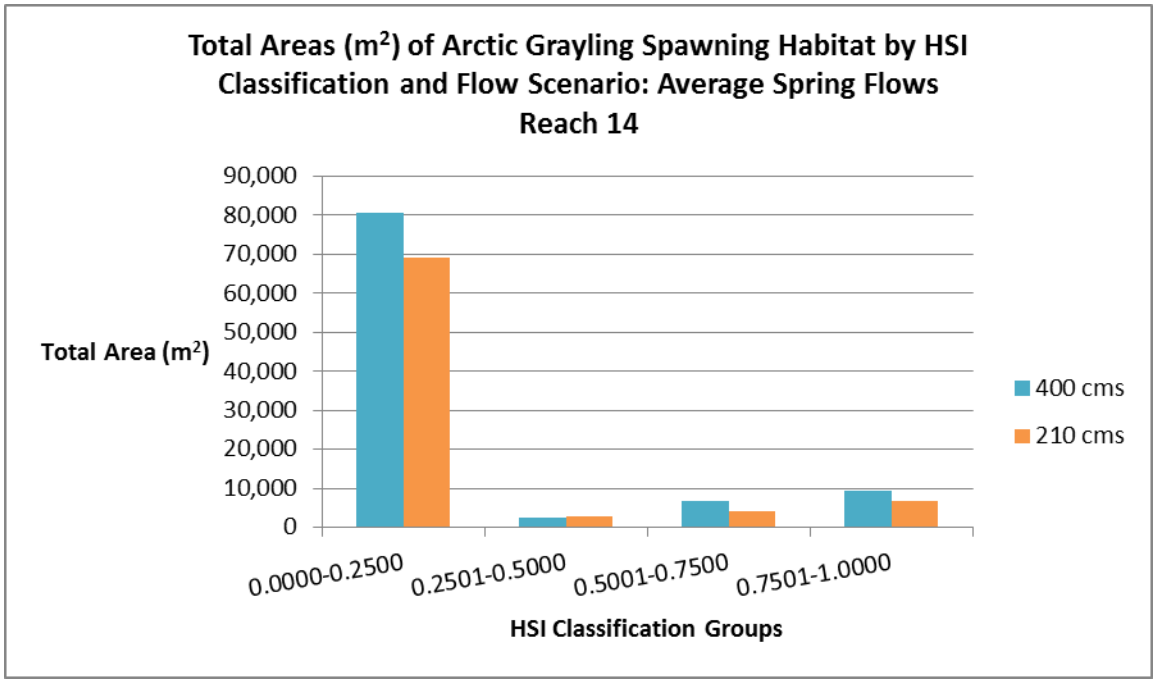


Figure E38: Total Areas of Arctic Grayling Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

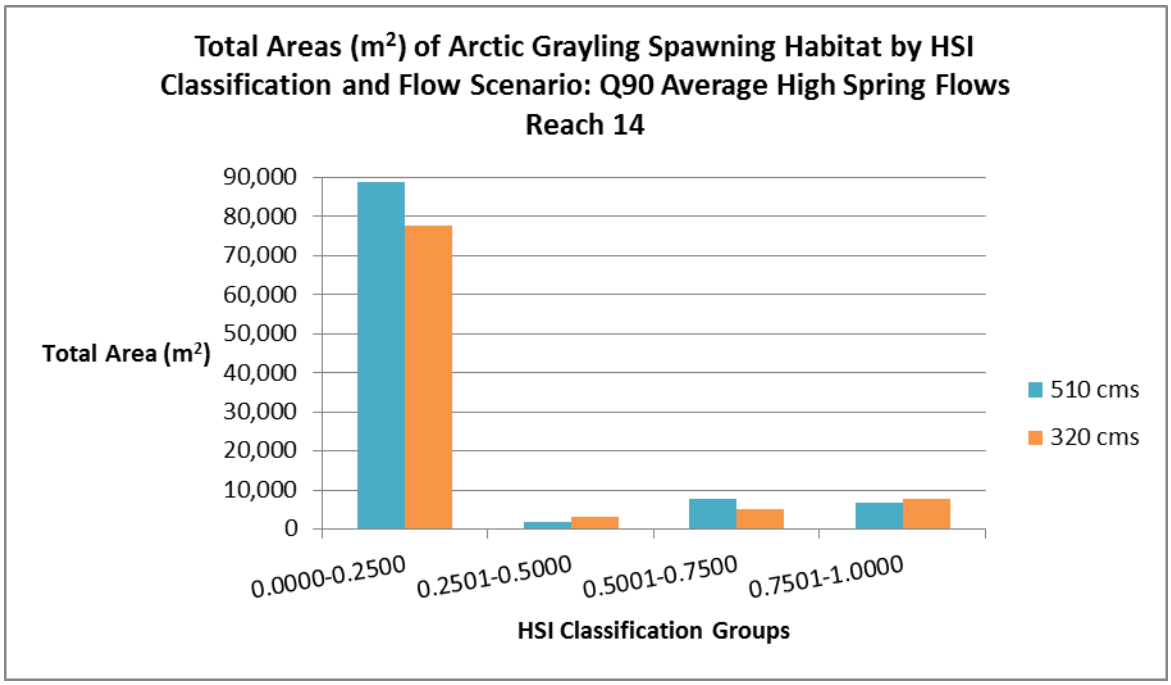


Figure E39: Total Areas of Arctic Grayling Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

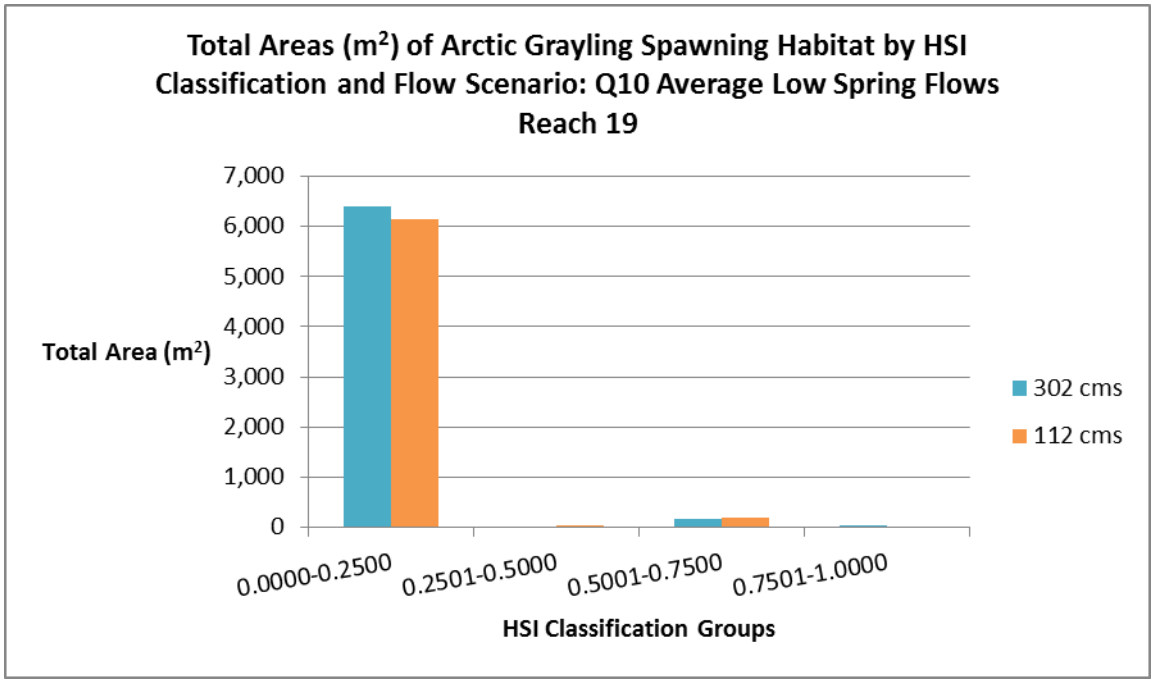


Figure E40: Total Areas of Arctic Grayling Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

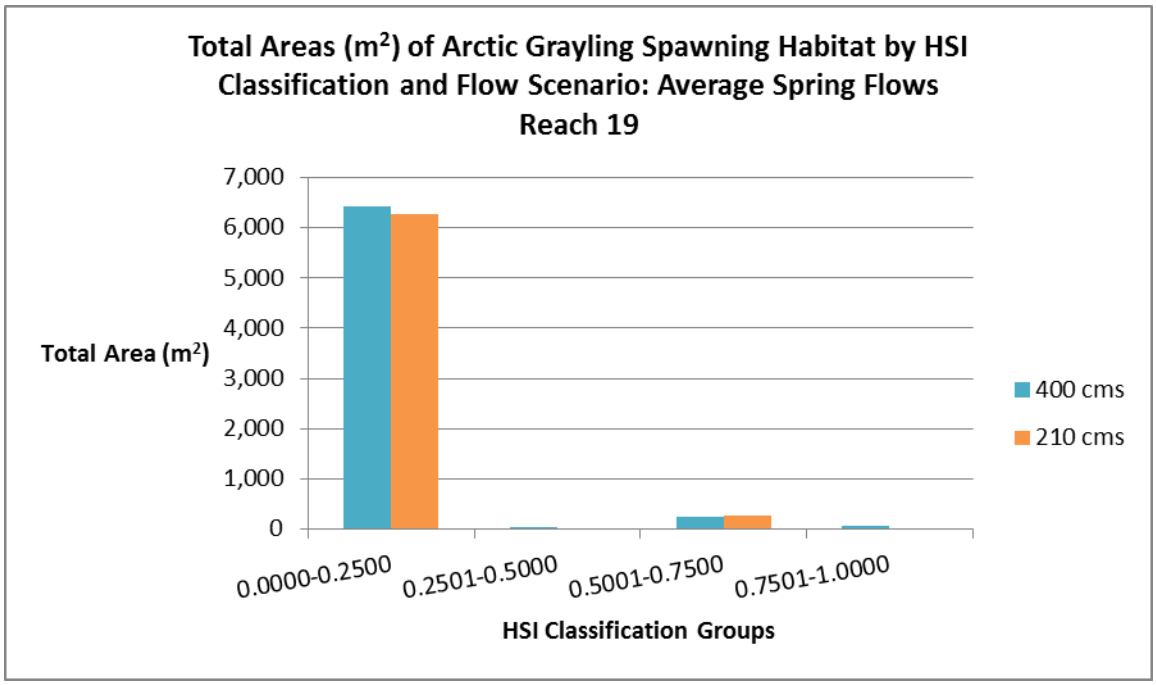


Figure E41: Total Areas of Arctic Grayling Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

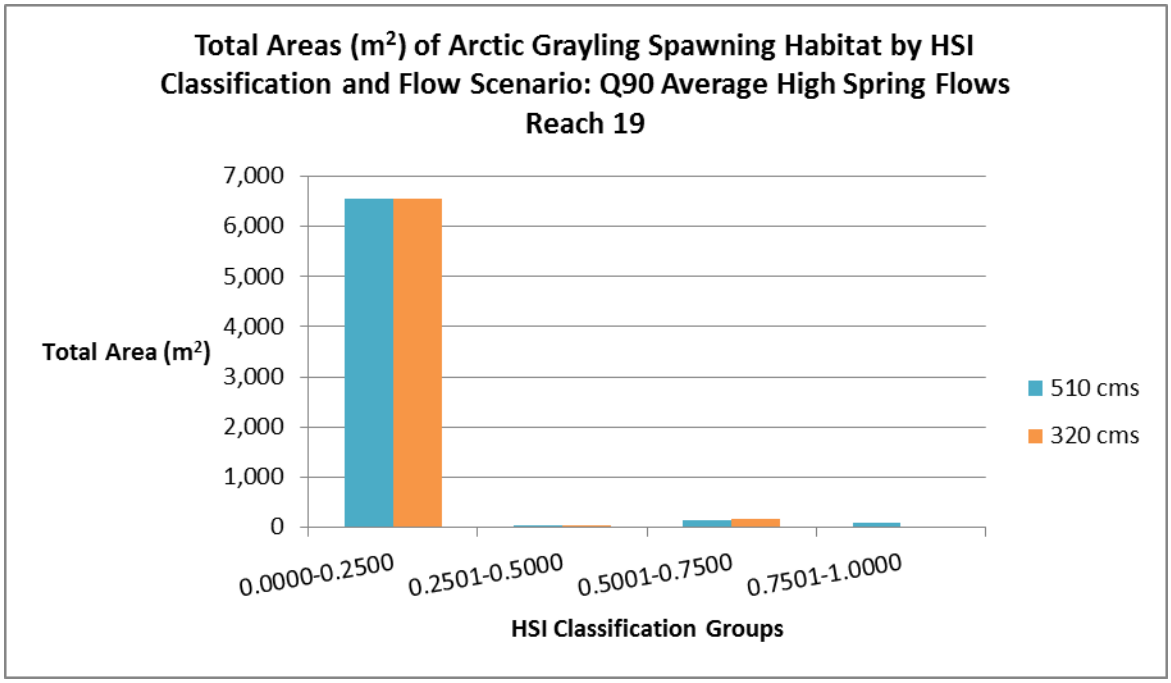


Figure E42: Total Areas of Arctic Grayling Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

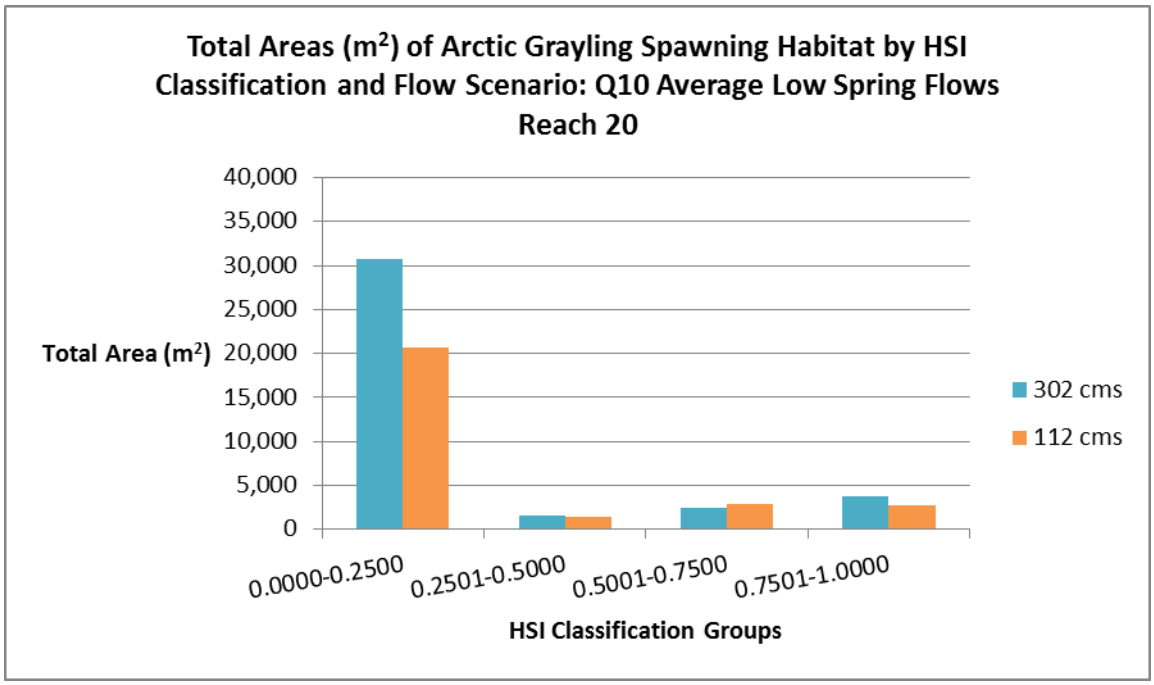


Figure E43: Total Areas of Arctic Grayling Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

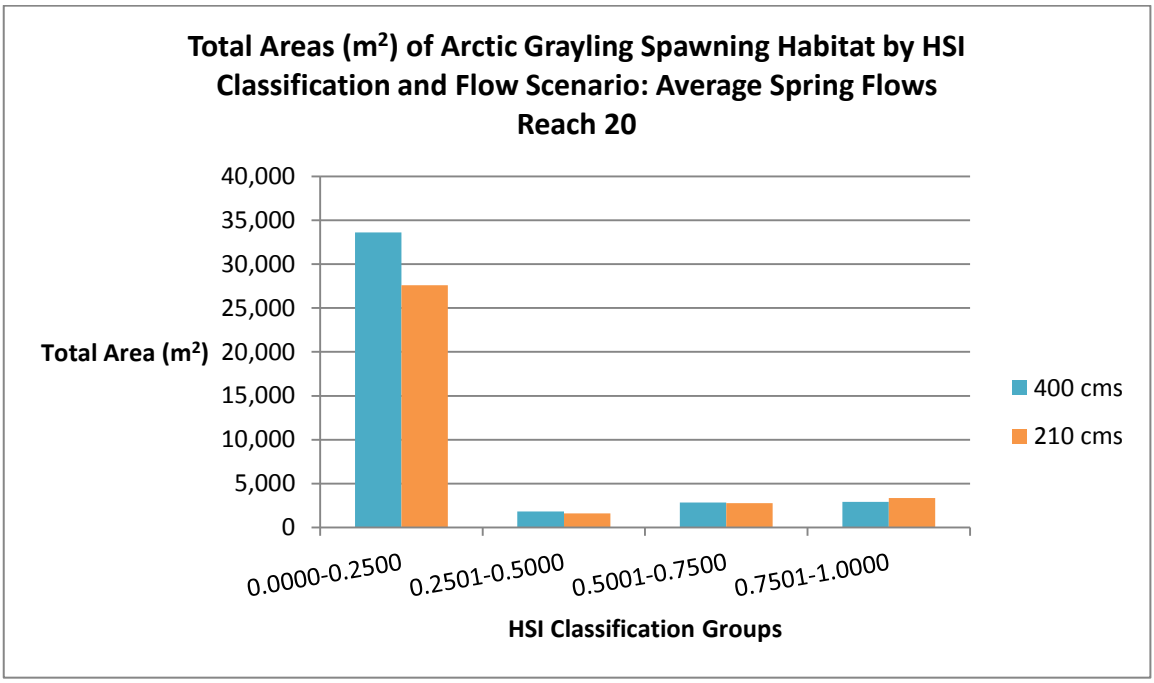


Figure E44: Total Areas of Arctic Grayling Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

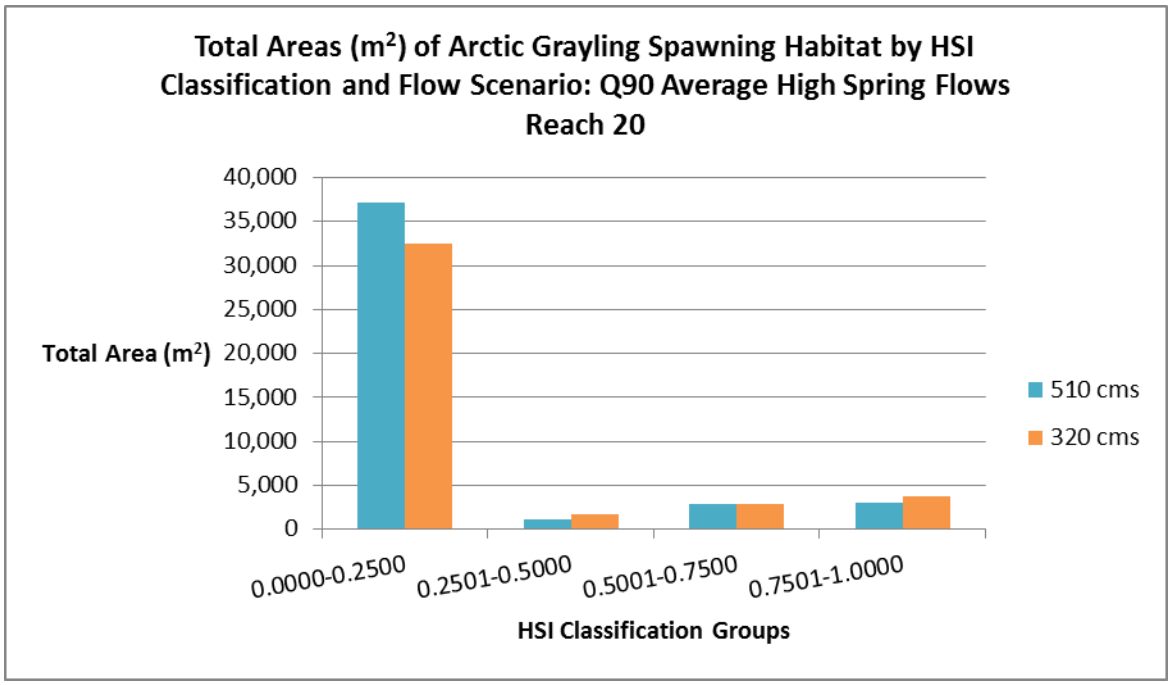


Figure E45: Total Areas of Arctic Grayling Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

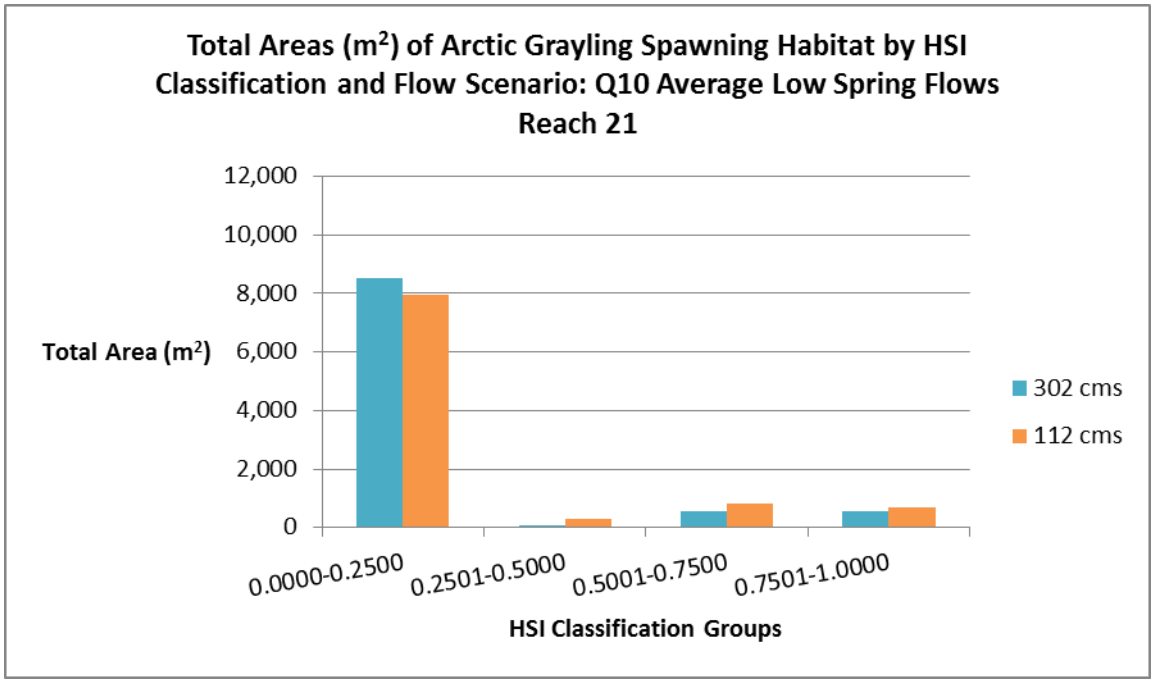


Figure E46: Total Areas of Arctic Grayling Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

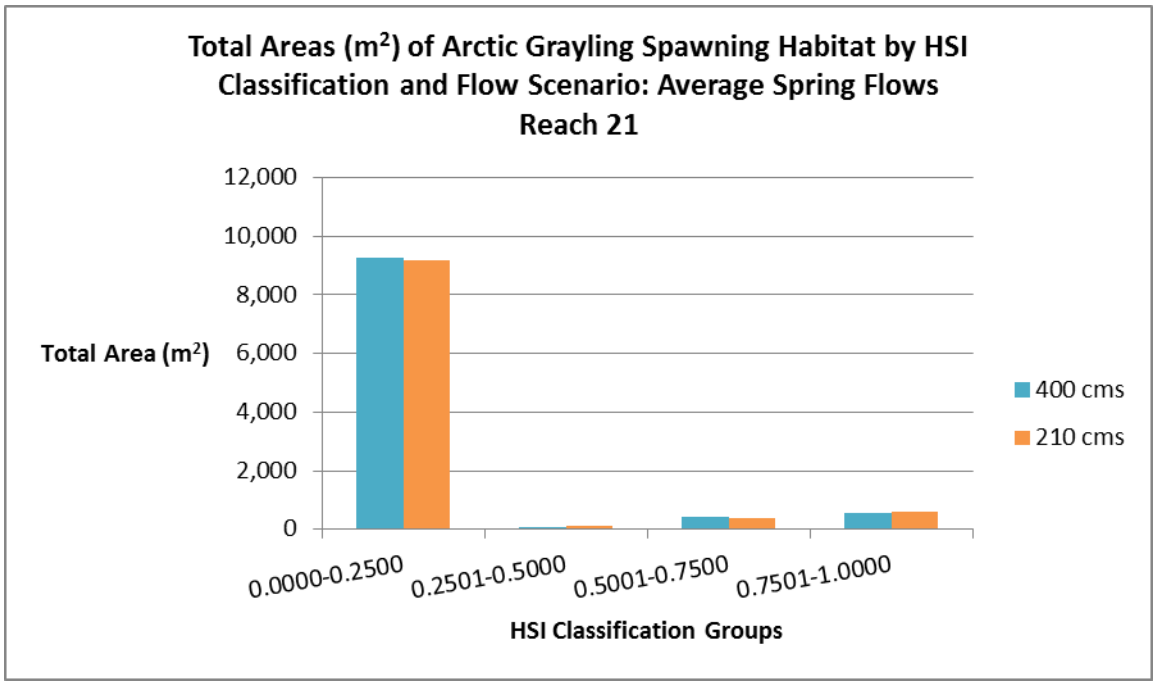


Figure E47: Total Areas of Arctic Grayling Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

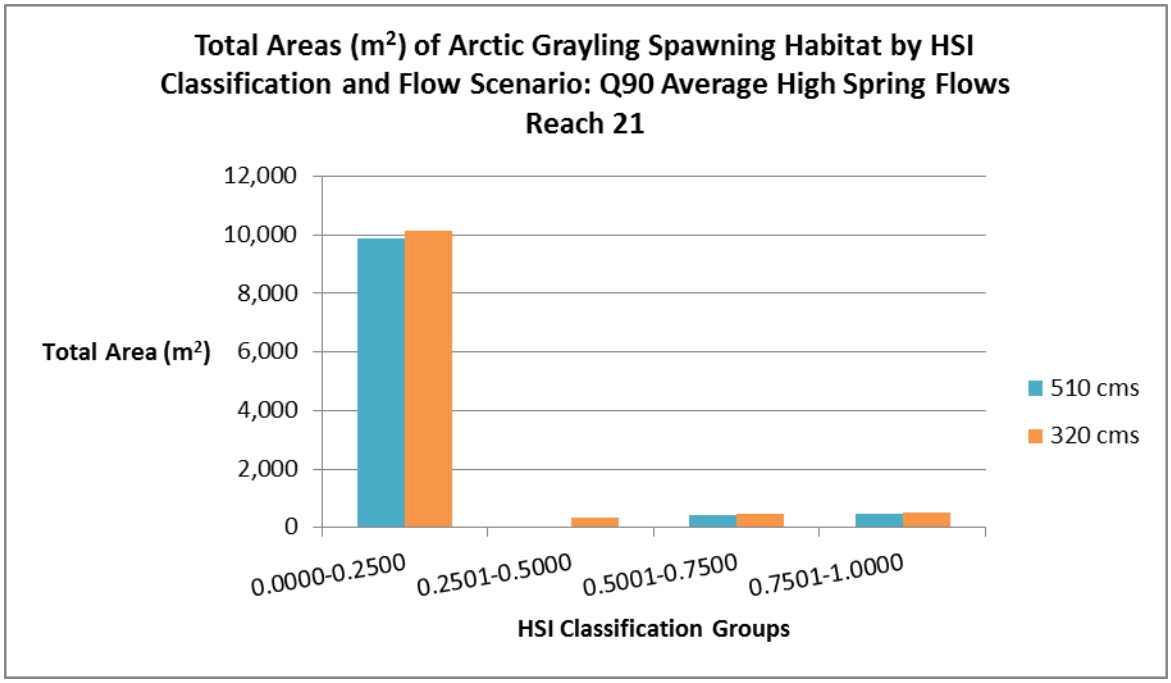


Figure E48: Total Areas of Arctic Grayling Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

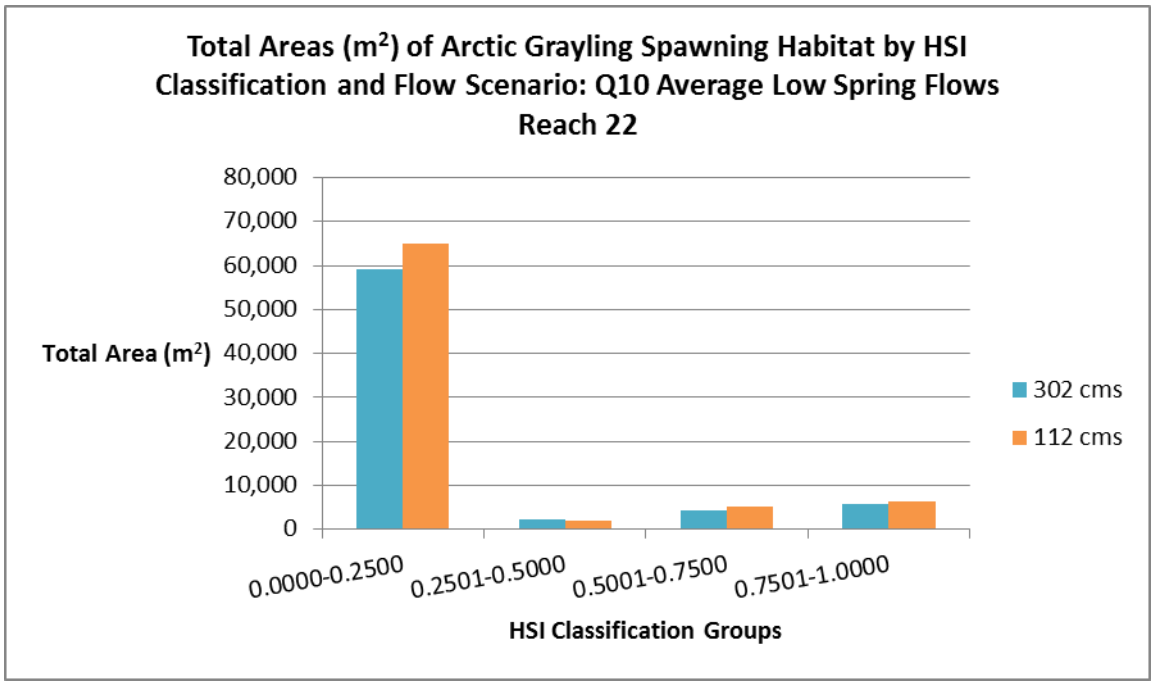


Figure E49: Total Areas of Arctic Grayling Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

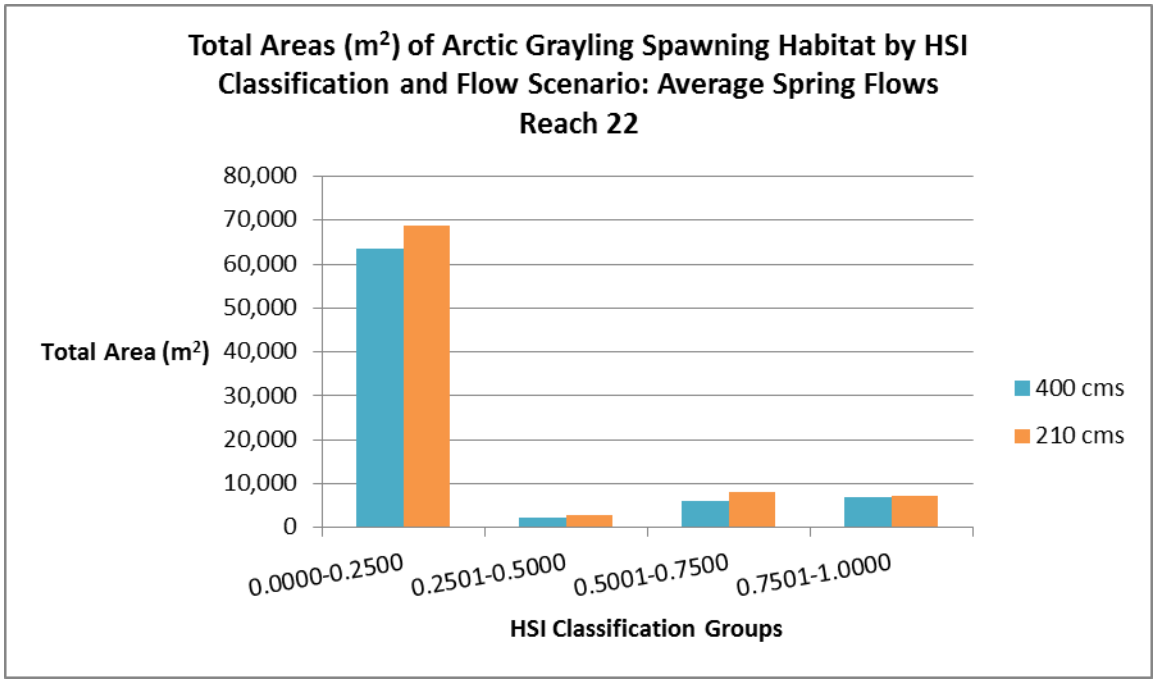


Figure 50: Total Areas of Arctic Grayling Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

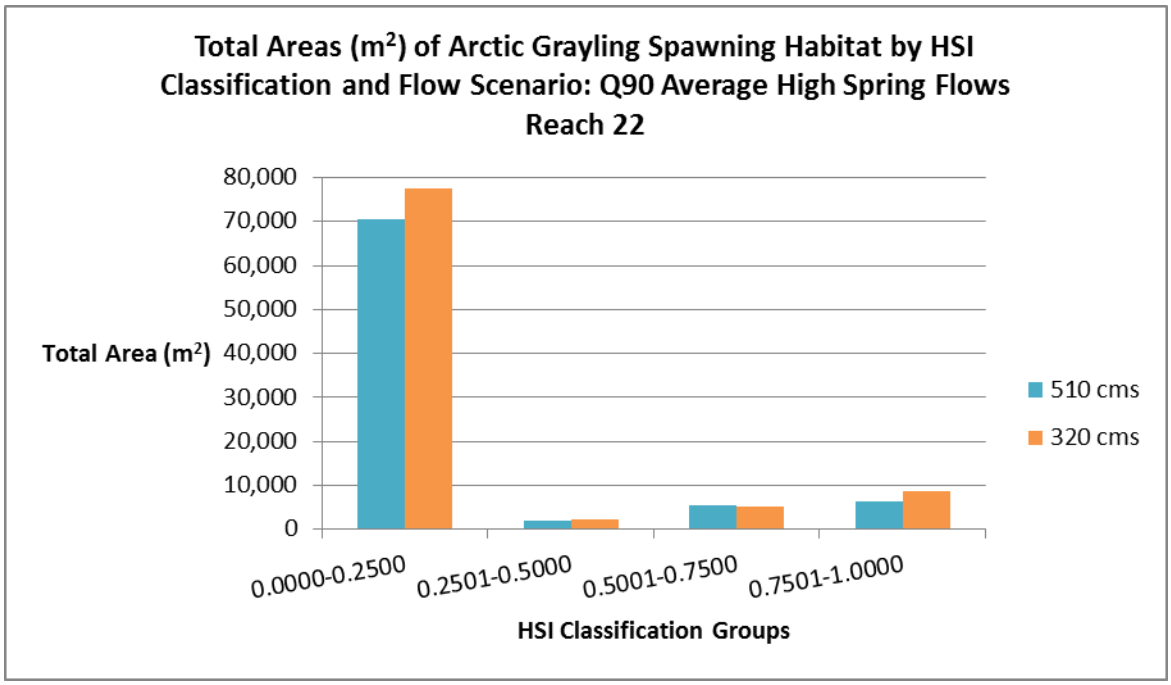


Figure E51: Total Areas of Arctic Grayling Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

Table E2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Longnose Sucker (*Catostomus catostomus*) by Reach for Six Spring Flows

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 2										
0.0000-0.2500	Unsuitable	37,564	30,762	-18.1	39,960	34,757	-13.0	42,319	38,268	-9.6
0.2501-0.5000	Poor	1,998	3,136	57.0	1,733	1,643	-5.2	1,094	1,906	74.2
0.5001-0.7500	Moderately Suitable	2,095	1,737	-17.1	1,276	1,646	29.0	1,386	1,656	19.5
0.7501-1.0000	Suitable	1,257	265	-78.9	1,148	1,120	-2.4	90	804	793.3
Reach 3										
0.0000-0.2500	Unsuitable	51,395	38,909	-24.3	55,509	46,986	-15.4	59,545	53,092	-10.8
0.2501-0.5000	Poor	2,870	3,916	36.4	2,557	2,683	4.9	3,556	2,691	-24.3
0.5001-0.7500	Moderately Suitable	2,435	88	-96.4	3,516	2,545	-27.6	3,224	2,691	-16.5
0.7501-1.0000	Suitable	4,400	2,843	-35.4	3,179	3,394	6.8	1,591	3,244	103.9
Reach 4										
0.0000-0.2500	Unsuitable	29,400	25,556	-13.1	31,284	27,336	-12.6	32,428	29,232	-9.9
0.2501-0.5000	Poor	1,099	1,014	-7.7	1,177	1,012	-14.0	1,925	1,024	-46.8
0.5001-0.7500	Moderately Suitable	675	478	-29.2	1,028	622	-39.5	1,138	1,222	7.4
0.7501-1.0000	Suitable	343	106	-69.1	829	369	-55.5	529	548	3.6
Reach 5										
0.0000-0.2500	Unsuitable	10,882	7,901	-27.4	12,051	10,008	-17.0	12,525	10,580	-15.5
0.2501-0.5000	Poor	634	718	13.2	676	461	-31.8	547	1,007	84.1
0.5001-0.7500	Moderately Suitable	544	247	-54.6	340	476	40.0	633	697	10.1
0.7501-1.0000	Suitable	332	458	38.0	307	508	65.5	262	139	-46.9

Table E2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Longnose Sucker (*Catostomus catostomus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 6										
0.0000-0.2500	Unsuitable	12,843	9,734	-24.2	14,418	11,646	-19.2	16,559	13,706	-17.2
0.2501-0.5000	Poor	1,147	779	-32.1	1,296	829	-36.0	430	1,042	142.3
0.5001-0.7500	Moderately Suitable	974	501	-48.6	856	701	-18.1	472	858	81.8
0.7501-1.0000	Suitable	519	389	-25.0	353	705	99.7	183	420	129.5
Reach 7										
0.0000-0.2500	Unsuitable	9,280	7,741	-16.6	9,872	8,338	-15.5	10,606	8,899	-16.1
0.2501-0.5000	Poor	447	562	25.7	332	390	17.5	642	313	-51.2
0.5001-0.7500	Moderately Suitable	261	80	-69.3	382	252	-34.0	201	515	156.2
0.7501-1.0000	Suitable	143	161	12.6	234	274	17.1	370	187	-49.5
Reach 8										
0.0000-0.2500	Unsuitable	18,116	16,909	-6.7	18,558	17,223	-7.2	18,902	18,324	-3.1
0.2501-0.5000	Poor	342	73	-78.7	517	289	-44.1	656	370	-43.6
0.5001-0.7500	Moderately Suitable	157	200	27.4	197	322	63.5	229	208	-9.2
0.7501-1.0000	Suitable	248	0	-100.0	291	80	-72.5	293	81	-72.4
Reach 9										
0.0000-0.2500	Unsuitable	29,586	27,056	-8.6	31,433	27,978	-11.0	32,236	30,108	-6.6
0.2501-0.5000	Poor	761	597	-21.6	1,031	851	-17.5	558	1,399	150.7
0.5001-0.7500	Moderately Suitable	783	116	-85.2	684	312	-54.4	1,431	698	-51.2
0.7501-1.0000	Suitable	761	165	-78.3	979	119	-87.8	859	772	-10.1

Table E2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Longnose Sucker (*Catostomus catostomus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 10										
0.0000-0.2500	Unsuitable	6,287	4,620	-26.5	7,013	5,927	-15.5	7,026	6,200	-11.8
0.2501-0.5000	Poor	252	291	15.5	185	228	23.2	369	311	-15.7
0.5001-0.7500	Moderately Suitable	96	91	-5.2	82	45	-45.1	121	0	-100.0
0.7501-1.0000	Suitable	264	472	78.8	197	148	-24.9	82	420	412.2
Reach 11										
0.0000-0.2500	Unsuitable	17,325	15,686	-9.5	17,781	16,238	-8.7	18,646	17,822	-4.4
0.2501-0.5000	Poor	584	944	61.6	669	718	7.3	917	411	-55.2
0.5001-0.7500	Moderately Suitable	206	77	-62.6	462	348	-24.7	519	170	-67.2
0.7501-1.0000	Suitable	100	101	1.0	347	126	-63.7	255	184	-27.8
Reach 12										
0.0000-0.2500	Unsuitable	6,949	5,622	-19.1	7,746	6,067	-21.7	8,509	6,682	-21.5
0.2501-0.5000	Poor	570	359	-37.0	570	420	-26.3	462	801	73.4
0.5001-0.7500	Moderately Suitable	173	268	54.9	309	522	68.9	485	278	-42.7
0.7501-1.0000	Suitable	230	255	10.9	770	292	-62.1	371	281	-24.3
Reach 13										
0.0000-0.2500	Unsuitable	32,699	30,647	-6.3	33,068	31,912	-3.5	33,049	32,717	-1.0
0.2501-0.5000	Poor	680	1,180	73.5	673	767	14.0	777	633	-18.5
0.5001-0.7500	Moderately Suitable	278	317	14.0	494	298	-39.7	359	122	-66.0
0.7501-1.0000	Suitable	108	79	-26.9	327	76	-76.8	303	150	-50.5

Table E2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Longnose Sucker (*Catostomus catostomus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 14										
0.0000-0.2500	Unsuitable	76,673	53,701	-30.0	82,513	66,040	-20.0	93,634	78,308	-16.4
0.2501-0.5000	Poor	5,852	4,284	-26.8	7,594	4,765	-37.3	6,186	5,789	-6.4
0.5001-0.7500	Moderately Suitable	5,570	3,818	-31.5	6,325	5,145	-18.7	3,650	5,432	48.8
0.7501-1.0000	Suitable	3,842	4,875	26.9	2,889	7,158	147.8	1,858	4,139	122.8
Reach 19										
0.0000-0.2500	Unsuitable	6,457	6,282	-2.7	6,614	6,425	-2.9	6,690	6,603	-1.3
0.2501-0.5000	Poor	172	77	-55.2	128	117	-8.6	36	112	211.1
0.5001-0.7500	Moderately Suitable	0	0	0.0	0	0	0.0	94	60	-36.2
0.7501-1.0000	Suitable	0	0	0.0	35	0	-100.0	0	0	0.0
Reach 20										
0.0000-0.2500	Unsuitable	30,602	21,592	-29.4	34,380	26,732	-22.2	37,380	32,347	-13.5
0.2501-0.5000	Poor	2,238	2,930	30.9	1,960	2,628	34.1	3,394	2,743	-19.2
0.5001-0.7500	Moderately Suitable	2,222	2,043	-8.1	3,195	2,069	-35.2	1,593	2,579	61.9
0.7501-1.0000	Suitable	3,509	1,134	-67.7	1,669	3,900	133.7	1,866	3,026	62.2
Reach 21										
0.0000-0.2500	Unsuitable	8,347	8,486	1.7	8,918	9,126	2.3	9,896	10,339	4.5
0.2501-0.5000	Poor	706	685	-3.0	713	544	-23.7	368	624	69.6
0.5001-0.7500	Moderately Suitable	369	475	28.7	323	439	35.9	165	165	0.0
0.7501-1.0000	Suitable	284	111	-60.9	356	204	-42.7	372	301	-19.1

Table E2: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to Longnose Sucker (*Catostomus catostomus*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 22										
0.0000-0.2500	Unsuitable	59,922	66,127	10.4	66,104	72,516	9.7	72,709	78,828	8.4
0.2501-0.5000	Poor	5,434	5,439	0.1	5,660	7,074	25.0	6,348	8,640	36.1
0.5001-0.7500	Moderately Suitable	4,003	4,493	12.2	4,154	4,594	10.6	3,608	4,603	27.6
0.7501-1.0000	Suitable	2,316	2,501	8.0	2,899	2,527	-12.8	1,843	1,603	-13.0

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

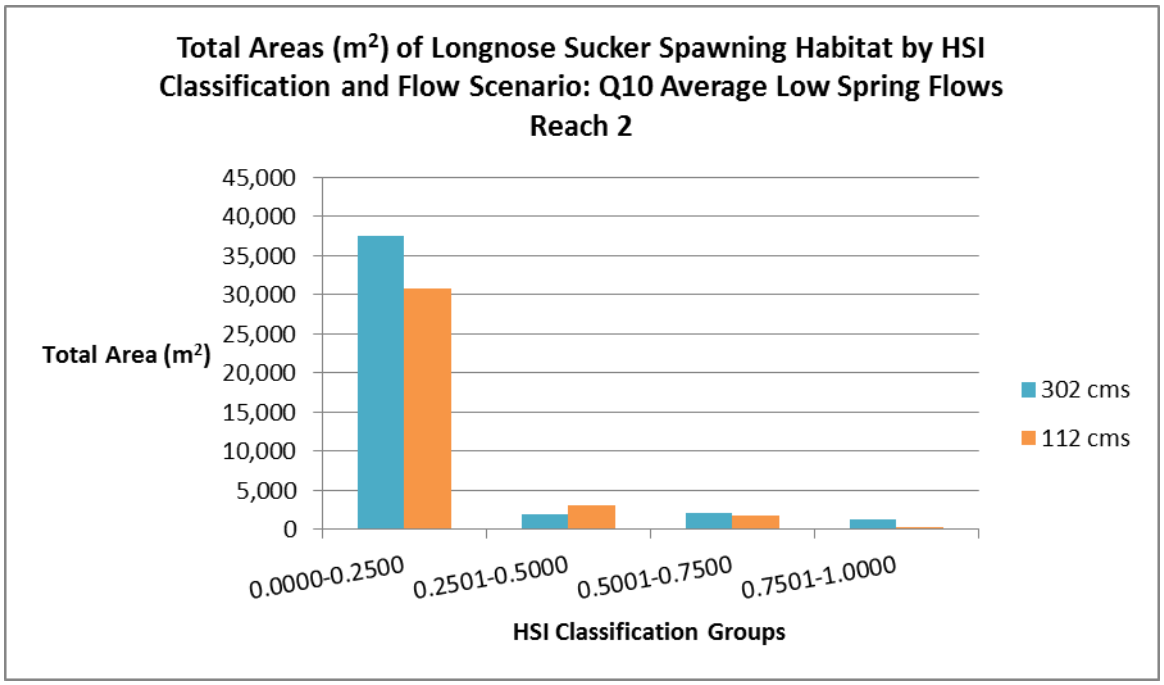


Figure E52: Total Areas of Longnose Sucker Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

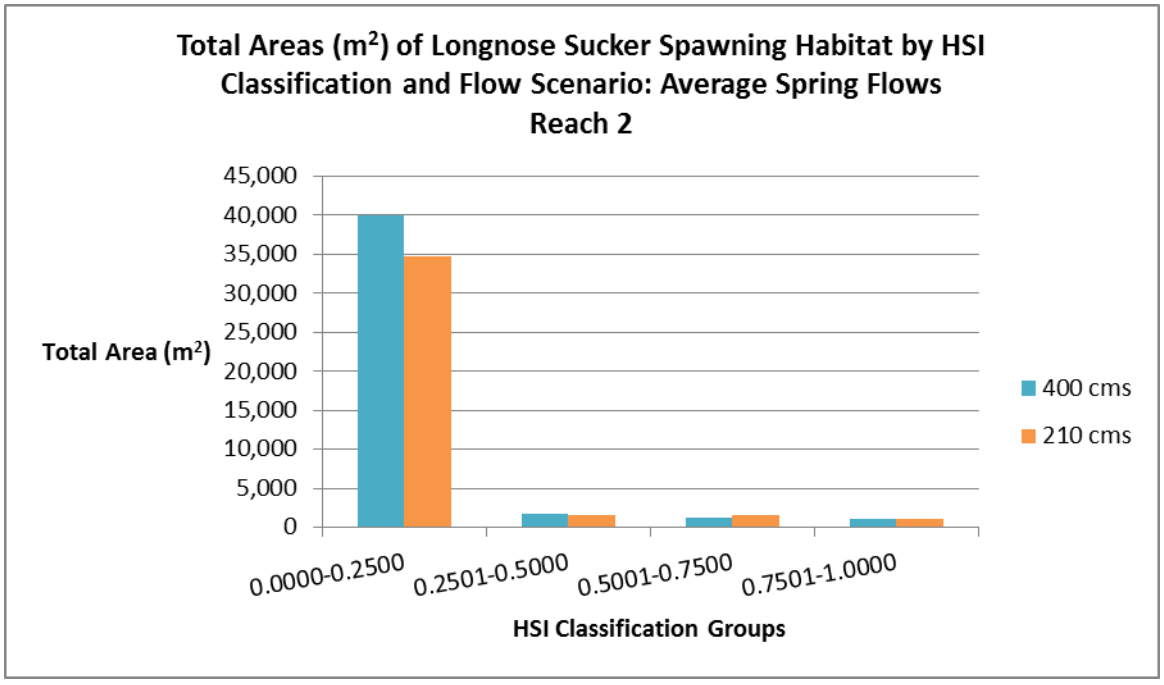


Figure E53: Total Areas of Longnose Sucker Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

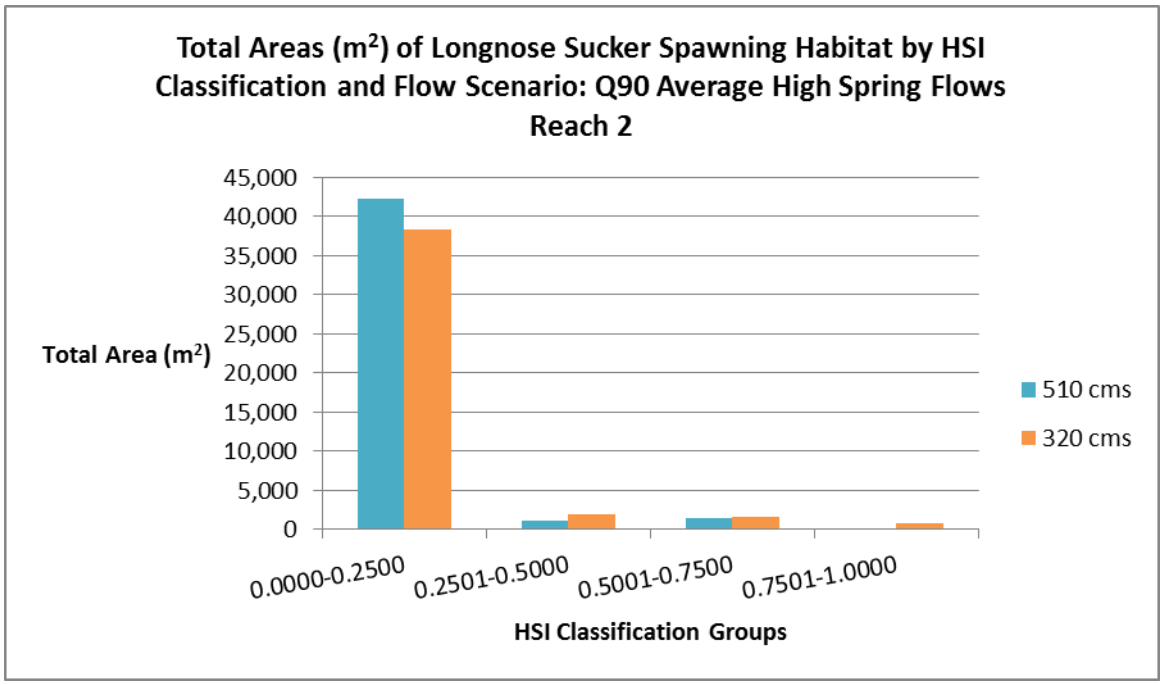


Figure E54: Total Areas of Longnose Sucker Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

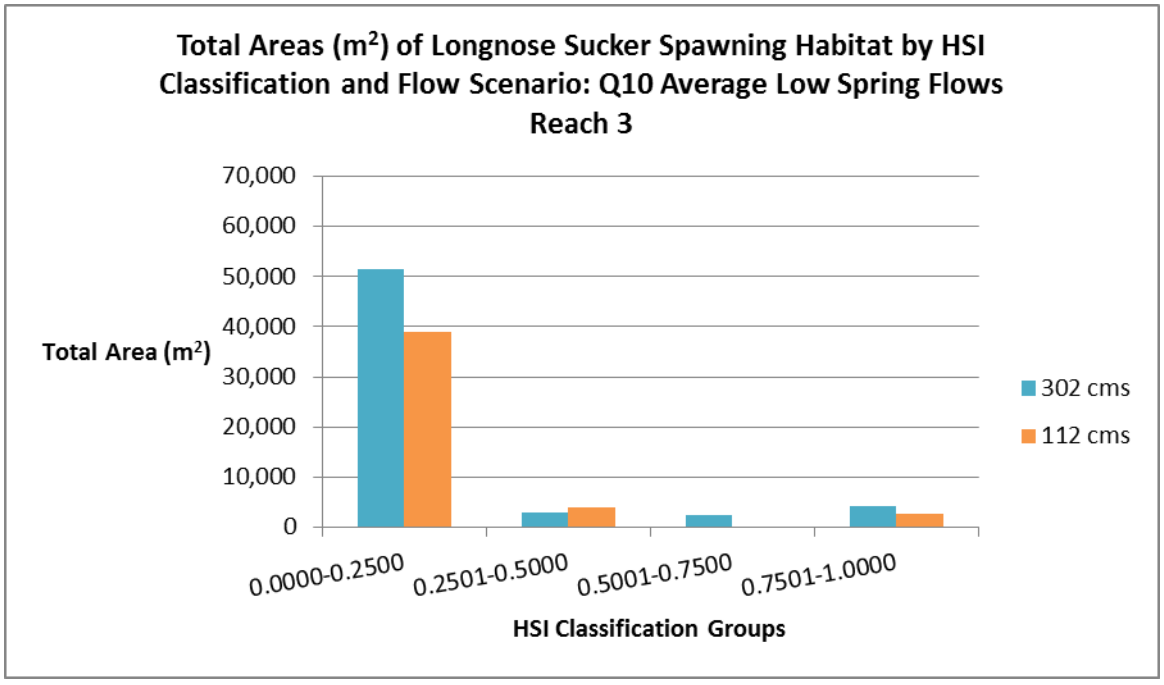


Figure E55: Total Areas of Longnose Sucker Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

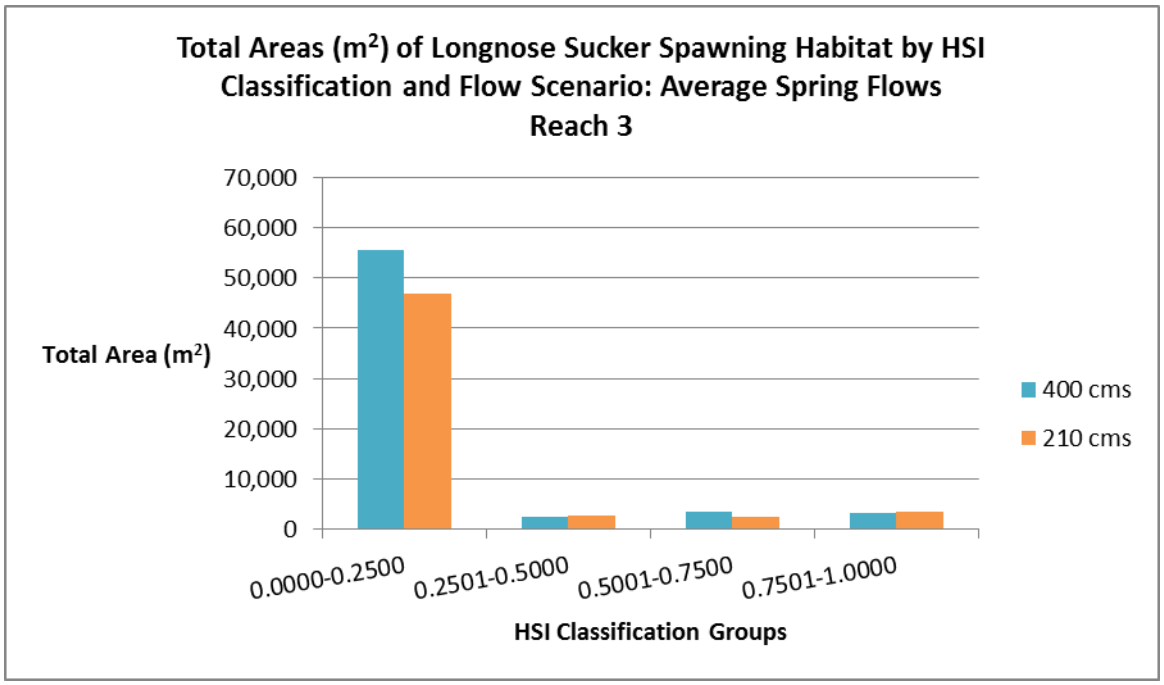


Figure E56: Total Areas of Longnose Sucker Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

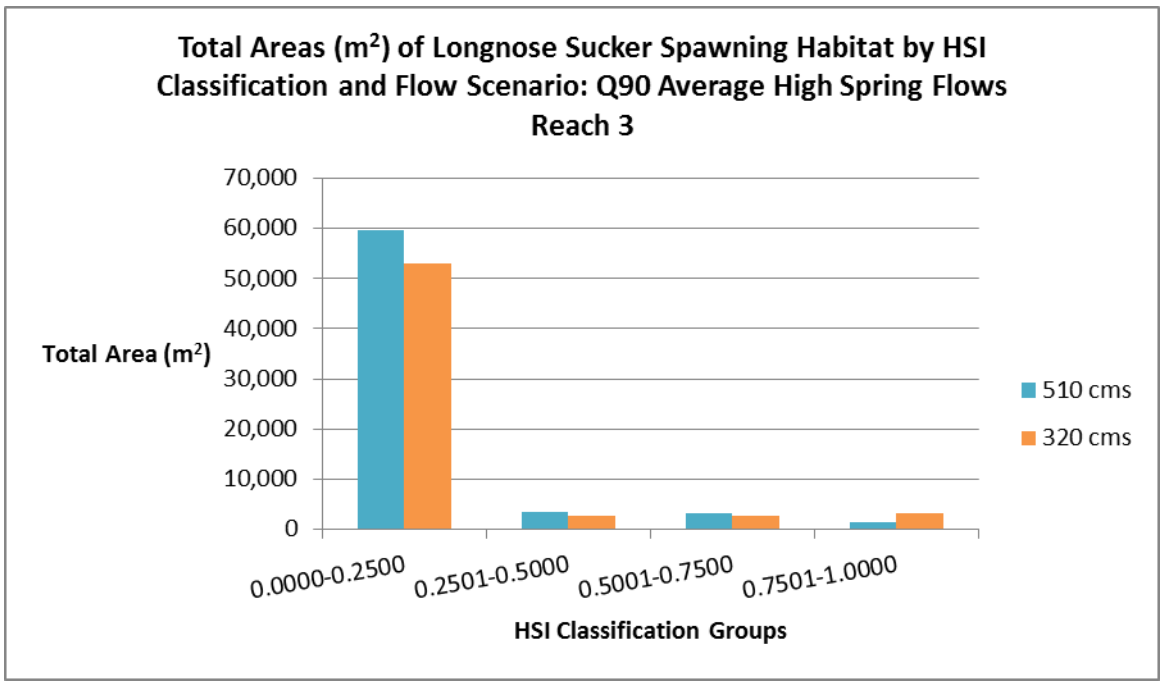


Figure E57: Total Areas of Longnose Sucker Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

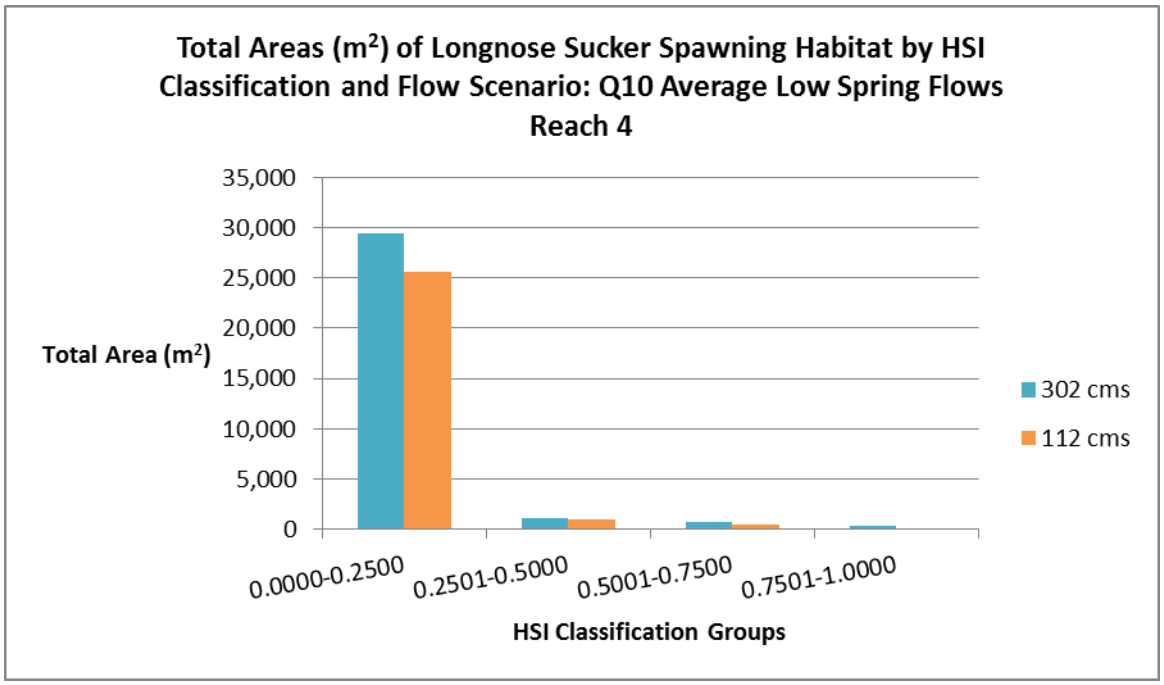


Figure E58: Total Areas of Longnose Sucker Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

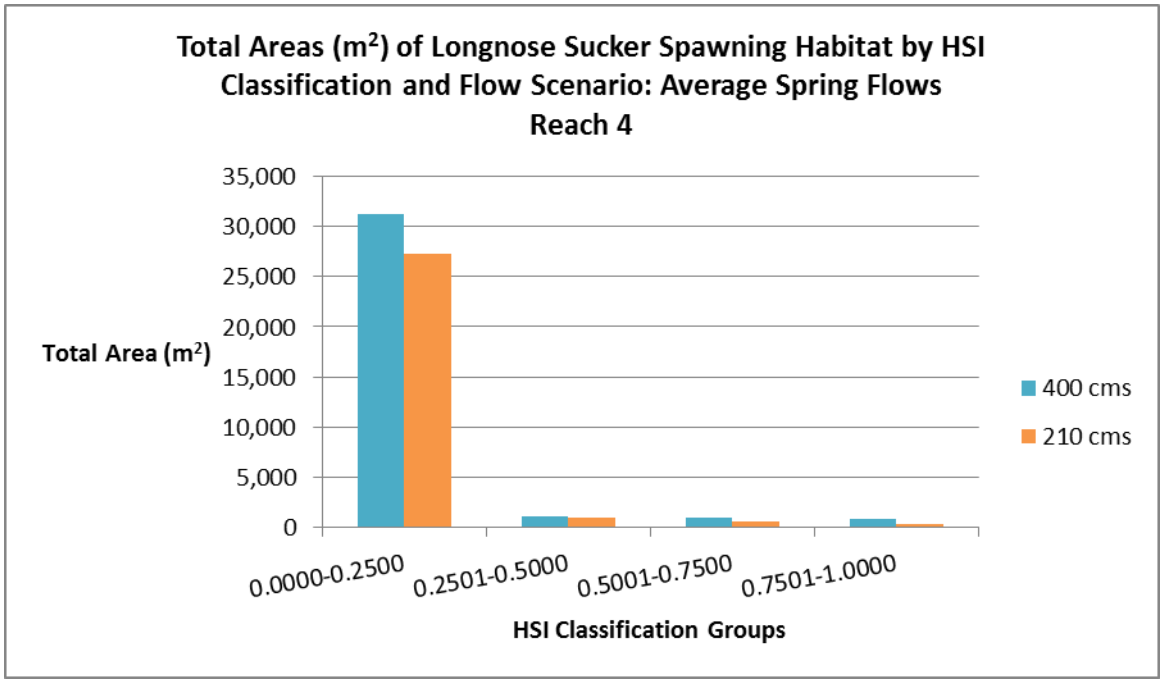


Figure E59: Total Areas of Longnose Sucker Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

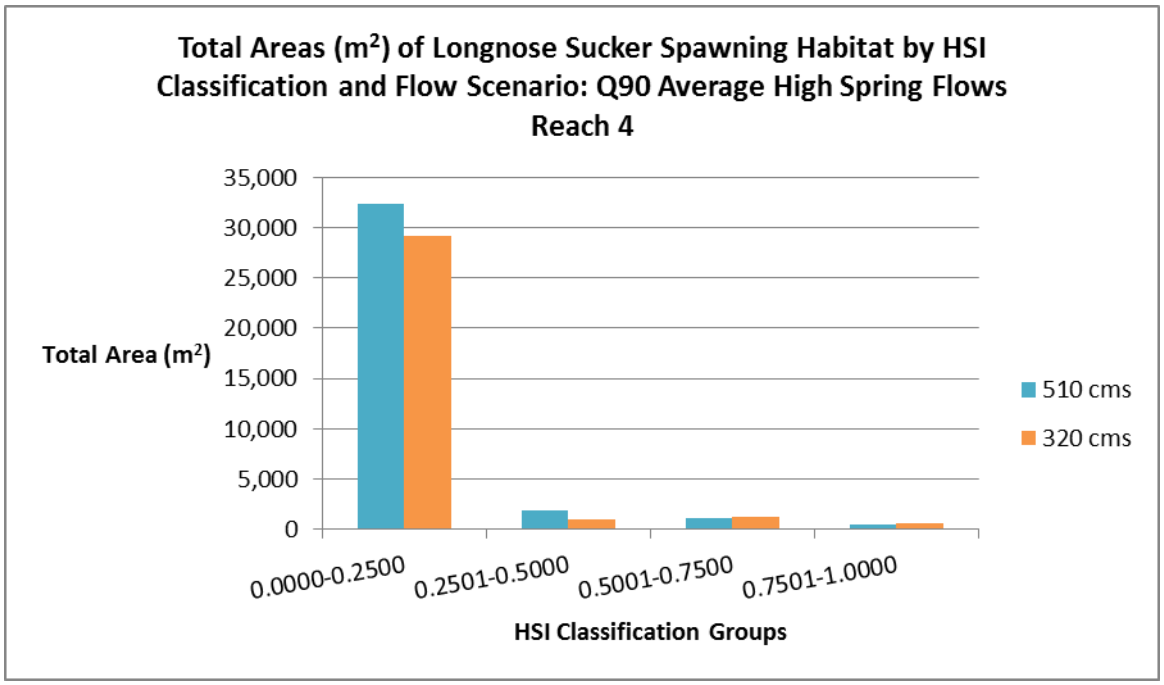


Figure E60: Total Areas of Longnose Sucker Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

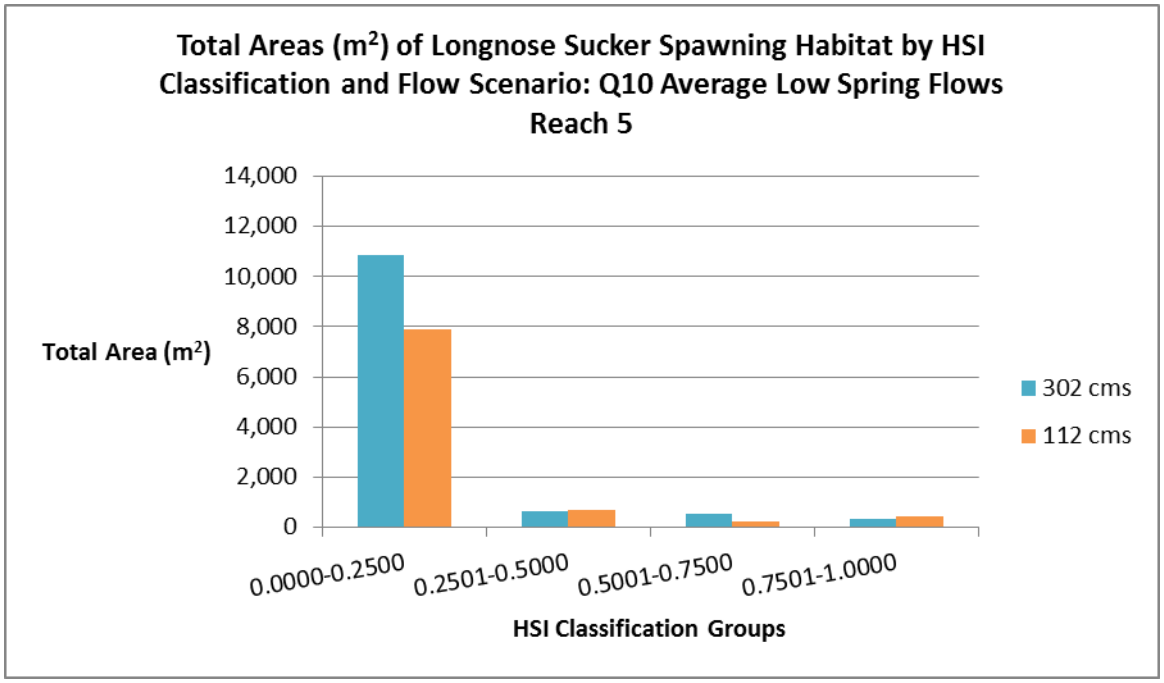


Figure E61: Total Areas of Longnose Sucker Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

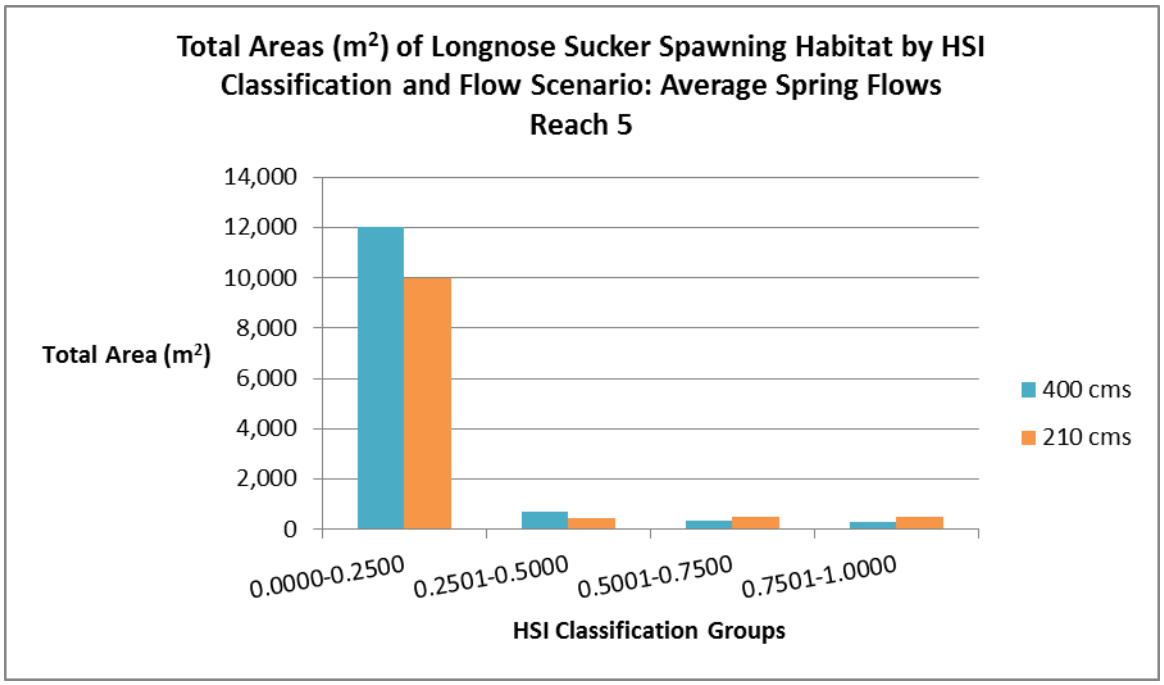


Figure E62: Total Areas of Longnose Sucker Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

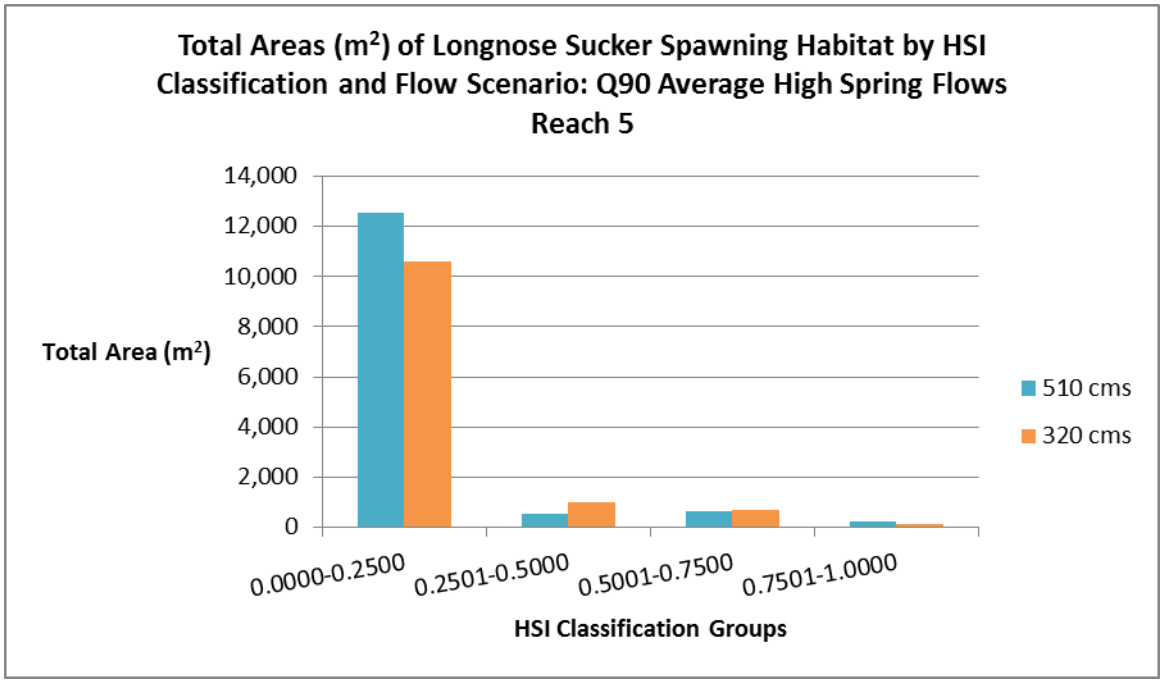


Figure E63: Total Areas of Longnose Sucker Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

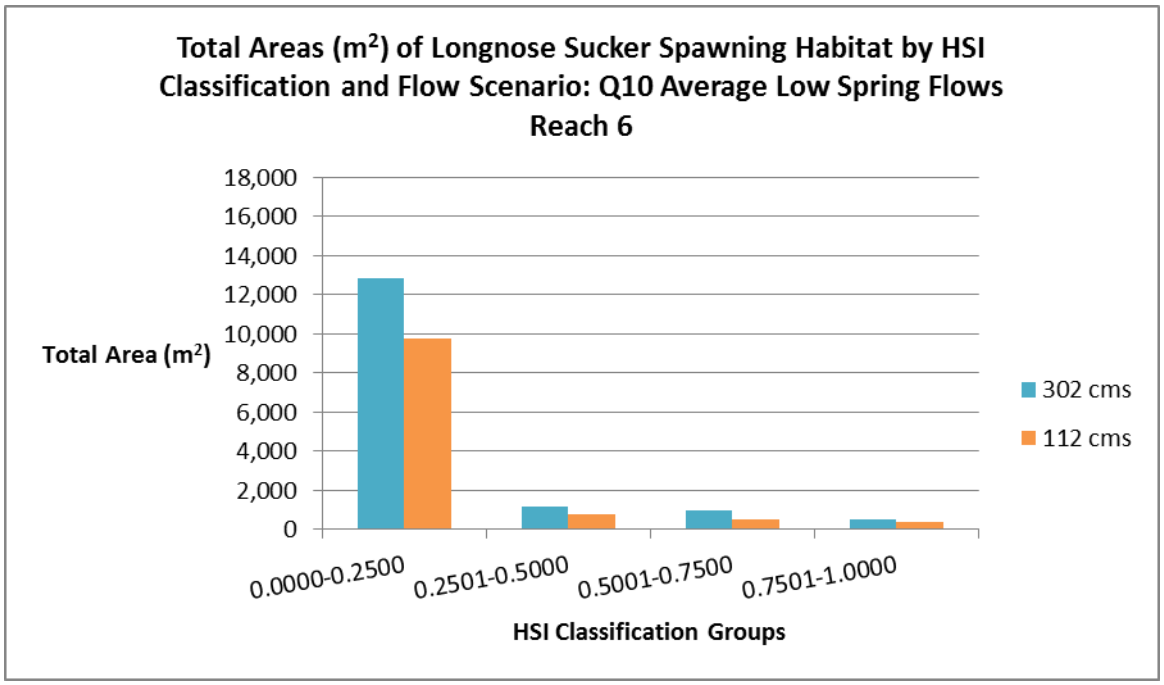


Figure E64: Total Areas of Longnose Sucker Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

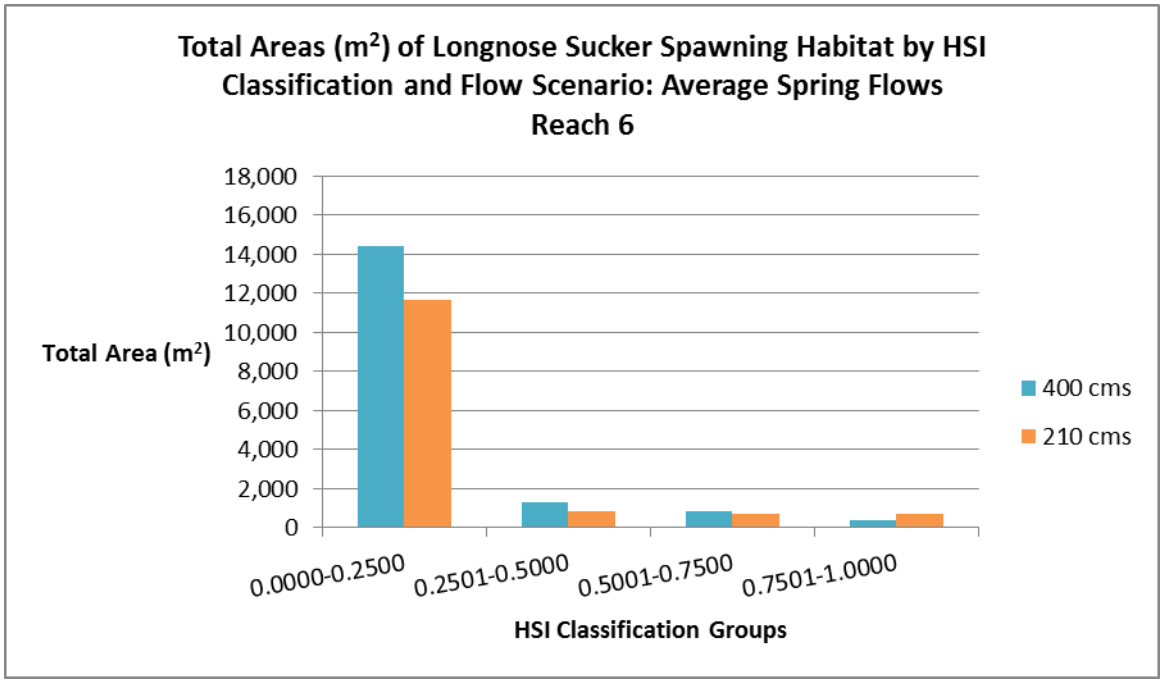


Figure E65: Total Areas of Longnose Sucker Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

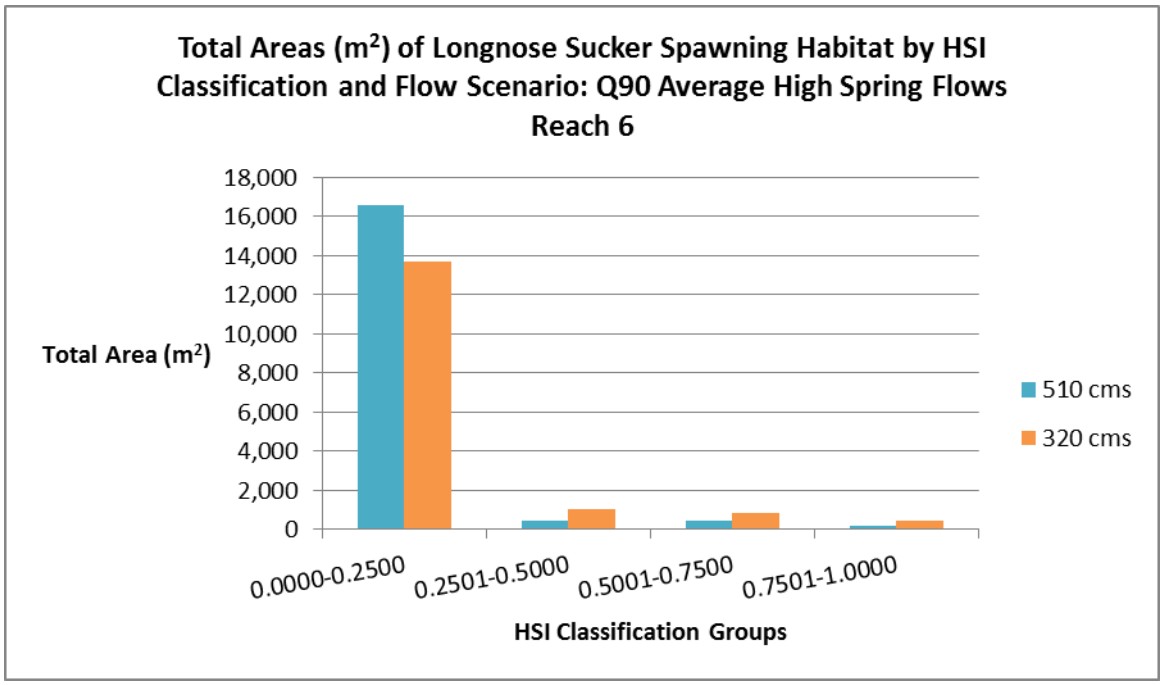


Figure E66: Total Areas of Longnose Sucker Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

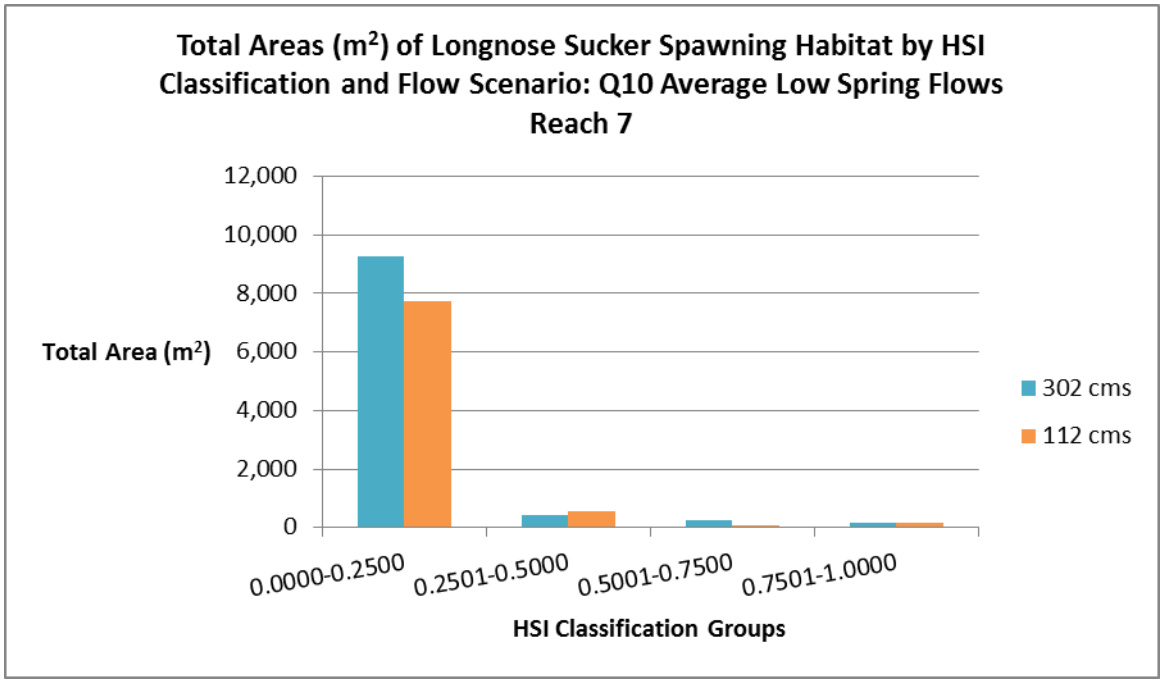


Figure E67: Total Areas of Longnose Sucker Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

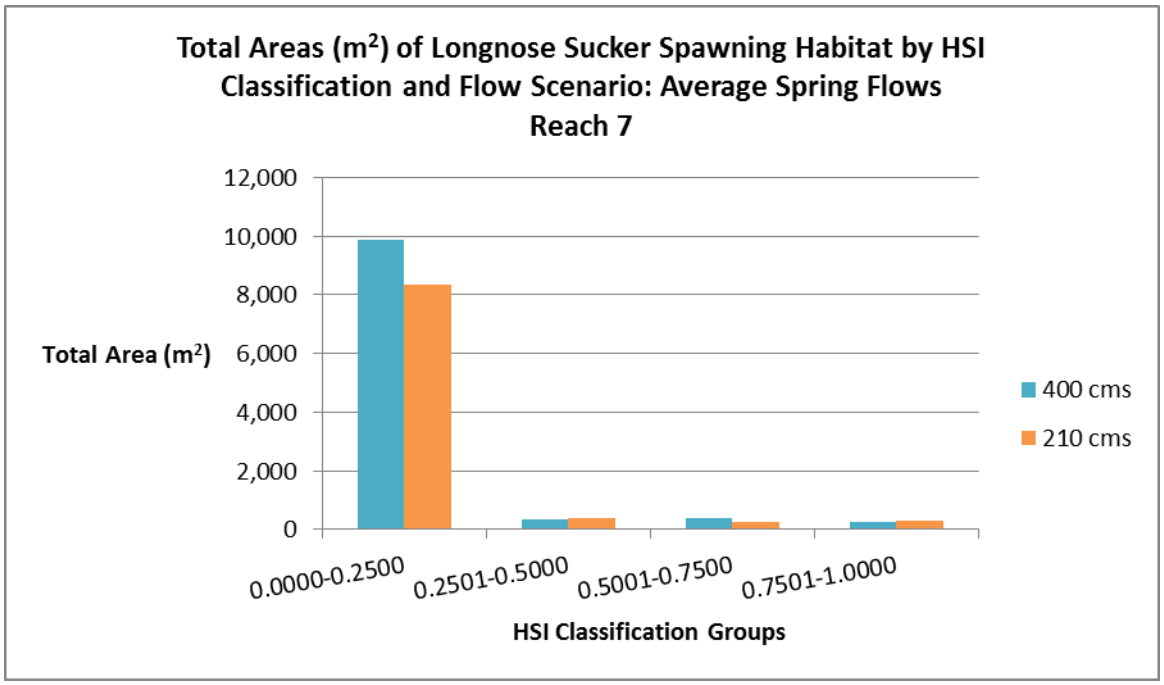


Figure E68: Total Areas of Longnose Sucker Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 400 m^3/ s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

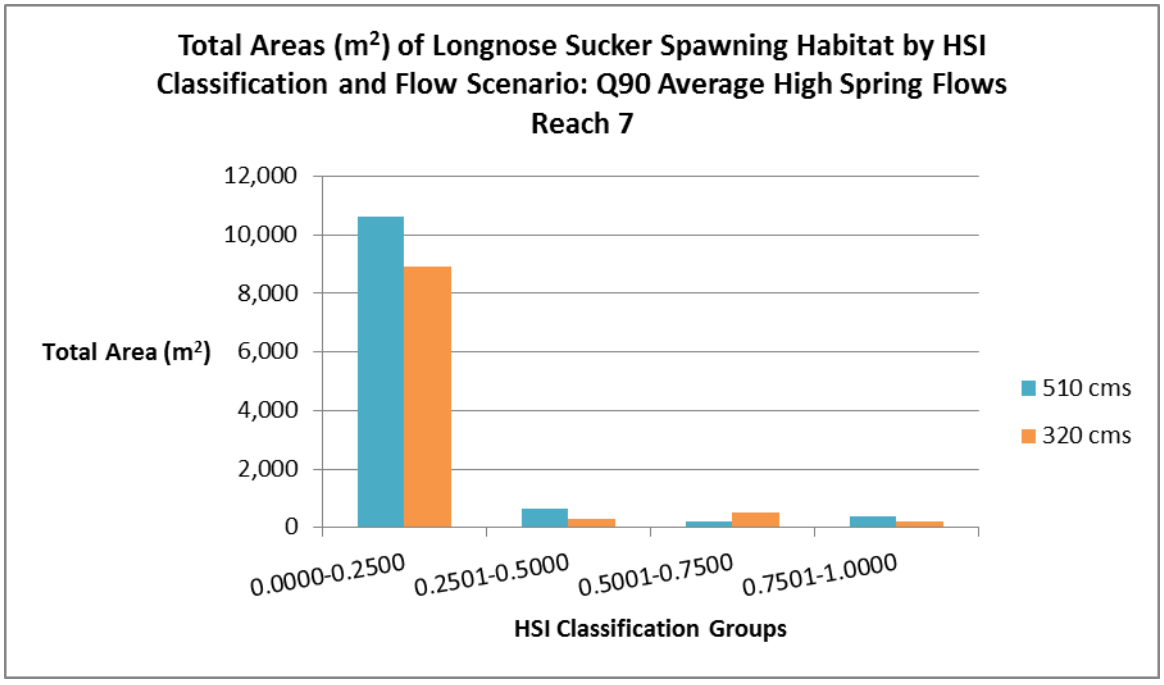


Figure E69: Total Areas of Longnose Sucker Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

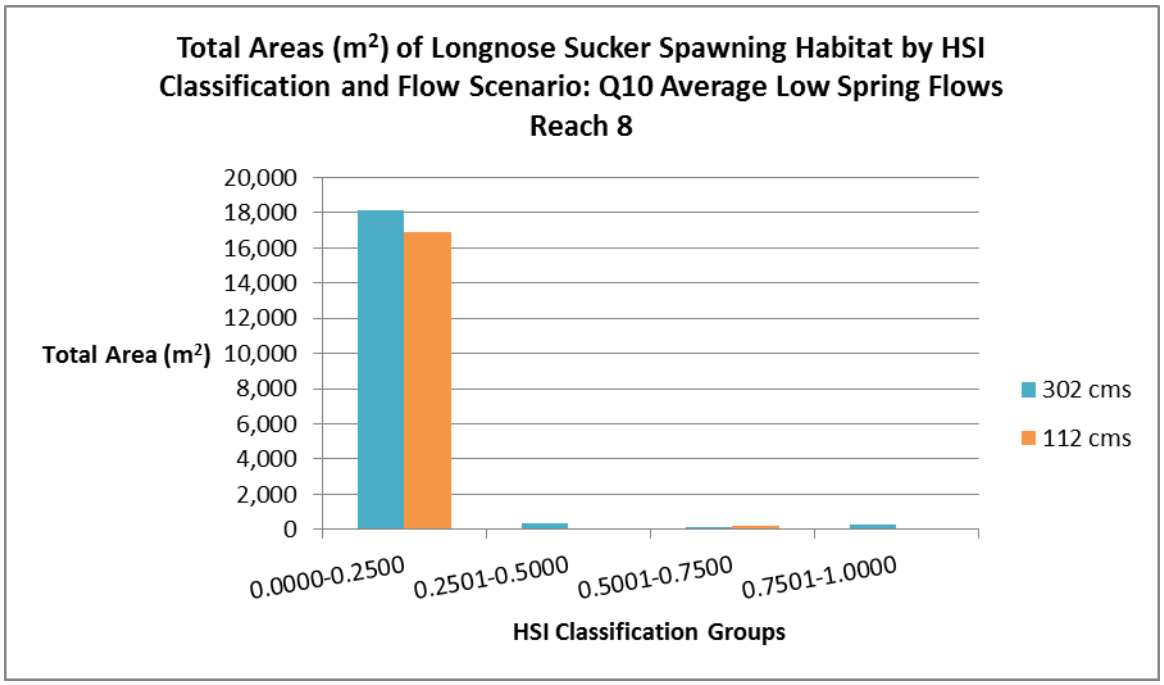


Figure E70: Total Areas of Longnose Sucker Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

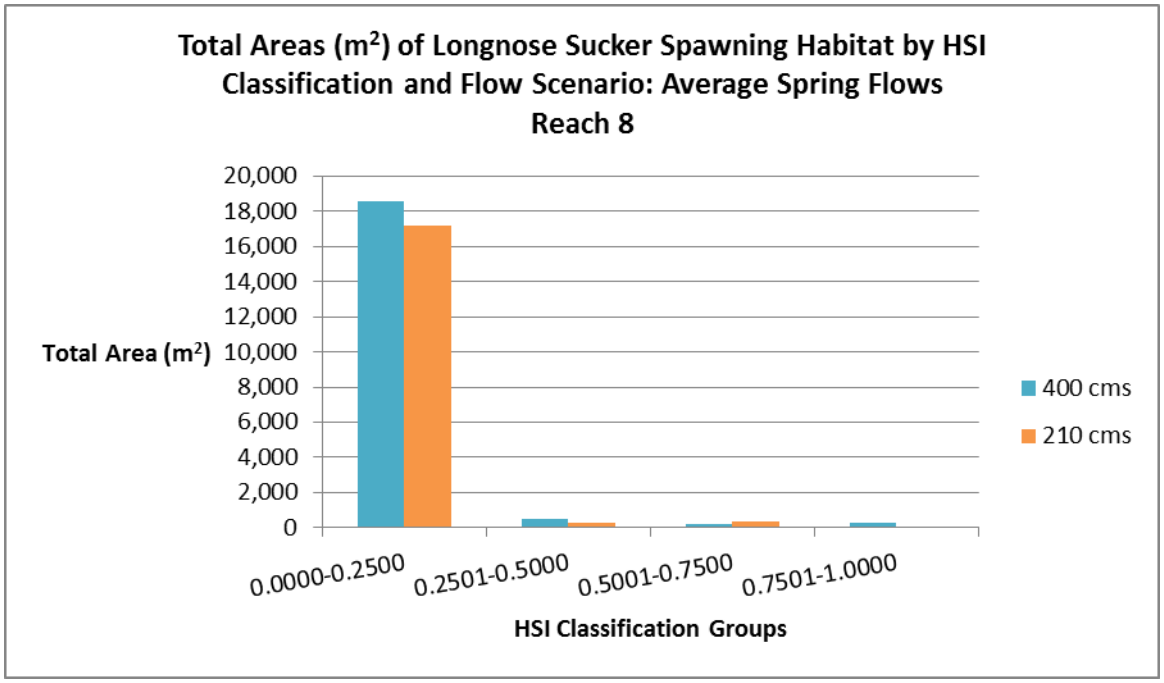


Figure E71: Total Areas of Longnose Sucker Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

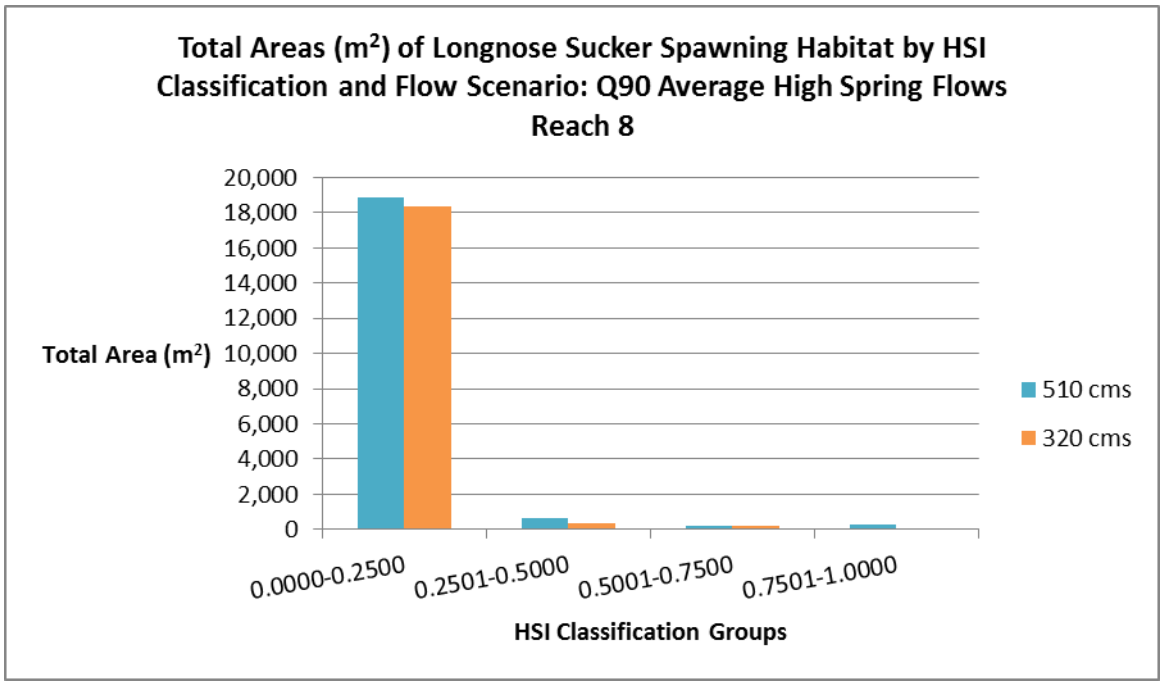


Figure E72: Total Areas of Longnose Sucker Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

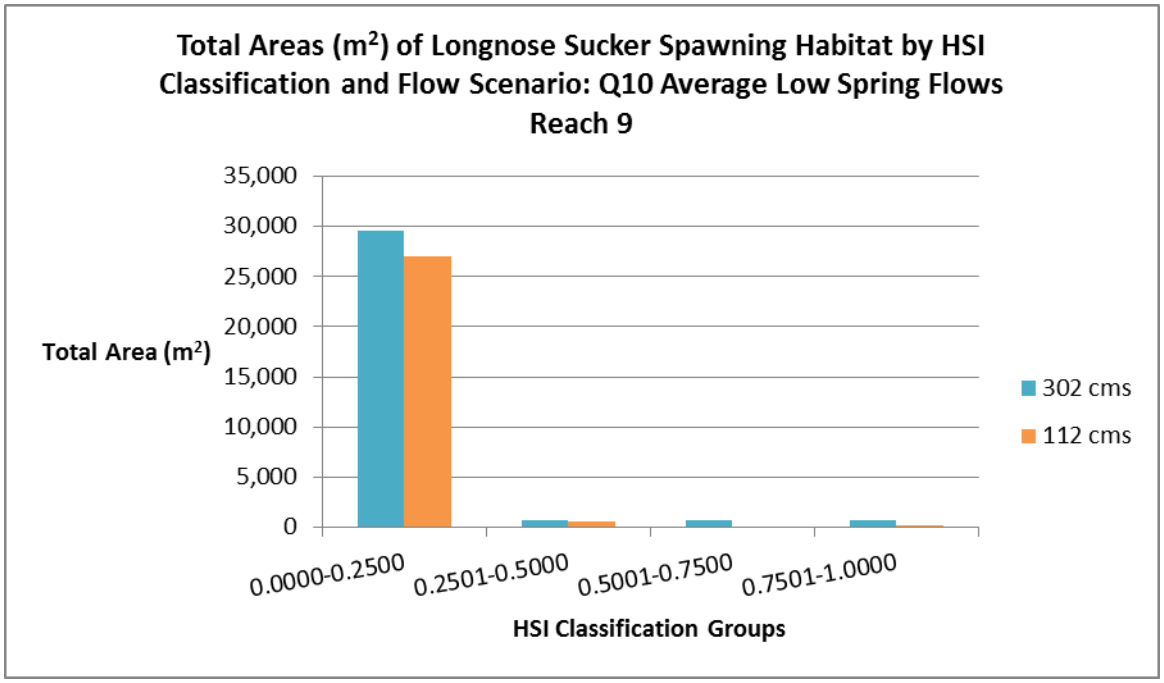


Figure E73: Total Areas of Longnose Sucker Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

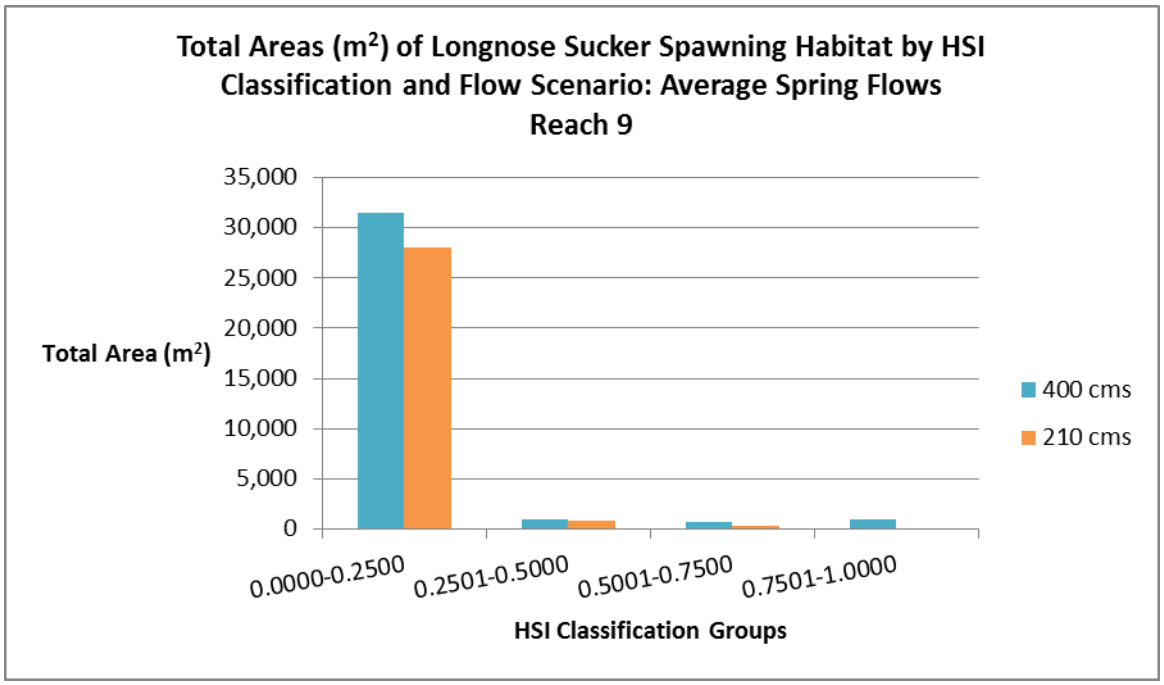


Figure E74: Total Areas of Longnose Sucker Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

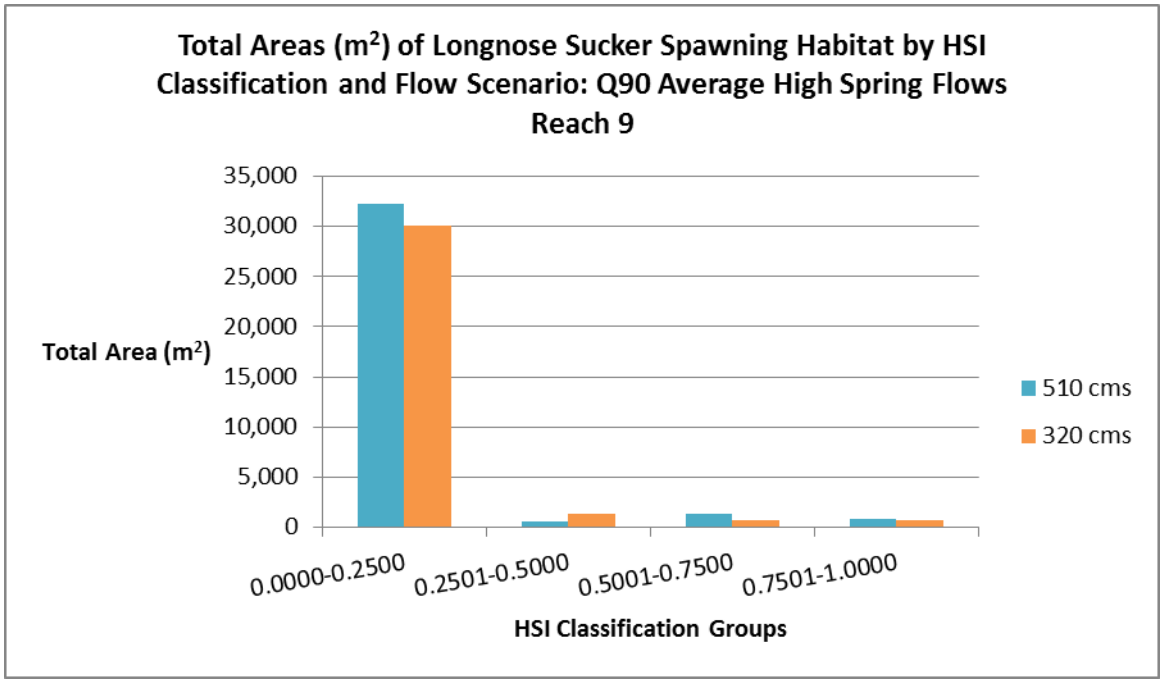


Figure E75: Total Areas of Longnose Sucker Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

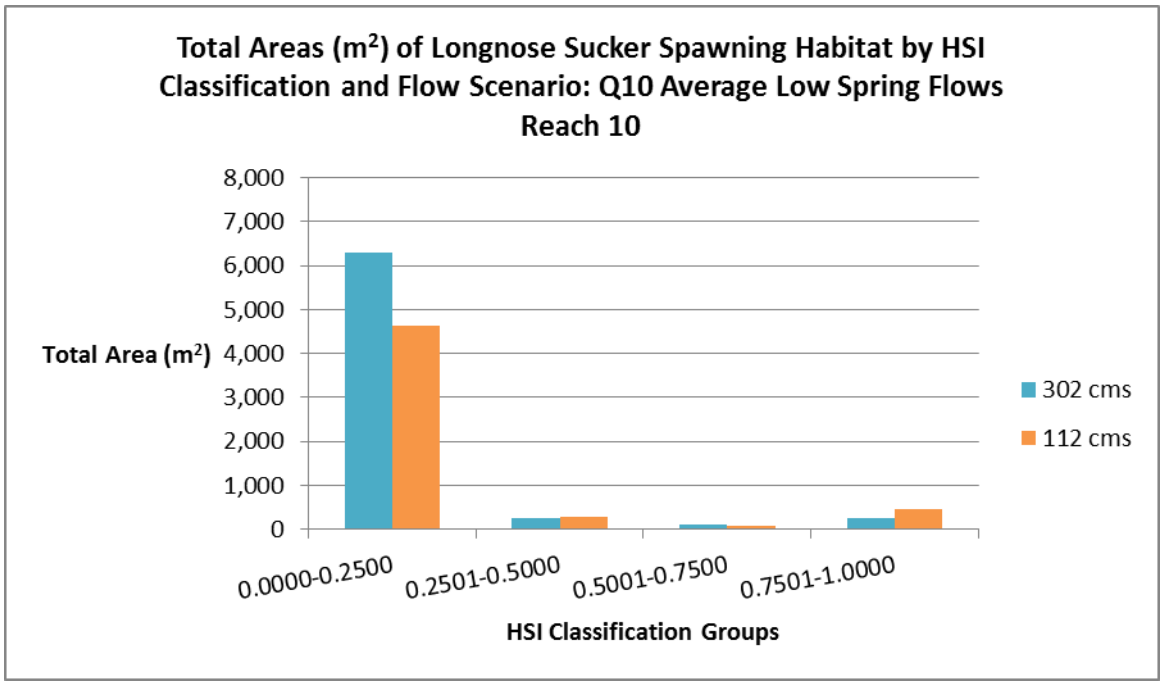


Figure E76: Total Areas of Longnose Sucker Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

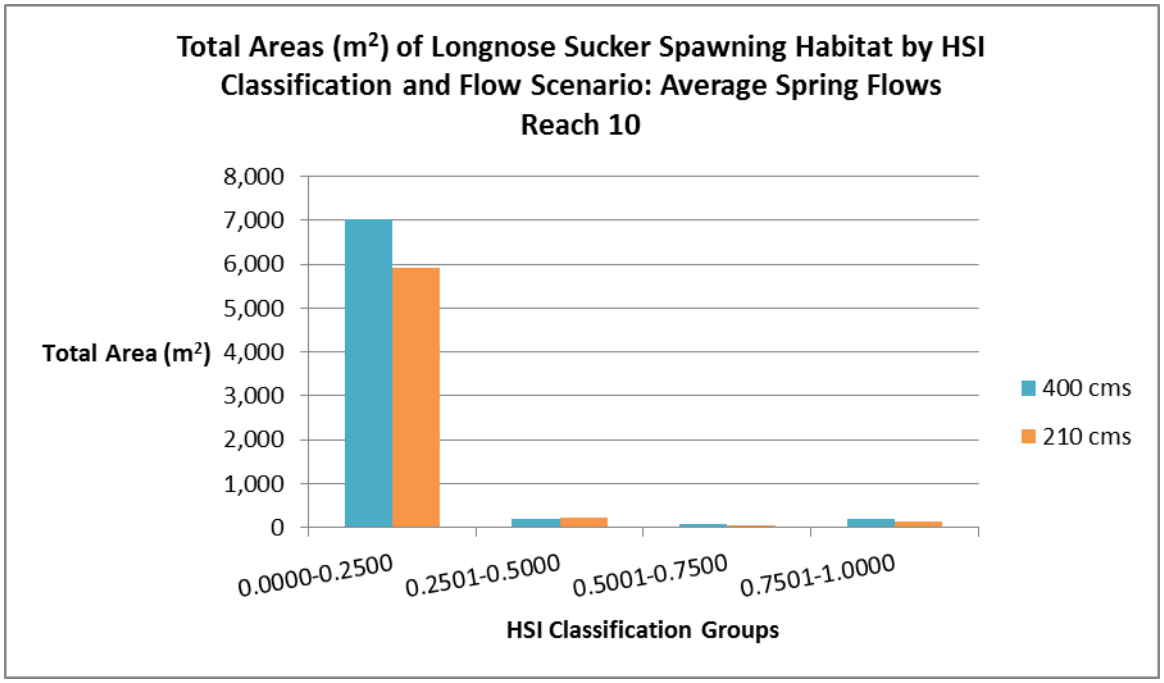


Figure E77: Total Areas of Longnose Sucker Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

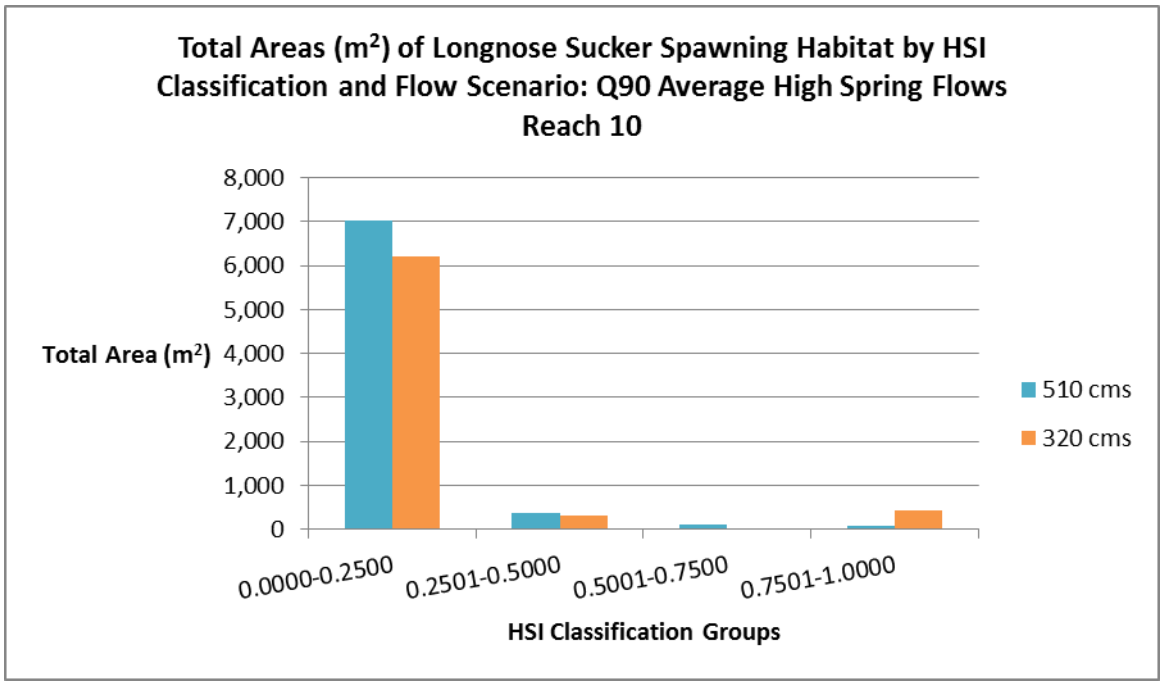


Figure E78: Total Areas of Longnose Sucker Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

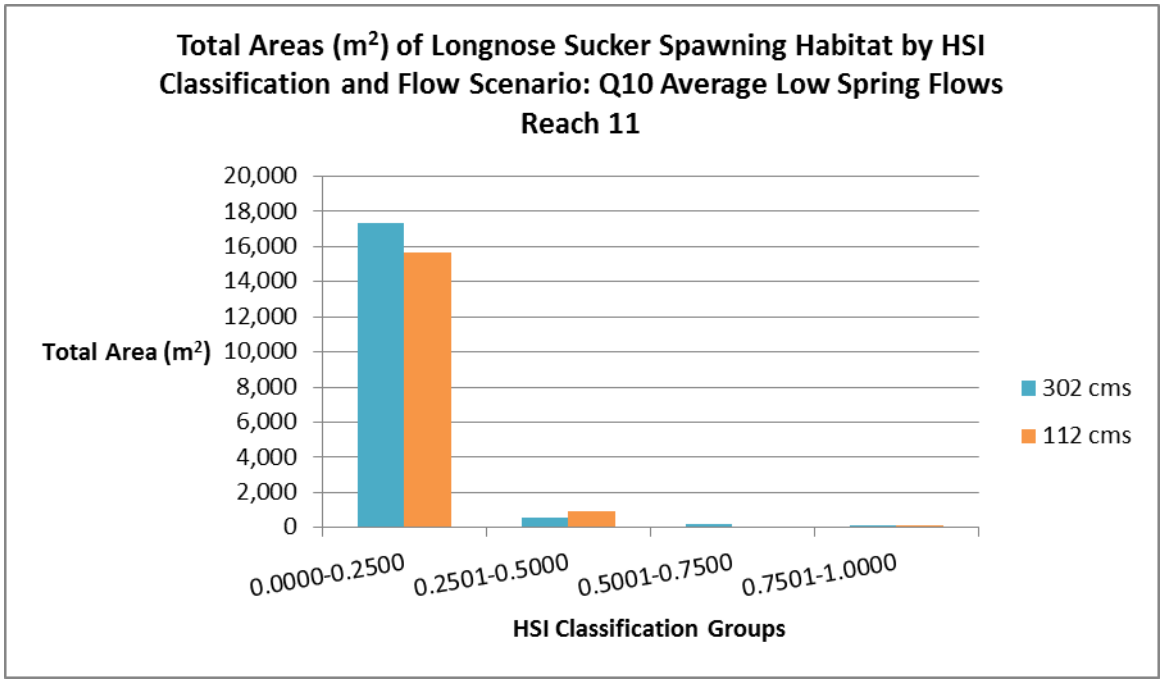


Figure E79: Total Areas of Longnose Sucker Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

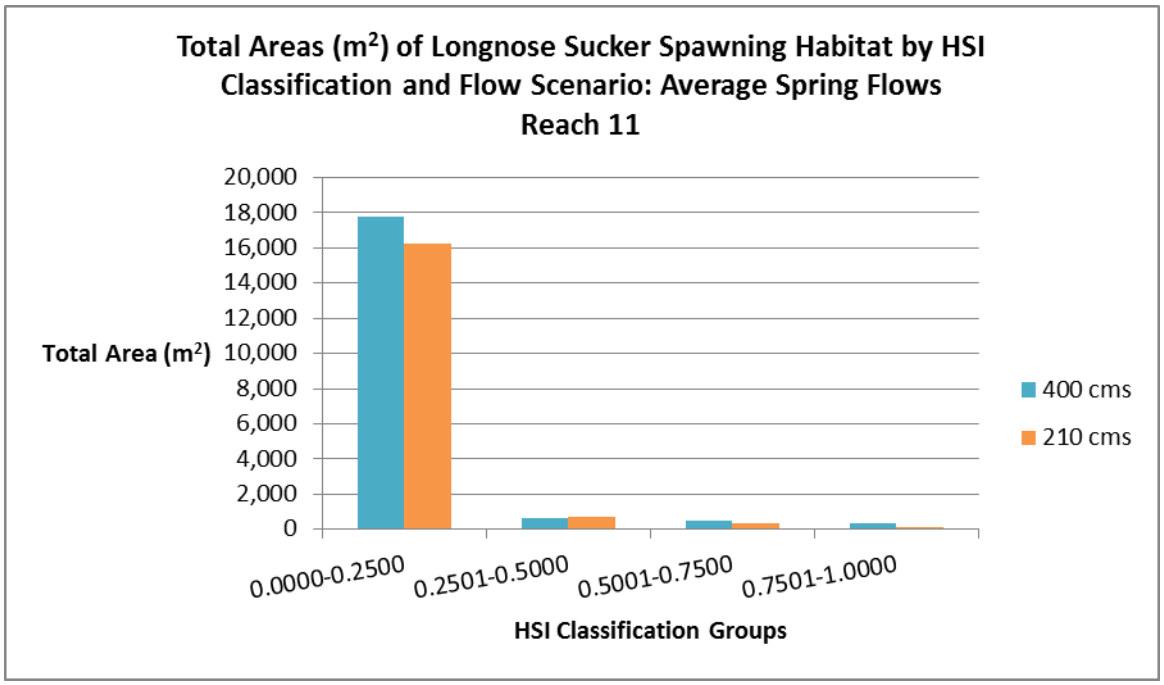


Figure E80: Total Areas of Longnose Sucker Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

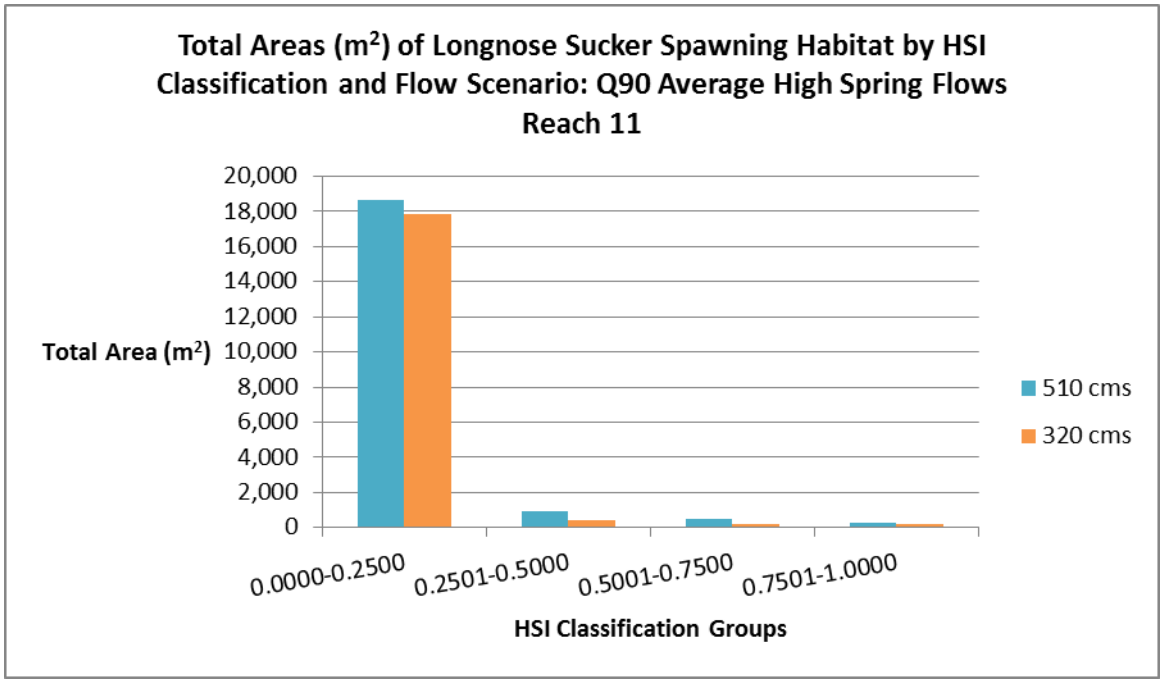


Figure E81: Total Areas of Longnose Sucker Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

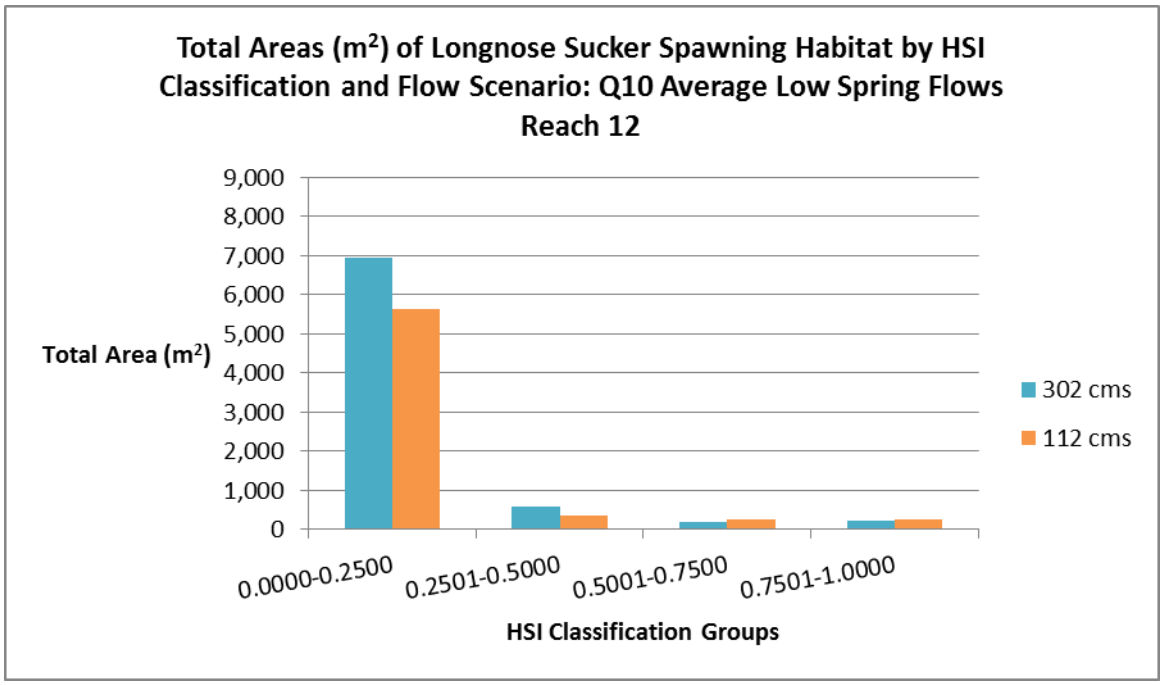


Figure E82: Total Areas of Longnose Sucker Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

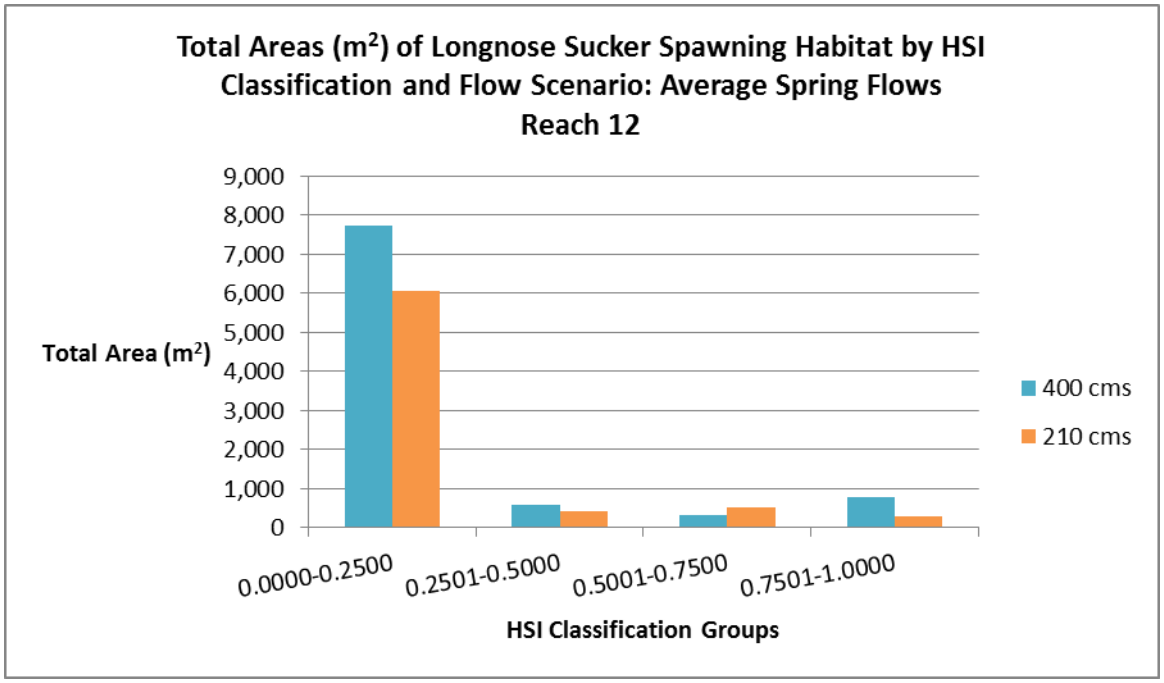


Figure E83: Total Areas of Longnose Sucker Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

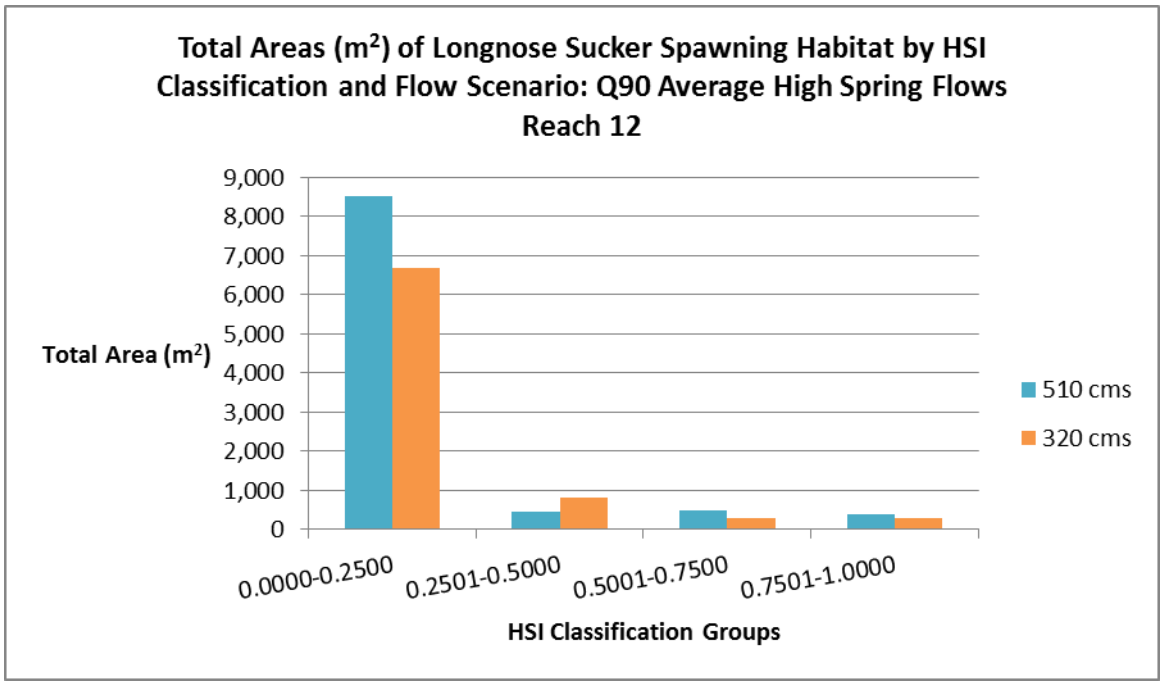


Figure E84: Total Areas of Longnose Sucker Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

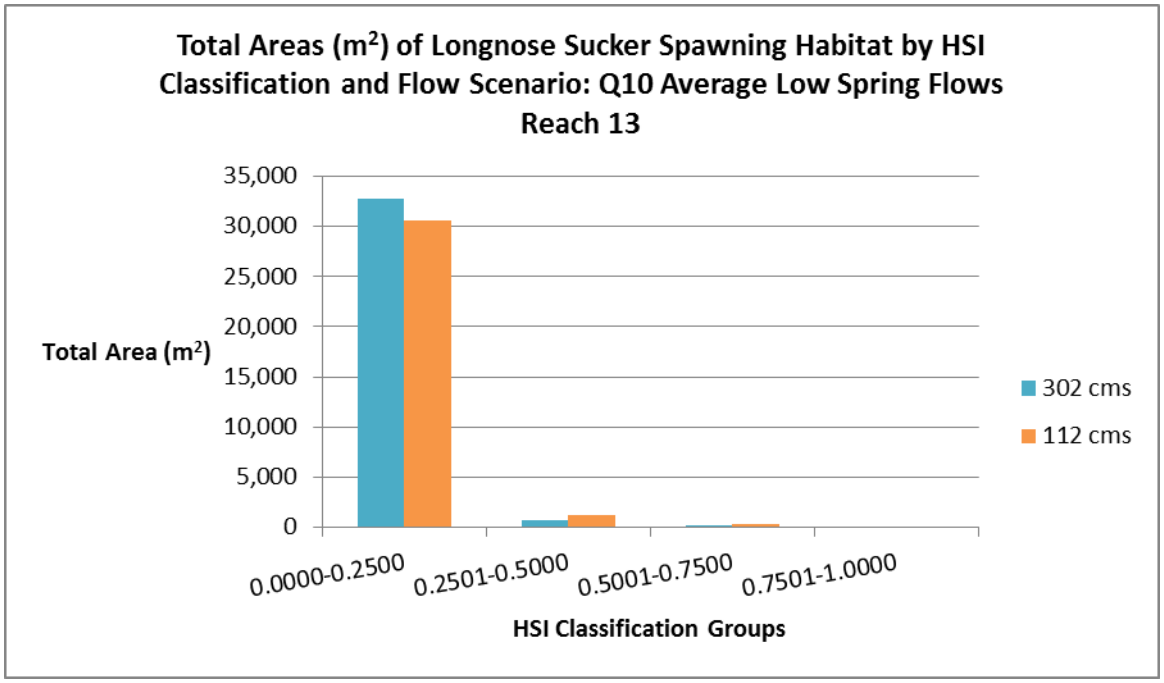


Figure E85: Total Areas of Longnose Sucker Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

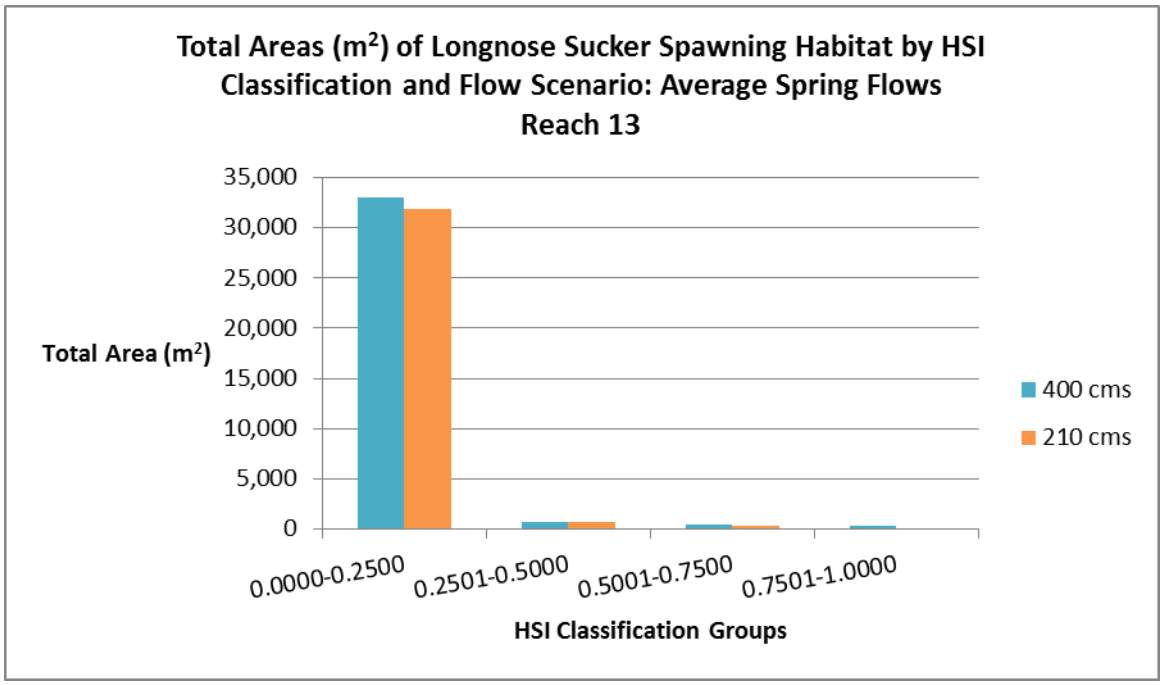


Figure E86: Total Areas of Longnose Sucker Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

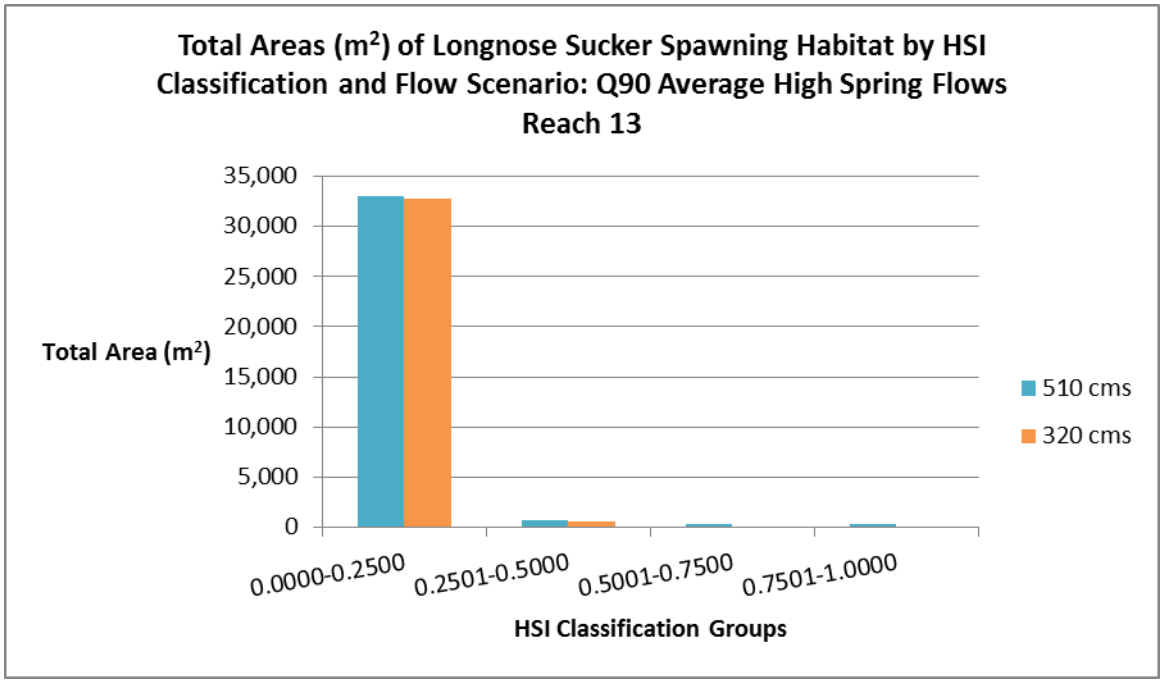


Figure E87: Total Areas of Longnose Sucker Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

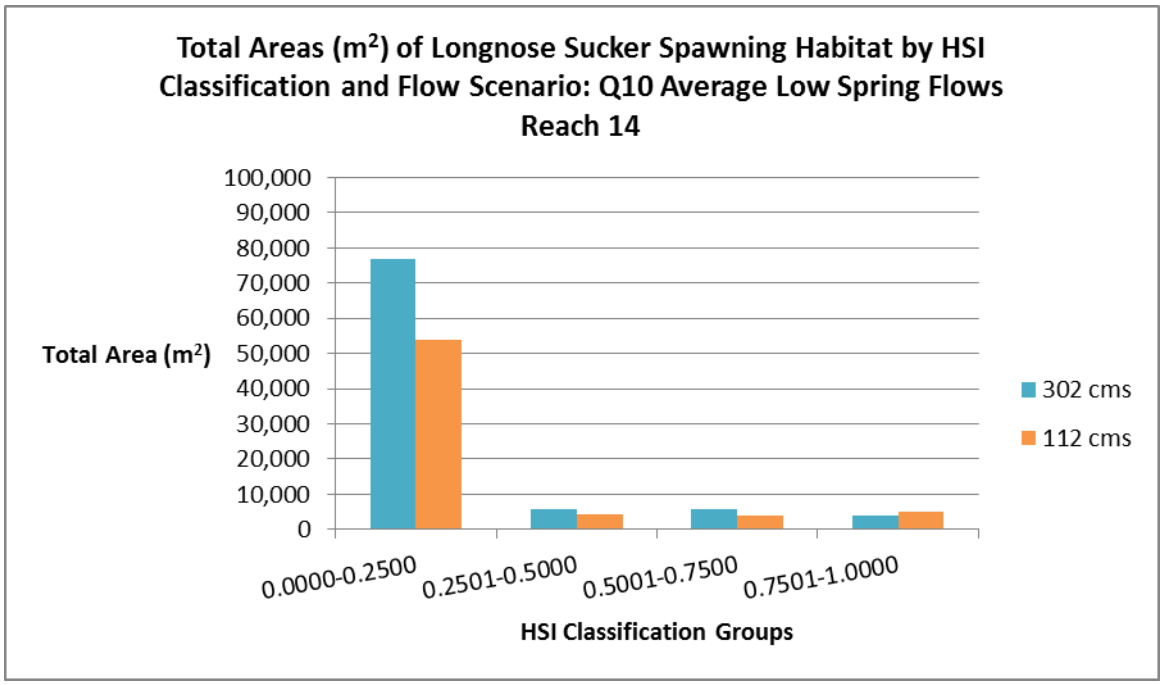


Figure E88: Total Areas of Longnose Sucker Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

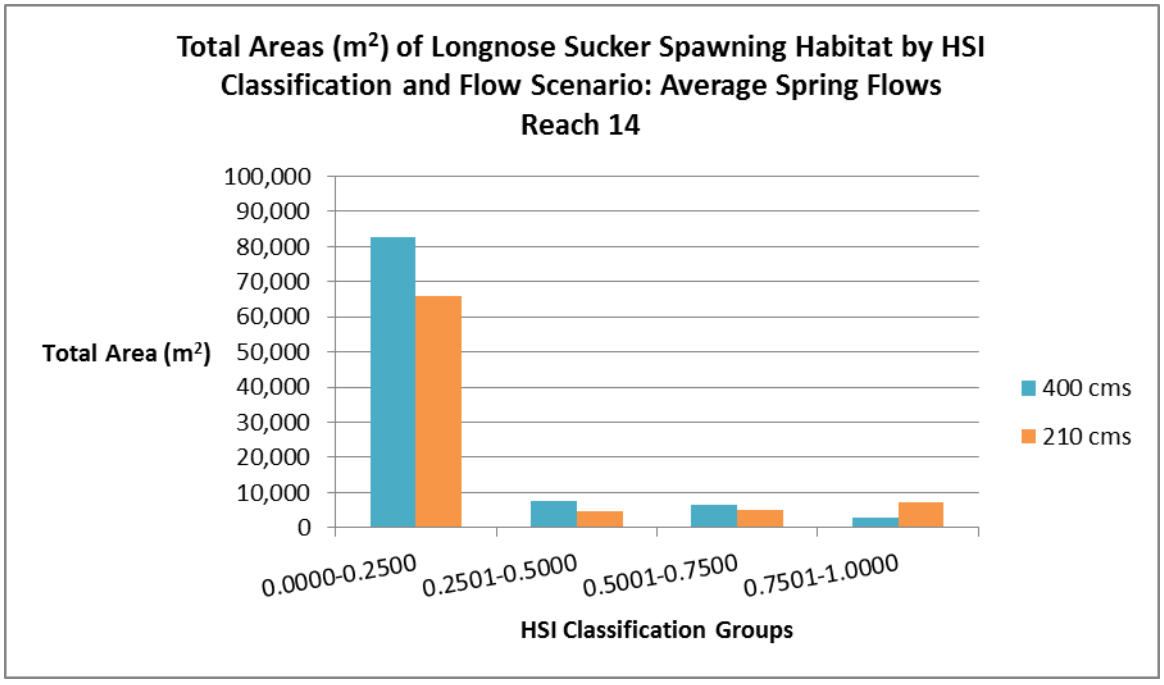


Figure E89: Total Areas of Longnose Sucker Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

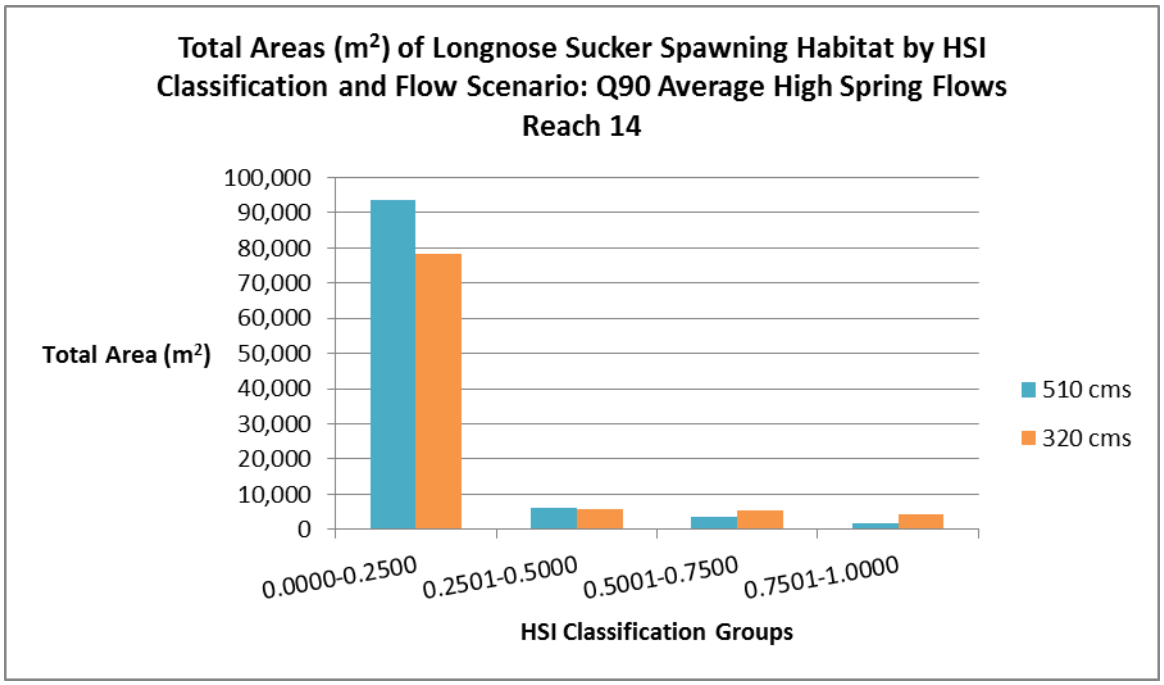


Figure E90: Total Areas of Longnose Sucker Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

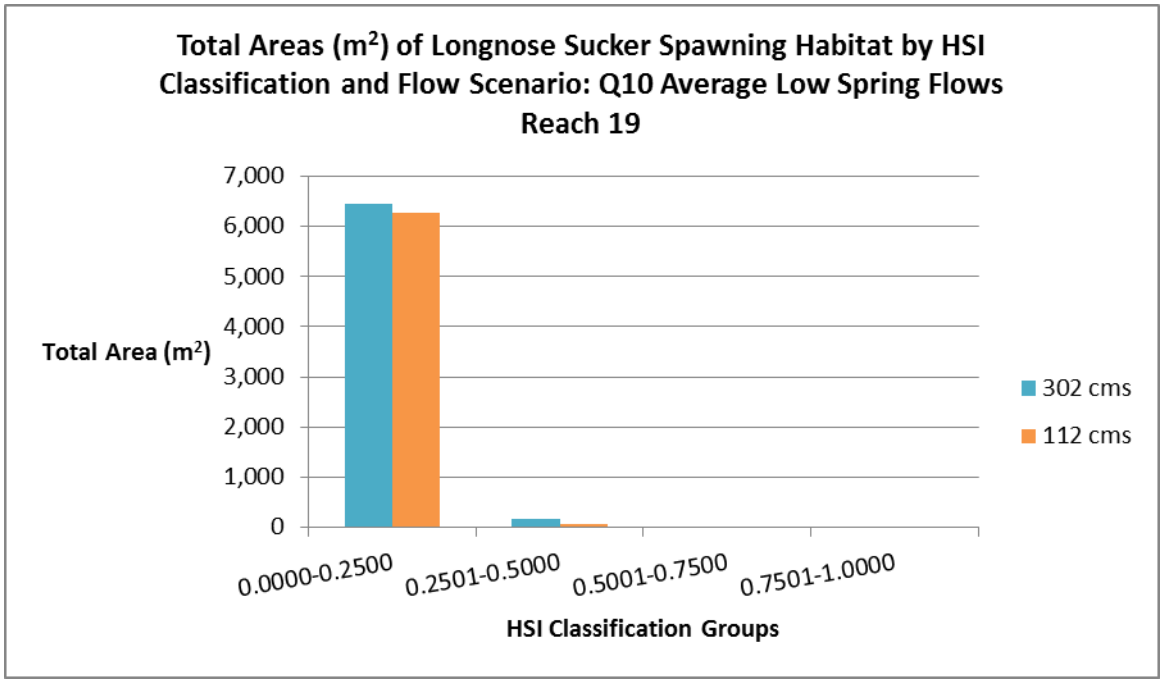


Figure E91: Total Areas of Longnose Sucker Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

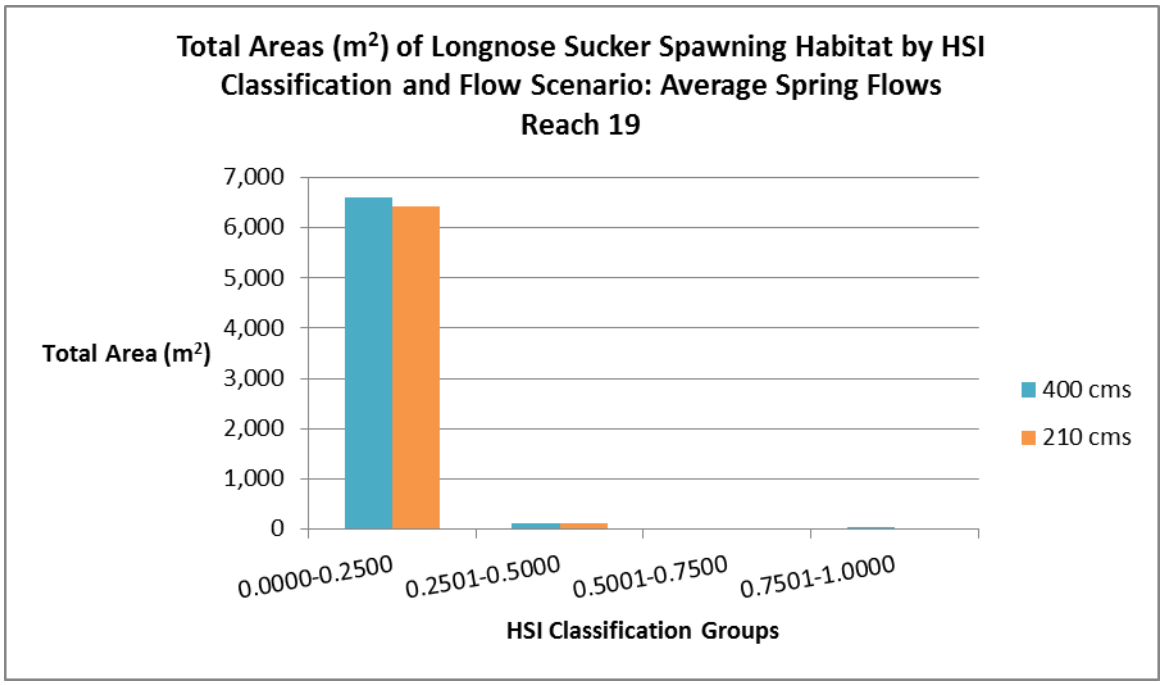


Figure E92: Total Areas of Longnose Sucker Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

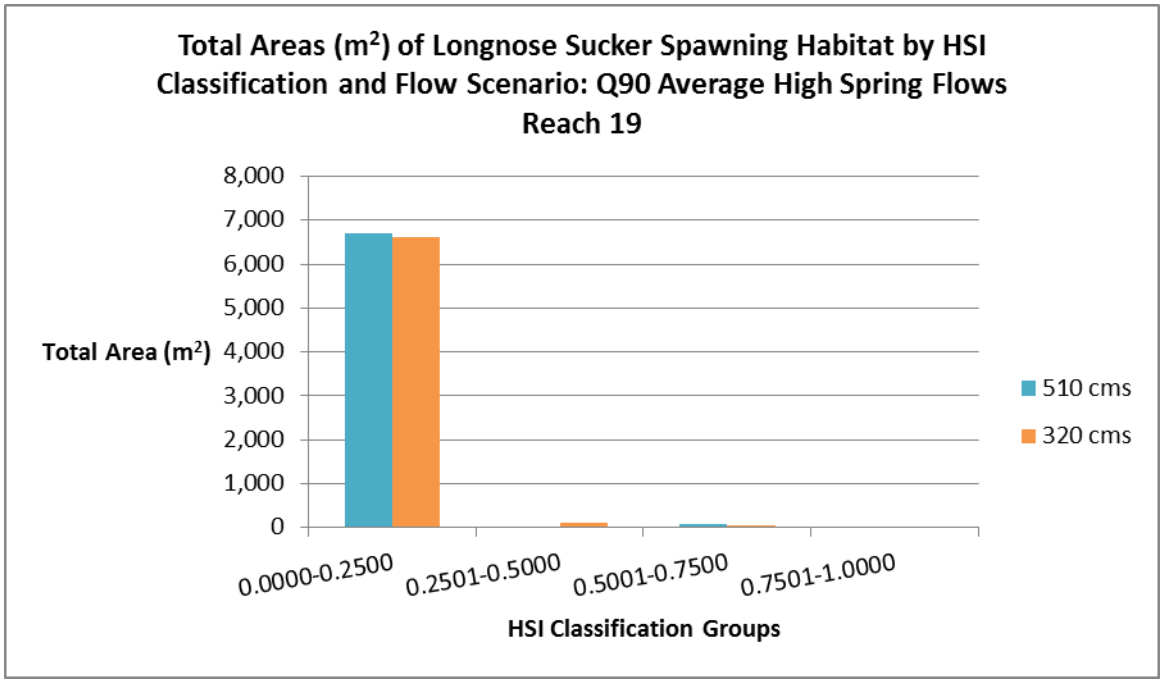


Figure E93: Total Areas of Longnose Sucker Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

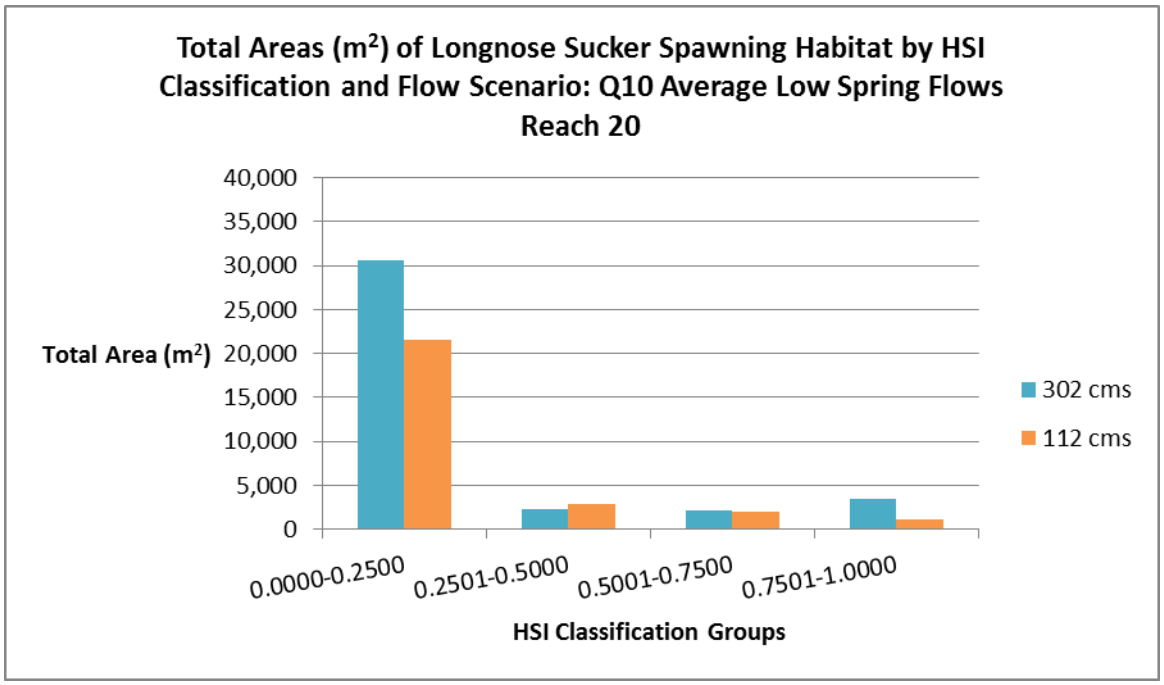


Figure E94: Total Areas of Longnose Sucker Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

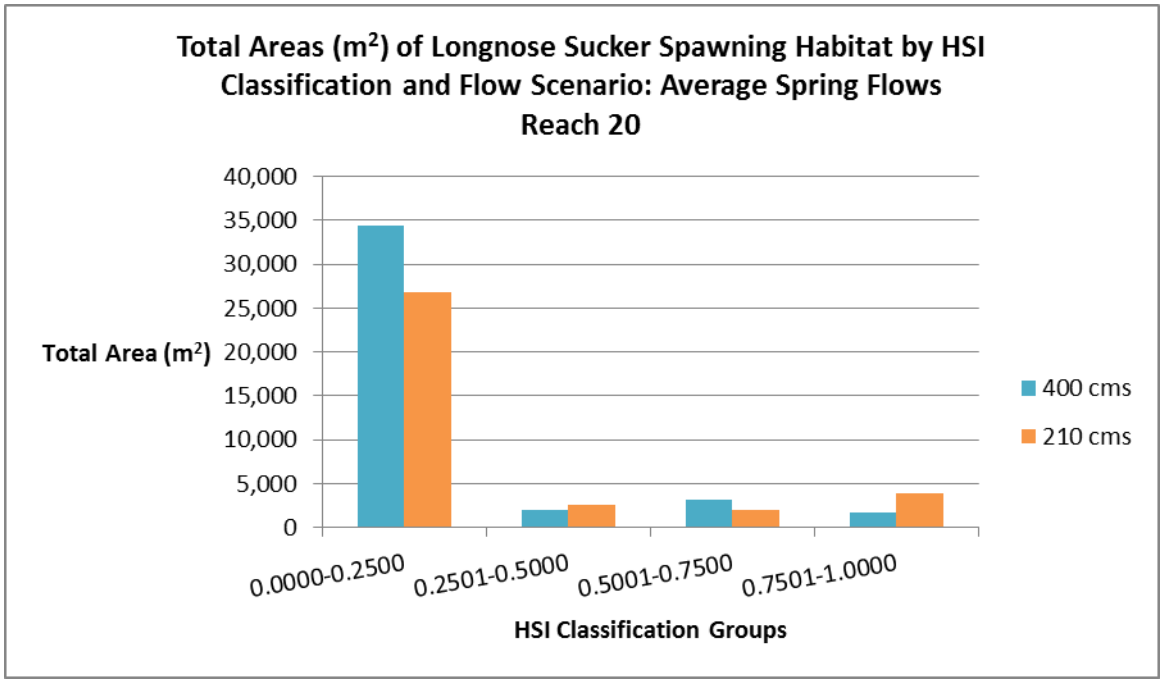


Figure E95: Total Areas of Longnose Sucker Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

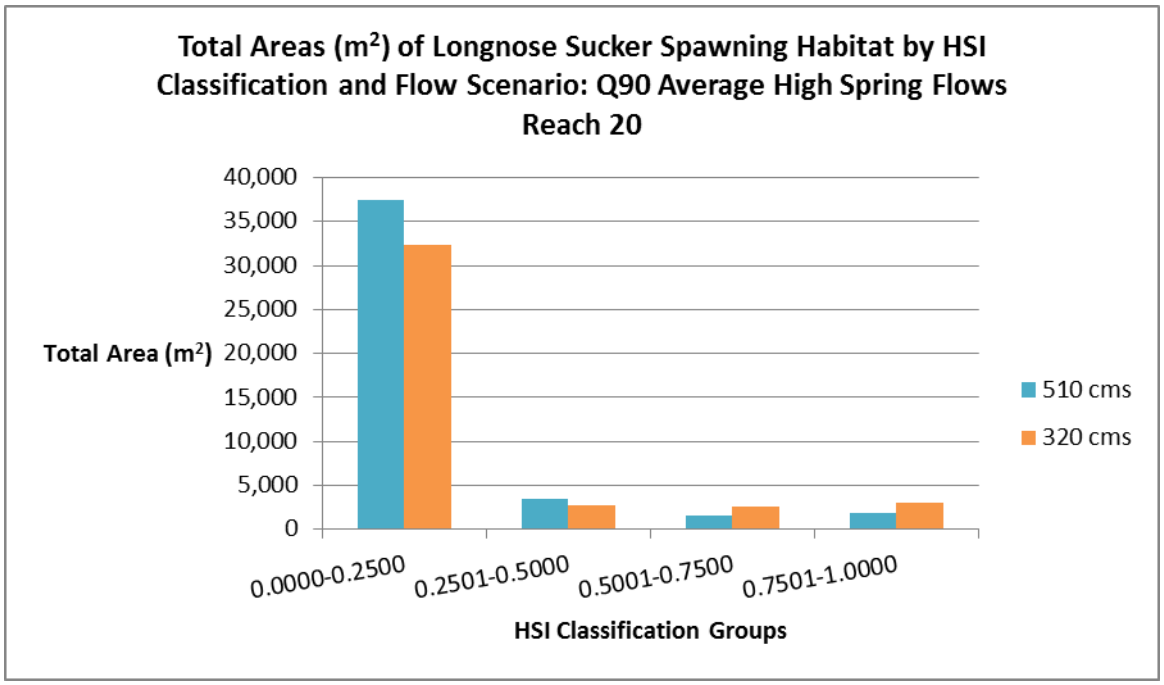


Figure E96: Total Areas of Longnose Sucker Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

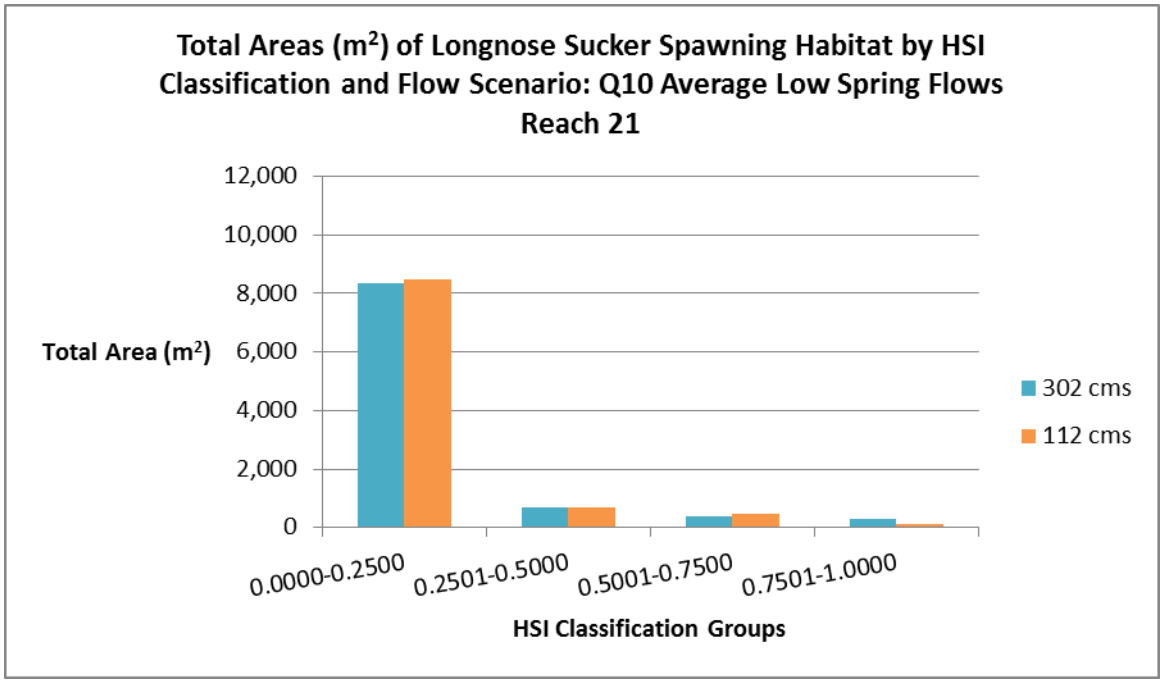


Figure E97: Total Areas of Longnose Sucker Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

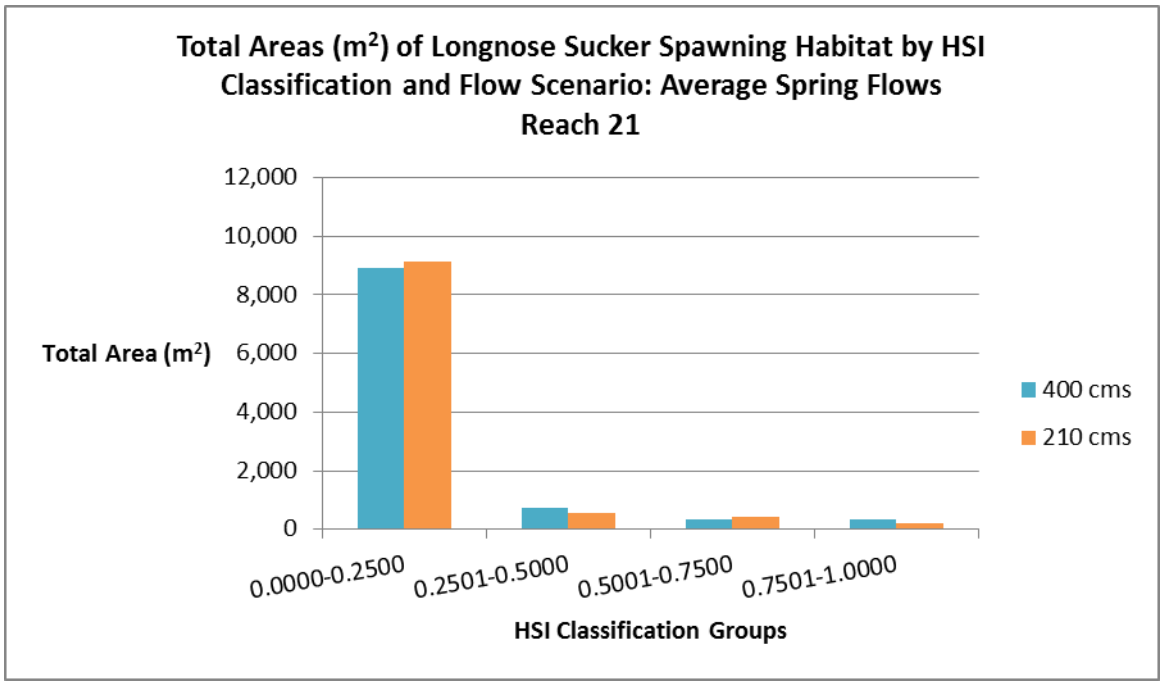


Figure E98: Total Areas of Longnose Sucker Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

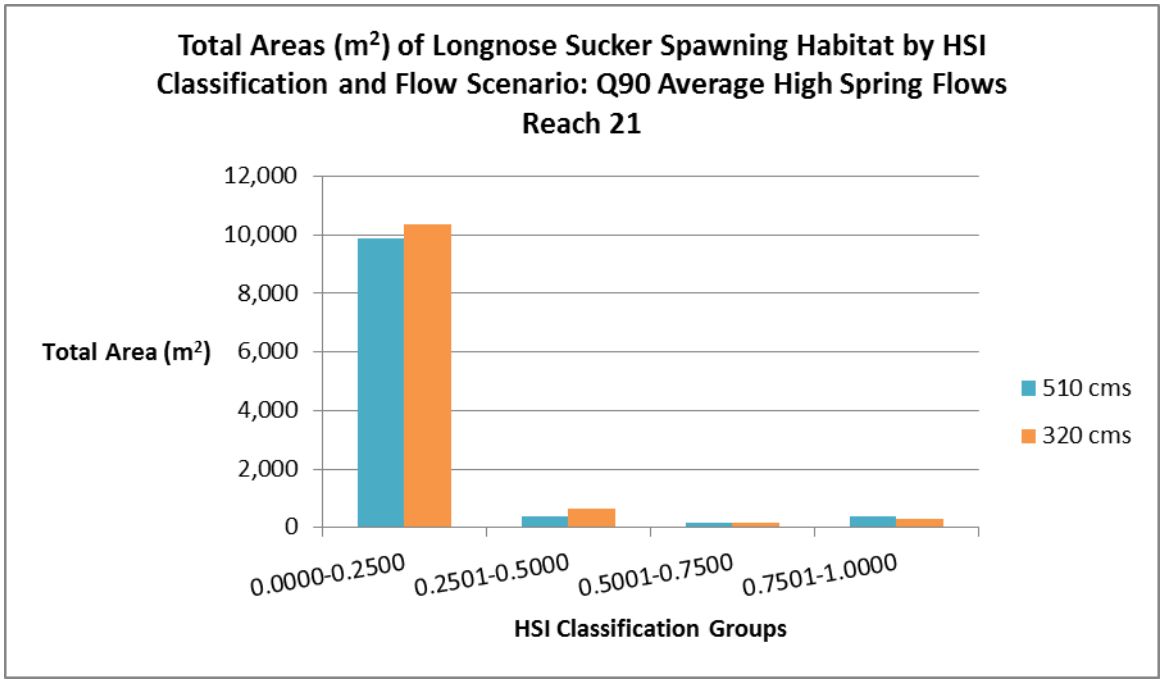


Figure E99: Total Areas of Longnose Sucker Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

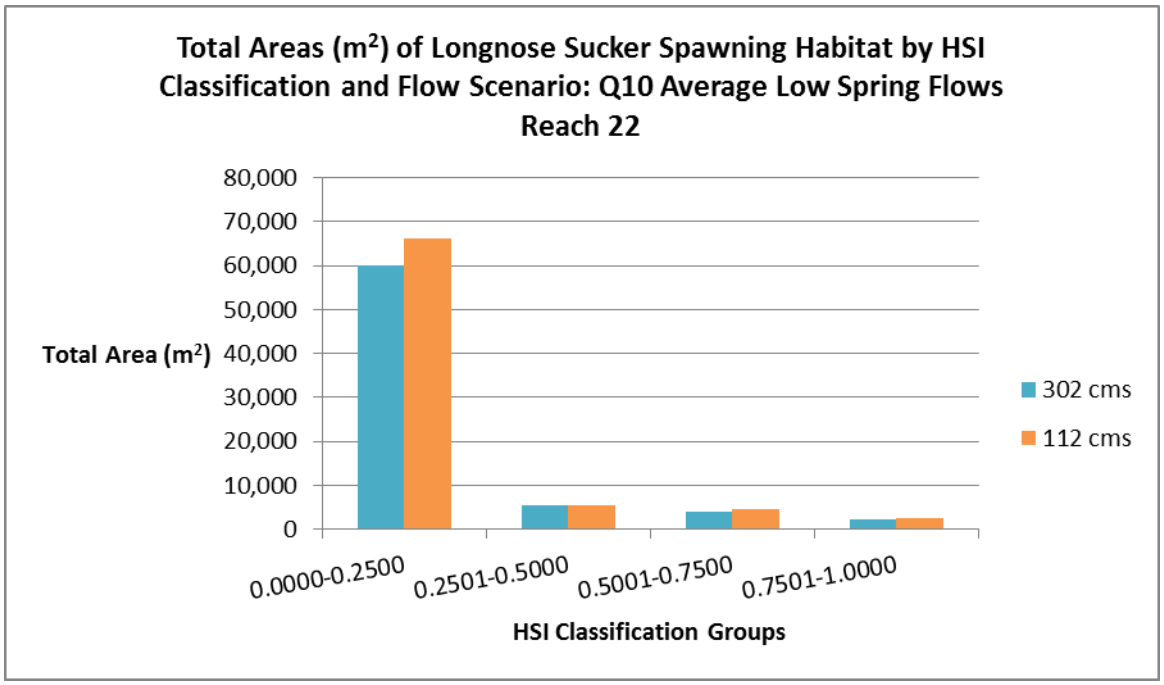


Figure E100: Total Areas of Longnose Sucker Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

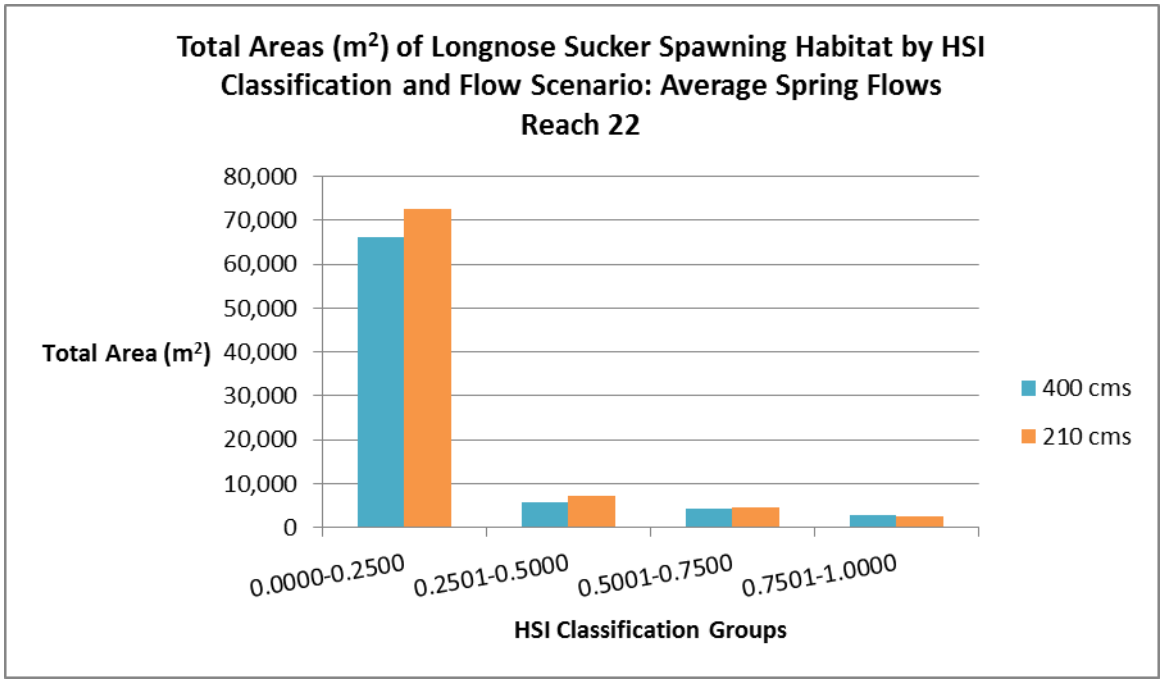


Figure 101: Total Areas of Longnose Sucker Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

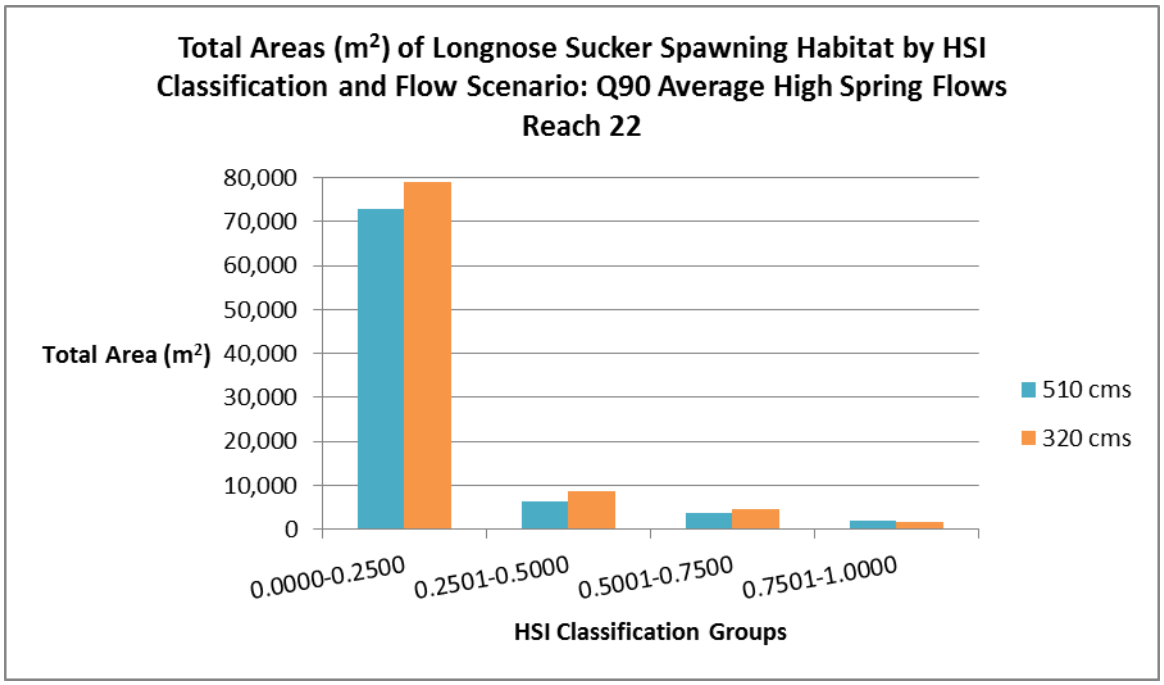


Figure 102: Total Areas of Longnose Sucker Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

Table E3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to White Sucker (*Catostomus commersonii*) by Reach for Six Spring Flows

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 2										
0.0000-0.2500	Unsuitable	40,652	35,476	-12.7	42,428	37,386	-11.9	44,549	41,222	-7.5
0.2501-0.5000	Poor	1,334	425	-68.1	585	930	59.0	339	696	105.3
0.5001-0.7500	Moderately Suitable	662	0	-100.0	746	394	-47.2	0	175	100.0
0.7501-1.0000	Suitable	267	0	-100.0	358	455	27.1	0	541	100.0
Reach 3										
0.0000-0.2500	Unsuitable	55,151	44,350	-19.6	60,212	51,087	-15.2	65,086	56,935	-12.5
0.2501-0.5000	Poor	2,345	1,599	-31.8	2,266	1,939	-14.4	1,694	2,118	25.0
0.5001-0.7500	Moderately Suitable	1,922	1,045	-45.6	1,514	1,414	-6.6	658	860	30.7
0.7501-1.0000	Suitable	1,683	1,071	-36.4	769	1,167	51.8	478	1,806	277.8
Reach 4										
0.0000-0.2500	Unsuitable	30,733	26,811	-12.8	32,968	28,739	-12.8	35,037	30,400	-13.2
0.2501-0.5000	Poor	567	269	-52.6	657	326	-50.4	624	1,149	84.1
0.5001-0.7500	Moderately Suitable	87	43	-50.6	402	193	-52.0	358	476	33.0
0.7501-1.0000	Suitable	129	30	-76.7	291	81	-72.2	0	0	0.0
Reach 5										
0.0000-0.2500	Unsuitable	11,845	8,773	-25.9	12,932	10,742	-16.9	13,361	11,953	-10.5
0.2501-0.5000	Poor	290	93	-67.9	182	317	74.2	423	390	-7.8
0.5001-0.7500	Moderately Suitable	132	279	111.4	138	187	35.5	183	80	-56.3
0.7501-1.0000	Suitable	125	180	44.0	122	208	70.5	0	0	0.0

Table E3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to White Sucker (*Catostomus commersonii*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 6										
0.0000-0.2500	Unsuitable	14,543	10,723	-26.3	16,256	12,783	-21.4	17,202	15,203	-11.6
0.2501-0.5000	Poor	575	385	-33.0	418	481	15.1	311	614	97.4
0.5001-0.7500	Moderately Suitable	228	215	-5.7	85	403	374.1	131	210	60.3
0.7501-1.0000	Suitable	136	81	-40.4	165	212	28.5	0	0	0.0
Reach 7										
0.0000-0.2500	Unsuitable	9,854	8,304	-15.7	10,247	8,911	-13.0	11,240	9,615	-14.5
0.2501-0.5000	Poor	189	206	9.0	363	95	-73.8	209	112	-46.4
0.5001-0.7500	Moderately Suitable	35	34	-2.9	161	200	24.2	182	187	2.7
0.7501-1.0000	Suitable	54	0	-100.0	48	48	0.0	188	0	-100.0
Reach 8										
0.0000-0.2500	Unsuitable	18,562	17,055	-8.1	19,162	17,666	-7.8	19,698	18,766	-4.7
0.2501-0.5000	Poor	79	127	60.8	208	182	-12.5	305	135	-55.7
0.5001-0.7500	Moderately Suitable	115	0	-100.0	155	53	-65.8	0	0	0.0
0.7501-1.0000	Suitable	107	0	-100.0	38	13	-65.8	76	81	6.6
Reach 9										
0.0000-0.2500	Unsuitable	30,548	27,559	-9.8	32,713	28,841	-11.8	33,969	31,664	-6.8
0.2501-0.5000	Poor	734	312	-57.5	594	333	-43.9	652	723	10.9
0.5001-0.7500	Moderately Suitable	494	63	-87.2	447	15	-96.6	318	333	4.7
0.7501-1.0000	Suitable	114	0	-100.0	372	72	-80.6	145	257	77.2

Table E3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to White Sucker (*Catostomus commersonii*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 10										
0.0000-0.2500	Unsuitable	6,501	4,972	-23.5	7,198	6,169	-14.3	7,445	6,482	-12.9
0.2501-0.5000	Poor	157	149	-5.1	92	41	-55.4	72	228	216.7
0.5001-0.7500	Moderately Suitable	76	145	90.8	96	64	-33.3	82	44	-46.3
0.7501-1.0000	Suitable	163	209	28.2	90	74	-17.8	0	177	100.0
Reach 11										
0.0000-0.2500	Unsuitable	18,082	16,707	-7.6	18,771	17,137	-8.7	19,999	18,320	-8.4
0.2501-0.5000	Poor	88	41	-53.4	191	220	15.2	171	172	0.6
0.5001-0.7500	Moderately Suitable	34	0	-100.0	15	58	286.7	167	0	-100.0
0.7501-1.0000	Suitable	12	60	400.0	283	16	-94.3	0	95	100.0
Reach 12										
0.0000-0.2500	Unsuitable	7,602	6,210	-18.3	8,439	6,887	-18.4	9,153	7,519	-17.9
0.2501-0.5000	Poor	138	69	-50.0	270	217	-19.6	302	242	-19.9
0.5001-0.7500	Moderately Suitable	80	131	63.8	414	79	-80.9	371	216	-41.8
0.7501-1.0000	Suitable	104	94	-9.6	272	118	-56.6	0	65	100.0
Reach 13										
0.0000-0.2500	Unsuitable	33,550	31,981	-4.7	33,905	32,873	-3.0	34,024	33,424	-1.8
0.2501-0.5000	Poor	118	163	38.1	417	164	-60.7	242	47	-80.6
0.5001-0.7500	Moderately Suitable	59	79	33.9	163	0	-100.0	84	79	-6.0
0.7501-1.0000	Suitable	37	0	-100.0	77	17	-77.9	138	72	-47.8

Table E3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to White Sucker (*Catostomus commersonii*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 14										
0.0000-0.2500	Unsuitable	85,646	59,949	-30.0	94,378	73,276	-22.4	101,822	86,970	-14.6
0.2501-0.5000	Poor	3,521	2,787	-20.8	3,004	3,988	32.8	2,114	3,411	61.4
0.5001-0.7500	Moderately Suitable	1,499	2,241	49.5	1,190	3,182	167.4	596	1,879	215.3
0.7501-1.0000	Suitable	1,271	1,701	33.8	749	2,662	255.4	796	1,409	77.0
Reach 19										
0.0000-0.2500	Unsuitable	6,630	6,359	-4.1	6,742	6,542	-3.0	6,726	6,716	-0.1
0.2501-0.5000	Poor	0	0	0.0	0	0	0.0	94	60	-36.2
0.5001-0.7500	Moderately Suitable	0	0	0.0	0	0	0.0	0	0	0.0
0.7501-1.0000	Suitable	0	0	0.0	35	0	-100.0	0	0	0.0
Reach 20										
0.0000-0.2500	Unsuitable	33,683	25,566	-24.1	38,313	29,901	-22.0	41,540	36,320	-12.6
0.2501-0.5000	Poor	2,506	1,060	-57.7	1,587	2,163	36.3	1,373	2,306	68.0
0.5001-0.7500	Moderately Suitable	1,484	656	-55.8	661	1,234	86.7	970	1,399	44.2
0.7501-1.0000	Suitable	897	417	-53.5	643	2,030	215.7	350	670	91.4
Reach 21										
0.0000-0.2500	Unsuitable	9,186	9,408	2.4	9,673	9,740	0.7	10,329	11,003	6.5
0.2501-0.5000	Poor	272	285	4.8	346	368	6.4	229	183	-20.1
0.5001-0.7500	Moderately Suitable	136	49	-64.0	142	86	-39.4	80	151	88.8
0.7501-1.0000	Suitable	112	16	-85.7	148	118	-20.3	162	92	-43.2

Table E3: Changes in the Total Area (m^2) of Unsuitable, Poor, Moderately Suitable, or Suitable Spawning Habitat Available to White Sucker (*Catostomus commersonii*) by Reach for Six Spring Flows (continued)

HSI Classification Group	HSI Classification Title	Total Area (m^2) by Reach								
		Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
		Baseline	With Project		Baseline	With Project		Baseline	With Project	
		302 m^3/s	112 m^3/s		400 m^3/s	210 m^3/s		510 m^3/s	320 m^3/s	
		Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Reach 22										
0.0000-0.2500	Unsuitable	67,127	73,481	9.5	74,078	81,850	10.5	81,236	90,334	11.2
0.2501-0.5000	Poor	3,174	3,394	6.9	2,918	2,851	-2.3	1,802	2,309	28.1
0.5001-0.7500	Moderately Suitable	736	1,012	37.5	967	1,091	12.8	940	779	-17.1
0.7501-1.0000	Suitable	638	674	5.6	856	917	7.1	530	251	-52.6

HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent.

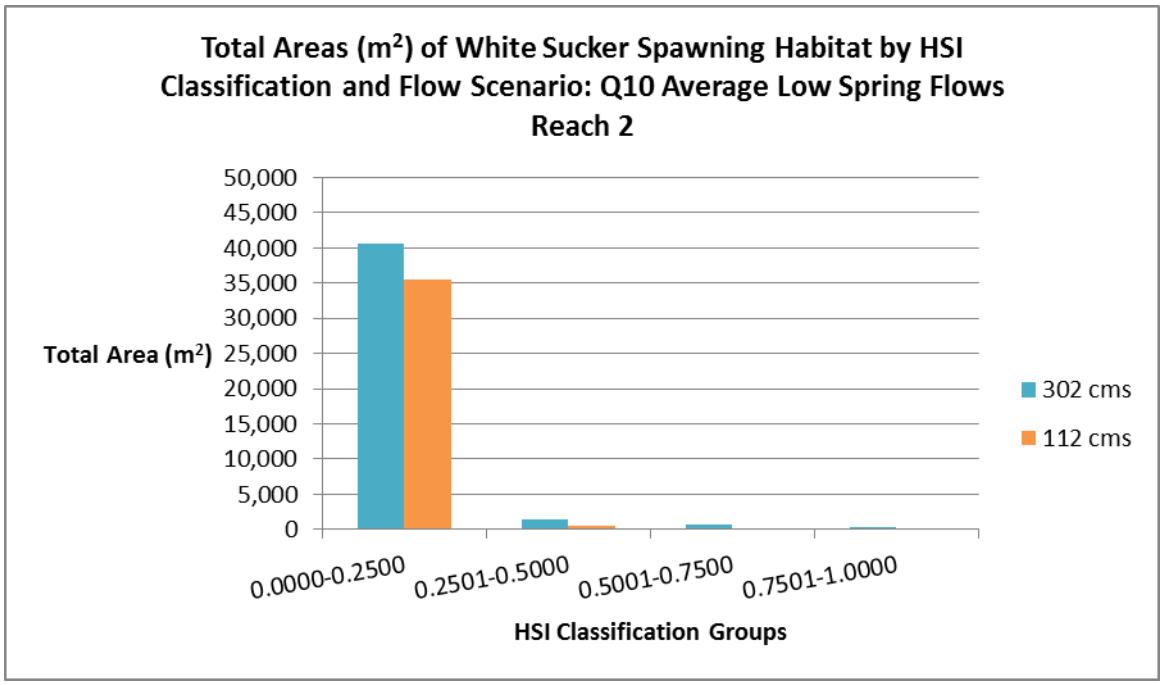


Figure E103: Total Areas of White Sucker Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

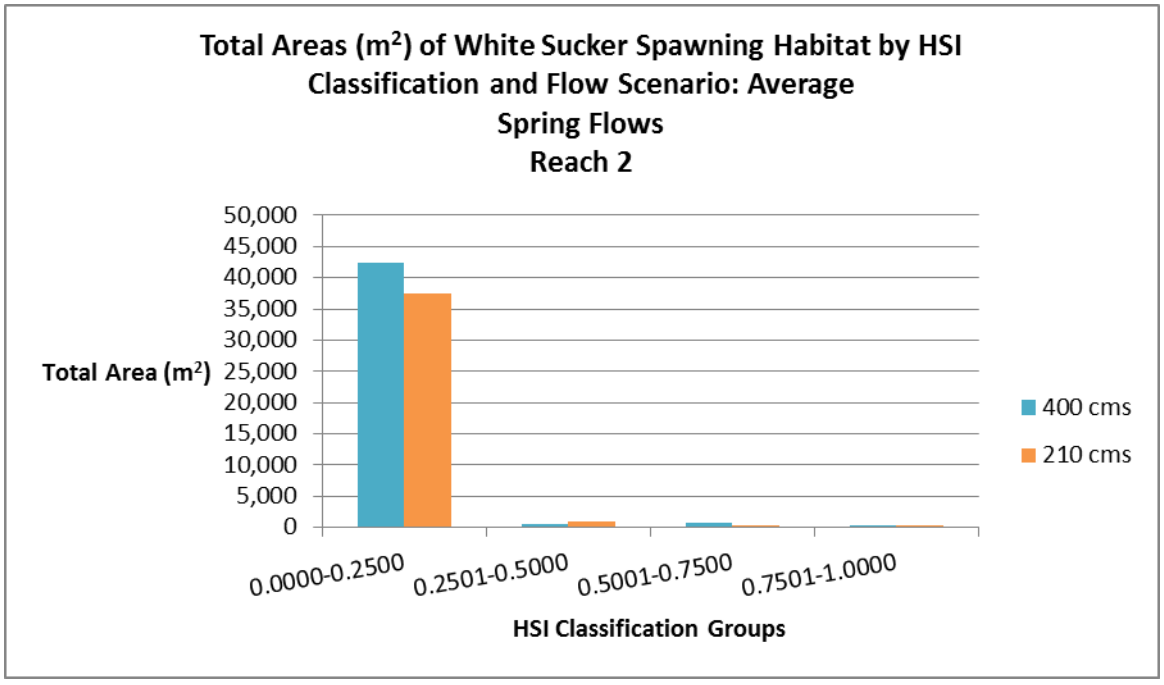


Figure E104: Total Areas of White Sucker Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 400 m^3/s /s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

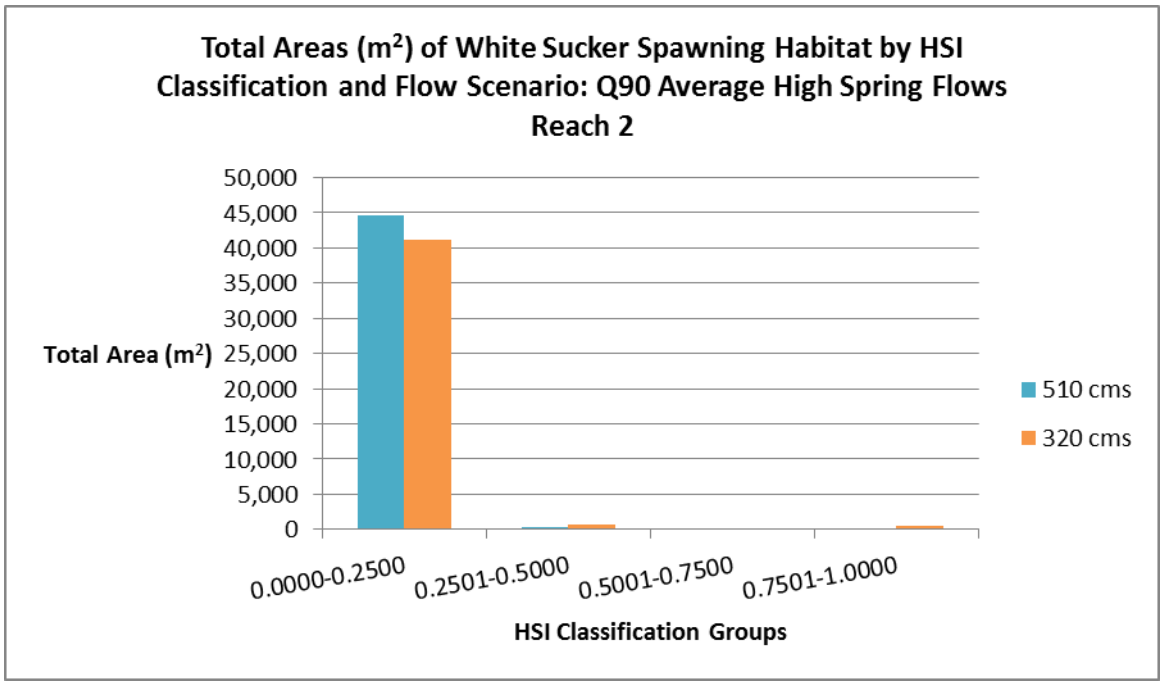


Figure E105: Total Areas of White Sucker Spawning Habitat in River Reach 2 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

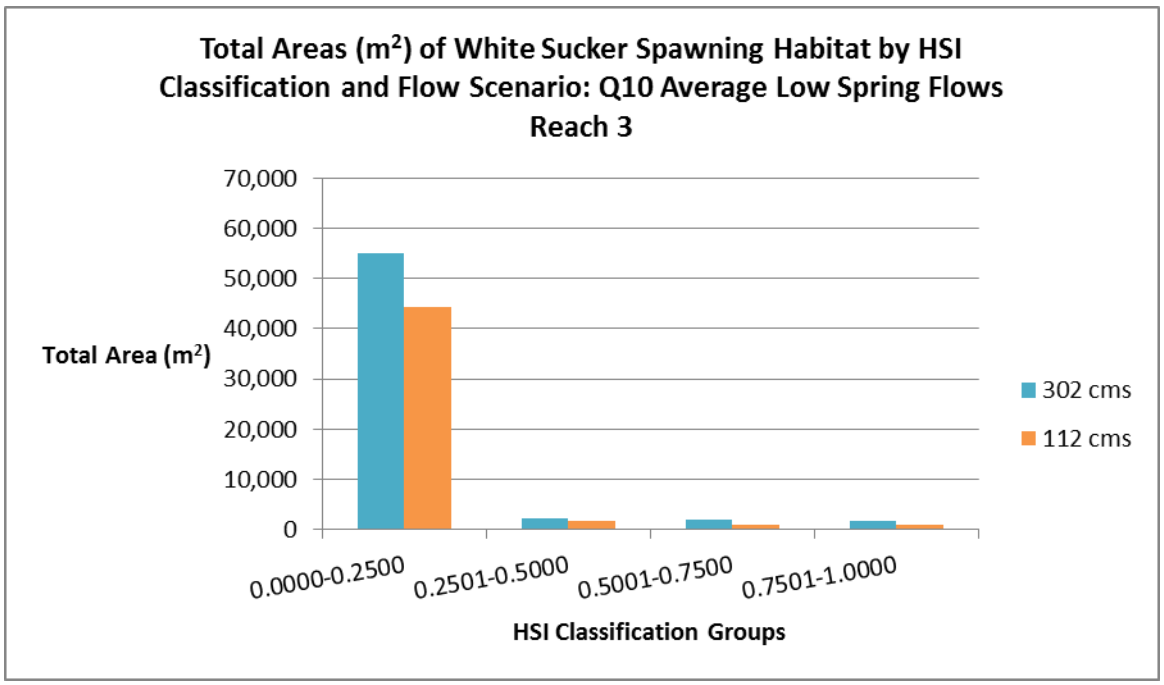


Figure E106: Total Areas of White Sucker Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

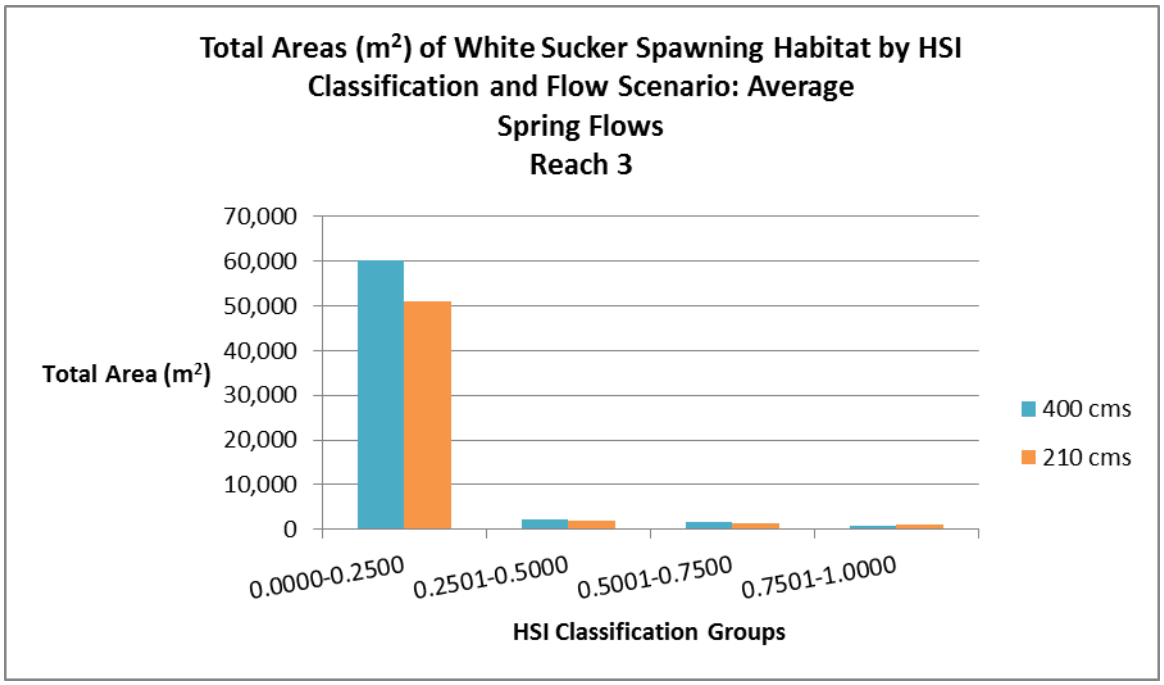


Figure E107: Total Areas of White Sucker Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

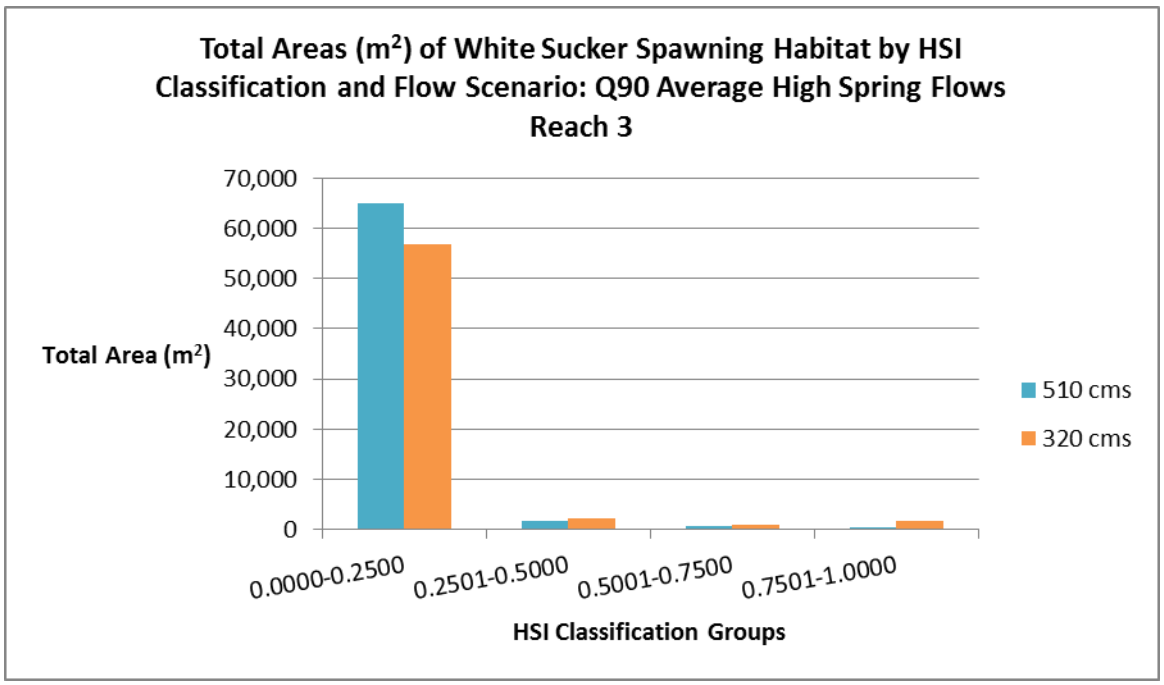


Figure E108: Total Areas of White Sucker Spawning Habitat in River Reach 3 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

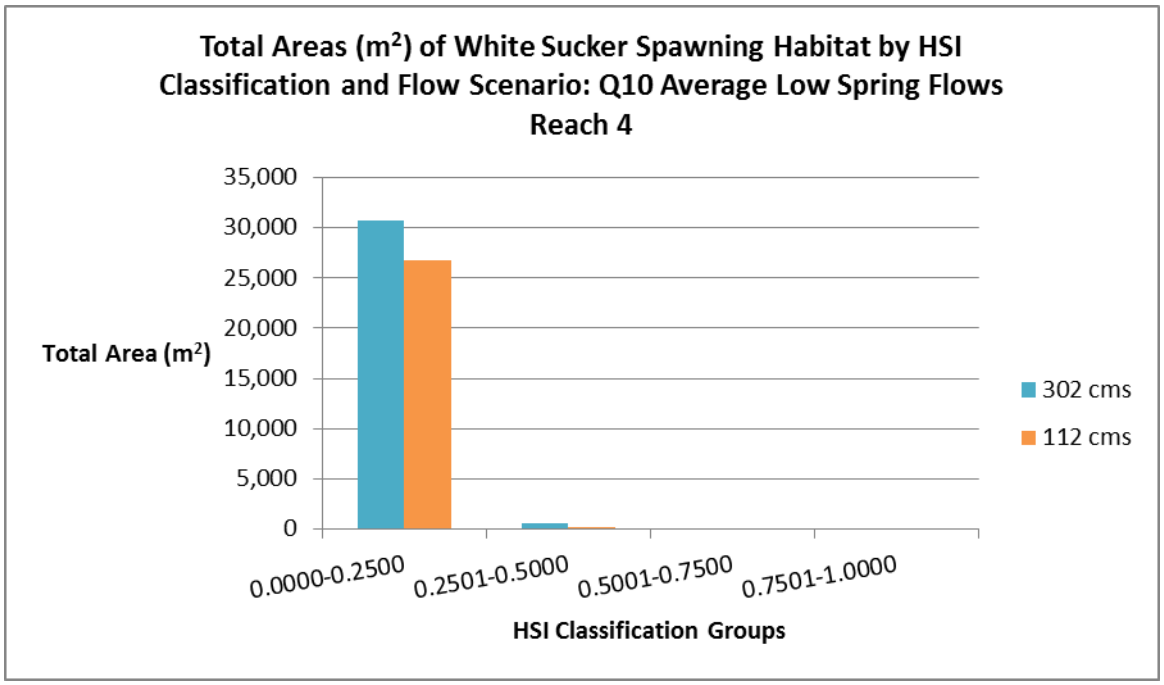


Figure E109: Total Areas of White Sucker Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

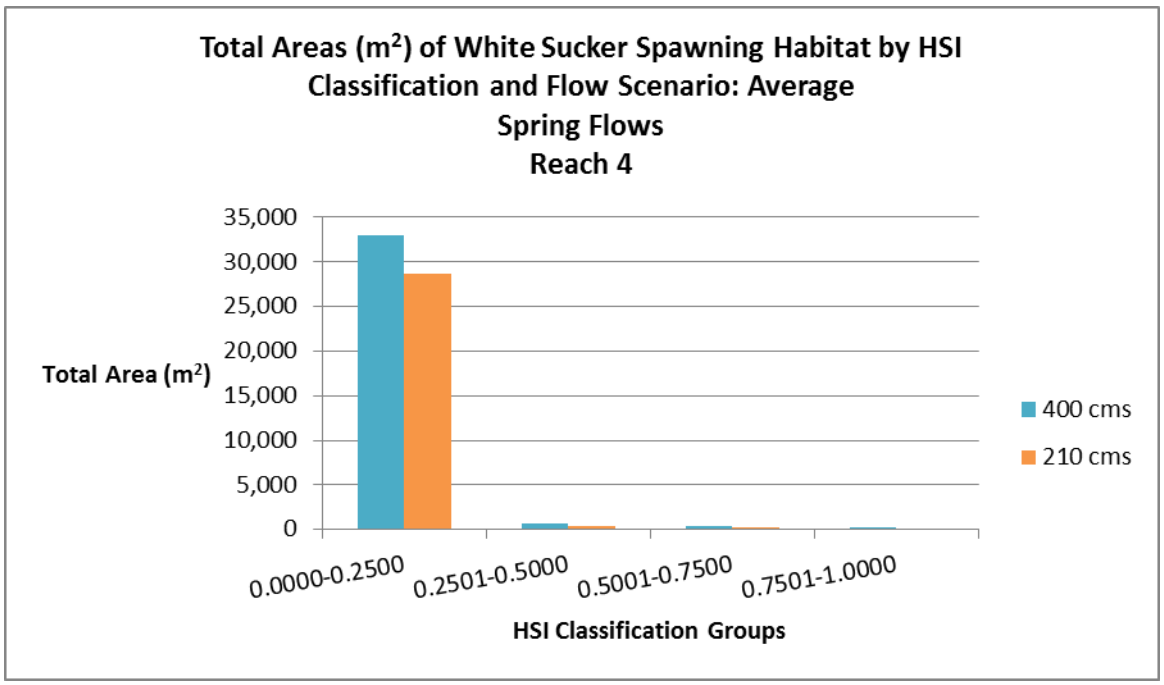


Figure E110: Total Areas of White Sucker Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

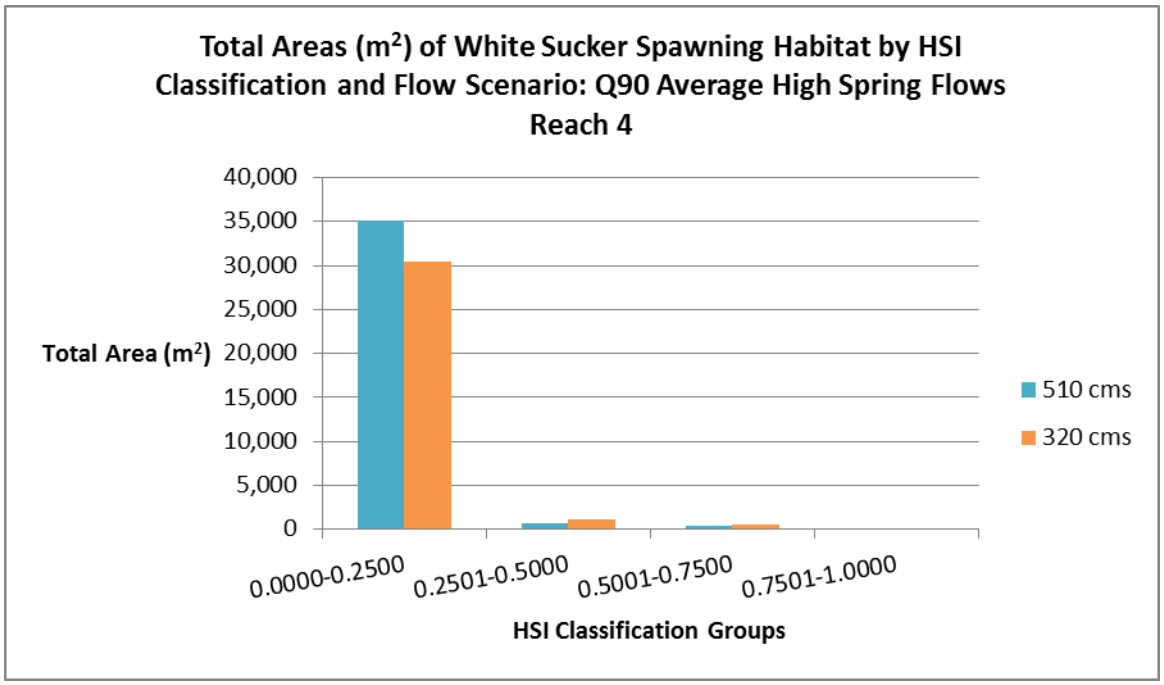


Figure E111: Total Areas of White Sucker Spawning Habitat in River Reach 4 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

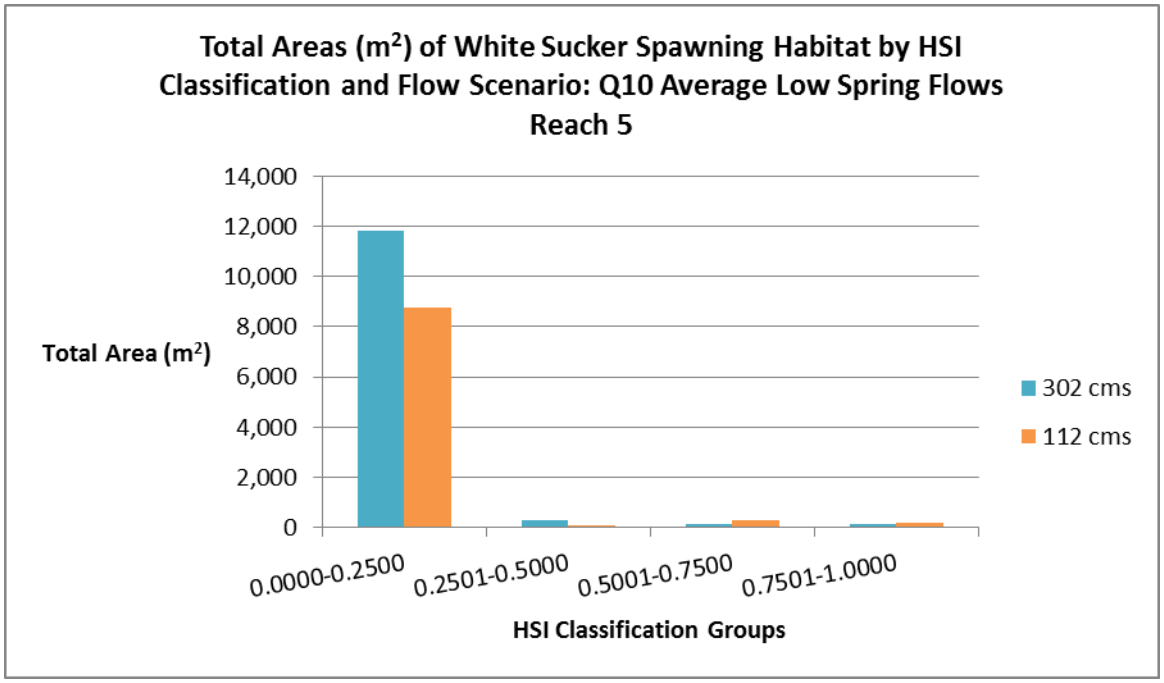


Figure E112: Total Areas of White Sucker Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

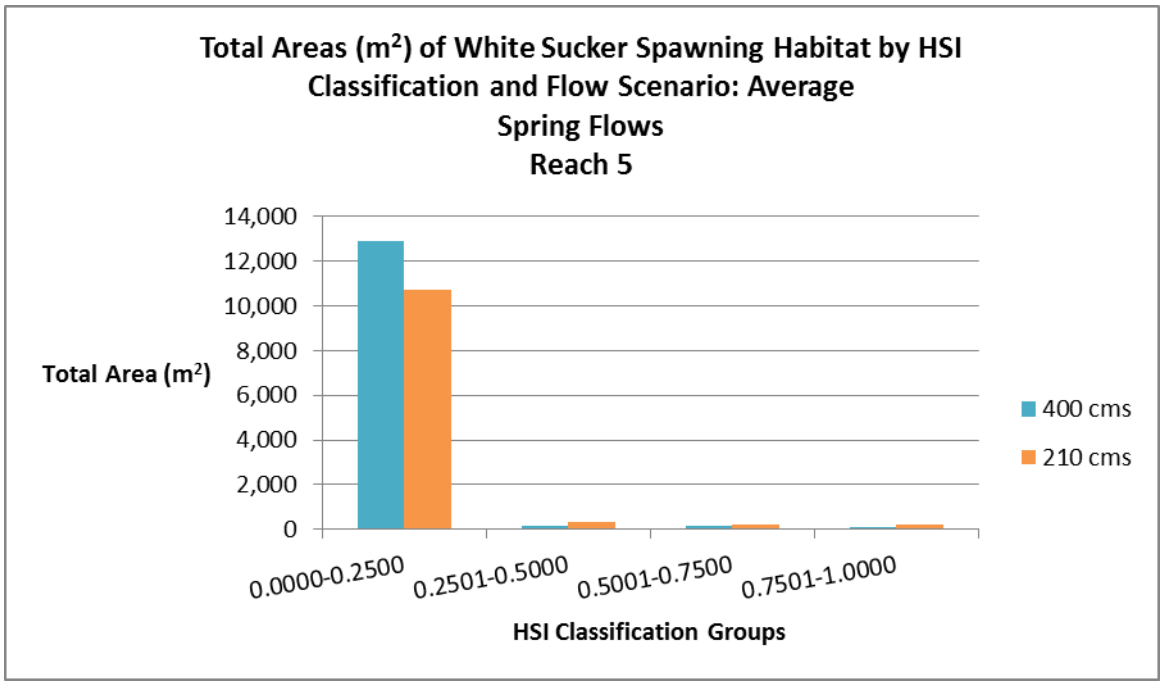


Figure E113: Total Areas of White Sucker Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

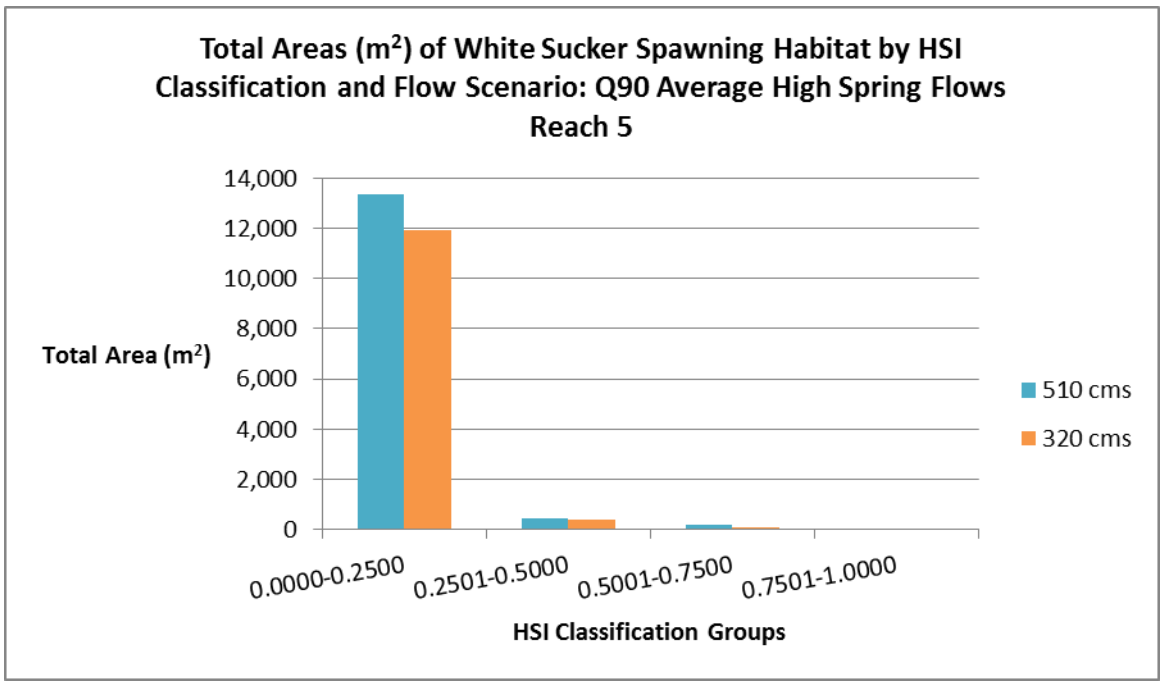


Figure E114: Total Areas of White Sucker Spawning Habitat in River Reach 5 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

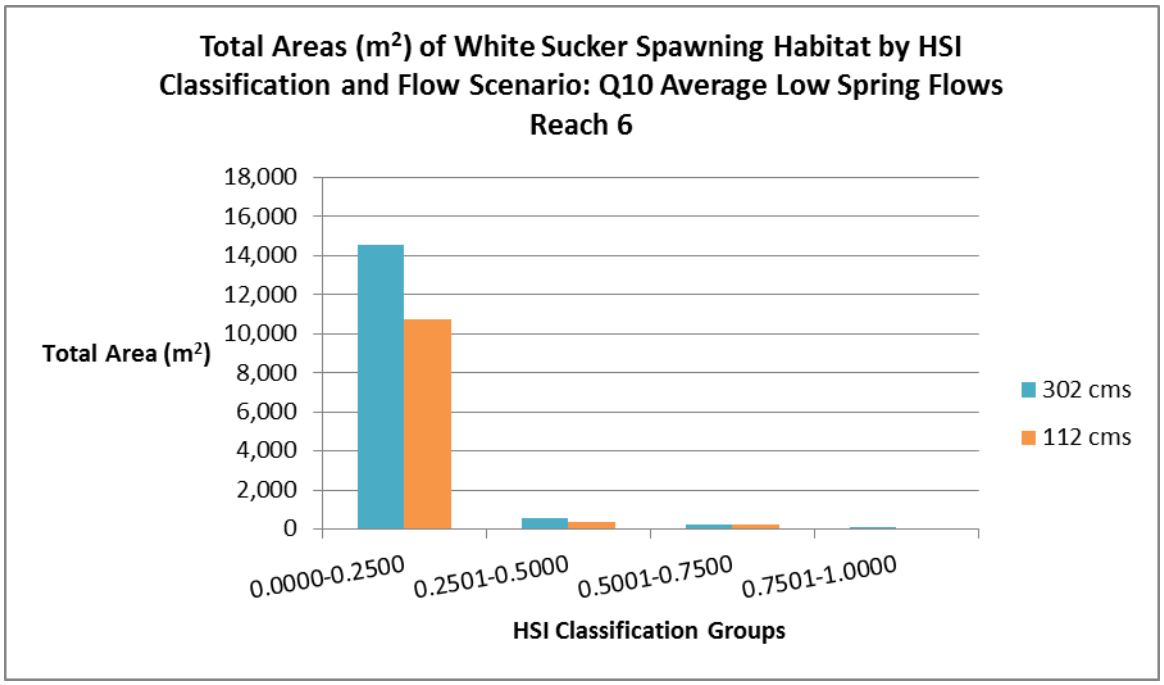


Figure E115: Total Areas of White Sucker Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

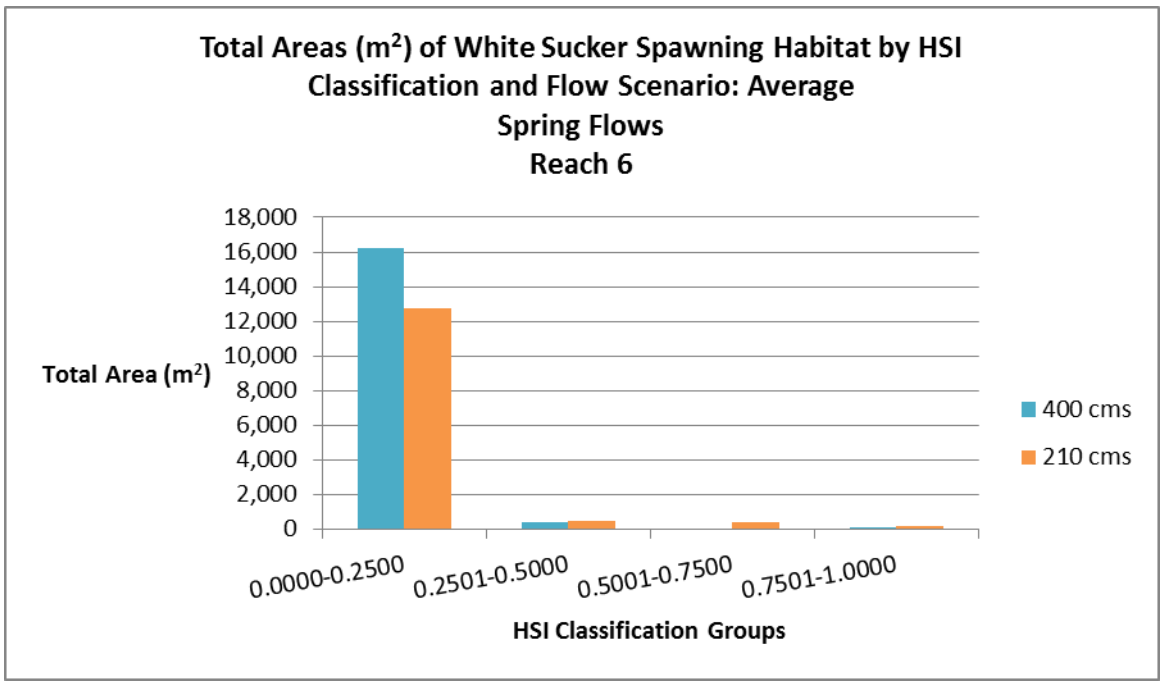


Figure E116: Total Areas of White Sucker Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

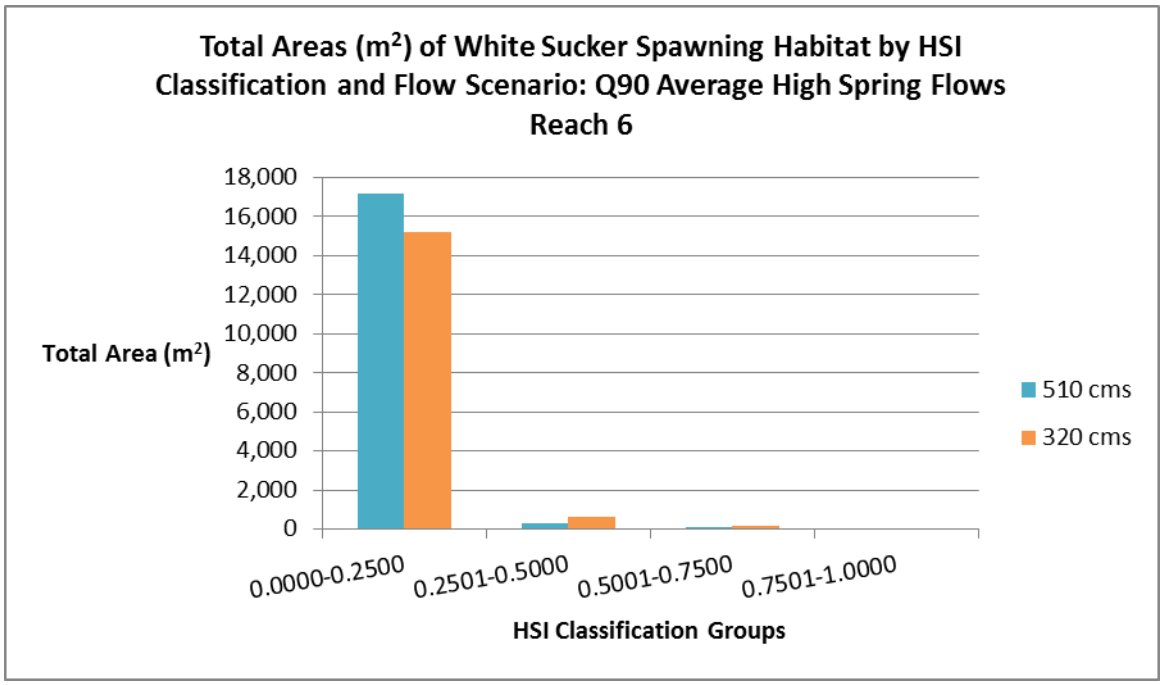


Figure E117: Total Areas of White Sucker Spawning Habitat in River Reach 6 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

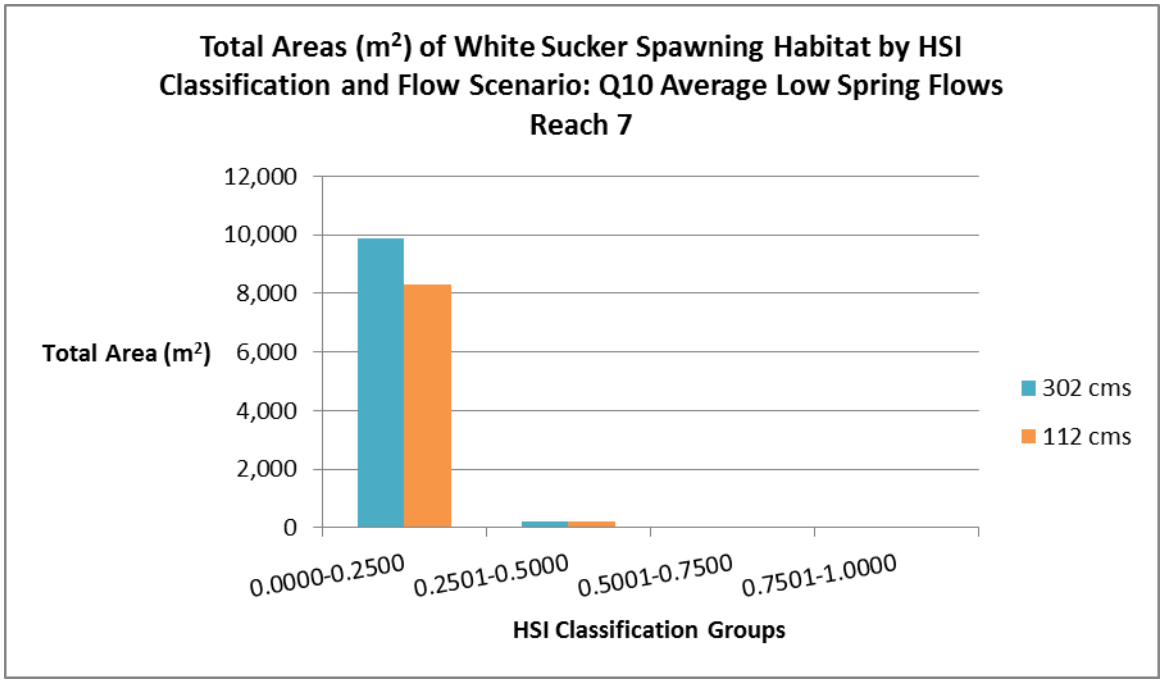


Figure E118: Total Areas of White Sucker Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

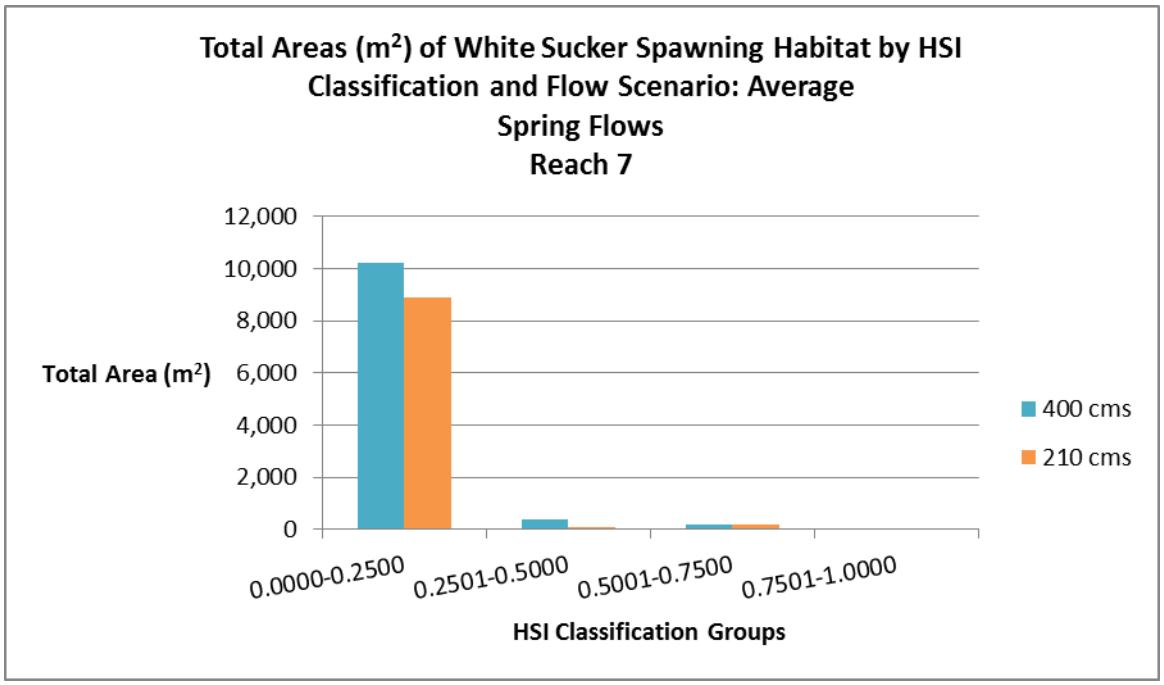


Figure E119: Total Areas of White Sucker Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

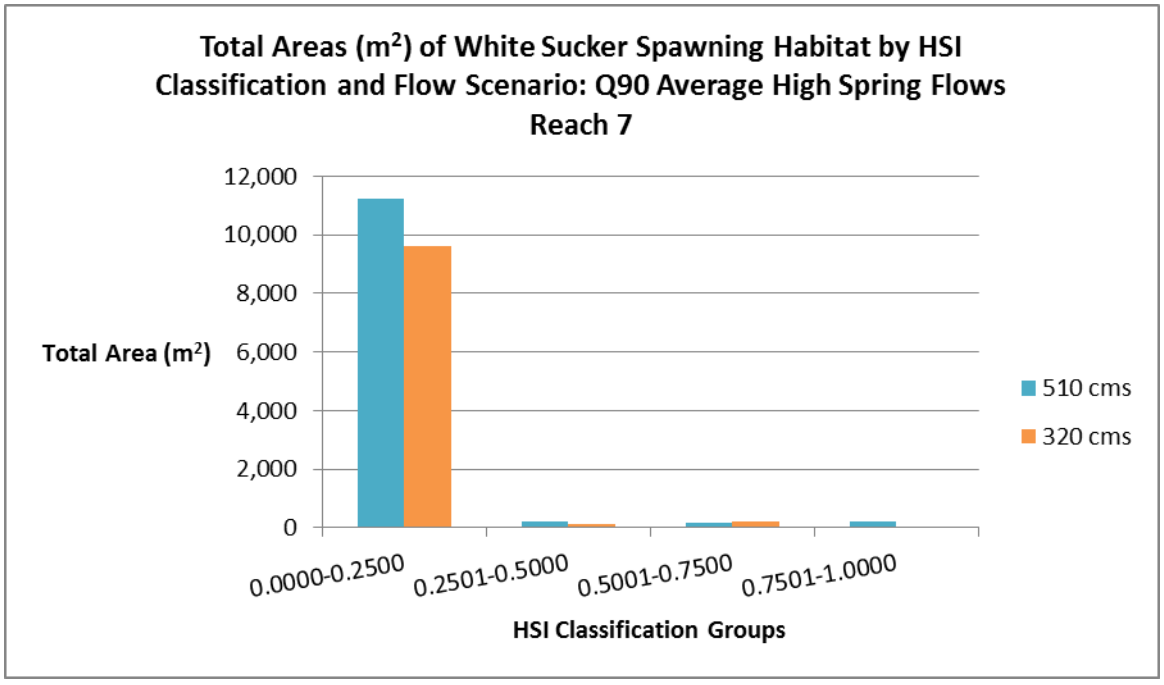


Figure E120: Total Areas of White Sucker Spawning Habitat in River Reach 7 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

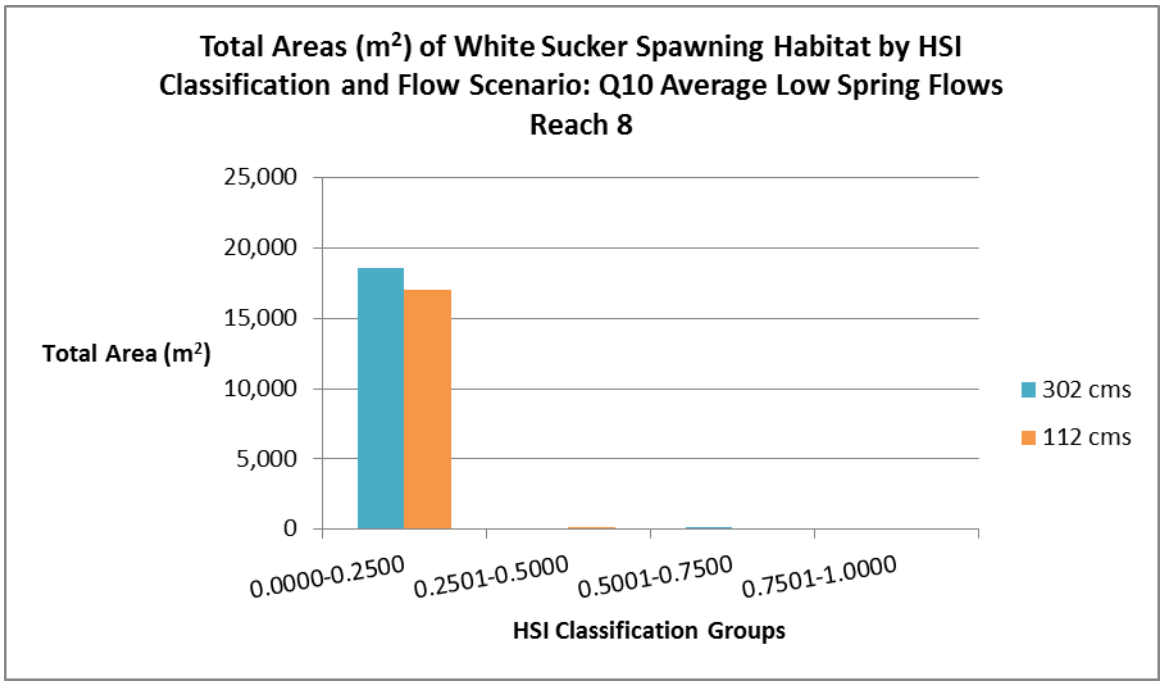


Figure E121: Total Areas of White Sucker Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

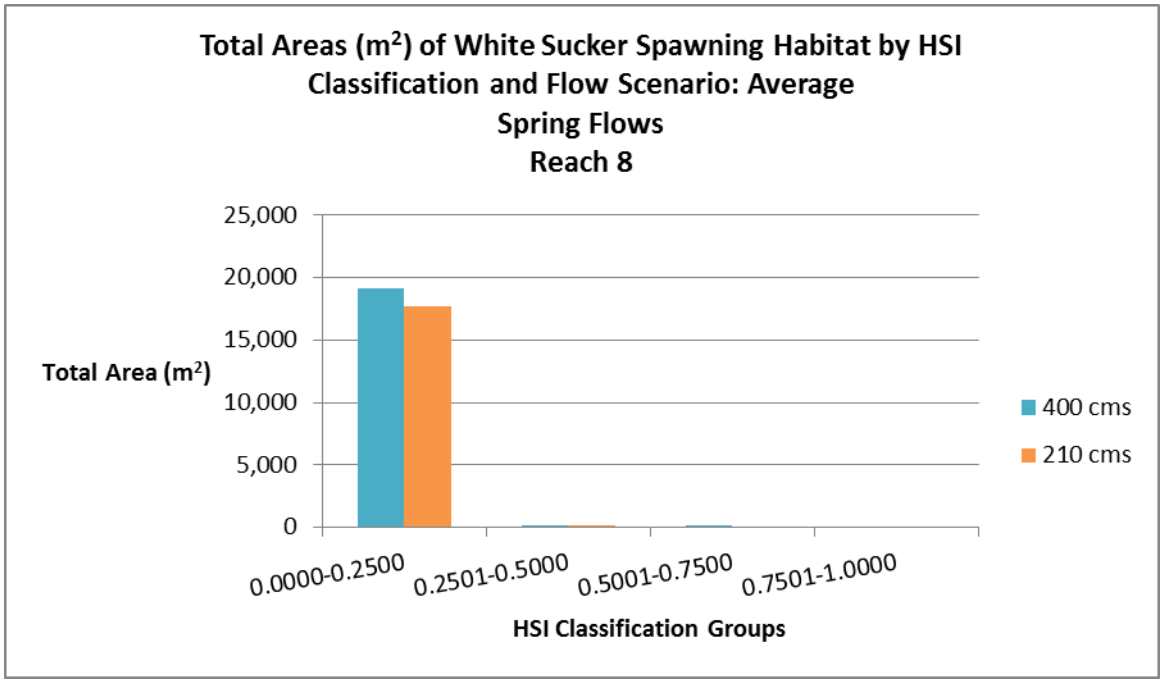


Figure E122: Total Areas of White Sucker Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

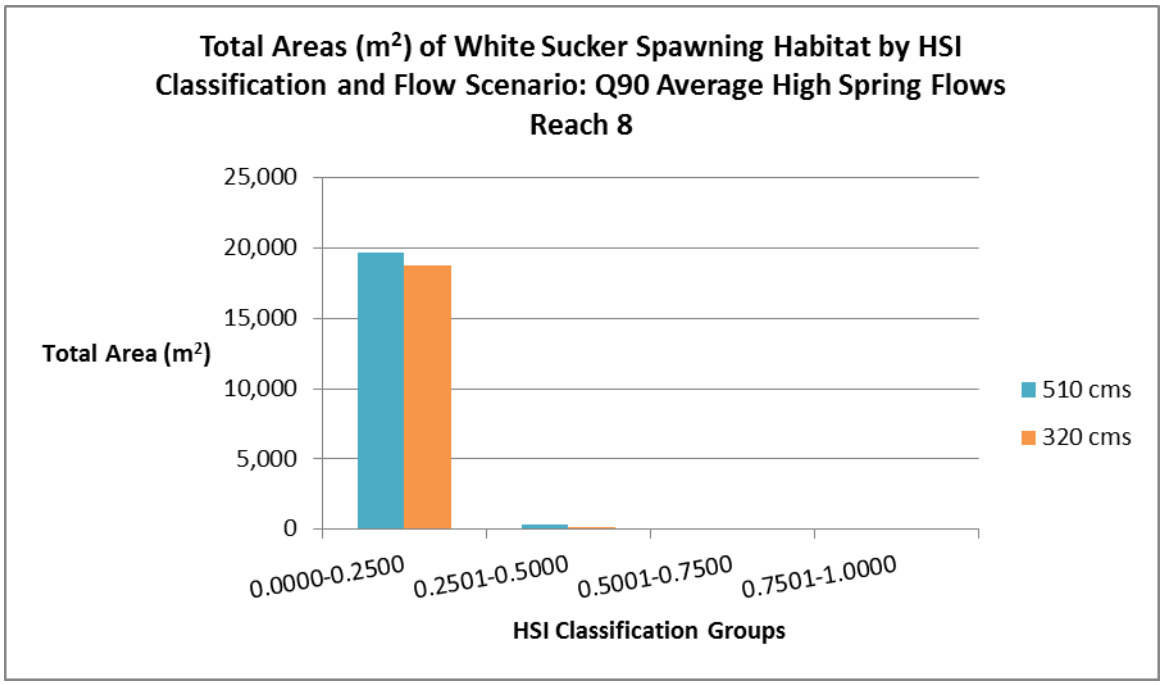


Figure E123: Total Areas of White Sucker Spawning Habitat in River Reach 8 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

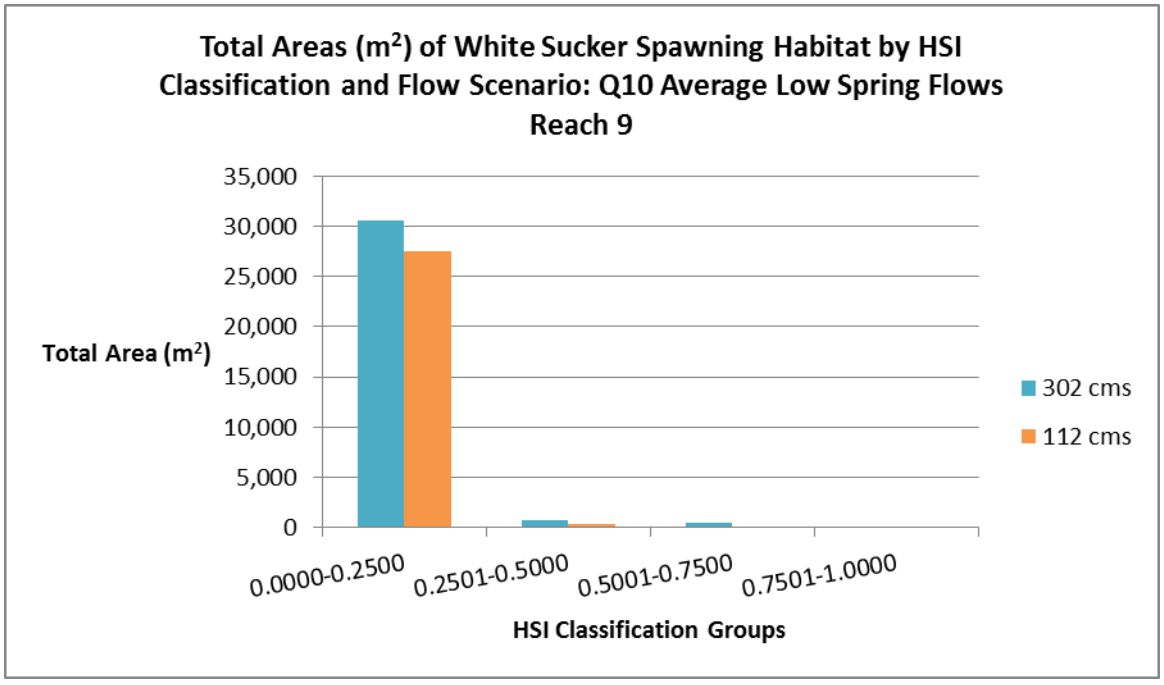


Figure E124: Total Areas of White Sucker Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

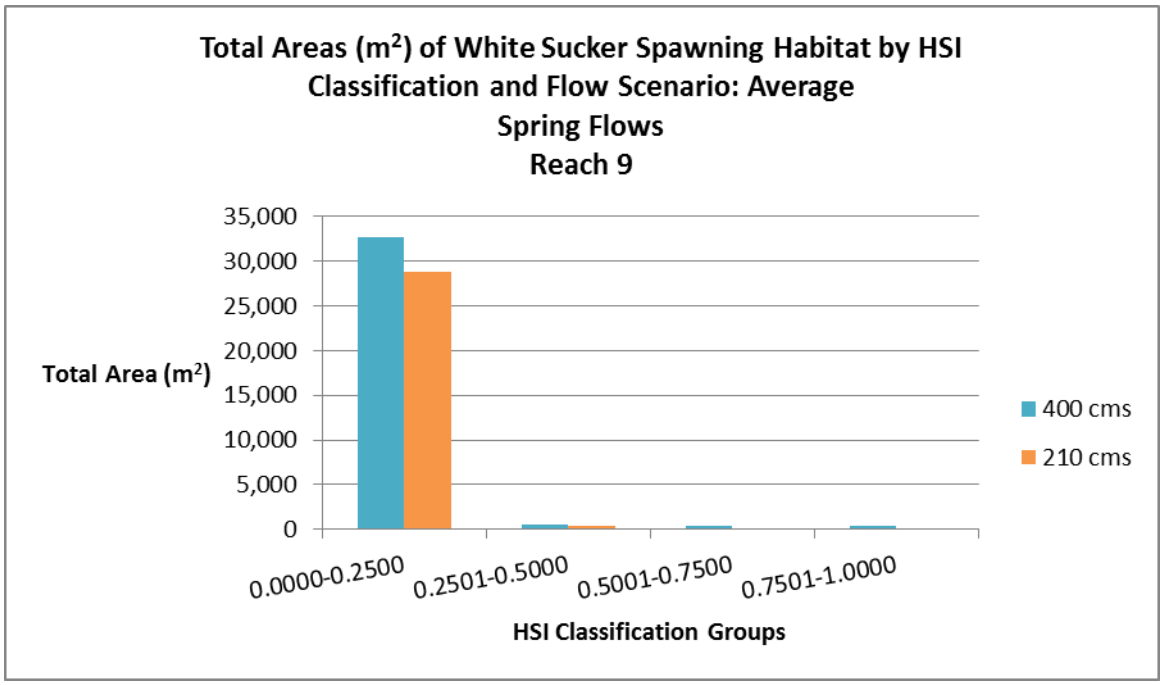


Figure E125: Total Areas of White Sucker Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

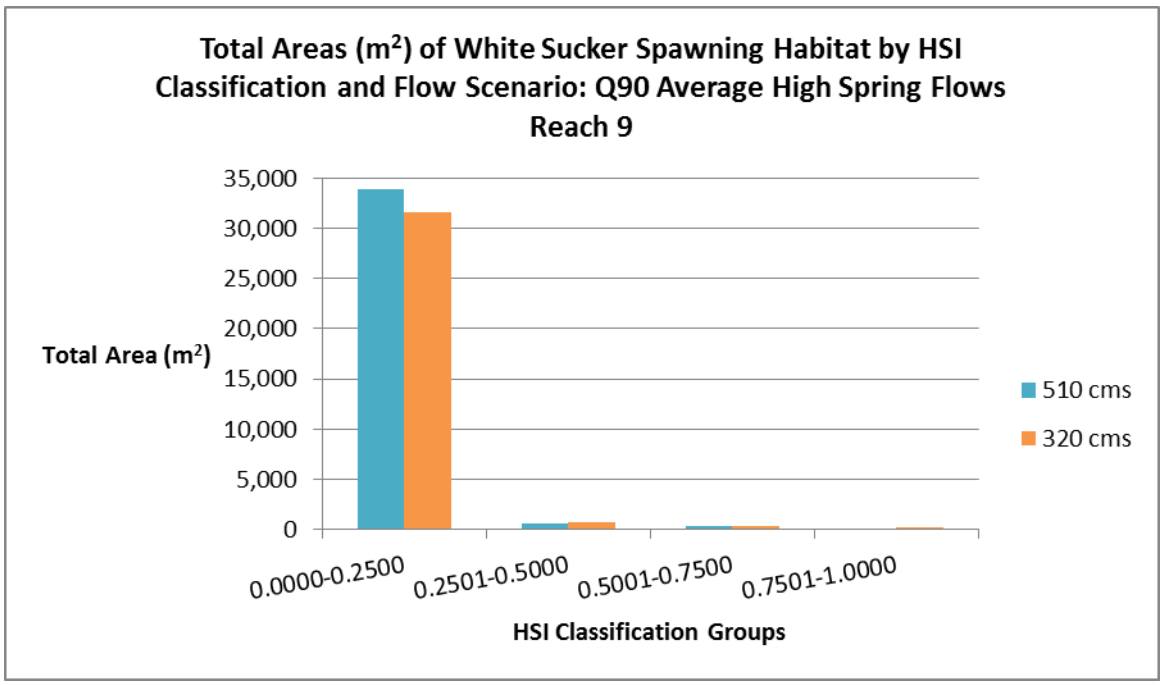


Figure E126: Total Areas of White Sucker Spawning Habitat in River Reach 9 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

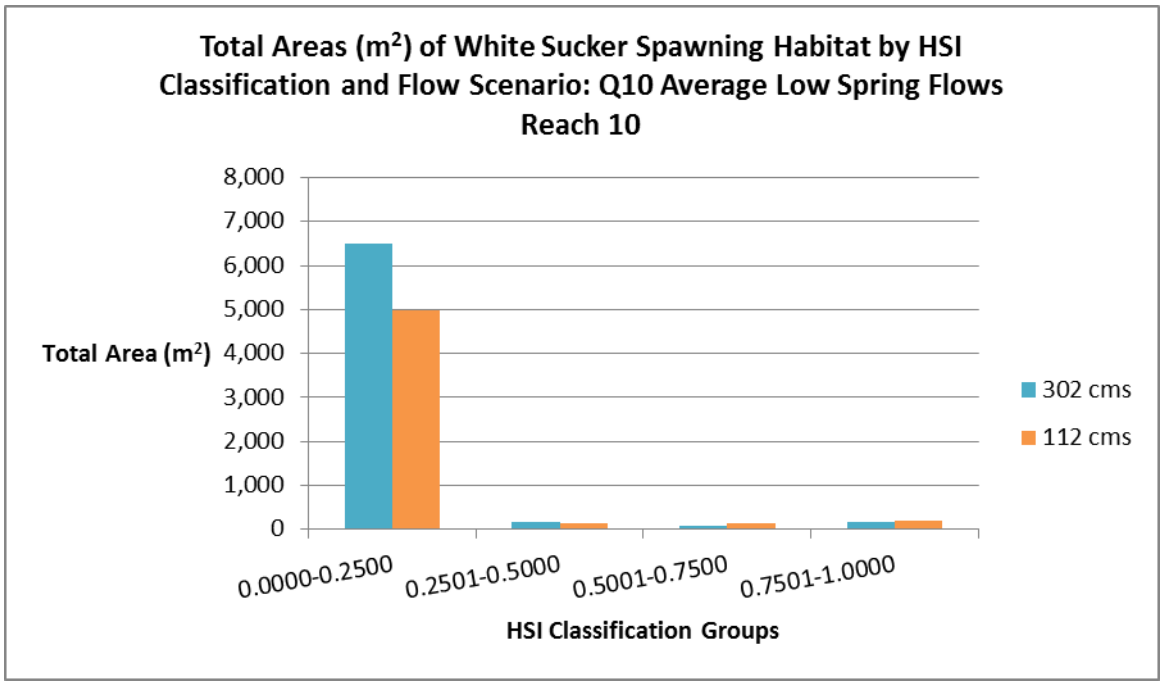


Figure E127: Total Areas of White Sucker Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

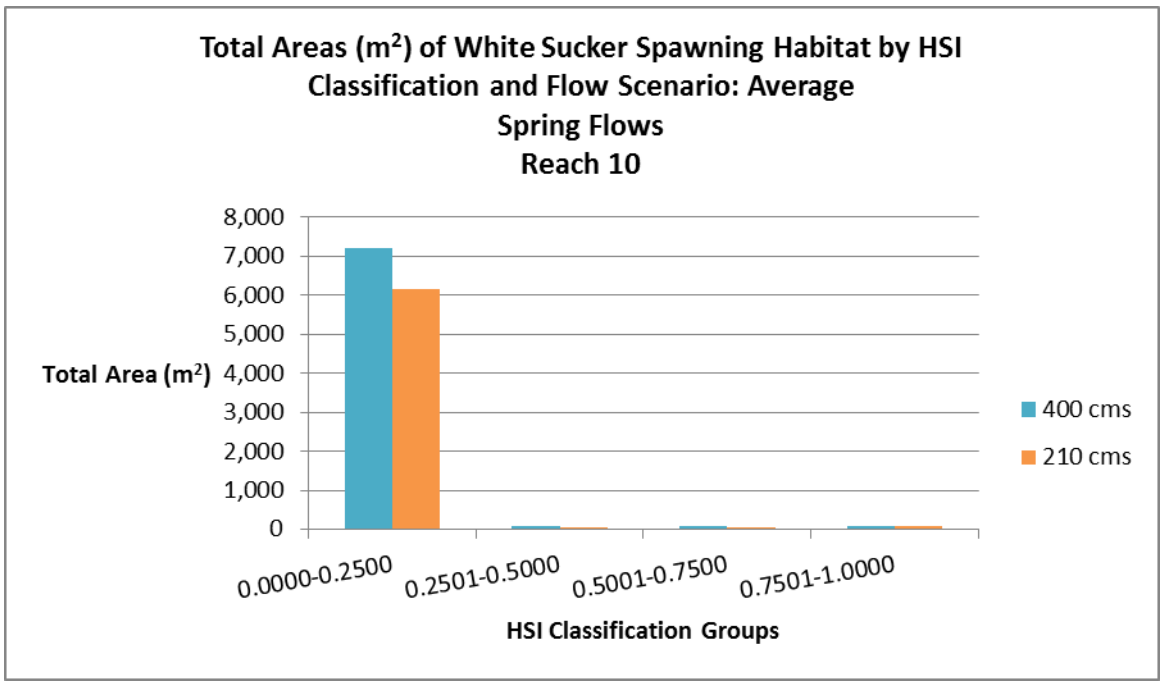


Figure E128: Total Areas of White Sucker Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

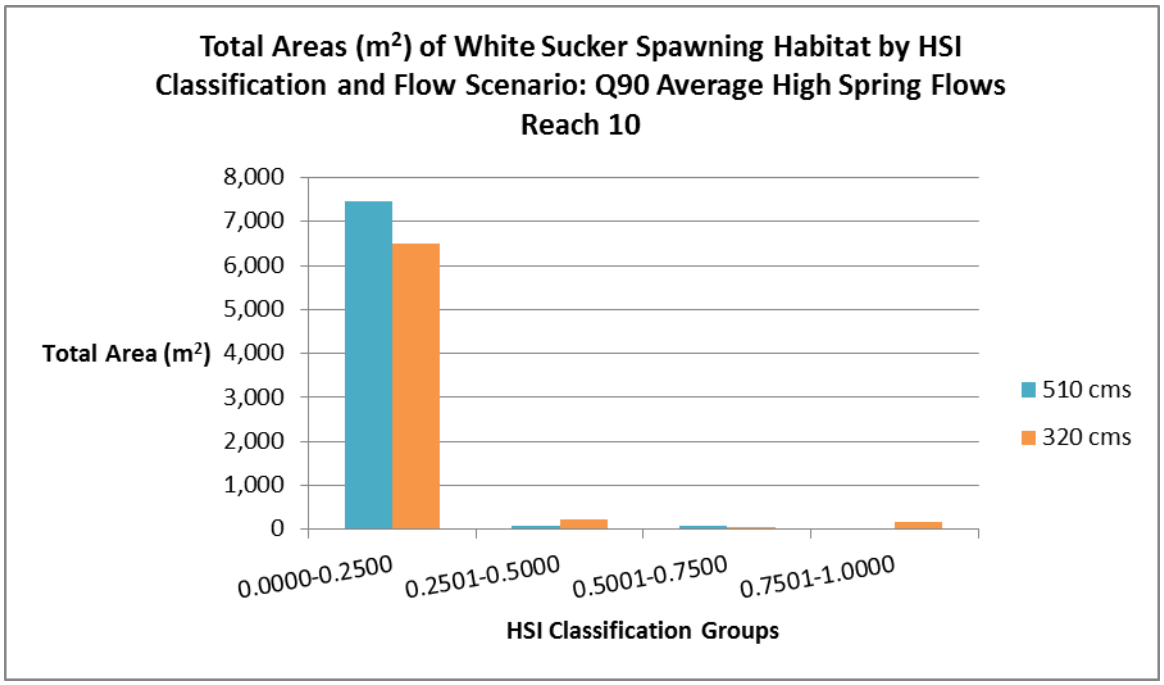


Figure E129: Total Areas of White Sucker Spawning Habitat in River Reach 10 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

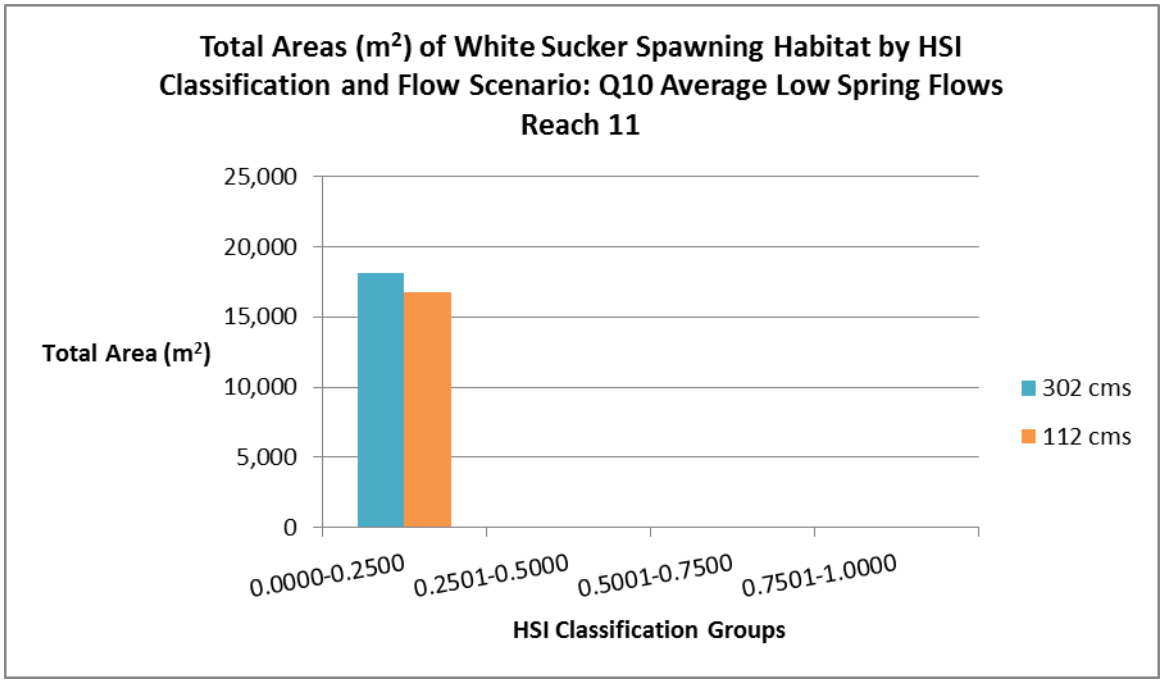


Figure E130: Total Areas of White Sucker Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

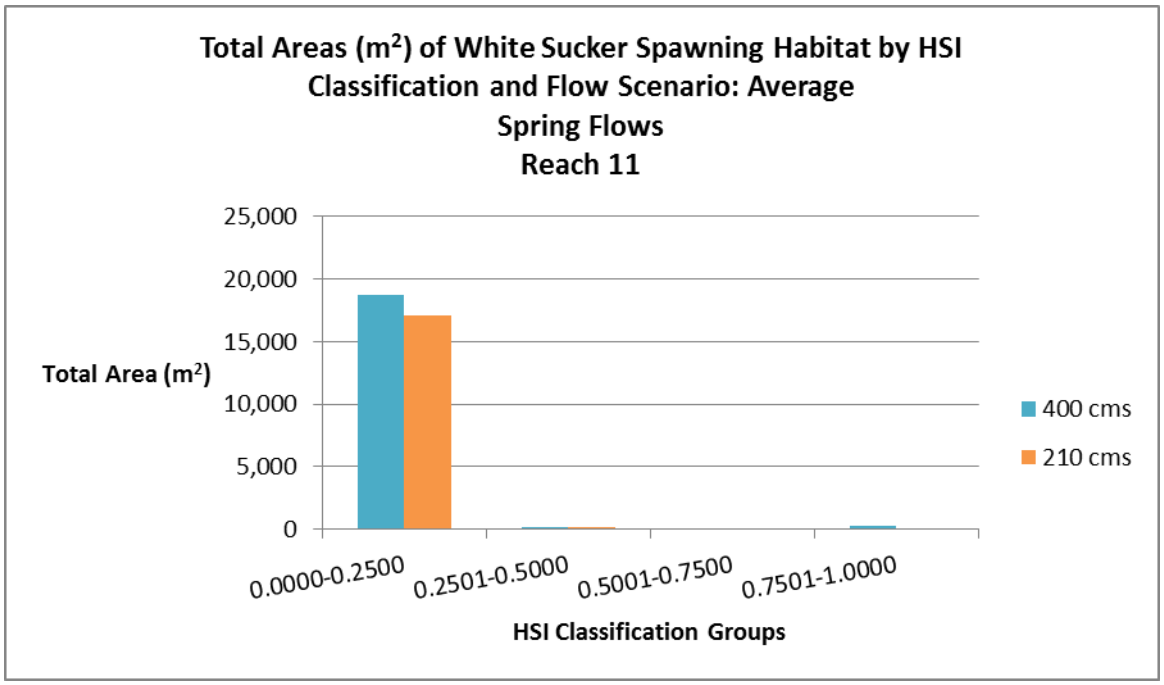


Figure E131: Total Areas of White Sucker Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

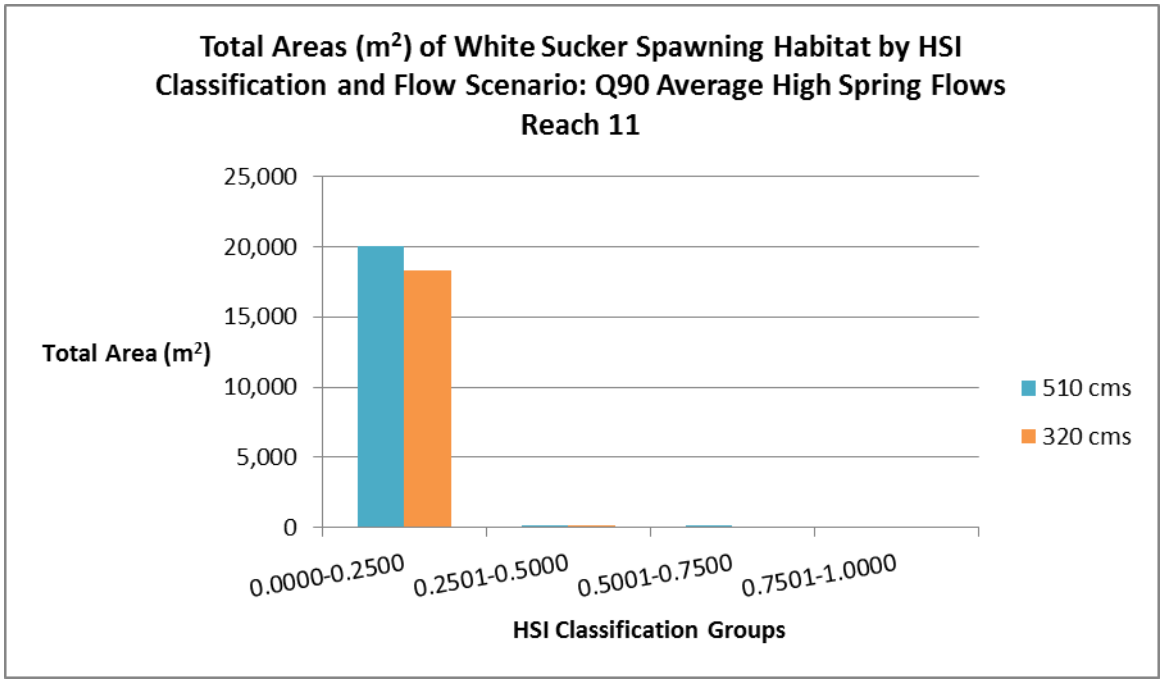


Figure E132: Total Areas of White Sucker Spawning Habitat in River Reach 11 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

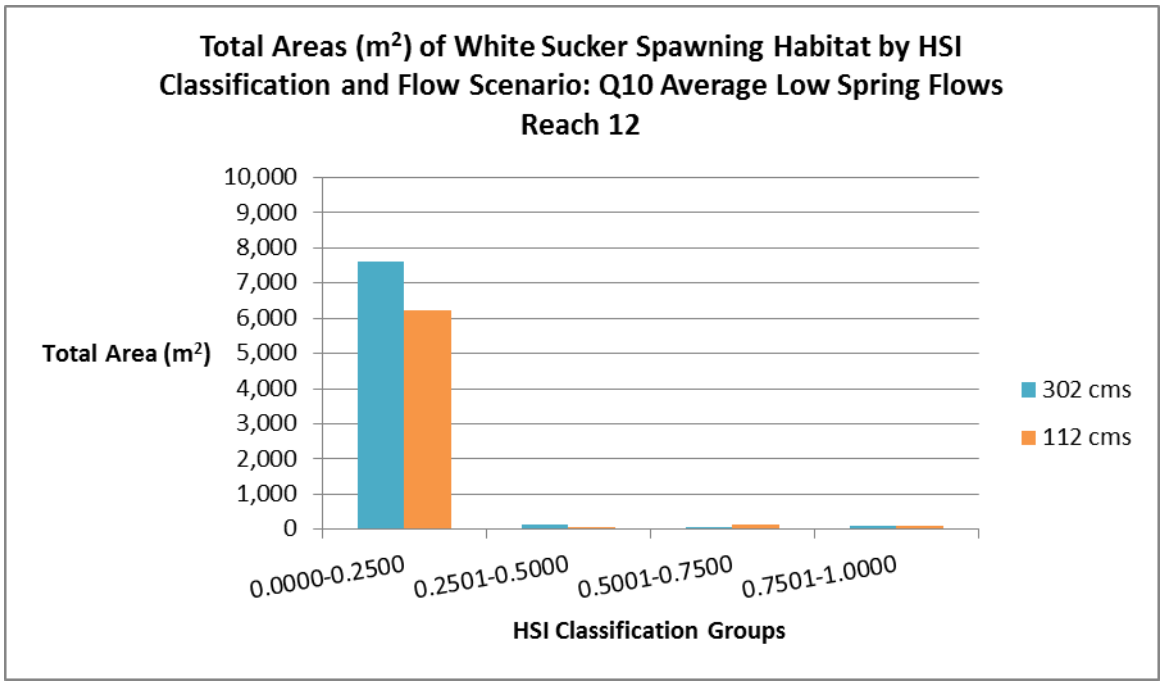


Figure E133: Total Areas of White Sucker Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

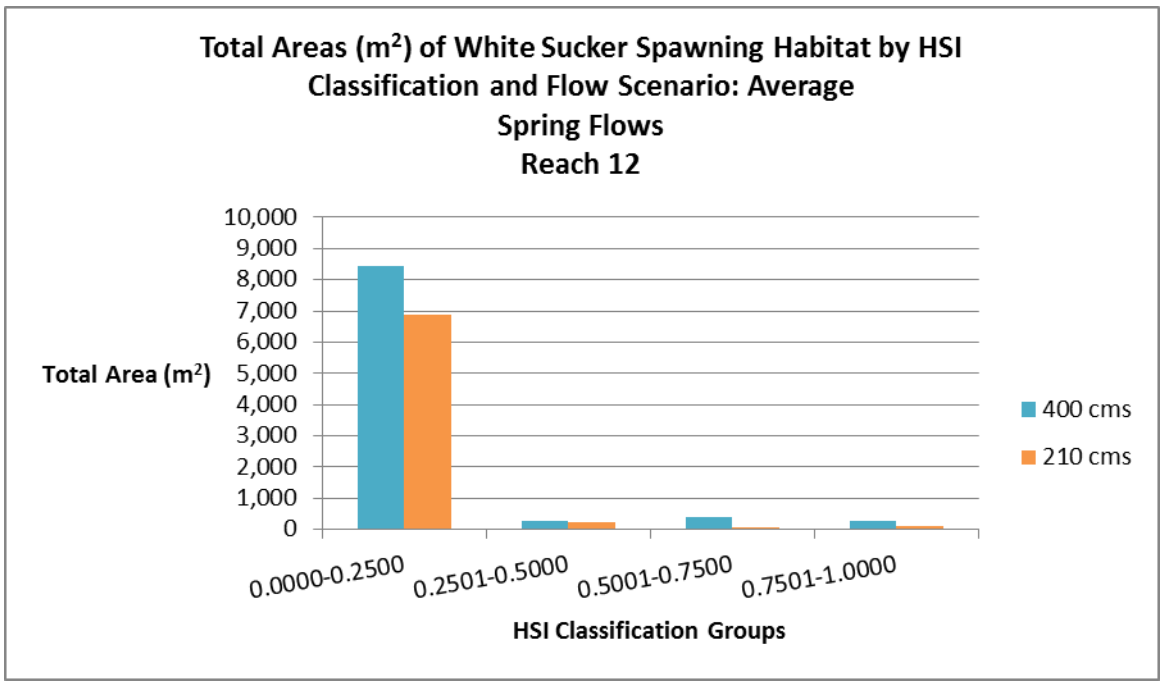


Figure E134: Total Areas of White Sucker Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

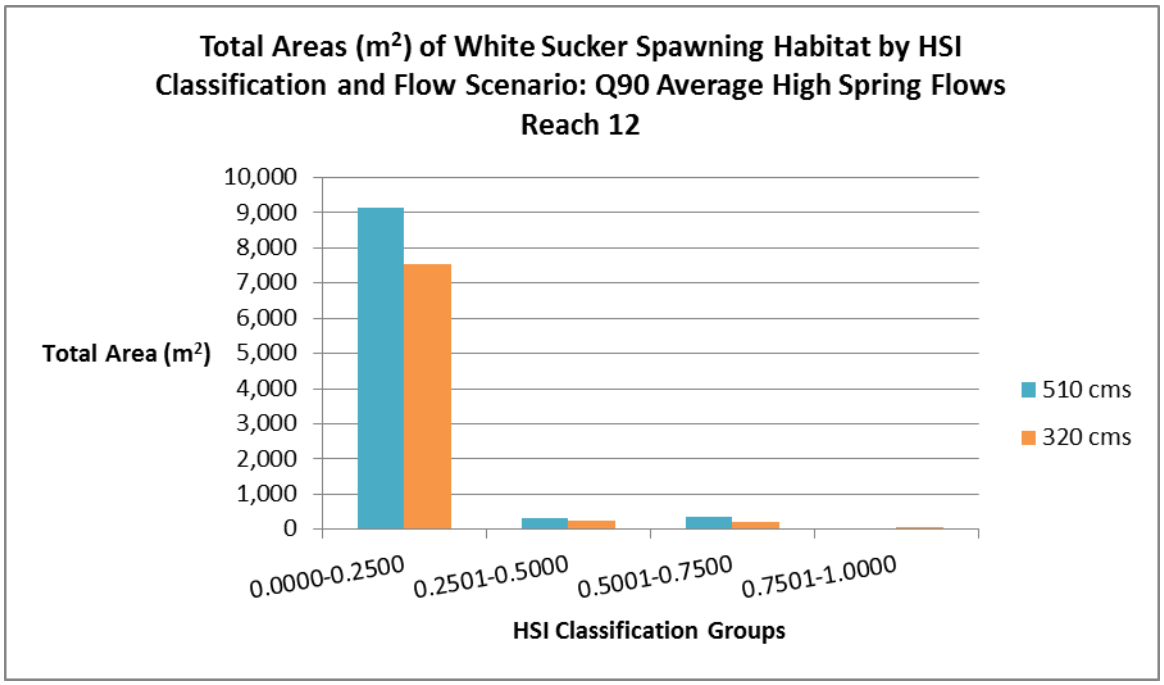


Figure E135: Total Areas of White Sucker Spawning Habitat in River Reach 12 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

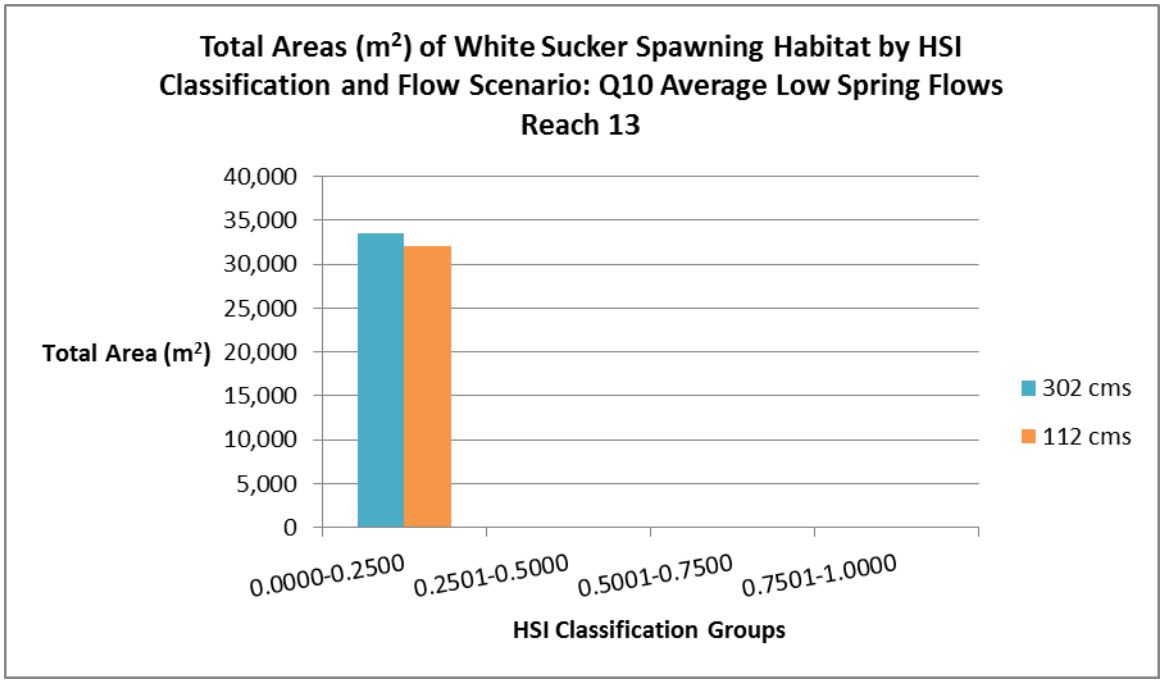


Figure E136: Total Areas of White Sucker Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 302 m^3//s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

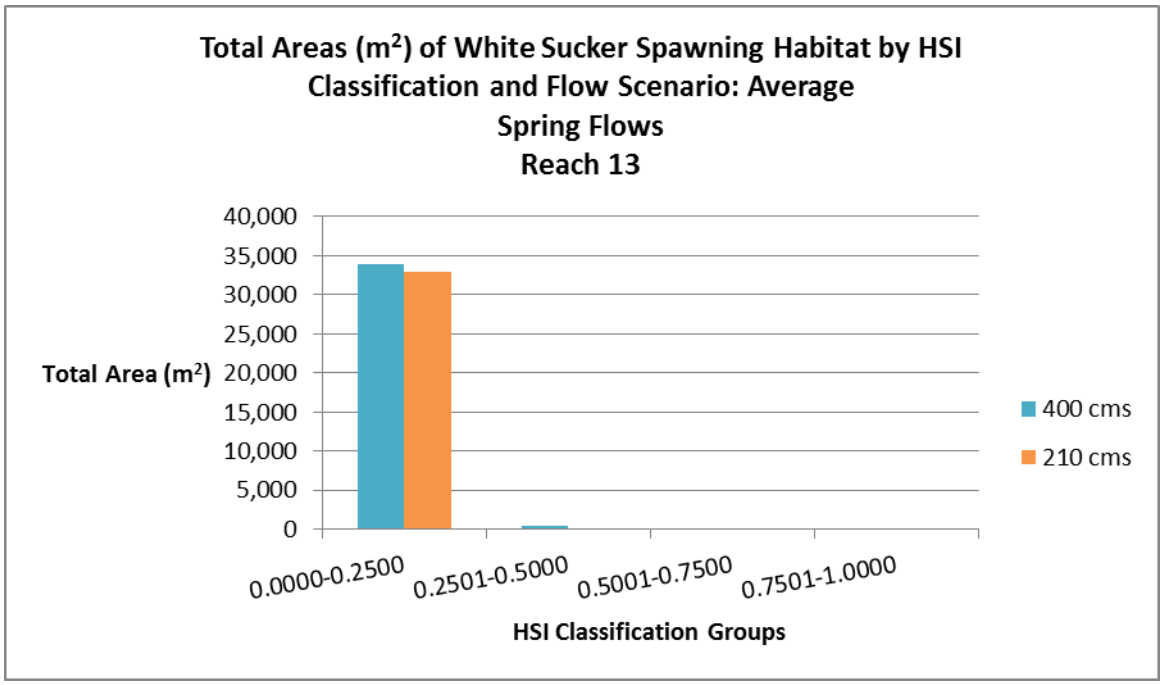


Figure E137: Total Areas of White Sucker Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

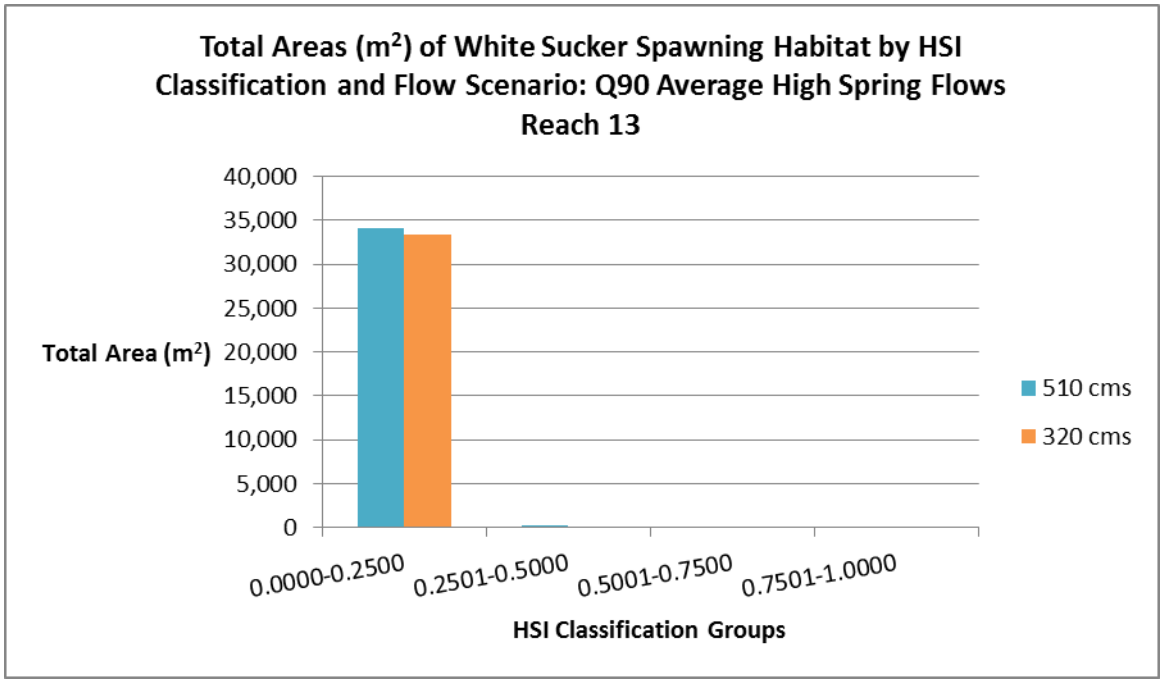


Figure E138: Total Areas of White Sucker Spawning Habitat in River Reach 13 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

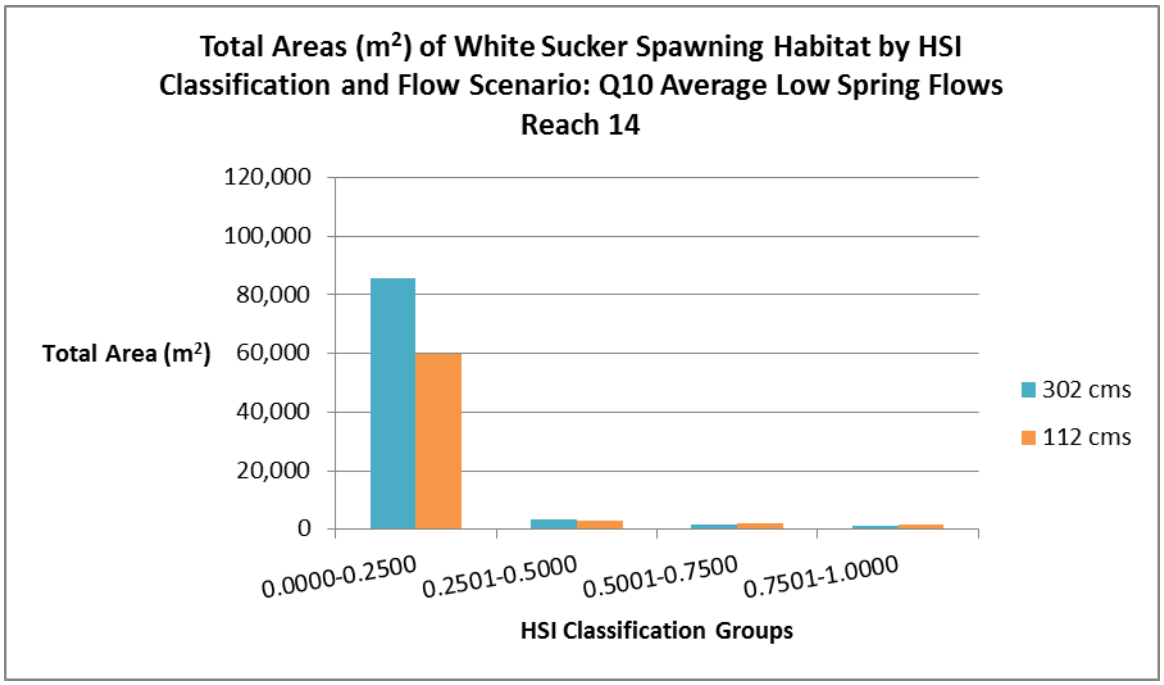


Figure E139: Total Areas of White Sucker Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

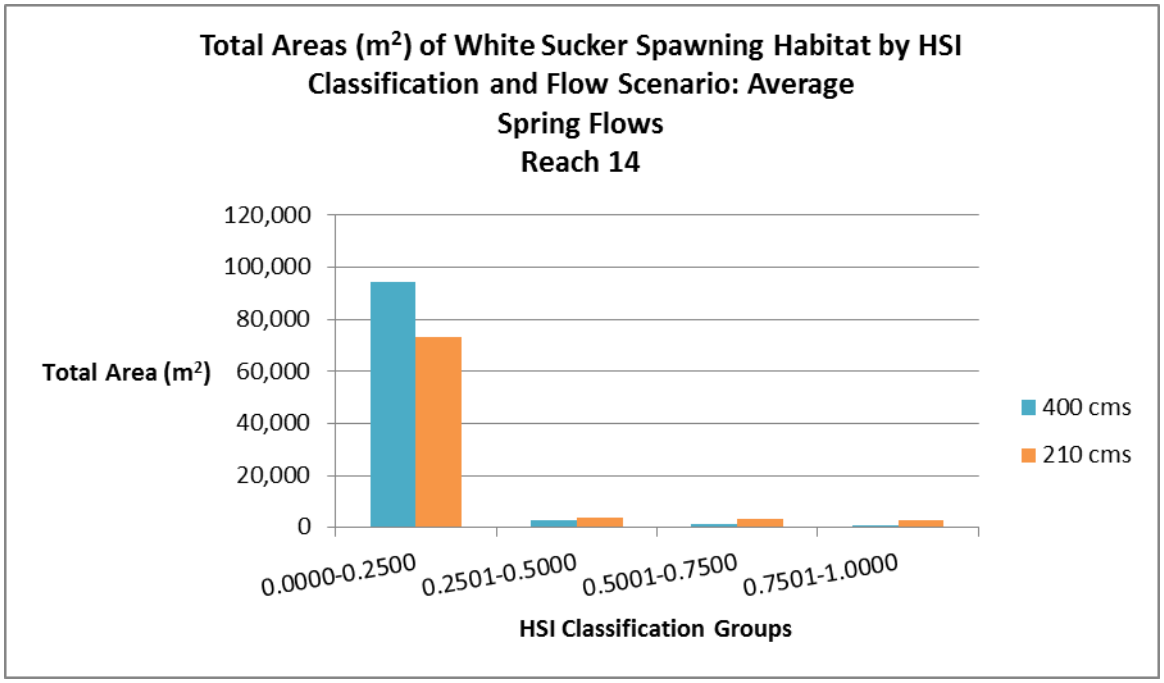


Figure E140: Total Areas of White Sucker Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

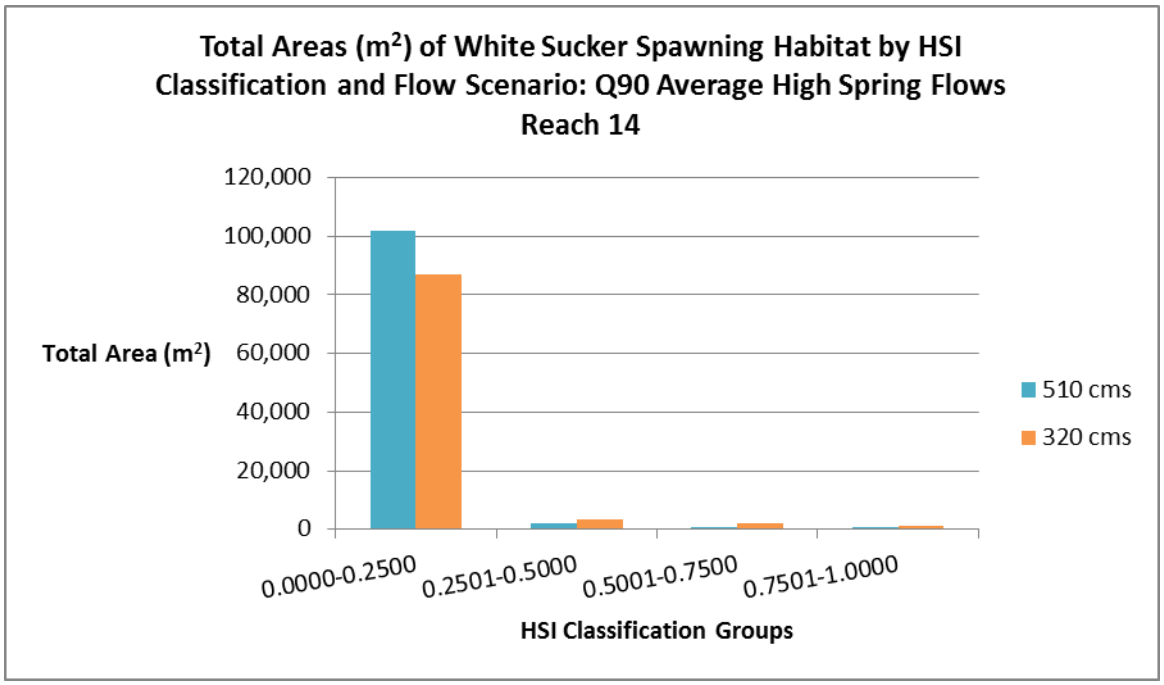


Figure E141: Total Areas of White Sucker Spawning Habitat in River Reach 14 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

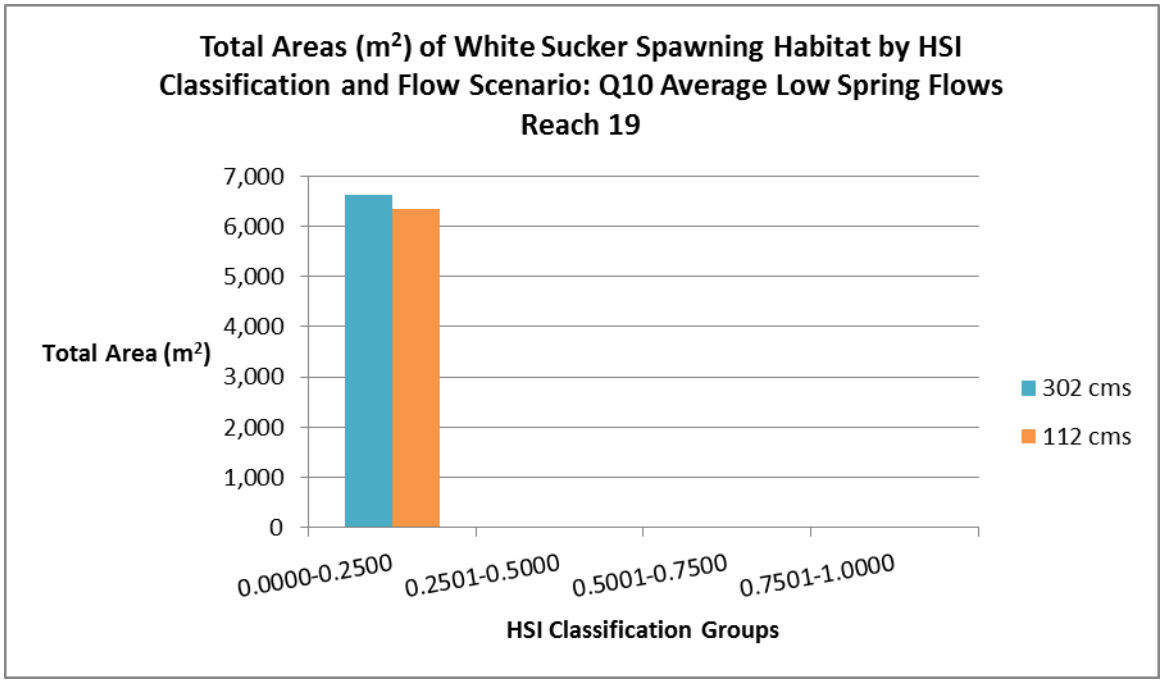


Figure E142: Total Areas of White Sucker Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

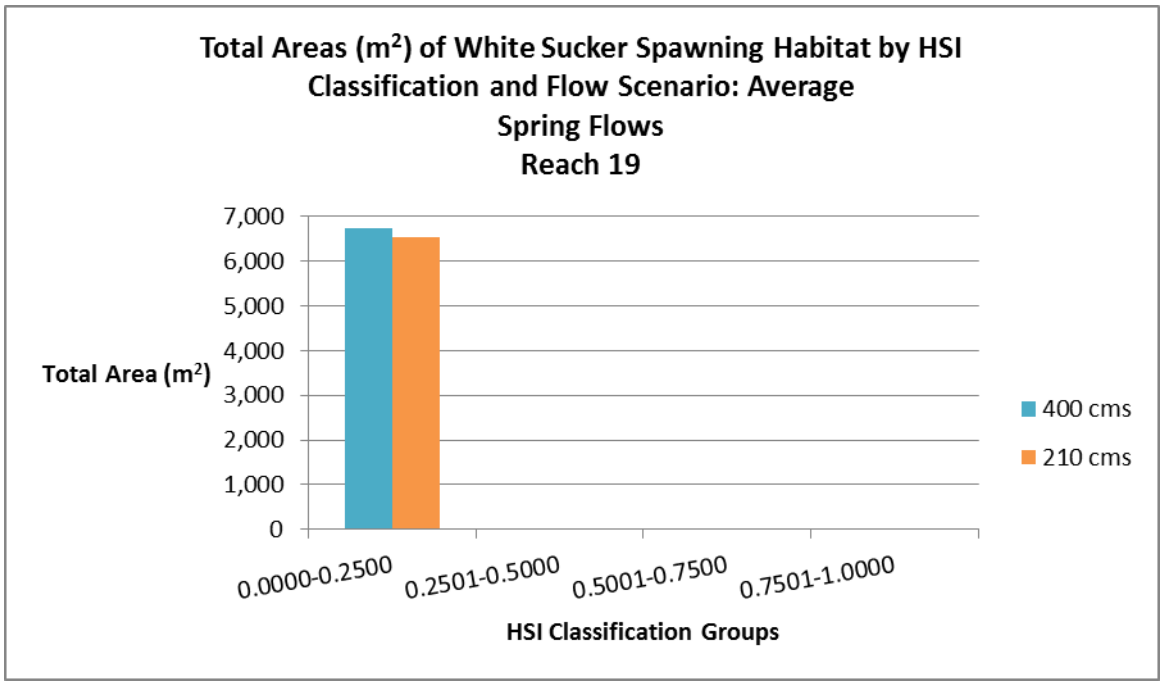


Figure E143: Total Areas of White Sucker Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

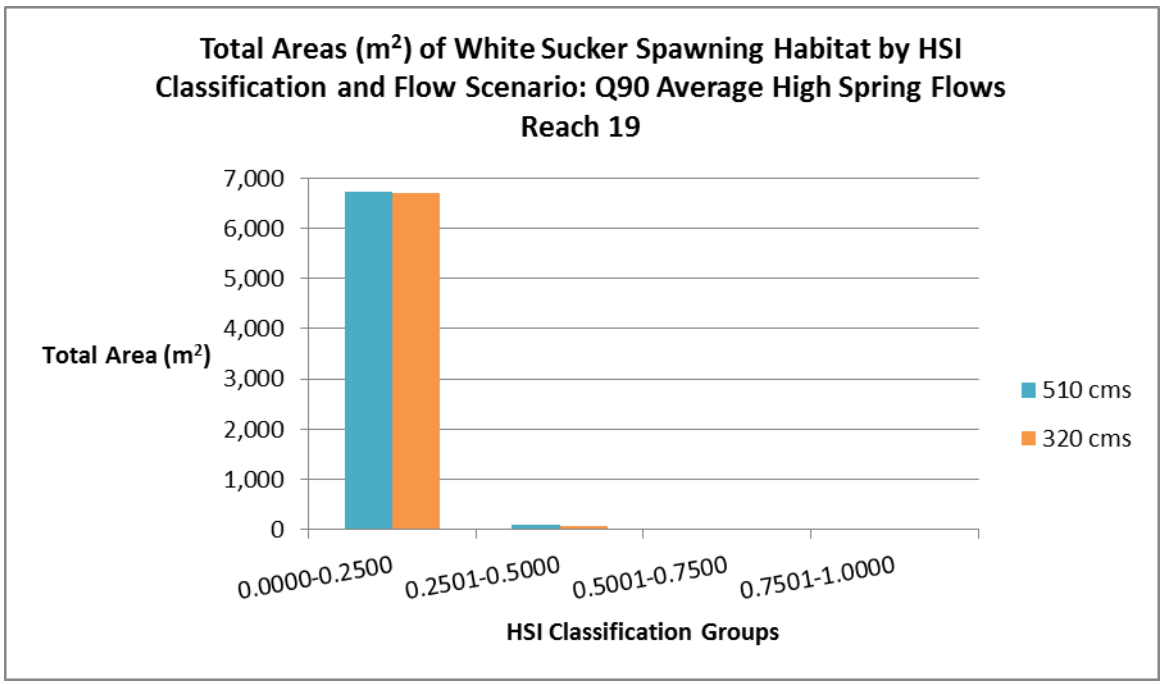


Figure E144: Total Areas of White Sucker Spawning Habitat in River Reach 19 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

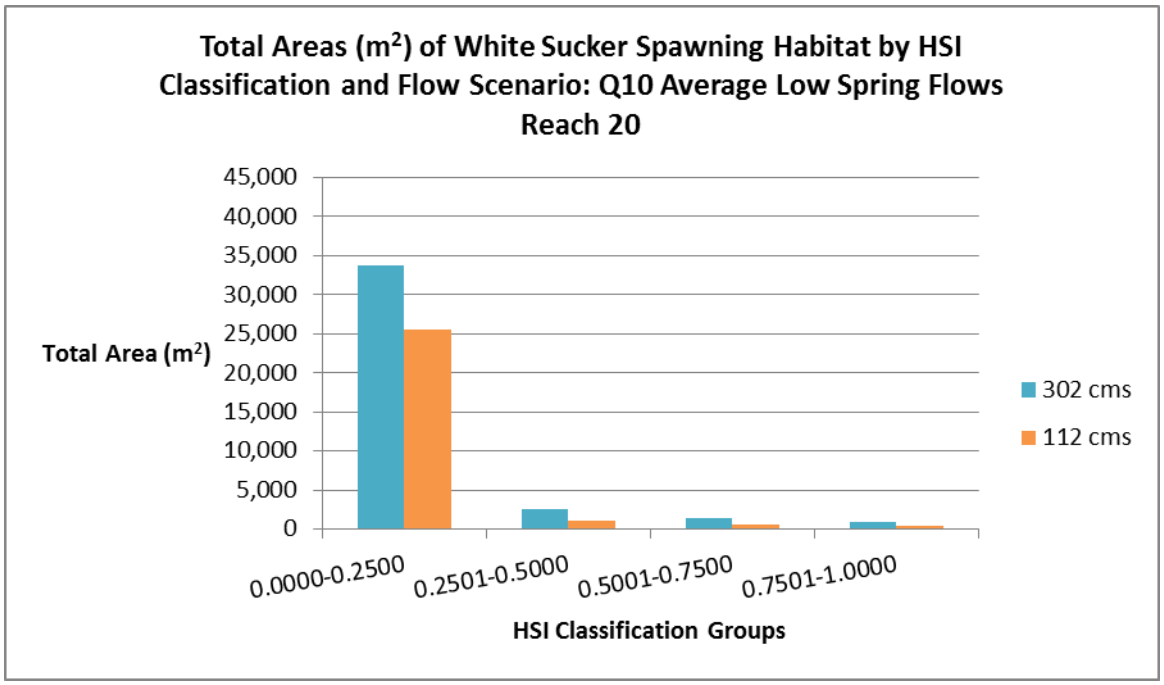


Figure E145: Total Areas of White Sucker Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

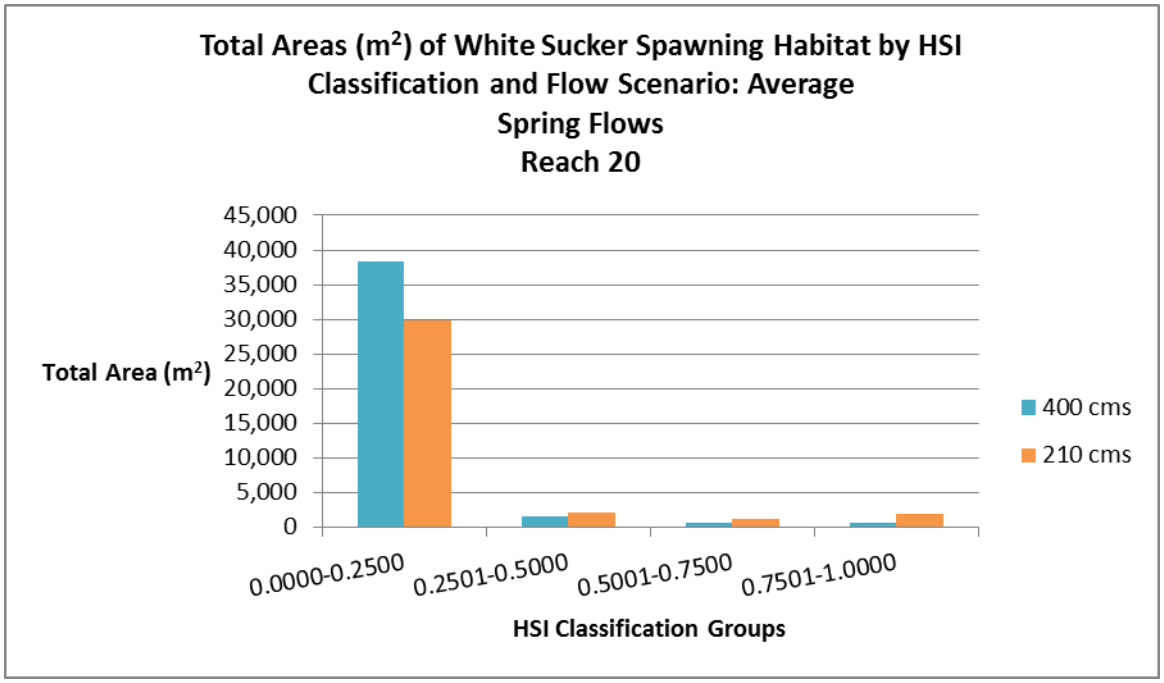


Figure E146: Total Areas of White Sucker Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

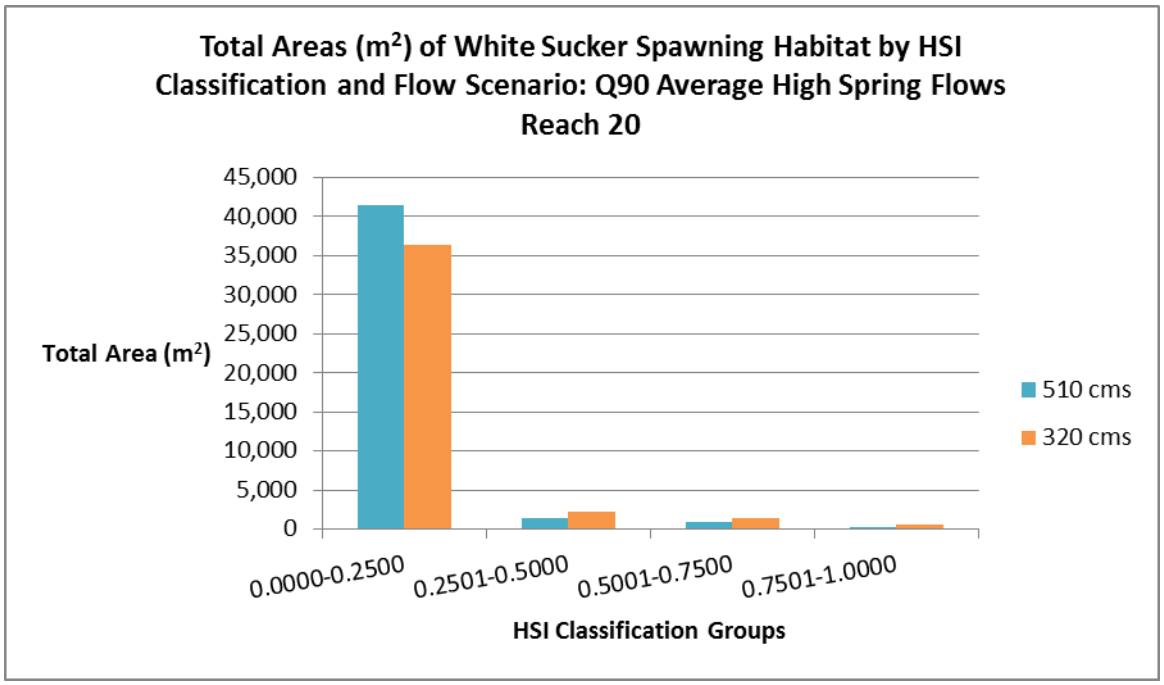


Figure E147: Total Areas of White Sucker Spawning Habitat in River Reach 20 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

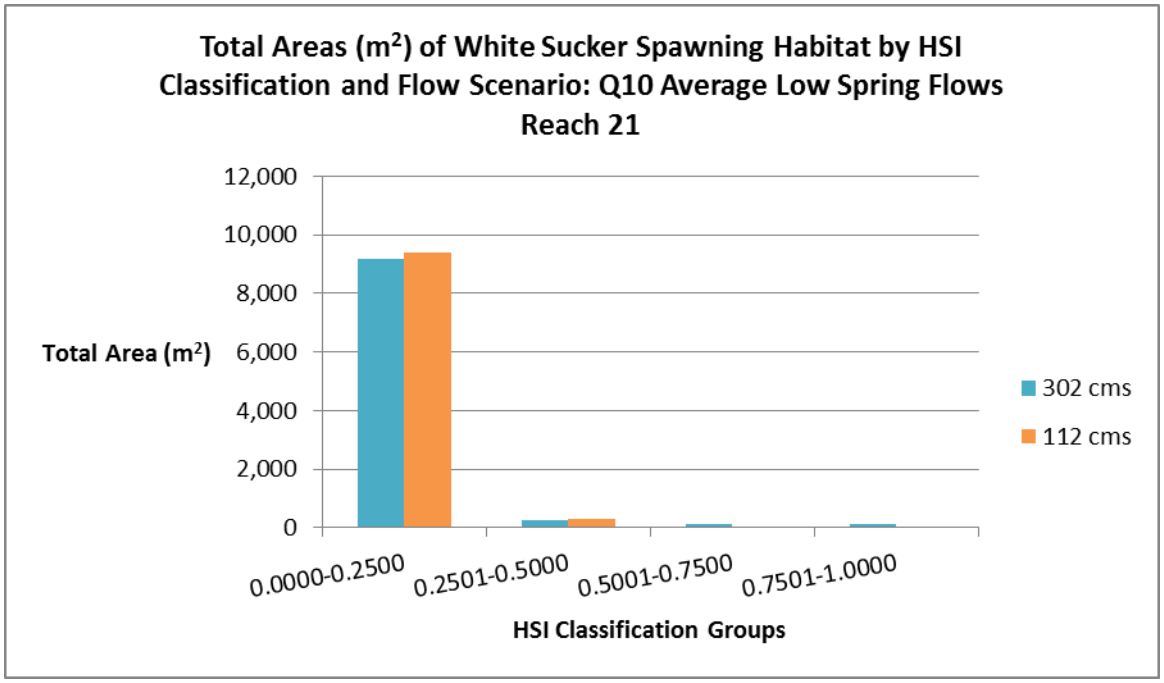


Figure E148: Total Areas of White Sucker Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

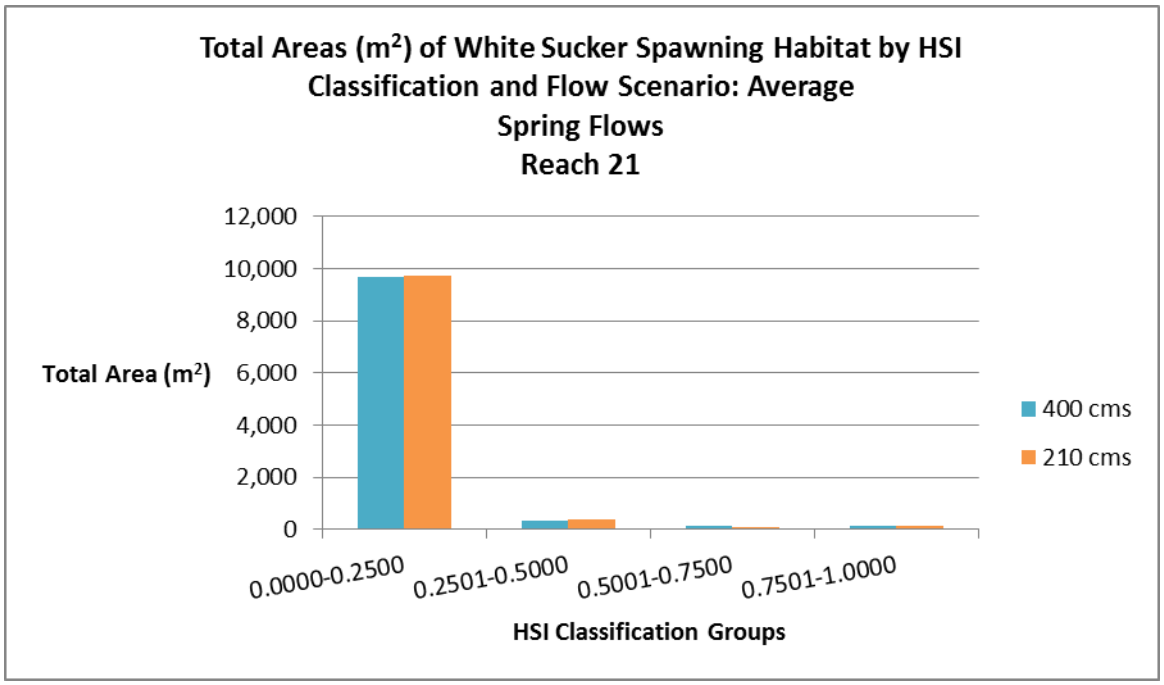


Figure E149: Total Areas of White Sucker Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

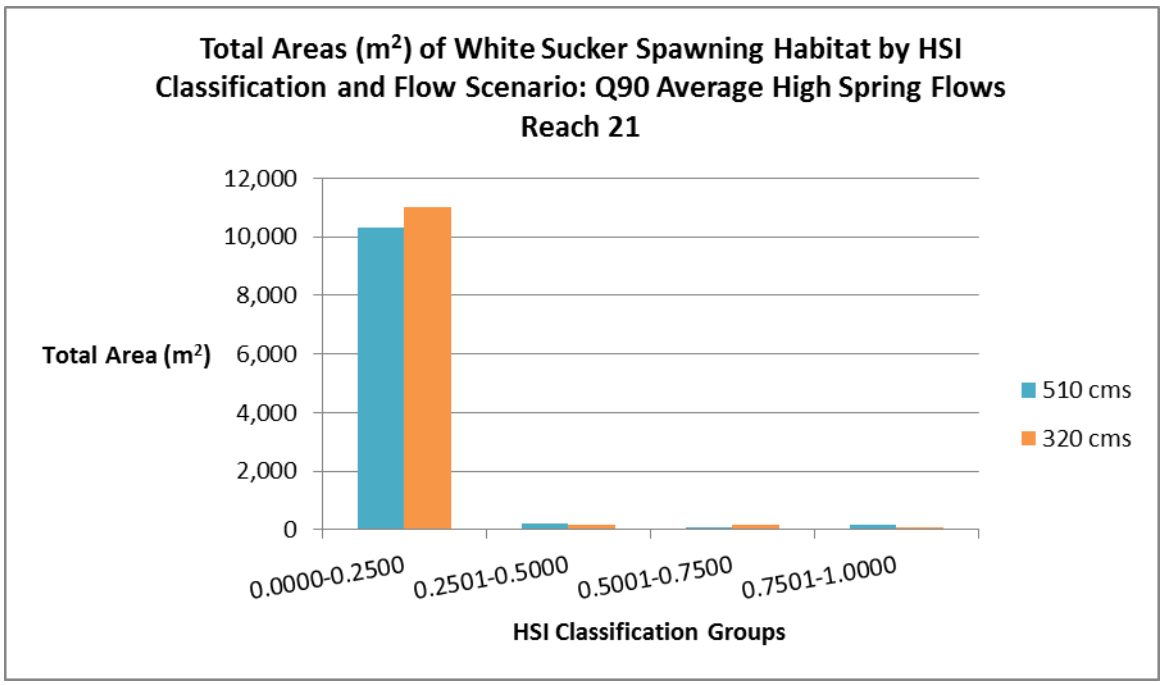


Figure E150: Total Areas of White Sucker Spawning Habitat in River Reach 21 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

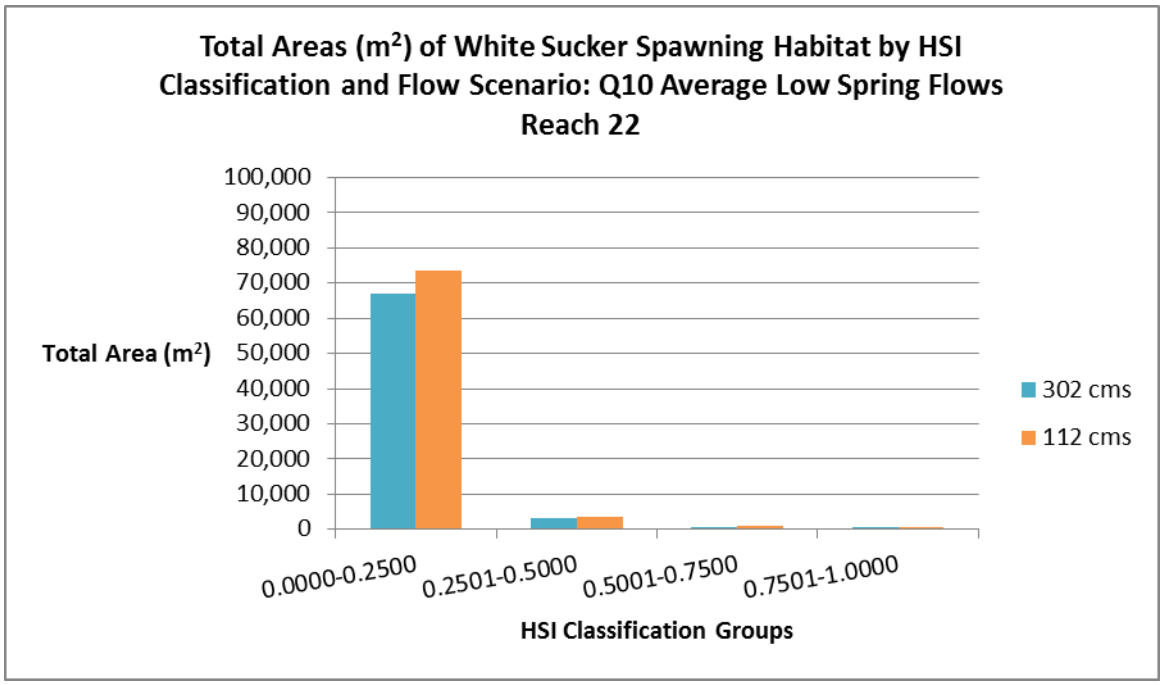


Figure E151: Total Areas of White Sucker Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 302 m^3/s and 112 m^3/s Flow Scenarios in the Fond du Lac River.

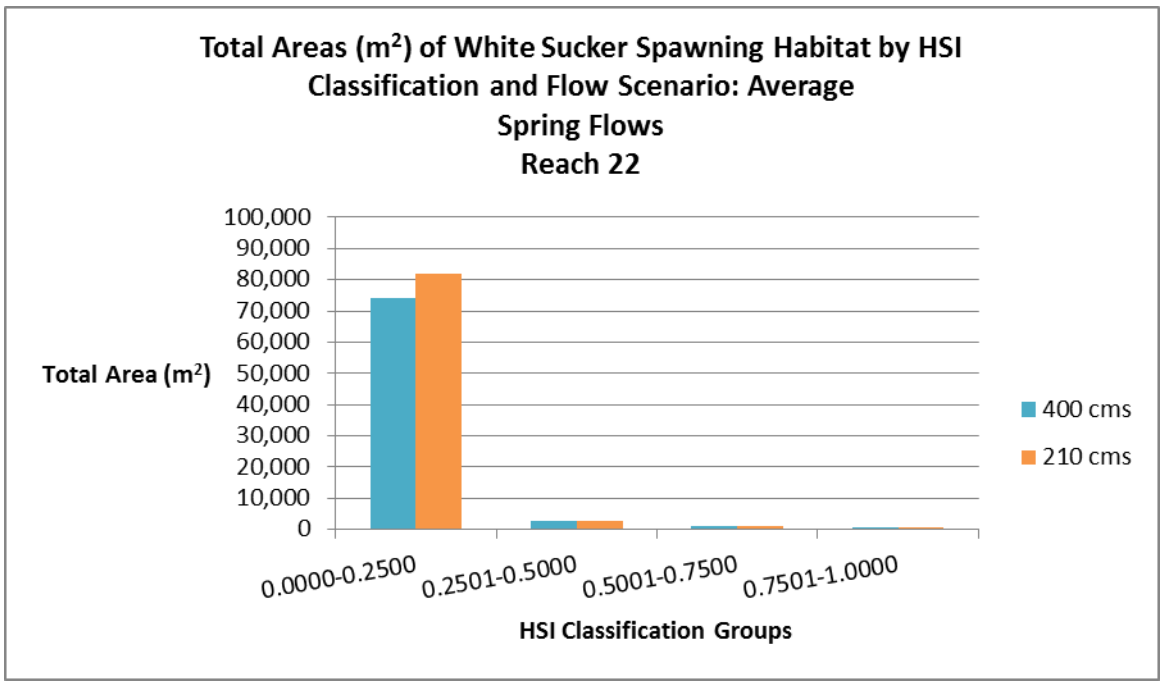


Figure E152: Total Areas of White Sucker Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 400 m^3/s and 210 m^3/s Flow Scenarios in the Fond du Lac River.

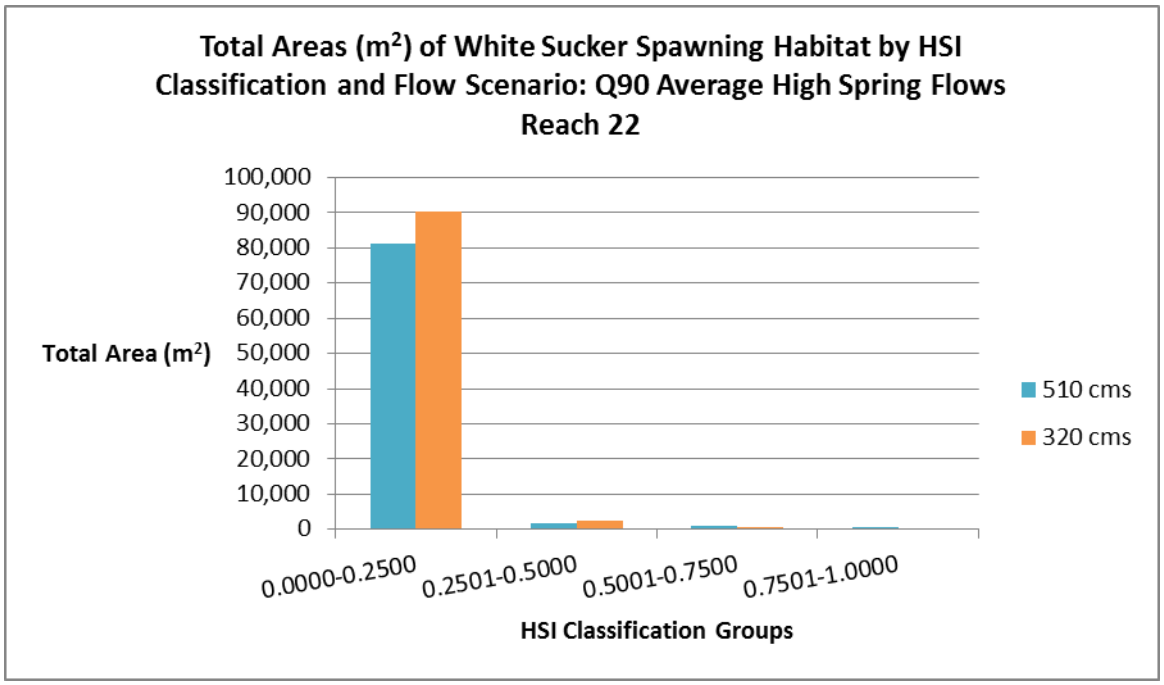


Figure E153: Total Areas of White Sucker Spawning Habitat in River Reach 22 between Black Lake and Middle Lake for 510 m^3/s and 320 m^3/s Flow Scenarios in the Fond du Lac River.

Appendix 12.1-F

Predicted Arctic Grayling (*Thymallus arcticus*) Overwintering Locations

LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

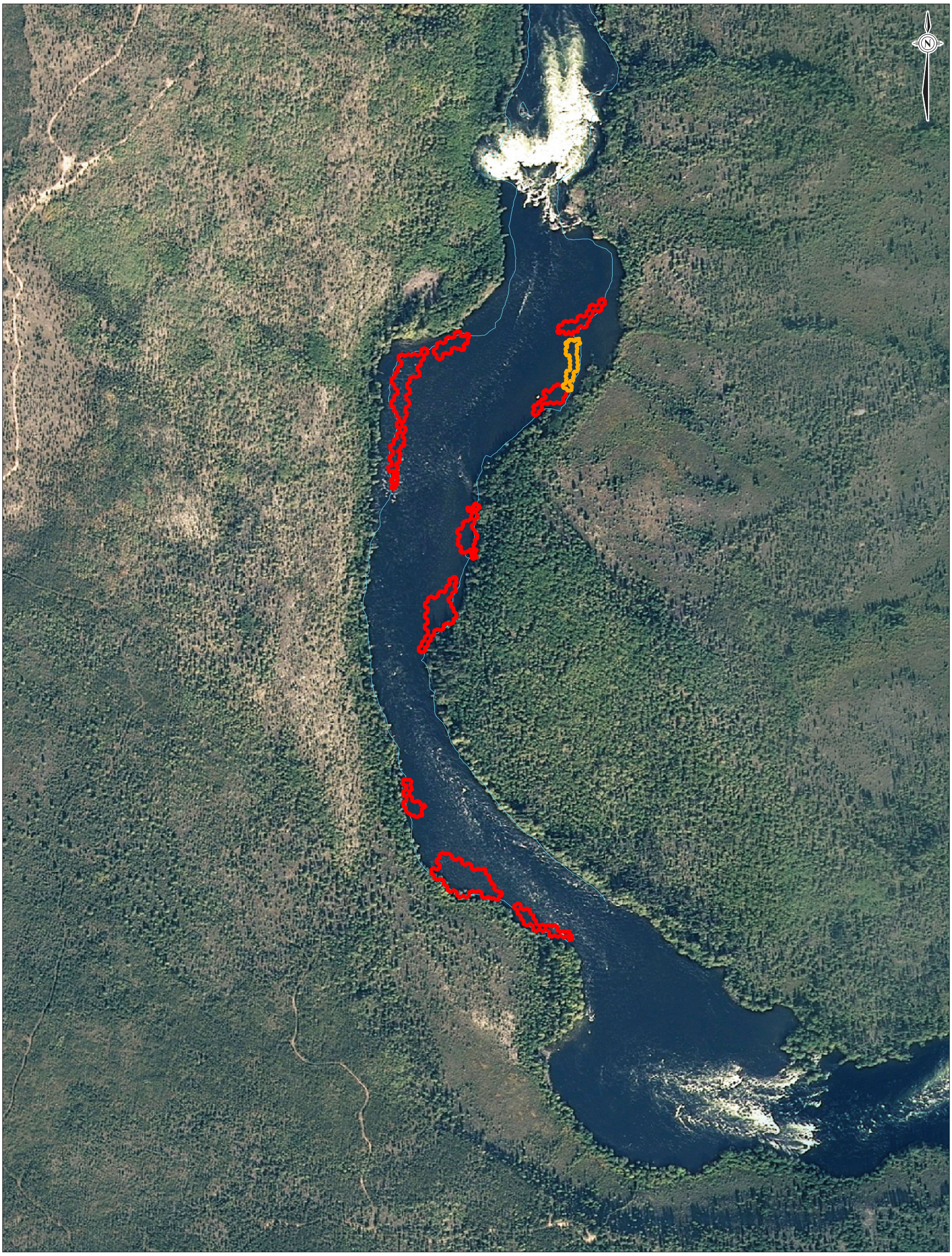
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 210 m³/s**

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13		
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

FIGURE: F1



LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

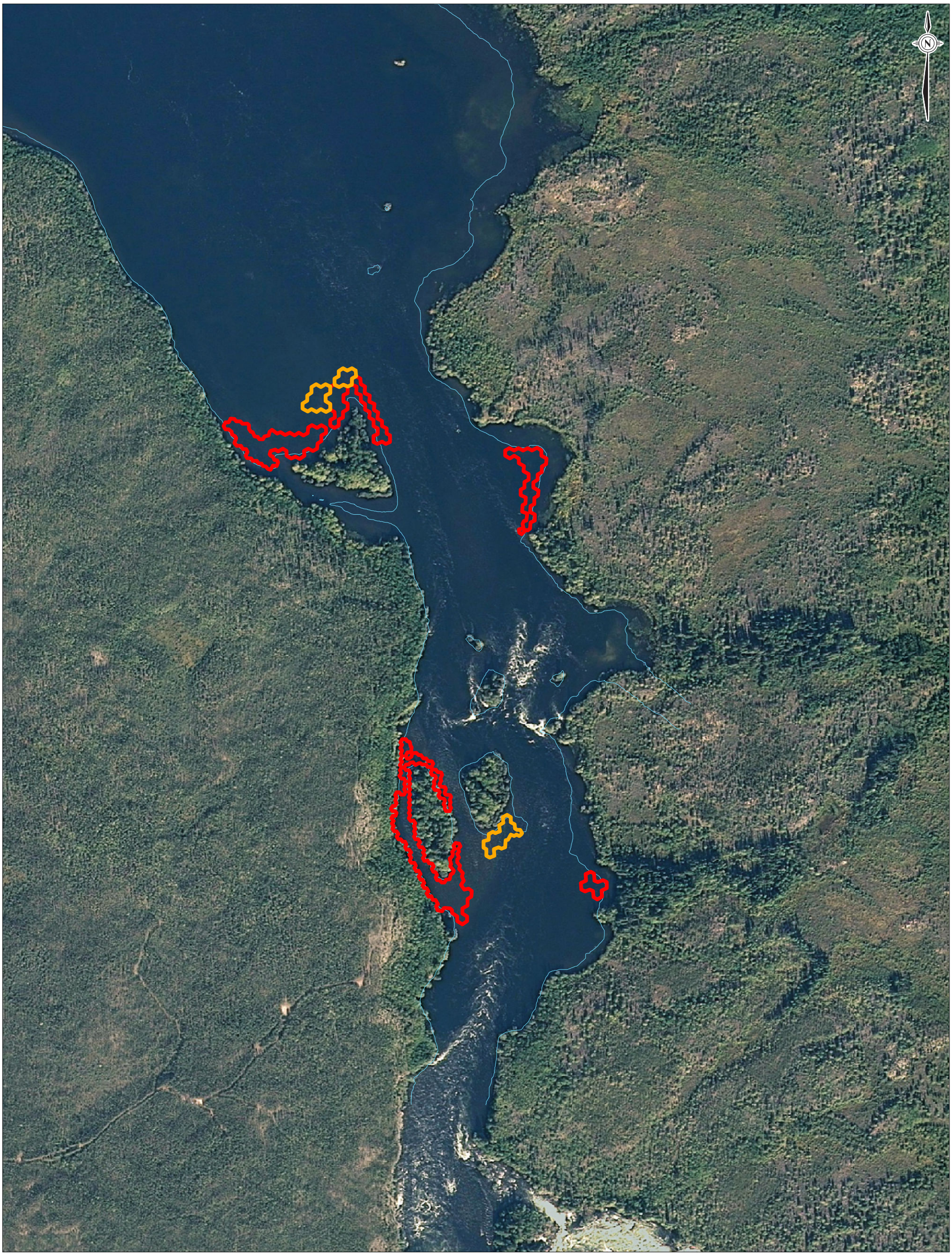
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 210 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F2	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 210 m³/s

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F3	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 50 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

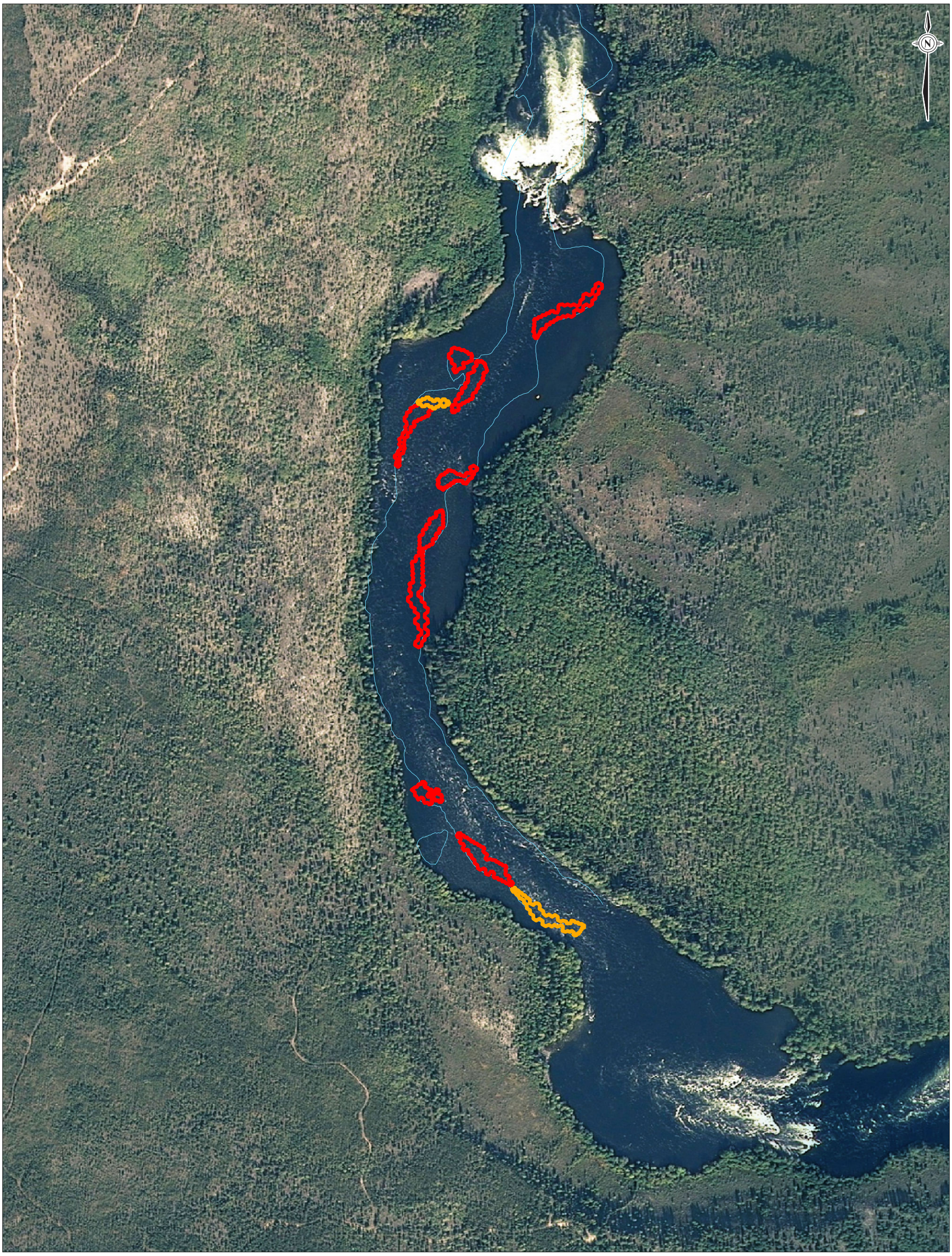
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 50 m³/s**

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13		
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

FIGURE: F4



LEGEND

- WATER'S EDGE AT 50 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

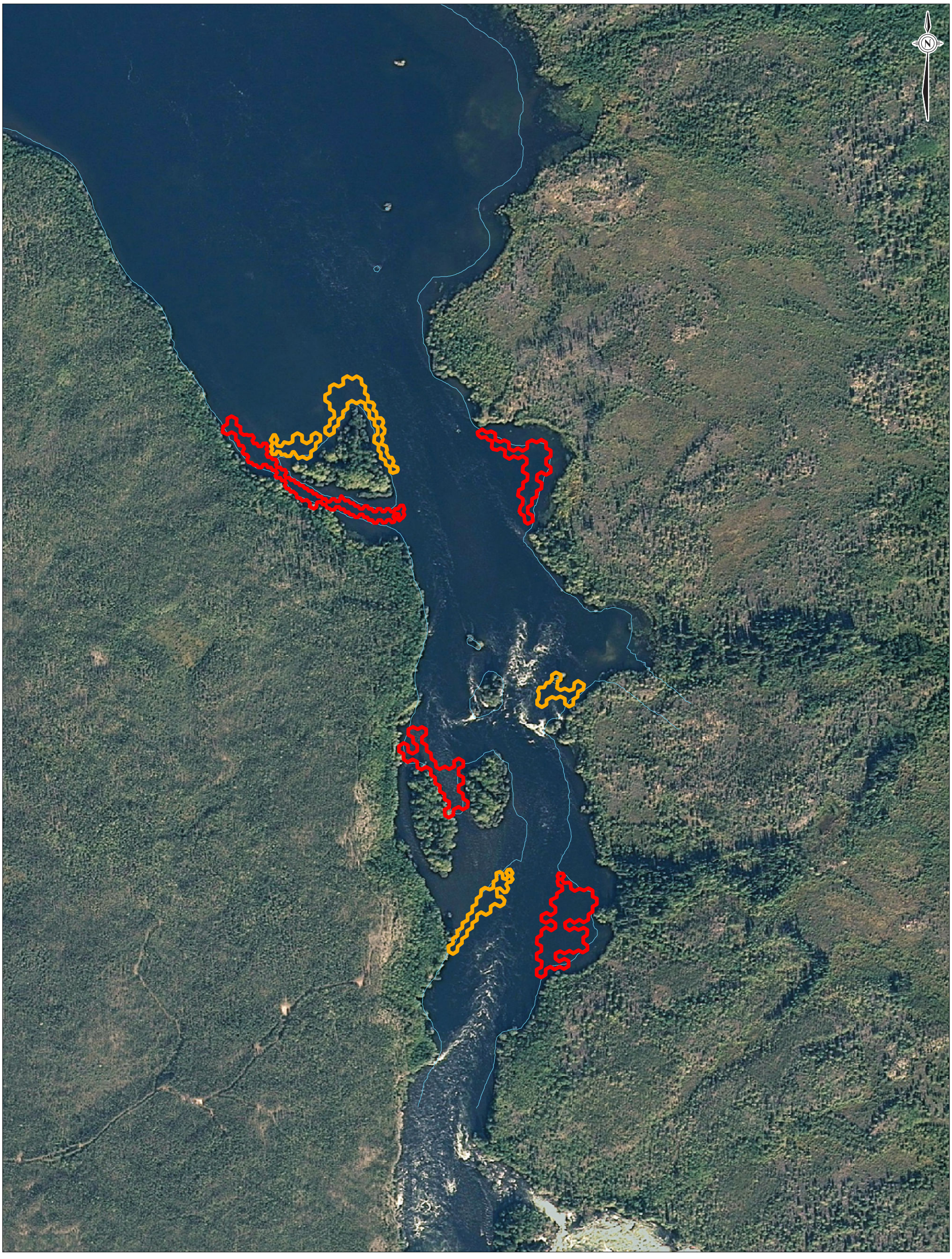
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 50 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F5	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 50 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 50 m³/s

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F6	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 40 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

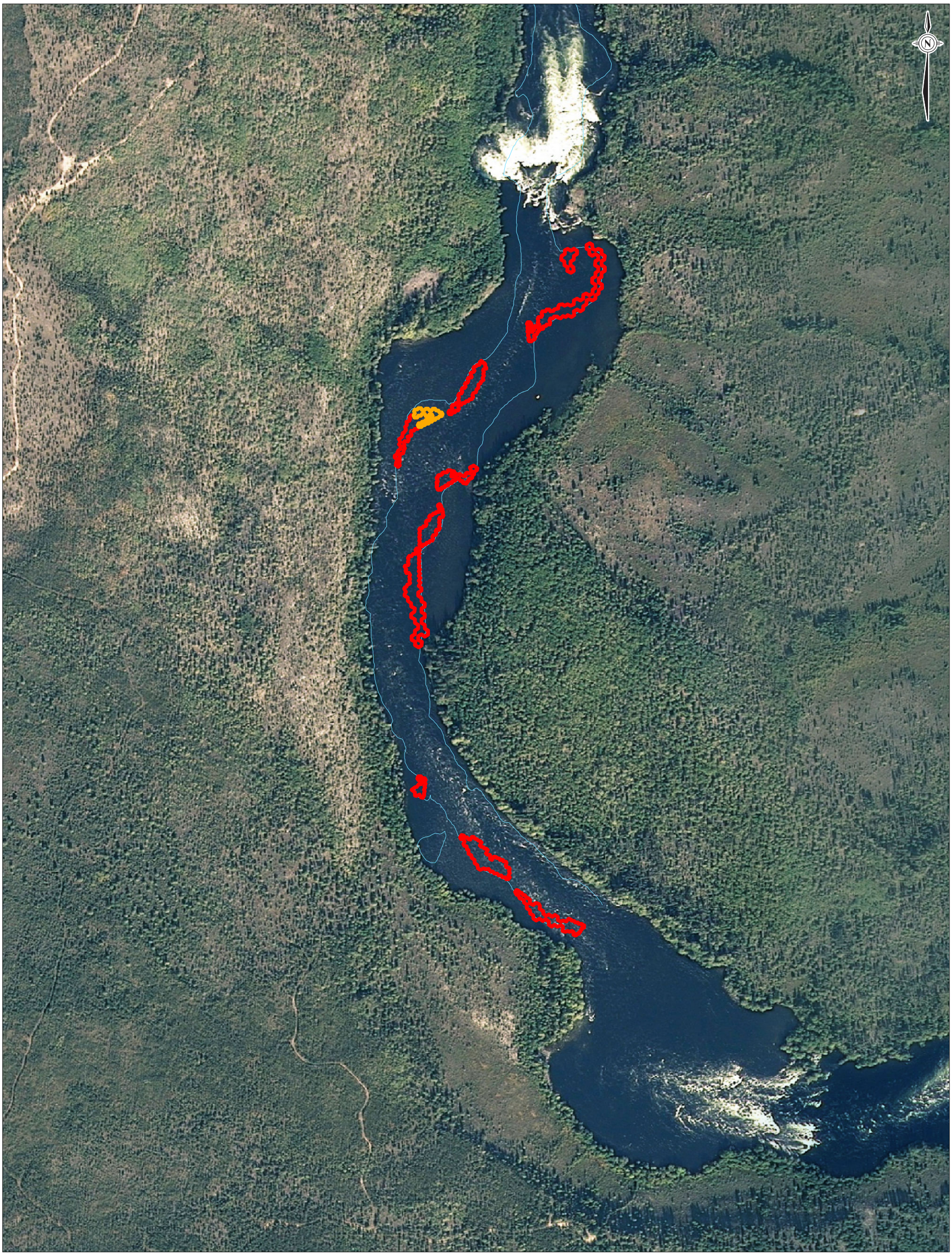
PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 40 m³/s**

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13	FIGURE: F7	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 40 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

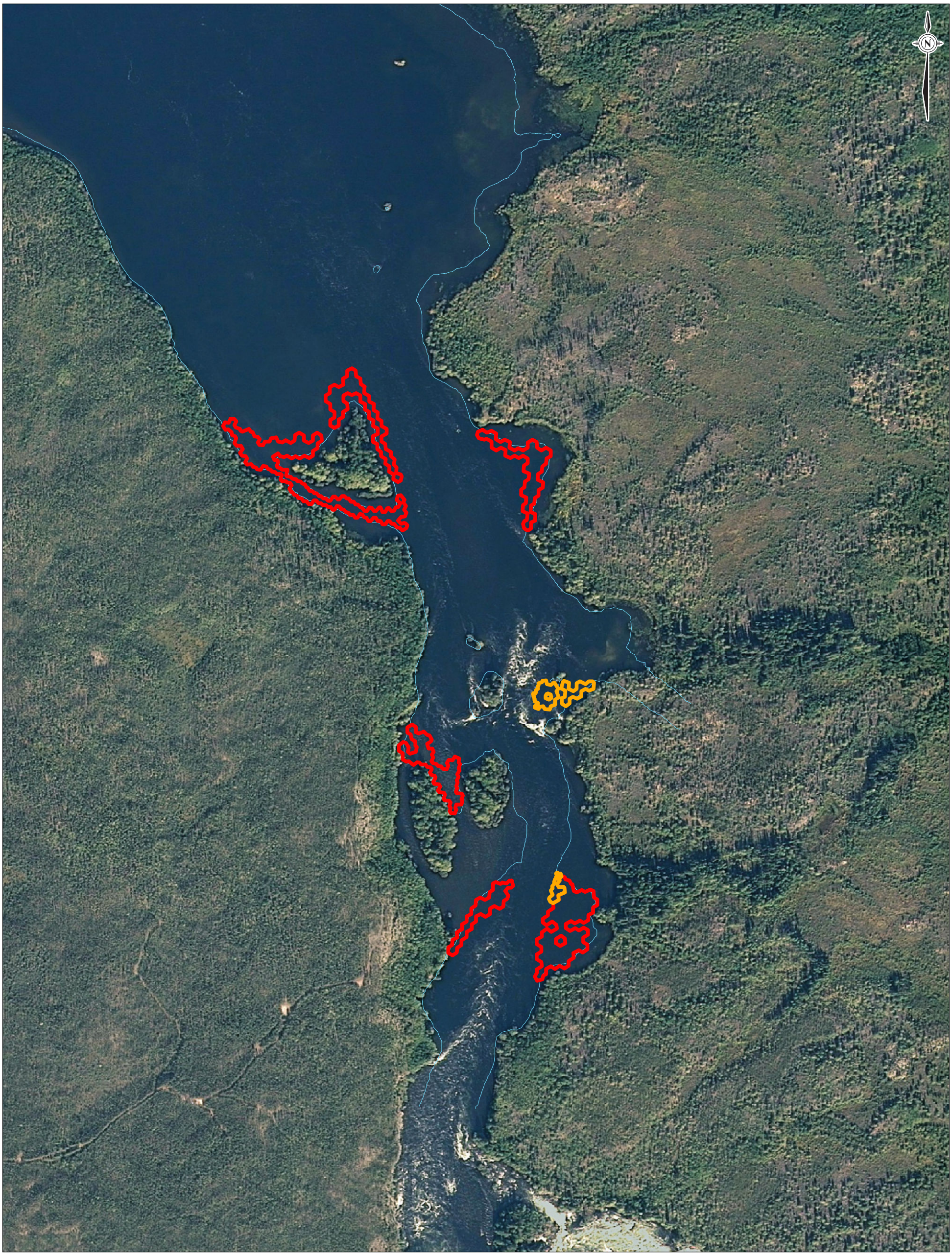
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 40 m³/s

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F8	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 40 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 40 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F9	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 30 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

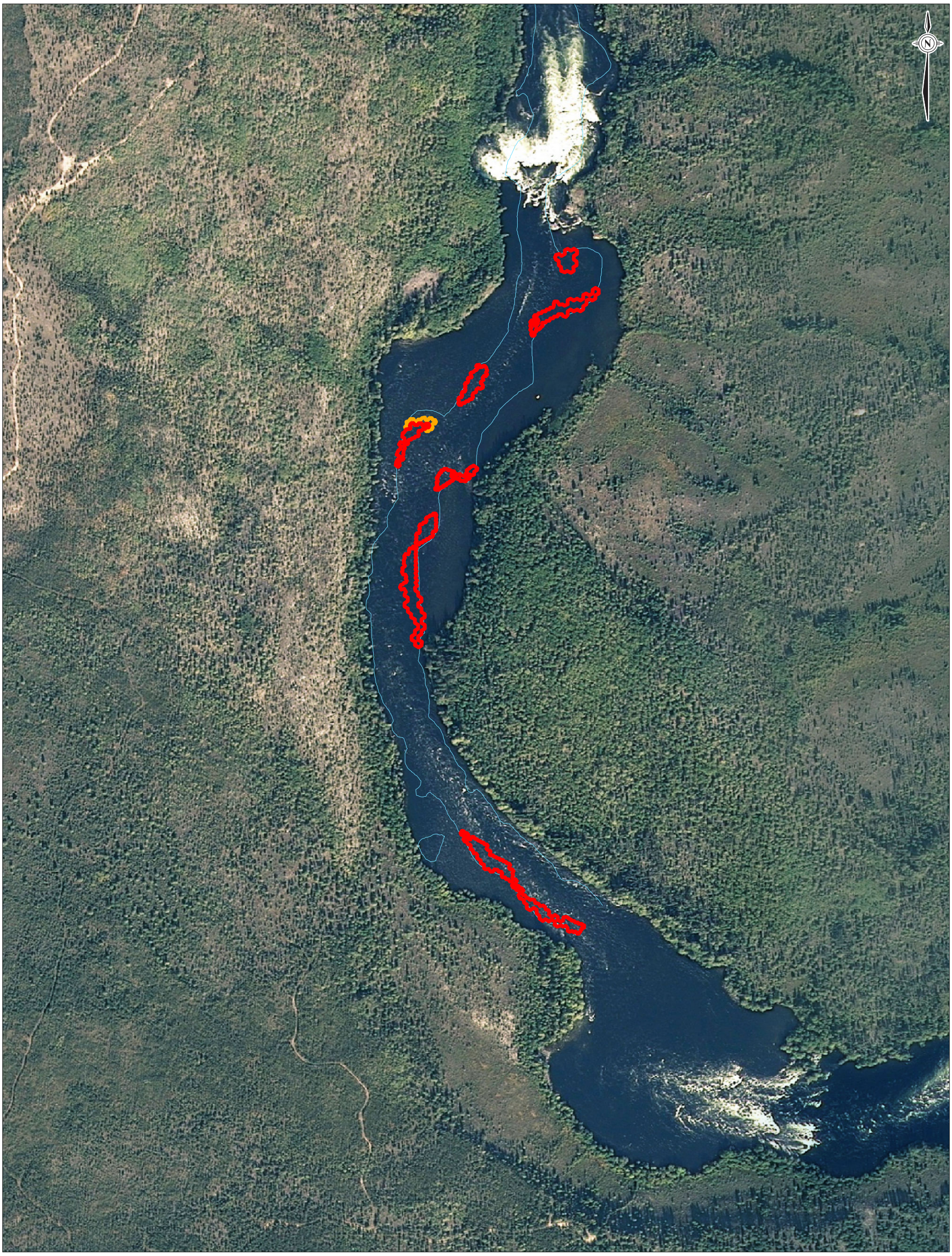
TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 30 m³/s**

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13	FIGURE: F10	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 30 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

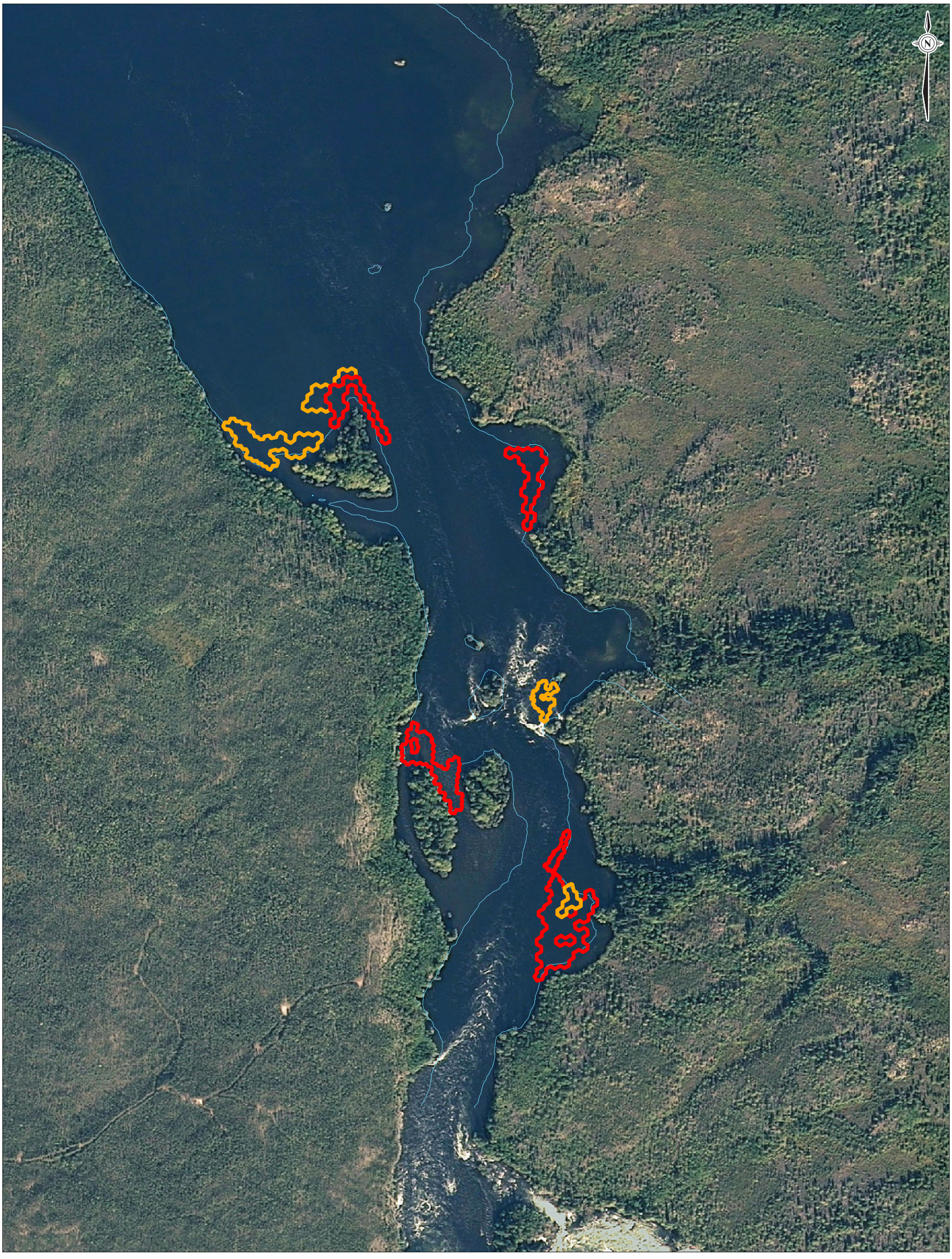
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 30 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F11	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 30 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR AGE-0 JUVENILE ARCTIC GRAYLING: 30 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F12	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

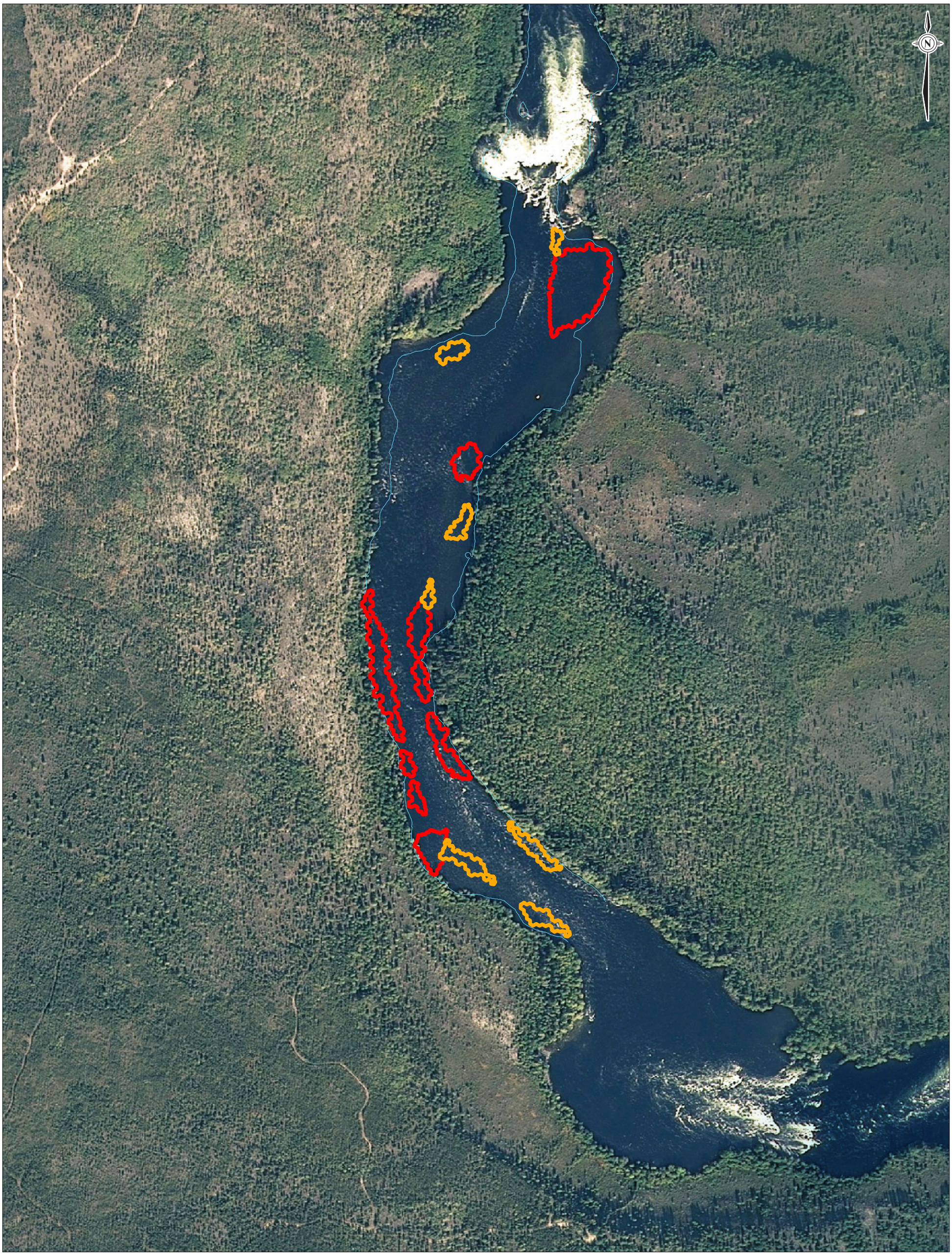
PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 210 m³/s**

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13	FIGURE: F13	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

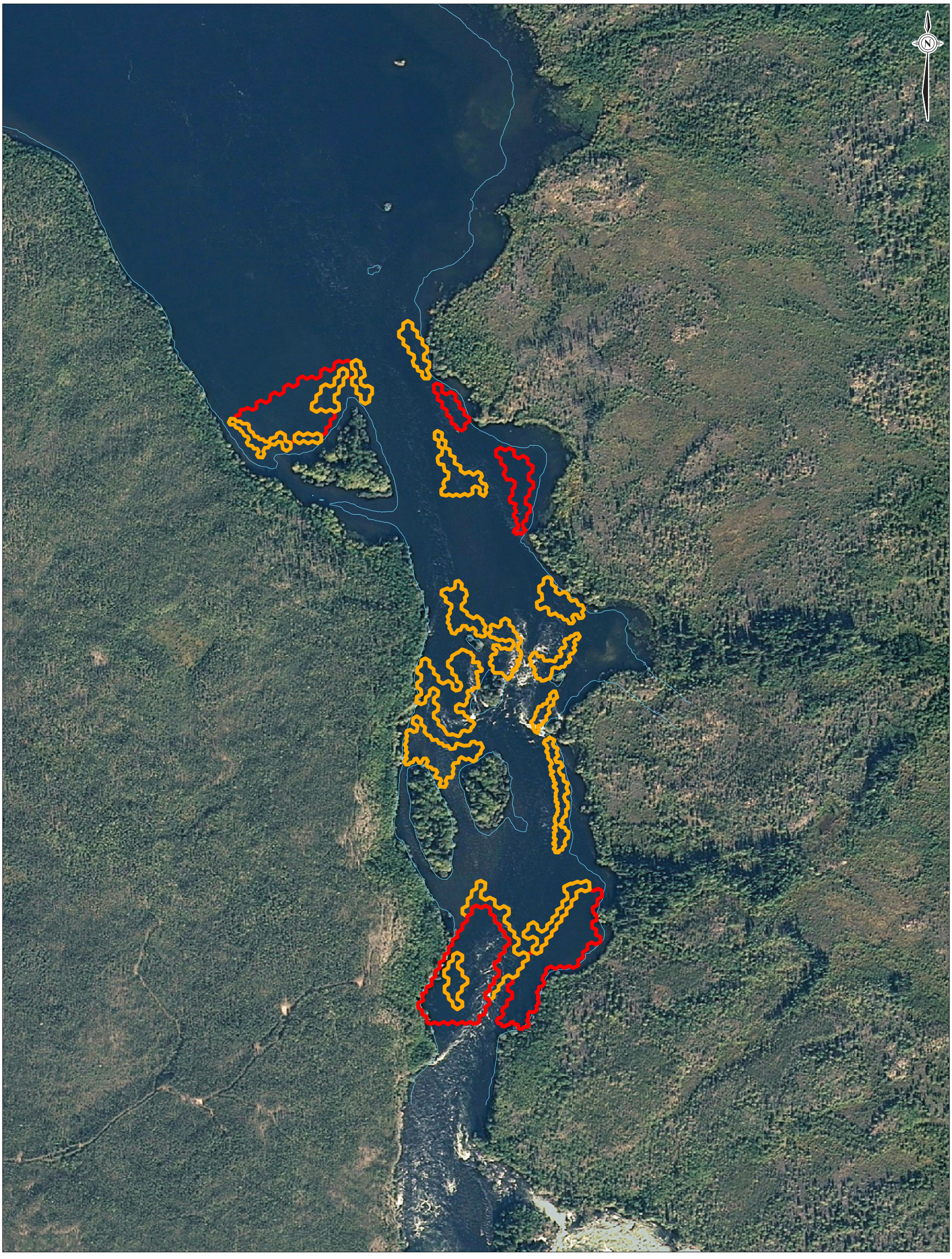
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 210 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F14	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 210 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F15	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 50 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

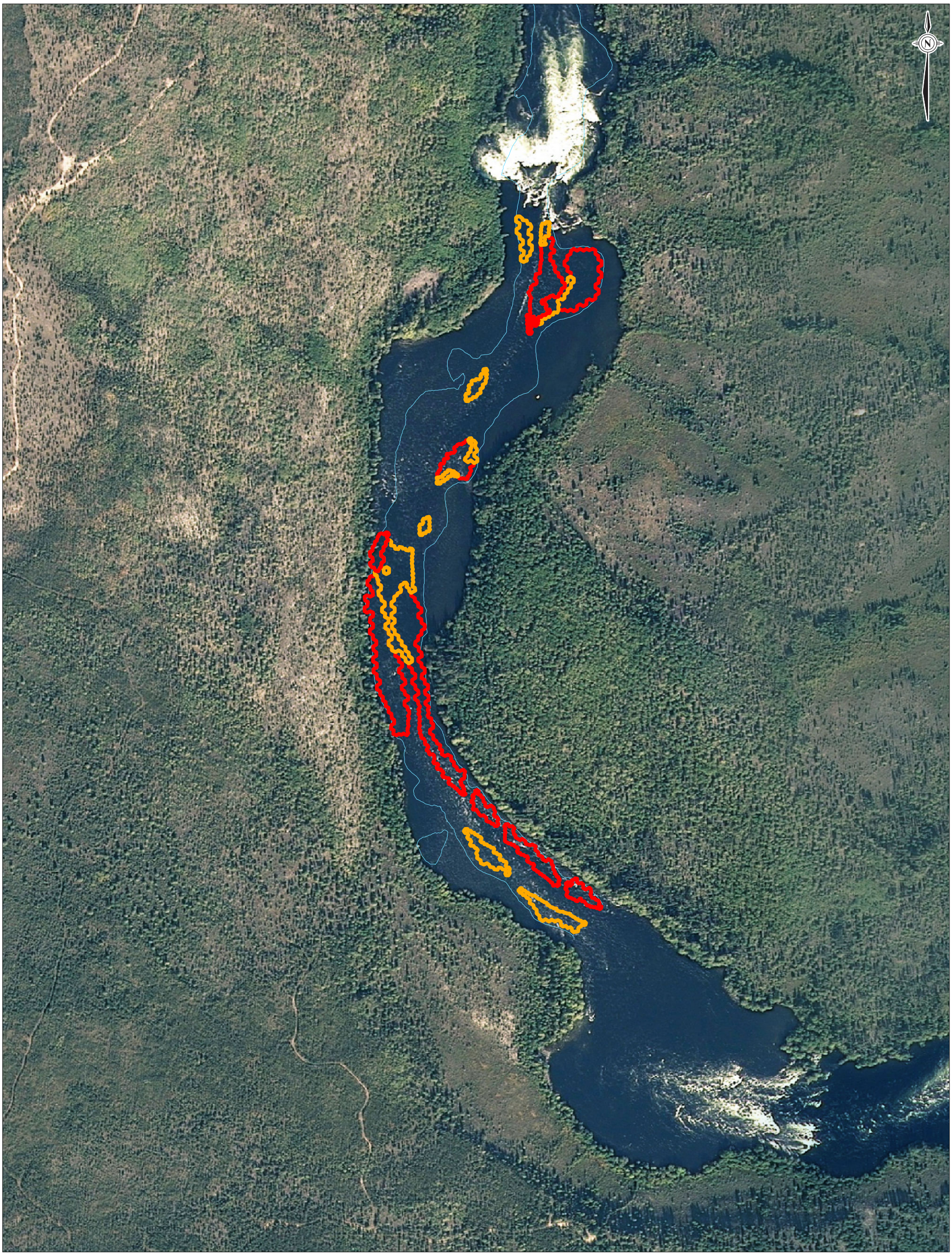
PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 50 m³/s**

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13	FIGURE: F16	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 50 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

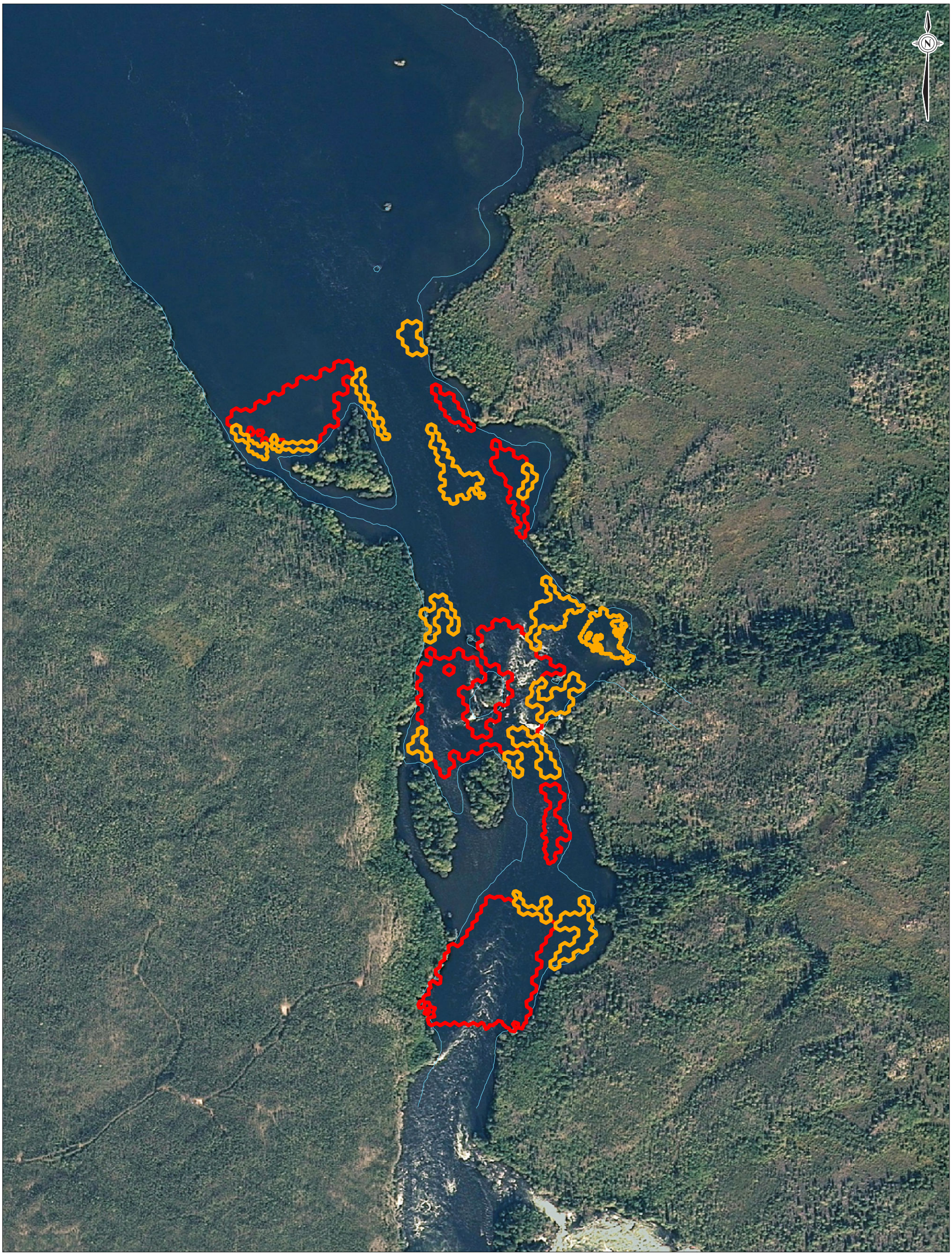
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 50 m³/s

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F17	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 50 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 50 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F18	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 40 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

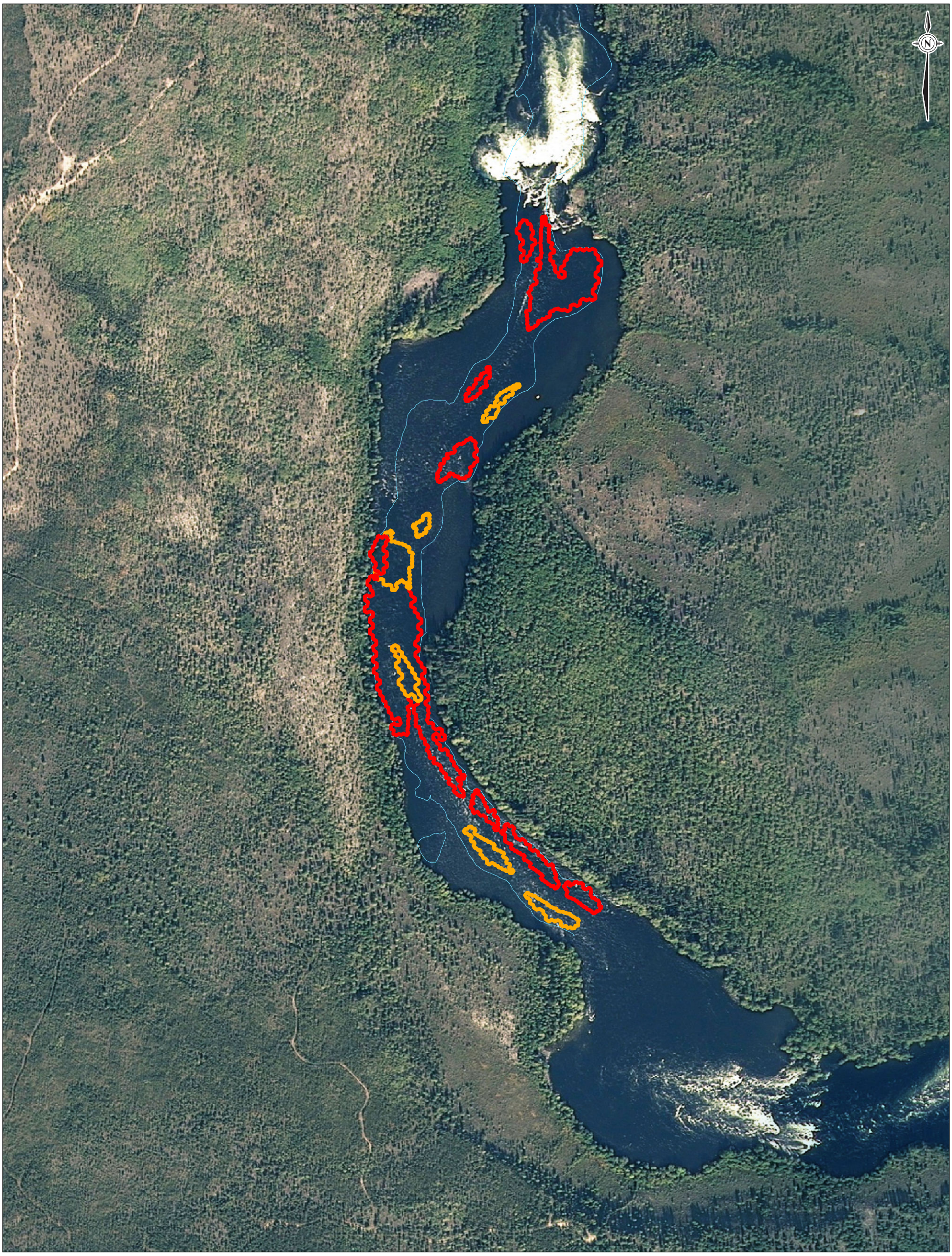
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 40 m³/s**

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13		
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

FIGURE: F19



LEGEND

- WATER'S EDGE AT 40 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
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NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 40 m³/s

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F20	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

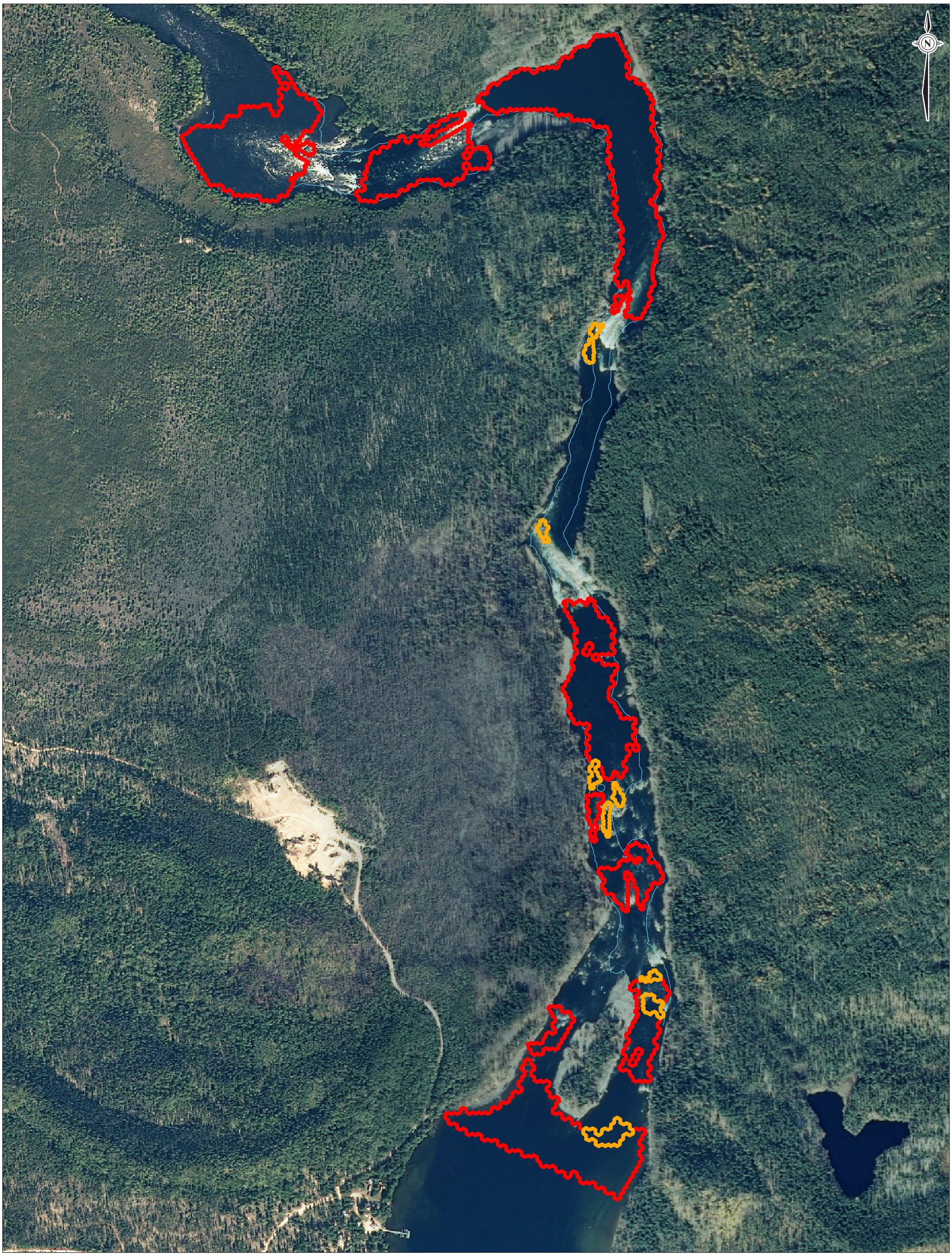
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 40 m³/s

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F21	
CHECK	AO	18/11/13		
REVIEW	BC	18/11/13		



LEGEND

- WATER'S EDGE AT 30 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 30 m³/s**

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	08/11/13		
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

FIGURE: F22

LEGEND

- WATER'S EDGE AT 30 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 30 m³/s

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
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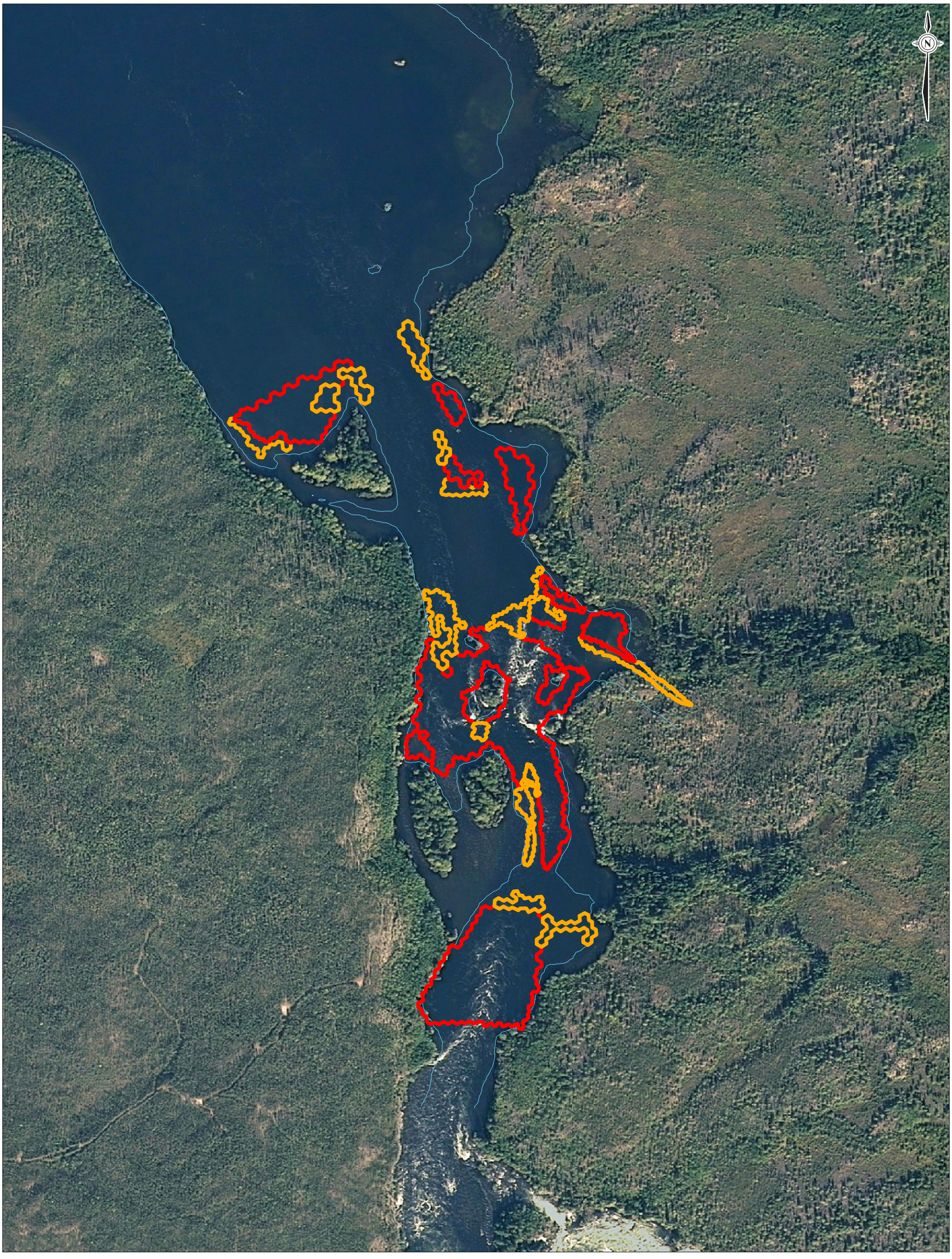
Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F23	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 30 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

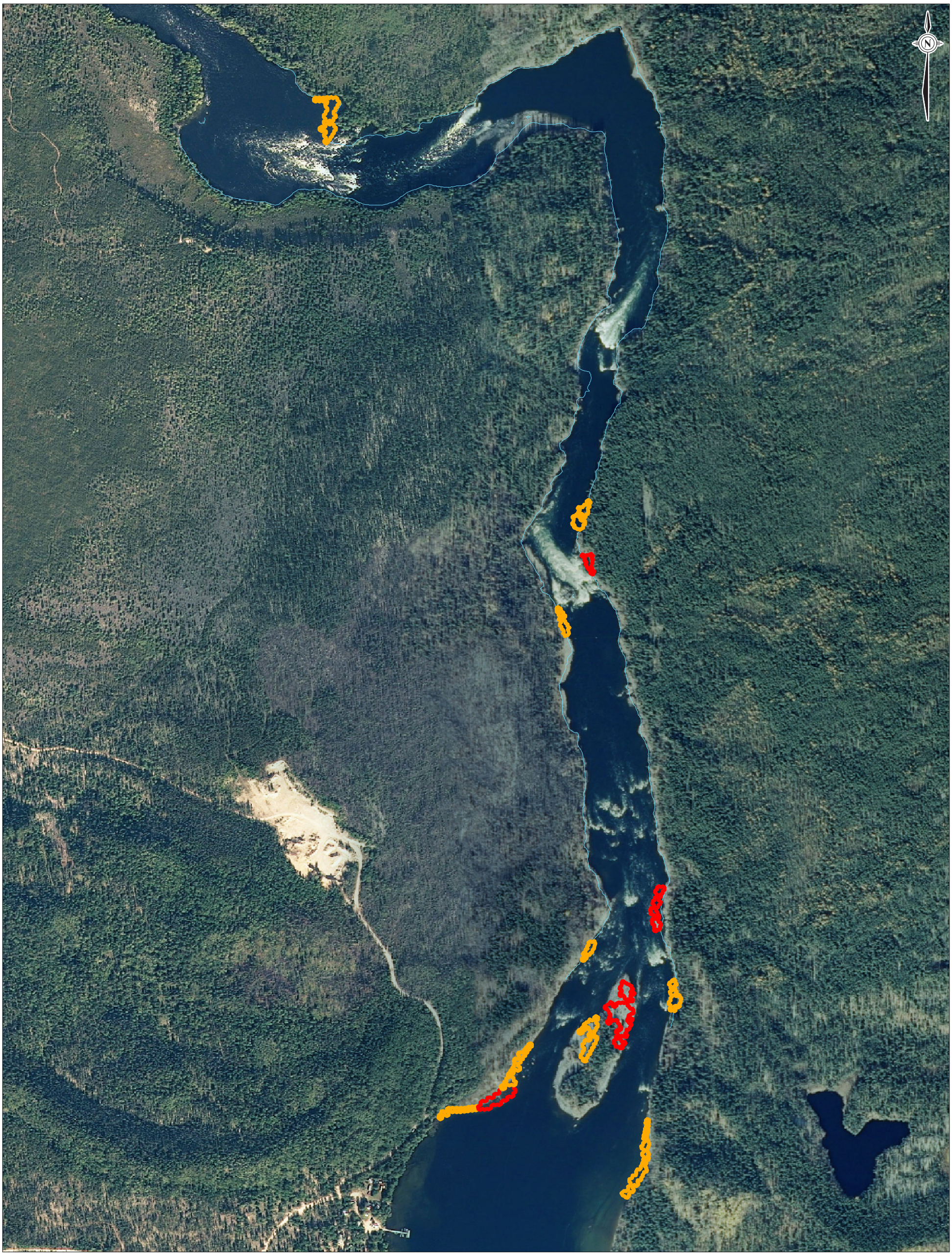
MODERATELY SUITABLE AND SUITABLE OVERWINTERING HABITAT FOR ADULT ARCTIC GRAYLING: 30 m³/s

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM	01/11/13	FIGURE: F24	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

Appendix 12.1-G

Predicted Arctic Grayling (*Thymallus arcticus*) Spawning Locations



LEGEND

- WATER'S EDGE AT 302 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

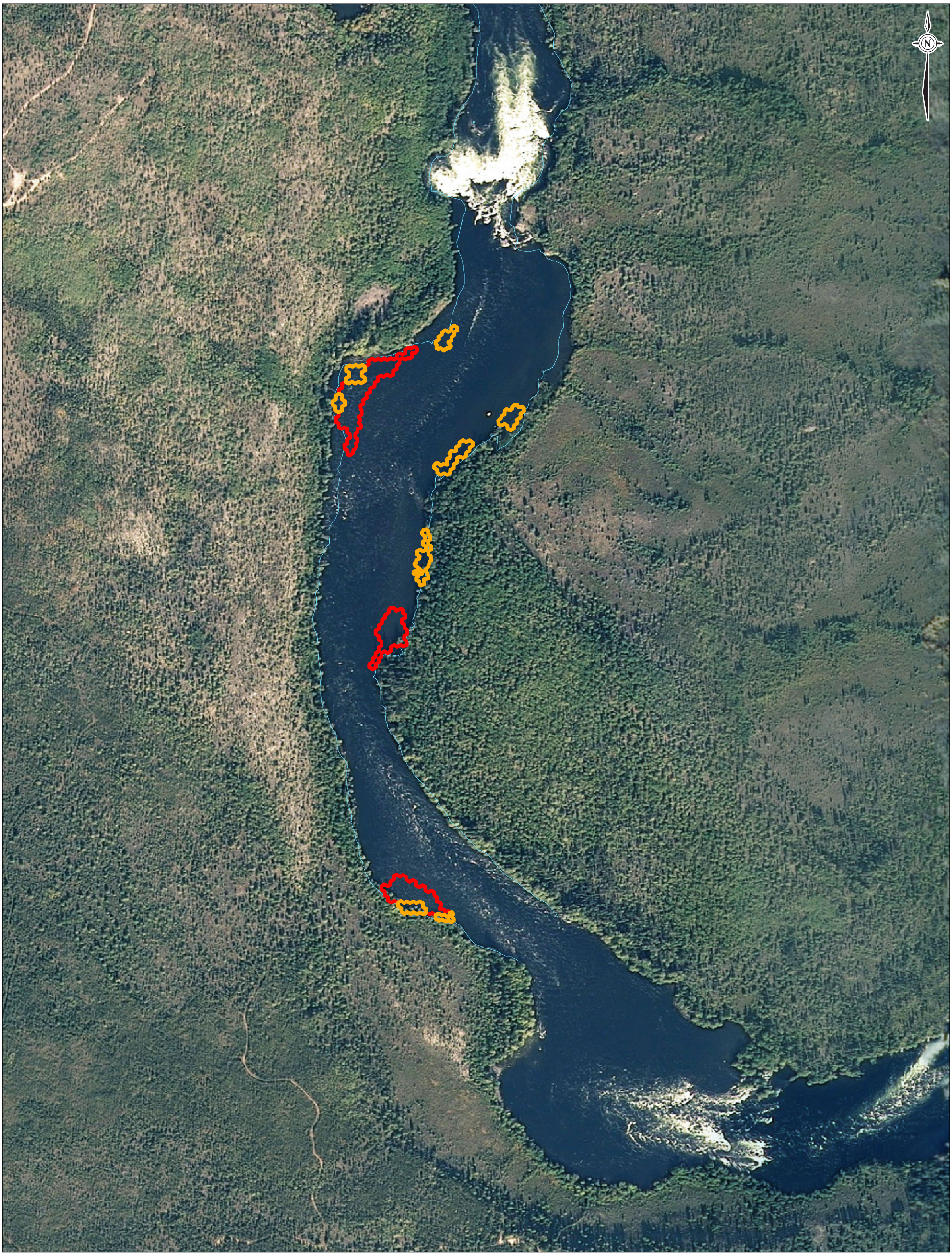
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 302 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G1	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 302 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

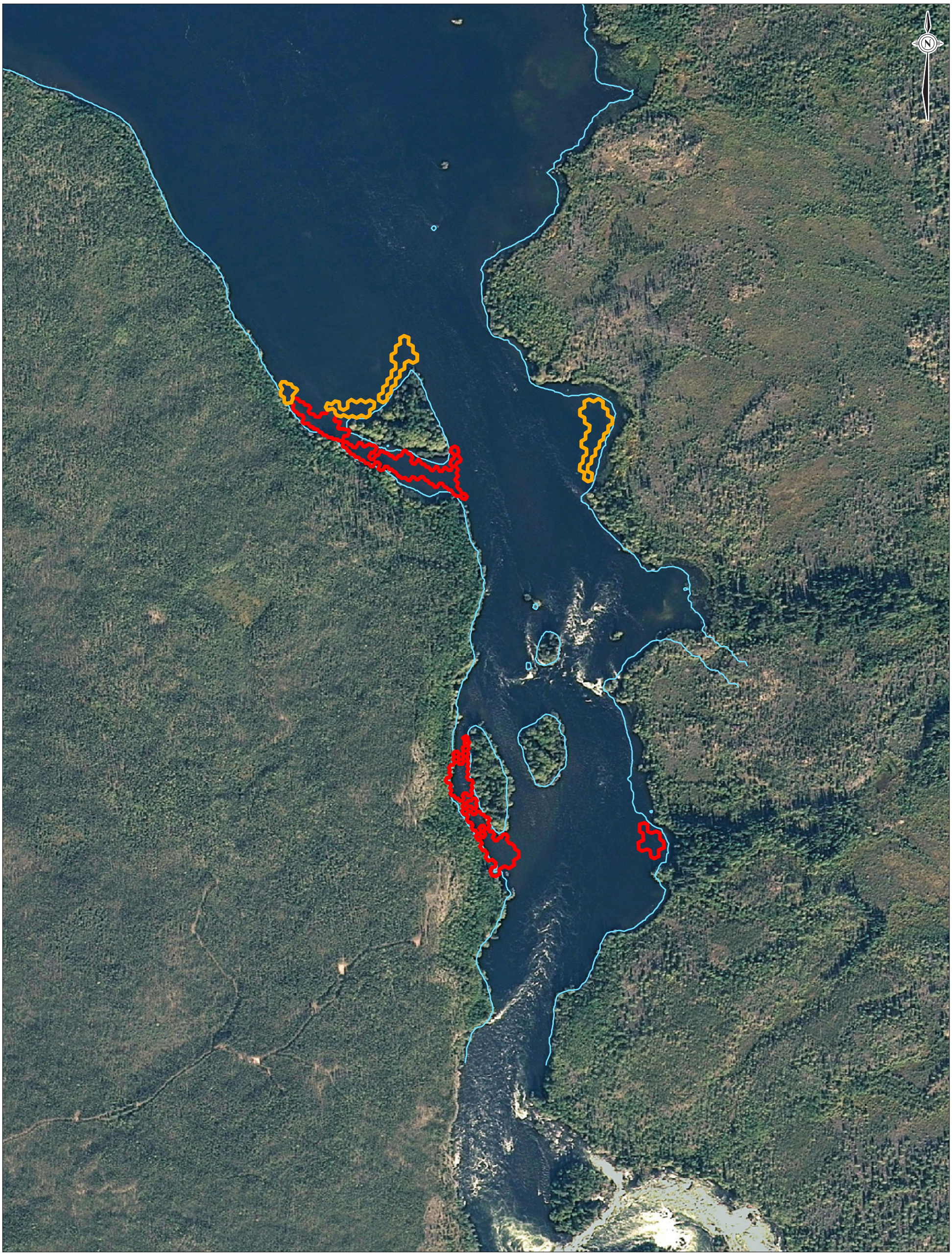
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 302 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G2	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 302 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE **MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 302 m³/s RIPARIAN FLOWS**

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G3	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 112 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
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PROJECT

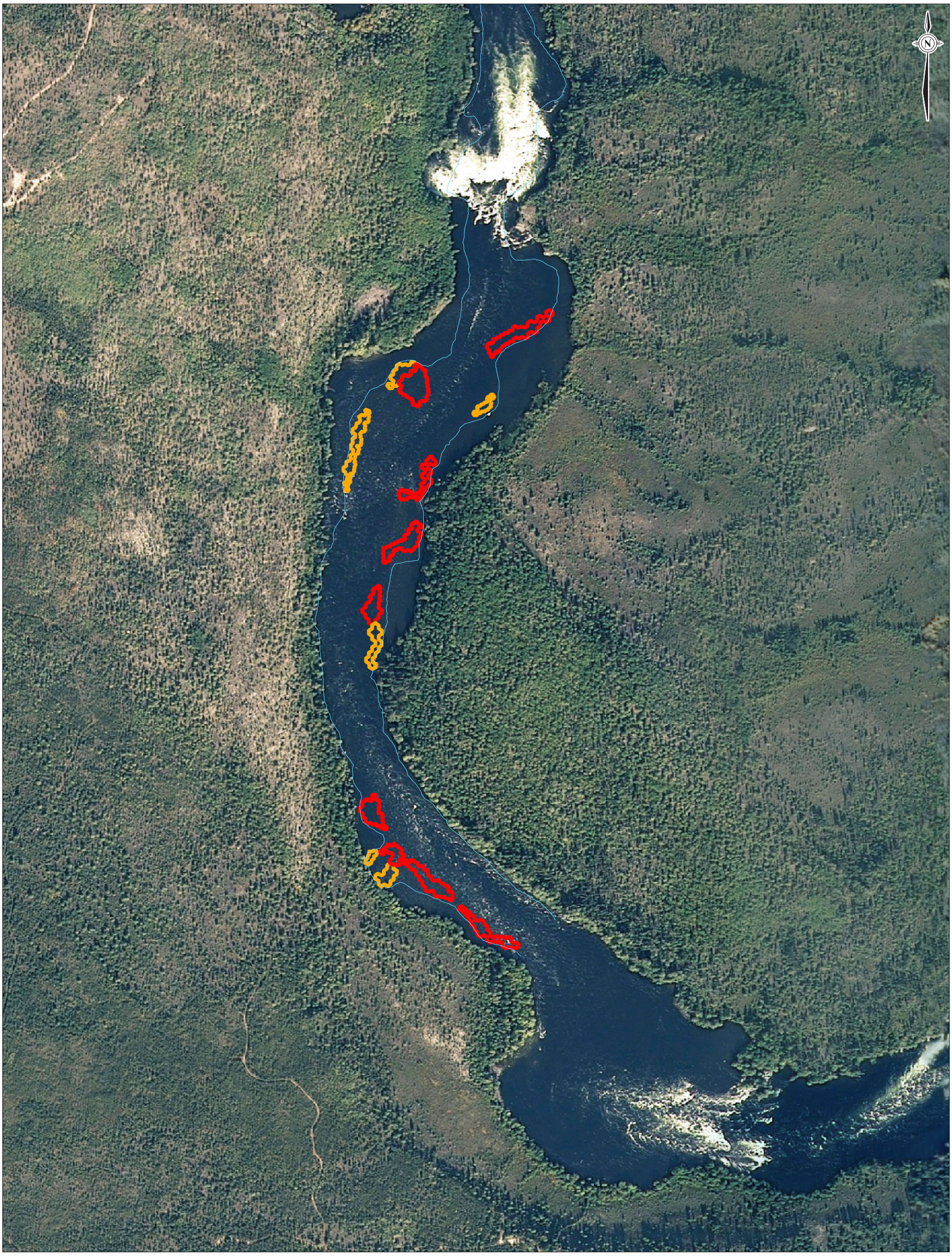
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 112 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G4	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 112 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

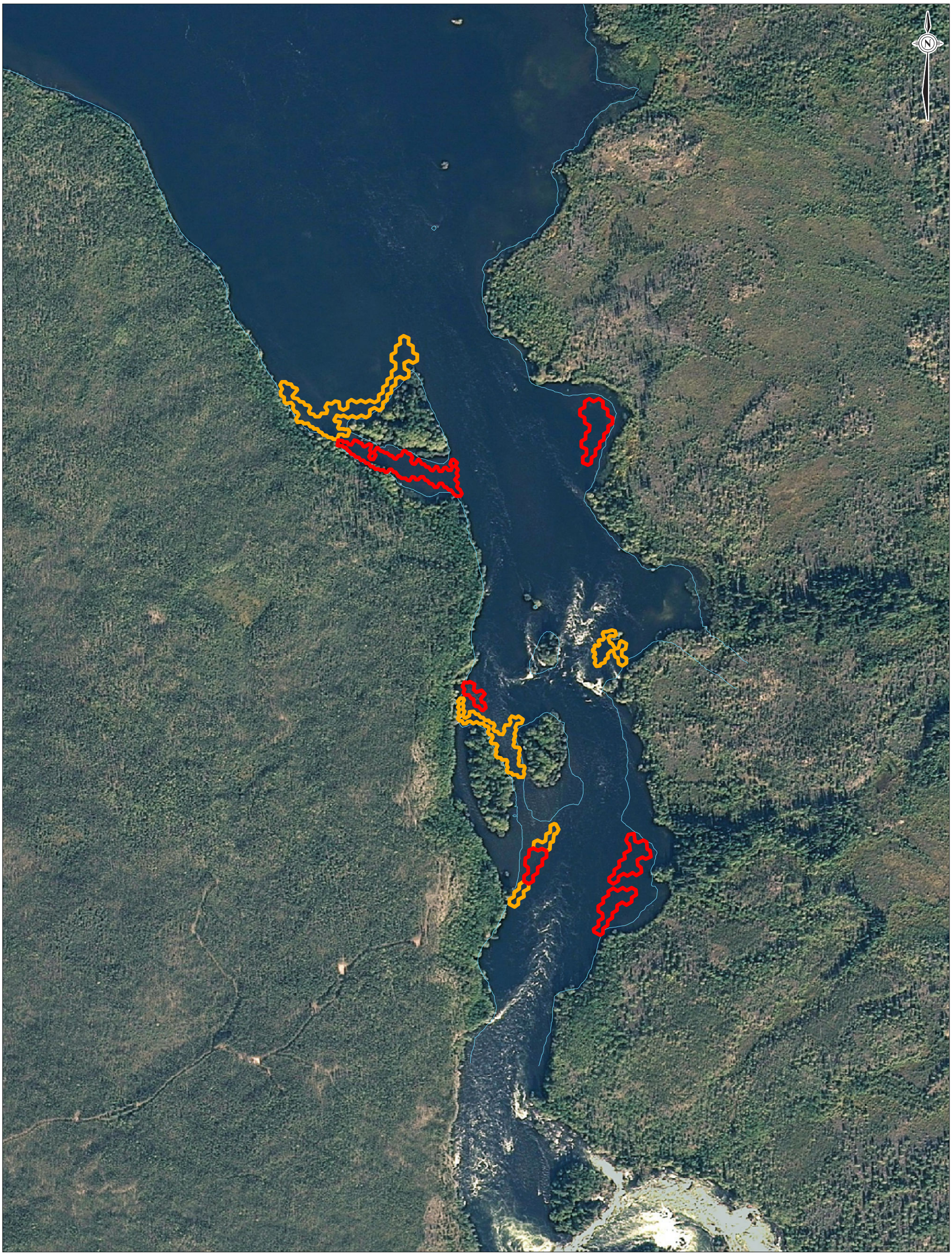
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 112 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G5	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 112 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
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NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 112 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G6	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 400 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
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NAD83 UTM ZONE 13

PROJECT

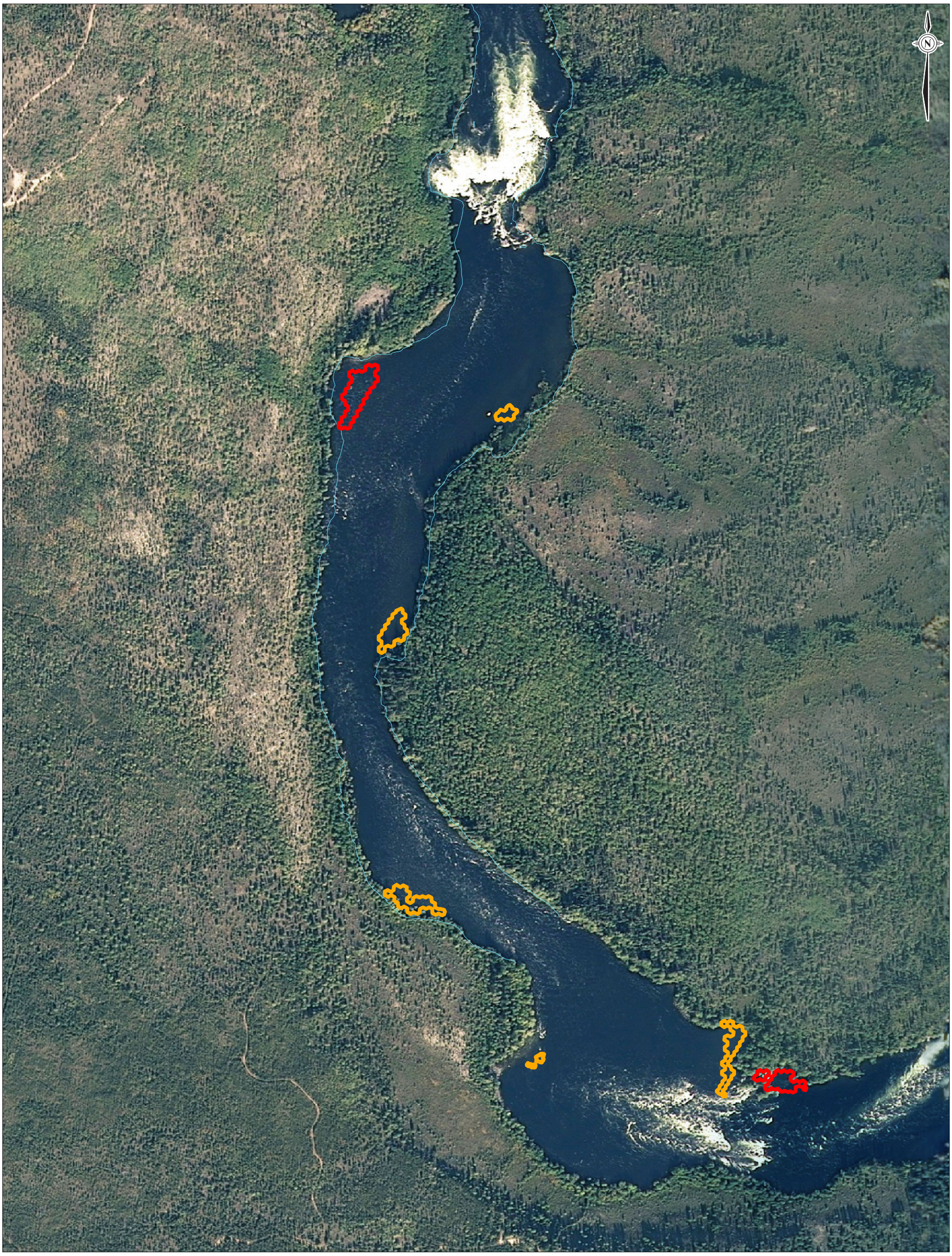
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 112 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G4	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 400 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 400 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G8	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

LEGEND

- WATER'S EDGE AT 400 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

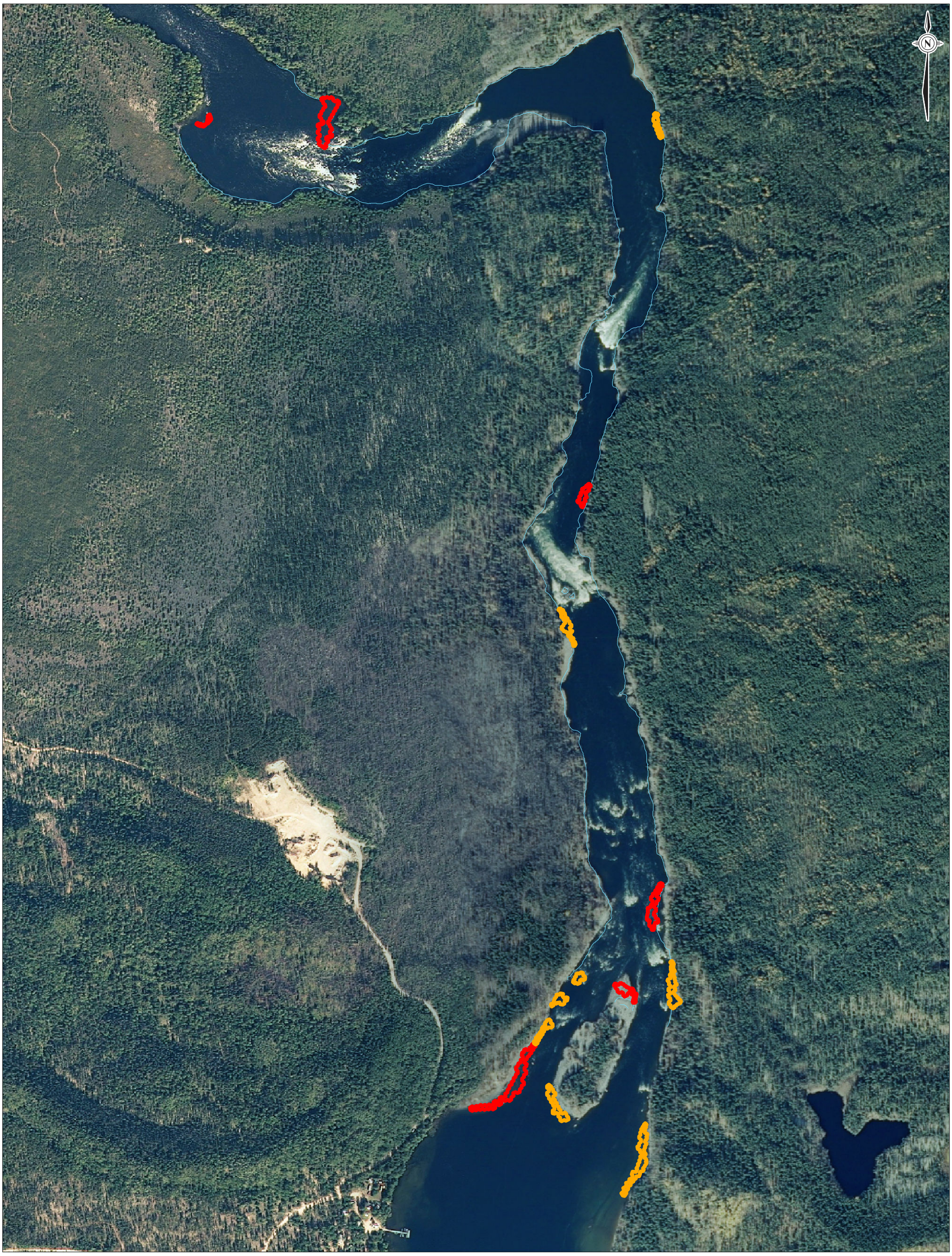
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 400 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G9	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

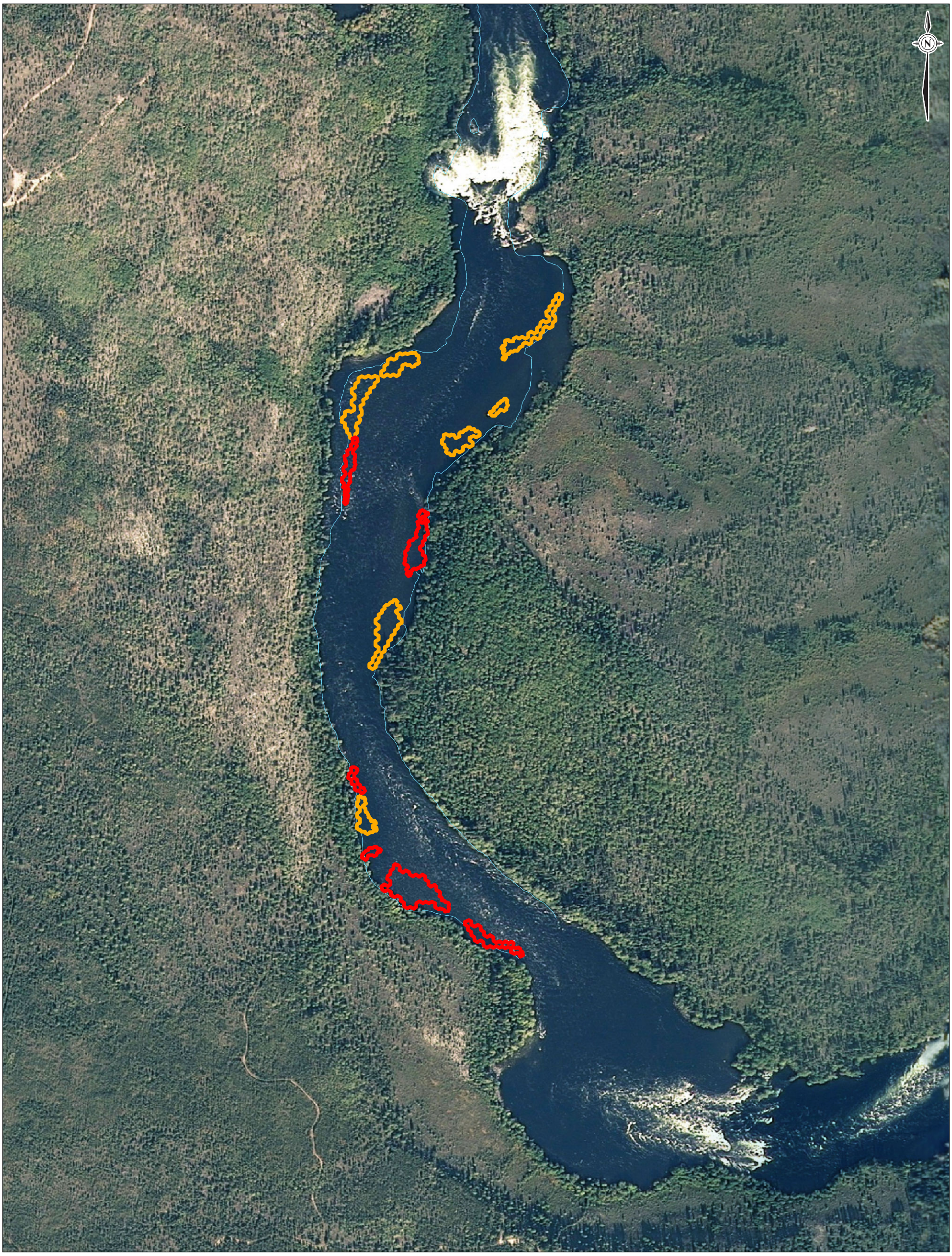
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 210 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G10	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

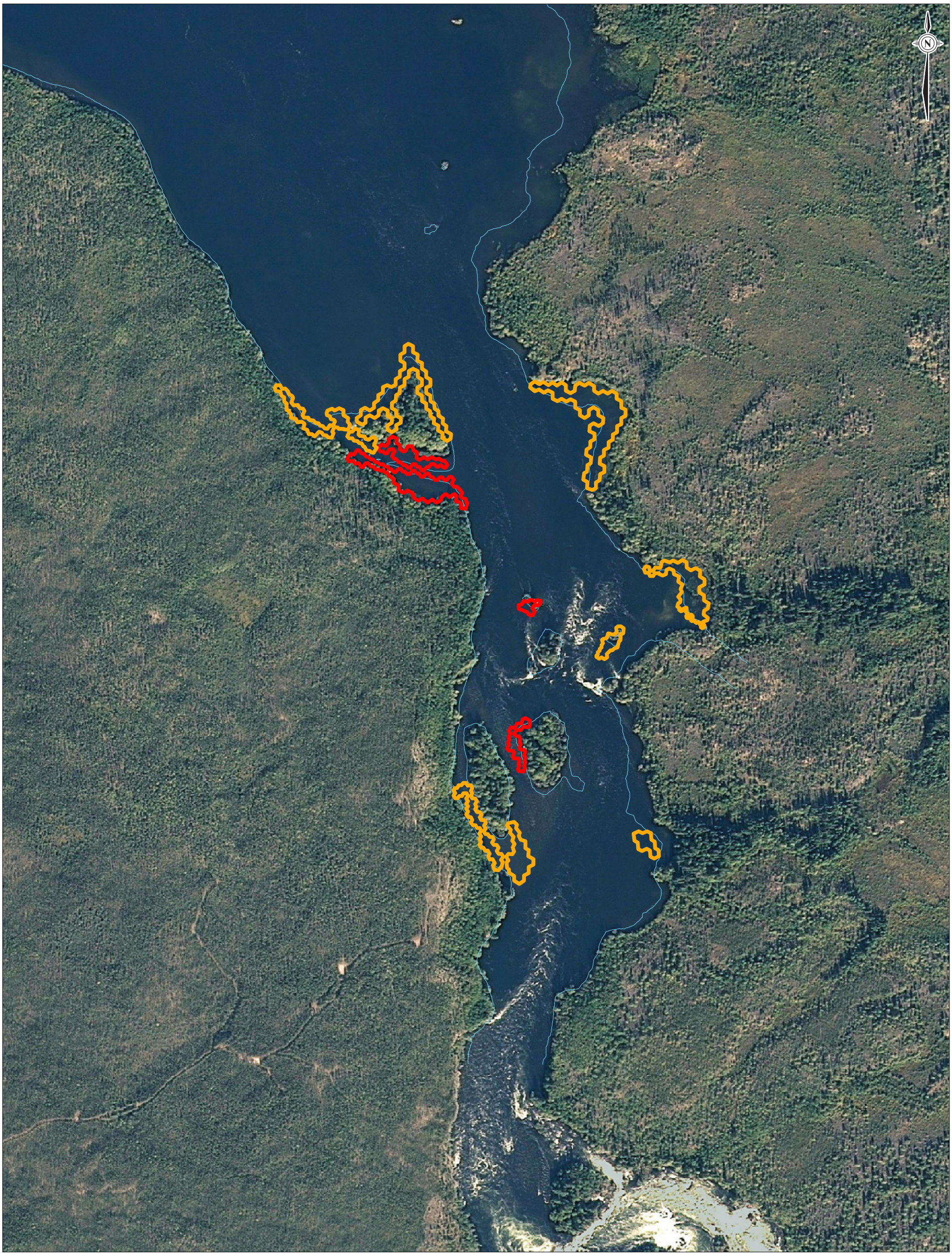
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 210 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G11	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 210 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
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NAD83 UTM ZONE 13

PROJECT

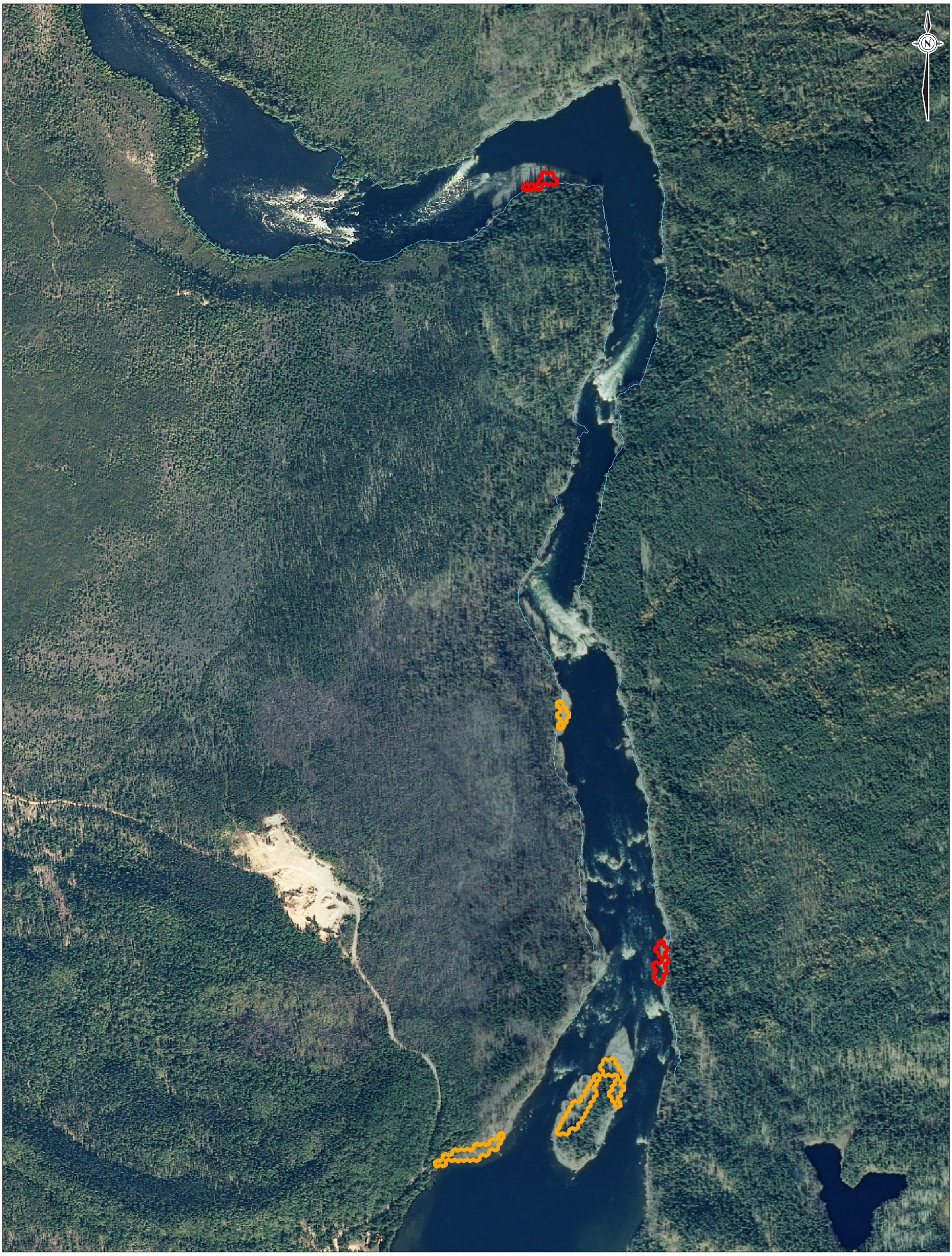
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 210 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G12	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 510 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
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PROJECT

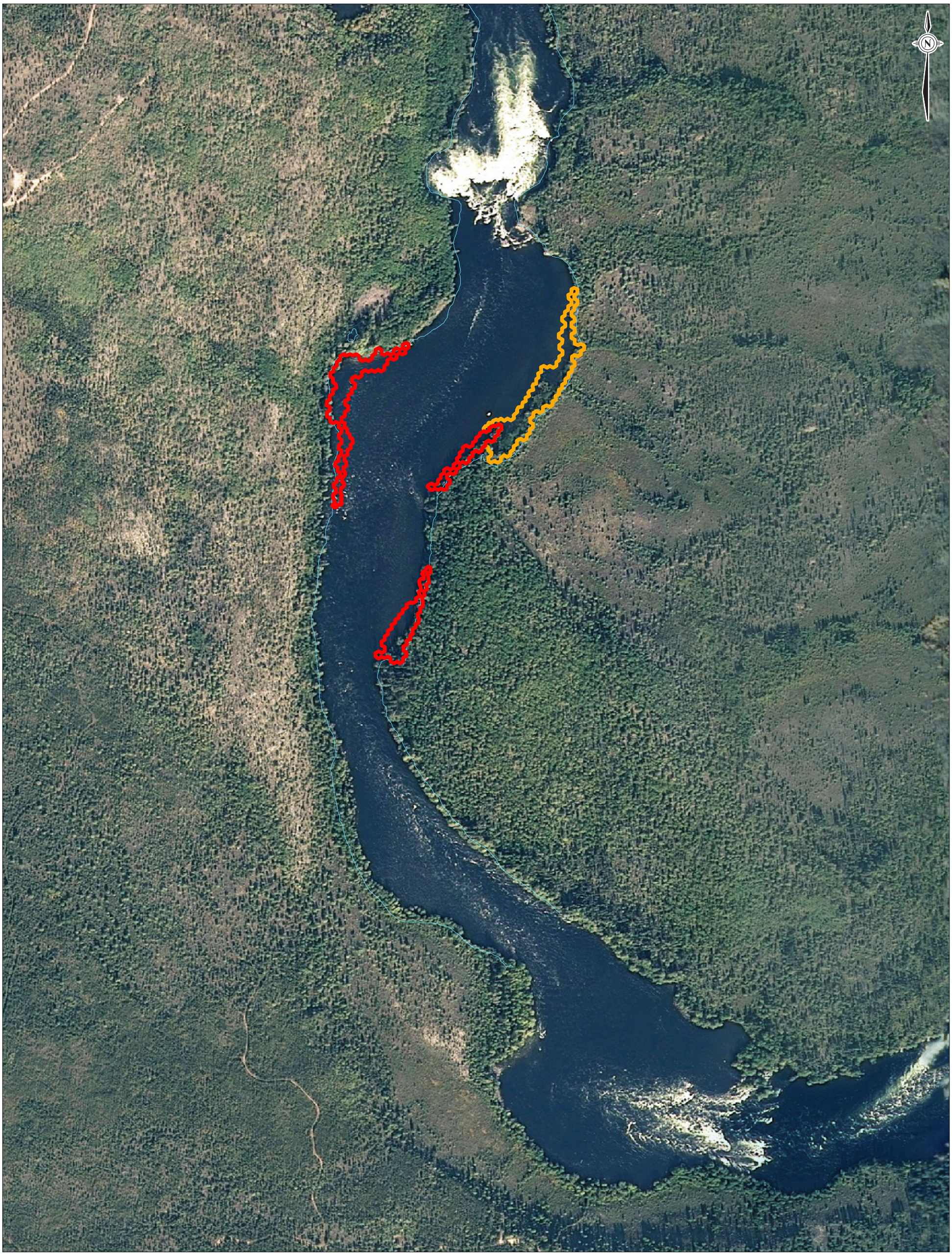
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 510 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G13	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 510 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

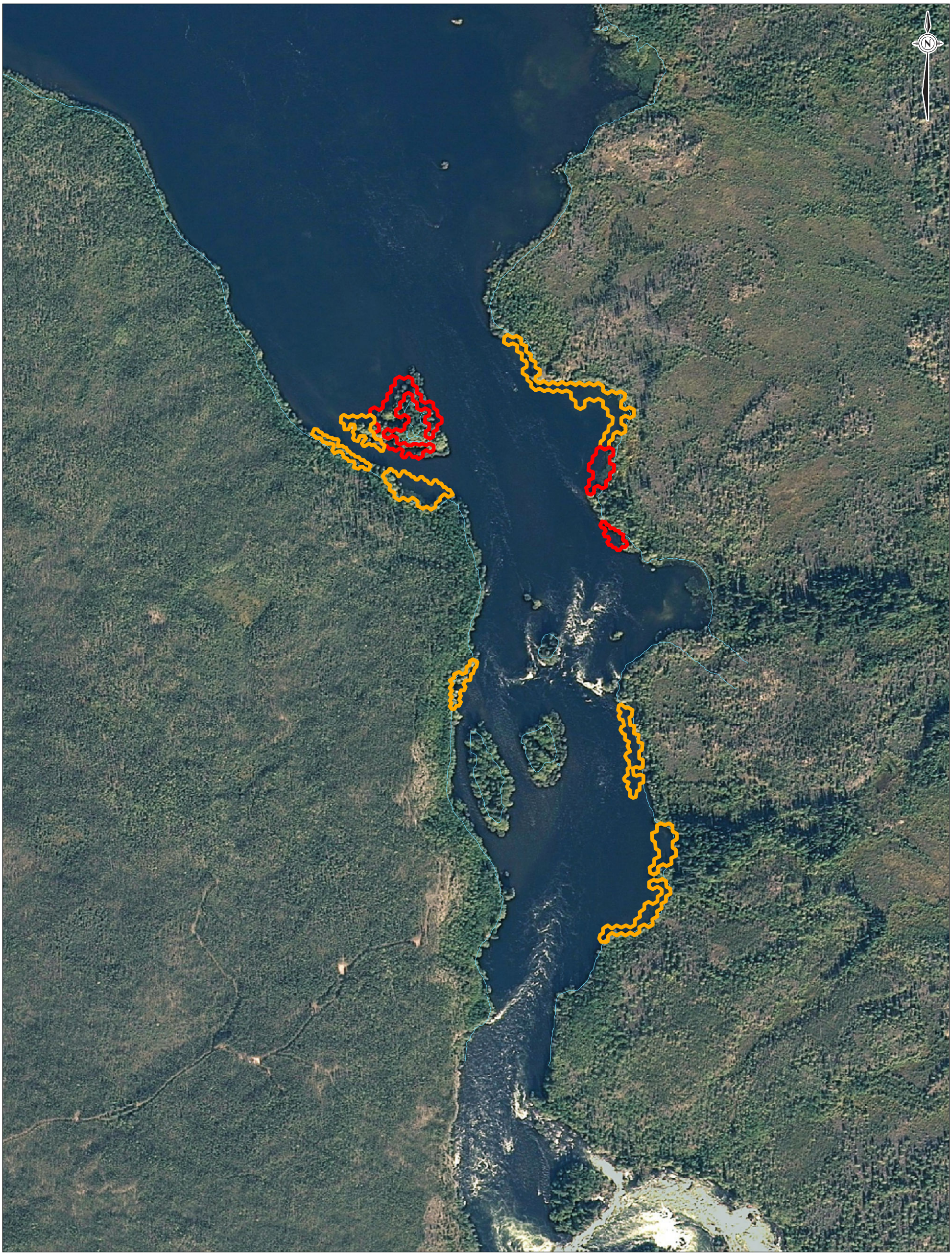
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 510 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G14	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 510 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100
SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 510 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
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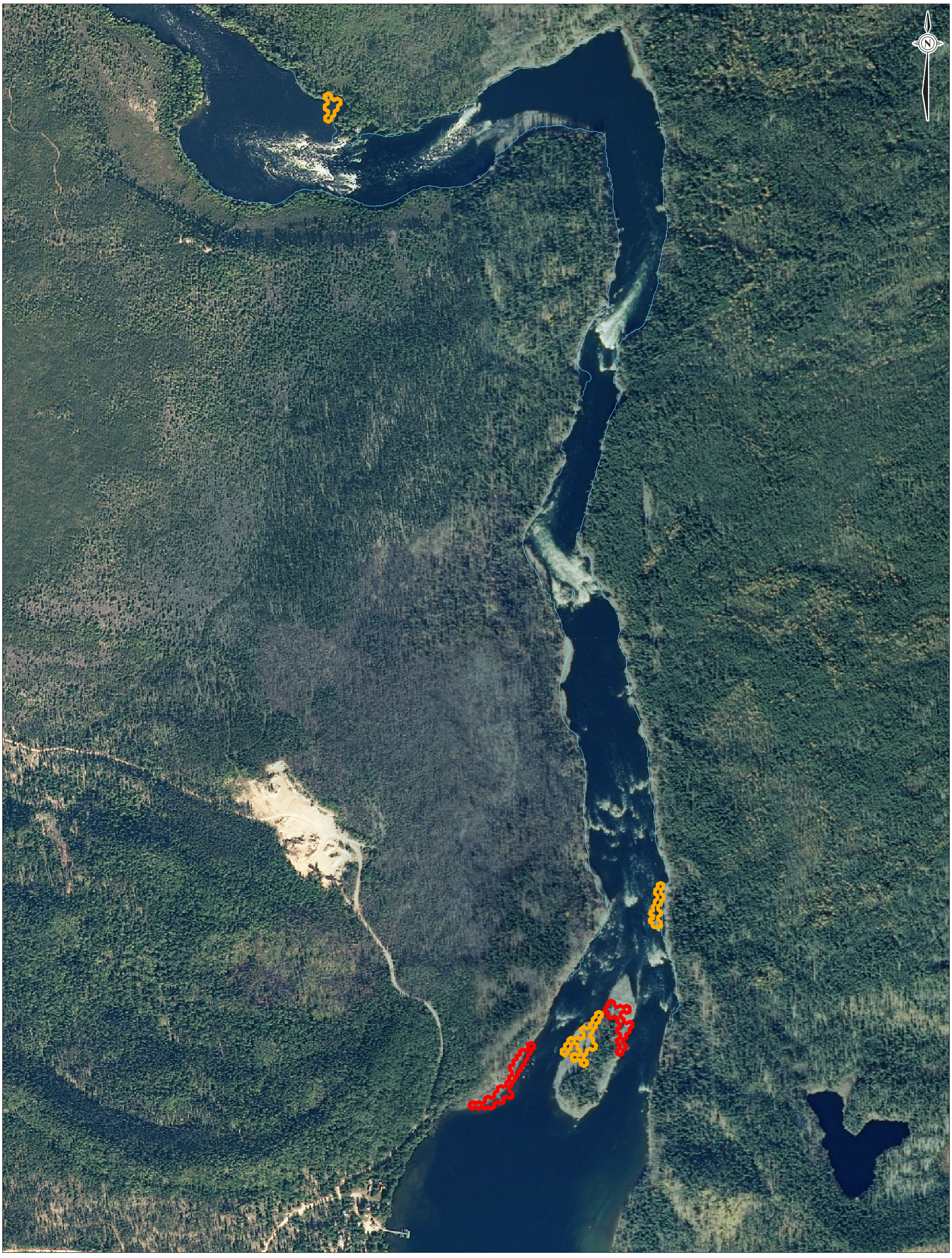
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 320 m³/s
- MODERATELY SUITABLE
- SUITABLE

150 0 150

SCALE 1:6,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

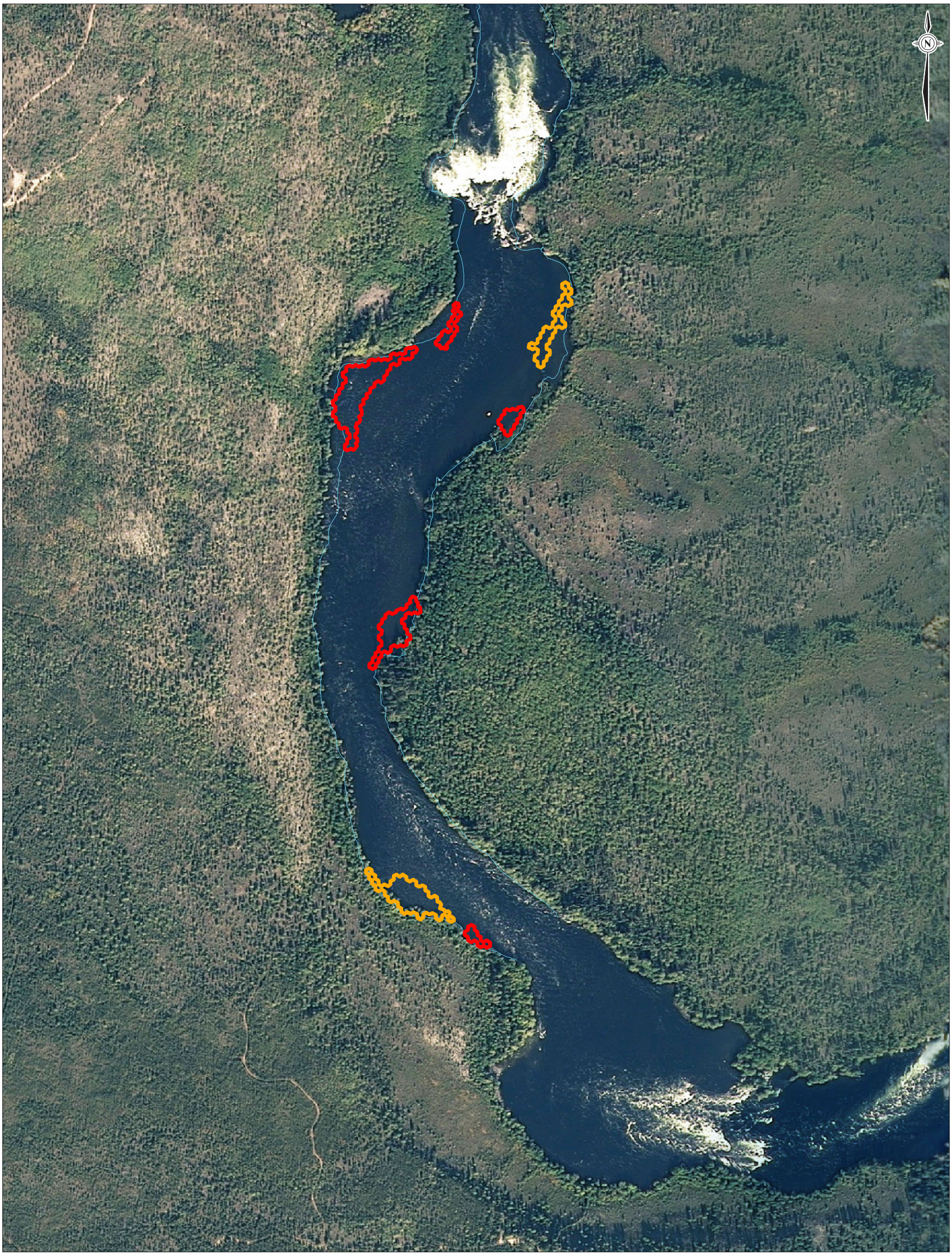
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 320 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G16	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 320 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

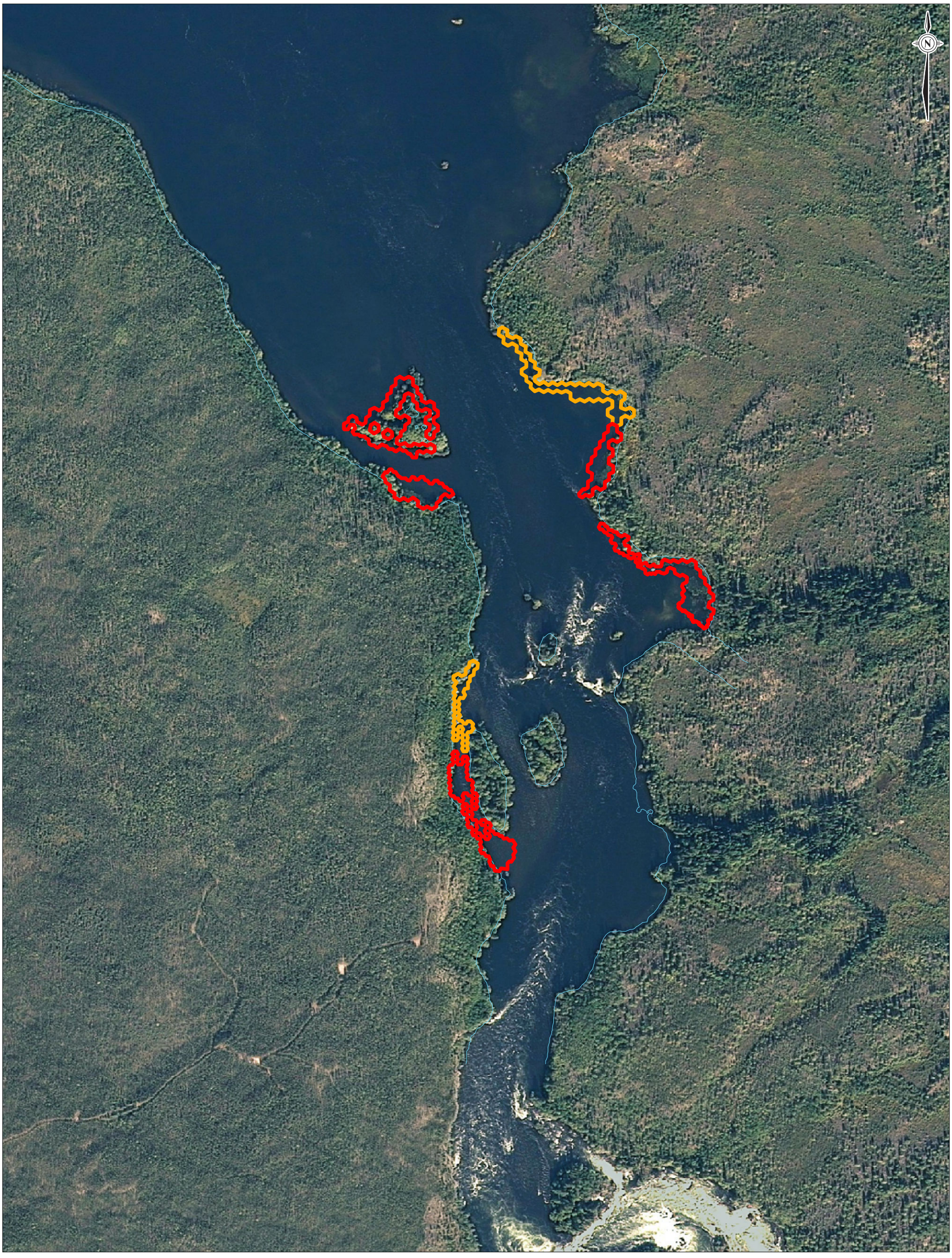
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 320 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G17	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		



LEGEND

- WATER'S EDGE AT 320 m³/s
- MODERATELY SUITABLE
- SUITABLE

100 0 100

SCALE 1:4,000 METRES

REFERENCE

2012 GOLDER FIELD SURVEY
FLYSASK ORTHOIMAGERY © SASKATCHEWAN GEOSPATIAL IMAGERY COLLABORATIVE, 2008 - 2011
NAD83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

MODERATELY SUITABLE AND SUITABLE ARCTIC GRAYLING SPAWNING HABITAT AT 320 m³/s RIPARIAN FLOWS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	08/11/13	FIGURE: G18	
CHECK	AO	15/11/13		
REVIEW	BC	15/11/13		

APPENDIX 12.2

Conceptual Fish Habitat Offsetting Plan

February 2014
Report No. 10-1365-0004/DCN-171

1.0 INTRODUCTION

The Saskatchewan Power Corporation (SaskPower), together with the Black Lake First Nation (BLFN), is proposing to construct and operate a new 50 megawatt (MW) water diversion-type hydroelectric generating station adjacent to the Fond du Lac River between Black Lake and Middle Lake. The proposed Tazi Twé Hydroelectric Project (the Project) will be located 7 kilometres (km) from the community of Black Lake and within the Chicken Indian Reserve No. 224 (Figure 1). The Hamlet of Stony Rapids is located approximately 25 km northwest of the proposed Project.

The energy produced by the Project will be integrated into the SaskPower electrical system to assist with accommodating the growing energy requirements of northern Saskatchewan communities and to support continued northern economic development. The Project's estimated gross average annual power generation will be approximately 400,000 megawatt hour (MWh) per year.

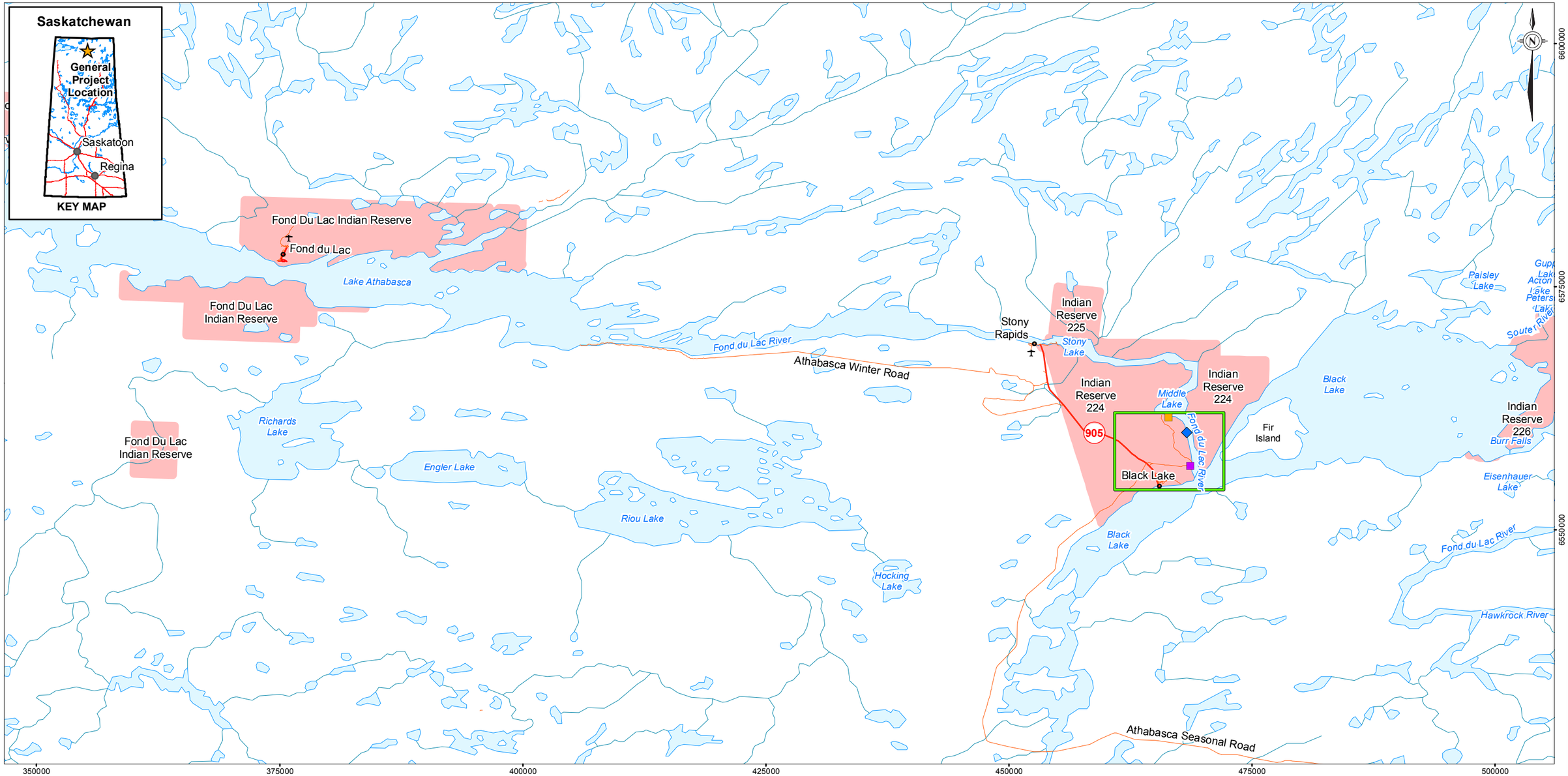
In January 2013, a Project Description was submitted to the Saskatchewan Ministry of Environment (MOE) and the Canadian Environmental Assessment Agency (Agency). On February 28, 2013, the Agency determined that a federal environmental assessment is required for the Project pursuant to the *Canadian Environmental Assessment Act* (*CEAA* 2012). The MOE has also determined that the Project is a "development" as defined by Section 2(d) of the *Saskatchewan Environmental Assessment Act* (*SEAA*).

Golder Associates Ltd. (Golder) was retained by SaskPower and the BLFN (together, the Proponent) to complete an environmental assessment (EA) and prepare an Environmental Impact Statement (EIS) to be submitted as part of the federal and provincial EA processes. Because the Project will have an impact on fish and fish habitat that are part of or support commercial, recreational or Aboriginal (CRA) fisheries, the Proponent also requested that Golder prepare a Fisheries Offsetting Plan.

1.1 Amendments to the *Fisheries Act*

On June 29, 2012, amendments to the federal *Fisheries Act* received Royal Assent; new Fisheries Protection Provisions included in the *Act* came into force on November 25, 2013. The recent amendments to the *Act* are intended to focus protection on the sustainability and ongoing productivity of CRA fisheries in Canada. It is anticipated the changes to the *Fisheries Act* will enhance existing compliance and protection tools, and provide clearer, more consistent standards and regulations.

The "Purpose" of the new Fisheries Protection Provisions and the "Factors" considered when issuing Authorizations or making regulations are included in the amendments to the *Fisheries Act*. The Purpose of the new provisions is to support the sustainability and ongoing productivity of CRA fisheries. Factors to be considered by Fisheries and Oceans Canada (DFO) when issuing *Fisheries Act* Authorizations include public interest; fisheries management objectives; mitigation measures or standards that may be available to avoid, minimize, or offset harm to fish; and whether fish are relevant to the ongoing productivity of a fishery.



LEGEND

- HAMLET OR COMMUNITY
- RUNWAY
- RIVER
- HIGHWAY
- ROAD
- INDIAN RESERVE
- WATERBODY
- ELIZABETH FALLS
- CAMP GRAYLING
- PERMANENT RESIDENT'S CABIN
- GENERAL PROJECT LOCATION

10 0 10
SCALE 1:400,000 KILOMETRES

REFERENCE

DMTI HIGHWAYS AND ROADS
NTS MAPSHEET 74I, 74J, 74O, 74P
NAD 83 UTM ZONE 13

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
LOCATION OF THE TAZI TWÉ HYDROELECTRIC PROJECT

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 1
GIS	SM	04/11/13		
CHECK	MT	04/11/13		
REVIEW	MM	04/11/13		

FIGURE: 1

The new Fisheries Protection Program contains prohibitions aimed at managing threats to fish that are part of, or support, a CRA fishery. Specifically, the *Act* states that "No person shall carry on any work, undertaking or activity that results in serious harm to fish that are part of a commercial, recreational or Aboriginal fishery, or to fish that support such a fishery" (Government of Canada 2012). Serious harm includes the killing of fish and the permanent alteration or destruction of fish habitats that are part of, or support, a fishery. This prohibition replaces previous prohibitions against killing fish by means other than fishing (Section 32 of the pre-June 29, 2012 *Act*) and the harmful alteration, disruption or destruction of fish habitat (Section 35 of the pre-June 29, 2012 *Act*).

New regulatory tools have been incorporated into the *Fisheries Act* to improve efficiency and modernize the regulations. The amendments describe the information proponents must provide to DFO prior to issuance of an Authorization, if one is required, as well as timelines for issuance of an Authorization. The amended *Act* also contains provisions for recognition of standards developed outside of DFO (e.g., where provincial regulations provide enhanced protection over *Fisheries Act* regulations and provisions).

The new *Act* allows the Minister to identify situations where Authorizations will not be required, or where additional protection for fish may be necessary (i.e., at locations deemed by the Minister to be ecologically significant for fish). The Minister may also identify opportunities where partnerships with other federal departments, provinces, or other groups may enhance protection of fisheries resources. Other government departments or provinces may receive authority to issue *Fisheries Act* Authorizations, provided that their regulations are consistent with those in the *Act*, and at the discretion of the Minister.

Enhancements to Compliance and Protection provisions under the new *Fisheries Act* include:

- increased fines and penalties for offences;
- streamlined, simplified enforcement for Ministerial Authorizations;
- updates to inspector powers to ensure compliance with prohibitions in Section 35 of the *Act*; and
- inclusion of a "duty to notify" provision that requires reporting and corrective action by persons whose actions result in harm to fish habitat.

Stakeholder groups that are expected to benefit from the amendments to the *Fisheries Act* include anglers, conservation groups, landowners and municipalities, industry, and the provinces and territories. The changes to the *Act* recognize the importance of recreational fisheries, as well as the involvement of conservation groups in fisheries protection activities. For landowners, municipalities, and industry, the new regulations are expected to provide increased clarity regarding which types of activities will or will not require review by DFO. Reviews will focus on activities that may impact the sustainability and productivity of CRA fisheries. Information requirements for industrial proponents are included in the regulations, along with timelines for permitting activities. The provincial and territorial governments are expected to benefit from the enhanced opportunities to work in partnership with DFO.

1.2 Objectives of the Fisheries Offsetting Plan

Under the *Fisheries Act*, any activity resulting in the death of fish or the permanent alteration or destruction of fish habitat is considered to be a source of serious harm to fish. Where possible, Project structures were designed to avoid or mitigate serious harm to fish that are part of or support CRA fisheries. However, it is anticipated that construction and operation of the Project will result in some residual serious harm to fish after implementation of avoidance and mitigation measures and standards. Therefore, the objectives of this conceptual Fisheries Offsetting Plan are:

- to describe plans to avoid and mitigate negative effects to fish and fish habitat;
- to quantitatively describe anticipated residual serious harm to fish that is likely to result from the Project, despite the implementation of avoidance and mitigation measures and standards;
- to describe potential measures for offsetting the residual serious harm to fish; and
- to describe how the selected measure(s) are anticipated to offset serious harm to fish.

Implementation of the selected measure(s) for offsetting residual harm to fish is expected to maintain or improve the productivity of CRA fisheries in the Project area.

1.3 General Site Description

The Project is located approximately 7 km northeast of the community of Black Lake, within the Chicken Indian Reserve No. 224 (Latitude: 59° 10’ 48” N, Longitude: 105° 32’ 12” W). The Project area has a subarctic continental climate with short, cool summers and long, cold winters. The area is separated into two Ecoregions; the Athabasca Plain Ecoregion occurs on the west side of the Fond du Lac River and the Tazin Lake Upland Ecoregion is on the east side of the river (Acton et al. 1998). The topography surrounding the proposed Project location is primarily bedrock-controlled with low to moderate relief. Active groundwater flow in the Project area is generally confined to localized shallow fracture systems and flow directions are believed to be similar to the topographic grade. Riparian areas are typically vegetated with black spruce (*Picea mariana*), jack pine (*Pinus banksiana*), white birch (*Betula papyrifera*), alders (*Alnus* sp.), and willows (*Salix* sp.).

The Project area is located in the Lake Athabasca drainage basin. The Fond du Lac River originates at the outflow of Wollaston Lake, and flows approximately 275 km reaching Lake Athabasca, approximately 50 km downstream of the Project. At the outlet of Black Lake, the Fond du Lac River has an upstream drainage area of 50,800 square kilometres (km^2). The Fond du Lac River between Black Lake and Middle Lake has a total length of 6.1 km and a total change in elevation of approximately 36 metres (m). This section of the river receives runoff from an area of 10.6 km^2. From 1947 to 2010, the Fond du Lac River had an average daily flow rate of 303 cubic metres per second (m^3/s), a maximum flow rate of 860 m^3/s, and a minimum flow rate of 115 m^3/s.

Black Lake is at the upstream end of the Project area and flows into the bypassed section of the Fond du Lac River and eventually into Lake Athabasca. Black Lake has three notable inflows: the Fond du Lac River, the Cree River, and the Chipman River, and one outflow: the Fond du Lac River. The Chipman River flows from the north and enters Black Lake at its most northern point. The Fond du Lac River is the largest inflow, with headwaters upstream of Wollaston Lake.

Black Lake has two main sections, one to the southwest of the outflow and a larger section to the northeast. The southwest section is approximately 25 km long and has a maximum width of less than 5 km while the northeast section is approximately 40 km long and has a maximum width of less than 20 km. Black Lake has a total surface area of 418 km^2 and has a maximum depth of about 58 m. In general terms, Middle Lake is a widening of the Fond du Lac River before the river continues toward Lake Athabasca. Middle Lake has a total surface area of 7.5 km^2 and a maximum depth of about 14 m.

The adjacent upland area is largely devoid of surface water, with the exception of some small ponds and wetland areas. There are three streams in the upland area, the largest of which drains an area of 80.5 km^2 and flows into the south end of Middle Lake.

1.3.1 Fish and Fish Habitat

Fish and fish habitat surveys were completed in Black Lake, the Fond du Lac River (between Black Lake and Middle Lake) and Middle Lake between June 2010 and July 2012 (Annex III). Sixteen fish species were captured in Black Lake (Table 1), 12 fish species were captured in the Fond du Lac River between Black Lake and Middle Lake (Table 2), and nine fish species were captured in Middle Lake (Table 3). A full discussion of the results of fish and fish habitat surveys is presented in Section 12 of the EIS.

Table 1: Fish Species Captured in Black Lake from May 2010 to February 2011

Common Name	Scientific Name	Total Number Captured
Arctic grayling	*Thymallus arcticus*	46
Burbot	*Lota lota*	112
Cisco[(a)]	*Coregonus artedi/Coregonus zenithicus*	9
Lake chub	*Couesius plumbeus*	130
Lake trout	*Salvelinus namaycush*	505
Lake whitefish	*Coregonus clupeaformis*	272
Longnose sucker	*Catostomus catostomus*	267
Ninespine stickleback	*Pungitius pungitius*	13
Northern pike	*Esox lucius*	45
Round whitefish	*Prosopium cylindraceum*	16
Slimy sculpin	*Cottus cognatus*	86
Spottail shiner	*Notropsis hudsonius*	6
Trout-perch	*Percopsis omiscomaycus*	7
Walleye	*Sander vitreus*	24
White sucker	*Catostomus commersonii*	372
Yellow perch	*Perca flavescens*	6

[(a)] Fish having morphometric and meristic characteristics of both common (*Coregonus artedi*) and shortjaw cisco (*Coregonus zenithicus*) were captured from the Project area.

Table 2: Fish Species Captured in the Fond du Lac River from May to October 2010 and in July 2012

Common Name	Scientific Name	Total Captured		
		Upstream (Black Lake Outflow)	Downstream (Middle Lake Inflow)	Middle Section (Fond du Lac River)
Arctic grayling	*Thymallus arcticus*	1,161	695	5
Burbot	*Lota lota*	1	15	0
Longnose sucker	*Catostomus catostomus*	1	282	1
White sucker	*Catostomus commersonii*	45	168	1
Lake whitefish	*Coregonus clupeaformis*	0	18	1
Round whitefish	*Prosopium cylindraceum*	0	0	5
Cisco[(a)]	*Coregonus artedi/Coregonus zenithicus*	0	24	0
Northern pike	*Esox lucius*	0	9	0
Walleye	*Sander vitreus*	1	3	2
Slimy sculpin	*Cottus cognatus*	1	573	0
Spottail shiner	*Notropsis hudsonius*	0	12	0
Trout-perch	*Percopsis omiscomaycus*	0	1	0

[(a)] Fish having morphometric and meristic characteristics of both common (*Coregonus artedi*) and shortjaw cisco (*Coregonus zenithicus*) were captured from the Project area.

Table 3: Fish Species Captured in Middle Lake from May 2010 to February 2011

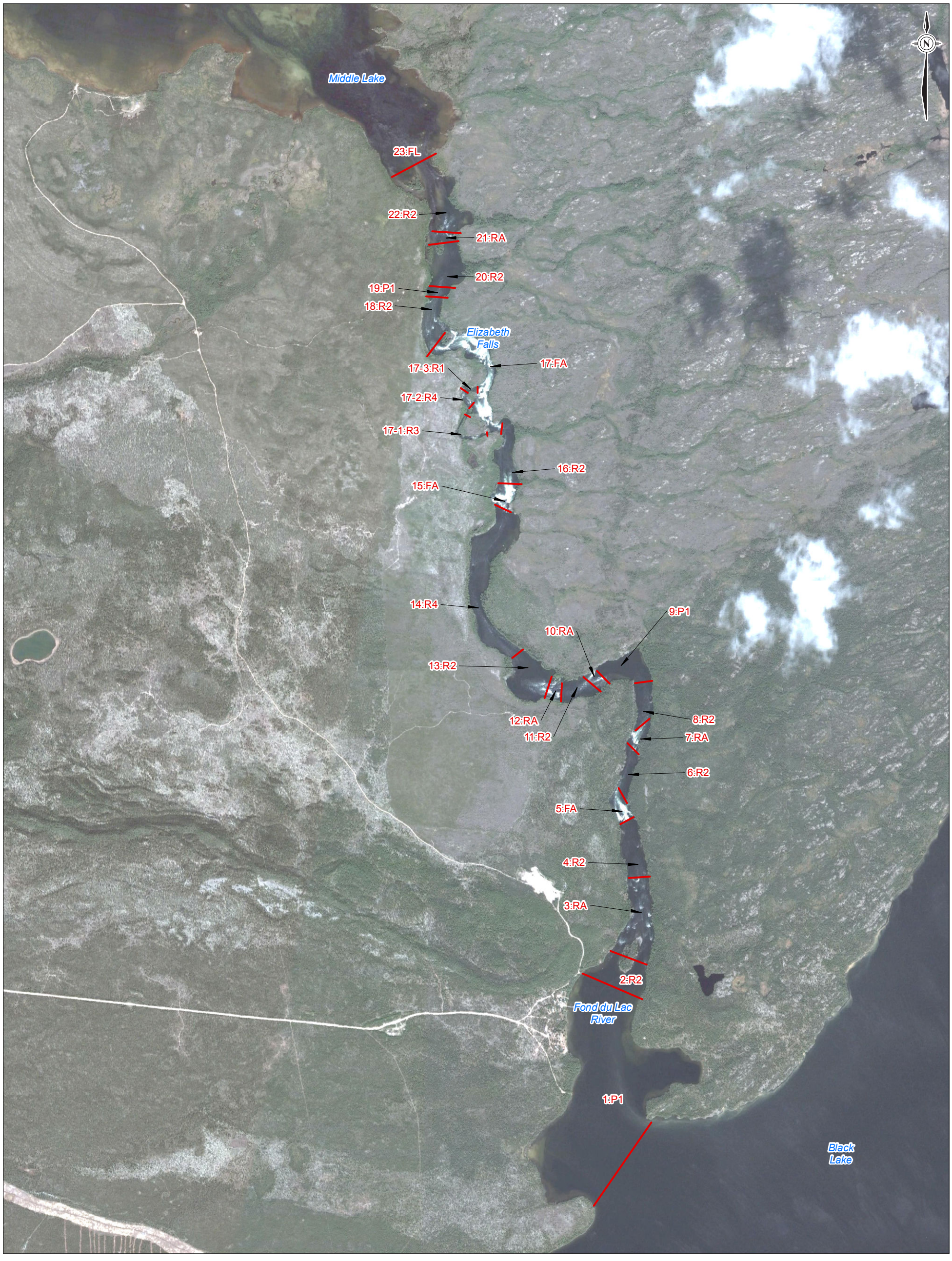
Common Name	Scientific Name	Total Number Captured
Arctic grayling	*Thymallus arcticus*	7
Burbot	*Lota lota*	25
Lake chub	*Couesius plumbeus*	4
Lake whitefish	*Coregonus clupeaformis*	34
Longnose sucker	*Catostomus catostomus*	23
Ninespine stickleback	*Pungitius pungitius*	28
Northern pike	*Esox lucius*	49
Slimy sculpin	*Cottus cognatus*	31
White sucker	*Catostomus commersonii*	50

A small number of fish species reported in the Project area were not captured during the 2010-2012 aquatic baseline surveys. Lake chub (*Couesius plumbeus*), ninespine stickleback (*Pungitius pungitius*), and yellow perch (*Perca flavescens*) have been reported in the Fond du Lac River (Saskatchewan Parks and Renewable Resources [SPRR] 1991) and walleye (*Sander vitreus*) in Middle lake (Envirocon 1974; SPRR 1991). Area residents have also reported the presence of lake trout (*Salvelinus namaycush*) in Middle Lake. Shortjaw cisco (*Coregonus zenithicus*) and deepwater sculpin (*Myoxocephalus thompsoni*) have been reported in Black Lake (SPRR 1991; Johnson 1971); however, cisco specimens captured during the 2010-2012 aquatic baseline surveys had morphometric and meristic characteristics of both common (*Coregonus artedi*) and shortjaw cisco (Golder 2013).

The dominant substrate types in the main basin of Black Lake are cobble and boulder, with some gravel and sand components. Shoreline substrates near the proposed water intake location are comprised primarily of cobble and boulder, with some gravel. A 30 m deep trough runs parallel with the shoreline between the northern extent of Black Lake and Fir Island. Emergent aquatic vegetation and low shrubs were the predominant vegetation identified along the shoreline near the proposed water intake (Annex III).

Baseline surveys identified major habitat types for 23 habitat reaches or channel units (i.e., section of channel having relatively homogenous water depth, velocity, and cover) in the Fond du Lac River between Black Lake and Middle Lake (Figure 2) (Annex III). Deep, fast-flowing runs, rapids, deep pools, and waterfalls are the most common type of habitat section in the Fond du Lac River between the Black Lake outflow and the Middle Lake inflow. By relative area contribution, flat water habitat located primarily in the Middle Lake outflow area was most abundant, followed by deep pool habitat located at the outlet of Black Lake and in several other reaches. Extensive riffle habitat and back eddies were present in many of the channel units. Elizabeth Falls and two additional waterfall-type habitats within the river were identified as barriers or potential barriers to upstream fish migration.

Substrate in Middle Lake consists of sand and silt, with areas of cobble and boulder (Annex III). Aquatic vegetation is present throughout much of the lake and is very dense along both sides of the main channel of the Fond du Lac River.



LEGEND

PRIMARY CLASSIFICATION (REACH NUMBER : CLASSIFICATION)

400 0 400

SCALE 1:20,000 METRES

REFERENCE

GOLDER ASSOCIATES © 2012
GOOGLE EARTH IMAGE © 2010 DIGITAL GLOBE
NAD 83 UTM ZONE 13

PROJECT

TAZI TWÉ HYDROELECTRIC POWER PROJECT

TITLE

RIVER REACHES OF THE FOND DU LAC RIVER BETWEEN BLACK LAKE AND MIDDLE LAKE

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
GIS	SM/LR	27/08/13		
CHECK	AO	18/11/13		
REVIEW	BC	18/11/13		

FIGURE: 2

1.3.1.1 *Fish Population Estimates*

Population estimates for Arctic grayling (*Thymallus arcticus*) in the Fond du Lac River were made in 1974 (Envirocon), in 1989 (Merkowsky), and 2010 (Annex III). For each study, population sizes were estimated for the upstream and downstream areas of the Fond du Lac River based on the presence of Elizabeth Falls as a likely barrier to upstream fish passage.

The 2010 Fond du Lac River Arctic grayling population estimates for the Grayling Island area near the outlet of Black Lake (upstream of Elizabeth Falls) and the section of Fond du Lac River just upstream of Middle Lake (downstream of Elizabeth Falls) compare favourably with population estimates from the two previous studies at these locations (Table 4). Based on a comparison of the 2010 results with those from the 1989 and 1974 reports, there is no indication that Arctic grayling populations in the Fond du Lac River are currently in decline.

Table 4: Arctic grayling (Thymallus arcticus) Population Estimates for the Fond du Lac River

Mark-Recapture Study (year)	Grayling Island Area			Upstream of Middle Lake		
	Population Estimate	High Estimate[(a)]	Low Estimate[(a)]	Population Estimate	High Estimate[(a)]	Low Estimate[(a)]
Envirocon (1974)	7,776	9,292	6,260	5,269	6,509	4,029
Merkowsky (1989)	5,024	50,240	897	3,844	12,012	1,643
Golder (Annex III) - Petersen Method[(b)]	9,067	14,498	3,635	4,558	9,951	-833.8
Golder (Annex III) - Chapman Method(c)	9,090	13,671	4,509	4,575	8,097	1,053

(a) High and low population estimates (confidence intervals) were determined such that the actual population size will fall between these values 19 times out of 20 (P=0.95).
(b) The Petersen method is a simple, commonly used method for calculating fish population size (Everhart and Youngs 1981).
(c) The Chapman method is a simple, commonly used method for calculating fish population size, and is recommended for use by the American Fisheries Society (AFS) (Hayes et al. 2007).

1.3.2 Area Fisheries

Fish populations in the Project area have been identified as important to CRA fisheries. Fish species that are harvested commercially or domestically in the Project area include lake whitefish (*Coregonus clupeaformis*), lake trout, northern pike (*Esox lucius*), walleye, suckers (*Catostomus* sp.), and Arctic grayling. Recreational species targeted by local anglers and visitors to Camp Grayling include Arctic grayling and northern pike.

Domestic fishing in the Project area takes place primarily on Stony Lake; however, some fishing does occur on Black Lake, which supports a small commercial fishery during summer, as well as on Middle Lake. Stony Lake and Black Lake are used for ice fishing. The cabin owner on Middle Lake is the main year-round domestic fisher on the lake; thin ice and open water conditions on Middle Lake limit its use during winter. Domestic fishing is primarily done by net and is non-selective. A summary of the CRA fisheries information available for the Project area is included in the Sections 1.3.2.1 through 1.3.2.3.

1.3.2.1 *Black Lake*

Black Lake has supported a recreational fishery since the 1950s, when the area's first fishing lodge opened. Currently, Camp Grayling is the only fishing lodge operating on Black Lake. The main Camp Grayling fishing lodge is located on the west shore of the Black Lake outflow bay. Camp Grayling promotes catch and release angling of trophy lake trout and northern pike. Bookings of non-resident anglers tend to peak in June and again in late August and early September. Residents of Black Lake and Stony Rapids also angle for northern pike and lake trout. In addition, the BLFN hosts an annual summer fishing derby and a winter ice fishing derby.

The MOE has established commercial fishing quotas for walleye and northern pike (1,100 kilograms [kg]), whitefish (55,000 kg), and trout (3,200 kg) captured from Black Lake (MOE – unpublished data 2013a). A summary of the production history of the Black Lake commercial fishery is provided in Table 5.

Table 5: Production History of the Commercial Fishery of Black Lake Saskatchewan (Saskatchewan Ministry of Environment [MOE] – unpublished data 2013b)

Year	Number of Kilograms (kg) Captured by Species				Total Weight of Fish Captured by Species (kg)
	Lake Whitefish	Walleye	Lake Trout	Northern Pike	
2000	400	-	1,774	-	2,174
2001	481	-	1,836	-	2,317
2002	665	-	2,964	-	3,629
2003	229	-	541	-	770
2004	452	-	400	-	852
2005	431	-	604	-	1,035
2006	-	-	-	-	-
2007	-	-	-	-	-
2008	-	718	-	-	718
2009	68	641	-	68	777
2010	-	-	-	-	-
2011	-	-	-	-	-
2012	34	104	79	47	264

kg = kilograms; lake whitefish = *Coregonus clupeaformis*; walleye = *Sander vitreus*; lake trout = *Salvelinus namaycush*; northern pike = *Esox lucius*

Members of the BLFN regularly deploy gillnets to capture fish for personal consumption and for use as food for their dogs. Popular fishing areas include the mouth of the Black Lake outflow bay, the channel between Fir Island and the west shoreline of Black Lake, and locations near the community of Black Lake. Members of the BLFN tend to focus angling efforts near the community of Black Lake, Fir Island, and the Cree River area. The Fond du Lac River inflow (Burr Falls) is also a popular angling destination for some residents of the BLFN. A number of private cabins are also located within the vicinity of Black Lake.

1.3.2.2 *Fond du Lac River*

Angling pressure on Arctic grayling from clients of Camp Grayling is usually limited to occasional “evening” trips to Grayling Island at the Black Lake outflow to the Fond du Lac River, where catch and release angling is practiced. The Fond du Lac River between Black Lake and Middle Lake receives some additional angling pressure from non-Aboriginal people. These anglers usually target Arctic grayling and release what they catch. There is no commercial fishery on the Fond du Lac River between Black Lake and Middle lake.

The Fond du Lac River at the Black Lake outflow bay is a popular destination for members of the BLFN who wish to target Arctic grayling during the spring spawning period. It is likely that many of the Arctic grayling captured during this time are kept for personal consumption. In addition, angling for Arctic grayling by members of the BLFN occurs throughout the open water season at different locations on the Fond du Lac River between Black Lake and Middle Lake.

1.3.2.3 *Middle Lake*

Middle Lake receives limited angling pressure from guided or un-guided recreational anglers. Previous operators of Camp Grayling took clients to Middle Lake for northern pike fishing and to access lower sections of the Fond du Lac River via boat. Middle Lake is not fished commercially.

Historically, Middle Lake was a summer gathering location for local First Nations. Today, at least one member of the BLFN maintains a cabin near Middle Lake and deploys gill nets in Middle Lake during the open-water period to catch fish for personal consumption.

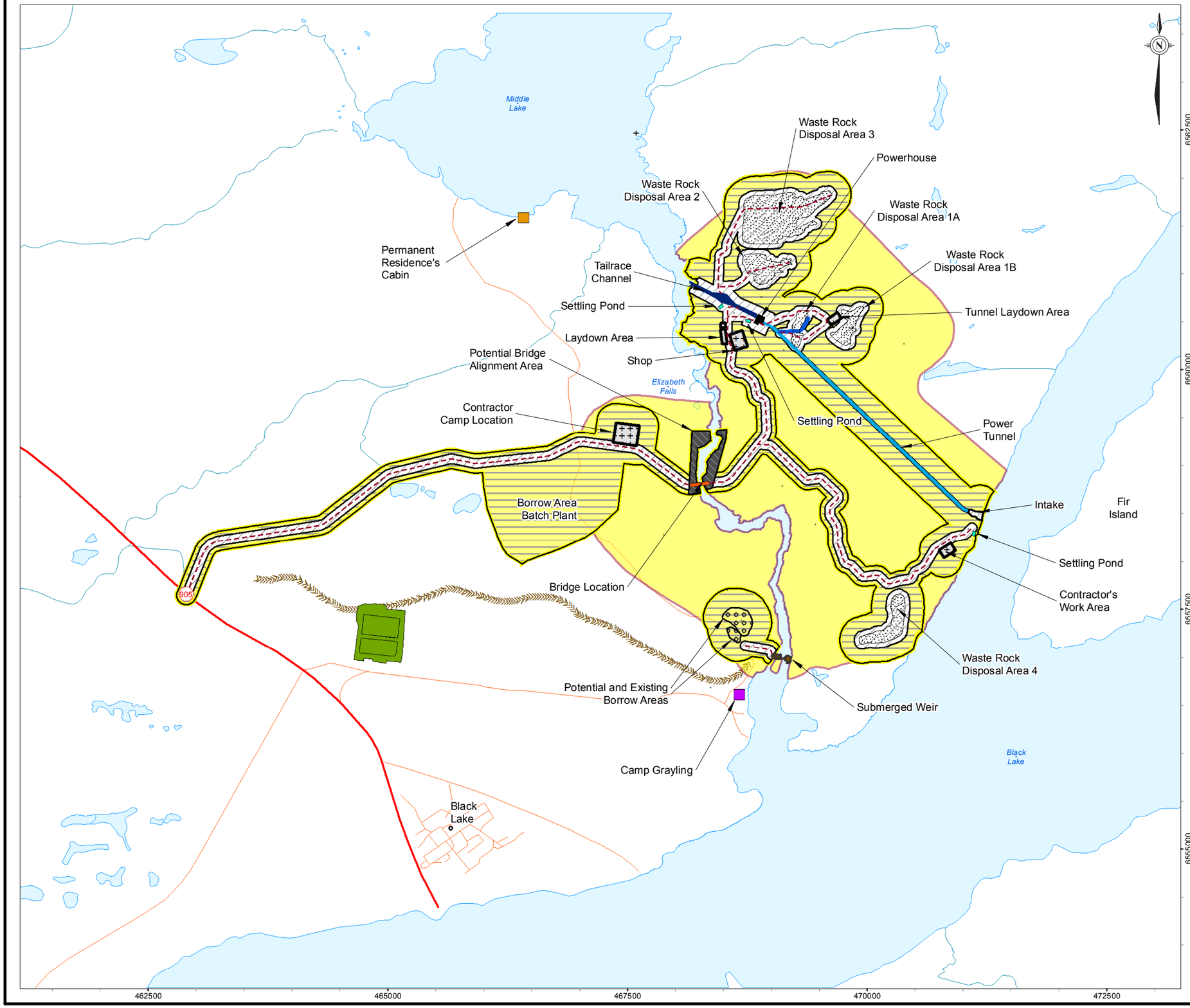
2.0 PROJECT DESCRIPTION

The proposed Project is a new 50 MW water diversion-type hydroelectric generating station adjacent to the Fond du Lac River between Black Lake and Middle Lake. The Project's estimated gross average annual power generation will be approximately 400,000 MWh per year. Water from Black Lake will be diverted through a water intake structure, power tunnel, powerhouse, and tailrace channel before being released back into the Fond du Lac River. Diverted water that is discharged at the tailrace outlet location in the Fond du Lac River will combine with riparian flows before entering Middle Lake.

The principle components of the Project include the following:

- gravel, all-season access road to the Project site from the all-season Highway 905 between the communities of Stony Rapids and Black Lake;
- bridge over the Fond du Lac River;
- powerhouse and associated infrastructure;
- water intake and power tunnel to convey flow from Black Lake to the powerhouse;
- tailrace channel from the powerhouse to the Fond du Lac River upstream of Middle Lake;
- submerged weir located in the Fond du Lac River at the outlet of Black Lake (i.e., at Grayling Island);
- transmission lines and switching stations to connect to the northern Saskatchewan electrical grid; and
- all related physical works and physical activities required to carry out these works, including cofferdams, access roads, laydown areas, construction camp, borrow areas, waste rock disposal areas, concrete batch plant, fuel storage facility and fueling areas, explosives storage, and sewage treatment and potable water facilities.

The Project footprint (Figure 3) will be as compact as possible to minimize the area affected by Project activities; the maximum area of disturbance is estimated to be 1,580 hectares (ha). Approximately 848 ha of this area will be reclaimed immediately following construction, with the remainder being reclaimed following Project closure. Project construction is expected to commence in Q3 of 2014 with the facility becoming operational in Q1 of 2018. The operational lifespan of the Project is anticipated to be 90 years.



LEGEND

- HAMLET OR COMMUNITY
- HIGHWAY
- ROAD
- ESKER
- RIVER
- WATERBODY
- CAMP GRAYLING
- PERMANENT RESIDENT'S CABIN
- POTENTIAL BRIDGE ALIGNMENT
- PERMANENT ROAD
- OPERATIONS FOOTPRINT
- PREDICTED PROJECT FOOTPRINT
- DISTURBANCE ASSESSMENT AREA
- CONTRACTOR CAMP / LAYDOWN AREA
- BORROW AREA
- SETTLING POND
- SPOIL DISPOSAL AREA
- POTENTIAL BRIDGE ALIGNMENT AREA
- INTAKE
- POWER HOUSE
- TAILRACE CHANNEL
- POWER TUNNEL
- SURGE FACILITY
- SUBMERGED WEIR
- BLACK LAKE SEWAGE LAGOON

REFERENCE

NAD83 UTM ZONE 13
NTS MAPSHEETS: 73P/3,4,5,6

1 0 1
SCALE 1:40,000 KILOMETRES

PROJECT
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE
TAZI TWÉ HYDROELECTRIC PROJECT SITE PLAN

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 5
GIS	SM	04/11/13		
CHECK	BC	04/11/13		
REVIEW	MM	04/11/13		

FIGURE: 3

2.1 Details on Project Structures and Mitigation Measures

Sections 2.1.1 through 2.1.8 of the Fisheries Offsetting Plan describes the Project structures and activities that may affect fish and fish habitat, and therefore cause serious harm to fish. Avoidance and mitigation measures that will be implemented to offset serious harm to fish are also discussed throughout Section 2.1. Some of these avoidance and mitigation measures may directly reduce the potential for serious harm to fish (e.g., adhering to in-water construction timing windows for the protection of fish eggs and fry) and others may protect fish indirectly (e.g., employing dust abatement methods to prevent road dust from entering the aquatic environment and possibly altering fish habitat).

2.1.1 General Avoidance and Mitigation Measures

Some avoidance and mitigation measures will apply to the whole Project site (i.e., general mitigation measures) or multiple Project structures and activities, rather than single Project components. These measures include the following:

- construction water pump intakes will be screened as per DFO's "Freshwater Intake End-of-Pipe Fish Screen Guideline" to prevent entrainment of fish (DFO 1995);
- construction of in-water works (i.e., water intake, bridge, weir, and tailrace outlet channel) will be completed in accordance with the conditions outlined in the DFO Authorization;
- an environmental monitor will be on site during in-water work to verify that compliance with the construction specifications and Project approvals is achieved;
- in-water works will be isolated from flowing water and adjacent lake or river habitats to reduce downstream or off-site effects;
- a turbidity/total suspended solids (TSS) regression will be developed and a Turbidity Monitoring Program will be implemented during in-water works;
- DFO In-Water Construction Timing Windows will be followed for the Project;
- an Erosion and Sediment Control Plan will be developed based on industry standard Best Management Practices (BMPs) defined in numerous established guidelines and policies, regulatory requirements and use of adaptive management monitoring and mitigation strategies;
- any materials used for shoreline stabilization will be clean and free of fine sediments and contaminants;
- dewatering operations will be directed to settling ponds prior to discharge to watercourses;
- water will be discharged to watercourses in a manner that does not cause erosion or other damage to adjacent areas;
- a compact layout of the surface facilities within local watersheds will limit the area that is disturbed by construction and operation;
- fish salvage activities, where required, will be completed by qualified biologists;

- fish handling time will be kept to a minimum as per MOE recommendations in the fishing permit; only a small number of salvaged fish will be measured for length and weight in order to decrease handling times and improve survival;
- appropriate non-lethal sampling methods (e.g., fyke traps, minnow traps and beach seines) will be used, in addition to short-duration small-mesh gillnet sets, to salvage fish from in-water work isolation areas;
- a Site Water Management Plan will be developed for the Project;
- construction equipment will be regularly maintained;
- a Water Quality Monitoring Plan will be implemented for the Project;
- an Environmental Protection Plan (EnvPP) will describe material handling protocols for the Project;
- potable water is anticipated to be sourced from one or more new wells located near the camp;
- surface runoff will be diverted around and away from waste rock disposal areas as much as possible;
- the site will be properly graded and will be surrounded by ditches and berms to capture runoff from the waste rock disposal areas;
- waste rock disposal areas will be placed in locations that can be modified to control run-on and run-off, if possible;
- runoff from the waste rock disposal areas will be directed to settling ponds prior to discharge to the Fond du Lac River; water quality will be confirmed before release to the environment;
- runoff from areas unaffected by the Project will be directed away from construction areas and allowed to discharge through natural channels;
- wastewaters released from settling ponds will meet applicable water quality guidelines (i.e., Canadian Council of Ministers of the Environment [CCME]) at the end of the mixing zone;
- contingency plans for off-site disposal of dewatered settling pond sludge will be included in a Construction Environmental Management Plan;
- where required, portable toilet facilities and holding tanks will be available throughout the construction site;
- waste from portable toilets and holding tanks at the construction camp will be hauled off-site and disposed of at the Black Lake sewage lagoon;
- black water (sewage) and grey water will be hauled off-site and disposed of at the new Black Lake lagoon;
- Waste Rock Management and Project Site Drainage Plans will be developed for the Project;
- excavated material will be stored away from watercourses or lakes;
- excavated rock and aggregate materials will be tested and specific mitigation measures will be applied if the material is identified to be acid-generating or contain elevated levels of metals or radionuclides;
- additional site investigation and laboratory testing of excavated materials will be completed upon completion of the final Project design and during construction of the Project;

- a Decommissioning and Reclamation Plan will be developed for the Project;
- all fuel storage tanks will be designed and constructed according to the American Petroleum Institute 650 standard and with lined and dyked containment areas to contain any potential fuel spills;
- fuel storage containers will be regularly inspected for leaks or damage and replaced when necessary;
- smaller storage tanks for engine oil, hydraulic oil, and waste oil and coolant will be double walled and located in lined and bermed containment areas;
- reagents and fuel Enviro-Tanks (if applicable) will be located in larger, double-walled containers;
- construction machinery, equipment, and vehicles will not be stored, refuelled, or repaired near waterbodies;
- vehicle fuelling stations will be located on a constructed pad sloping toward a collection point so that any spills of fuel can be contained and collected for shipment off-site;
- an Emergency Response Plan will be developed;
- spill response material (e.g., sorbent pads) will be stored on-site in designated areas and in vehicles;
- contaminated (impacted) soils will be removed and disposed of in an approved landfill or waste management facility;
- embankment dykes will be stripped of vegetation, topsoil, and roots to expose the mineral soil subgrade as necessary to accommodate the size of the footprint;
- settling pond embankments will be topsoiled, seeded, or protected with gravel or riprap immediately following construction; and
- settling ponds will be regularly inspected for sediment accumulation and stability of embankments, outlets, and spillways.

2.1.2 Access Roads

Road access to the site from southern Saskatchewan will be via Highways 102 and 905 from La Ronge to Points North. The primary access road for the Project site will be the Athabasca Seasonal Road between Points North and Black Lake. Permanent roads for the Project site will be designed to meet current provincial road design standards and construction activities will comply with applicable provincial and federal regulations and guidelines. Temporary access roads will be removed and reclaimed once Project construction is complete. Culverts will be installed along roadways where drainage crossings have been identified. None of these watercourses have been identified, or are suspected, to support fish populations. If fish movement at these drainage crossings becomes apparent during or following construction, culvert design will be altered to accommodate fish passage. Best Management Practices (BMPs) for culvert design and installation will be followed.

Additional avoidance and mitigation measures associated with road construction, maintenance, and use include:

- completion of a site-specific assessment prior to soil salvage to identify surficial stripping depths and develop a site-specific soil salvage plan;

- site clearing during construction of the Project infrastructure (e.g., roads, laydown areas) and salvage of soil materials will be completed during dry or frozen conditions, where and when practical;
- salvaged topsoil will be stored on-site and away from surface waterbodies;
- disturbed areas (e.g., access roads and banks) will be graded to a stable angle, reclaimed and revegetated after work is completed;
- site drainage and surface runoff will be managed through the incorporation of erosion control methods (e.g., ditch blocks, silt fences) so that overland flow does not direct sediment-laden water into any natural watercourses;
- erosion control practices will be applied to salvaged topsoil to reduce potential erosion and sediment transport offsite;
- using a shuttle to transfer incoming and outgoing workers between Stony Rapids and Black Lake to the site to reduce the use of personal vehicles;
- gasoline-fueled vehicles will meet or exceed Environmental Protection Agency (EPA) Tier 2 Bin 6 air quality emissions standards;
- all unpaved roads will be watered on a regular basis to prevent wind driven fugitive dust;
- a speed limit will be enforced on all unpaved roads on site;
- ditch capacities will be sized to accommodate an extreme daily rainfall event; and
- riprap energy dissipaters and ditch lining will be installed in areas where runoff velocities are deemed excessive to reduce soil erosion.

2.1.3 Bridge

A bridge across the Fond du Lac River will be constructed approximately 600 m upstream of Elizabeth Falls to provide access to the east side of the river. The bridge will have a single centre pier; however, two additional temporary piers could be required during construction. A temporary groin or work platform will extend approximately half way across the river to provide access to the centre pier installation site. The groin will be constructed of coarse rock and will allow water to percolate through. Bridge construction will occur during winter (i.e., under low flow conditions and outside spring spawning timing windows) and will require a DFO Authorization. General avoidance and mitigation measures listed in Section 2.1.1 will be implemented during bridge construction, where applicable.

Under historically normal flow conditions, current velocities at the site of the single centre pier are above those preferred by overwintering fish. It is therefore anticipated that suitable overwintering habitat will not be lost as a result of the single centre pier; suitable winter habitat will develop around it or near it during Project operation (i.e., because of reduced current velocities). It is anticipated the bridge abutments will be located below the historically normal high-water mark, but above the high-water mark anticipated for the period of Project operation. Therefore, the footprints of the bridge abutments are not expected to cover (i.e., destroy) fish habitat.

Efforts to mitigate the effects of improved access to fishing areas on the east side of the Fond du Lac River once the bridge is completed may include:

- developing and implementing an Access Management Plan for the Project;
- restricting all public access to the construction, laydown, and camp areas until Project construction is completed;
- instituting a ”no hunting, trapping, harvesting, or fishing policy” for Project employees during construction;
- banning contractor and contractor employees working on site who are not members of the BLFN from fishing in designated Project areas after work-hours; and
- prohibiting the use of all-terrain vehicles on site.

Restricted fishing areas will be determined based on engagement with the BLFN. The “no hunting, trapping, harvesting, or fishing policy” will also be developed in consultation with the BLFN.

2.1.4 Powerhouse and Turbines

The proposed Project is designed to have a 50 MW generating capacity and an estimated gross average annual generation of approximately 400,000 MWh per year. The plant will operate as a water diversion type facility with a gross head of approximately 36 m and a 190 m^3/s discharge rate.

The Project will be managed to maintain minimum seasonal riparian flows in the Fond du Lac River between Black Lake and the tailrace outlet. Minimum riparian flows will be maintained at 70 m^3/s during the spring pre-spawning and spawning period (May 1 to June 30) and at 40 m^3/s during the rest of the year to maintain critical fish habitats (e.g., overwintering areas) and fish populations within the Fond du Lac River. A flow bypass system will be used to maintain water levels on key Arctic grayling spawning areas in the Fond du Lac River downstream of the tailrace outlet in the event of a plant outage during the spawning and rearing period (May 15 to July 15).

Turbines used at hydroelectric power generating facilities in Canada and the United States are predominantly Kaplan or Francis style turbines (Canadian Electricity Association [CEA] 2001; Odeh 1999). Kaplan turbines were selected as part of the final Project design; this turbine type is considered to be more “fish-friendly” than the Francis type of turbine and would be expected to result in lower mortality rates for entrained fish.

Based on a gross head of 36 m, it is estimated pressures behind the turbine units will drop to approximately one-third of those expected at the intake structure. This falls within the 30% minimum pressure criteria (Abernethy et al. 2001; Alden Research Laboratory Inc. [ARL] 1996; Odeh 1999) that is expected to protect most physostomous fish from pressure-related injuries. Selection of a modern Kaplan turbine design that allows for adjustment of the pressure nadir may further reduce fish mortality rates (Abernethy et al. 2001).

Scheduled maintenance shutdowns will occur annually on a unit-by-unit basis and are estimated to last from a few days up to two weeks. Only one unit at a time will be removed from service for maintenance. Maintenance shutdowns will be timed to limit downstream effects (i.e., during winter or other periods when there is less flow available to pass through the powerhouse, or during summer when sufficient in-river flows are available). Each unit may be taken out of service, once per month for less than eight hours, to perform minor adjustments, inspections, and maintenance. Major overhaul work on the turbine and generator units will be completed approximately every 30 years. During planned maintenance shutdowns, downstream flows will be maintained by bypassing water around the powerhouse using a bypass conduit, if required.

2.1.5 Water Intake

The water intake will be located on the northwest shore of Black Lake, and will be set back from the shoreline and into the bedrock by approximately 105 m. An approach channel will be constructed between the lake and the intake; the bottom of the upstream end of the approach channel will be approximately 4.5 m below the normal lake level. The approach channel drops to a depth of 13 m below surface as it approaches the face of the water intake. Water will be withdrawn from near the surface of the lake (i.e., from the surface to a depth of 5 m due to vertical mixing at the upstream end of the approach channel). The water intake is designed to minimize hydraulic losses, maintain water intake flow temperatures that are similar to water temperatures at the natural Black Lake outflow, prevent entrainment of air into the power tunnel, and achieve compliance with industry and regulatory standards.

Construction of the water intake will require excavation of overburden adjacent to Black Lake, as well as in-water work. These activities have the potential to affect water quality and aquatic habitat. Environmental design features and mitigation measures to be used during construction of the water intake include:

- using a cofferdam and/or turbidity barrier to contain sediment released during in-water construction; and
- completing fish salvage activities before commencing in-water construction.

The water intake opening will be fitted with an “exclusion bar rack” to prevent debris and ice from entering the power tunnel and causing damage or blockages. The “exclusion bar rack” is also designed to be a visual deterrent for fish that enter the water intake approach channel. Other mitigation measures incorporated into the Project design to minimize fish injury and mortality resulting from impingement or entrainment in the water intake include the following:

- selecting an intake location away from sensitive fish habitat (i.e., areas where fish may congregate to spawn);
- constructing a shallow intake to reduce the entrainment of deep-water species such as lake trout, lake whitefish, and cisco (*Coregonus* sp.);
- constructing a wide, shallow intake approach to reduce temperature differences between water entering the river at the tailrace outlet channel (i.e., water that has been diverted through the powerhouse) and water that naturally enters the Fond du Lac River through the Black Lake outlet;
- sizing the intake opening so that water velocities in the approach channel are below burst speeds of resident fish, thereby promoting avoidance behavior; and
- configuring the intake structure so that the soffit (ceiling) of the intake passage will be set low enough to prevent entrainment of air into the power tunnel, subsequently reducing the potential for gas bubble trauma in entrained fish and the plunging of air to depth at the tailrace outlet.

2.1.6 Power Tunnel

The power tunnel will be 11 m wide by 10 m high, with a horseshoe shaped (∩) cross-section. With the currently preferred tunnel alignment, the length of the power tunnel is 2.95 km. A drill-and-blast method will be used to complete the power tunnel excavation. A Blasting Plan will be developed for the Project and will contain provisions for reducing blasting overpressures and vibration levels to achieve compliance with DFO guidelines (Wright and Hopky 1998).

The equipment used for hauling and mucking operations will operate using diesel fuel with an ultra-low sulfur diesel content less than 15 parts per million (ppm). Heavy-duty stationary and mobile diesel-fueled equipment fleet will meet or exceed EPA Tier 2/3 air quality emissions standards. A forced air method of ventilation will be used for venting of dust, gases and fumes from inside the power tunnel following blasting.

Water required for power tunnel excavation will be pumped primarily from Black Lake. Water pipes that are 50 millimetres (mm) in diameter will supply tunnel faces with water for drilling, flushing drill holes, cleaning rock surfaces, and watering muck piles for dust reduction.

Best practices, as outlined in the Blasting Plan for the Project, will be applied to blasting activities to reduce any potential for enhanced nitrogen loading of groundwater inflows due to the placement and use of ammonium nitrate/fuel oil (ANFO) during construction. Groundwater originating from construction of the power tunnel will be collected, treated if required, and monitored to confirm discharge criteria are met prior to release into the receiving environment.The current maximum upper bound estimate of the groundwater inflow to the tunnel and tailrace channel during construction is 4,700 cubic metres per day (m^3/d).

During operations, the power tunnel will be drained for inspection for one week approximately every five years. Power tunnel seepage water will be monitored for quality and quantity and treated or managed to acceptable standards before discharge to the environment.

When the Project is decommissioned, a series of concrete bulkheads will be placed in the power tunnel, if necessary, to isolate mineralized bedrock zones and to reduce potential for mineralized groundwater to discharge through the power tunnel. Quality of groundwater discharging through the power tunnel at the decommissioning phase will be monitored and sampled, if required.

2.1.7 Tailrace Channel

Water diverted from Black Lake for power generation will be returned to the Fond du Lac River at a location upstream of Middle Lake by way of the tailrace channel. The proposed tailrace will be approximately 850 m long with near vertical sides (1 horizontal to 10 vertical [1 H: 10V]). To reduce head loss at a capacity of 50 MW and a full plant discharge of 190 m^3/s, the tailrace channel will have a 20 m width with a flow depth of 6.8 m. The average flow velocity in the tailrace will be about 1.4 metres per second (m/s).

An estimated 60,000 to 481,000 cubic metres (m^3) of overburden and 475,000 to 537,000 m^3 of waste rock will be removed during the excavation of the tailrace channel. During tailrace channel construction, a rock and overburden plug will be left at the end of the tailrace channel outlet to isolate the active work area from the Fond du Lac River.

A cofferdam may be necessary if additional in-river excavation is required to improve channel hydraulics at the tailrace outlet. The cofferdam would be constructed by placing two rockfill sections first, then depositing semi-impervious material between them to minimize the release of fines into the river. The cofferdams would be removed following completion of the tailrace channel outlet excavation. Turbidity curtains will be used where possible during construction to minimize the amount of fine sediments entering the river. Fish salvage activities will be completed for the in-water work area prior to commencement of construction.

The tailrace channel will be designed and constructed to include the following design features and mitigations for the protection of fish:

- designing a sub-surface tailrace outlet to reduce the plunging of air and water to depth;

- selecting a tailrace outlet location upstream of important Arctic grayling spawning habitat near the Fond du Lac River outflow to Middle Lake to maintain minimum required flows at this location; and
- developing a featureless tailrace channel design to minimize prolonged occupation of the tailrace channel by fish.

Flow velocities in the tailrace channel will exceed the prolonged swimming speeds of resident fish and there will be no velocity refugia that would allow fish to rest as they attempt to migrate up the tailrace channel. The tailrace channel is not expected to be attractive habitat for fish due to the steeply sloping sides and lack of cover (e.g., substrate, vegetation) in the channel.

2.1.8 Submerged Weir

The construction of the Project will create a second flow outlet for Black Lake. Without mitigation, the added flow capacity would lead to a small reduction in the long-term water levels of Black Lake and permanent alterations or losses of fish habitat. To avoid this level reduction, a submerged rockfill weir will be installed at the outlet of Black Lake to maintain water levels within the historical range. The weir will be located on the Fond du Lac River at the outlet of Black Lake at Grayling Island. The length of weir to the west of Grayling Island will be approximately 85 m, while the length of weir to the east of the island is approximately 80 m. The weir is not required to act as a water retention structure so a central impervious core will not be required. The submerged rockfill weir will have a triangular cross section with a 5H:1V slope on the upstream face and a 20H:1V slope on the downstream face. This weir configuration will allow for safe downstream passage at the Black Lake outflow to the Fond du Lac River for all fish species and life stages at all lake levels and discharges. Flow velocities at the submerged weir will not exceed swimming thresholds of upstream-migrating Arctic grayling.

The submerged weir will be constructed once the powerhouse is operational. Construction will consist of the advancement of clean rockfill material from each shore of the Fond du Lac River towards Grayling Island. The rock material used to construct the submerged weir will have low potential for acid generation or radioactive materials. Construction of the submerged weir will be completed in accordance with the applicable avoidance and mitigation measures listed in Section 2.1.1 (i.e., mitigations for in-water construction). These include adherence to conditions of the DFO Authorization, Erosion and Sediment Control Plan, and Turbidity Monitoring Program.

2.2 Project Schedule

The Project schedule has been defined by major Project phases (Table 6). The following schedule is indicative of overall project design and planning throughout 2013. The project schedule could be change pursuant to finalising project design and regarding the regulatory approval process. The Proponent will advise of changes, as appropriate. The major Project phases and their estimated timelines are as follows:

- construction: September 2014 to December 2017;
- operations: January 2018 to approximately January 2108; and
- decommissioning and reclamation: approximately two years following cessation of operations.

Table 6: Tazi Twé Hydroelectric Project Schedule

Project Phase	Tasks	Year																	
		2014				2015				2016				2017				2018 to 2108	Approximately two years following the cessation of operations
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4		
Construction																			
	Contractor mobilization and setup of construction camp																		
	Construction of access roads and bridge																		
	Construction of powerhouse and intake structures																		
	Excavation of water intake, power tunnel, powerhouse, and tailrace channel																		
	Installation of turbines and generators																		
	Commissioning and plant start-up																		
	Construction of submerged weir																		
Operations																			
Decommissioning and Reclamation																			

Note: Assuming three months after Environmental Impact Statement (EIS) approval the permit for full construction will be received.

3.0 RESIDUAL SERIOUS HARM TO FISH

Construction and operation of the Project is anticipated to result in residual serious harm to fish, despite the implementation of avoidance and mitigation measures. Project components and activities that are expected to result in residual serious harm to fish that are part of or support a CRA fishery include:

- permanent alteration and destruction of fish habitat at the water intake structure, submerged weir, tailrace outlet, and bridge footprints;
- incidental mortality of fish salvaged from in-water work isolation areas (i.e., death of fish);
- death of fish impinged or entrained at the water intake in Black Lake; and
- permanent alteration of fish habitat resulting from Project operation and changes to hydrology in the Fond du Lac River.

The potential for these Project components and activities to adversely affect the sustainability and continued productivity of CRA fisheries are discussed Sections 3.1 through 3.4 of this Offsetting Plan; options for offsetting predicted effects to the productivity of CRA fisheries are discussed in Section 4.

3.1 Structural Footprints

The water intake in Black Lake, the submerged weir structure at the outlet of Black Lake, the tailrace channel outlet in the Fond du Lac River, and the single-pier bridge across the Fond du Lac River are expected to permanently alter or destroy fish habitat. However, it is anticipated that these structures will not impact fish habitat in such a way that the productivity of CRA fisheries will be affected. These structures will not occupy areas of unique habitat, or habitats considered critical for the maintenance of self-sustaining fish populations (i.e., areas ideal for spawning or rearing).

Aquatic habitat surveys and focussed spawning surveys conducted on Black Lake suggest that the proposed water intake location is not likely to contain sensitive or critical fish habitat (Annex III). Similar types of habitats that might be used by small-bodied fish and juvenile large-bodied fish are abundant throughout Black Lake (i.e., the water intake footprint would affect a relatively small proportion of this habitat type) (Annex III). Small-bodied fish species and juvenile large-bodied fish that use this area likely will be displaced to other similar habitats on either side of the proposed water intake location. Spawning surveys conducted in Black Lake to identify potentially sensitive, shallow water fish habitats that would provide suitable spawning and rearing habitats for lake trout, lake whitefish, and burbot (*Lota lota*) did not identify any evidence of spawning activity near the water intake (Annex III).

The submerged weir is designed to maintain the historical range of water levels in Black Lake, and subsequently, maintain fish habitat that would have otherwise been affected by reduced water depths and volumes resulting from Project-related water withdrawal. Arctic grayling spawning areas immediately upstream of the proposed weir will be maintained; current flows (albeit reduced) and wave action are expected to be sufficient to keep the spawning substrates clear of fine sediments.

The bay at the proposed tailrace channel outlet is composed of a large slack water area along the east shore of the Fond du Lac River during average or higher flows, as well as an area with faster flows located along the downstream outlet of the bay. During lower flows the slack water area dries or becomes very shallow. Northern

pike are known to frequent this location. It is anticipated that northern pike and lake whitefish displaced from this area by the tailrace outlet channel will move the short distance downstream to suitable habitats in Middle Lake, as they currently do during periods of lower than average flows.

The single permanent pier for the bridge across the Fond du Lac River is not expected to result in permanent alteration or destruction of overwintering habitat for large-bodied fish. Under normal flow conditions, water velocities at this location are above the velocity tolerances of fish. Therefore, the pier footprint is not expected to be limiting to fish populations under conditions of Project operation, because suitable habitat will be abundant at this location when flows and water velocities are reduced as a result of Project operation (EIS Appendix 12.1). It is anticipated the permanent bridge abutments will be located below the historically normal high-water mark, but above the high-water mark anticipated for the period of Project operation. Because overwintering habitat is available throughout this section of river, habitat lost to the bridge footprint is not considered to be critical to the maintenance of self-sustaining, productive fish populations in the river.

3.2 Fish Salvage

Fish salvage operations are generally completed to prevent injury or mortality to fish stranded within work isolation areas. The primary objective is to recover trapped fish and return them to the surrounding waterbody or watercourse without injury or mortality. However, due to the size and depths of the isolated work areas required for the Project, it is unlikely that 100 percent (%) of the trapped fish will be salvaged. Sampling and handling of fish is also expected to result in some incidental mortalities. However, it is anticipated that the number of mortalities will not be of sufficient magnitude to cause effects to the productivity of CRA fisheries in the Project area.

3.3 Impingement and Entrainment at the Water Intake

Entrainment of fish at the water intake in Black Lake and the subsequent passage of fish through the power tunnel, powerhouse and turbines, and tailrace channel are expected to result in some residual serious harm to fish (i.e., fish injury and mortality). However, this residual serious harm to fish is not anticipated to impact the sustainability and productivity of CRA fisheries in the area.

3.3.1 Black Lake

None of the fish species documented in Black Lake are known to undertake annual or regular downstream migrations for spawning, rearing, or foraging purposes. However, some fish currently drift downstream out of Black Lake into the Fond du Lac River via the Black Lake outflow. It is anticipated that some Black Lake fish will passively drift into the vicinity of the water intake where they could be potentially impinged on the “exclusion bar racks” or entrained with power tunnel inflows. However, the total number of fish leaving the Black Lake fish community is not expected to change over the current level of out-migration because overall Black Lake outflow rates and volumes will not change with the development of the Project. Out-migration of fish from Black Lake once the Project is operating is expected to be similar to current levels. Although Black Lake effectively will have two outlets when the power plant is in operation, each will only carry approximately one-half of the current Black Lake outflow total. Because the natural Fond du Lac River outflow will be reduced from current levels, the outlet velocities also will be reduced, potentially resulting in fewer fish being entrained with lake outflows than are currently. With the exception of Arctic grayling, it is not believed that most fish species are able to return to Black Lake after they have been carried downstream into the rapid flows of the Fond du Lac River. Anticipated lake outflow conditions associated with the water intake are expected to closely resemble the outflow conditions

at the natural Black Lake outflow to the Fond du Lac River. Therefore, impingement or entrainment of fish at the water intake is not expected to have an impact on the productivity of Black Lake fisheries.

3.3.2 Fond du Lac River and Middle Lake

For Arctic grayling and other species in the Project area, entrainment induced mortality is not expected to result in a measureable decrease in recruitment downstream of the tailrace channel outlet. Arctic grayling were not captured during the focused fish survey completed at the water intake location during 2012 and relatively few (n = 46) Arctic grayling were captured in Black Lake between 2010 and 2012 (Table 1). Therefore, it is anticipated that Arctic grayling are unlikely to enter the water intake and become entrained in the power tunnel; no measureable loss to Arctic grayling recruitment is expected downstream of the tailrace channel. The remaining fish species that were identified as important to CRA fisheries in the area have life history requirements (i.e., habitat preferences and spawning migration behaviours) that are expected to reduce the potential for entrainment and therefore minimize potential losses to recruitment downstream of the tailrace channel. Life history requirements of Black Lake fish species as they relate to the potential for entrainment are discussed in Section 12 and Appendix 12.3 of the Project EIS.

3.4 Changes to Hydrology and Fish Habitat

Project operation and subsequent changes to hydrology in the Fond du Lac River are expected to result in some residual serious harm to fish through the permanent alteration of Arctic grayling spawning habitat. Because the submerged weir will maintain water levels in Black Lake and the upper reaches of the Fond du Lac River, the Arctic grayling population near Grayling Island at the Black Lake outflow is not expected to experience reduced productivity. However, Arctic grayling populations in the middle section of the Fond du Lac River between Black Lake and Middle Lake are expected to be affected by Project operation and reduced flows, as is the Arctic grayling population that spawns adjacent to the east shore of the river, immediately downstream of the tailrace outlet bay.

3.4.1 Middle Section of the Fond du Lac River

Changes to hydrology resulting from Project operation are expected to have the greatest effect on fish habitat quantity and quality in Fond du Lac River Reaches 3 through 21 (EIS Section 12 and Appendix 12.1). These reaches are located downstream of the proposed submerged weir at Grayling Island and upstream of the proposed tailrace channel outlet location in Reach 22 (Figure 2, above). The submerged weir is expected to maintain historically normal water levels in Black Lake and Reach 2 of the Fond du Lac River; riparian flows and water levels are expected to return to relatively normal levels below the tailrace channel outlet in Reach 22.

Habitat Suitability Indices (HSIs) were developed for Arctic grayling, longnose sucker (*Catostomus catostomus*), and white sucker (*Catostomus commersonii*) in the Fond du Lac River between Black Lake and Middle Lake based on the depth and velocity preferences of these species. The depths and velocities preferred by overwintering adult and age-0/juvenile life stages were considered. Similarly, depth and velocity preferences of spawning Arctic grayling, longnose sucker, and white sucker were examined; substrate was also considered as part of the spawning habitat assessments for Arctic grayling. The development, results, and interpretation of the HSIs are discussed in detail in Appendix 12.1 of the Project EIS.

The results of the overwintering HSI analyses for Arctic grayling indicate that there will be an overall decrease in unsuitable overwintering habitat for age-0, juvenile, and adult fish when riparian flows are reduced because of Project operation; the total areas of suitable overwintering habitat will increase. This is because much of the

unsuitable overwintering habitat available to Arctic grayling under historical winter flow conditions will be lost as water surface areas and volumes in Reaches 3 through 21 decrease because of Project operation. The overall increase in suitable overwintering habitat for Arctic grayling is largely attributable to the decreases in flow velocity that are expected to occur throughout the river when riparian flows are reduced from historically normal values to proposed Project flows.

Habitat Suitability Indices (HSIs) were developed for spring spawners (i.e., Arctic grayling and suckers [*Catostomus* sp.]) in the Fond du Lac River based on historical average Q10 low spring flows, historical average spring flows, and Q90 high spring flows (EIS Appendix 12.1). Depth, velocity and substrate data were used in the analyses for Arctic grayling. Because substrate type (e.g., cobble, boulder, gravel) may be an important factor in determining where Arctic grayling prefer to spawn, the distribution of potentially suitable and unsuitable substrates within the modelled sections of the Fond du Lac River was predicted based on substrate particle sizes and water velocities (Appendix 12.1 of the EIS). Suitable spawning substrates are expected to occur at approximately 90% of the areas predicted to have moderately suitable or suitable combinations of depth and velocity for spawning Arctic grayling. Spawning HSIs for longnose sucker and white sucker were based on depths and velocities; it was assumed suitable spawning substrates for these two species will be available throughout the river.

The total areas (square metres [m^2]), of Fond du Lac River reaches 3 through 21 that are predicted to have suitable spawning substrates and "suitable" combinations of depth and velocity for spawning Arctic grayling are presented in Table 7. Total areas that are predicted to have suitable substrates and "moderately suitable' combinations of depth and velocity are also shown in the Table. Predictions are based on the assumption that 90% of areas having "moderately suitable" or "suitable" depths and velocities will also have suitable substrates.

Based on the HSI analyses in Appendix 12.1 of the EIS and the data summarized in Table 7, it is anticipated that approximately 8,000 m^2 of suitable Arctic grayling spawning habitat will be permanently altered (i.e., will no longer be "suitable") or destroyed (i.e., will become dry or inaccessible) when the Project is operating at 190 m^3/s capacity and natural Fond du Lac River flows are in the average to low range. At high spring flows, Project operation is anticipated to have a smaller impact on Arctic grayling spawning habitat, with approximately 3,000 m^2 being permanently altered or destroyed. At low spring flows (i.e., Q10 average low), approximately 1,250 m^2 of moderately suitable habitat will be gained; it is anticipated this perceived "gain" is the result of what was considered suitable habitat prior to Project operation becoming slightly less suitable (i.e., moderately suitable) as a result of water withdrawal and changes to depth and/or velocity in the river. At average to above average spring flows in the Fond du Lac River, approximately 4,700 to 7,000 m^2 of moderately suitable Arctic grayling spawning habitat will be permanently altered or destroyed.

The alteration and destruction of suitable Arctic grayling spawning habitat in Fond du Lac River reaches 3 through 21 that is predicted to result from Project operation may affect the productive capacity of the resident Arctic grayling population. Offsetting may be required to maintain the productivity of CRA fisheries at this location.

Table 7: Total Areas (m^2) of Arctic Grayling (*Thymallus arcticus*) Spawning Habitat in Fond du Lac River Reaches 3 through 21

Classification	Total Predicted Area (m^2)								
	Q10 Average Low Spring Flow			Average Spring Flow			Q90 Average High Spring Flow		
	Baseline (302 m^3/s)	With Project (112 m^3/s)		Baseline (400 m^3/s)	With Project (210 m^3/s)		Baseline (510 m^3/s)	With Project (320 m^3/s)	
	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change	Area (m^2)	Area (m^2)	% Change
Moderately Suitable[(a)]	17,959	19,209	7.0	19,197	14,438	-24.8	24,241	17,303	-28.6
Suitable[(b)]	22,798	14,587	-36.0	25,983	17,959	-30.9	22,462	19,487	-13.2

(a) refers to areas having suitable substrates and combinations of depth and velocity that are considered moderately suitable (see Appendix 12.1 of the EIS)
(b) refers to areas having suitable substrates and suitable combinations of depth and velocity
HSI = Habitat Suitability Index; m^2 = square metres; m^3/s = cubic metres per second; % = percent

3.4.2 Downstream of the Tailrace Outlet

River2D analyses and modelled flows for the 48 years of record indicate that the key Arctic grayling spawning and rearing area located on the west shore of the Fond du Lac River downstream of the tailrace channel outlet is naturally dry during some low-flow years (i.e., 13% of the time). Spawning is expected to be unsuccessful at this location approximately one year in ten under natural conditions; however, the overall rate of reproduction is sufficient to sustain the Arctic grayling population. If no bypass capacity were installed for the Project, it is estimated that this spawning area would be dry for approximately one in every three years (i.e., 31% of the time). With the Project operating and the 80 m^3/s proposed bypass capacity in place, it is estimated that the spawning area downstream of the tailrace channel in Reach 22 will be dry 23% of the time that unplanned outages occur during the spawning period. This is equivalent to the current natural annual spawning failure rate resulting from low flows (13%) plus a 10% incremental annual spawning failure rate due to Project-induced low flows. Because spawning at this location is expected to be unsuccessful for two out of ten years when the Project is operational, a decrease in the productive capacity of this population is expected to occur. This decline in productivity will require offsetting.

3.4.3 Middle Lake

Middle Lake is expected to receive relatively normal riparian flows throughout Project operation. Therefore, no serious harm to fish is expected to occur in Middle Lake; CRA fisheries will not be impacted at this location as a result of Project operation and changes to hydrology.

4.0 FISHERIES OFFSETTING

This section describes the potential options for offsetting serious harm to fish that support a CRA fishery, as well as a discussion on how the potential measures are expected to offset serious harm to fish. The offsetting options presented in the Fisheries Offsetting Plan have been prepared, in consultation with DFO and MOE, to maintain or improve fish habitats that support a CRA fishery.

4.1 Offsetting Options

4.1.1 Middle Section of the Fond du Lac River

When the Project is operating at a capacity of 190 m^3, areas of suitable Arctic grayling spawning habitat in the bypassed river reaches are expected to decrease by approximately 13 to 36% (i.e., 3,000 to 8,000 m^2). This decrease in suitable spawning habitat area may affect the productivity of the Arctic grayling population that inhabits the middle section of the Fond du Lac River between Black Lake and Middle Lake. In order to offset potential effects to the population, it is recommended that monitoring and offsetting activities be implemented. One offsetting option under consideration is to sort and stockpile 3,000 m^3 of cobble-sized rock that may be used to create new or improve existing spawning habitats in the middle section of the river. It is anticipated that 10,000 m^2 of spawning habitat could be created or improved if sorted rock were spread over boulder substrates at an approximate depth of 0.30 m. This offsetting option is expected to improve Arctic grayling spawning habitat by increasing the overall area (m^2) of cobble-sized substrates that are attractive to pre-spawn Arctic grayling. This option is also expected to provide additional protection to eggs and fry; crevices between the cobbles are expected to provide sufficient cover for eggs and fry, but be small enough to reduce the potential for predation by slimy sculpins (*Cottus cognatus*) and other fish that may attempt to consume Arctic grayling eggs or fry.

4.1.1.1 *Options for Off-site Offsetting*

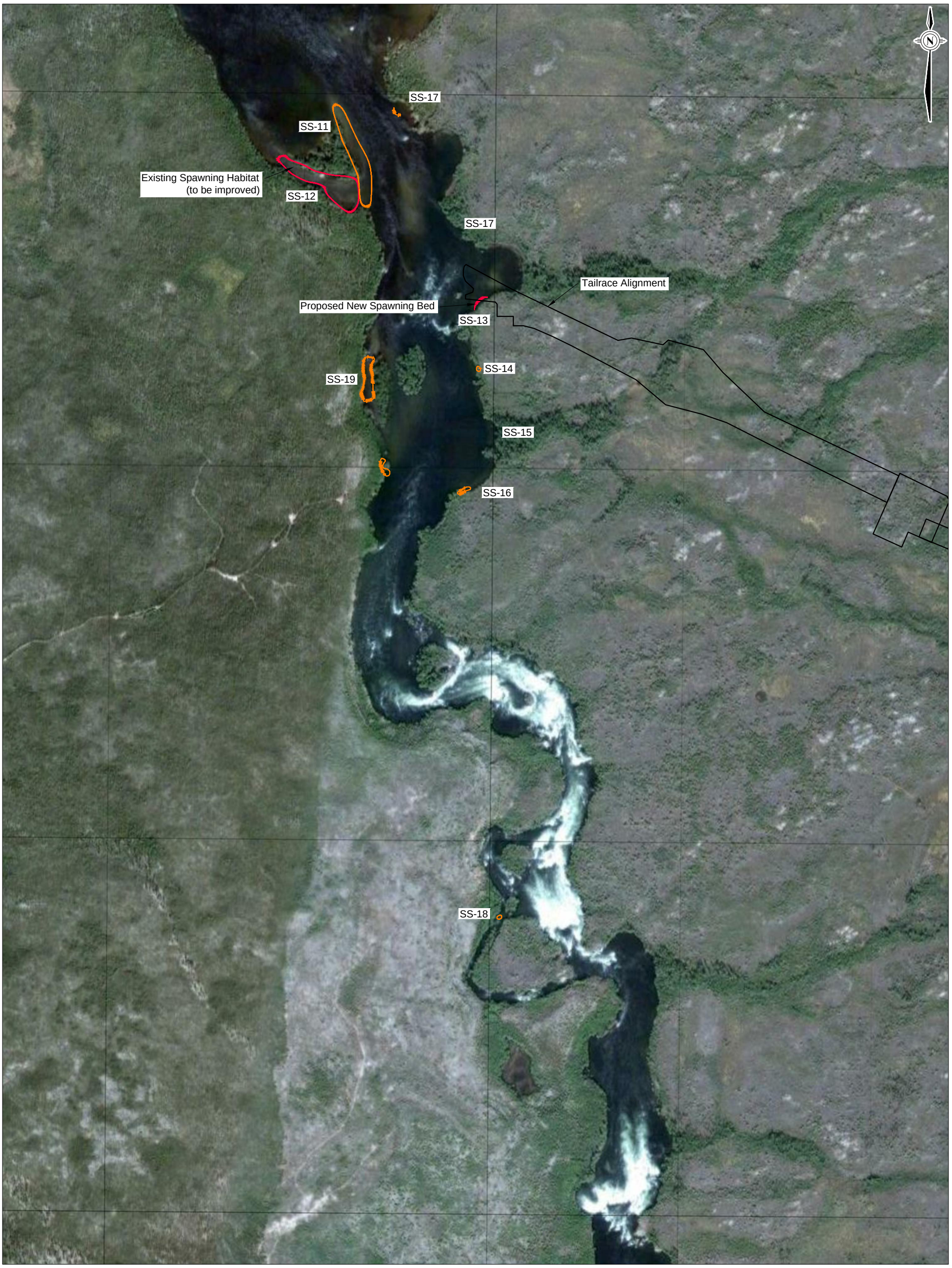
Off-site offsetting options will be considered in consultation with MOE. Offsetting options for the Project were discussed with a DFO representative (Ernest Watson) on November 8, 2013. It was indicated that because spawning habitat in the middle section of the Fond du Lac River may not be a limiting factor for the ongoing productivity of the local population and offsetting at this location may not be feasible or successful, off-site offsetting options should be considered. It may be more beneficial to local fisheries to accept population changes in the middle section of the river between Black Lake and Middle Lake and focus offsetting activities elsewhere (i.e., maintain productivity of a fishery in another location where efforts are more likely to be successful). The acceptance and implementation of off-site offsetting options will depend on Saskatchewan MOE's fisheries management objectives.

One option for off-site offsetting was put forward during the November 8, 2013 discussion with DFO. Local knowledge of the Black Lake area indicates there is an Arctic grayling spawning migration stream that flows into Middle Lake from the southwest. This particular stream is currently crossed by a roadway that leads to Middle Lake. Two culverts were installed at the road crossing to maintain stream flow; however, these culverts are considered under-sized for the stream, and are a likely barrier to fish movement. It is anticipated that replacement or improvement of this crossing may be a viable offsetting option for the Project because it would improve a known migration corridor for spawning Arctic grayling. The crossing is located on BLFN reserve land and in close proximity to the community of Black Lake. It is anticipated the community will be receptive to this option.

4.1.2 Downstream of the Tailrace

Because Project operation is expected to result in a 10% incremental increase in spawning failure for Arctic grayling that spawn immediately below the tailrace outlet bay in the Fond du Lac River, offsetting will be required. The objective of offsetting activities at the tailrace outlet location is to create spawning habitat that is suitable at average to below-average flow years; during high-flow years, there will be a greater volume of water in the river, and larger areas (m^2) of suitable spawning habitat will remain functional (i.e., wetted). One option is to create new spawning beds that will be accessible and useable by Arctic grayling that inhabit this section of the river. The orientation of the tailrace outlet channel will create a V-shaped, back-water eddy immediately adjacent and upstream of the tailrace outlet (Figure 4); this area has been identified as potentially suitable for construction of a new spawning bed. The new spawning area would be constructed at an elevation where eggs and fry would not be lost at low riparian flows.

A second offsetting option under consideration for the tailrace outlet location is to improve the existing spawning habitat at the known spawning area adjacent to the west shore, immediately downstream of the tailrace outlet (Figure 4).



100 0 100

SCALE 1:6,000 METRES

LEGEND

- LOW TO MODERATE EGG NUMBERS
- HIGH EGG NUMBERS

REFERENCE

Google Earth Image: Image © 2007 DigitalGlobe

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

2010 AND 2012 FOND DU LAC RIVER OUTFLOW ARCTIC GRAYLING SPAWNING LOCATIONS

Tazi Twé Hydroelectric Project

PROJECT		10-1365-0004	FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	BDS	22/06/12	FIGURE: 4	
CHECK	LT	24/07/13		
REVIEW	BC	24/07/13		

4.2 Proposed Offsetting

The proposed options for offsetting serious residual harm to Arctic grayling in the Fond du Lac River between Black Lake and Middle Lake include off-site offsetting to be completed at a stream crossing near Middle Lake, as well as the creation and/or improvement of Arctic grayling spawning habitat immediately below the tailrace outlet. The off-site offsetting option is preferable because the road crossing near Middle Lake will be easier to access, and as indicated by DFO, habitat improvement efforts may be more successful at this location. Because many of the bypassed river reaches are difficult to access, moving large excavation equipment into sites where offsetting would be most beneficial may not be feasible or safe in some cases, and may lead to incidental destruction of riparian habitats.

Offsetting at the tailrace outlet location is thought to be an acceptable option because this area is more easily accessed, and excavation equipment required at this location for tailrace construction can be used for offsetting (i.e., habitat construction) purposes. Improvements and additions to Arctic grayling spawning habitats at this location are expected to be successful because it is known that a large number of fish congregate in this general area to spawn under current conditions, and the tailrace outlet configuration is expected to create an eddy area of flow velocity and depth conducive to Arctic grayling spawning (i.e., all that would be required is the addition of suitable substrate at the correct depth).

Because offsetting activities will require in-water work, it is possible that implementation of the offsetting plan may have short term adverse effects on fish and fish habitat. Therefore, a number of avoidance and mitigation measures will be required to minimize these effects. Avoidance and mitigation measures implemented during offsetting will include:

- adherence to DFO In-Water Construction Timing Windows;
- adherence to BMPs, guidelines and policies, regulatory requirements and use of adaptive management monitoring and mitigation strategies;
- disturbed areas (e.g., access roads and banks) will be graded to a stable angle and revegetated after work is completed;
- having an environmental monitor on-site during in-water work to monitor that compliance with the offsetting plans and approvals is achieved;
- isolating in-water work from adjacent habitats, if required;
- appropriate controls (e.g., turbidity curtains) to contain sediment released during in-water construction;
- a turbidity/TSS regression and Turbidity Monitoring Program, if required;
- excavation equipment will be regularly maintained, and will be free of leaks;
- rock used in offsetting activities will be free of fines and contaminants;
- in-water activities will be completed in winter when water levels are low, or within work isolation areas;
- if surface water is to be used for industrial purposes during offsetting activities, pump intakes will be screened in accordance with DFO's "Freshwater Intake End-of-Pipe Fish Screen Guideline" (DFO 1995);

- excavated materials or stockpiled cobble materials will be stored away from watercourses or lakes;
- excavation machinery, equipment, and vehicles will not be stored, refuelled, or repaired near waterbodies;
- an Emergency Response Plan will be developed for the site; and
- spill response materials will be stored on-site in designated areas and vehicles.

Additional avoidance and mitigation measures may be implemented during offsetting, where deemed necessary and appropriate.

4.3 Monitoring

A monitoring program will be designed and implemented to determine that compliance with the *Fisheries Act* Authorization is achieved and the Fisheries Offsetting Program has been implemented effectively. Results of the monitoring program will be used as an indicator of program performance and regulatory compliance (i.e., is fisheries productivity being effectively protected and maintained).

Because the goal of offsetting activities is to maintain or improve the productivity of fish populations that are important to CRA fisheries, it is recommended that mark-recapture population studies be included in the monitoring program. Population estimates based on mark-recapture data can be compared with pre-Project population estimates (Section 1.3.1.1) to monitor whether the selected offsetting options are successful in maintaining Arctic grayling populations and whether further offsetting may be required.

4.4 Timeline

This conceptual Fisheries Offsetting Plan will be finalized in consultation with DFO and MOE. It is anticipated that strategic planning for offsetting activities will commence once the Project has received regulatory approval. Offsetting activities will be scheduled for the construction phase of the Project in order to make use of excavation equipment and personnel that will already be onsite (e.g., at the tailrace outlet construction location).

4.5 Contingency Measures

The Proponent is expected to identify contingency measures to be implemented in the event that the preferred fisheries offsetting options are unsuccessful in offsetting serious harm to fish. Potential contingency measures will be discussed with DFO and MOE and a finalized description of these measures will be presented in the finalized Fisheries Offsetting Plan.

4.6 Financial Costs

The financial costs of implementing each of the preferred offsetting options have not been determined at this time. This information will be included in the finalized Fisheries Offsetting Plan.

4.7 Land Access

Because the Project and proposed offsetting locations are on lands owned by the BLFN, land access authorizations will not be required. Appropriate licensing and approvals will be requested from the Saskatchewan Water Security Agency, as required.

5.0 FISHERIES OFFSETTING SUMMARY

Effects to the productivity of CRA fisheries in the Project area are expected to result from changes to hydrology in the Fond du Lac River and subsequent changes to Arctic grayling spawning habitat. A decrease in the total area of suitable Arctic grayling spawning habitat is expected to occur in the bypassed section of the Fond du Lac River during the period of Project operation. Operation of the Project is also expected to result in an approximately 10% incremental increase in annual spawning failure for Arctic grayling populations that spawn immediately downstream of the tailrace outlet bay.

The planned fisheries offsetting activities will focus on improving a spawning migration corridor used by Arctic grayling, as well as creating a new spawning area at the tailrace outlet location in the Fond du Lac River.

With the implementation of this Fisheries Offsetting Plan, it is anticipated that the Project will have no net adverse effect to fish populations and CRA fisheries in the Project area (i.e., Black Lake, Middle Lake and the section of the Fond du Lac River between Black Lake and Middle Lake).

To implement the Fisheries Offsetting Plan, the following milestones will need to be achieved:

- issuance of a *Fisheries Act* Authorization for the Project, which will include the details of the offsetting and monitoring requirements;
- receipt of DFO and MOE approval of the Fisheries Offsetting Plan;
- development of a detailed construction plan as well as an estimate of the timeline, materials and costs required for offsetting; and
- review of the proposed Fisheries Offsetting Plan with area residents and members of the BLFN.

6.0 CONCLUSIONS

While the Project structures were designed to avoid or mitigate potential serious harm to fish, including the loss or alteration of fish habitat, it is expected that some effects to the productivity and sustainability of area fisheries will occur. Improvements to existing Arctic grayling spawning habitat and the creation of new spawning habitat at the tailrace outlet location is expected to enhance productivity through increased spawning and rearing success.

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APPENDIX 12.3

Intake Depth Assessment Tech Memo

February 2014
Report No. 10-1365-0004/DCN-171

TECHNICAL MEMORANDUM

DATE August 26, 2013 **PROJECT No.** 10-1365-0004/25000-DCN-171

TO Gordon McPhail
KGS Group

CC Stan Saylor and Jackie Lukey, SaskPower

FROM Brian Christensen, Amy Ofukany **EMAIL** Brian_Christensen@golder.com

TAZI TWÉ HYDROELECTRIC PROJECT: INTAKE DEPTH AND POTENTIAL IMPLICATIONS FOR FISH INHABITING THE BLACK LAKE INTAKE AREA

1.0 INTRODUCTION

Saskatchewan Power Corporation (SaskPower) and the Black Lake First Nation (BLFN) are currently developing plans for construction of the Tazi Twé Hydroelectric Project (the Project). The proposed Project is anticipated to be a 50 megawatt (MW) water diversion type electrical generating facility that will be located adjacent to the Fond du Lac River between Black Lake and Middle Lake.

A submerged intake on the northwest shore of Black Lake will be used to divert water for hydropower generation. The intake is anticipated to be a concrete bellmouth structure that will be pushed back from the existing shoreline and into the bedrock by approximately 105 metres (m). An approach channel will be constructed between the lake and the intake; the bottom of the channel is currently expected to be approximately 4.5 m below the normal lake level. Water diverted through the intake will pass through a power tunnel and powerhouse before being returned to the Fond du Lac River via a tailrace channel outlet located just upstream of Middle Lake.

Diversion of water for hydroelectric power generation can affect water quality, as well as fish survival and health. Changes to water temperatures at the intake site and in waterbodies downstream of the discharge location are often among the most prevalent water quality issues encountered (Oak Ridge National Laboratory [ORNL] et al. 2010). Water diverted for power generation is often withdrawn from near the reservoir bottom; in temperate regions where lakes and reservoirs tend to be thermally stratified this can lead to withdrawal of cooler water in the summer and relatively warm water in the winter (ORNL et al. 2010). Untimely changes to water temperatures can affect processes and behaviors that are important to survival of fish, such as spawning, embryo development, and food production (Scotland and Northern Ireland Forum for Environmental Research [SNIFFER] 2011). In addition to changes to water quality, withdrawal of water for power generation may cause physical injury to fish. Injury and/or mortality can occur when fish are drawn into the intake structure becoming entrained and/or impinged.

2.0 SCOPE

Golder Associates Ltd. (Golder) was requested by SaskPower Corporation to evaluate three intake depth scenarios that are currently under consideration for the Project. The intakes assessed included a 3 m deep

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intake, a 5 m deep intake, and an intake that would span from approximately 2 m below the water's surface to a depth of about 11 m (hereafter "deep-water" intake). The purpose of Golder's evaluation was to determine which intake depth scenario would minimize temperature effects that may occur as a result of water diversion, as well as mitigate the potential entrainment and/or impingement of fish. Golder is pleased to provide SaskPower Corporation with this technical memorandum summarizing the intake depth assessment.

3.0 METHODS

3.1 Temperature Data for the Black Lake Intake Area

Temperature profile data for the Black Lake intake area were collected by Golder in 2010 and 2011. Measurements were obtained from station BKL-02, the water quality station located nearest the proposed intake site (Figure 1), using a calibrated, hand-held YSI 600 QS-O-M multi-parameter sonde. Vertical profile sampling was completed at 1.0 m increments throughout the water column.

3.2 Attraction, Entrainment, and Impingement of Fish

A review of the relevant literature and a desktop assessment were performed to determine which of the three intake depth scenarios (3 m, 5 m, or deep-water) being considered, if any, provided additional protection against the attraction, entrainment, or impingement of fish. Fish capture data collected by Golder for the proposed Black Lake intake area were consulted in order to identify which species were typically found in the vicinity of the intake. Life history characteristics (e.g., depth preferences, migratory behaviours) were used to identify which species were most likely to be at risk of injury or mortality as a result of entrainment and/or impingement due to power tunnel flows.

4.0 RESULTS

4.1 Temperature

Temperature profiles at BKL-02, the water quality station closest to the proposed intake location in Black Lake, were vertically homogeneous during the spring and fall 2010 sampling events (Table 1) (Golder 2013a). This indicated that the water column in this region of Black Lake was typically well mixed by temperature- and density-driven lake turnover occurring in spring and fall. The development of a seasonal thermocline was evident during the summer 2010 sampling. At station BKL-02, the summer thermocline was observed at depths between 12 and 16 m. During the winter of 2011, Black Lake was inversely stratified (Table 1). Cooler waters approaching 0 degrees Celsius (°C) occurred immediately below the ice and water temperatures increased with increasing depth. The temperature profiles taken at BKL-02 (near the proposed water intake), closely resembled temperature profiles taken at BKL-03, the other deep water limnology station in Black Lake, during each of the four seasonal sampling seasons (Golder 2013a).

500 0 500

SCALE 1:25,000 METRES

LEGEND

⊗ TEMPERATURE PROFILE LOCATION

REFERENCE

GOOGLE EARTH IMAGE: IMAGE © 2007 DIGITALGLOBE

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

2010 AND 2011 BLACK LAKE TEMPERATURE PROFILE LOCATION

Tazi Twé Hydroelectric Project

PROJECT	10-1365-0004		FILE No.	
DESIGN			SCALE AS SHOWN	REV. 0
CADD	TAH/AL	16/05/13	FIGURE: 1	
CHECK	AO	22/01/14		
REVIEW	BC	22/01/14		

\\golder.gds\gal\Saskatoon\GIS\CLIENTS\SASKPOWER\Elizabeth Falls Power Project\Figures\10-1365-0004 SaskPower Elizabeth Falls EA\25000 EIS Prep\S12_FishAppendix 12.3\10-1365-0004 Sampling Locations.dwg 1/22/2014 9:08 AM

Table 1: Temperature Profiles at BKL-02, Near the Proposed Intake Location in Black Lake by Season

Spring 2010 (5/29/2010)			Summer 2010 (8/25/2010)			Fall 2010 (9/26/2010)			Winter 2010 (2/21/2010)		
Max Depth (m)	Profile Depth (m)	Water Temperature (°C)	Max Depth (m)	Profile Depth (m)	Water Temperature (°C)	Max Depth (m)	Profile Depth (m)	Water Temperature (°C)	Max Depth (m)	Profile Depth (m)	Water Temperature (°C)
	0.2	4.0		0.2	15.3		0.2	10.7		1.0	0.5
	1.0	3.8		1.0	15.2		1.0	10.7		2.0	0.5
	2.0	3.6		2.0	15.1		2.0	10.7		**3.0**	**0.5**
	3.0	**3.6**		**3.0**	**15.1**		**3.0**	**10.7**		4.0	0.4
	4.0	3.5		4.0	15.0		4.0	10.7		**5.0**	**0.6**
	5.0	**3.5**		**5.0**	**14.9**		**5.0**	**10.7**		6.0	0.7
	6.0	3.5		6.0	14.9		6.0	10.7		7.0	0.7
	7.0	3.4		7.0	14.9		7.0	10.7		8.0	0.9
	8.0	3.5		8.0	14.8		8.0	10.7		9.0	1.1
	9.0	3.6		9.0	14.8		9.0	10.7		10.0	1.2
	10.0	3.5		10.0	14.5		10.0	10.7		11.0	1.3
	11.0	3.5		11.0	14.2		11.0	10.7		12.0	1.3
29.0	12.0	3.5	30.2	12.0	14.1	31.0	12.0	10.7	28.3	13.0	1.4
	13.0	3.5		13.0	13.6		13.0	10.7		14.0	1.6
	14.0	3.5		14.0	13.2		14.0	10.7		15.0	1.7
	15.0	3.6		15.0	12.0		15.0	10.7		16.0	2.0
	16.0	3.6		16.0	11.1		16.0	10.7		17.0	2.0
	17.0	3.7		17.0	10.5		17.0	10.7		18.0	2.1
	18.0	3.7		18.0	10.3		18.0	10.7		19.0	2.2
	19.0	3.7		19.0	10.2		19.0	10.7		20.0	2.3
	20.0	3.7		20.0	10.1		20.0	10.6		21.0	2.4
	21.0	3.8		21.0	10.1		21.0	10.6		22.0	2.4
	22.0	3.8		22.0	10.1		22.0	10.6		23.0	2.5
	23.0	3.8		23.0	10.0		23.0	10.6		24.0	2.6
	24.0	3.8		24.0	9.9		24.0	10.6		25.0	2.6

Table 1: Temperature Profiles at BKL-02, Near the Proposed Intake Location in Black Lake by Season (continued)

Spring 2010 (5/29/2010)			Summer 2010 (8/25/2010)			Fall 2010 (9/26/2010)			Winter 2010 (2/21/2010)		
Max Depth (m)	**Profile Depth (m)**	**Water Temperature (°C)**	**Max Depth (m)**	**Profile Depth (m)**	**Water Temperature (°C)**	**Max Depth (m)**	**Profile Depth (m)**	**Water Temperature (°C)**	**Max Depth (m)**	**Profile Depth (m)**	**Water Temperature (°C)**
	25.0	3.8		25.0	9.7		25.0	10.6		26.0	2.7
	26.0	3.8		26.0	9.4		26.0	10.6		27.0	2.8
	27.0	3.8		27.0	9.3		27.0	10.6		28.0	2.9
29.0	28.0	3.8	30.2	28.0	9.0	31.0	28.0	10.6	28.3	-	-
	29.0	3.8		29.0	8.9		29.0	10.4		-	-
	-	-		30.0	8.6		30.0	10.4		-	-
	-	-		-	-		30.5	10.4		-	-

Notes: sample dates are in mm/dd/yyyy format, where mm = month, dd= day and yyyy= year; m = metres; °C = degrees Celcius; - = no data available; temperature values measured at three and five metre depths are bolded in the table.

Temperatures measured at the 3 and 5 m depths of BKL-02 differed by 0.2°C or less, depending on the sampling season. Some vertical mixing of water at the intake is expected; therefore temperature data was considered over a range of 2 to 6 m for the shallow-water (i.e., 3 and 5 m) intakes. Because water temperatures measured at these depths exhibited little variability (i.e., less than or equal to [≤] 0.3°C) within each season, vertical mixing is not expected to result in a temperature difference between the 3 and 5 m intakes. Although the data presented in Table 1 represents a single annual cycle, it is anticipated that the temperature of the water entering the Black Lake intake would be similar at intake depths of 3 or 5 m.

Because Black Lake is thermally stratified in summer and winter (Table 1), it is anticipated that a deep-water intake may withdraw a larger volume of cool bottom water in the summer, and relatively warm water in the winter. Temperature data (Table 1) was evaluated for depths ranging from 1 to 12 m in order to account for vertical mixing at the deep-water intake. The average temperatures (plus or minus [±] one standard deviation) of water withdrawn in spring, summer, fall, and winter are expected to be approximately 3.5 ± 0.1°C, 14.8 ± 0.3°C, 10.7°C, and 0.8 ± 0.3°C, respectively. In spring and fall, temperatures of water withdrawn from the deep-water intake would be very similar (i.e., within 0.2°C) to those of the shallow-water intakes. However, water withdrawn from the deep-water intake may be up to 0.7°C cooler (summer) or warmer (winter) than water withdrawn at 3 or 5 m deep.

4.2 Attraction, Entrainment and Impingement

4.2.1 Black Lake Fish

Fish species captured from Black Lake by Golder personnel during aquatic baseline surveys completed between spring 2010 and summer 2012 are presented in Table 2 (Golder 2013a).

Table 2: Fish Species Captured from Black Lake between Spring 2010 and Summer 2012

Common Name	Scientific Name	Species Code	Total Number Captured
Arctic grayling	*Thymallus arcticus*	ARGR	46
Burbot	*Lota lota*	BURB	112
Cisco species [(a)]	*Coregonus* spp.	CISC	15
Lake chub	*Couesius plumbeus*	LKCH	135
Lake trout	*Salvelinus namaycush*	LKTR	519
Lake whitefish	*Coregonus clupeaformis*	LKWH	305
Longnose sucker	*Catostomus catostomus*	LNSC	272
Ninespine stickleback	*Pungitius pungitius*	NNST	13
Northern pike	*Esox lucius*	NRPK	44
Round whitefish	*Prosopium cylindraceum*	RNWH	23
Slimy sculpin	*Cottus cognatus*	SLSC	86
Spottail shiner	*Notropis hudsonius*	SPSH	6
Trout-perch	*Percopsis omiscomaycus*	TRPR	7
Walleye	*Sander vitreus*	WALL	40
White sucker	*Catostomus commersonii*	WHSC	375
Yellow perch	*Perca flavescens*	YLPR	7

[(a)] Specimens exhibited characteristics of shortjaw cisco (*Coregonus zenithicus*) and the common cisco (*Coregonus artedi*).

Historical fisheries information indicates that both shortjaw cisco (*Coregonus zenithicus*) and common cisco (*Coregonus artedi*) are found in Black Lake. Where these specimens are found together in deep lakes, shortjaw cisco are generally found at greater depths than common cisco (Stewart and Watkinson 2004). Shortjaw cisco is categorized as a threatened species by the *Committee on the Status of Endangered Wildlife in Canada* (COSEWIC) (COSEWIC, 2012), and is being considered for listing under the *Species at Risk Act*. Detailed photographs and voucher specimens were collected and sent for identification to a Golder fisheries biologist with expertise in cisco biology (Paul Vecsei, Yellowknife, NWT). The taxonomic assessment of Black Lake cisco was inconclusive as examined specimens exhibited morphometric and meristic features characteristic of both shortjaw cisco and the common cisco.

4.2.2 Fish and Fish Habitat at the Intake Location

The shoreline habitat near the proposed water intake location consists of a cobble and boulder shelf that extends approximately 50 m outward from shore before dropping off rapidly into a 25 to 30 m deep zone. Along the shelf the substrate size increases as the depth increases and becomes boulder dominant at the drop-off. At depths of 20 to 30 m, the bottom levels off with substrates becoming depositional in nature consisting of finer sand/silt.

In 2012, Golder completed a focused fish survey at the proposed water intake location in Black Lake (Golder 2013a, b). Species captured at this location included cisco (*Coregonus* sp.), lake chub (*Couesius plumbeus)*, lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), longnose sucker (*Catostomus catostomus*), round whitefish (*Prosopium cylindraceum)*, walleye (*Sander vitreus*), white sucker (*Catostomus commersonii*), and yellow perch (*Perca flavescens*). Cobble and boulder substrates along the shelf provide suitable cover for lake chub and juvenile large-bodied fish, including yellow perch. The habitat along the steep drop-off was found to support adult cisco, lake trout, round whitefish, lake whitefish, longnose sucker, white sucker, and walleye. Lake trout, cisco and whitefish change their vertical distribution in the water column based on seasonal temperature changes (Scott and Crossman, 1973). During spring and fall when Black Lake is relatively homothermous, these species may be found at all depths; when the lake stratifies in summer, they descend to cool water below the thermocline.

Black Lake fish species that were not captured during the 2012 survey of the intake location included Arctic grayling (*Thymallus arcticus*), burbot (*Lota lota*), ninespine stickleback (*Pungitius pungitius)*, northern pike (E*sox lucius*), slimy sculpin (*Cottus cognatus*), spottail shiner (*Notropis hudsonius*), and trout-perch (*Percopsis omiscomaycus*). Although no burbot were captured within the intake area, it is possible this species inhabits depths within the 25 to 30 m deep zone. The intake area is unlikely to provide suitable habitat for northern pike as aquatic vegetation at this location is limited, even in the shallow-water areas.

4.2.3 Intake Depth and Potential Implications for Fish

Based on life history information for fish captured from the proposed Black Lake intake area, it is anticipated that most fish species will have the potential to interact with the power tunnel intake at some point throughout the annual lake temperature cycle, regardless of whether the intake is positioned at three metres depth, 5 m depth, or over a span of 2 to 11 m deep. However, it is expected that construction and operation of a 3 m deep intake may be slightly more protective for lake trout, cisco, and whitefish species that generally seek cooler, deeper water during the late spring, summer, and early fall periods. Because the area does not contain suitable habitat for northern pike, and none were captured during the focused fisheries survey, it is not anticipated that the development of a shallow-water intake (i.e., at either 3 or 5 m depth) will affect populations of this species in Black Lake.

In addition, none of the fish species documented in Black Lake are known to undertake annual or regular downstream migrations for spawning, rearing, or foraging purposes. Most fish species within Black Lake are year-round residents (e.g., lake trout, lake whitefish, cisco), or may ascend tributary streams to feed or spawn (e.g., northern pike, walleye) (Stewart and Watkinson, 2004). It is known that some number of fish currently drift downstream out of Black Lake into the Fond du Lac River via the Black Lake outflow. It is also anticipated that some Black Lake fish will passively drift into the vicinity of the power tunnel intake where they will be entrained by power tunnel flows. However, the total number of fish leaving the Black Lake fish community is not expected to change over the current level of out-migration because overall Black Lake outflow rates and volumes will not change with the development of the Project. Out-migration of fish from Black Lake once the Project is operating is expected to be similar to current levels. Although Black Lake effectively will have two outlets once the power plant is in operation, each will only carry approximately half of the current Black Lake outflow total. Because the natural Fond du Lac River outflow will be reduced from current levels, the outlet velocities will also be reduced, potentially resulting in fewer fish being entrained with lake outflows than are currently. With the exception of Arctic grayling, it is not believed that fish are able to return to Black Lake once they have been carried downstream into the rapid flows of the Fond du Lac River. Anticipated lake outflow conditions associated with the power tunnel intake are expected to closely resemble the outflow conditions at the natural Black Lake outflow to the Fond du Lac River.

For fish that do enter the power tunnel intake area, the likelihood of entrainment largely depends on the velocity of water entering the intake, as well as the fish's ability to resist the water flow (CH2M HILL 2007). Based on the proposed design for the Project's water intake, velocities in the centre portion of the approach channel will range from 0.6 to 1.0 metres per second (m/s) but are expected to be much lower (i.e., ≤ 0.6 m/s) along the sides of the channel. Velocities at the "exclusion bar racks" are expected to be less than (<) approximately 1.1 m/s; this is below or within the ranges of burst or startle swimming speeds that can be attained by adult resident fish species. It is anticipated that fish will be visually deterred by the "exclusion bar rack" and will be able to dart away from the high velocity areas in front of the water intake openings. Fish will be able to return to Black Lake out of the approach channel if they remain in the low-velocity areas along the edges; a short swim at burst speed may be required to move from the edge of the approach channel back into the main body of Black Lake.

Burst or startle speeds (i.e., greatest swimming speed that can be reached and maintained for less than 15 seconds), as well as prolonged swimming speeds (i.e., a moderate speed that can be maintained for up to 200 minutes) for fish species captured within the proposed Black Lake intake area are summarized in Table 3. Swimming speeds for Arctic grayling and northern pike are also included.

Table 3: Burst Swimming Speeds and Prolonged Swimming Speeds of Selected Black Lake Fish Species

Common Name	Scientific Name	Reported Fish Length [a]	Burst Swimming Speed [b] (m/s)	Prolonged Swimming Speed [c] (m/s)		Reference(s)
				Speed (m/s)	Duration (s)	
Salmonids and walleye	*Salmonidae* and *Percidae*, respectively	100 mm	1.0 to 3.9	0.4 to 1.6	600	Gervais and Katopodis 2012
		250 mm	1.2 to 4.4	0.5 to 1.8	600	
		400 mm	1.2 to 4.7	0.5 to 1.9	600	
Arctic grayling	*Thymallus arcticus*	203 to 305 mm FL	2.1 to 4.3	-	-	Bell 1991
		200 mm FL	0.90 to 4.0	0.5 to 0.9	1800	Shumilak and Remnant 1999
		70 to 370 mm	-	0.52 to 0.72	600	Katopodis 1992
Cisco species [d]	*Coregonus* spp.	133 mm [e]	-	0.46 to 0.63	433 to 1800	Katopodis 1992
Lake chub	*Couesius plumbeus*	-	-	-	-	Peake 2008 [f]
Lake trout	*Salvelinus namaycush*	455 to 895 mm TL	0.46 to 3.2	-	-	Dunlop et al. 2010
Lake whitefish	*Coregonus clupeaformis*	152 to 457 mm	0.91 to 1.2	-	-	Jones et al. 1974
		60 to 510 mm	-	0.34 to 0.59	72 to 1278	Katopodis 1992
Longnose sucker	*Catostomus catostomus*	100 to 460 mm	1.2 to 2.4	-	-	Bell 1991
		40 to 530 mm FL	-	0.23 to 0.91	600	Katopodis 1992
Northern pike	*Esox lucius*	100 mm	0.9 to 2.0	0.3 to 0.6	600	Gervais and Katopodis 2012
		250 mm	1.0 to 2.3	0.3 to 0.7	600	
		400 mm	1.0 to 2.5	0.4 to 0.8	600	
		412 mm (average FL)	2.8 to 3.4	-	-	Frith and Blake 1995
		170 to 200 mm	1.5 to 2.1	-	-	Wolter and Arlinghaus 2003 as cited in KGS and North/South Consultants Inc. 2008
		120 to 620 mm	-	0.19 to 0.47	600	Jones et al. 1974
Round whitefish	*Prosopium cylindraceum*	-	-	-	-	-
Walleye	*Sander vitreus*	180 to 670 mm FL	1.60 to 2.60	0.30 to 0.73	3600	Peake et al. 2000
		80 to 380 mm	-	0.38 to 0.84	600	Katopodis 1992
White sucker	*Catostomus commersonii*	170 to 370 mm FL	-	0.48 to 0.73	600	Katopodis 1992
Yellow perch [g]	*Perca flavescens*	95 mm	-	0.02 to 0.34	-	Beamish 1978 as cited in KGS and North/South Consultants Inc. 2008

[a] Attainable swim speeds within a species are often dependent on the fish size (Peake et al. 2000).
[b] Burst or startle speed is the greatest swimming speed that can be reached and maintained for less than 15 seconds (Katopodis 1992).
[c] Prolonged speed is a moderate swimming speed that can be maintained for up to 200 minutes (Katopodis 1992); speeds and the duration over which fish can maintain the reported speed are included in the table.
[d] Specimens exhibited characteristics of shortjaw cisco (*Coregonus zenithicus*) and the common cisco (*Coregonus artedi*).
[e] Prolonged swim speed data is for anadromous common cisco (*Coregonus artedi*).
[f] No burst speed data could be found for lake chub (*Couesius plumbeus*); the lack of data was reiterated by Peake 2008.
Notes: m/s = metres per second; s = seconds; mm = millimetres; FL = fork length; TL = total length; - = no data available

5.0 SUMMARY

It is not anticipated there will be appreciable differences in the temperature of water withdrawn from depths of 3 or 5 m based on Black Lake water temperature profile measurements collected near the proposed intake location during 2010 and 2011. The temperature profile data also suggests that relative to either of the shallow-water intakes, a deep-water intake spanning depths from 2 to 11 metres would withdraw greater volumes of cooler mid-depth water in the summer, and warmer mid-depth water in the winter.

Based on a review of fish capture data from the proposed intake location and life history information for captured species, intake depths of either 3 or 5 m appear to be almost equally suitable for reducing entrainment of fish species captured in the area. A deep-water intake is expected to encroach on habitats used by lake trout, whitefish species and cisco, especially during the summer period. Reducing velocities at the ”exclusion bar rack” face as much as possible will potentially reduce the frequency of fish entrainment or impingement, although adult fish of most species in the vicinity of the intake appear to have burst swimming speeds in excess of the proposed ”exclusion bar rack” face velocity of 1.1 m/s.

Amy Ofukany, M.Sc.
Aquatic Biologist

Brian Christensen, M.Sc.
Associate, Senior Environmental Scientist

AO/BLC/AL/jlb

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APPENDIX 12.4

Entrainment Assessment Tech Memo

February 2014
Report No. 10-1365-0004/DCN-171

TECHNICAL MEMORANDUM

DATE November 12, 2013 **PROJECT No.** 10-1365-0004/25000/35/DCN-171

TO Stan Saylor, Jackie Lukey
SaskPower

CC Gordon McPhail, Rick Martin, KGS

FROM Brian Christensen, Amy Ofukany **EMAIL** Brian_Christensen@golder.com

TAZI TWÉ HYDROELECTRIC PROJECT: INJURY AND MORTALITY OF ENTRAINED FISH

1.0 INTRODUCTION

SaskPower Corporation (SaskPower) and the Black Lake First Nation (BLFN) are currently developing plans for construction of the Tazi Twé Hydroelectric Project (the Project). The proposed Project is anticipated to be a 50 megawatt (MW) water diversion type electrical generating facility that will be located adjacent to the Fond du Lac River between Black Lake and Middle Lake.

A submerged water intake on the northwest shore of Black Lake will be used to divert water for hydropower generation. Water withdrawal from Black Lake may result in the impingement or entrainment of fish. Entrained fish may be injured or killed as they pass through the water intake, power tunnel, and tailrace.

2.0 SCOPE

Golder Associates Ltd. (Golder) was requested by SaskPower to review and evaluate potential sources of injury and/or mortality for fish entrained in the Project's hydropower generating facilities. A review of relevant literature was completed for the turbine types under consideration for the Project and associated sources of fish injury and mortality were assessed. Golder is pleased to provide SaskPower with this technical memorandum summarizing the potential effects of the Project to entrained fish.

3.0 TURBINE SELECTION FOR THE PROJECT

Hydroelectric facilities in Canada generally use either Kaplan or Francis turbines for power generation (Canadian Electricity Association [CEA] 2001). A large proportion of the hydroelectric power generated in the United States also comes from low- to medium- head facilities containing one of these turbine types (Becker et al. 2003; Odeh 1999). Both Kaplan and Francis style turbines were considered for the Project; however, Kaplan turbines were selected as part of the Project design. Therefore, the discussion of injury and mortality of entrained fish is focused on data for Kaplan turbines.

Fish mortality rates reported for Kaplan turbines are generally lower than those reported for Francis turbines. For example, the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER; 2011) reported mortality rates of 5 to 20 percent (%) for juvenile salmonids entrained in Kaplan turbines; mortality associated with Francis turbines was between 5 and 90%. Higher mortality rates associated with Francis turbines have generally been attributed to the fact that they are typically installed at higher-head facilities (Collins 1984; Larinier

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and Travade 2002). However, a number of design features associated with the Kaplan turbine have been identified as being more fish-friendly relative to the Francis turbine.

One advantage of Kaplan turbines is that blade pitch can be adjusted to accommodate variations in water flow and thereby maintain efficiency over a wider range of operating conditions (Paish 2002). Adjusting blade pitch in response to changes in flow minimizes the formation of shear zones within the draft tube (United States Army Corps of Engineers [USACE] 1995 as cited in Odeh 1999). This source of shear stress, which may be highly injurious to entrained fish (see below), cannot be mitigated in a Francis turbine where the blades are fixed. When flows through a Francis turbine decrease to below 50% of normal, the system becomes inefficient (Paish 2002) and rates of fish injury and mortality tend to be higher than if the facility were operating at maximum efficiency (CEA 2001).

The numbers of turbine blades and blade spacings is also thought to influence injury and mortality rates of passed fish. Kaplan turbines typically have four to six blades (Collins 1984; Ferguson et al. 2008). Francis turbines generally have a greater number of blades (i.e., 13 to 17) and smaller blade spacings than Kaplan turbines; as a Francis turbine gets smaller, the spacings between the blades also gets smaller (Collins 1984; Ferguson et al. 2008; Odeh 1999). The larger spacings between fixed (e.g., a wicket gate) and rotating (i.e., runner) parts in a Kaplan turbine are generally associated with a decreased incidence of grinding and abrasion injuries in fish, relative to Francis turbines (Odeh 1999). Because Kaplan turbines have a reduced number of blades and water flow between the blades is maximized, probability of injury or a lethal strike is expected to be lower than in Francis turbines (Odeh 1999). Mortality rates reported for fish entrained through Francis turbines are presented in Table 1. Average mortality rates reported for juvenile salmonids and other groups, such as juvenile clupeids, were as low as 2.3% and 3.6%, respectively (EPRI 1992; Stokesbury and Dadswell 1991).

Table 1: Mortality Rates Reported for Fish Entrained in Kaplan Turbines

Species/Group	Lifestage/Body Size	Mortality Rate (%)	Reference(s)
Salmonids (e.g., lake trout, whitefish, cisco species)	Juvenile	≤ 5 to 20 (range)	Larinier and Travade 2002; SNIFFER 2011
		2.5 to 5 (range)[(a)]	Čada 2001
	83.4 to 99.4 mm	2.3	EPRI 1992
General	80 to 440 mm	17.3	EPRI 1992
	116 to 467 mm	43.0 (total)	EPRI 1992
	-	< 10	Collins 1984

[(a)] values are based on a number of conventional Kaplan turbine units at facilities in the United States.
% = percent; ≤ = less than or equal to; SNIFFER = Scotland and Northern Ireland Forum for Environmental Research; mm = millimetres; EPRI = Electric Power Research Institute; - = not reported; < = less than.

4.0 FISH ENTRAINMENT

Based on the current Project design, the water intake structure will be pushed back from the natural shoreline and into the bedrock by approximately 105 m. Velocities in the centre portion of the intake approach channel will range from 0.6 to 1.0 metres per second (m/s) and are expected to be much lower (i.e., less than or equal to [≤] 0.6 m/s) along the sides of the channel. Velocities at the face of each "exclusion bar rack" are expected to be less than (<) 1.4 m/s. This is below or within the ranges of burst swimming speeds (i.e., speeds that can be attained and maintained for 15 seconds) for fish species in Black Lake (Table 2). In general, members of the catostomid, percid, coregonid and salmonids families found in Black Lake that have body lengths greater than 150 millimetres (mm) are expected to have burst swimming speeds sufficient to avoid the "exclusion bar rack" (Gervais and Katopodis 2012). Northern pike larger than approximately 250 mm in length are also expected to have burst speeds sufficient to avoid the "exclusion bar rack" (Gervais and Katopodis 2012). It is anticipated that fish will be visually deterred by the "exclusion bar rack" and will be able to dart away from the high velocity areas in front of the intake openings. Fish will be able to travel out of the approach channel if they remain in the low-velocity areas along the edges; a short burst swim may be required to move from the edge of the approach channel back into the main body of Black Lake.

The majority of fish that become entrained in hydroelectric turbine facilities are small young-of-the-year (YOY) specimens. The Electric Power Research Institute (1992) estimates that more than 90% of entrained fish are smaller than 200 mm in length. These small YOY fish are unlikely to have burst speeds sufficient to avoid hydroelectric water intakes and are often abundant in lake habitats where water intakes are frequently constructed (CH2M HILL 2007).

The most common causes of injury and mortality for fish that become entrained in hydroelectric turbine facilities are blade strikes and pressure stresses (SNIFFER 2011). Fish may also be injured or killed by the shearing forces of moving water masses, turbulence, cavitation, grinding, or collision with fixed structures within the power tunnel (Schilt 2007). Physical injuries sustained by entrained fish may include loss of the protective mucous layer and scales, torn gill covers, decapitation, bruising, rupture of the swim bladder, and hemorrhage (Čada et al. 1997). Fish that survive entrainment may be more susceptible to predation and/or disease as a result of physiological stress and/or disorientation. These indirect effects of entrainment have not been the subject of scientific research, and are poorly understood at this time (Halls and Kshatriya 2009).

5.0 FISH INJURY AND MORTALITY

5.1 Blade Strike

The likelihood that a fish will be injured or killed as a result of a blade strike is dependent on a number of factors (USACE 1995, as cited in Čada et al. 1997), including:

- characteristics of the entrained fish (e.g., species, length, weight);
- characteristics of the turbine (e.g., number of blades, blade shape, blade velocity, size and number of openings between the vanes and blades); and
- the interaction between the fish and the turbine (e.g., orientation of the fish's body relative to the blade edge, swimming velocity of the fish relative to the blade velocity).

Table 2: Burst Swimming Speeds and Prolonged Swimming Speeds of Selected Fond du Lac River and Black Lake Fish Species

Common Name	Scientific Name	Reported Fish Length [a]	Burst Swimming Speed[b] (m/s)	Prolonged Swimming Speed[c] (m/s)		Reference(s)
				Speed (m/s)	Duration (s)	
Salmonids and walleye	*Salmonidae* and *Percidae*, respectively	100 mm	1.0 to 3.9	0.4 to 1.6	600	Gervais and Katopodis 2012
		250 mm	1.2 to 4.4	0.5 to 1.8	600	
		400 mm	1.2 to 4.7	0.5 to 1.9	600	
Arctic grayling	*Thymallus arcticus*	203 to 305 mm FL	2.1 to 4.3	-	-	Bell 1991
		200 mm FL	0.90 to 4.0	0.5 to 0.9	1800	Shumilak and Remnant 1999
		70 to 370 mm	-	0.52 to 0.72	600	Katopodis 1992
Cisco species [d]	*Coregonus* spp.	133 mm [e]	-	0.46 to 0.63	433 to 1800	Katopodis 1992
Lake chub	*Couesius plumbeus*	-	-	-	-	Peake 2008 [f]
Lake trout	*Salvelinus namaycush*	455 to 895 mm TL	0.46 to 3.2	-	-	Dunlop et al. 2010
Lake whitefish	*Coregonus clupeaformis*	152 to 457 mm	0.91 to 1.2	-	-	Jones et al. 1974
		60 to 510 mm	-	0.34 to 0.59	72 to 1278	Katopodis 1992
Longnose sucker	*Catostomus catostomus*	100 to 460 mm	1.2 to 2.4	-	-	Bell 1991
		40 to 530 mm FL	-	0.23 to 0.91	600	Katopodis 1992
Northern pike	*Esox lucius*	100 mm	0.9 to 2.0	0.3 to 0.6	600	Gervais and Katopodis 2012
		250 mm	1.0 to 2.3	0.3 to 0.7	600	
		400 mm	1.0 to 2.5	0.4 to 0.8	600	
		412 mm (average FL)	2.8 to 3.4	-	-	Frith and Blake 1995
		170 to 200 mm	1.5 to 2.1	-	-	Wolter and Arlinghaus 2003 as cited in KGS and North/South Consultants Inc. 2008
		120 to 620 mm	-	0.19 to 0.47	600	Jones et al. 1974
Round whitefish	*Prosopium cylindraceum*	-	-	-	-	-
Walleye	*Sander vitreus*	180 to 670 mm FL	1.60 to 2.60	0.30 to 0.73	3600	Peake et al. 2000
		80 to 380 mm	-	0.38 to 0.84	600	Katopodis 1992
White sucker	*Catostomus commersonii*	170 to 370 mm FL	-	0.48 to 0.73	600	Katopodis 1992
Yellow perch [g]	*Perca flavescens*	95 mm	-	0.02 to 0.34	-	Beamish 1978 as cited in KGS and North/South Consultants Inc. 2008

[a] Attainable swim speeds within a species are often dependent on the fish size (Peake et al. 2000).
[b] Burst or startle speed is the greatest swimming speed that can be reached and maintained for less than 15 seconds (Katopodis 1992).
[c] Prolonged speed is a moderate swimming speed that can be maintained for up to 200 minutes (Katopodis 1992); speeds and the duration over which fish can maintain the reported speed are included in the table.
[d] Specimens exhibited characteristics of shortjaw cisco (*Coregonus zenithicus*) and the common cisco (*Coregonus artedi*).
[e] Prolonged swim speed data is for anadromous common cisco (*Coregonus artedi*).
[f] No burst speed data could be found for lake chub (*Couesius plumbeus*); the lack of data was reiterated by Peake 2008.
m/s = metres per second; s = seconds; mm = millimetres; FL = fork length; TL = total length; - = no data available

Fish size is considered to be an important determinant of whether injury or mortality from a blade strike will occur; relatively small fish are thought to be less vulnerable, with the likelihood of mortality increasing as fish size increases. Ichthyoplankton (i.e., fish eggs and larvae) entrained in propeller-type turbines (e.g., Kaplan turbines) are generally swept passively along the blade surface and through the turbines; they rarely come into contact with leading edges of the blades (Čada et al. 1990). It is anticipated that less than 5% of ichthyoplankton would be damaged or killed during turbine passage (Čada 1990).

The probability of blade strike and associated injury or mortality is greatest for large-bodied adult fish. Adult fish have fully-developed swimming abilities and may actively swim into blade edges, rather than passing through the turbines with the stream of water. The swimming behaviour of entrained adult fish makes it difficult to confidently estimate the probability that strike and injury or mortality will occur (Čada et al. 1997). A fish may react by attempting to swim or dart around the turbine blades or other obstacles within the power tunnel; another fish of similar size, species, etc. may remain unreactive and follow the water flow. Also, because larger fish have larger body surface areas that could potentially come into contact with the blades, there is an increased likelihood that a blade strike will occur as fish increase in size. For example, a 100 to 199 mm fish would be expected to have an approximately 20% chance of blade strike injury while passing through a Kaplan turbine system; a 300 to 600 mm fish will have an approximately 57% chance of being injured by a blade strike (EPRI 1992).

To reduce fish mortalities resulting from blade strike, the number of leading blade edges on turbines should be minimized and the amount of flow passing between the blades should be maximized so that fish are kept away from the blades (Odeh 1999). The turbine units proposed for the Project are expected to rotate at an approximate speed of 200 rotations per minute (rpm). If a six-blade turbine were rotating at this speed, then a blade would go past a fixed point 1,200 times in one minute, or approximately 20 times in one second. The larger blade spacings associated with a six-blade Kaplan turbine might reduce the probable strike rate for an entrained fish, relative to other turbine types (i.e., a 13- or 15-blade Francis turbine) ; however, even at a rate of 20 blade passes per second, it is highly likely that a passing fish will be struck.

The probability that an entrained fish will be injured or killed by a blade strike also depends on which portion of the blade strikes the fish. Fish that do not pass through the turbine after the sweep of one blade and before the next may be struck by the leading edge of a blade or “slapped” by the blade surface (Deng et al. 2005). Contact with the tip of a runner blade is likely to be more injurious to fish than a strike closer to the turbine hub due to the higher collision velocity at the outer edge of the blade (Turnpenny et al. 1992). Contact at the hub of the turbine may also cause injury or mortality to fish through the effects of grinding within the hub gaps (see below) (Čada 2001).

5.2 Pressure Increases and Decreases

The power tunnel dimensions will be optimized based on the rock quality encountered and hydraulic requirements, but is expected to be up to 11 m wide by 10 m high, with a horseshoe shaped (∩) cross-section. With the currently preferred tunnel alignment, the length of the power tunnel is 2.95 km. Static pressure within the power tunnel at the Tazi Twé facility is expected to increase from 7.5 m of head at the centre of the water intake opening to approximately 33 m of head just in front of the turbines, before dropping rapidly to 2.5 m of head immediately behind the turbines. This initial increase and subsequent decrease in pressure can occur in as little as 15 seconds (Čada 1990). This means that a fish entering the power tunnel would experience a rapid, initial pressure increase of approximately 2.5 atmospheres (atm), then an immediate drop in pressure equivalent to approximately 3 atm. Under normal conditions in an unregulated river, fish would be expected to experience pressure changes in the range of 1 to 2 atm (SNIFFER 2011).

Laboratory experiments with a variety of species have demonstrated that fish are unlikely to be injured or killed by pressure increases associated with entrainment in a hydroelectric facility. However, it has been suggested there is some risk that pressure increases will stun the fish, rendering them more vulnerable to other sources of injury or mortality (e.g., predation) (Čada et al. 1997). Increasing water pressures may also cause the swim bladders of entrained fish to compress slightly (Abernethy et al. 2001).

Pressure-related injuries and mortality are most likely to occur immediately downstream of the turbines, where pressures rapidly drop to sub-atmospheric levels (Abernethy et al. 2001; Čada et al. 1997). The rapid nature of the pressure decrease does not generally afford fish enough time to vent gas from their expanding swim bladders. Physostomous fish (i.e., fish having a swim bladder that can be vented via a pneumatic duct to the esophagus) are less sensitive to pressure decreases than physoclistous fish (i.e., fish that do not have a pneumatic duct) (CH2M HILL 2003). Physostomids can generally adjust to pressure decreases within a few seconds; however, it has been reported that pressures decreases occurring immediately behind most turbines are so rapid that even physostomous fish may not be able to respond quickly enough (Čada et al. 1997). Physoclistous fish are sensitive to pressure changes because gas pressure within the swim bladder is regulated by diffusion of gases into the bloodstream, a process which may take hours (Abernethy et al. 2001). Most Black Lake fish species are physostomids; physoclistous species include lake chub (*Couesius plumbeus*), walleye (*Sander vitreus*), and yellow perch (*Perca flavescens*). Slimy sculpin (*Cottus cognatus*) are the only Black Lake fish species lacking a swim bladder, and are therefore believed to be the resident species that is most resistant to pressure changes (Čada et al. 1997).

Inability of physostomous or physoclistous fish to adjust to rapid pressure decreases within the power generating facility may result in distension or rupture of the swim bladder, decreased swimming ability, and direct mortality (Abernethy et al. 2001; Čada et al. 1997). Mortality is most likely to occur in larger fish that have fully developed swim bladders; eggs, larvae, and even small juvenile fish are less likely to be damaged by changes in pressure (CH2M HILL 2003; Čada 1990).

Some investigators have suggested that minimum pressure criteria be incorporated into the design of hydropower generating facilities as a means of protecting entrained fish from pressure-related injuries or mortality. Čada et al. (1997) recommended that pressures within the power tunnel be maintained at or above 60% of the pressure value to which fish were acclimated prior to entrainment. Based on the current design of the proposed Tazi Twé generating facility, pressures immediately behind the turbine are expected to decrease to approximately one third of those expected at the intake structure. This falls outside the minimum pressure criteria suggested by Čada et al. (1997), but is within the 30% criterion reported elsewhere (Alden Research Laboratory, Inc. [ARL] 1996; Abernethy et al. 2001). The 30% minimum pressure criterion is likely to be protective of fish that are adapted to deep water (e.g., lake trout [*Salvelinus namaycush*]), but not physoclistous species such as walleye and yellow perch (Abernethy et al. 2001).

5.3 Dissolved Gas Super-Saturation

Dissolved gas concentrations in temperate rivers and lakes are generally at or below 100% saturation; however, as water passes through a hydroelectric turbine, it may become super-saturated with dissolved gases (Becker et al. 2003). Exposure of fish to water that is at or above 110% saturation can lead to Gas Bubble Trauma (GBT), the formation of gas bubbles within the bloodstream and tissues (CEA 2001). Bubbles that form in some tissues such as fins, gills, and the lateral line may be reabsorbed (Abernethy et al. 2001). Disruption of neurological, cardiovascular, respiratory, and osmoregulatory functions of fish can also occur as a result of GBT. Impaired fish may be more susceptible to predation downstream of the tailrace, or may be more likely to succumb to bacterial, viral, or fungal infections (CEA 2001).

The effects of gas supersaturation and GBT to entrained fish can typically be mitigated through facility design (CEA 2001). The proposed Tazi Twé generating facility has been designed to incorporate a subsurface intake and tailrace. These design features should reduce the amount of air entrained in the system via the intake and minimize the plunging of air and water to depth at the tailrace outlet (CEA 2001). Therefore, pressure changes within the turbine system at the Tazi Twé facility are anticipated to have the greatest influence on gas supersaturation.

Characteristics (e.g., depth, turbulence) of the receiving waters immediately downstream of the power plant discharge determine the rate of degassing for water released from the power generating facility. Gases in super-saturated waters dissipate more quickly in shallow, well-mixed areas of rivers; degassing potential is much lower in river reaches or lakes that are deep or calm (Parametrix, Inc. [Parametrix] 2005). The tailrace channel is expected to be approximately 1,100 m long, 20 m wide, and contain flows 6.8 m deep. Design velocity is predicted to be 1.1 m/s. Because air entrainment within the system is expected to be minimal, it is anticipated that mixing of Project and riparian flows below the tailrace outlet should be sufficient to minimize the occurrence of super-saturated conditions in the Fond du Lac River below the tailrace outlet and downstream in Middle Lake.

5.4 Cavitation

At locations within hydropower facilities where pressures decrease to levels at or below the vapour pressure of water (i.e., immediately behind the turbines), tiny vapour bubbles can form within the flowing water mass (Turnpenny et al. 1992). Cavitation occurs when these vapour bubbles move to regions of higher pressure, collapse, and release a pressure wave (Čada et al. 1997). Because the pressure behind the turbines at the Tazi Twé facility is anticipated to be approximately one third of the ambient pressure at the intake based on current design, some cavitation is expected to occur. However, because cavitation tends to occur in a relatively limited area of most power generating facilities and the pressure waves generated by cavitation tend to decrease rapidly as they extend out from the center of collapse, mortality resulting from cavitation is expected to be low for most entrained fish (Čada 1997; Čada et al. 1997).

5.5 Shear

Entrained fish may be injured or killed as a result of shearing forces that occur when two water masses move past each other at differing velocities. Shearing forces occur on a plane that is parallel to the surface of a fish's body (Gordon et al. 1992), and can cause crushing of internal organs, hemorrhaging, corneal rupture, exopthalmia (i.e., "pop-eye"), and stripping of the fish's protective outer mucous layer and scales (Čada et al. 1997; Turnpenny et al. 1992). Fish eggs and larvae are easily deformed and subsequently killed by relatively low shear forces; rapid spinning associated with shearing water masses is also believed to be highly damaging to eggs (Morgan et al. 1976). Morgan et al. (1976) reported that a shear force of 350 dynes per square centimetre (dynes/cm^2; equivalent to approximately 0.00034 atm) was sufficient to kill 36% of striped bass (*Morone saxatilis*) eggs and 38 % of white perch (*Morone americana*) eggs over the course of one minute.

5.6 Turbulence

Turbulence refers to small-scale, irregular movements of fluid particles that can occur within a larger mass of fluid that appears to be moving in a single direction (e.g., flowing down a tailrace) (Čada et al. 1997; Vogel 1981). Small amounts of turbulence within a hydropower facility may distort or compress the bodies of entrained fish. The draft tube and tailrace are generally the most turbulent sections of hydropower facilities (Čada 2001). Fish may become disoriented as they spin in the turbulent water, and may therefore become easier prey for larger fish and fish-eating birds (Čada et al. 1997).

5.7 Grinding

Fish may be injured or killed as they are drawn through narrow gaps between components of the turbine assembly. Grinding occurs when fish enter these small gaps, and typically results in localized bruising. Other injuries or sources of mortality associated with grinding include decapitation and deep cuts (Čada et al. 1997).

5.8 Abrasion in the Power Tunnel

Abrasion-type injuries are expected to occur when flow velocities through the power tunnel are high and fish are unable to avoid collisions with rough features (i.e., bedrock) or structures inside the power tunnel (SNIFFER 2011). These types of injuries are generally considered to be indirect sources of fish mortality (Čada 2001). Collisions with the walls of the power tunnel may disorient fish and make them more susceptible to predation once they exit the tailrace outlet; stripping off mucus, scales and/or skin may render fish more susceptible to bacterial or fungal infections (Čada 2001).

Based on the size of power tunnel proposed for the Project (i.e., 10 m high and 11 m wide) and 190 cubic metre per second (m^3/s) flows through the facility, water velocities in the power tunnel are expected to be between 2.0 and 2.4 m/s. These velocities are at the upper end of burst swimming speeds that can be attained by Arctic grayling and longnose sucker and above those that can be attained by most other fish species occurring in Black Lake and the Fond du Lac River (Table 2). Therefore, it is unlikely that most species of fish entrained in the power tunnel flow will be able to sense and avoid the bedrock walls of the tunnel. However, under current flow conditions, fish that passively drift out of Black Lake and down the Fond du Lac River are likely to encounter velocities of this magnitude or greater as they move through the various river reaches. It is anticipated that if a fish of a certain species and size were to become entrained by water intake flows, abrasion-type injuries resulting from tunnel passage would be of similar or lesser severity than those sustained by the same fish if it were to passively drift from Black Lake to the tailrace outlet location via the natural river channel.

6.0 SUMMARY

It is anticipated that blade strikes and the rapid decrease in pressure immediately behind the turbines will be the predominant causes of fish injury and mortality for the Tazi Twé power generating facility. Lake chub, walleye, and yellow perch are expected to be most vulnerable to pressure-related mortality due to their inability to vent their swim bladders under changing pressure conditions. Eggs, larvae, small juvenile fish, and fish species that lack swim bladders are expected to be relatively insensitive to pressure changes.

Incidence of gas super-saturation and GBT is anticipated to be low for the Tazi Twé facility, based on intake and tailrace designs.

7.0 CLOSURE

Should you have any comments or questions regarding the contents of this technical memo, please contact the undersigned at 306-665-7989.

Amy Ofukany, M.Sc.
Aquatic Biologist

Brian Christensen, M.Sc.
Associate, Senior Environmental Scientist

AO/BC/rz/jlb

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APPENDIX 16.1

Heritage Conservation Branch Letters File No. 12-1445

Ministry of Parks,
Culture and Sport

Heritage Conservation Branch
9th Floor 1919 Saskatchewan Dr.
Regina, Saskatchewan
S4P 4H2

(306) 787-5774
nathan.friesen@gov.sk.ca

July 10, 2012

Our File: 12-1445

Mr. Patrick Young
Golder Associates Ltd.
Agent for: **SaskPower**
1721 8th Street E
SASKATOON SK S7H 0T4

Dear Mr. Young:

RE: SaskPower Elizabeth Falls Hydroelectric Development:
HERITAGE RESOURCE REVIEW

Thank you for referring this development proposal to our office for heritage resource review.

In determining the need for, and scope of, heritage resource impact assessment (HRIA) pursuant to S. 63 of *The Heritage Property Act*, the following factors were considered: the presence of previously recorded heritage sites, the area's overall heritage resource potential, the extent of previous land disturbance, and the scope of new proposed land development.

There is one known archaeological sites in potential conflict with the proposed development, namely site IhNj-6. This site is an artifact scatter located on the west side of the Fond du Lac River valley and may be impacted by the proposed tailrace spur channel development near Elizabeth Falls. The project will impact areas of native boreal forest located within 250 m of Fond du Lac River, Black Lake and Middle Lake. The area on the western side of Fond du Lac River along the valley edge is of particular interest, while the area on the east side of the river is highly sloped and of less significance. As well, the developments along the shore of Black Lake, the two possible bridge locations and the tailrace spur channel along north end of Fond du Lac are all areas of high archaeological significance. The heritage potential for this project is considered to be high. Accordingly, an HRIA is required only for portions of the development located within 250 m of Fond du Lac River, Black Lake and Middle Lake.

The HRIA study, including systematic pedestrian survey and sub-surface test exploration, is a proponent responsibility. The study will first establish the presence of heritage sites within the project area, as well as where suitable site avoidance measures (including the right-of-way relocation) may be implemented. The study

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will also establish the content, structure, and importance of those heritage sites located in unavoidable conflict with development. On that basis, both the need for and scope of any mitigation follow-up (including archaeological salvage excavation or other preservation action) will be determined. The HRIA must be carried out by qualified personnel under an approved investigation permit issued through this office. Normally, two days are required to process a heritage contractor's permit application.

If you have any questions regarding this project please do not hesitate to contact me or Jennifer Thompson at the above address or by calling 787-2848.

Sincerely,

ORIGINAL SIGNED BY

Nathan Friesen
Senior Archaeologist
Archaeological Resource Management

Ministry of
Tourism, Parks,
Culture and Sport

Heritage Conservation Branch
9th Floor 1919 Saskatchewan Dr.
Regina, Saskatchewan
S4P 4H2

(306) 787-5774
nathan.friesen@gov.sk.ca

June 24, 2013

Our File: 12-1445

Mr. Patrick Young
Golder Associates Ltd.
Agent for: **SaskPower**
1721 8th Street E
SASKATOON SK S7H 0T4

Dear Mr. Young:

RE: SaskPower Tazi Twe Hydroelectric Development:
HERITAGE RESOURCE REVIEW

Thank you for referring this revised development proposal to our office for heritage resource review.

In determining the need for, and scope of, heritage resource impact assessment (HRIA) pursuant to S. 63 of *The Heritage Property Act*, the following factors were considered: the presence of previously recorded heritage sites, the area's overall heritage resource potential, the extent of previous land disturbance, and the scope of new proposed land development.

There are no known archaeological sites in potential conflict with the revisions to the proposed development. The revised access roads for this project will impact areas of native boreal forest located within 250 m of two unnamed creeks that drain into Middle Lake. The heritage potential for the revised portion of this project is considered to be moderate to high. Accordingly, an HRIA is required only for portions of the access roads that are located within 250 m of the two unnamed creeks.

The HRIA study, including systematic pedestrian survey and sub-surface test exploration, is a proponent responsibility. The study will first establish the presence of heritage sites within the project area, as well as where suitable site avoidance measures (including the right-of-way relocation) may be implemented. The study will also establish the content, structure, and importance of those heritage sites located in unavoidable conflict with development. On that basis, both the need for and scope of any mitigation follow-up (including archaeological salvage excavation or other preservation action) will be determined. The HRIA must be carried out by qualified personnel under an approved investigation permit issued through this office. Normally, two days are required to process a heritage contractor's permit

...2

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application.

If you have any questions regarding this project please do not hesitate to contact me or Jennifer Thompson at the above address or by calling 787-2848.

Sincerely,

ORIGINAL SIGNED BY

Nathan Friesen
Senior Archaeologist
Archaeological Resource Management

Saskatchewan

Ministry of
Tourism, Parks,
Culture and Sport

Heritage Conservation Branch
9th Floor 1919 Saskatchewan Dr.
Regina, Saskatchewan
S4P 4H2

(306) 787-5774
nathan.friesen@gov.sk.ca

July 17, 2013

Our File: 12-1445

Mr. Patrick Young
Golder Associates Ltd.
Agent for: **SaskPower**
1721 8th Street E
SASKATOON SK S7H 0T4

Dear Mr. Young:

RE: SaskPower Tazi Twe Hydroelectric Development:
HERITAGE RESOURCE IMPACT ASSESSMENT RESULTS

Please be advised we received (July 12, 2013) your report on the heritage resource impact assessment (HRIA) of this project completed under Investigation Permit #12-162.

Four previously recorded sites were observed in the course of pedestrian survey and testing of the development area. These sites are not in conflict with the development and will be avoided. However, IgNj-6, an historic Dene cemetery, is within 60m of an existing road, and it must be flagged for avoidance if working within nearby areas. Provided sites are avoided as planned, this office has no further concerns relating to this project.

On behalf of the Heritage Conservation Branch, please accept our appreciation for having commissioned this investigation, and for your continuing assistance and support in preserving Saskatchewan's archaeological heritage.

Sincerely,

ORIGINAL SIGNED BY

Nathan Friesen
Senior Archaeologist
Archaeological Resource Management

Acid-free Paper

APPENDIX 18.1

Tazi Twé Employment & Training Year-end Report – December 2013

February 2014
Report No. 10-1365-0004/DCN-171

Tazi Twé Employment & Training Initiative:

The Elizabeth Falls Hydro Limited Partnership (EFHLP), Black Lake First Nation, and SaskPower, are joint partners in the development of the training methodology, which aims to create a skilled workforce. Through partnerships with Aboriginal Affairs Northern Development Canada (AANDC), Northlands College, Prince Albert Grand Council (PAGC), and Ministry of Economy an effective aboriginal training program for northern Saskatchewan has been delivered prior to construction of the proposed hydroelectric project.

The Employment and Training program is designed to train as many employable people as possible in the Black Lake First Nation (BLFN) and surrounding region.

The development of partnerships is instrumental in facilitating the successful delivery of the Employment and Training Program for the Tazi Twé Hydroelectric Project. The delivery of training in the Athabasca region in the past number of years has been very successful through the evolution of new and innovative techniques.

The EFHLP and SaskPower worked together and prepared the Employment and Training Charter in May 2013 to support the training initiatives for the construction of the Tazi Twé Hydroelectric Station and followed up with the program details (Tazi Twé Employment & Training Program) in July 2013.

The program objectives are to train 64 candidates (32 in the fall 2013 and 32 in the winter 2014) and provide other specialized training based on the needs of the contractor.

The Partnership has developed a broad base of trust and understanding with the project participants (AANDC, BLFN, Northlands College, etc.) that should help minimize any future training finance risks.

The EFHLP and SaskPower have worked closely with the Saskatchewan Ministry of the Economy, AANDC, PAGC, BLFN/NCBR coordinator to procure the necessary initial funding for the training programs.

Curriculum Development:

Northlands College has been selected by the proponent as the training institute and service provider that will deliver the specifically designed training programs.

The courses developed and offered for the Tazi Twé employment and training program are focused on the skill sets required to meet the needs of the project. Academic upgrades in Mathematics, English & Science, Safety, and life skills for the students are also included in the course.

Recruitment for fall 2013 Session:

The recruitment and selection team consisted of the BLFN education coordinator, NCBR coordinator, a SaskPower representative and the Northlands College Education Coordinator. Application, testing and candidate interviews for the Tazi Twé fall 2013 training programs were held at Black Lake June 5, 6, 7, 12 & 13. During the recruitment activity a total of 102 applications were submitted.

Selection Process:

In total 32 people were selected for fall 2013 training to be trained in work readiness and academic preparation courses - 8 candidates were selected as spares (4 each for two streams).

A potential contractor (early contractor) who was on site early in the recruitment process began developing a training strategy that will maximize local hiring for the construction phase of the project.

The first Certified Workforce Education - Job Readiness and Academic training session started in Black Lake September 3, 2013.

Training Facilities:

- The BLFN facilities at Black Lake are being utilized for the pre-employment training and the Northlands College facilities (ex: La Ronge) will be used for the more advanced trades training and education upgrading as per the demand.
- Northlands College will relocate the Heavy Equipment Operator Training Simulator to Black Lake and it will be housed in the Fire Hall at Black Lake. Training will be focused on the following; Rock Truck, Dozer, Loader, and Excavator.

Safety, Brush clearing and Chainsaw Training

In October a series of brush clearing/chainsaw training and first-aid training sessions were conducted at BLFN

Carpentry training - Work in the community

Students from the Tazi Twé training program have been building projects for Black Lake community members. Having the students giveback to the community provided momentum for the Project and enabled them to enjoy learning and practising their new skills.

<u>Training participation:</u>

- 16 students enrolled in the Certified workforce education (academic), 6 Students completed.
- 16 Students enrolled in the Certified workforce education (job readiness), 14 students completed.
- Total participation - 32 students - 20 completed the program.

Recruitment for winter 2014 Session:

Northlands College had 36 new applicants attend intake testing on November 25-27, and they introduced drug and alcohol testing protocols to the two classes that are currently running. A potential contractor (early contractor) who was on site during the recruitment process and also interviewed the existing students who are undergoing training to assess their skill sets.

2014 Training Plan:

The training process is based on a laddering concept where the students proceed through training as follows; Certified Workforce Education - Academic, advance to Certified Workforce - Job Readiness, and move on to specific training for Heavy Equipment Operator, Industrial Mechanic, Institutional Cooking, Carpentry, etc. The following detail below is from Northlands College.

Details:

- 16 students - Certified Workforce Education - Academic - 06-Jan-14 to 09-May-14
- 16 students - Certified Workforce Education - Job Readiness - 06-Jan-14 to 09-May-14
  - 8 - Safety Training (Heavy Equipment Operator - simulator) - 13-Jan-14 to 07-Mar-14
  - 8 - Safety Training (Heavy Equipment Operator - simulator) - 18-Mar-14 to 23-May-14
- Security guard training (including a Driver Training component) will be considered in the New Year - expected enrolment 12 students.
- Home Building Maintenance and Repair Program will begin in the New Year - expected enrolment is 12 - 14 students.
- Industrial mechanic training is scheduled for fall 2014
- Specialty Courses - Northlands College will provide or facilitate any short programs identified by the contractor.

Once the Project receives final approval, SaskPower will recruit, select and train individuals to maintain and operate the Tazi Twé Hydroelectric Station.

A final report will be issued by Northlands College to ensure the objectives of the Employment and Training Program are being achieved. Training delivered to the candidates will be evaluated to ensure they are provided the essential skills to do their jobs safely, competently and productively.

Conclusion

Overall, the employment & training program accomplishment to date are completely based on the team effort and development of mutually beneficial partnerships with all the entities.

Black Lake First Nation, SaskPower and the Athabasca Basin will all benefit from this pre-project employment and training initiative for the proposed Tazi Twé Hydroelectric project.