REPORT

January 2014

# ANNEX II - GEOLOGY AND HYDROGEOLOGY BASELINE REPORT

# Tazi Twé Hydroelectric Project

**Submitted to:**
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S4P 0S1

**Report Number:** 10-1365-0004/DCN-072

# List of Acronyms

| Term | Definition |
|---|---|
| ARD | acid rock drainage |
| BLFN | Black Lake First Nation |
| CLO | Cigar Lake Operation |
| EA | Environmental Assessment |
| EIS | Environmental Impact Statement |
| LSA | local study area |
| MCA | McArthur River Operation |
| MCL | McClean Lake Operation |
| MCL-MW | Midwest Project |
| Project | Tazi Twé Hydroelectric Project |
| $RMR_{89}$ | rock mass rating 1989 |
| RQD | rock quality designation |
| RSA | regional study area |
| TDS | total dissolved solids |
| UCS | unconfined compressive strength |

# List of Units

| Term | Definition |
|---|---|
| µg/L | micrograms per litre |
| µS/cm | microSiemens per centimetre |
| cps | counts per second |
| km | kilometre |
| m | metre |
| m/s | metres per second |
| $m^3/s$ | cubic metres per second |
| mg/L | milligrams per litre |
| mg/L as $CaCO_3$ | milligrams per litre as calcium carbonate |
| MPa | megapascal |
| MW | megawatt |

# Table of Contents

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# 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 (SaskPower) are the Proponents of the Tazi Twé Hydroelectric Project (Project). Black Lake First Nation's interest in the Project is being held through the Elizabeth Falls Hydro Limited Partnership (EFHLP).

## 1.2 Project Overview

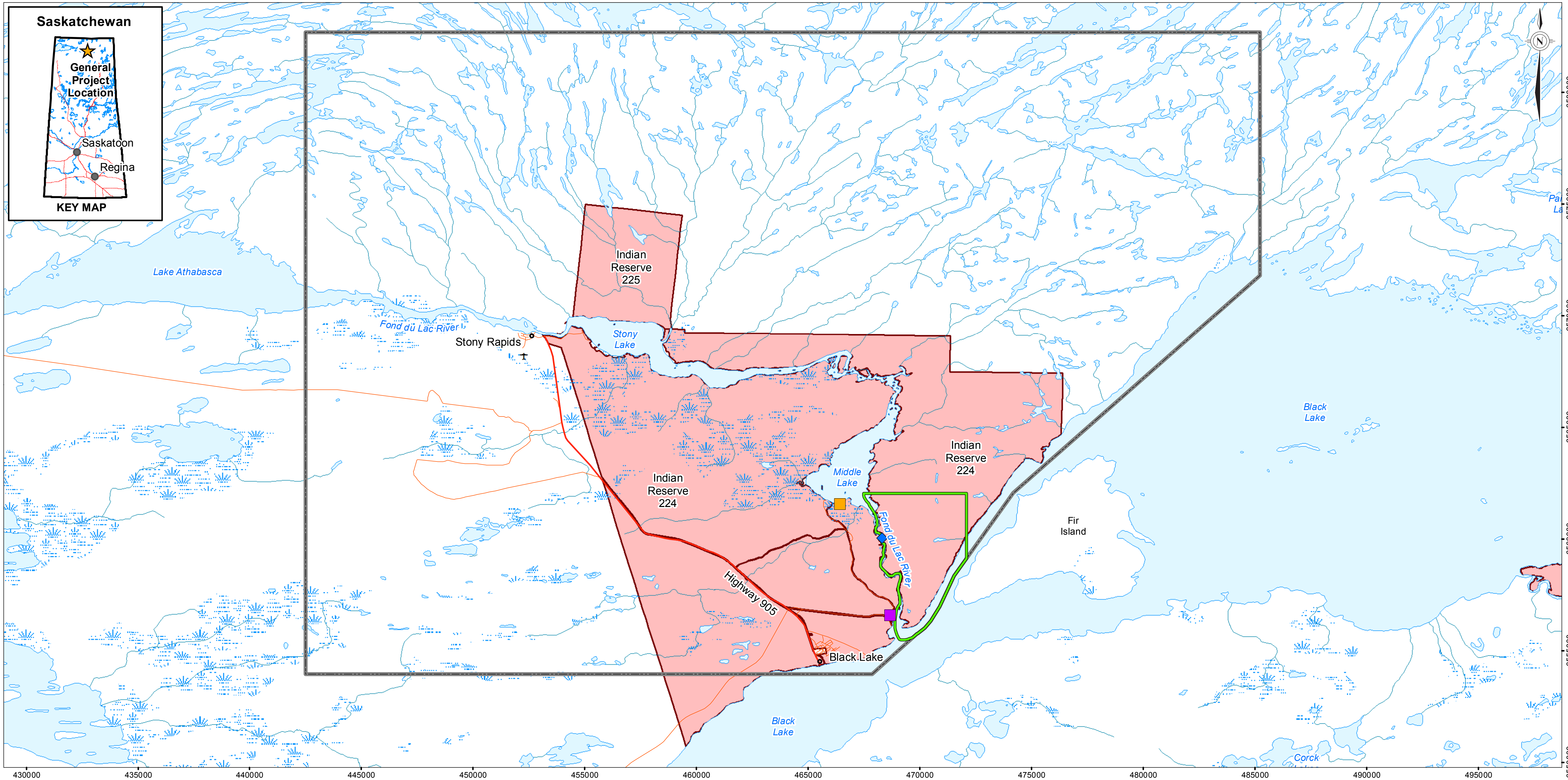
The proposed Project will be a 50 megawatt (MW) water diversion type electrical generating station. The Project is located on the Chicken Indian Reserve 224, approximately 7 kilometres (km) from the community of Black Lake adjacent to the Fond du Lac River between Black Lake and Middle Lake (Figure 1.2-1). Black Lake has an approximate area of 418 square kilometres ($km^2$) and discharges an average flow of 305 cubic metres per second ($m^3$/s) into the Fond du Lac River. The Fond du Lac River traverses Elizabeth Falls on its way to Middle Lake. Water from Black Lake will be diverted through an intake and power tunnel to the powerhouse before being released through a tailrace channel into the Fond du Lac River, which ultimately discharges into Middle Lake.

The principal components of the Project consist of the following:

- gravel, all-season access road to the Project site from the all-season road 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 just upstream of Middle Lake;
- submerged weir located in the Fond du Lac River at the outlet of Black Lake 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 the associated coffer dams, access roads, laydown areas, construction camp, borrow areas, waste rock piles, concrete batch plant, fuel storage facility and fueling areas, explosives storage, construction camp, and sewage treatment and potable water facilities.

## 1.3 Objective of the Baseline Report

The objective of baseline reporting is to provide information on the current environmental conditions related to the geology and hydrogeology in the Project area. This information will be used to support assessment of the effects of the proposed Project on biophysical and socio-economic environments in the area.




**LEGEND**

- VILLAGE
- ROAD
- RIVER
- WETLAND
- WATERBODY
- INDIAN RESERVE
- ELIZABETH FALLS
- CAMP GRAYLING
- PERMANENT RESIDENT'S CABIN
- GEOTECHNICAL LOCAL STUDY AREA
- GEOTECHNICAL REGIONAL STUDY AREA

5 0 5

SCALE 1:175,000 KILOMETRES

**REFERENCE**

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

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 | 10/07/13 | |
| CHECK | EAM | 19/07/13 | |
| REVIEW | MT | 19/07/13 | |

**FIGURE: 1.2-1**

# 2.0 STUDY AREAS

## 2.1 Local Study Area

The local study area (LSA) for the geology and hydrogeology environment is based on the predicted direct and indirect effects from the Project on the groundwater environment. For example, direct effects may include changes to groundwater flow and water quality resulting from the excavation of the water diversion tunnel.

Potential direct and indirect effects to the groundwater environment from the Project are predicted to occur within the area shown in Figures 1.2-1 and 2.1-1. Thus, the LSA for the geology and hydrogeology environment includes the area constrained by Black Lake to the east, Middle Lake to the northwest, and the Fond du Lac River to the west.

## 2.2 Regional Study Area

The regional study area (RSA) for the geology and hydrogeology environment is based on the potential larger-scale direct and indirect effects from the Project. For example, larger-scale direct and indirect effects from the project may include cumulative and incremental Project effects.

While no direct or indirect effects are predicted to occur upstream of Black Lake, larger-scale direct effects and indirect effects may propagate into the downstream environment. Lake Athabasca is the receiving waterbody of the Fond du Lac River and is considered to be the downstream extent of the RSA. Thus, the RSA for the geology and hydrogeology environment is shown in Figure 1.2-1 and is defined as Black Lake, the Fond du Lac River, and the eastern end of Lake Athabasca.

# 3.0 METHODS

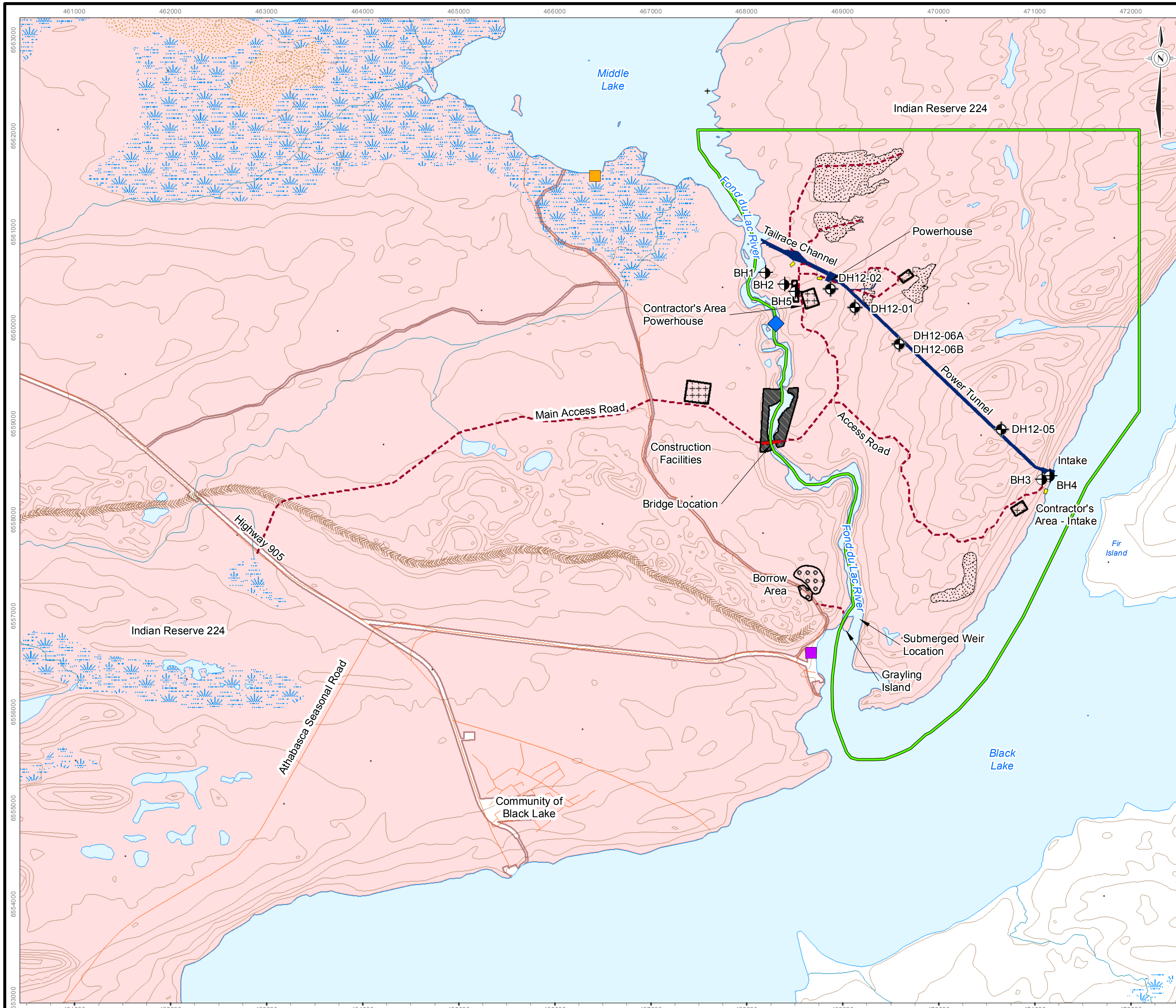
## 3.1 Desktop Study

Existing surface, subsurface, and groundwater information was compiled to provide a preliminary geological characterization within the RSA and LSA. Compilation of existing information included the collection of existing borehole logs, study reports, and publications. The information was obtained from several sources referenced throughout the report, and included:

- compilation of regional geology and hydrogeology maps and reports;
- compilation of site investigations conducted as part of the Project feasibility study, as reported by Acres (2002 and 2005) and Hatch Ltd. (2012);
- Project design components, including geological and hydrogeological modelling; and
- supporting concurrent baseline studies for the Project Environmental Assessment (EA).

## 3.2 Drilling Program

A drilling program was completed at the Project site in October 2013 for the purpose of acquiring additional geologic and hydrogeologic information. The program included bedrock coring, hydrogeological testing, borehole geophysics logging, monitoring well, drive point piezometer and vibrating wire installations, thermocouple installations and laboratory testing on core samples and water samples (both surface and groundwater). The locations of the boreholes and monitoring wells/drive point piezometers are shown in Figures 2.1-1 and 3.2-1, respectively. The results from this program are summarized in the following sections.




## LEGEND

- ELIZABETH FALLS
- CAMP GREYLING
- PERMANENT RESIDENT'S CABIN
- CONTOUR LINE
- ROAD
- RIVER
- WETLAND
- WATERBODY
- INDIAN RESERVE
- GEOLOGY & HYDROGEOLOGY LOCAL STUDY AREA
- 2012 BOREHOLE LOCATION
- 2002 BOREHOLE LOCATION

SPECIFIC CONSTRUCTION SITES

- POTENTIAL BRIDGE ALIGNMENT
- PERMANENT ROAD
- CONTRACTOR CAMP / LAYDOWN AREA
- BORROW AREA
- SPOIL DISPOSAL AREA
- POTENTIAL BRIDGE ALIGNMENT AREA
- TUNNEL AND TAILRACE ALIGNMENT
- SETTLING POND

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

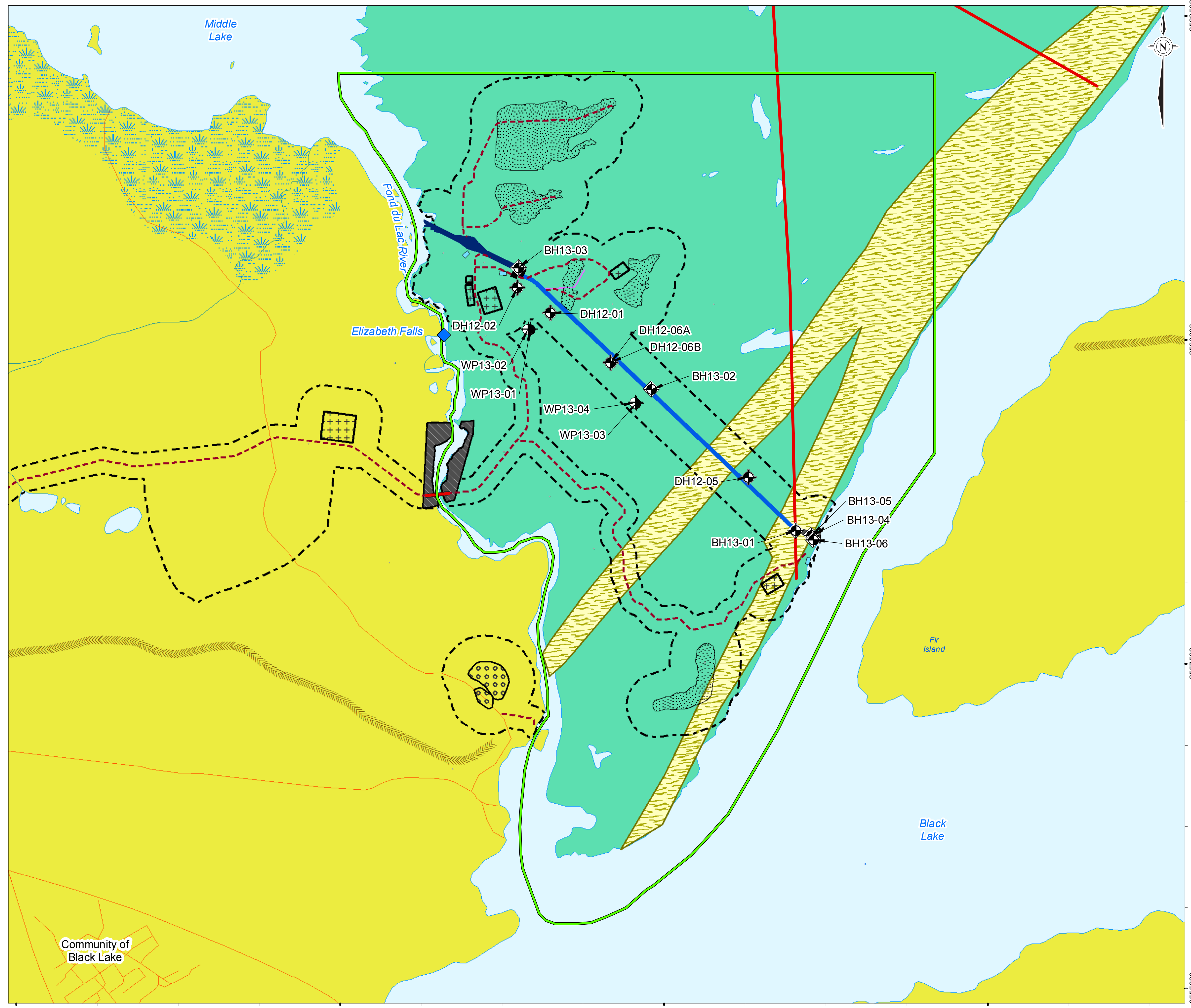
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

# BOREHOLE LOCATION PLAN

Golder Associates
Saskatoon, Saskatchewan

| PROJECT | | 10-1365-0004 | FILE No. | |
|---|---|---|---|---|
| DESIGN | | | SCALE AS SHOWN | REV. 7 |
| GIS | SM | 18/11/13 | **FIGURE: 2.1-1** | |
| CHECK | EAM | 19/11/13 | | |
| REVIEW | MT | 19/11/13 | | |




## LEGEND

- GEOTECHNICAL LOCAL STUDY AREA
- ELIZABETH FALLS
- RIVER
- ROAD
- WETLAND
- WATERBODY

SPECIFIC CONSTRUCTION SITES

- BRIDGE ALIGNMENT
- PERMANENT ROAD
- PREDICTED PROJECT FOOTPRINT
- CONTRACTOR WORK AREA
- BORROW AREA
- SETTLING POND
- SPOIL DISPOSAL AREA
- BRIDGE ALIGNMENT AREA
- INTAKE
- POWER HOUSE
- TAILRACE
- POWER TUNNEL
- TUNNEL ADIT
- 2012 BOREHOLE LOCATION
- 2013 BOREHOLE LOCATION
- 2013 DRIVE POINT PIEZOMETER
- FAULT OR MAJOR AIRPHOTO LINEAMENT INTERPRETED AS A MASTER FRACTURE
- ESKER
- ATHABASCA FORMATION WELL BEDDED LAYERS OF SANDSTONE AND CONGLOMERATES
- CRYSTALINE GNEISS COMPLEX PRECAMBRIAN GRANITE INTRUDED BY A SWARM OF DIABASE DYKES
- BLACK LAKE SHEAR ZONE MYLONTIC ROCKS IN THE BLACK LAKE SHEAR ZONE GENERALLY PALE TO DARK GREY, VERY FINE GRAINED FELSIC

## REFERENCE

NAD83 UTM ZONE 13
LOCAL GEOLOGY PROVIDED BY HATCH ENGINEERING, 2012
GEOLOGY: GILBOY, C.F. (1978): RECONNAISSANCE GEOLOGY, STONEY RAPIDS AREA (PARTS OF NTS AREA 74P) IN SUMMARY OF INVESTIGATIONS 1978, SASKATCHEWAN, GEOLOGICAL SURVEY, SASK-MINERAL RESOURCES, MISC. REP. 78-10, PP 35-42

0.5 0 0.5
SCALE 1:30,000 KILOMETRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

**LOCATION OF GROUNDWATER MONITORING WELLS**

Golder Associates
Saskatoon, Saskatchewan

| | | | |
|---|---|---|---|
| PROJECT | | 10-1365-0004 | FILE No. |
| DESIGN | | | SCALE AS SHOWN REV. 7 |
| GIS | SM | 19/07/13 | |
| CHECK | DL | 22/01/14 | FIGURE: 3.2-1 |
| REVIEW | MT | 22/01/14 | |

# 4.0 GEOLOGY

## 4.1 Introduction

Characterization of the Project area's geology provides the framework for defining potential interactions between the Project and the subsurface environment. A desktop study was conducted to better define the presence and spatial extent of geological units present within the RSA and LSA. Methods utilized in this process include review of existing reports on the geology of the area and use of historical boreholes within the LSA.

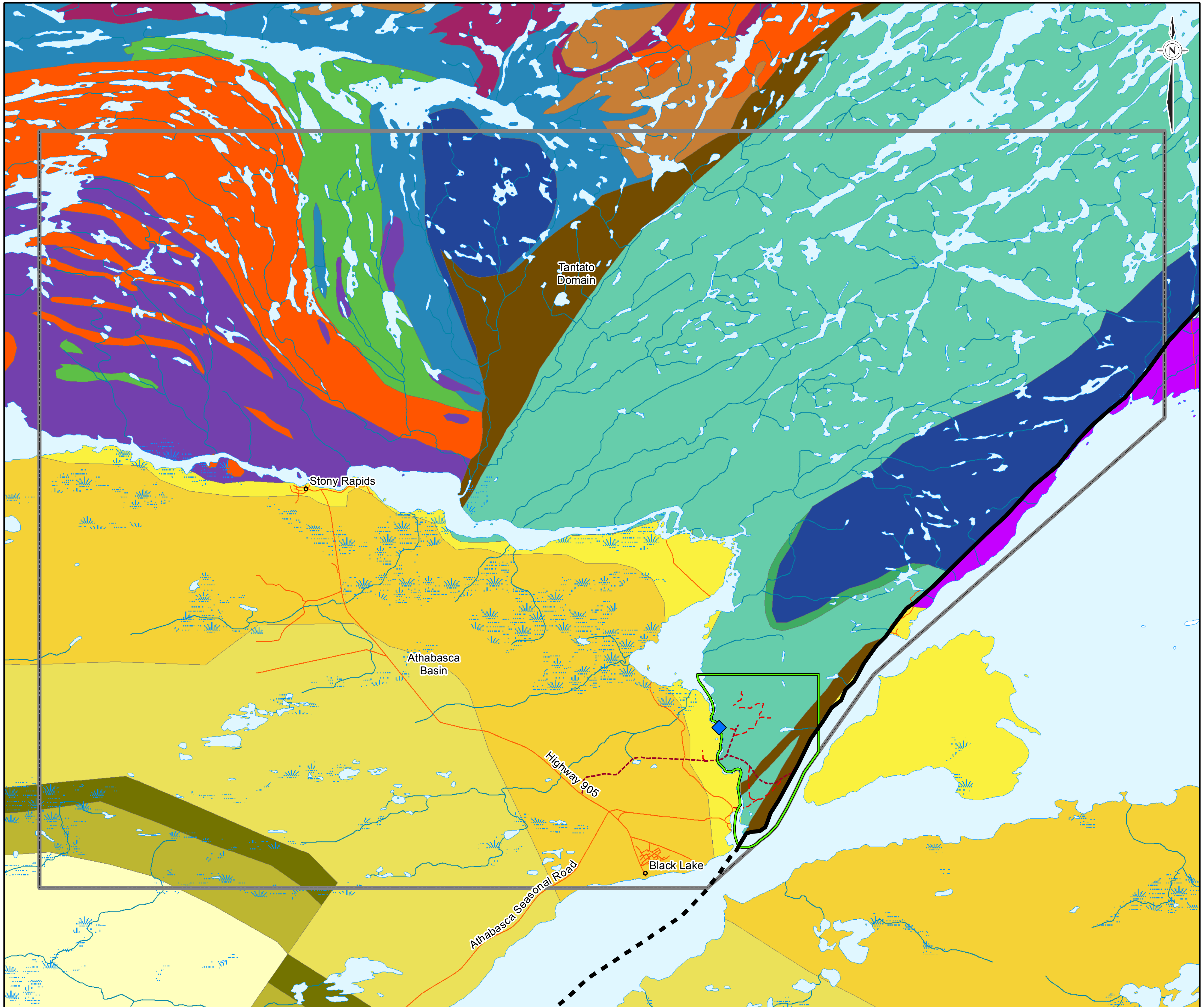
The information provided in this section includes bedrock geology, seismic, Quaternary geology, and mineralization potential.

## 4.2 Bedrock Geology

The bedrock in the RSA (Figure 4.2-1) and LSA (Figure 4.2-2) consists of Archean to Paleo-proterozoic age crystalline greenstones, mylonites, and gneiss complexes of the Rae Province of the Canadian Shield, as well as Paleo-proterozoic age sandstones and conglomerates of the Athabasca Group (SGS 1999). The north and eastern portion of the RSA, as well as the LSA, are located within the Tantato Domain, which is defined as the area between the Black Lake and Grease River Shear Zones. The south and western portion of the RSA, including the western bank of the Fond du Lac River adjacent to the LSA, are located within the Athabasca Basin. The Athabasca Basin sediments within the RSA are comprised of fluviatile conglomerate and sandstone of the Manitou Falls Formation of the Athabasca Group (Gilboy and Raemakers 1981). The predominant rock type within the LSA is a hybrid gneiss complex comprised of felsic gneiss, amphibole schists and gneiss, and semipelitic to psammitic biotite schists and gneiss. This area is part of the Chipman Sill Swarm marking a zone most intensely intruded by metadiabase sills (Gilboy 1980).

Acres (2002), Hatch (2012) and Golder (2013) completed subsurface investigations in the water intake, power tunnel, powerhouse, and tailrace channel areas of the Project. These investigations included desktop study of regional geology, outcrop mapping, detailed core logging, rock mass classification, laboratory strength testing, and thin section analysis. In general, conditions encountered during these field investigations included gneissic rock with foliations striking southwest steeply dipping to the northwest and wide to moderate spacing of joints on outcrops (Acres 2002). Geological conditions observed at each of the areas investigated at the Project site are outlined in Table 4.2-1

As part of the 2012 and 2013 investigation, laboratory analysis was completed on selected rock core samples. Testing completed included unconfined compressive strength (UCS), Cerchar Abrasivity Index (CAI) testing and petrographic analysis. In total, UCS testing was completed on 23 samples. Test results indicated that more than 95 percent (%) of the samples have UCS values between 25 and 250 megapascals (MPa). The majority of samples with UCS values less than 90 MPa shows that the samples typically failed along foliation or some other discontinuity, thus indicating the intact strength of the rock is higher than the measured UCS value. The CAI testing was conducted on six samples, the results of which were not available at the time of reporting. Twenty samples were subjected to petrographic analysis. The results indicated that the rock along the tunnel alignment was mineralogically composed of variations of mafic dykes, gneiss and metagabbro.




## LEGEND

- ELIZABETH FALLS
- PROPOSED TEMPORARY ACCESS
- PROPOSED ACCESS ROAD
- ROAD
- GEOTECHNICAL LOCAL STUDY AREA
- GEOTECHNICAL REGIONAL STUDY AREA

BLACK LAKE SHEAR ZONE

TANTATO DOMAIN

- AMPHIBOLE GNEISS
- AMPHIBOLITE
- ARKOSIC BIOTITE GNEISSES
- BIOTITE GNEISS
- BIOTITE GRANODIORITE
- GARNET-FELDSPAR GNEISS
- GRANITE AND PEDMATITE
- HYBRID GNEISS COMPLEX
- MAFIC HYPERTHENE GNEISS
- MYLONITE/CATACLASTIC ROCKS
- PELITIC TO PSAMMITIC PARAGNEISS

ATHABASCA BASIC

- CLAY-INTRACLAST-RICH QUARTZARENITE
- LOWER CONGLOMERATIC QUARTZARENITE
- PEBBLY QUARTZARENITE
- QUARTZARENITE
- QUARTZARENITE, PEBBLY QUARTZARENITE
- UPPER CONGLOMERATIC QUARTZARENITE
- UPPER QUARTZ-PEBBLY QUARTZARENITE

## REFERENCE

GEOLOGICAL ATLAS OF SASKATCHEWAN,
SASKATCHEWAN ENERGY AND RESOURCES
GOVERNMENT OF CANADA, NATURAL RESOURCES CANADA, CENTRE FOR TOPOGRAPHIC INFORMATION, 2001
PROJECTION: UNIVERSAL TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 13

3 0 3

SCALE 1:150,000 KILOMETRES

PROJECT

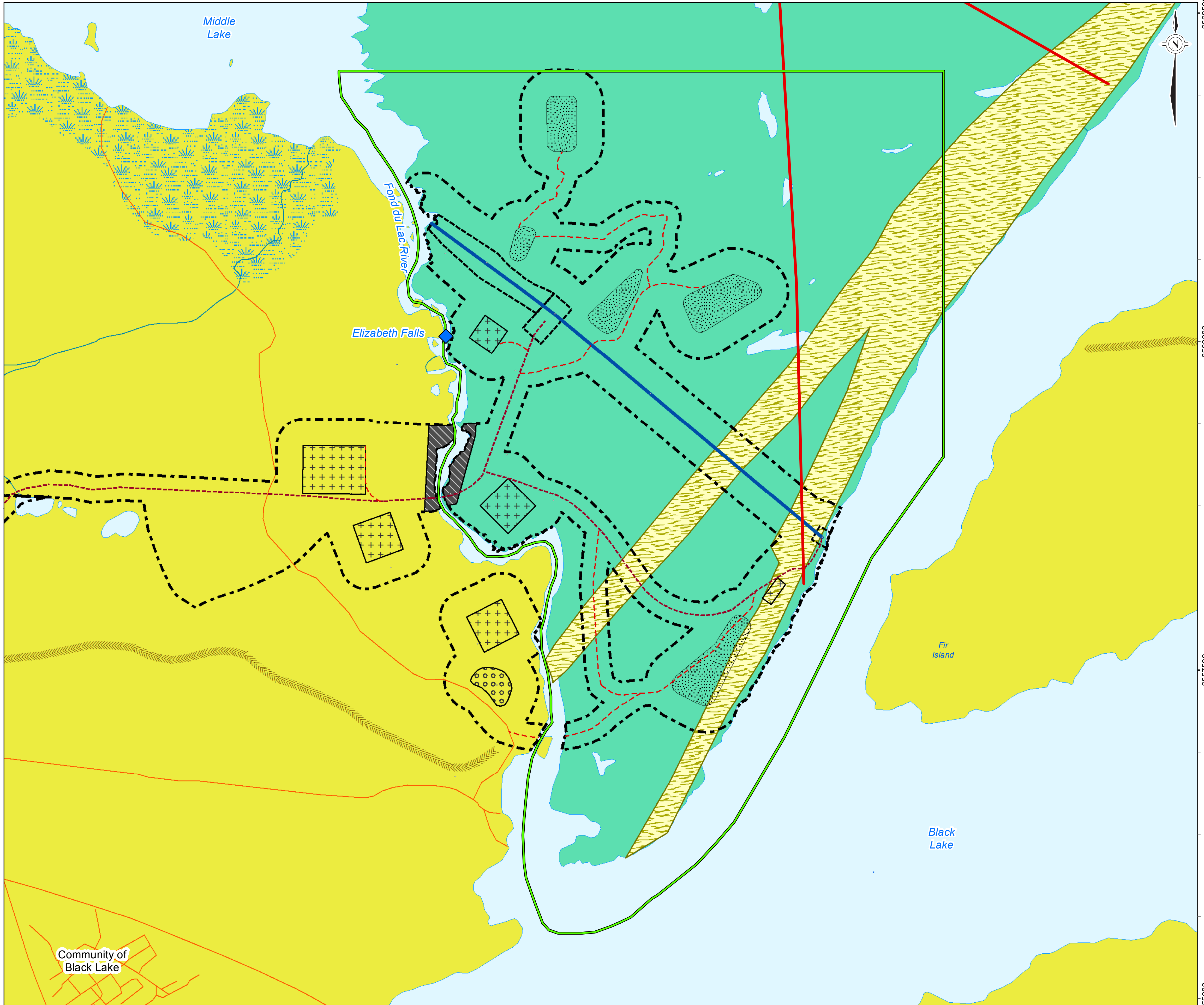
TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

# REGIONAL GEOLOGY

Golder Associates
Saskatoon, Saskatchewan

| | | | |
|---|---|---|---|
| PROJECT | | 10-1365-0004 | FILE No. |
| DESIGN | | | SCALE AS SHOWN REV. 6 |
| GIS | SM | 15/07/13 | |
| CHECK | EAM | 19/07/13 | FIGURE: 4.2-1 |
| REVIEW | MT | 19/07/13 | |




## LEGEND

- GEOTECHNICAL LOCAL STUDY AREA
- ELIZABETH FALLS
- RIVER
- ROAD
- WETLAND
- WATERBODY

SPECIFIC PROJECT SITES

- PROPOSED TEMPORARY ACCESS ROAD
- PROPOSED ACCESS ROAD
- PROJECT AXIS
- CONSTRUCTION FOOTPRINT
- BORROW AREA
- BRIDGE ALIGNMENT AREA
- CONTRACTOR CAMP
- DISPOSAL AREA
- FENCE
- FAULT OR MAJOR AIRPHOTO LINEAMENT INTERPRETED AS A MASTER FRACTURE
- ESKER
- ATHABASCA FORMATION WELL BEDDED LAYERS OF SANDSTONE AND CONGLOMERATES
- CRYSTALINE GNEISS COMPLEX PRECAMBRIAN GRANITE INTRUDED BY A SWARM OF DIABASE DYKES
- BLACK LAKE SHEAR ZONE MYLONTIC ROCKS IN THE BLACK LAKE SHEAR ZONE GENERALLY PALE TO DARK GREY, VERY FINE GRAINED FELSIC

## REFERENCE

DATUM: NAD83 PROJECTION: UTM ZONE 13
LOCAL GEOLOGY PROVIDED BY HATCH ENGINEERING, 2012
GEOLOGY: GILBOY, C.F. (1978): RECONNAISSANCE GEOLOGY, STONEY RAPIDS AREA (PARTS OF NTS AREA 74P) IN SUMMARY OF INVESTIGATIONS 1978, SASKATCHEWAN, GEOLOGICAL SURVEY, SASK-MINERAL RESOURCES, MISC. REP. 78-10, PP 35-42

0.5 0 0.5
SCALE 1:30,000 KILOMETRES

PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

**GEOLOGY OF THE LOCAL STUDY AREA**

Golder Associates
Saskatoon, Saskatchewan

| | | | |
|---|---|---|---|
| PROJECT | | 10-1365-0004 | FILE No. |
| DESIGN | | | SCALE AS SHOWN REV. 7 |
| GIS | SM/LR | 19/07/13 | FIGURE 4.2-2 |
| CHECK | EAM | 19/07/13 | |
| REVIEW | MT | 19/07/13 | |

**Table 4.2-1: Summary of Geology Observed during 2002, 2012 and 2013 Field Programs (Acres 2002, Hatch 2012, Golder 2013)**

| Project Area | Geological Description | Strength | Rock Quality | Depth of Surficial Soils | Description of Soils | Number of Boreholes Completed |
|---|---|---|---|---|---|---|
| Intake | mylonitic Gneiss, light to dark grey, fine grained, faintly weathered and mylonite, pink, fresh, foliated with healed fault breccia, within the Black Lake Shear Zone | medium strong to very strong UCS = 25 to 170 MPa | fair | 0 to 19.7 m | sand, gravel, cobbles and boulders | 7 |
| Tunnel | granitic, felsic Gneiss, grey to dark grey, folidated, intruded by dark grey to green fine grained diabase dykes | very strong UCS = 100 to 250 MPa | good to excellent RQD average = 83% to 94% $RMR_{89}$ average = 73 to 80 | 0 to 5.3 m | organics, sand, gravel, cobbles and boulders | 6 |
| Powerhouse | granitic, felsic Gneiss and chloritic schist with possible diabase dykes, grey to dark grey, faintly weathered joint surfaces, foliated | very strong UCS = 100 to 250 MPa | good RQD average = 83% $RMR_{89}$ average = 74 | 0 to 0.5 m | organics, cobbles | 3 |
| Tailrace | granitic, felsic Gneiss and chloritic schist, hemitite altered and stained, fresh to slightly weathered, foliated | strong | good RQD average = 76% $RMR_{89}$ average = 67 | 8.7 to 19.7 m | sand, gravel, cobbles and boulders<br><br>the upper 4 m of the 2012 borehole had silt and clay | 2 |

MPa = megapascals, m = metres, UCS = unconfined compressive strength, RQD = rock quality designation, $RMR_{89}$ = rock mass rating 1989
RQD, $RMR_{89}$ and UCS test results from Hatch 2012
Rock quality descriptions based off of Deere et al. 1967 and Bieniawski 1989

Structural features within the RSA and LSA include foliation (most prominent), shear zones (Black Lake Shear Zone), faulting and jointing. The Black Lake Shear Zone marks the contact between the Rae Province and Hearne Province, and delineates the eastern extent of the Tantato Domain. It was formed during the Hudsonian Orogeny (Gilboy and Raemakers 1981). The LSA includes the southern portion of the Black Lake Shear Zone that strikes parallel to the northeastern shore of Black Lake. It is approximately 100 to 500 m wide, and in the LSA represents a high angle reverse fault, that down-threw Athabasca Group sediments to the southeast. Rocks in the Black Lake Shear Zone within the LSA are primarily mylonite (Gilboy and Raemakers 1981). In addition to the Black Lake Shear Zone, there are distinct areas of faulting, jointing and topographic lineaments the may represent brittle fracturing within the RSA (Gilboy 1978).

The Project area is located within the Interior Platform Seismic Zone (Earthquakes Canada 2013). This zone is a relatively stable zone seismically. Seismic activities are predominantly limited to southern Saskatchewan, and are generally related to potash mining activities. Based on a search of the Earthquakes Canada database, no seismic events have been recorded within a 100 km radius of the Project area since 1985. Based on the Earthquakes Canada "Maps of Earthquakes Canada – 1627 to 2010", which shows greater than 3 magnitude earthquake locations within Canada, no earthquakes of a magnitude greater than 3 have occurred in the RSA or LSA.

## 4.3 Quaternary Geology

The topography surrounding the RSA and LSA is primarily bedrock controlled ridges generally striking north to south with low to moderate relief (Acres 2002). The area forms part of the Lake Athabasca drainage area. Prominent landforms in the RSA and LSA are a result of past glaciations. Within the LSA, glaciation produced well rounded erosion-resistant exposed bedrock with thin and patchy overlying soil materials. To the west of the LSA, within the Athabasca Basin, glacial plain areas with gentle relief composed of glacial deposits consisting of lacustrine sand, silt, and till were produced. To the west of the LSA, an esker composed primarily of sand and gravel runs east to west for approximately 13 km, as shown on Figure 4.2-2 (Hatch 2012). This esker is a source of aggregate and construction material in the area. On the east side of the LSA, along the west side of Black Lake, terraces up to 100 m in width have been cut into the surrounding topography by glaciation. These terraces contain deposits of glacial sands that have been reworked by wave action, as well as talus (Hatch 2012).

Descriptions of the soil material encountered during the subsurface investigations were provided during the site investigations undertaken in 2002 (Acres 2002), 2012 (Hatch 2012) and 2013 (Golder 2013). In general, soil materials encountered included sand, gravel, cobbles, and boulders with occasional organic material. At one location investigated in 2012 near the tailrace channel, silt and clay were encountered in the upper 4 m of strata. Gradational analysis was completed for six samples during the 2012 program, and results indicated that soil materials consisted of 0% to 36% gravel, 27% to 90% sand, and 1% to 44% fines (with the exception of the silt and clay material encountered near the tailrace channel, where fines were 73%; Hatch 2012). Based on observations made during the investigations in 2002, 2012 and 2013, the areas with the most extensive soil cover exist near the proposed water intake area and along the tailrace channel.

## 4.4 Mineralization

Metallic mineral resources occur in the Canadian Shield area of Saskatchewan. Uranium, gold, copper, zinc, silver and cadmium are currently mined in Saskatchewan. Within the RSA, the only known deposits consist of uranium and are discussed in more detail below. There are no known deposits occurring within the LSA.

There are several known uranium deposits within vicinity of the LSA. Based on the information obtained from the Saskatchewan Mineral Deposit Index (SMDI) (2012), the Nisto Mine, located approximately 5 km north 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 Shear Zone. In the immediate showing area, there are three sets of fractures that occur on the hanging wall side of the fault located along the Black Lake shear zone. The set with the strongest mineralization is steeply dipping and strikes 040°, while weaker mineralization is associated with the two other sets, which include a vertical and northwest-striking set and a steeply dipping east-striking set. Most of the fractures are 0.15 m wide, with a few shear zones up to 0.8 m wide. The length of the fractures varies from a few metres to over 150 m. 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.

It should be noted that a geological mapping program found no evidence of uranium mineralization in the surface outcrops between Black Lake and the Fond du Lac River (Acres 2005 and Golder 2013). In addition, there was no evidence of uranium mineralization noted in the drill core obtained in 2002 (Acres 2002) and 2013 (Golder 2013).

The bedrock cores from the boreholes drilled during the 2012 and 2013 geotechnical investigation program were drilled in close proximity to the Black Lake Shear Zone. The core was scanned using a scintillometer to determine if any potential radiation occurred near the LSA. The radiation levels obtained were typically less than 150 counts per second (cps), typical of ordinary background levels and 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 in 2012 or 2013.

# 5.0 HYDROGEOLOGY

## 5.1 Introduction

The information provided in this section is based on a review of the RSA and LSA hydrogeology, previous studies across the Canadian Precambrian Shield, hydrogeological modelling undertaken to support design activities and previous site investigations, including the most recent in October 2013.

## 5.2 Bedrock Hydrogeology

### 5.2.1 Groundwater Flow

Precambrian Canadian Shield bedrock formations in Saskatchewan do not readily permit groundwater flow, except as fracture flow. There is little known about their hydraulic properties as very few boreholes have been completed in the Precambrian basement in this part of Saskatchewan. Experience from other areas in the Canadian Shield, however, has shown that active groundwater flow is generally confined to localized shallow fracture systems. In Ontario, Singer and Cheng (2002) studied the groundwater movement in shallow bedrock of the Canadian Shield and reported that it is controlled by the secondary permeability created by fractures. Everitt et al. (1996) reported that in Manitoba's Lac du Bonnet Batholith, groundwater movement is largely controlled by a fractured zone down to about 200 m depth. It is expected that groundwater flow within Canadian Shield rocks in Saskatchewan will be similar to those found in other locations within the Canadian Shield.

During the field investigations undertaken at the Project location in 2002, 2012 and 2013, some hydrogeological observations and downhole testing were completed. Hydrogeological testing (Lugeon, falling head and constant rate injection tests) was conducted at 10 boreholes between 2012 and 2013 to determine hydraulic conductivity in the bedrock. Monitoring wells were installed in the vicinity of the Project to measure groundwater levels and quality in both the overburden and bedrock during the 2013 investigation. Observations from the hydrogeologic testing at site can be summarized as follows:

- no differences in hydraulic conductivity were noted between different rock units tested;
- the upper 45 m of bedrock appears to be more permeable than the lower 45 m of bedrock;
- the geometric mean hydraulic conductivity measured in the upper 45 m of bedrock was $1.3 \times 10^{-7}$ m/s;
- the geometric mean hydraulic conductivity measured in the bedrock below 45 m was $5.5 \times 10^{-8}$ m/s; and
- the geometric mean hydraulic conductivity based on all tests completed within bedrock was $9.6 \times 10^{-8}$ m/s.

Within the bedrock, modeling efforts have shown that groundwater mounds near the surface of the bedrock, and that groundwater will flow in a radial pattern from local topographic highs to Black Lake, the Fond du Lac River and Middle Lake. Groundwater elevations in the bedrock and overburden measured in the monitoring wells installed during the 2013 investigation support the modelling results with the highest groundwater levels in areas of highest topographic relief and lower groundwater levels in the low-lying topographic areas (e.g., near Black Lake and Fond du Lac River).

### 5.2.2 Groundwater Chemistry – Desktop Study

A desktop study on groundwater quality within crystalline rocks typical of the Canadian Shield was completed. Data sources researched were readily available within the public domain, and included Environmental Impact Statement (EIS) reports for existing projects located within the Athabasca Region of Northern Saskatchewan, online publications from the Saskatchewan and Manitoba governments, journal entries, and online resources from Atomic Energy Canada Limited.

The Athabasca Basin area of northern Saskatchewan has been extensively developed and mined for uranium deposits. While these developments mainly focus on the Athabasca Group formations, the entire area is underlain by crystalline Canadian Shield rocks (typically referred to as basement), similar to those encountered in the Project area. Some baseline water chemistry data for the crystalline rocks were obtained during exploration and mine development activities within the Athabasca Basin. Since these crystalline ‘basement’ rocks are from similar geological domains, were placed in the same formational events, and are of similar age and composition, it is reasonable to estimate that the groundwater quality within the crystalline rock in the Project area will be similar to the groundwater quality of the crystalline ‘basement’ of the Athabasca Basin. Published studies of groundwater quality at various sites located within the Canadian Shield have reported similarities within the groundwater chemistry at similar depths. In addition to the information obtained from studies completed within the Athabasca Basin, groundwater chemistry data from sites in Yellowknife, Northwest Territories, Thompson, Manitoba, and Sudbury, Ontario were also evaluated. It is also reasonable to conclude that basic groundwater chemistry in these areas of the Canadian Shield will be similar to basic groundwater chemistry in the crystalline rocks in the Project location.

Groundwater chemistry data obtained for the above noted reference sites within the Canadian Shield have been summarized in Table 5.2-1. Sites referenced include the McClean Lake Operation (MCL), Midwest Project (MCL – MW), McArthur River Operation (MCA), and Cigar Lake Operation (CLO) in northern Saskatchewan, as well as two sites from Yellowknife, Northwest Territories, one site in Thompson, Manitoba, and one site in Sudbury, Ontario. It should be noted that the data sets referenced were from depths within the upper portion of the crystalline formations sampled, and were not within any mineralization or ore bodies. These data were selected in an effort to consider similar settings to that of the proposed Project.

Although there is some natural scatter in the groundwater chemistry data due to interaction with the local geology of the areas sampled, there are some general similarities that may be applied to the Project location. In general, groundwater samples had total dissolved solids (TDS) concentrations of less than 1,000 mg/L. With the exception of the water sample from CLO, which was collected in a weathered zone of crystalline rock below the ore body, groundwater samples collected from the crystalline Canadian Shield rock within sites located in northern Saskatchewan had TDS of less than 100 mg/L. Most of the groundwater samples are calcium/sodium and bicarbonate rich, and all groundwater samples collected in northern Saskatchewan had major cation and anion concentrations of less than 100 mg/L. In general, reported dissolved metal concentrations within the groundwater samples referenced were low.

A piper diagram plotting the major cation and anion chemistry of the groundwater samples referenced (with the exception of the sample from Midwest Lake due to lack of data) is included below in Figure 5.2-1. While this diagram shows the natural scatter of the groundwater chemistry data, some general observations can be made. Most of the groundwater samples are grouped in the bottom left side of the diamond plot. This indicates that the dominant anion within these waters is bicarbonate, while the major cation within these waters is either calcium or sodium/potassium. Based on this grouping, groundwater chemistry reported from MCL, MCA, Yellowknife (both sites), and Thompson appear to have similar composition and was used to estimate some ‘typical’ groundwater chemistry values that may be applied at the Project.

Table 5.2-2 presents the average, maximum and minimum values estimated for each analyte presented in Table 5.2-1. These were calculated from the available data from the reference sites that were grouped on the piper plot. These ‘typical’ values were used to estimate the groundwater quality prior to acquiring site-specific groundwater data. Site-specific groundwater information collected from the Project site in 2013 are compared to this surrogate data for the Project in Section 5.2.2.

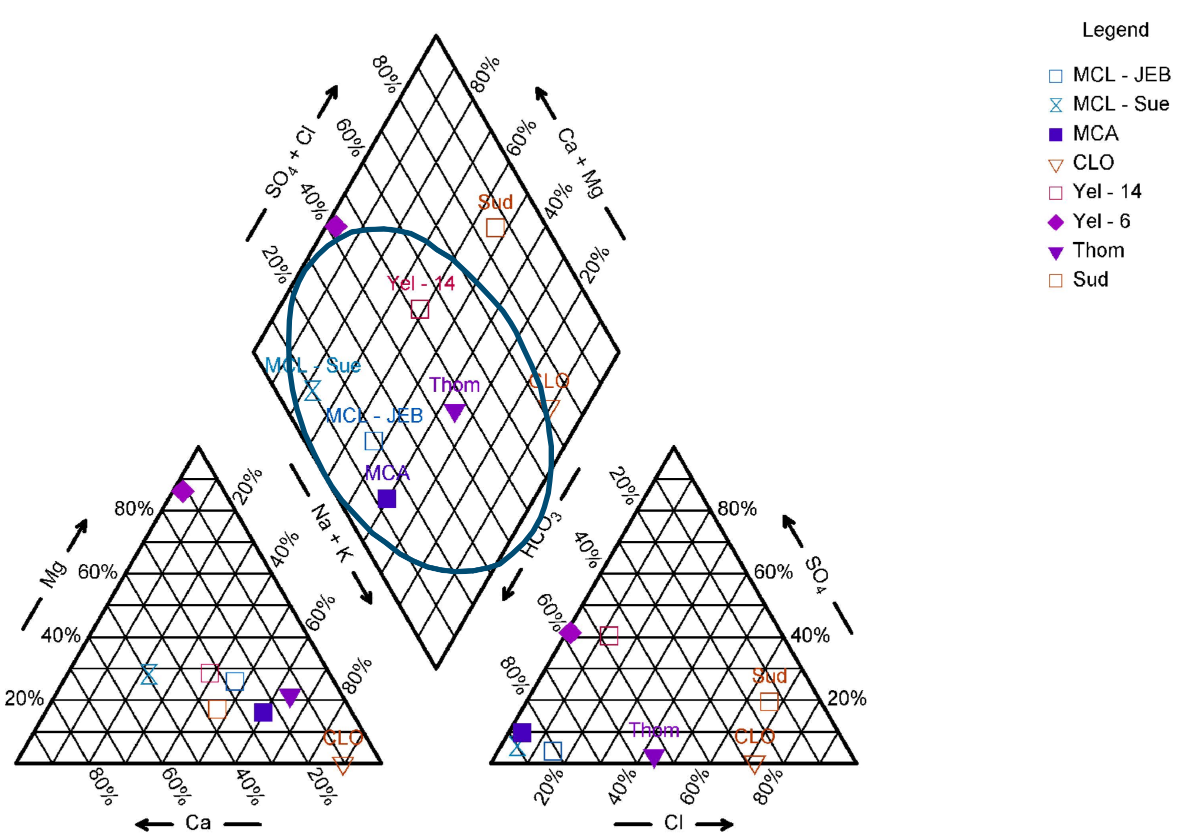
**Table 5.2-1: Groundwater Chemistry Data from Crystalline Canadian Shield Rock**

| Parameter | Units | Site Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | McClean Lake Operation | | | McArthur River Operation[c, d] | Cigar Lake Operation[e] | Yellowknife[f] | Yellowknife[f] | Thompson[f] | Sudbury[f] |
| | Sub-area | JEB Area[a] | Sue/McClean Lake Areas[a] | Midwest Area[a, b] | | | | | | |
| | Sampling Location | 95-02A | 97-03A | GW94-1 | BH254-1 Sa32 | BH 199 | 14 | 6 | 400-1 | DOW0002 |
| Alkalinity | mg/L as $CaCO_3$ | 39 | 43 | - | 7 | 0.94 | - | - | - | - |
| Calcium | mg/L | 5 | 8.7 | - | 0.5 | 6.08 | 80 | 103 | 23.6 | 21 |
| Chloride | mg/L | 5.1 | 1.4 | - | 0.2 | 86.3 | 51 | 4 | 123 | 63 |
| Bicarbonate | mg/L | 47 | 48 | - | 8 | 57.1 | 341 | 350 | 264 | 23 |
| Potassium | mg/L | 2.9 | 2.4 | 1.9 | <0.2 | 5.55 | 4.3 | 5.7 | 6.2 | 1.8 |
| Magnesium | mg/L | 2.9 | 3 | - | 0.2 | - | 42.3 | 475.9 | 21.6 | 6 |
| Sodium | mg/L | 8.3 | 3.1 | - | 1.3 | 57 | 107 | 26 | 119 | 30 |
| Sulphate | mg/L | 1.7 | 2.3 | - | 0.7 | 0.53 | 227 | 197 | 9 | 25 |
| Specific Conductivity | µS/cm | 98.4 | 97.1 | - | 15 | 422 | - | - | - | - |
| pH | - | 7.16 | 6.65 | 7.28 | 7.02 | 7.71 | 7.4 | 7.25 | 7.5 | - |
| Total Dissolved Solids | mg/L | 61 | 61 | 57 | 20 | 227.3 | 853 | 739 | 579 | 185 |
| Arsenic | µg/L | 0.5 | 0.6 | 23 | <0.5 | 54 | - | - | - | - |
| Aluminum | mg/L | 0.004 | 0.004 | - | 0.012 | - | - | - | 0.07 | 0.05 |
| Cadmium | mg/L | 0.001 | 0.001 | 0.001 | <0.001 | - | - | - | - | - |
| Copper | mg/L | 0.001 | 0.001 | 0.003 | <0.001 | 0.0072 | - | - | <0.01 | - |
| Iron | mg/L | 1 | 0.3 | 2.2 | 0.061 | - | - | - | 0.07 | 0.05 |
| Manganese | mg/L | 0.15 | 1.38 | 0.47 | 0.024 | - | - | - | 0.02 | 0.05 |
| Molybdenum | mg/L | 0.001 | 0.001 | 0.007 | <0.005 | 0.0097 | - | - | - | - |
| Nickel | mg/L | 0.001 | 0.003 | 0.013 | <0.001 | 0.0015 | - | - | <0.09 | - |

**Table 5.2-1: Groundwater Chemistry Data from Crystalline Canadian Shield Rock (continued)**

| Parameter | Units | Site Location | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | McClean Lake Operation | | | McArthur River Operation[c, d] | Cigar Lake Operation[e] | Yellowknife[f] | Yellowknife[f] | Thompson[f] | Sudbury[f] |
| | Sub-area | JEB Area[a] | Sue/McClean Lake Areas[a] | Midwest Area[a, b] | | | | | | |
| | Sampling Location | 95-02A | 97-03A | GW94-1 | BH254-1 Sa32 | BH 199 | 14 | 6 | 400-1 | DOW0002 |
| Lead | mg/L | 0.002 | 0.002 | 0.016 | <0.005 | - | - | - | <0.12 | - |
| Zinc | mg/L | 0.005 | 0.009 | 0.13 | <0.005 | - | - | - | - | - |
| Uranium | µg/L | 0.2 | 0.2 | 384 | 2.2 | 8.92 | - | - | - | - |

(a) AREVA 2011a
(b) AREVA 2011b
(c) Wittrup1995
(d) Wittrup1992
(e) Cigar Lake Mining Corporation 1995
(f) Frape and Fritz 1987
'-' = no data available; mg/L = milligrams per litre, mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; µg/L = micrograms per litre; µS/cm = microSiemens per centimetre; < = less than




PROJECT

TAZI TWÉ HYDROELECTRIC PROJECT

TITLE

**PIPER DIAGRAM OF CANADIAN SHIELD GROUNDWATER**

Golder Associates
Saskatoon, Saskatchewan

| | | | | |
|---|---|---|---|---|
| PROJECT | | 10-1365-0004 | FILE No. | |
| DESIGN | | | SCALE AS SHOWN | REV. 0 |
| GIS | SM/LR | 19/07/13 | **FIGURE: 5.2-1** | |
| CHECK | EAM | 19/07/13 | | |
| REVIEW | MT | 19/07/13 | | |

**Table 5.2-2: Estimated Groundwater Chemistry Values for the Project**

| Parameter | Units | Average | Maximum | Minimum | Count |
|---|---|---|---|---|---|
| Alkalinity | mg/L as $CaCO_3$ | 30 | 43 | 7 | 3 |
| Calcium | mg/L | 36.8 | 103 | 0.5 | 6 |
| Chloride | mg/L | 30.8 | 123 | 0.2 | 6 |
| Bicarbonate | mg/L | 176 | 350 | 8 | 6 |
| Potassium | mg/L | 3.6 | 6.2 | 0.2 | 6 |
| Magnesium | mg/L | 91.0 | 475.9 | 0.2 | 6 |
| Sodium | mg/L | 44.1 | 119 | 1.3 | 6 |
| Sulphate | mg/L | 73.0 | 227 | 0.7 | 6 |
| Hardness | mg/L as $CaCO_3$ | 20 | 34 | 2 | 3 |
| Specific Conductivity | µS/cm | 70.2 | 98.4 | 15 | 3 |
| pH | - | 7.16 | 7.5 | 6.65 | 6 |
| Total Dissolved Solids | mg/L | 386 | 853 | 20 | 6 |
| Arsenic | µg/L | 0.5 | 0.6 | 0.5 | 3 |
| Aluminum | mg/L | 0.023 | 0.07 | 0.004 | 4 |
| Cadmium | mg/L | 0.001 | 0.001 | 0.001 | 3 |
| Copper | mg/L | 0.003 | 0.01 | 0.001 | 4 |
| Iron | mg/L | 0.36 | 1 | 0.061 | 4 |
| Manganese | mg/L | 0.39 | 1.38 | 0.02 | 4 |
| Molybdenum | mg/L | 0.002 | 0.005 | 0.001 | 3 |
| Nickel | mg/L | 0.024 | 0.09 | 0.001 | 4 |
| Lead | mg/L | 0.032 | 0.12 | 0.002 | 4 |
| Selenium | mg/L | 0.0001 | 0.0001 | 0.0001 | 2 |
| Zinc | mg/L | 0.006 | 0.009 | 0.005 | 3 |
| Uranium | µg/L | 0.87 | 2.2 | 0.2 | 3 |

mg/L = milligrams per litre, mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; µg/L = micrograms per litre; µS/cm = microSiemens per centimetre; Count = the number of samples with data considered in the calculation of the statistics presented

### 5.2.3 Groundwater Chemistry – Site-specific

#### *5.2.3.1 Drilling Program Results*

As outlined in Section 3.2, a drilling program was completed at the Project site for the purpose of acquiring baseline groundwater chemistry data (Figure 3.2-1). The groundwater chemistry results for the monitoring wells and drive points are provided in Table 5.2-3.

Aluminum and iron concentrations are elevated in the drive point piezometer WP13-01 compared to the monitoring wells. This is likely due to the oxidizing conditions in the shallow groundwater compared to the deeper bedrock groundwater resulting in the dissolution of aluminum and iron oxides in the strata.

Uranium concentrations range between 1 and 7.8 µg/L at all the monitoring wells installed except BH13-01 (302 µg/L). BH13-01 was installed within the Black Lake Shear Zone (mylonitic gneiss) and intersected two major faults (approximately 0.5 m). The fact that known uranium deposits have been identified in the shear zone and that uranium readily dissolves when exposed to water, the elevated uranium concentrations at this location are likely not indicative of uranium concentrations in groundwater across the site and localized in nature. This is further supported by the low uranium concentrations at BH13-02 and BH13-03, installed along the tunnel alignment to the northwest.

It should be noted that the groundwater water quality results for BH13-05 may not be representative of actual site conditions at this location. The water quality results show a pH of 10.7 at this monitoring well, which is typically the result of grout impacts in the monitoring well. The elevated pH in the monitoring well will result in dissolution/precipitation reactions that would not typically occur under more neutral pH values (e.g. 6.5 to 9). Based on the pH values from the other monitoring wells and drive points, a neutral pH would be expected in the groundwater at this location.

**Table 5.2-3: Site-specific Groundwater Chemistry Values for the Project (October 2013)**

| Parameter | Units | BH13-01 | BH13-02 | BH13-03 | BH13-05 | WP13-01 | WP13-04 |
|---|---|---|---|---|---|---|---|
| **Conventional** | | | | | | | |
| pH | pH units | 8.93 | 8.95 | 8.30 | 10.71 | 6.43 | 6.95 |
| Specific Conductivity | µS/cm | 212 | 320 | 153 | 393 | 80 | 119 |
| Total Alkalinity | mg/L as $CaCO_3$ | 102 | 140 | 69 | 114 | 40 | 59 |
| Total Hardness | mg/L | 75 | 41 | 50 | 28 | 41 | 79 |
| Total Dissolved Solids | mg/L | 134 | 207 | 130 | 219 | 171 | 229 |
| **Nutrients** | | | | | | | |
| Ammonia as N | mg/L as N | 0.08 | -- | -- | 0.31 | -- | -- |
| Nitrate (calculated) | mg/L as N | <0.09 | <0.04 | <0.04 | <0.04 | <0.04 | <0.04 |
| Phosphorus | mg/L | 0.01 | -- | -- | | -- | -- |
| **Major Ions** | | | | | | | |
| Bicarbonate | mg/L | 105 | 146 | 84 | <1 | 49 | 72 |
| Calcium | mg/L | 16 | 8.4 | 10 | 11 | 8.6 | 12 |
| Chloride | mg/L | 1.5 | 24 | 2.4 | 6 | 0.2 | 1.4 |
| Fluoride | mg/L | 0.40 | 0.34 | 0.17 | 0.46 | 0.06 | 0.14 |
| Magnesium | mg/L | 7.2 | 3.2 | 3.8 | 2 | 4.6 | 12 |
| Potassium | mg/L | 3.3 | 2.0 | 1.5 | 31 | 3.0 | 12 |
| Sodium | mg/L | 16 | 57 | 16 | 37 | 1.3 | 6.1 |
| Sulphate | mg/L | 10 | 2.4 | 12 | 23 | 1.3 | 5.4 |
| **Dissolved Metals** | | | | | | | |
| Aluminum | mg/L | 0.016 | 0.025 | 0.023 | <0.005 | 0.95 | -- |
| Antimony | mg/L | 0.0055 | 0.0076 | 0.0086 | <0.002 | <0.002 | -- |
| Arsenic | mg/L | 0.020 | 0.022 | 0.092 | 0.001 | 0.001 | -- |
| Barium | mg/L | 0.0077 | 0.0031 | 0.0011 | 0.096 | 0.033 | -- |
| Beryllium | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.001 | <0.001 | -- |
| Bismuth | mg/L | <0.0002 | <0.0002 | <0.0002 | <0.002 | <0.002 | -- |
| Boron | mg/L | 0.12 | 0.48 | 0.10 | 0.1 | 0.1 | -- |

**Table 5.2-3: Site-specific Groundwater Chemistry Values for the Project (October 2013) (continued)**

| Parameter | Units | BH13-01 | BH13-02 | BH13-03 | BH13-05 | WP13-01 | WP13-04 |
|---|---|---|---|---|---|---|---|
| **Dissolved Metals** | | | | | | | |
| Cadmium | mg/L | 0.00001 | <0.00001 | <0.00001 | <0.0001 | 0.0001 | -- |
| Chromium | mg/L | 0.0006 | <0.0005 | <0.0005 | <0.005 | 0.010 | -- |
| Cobalt | mg/L | 0.0015 | 0.0001 | <0.0001 | <0.001 | <0.001 | -- |
| Copper | mg/L | 0.0008 | <0.0002 | 0.0002 | 0.002 | 0.004 | -- |
| Iron | mg/L | 0.29 | 0.021 | 0.010 | <0.005 | 5.8 | -- |
| Lead | mg/L | 0.0005 | 0.0001 | <0.0001 | <0.001 | 0.001 | -- |
| Lithium | mg/L | 0.023 | 0.012 | 0.0085 | 0.0034 | 0.002 | -- |
| Manganese | mg/L | 0.0033 | 0.0049 | 0.0052 | <0.005 | 0.12 | -- |
| Mercury | mg/L | 0.00007 | <0.00002 | <0.00002 | <0.00002 | <0.00002 | -- |
| Molybdenum | mg/L | 0.0051 | 0.0053 | 0.013 | 0.018 | 0.002 | -- |
| Nickel | mg/L | 0.0009 | 0.0038 | 0.0013 | <0.001 | 0.016 | -- |
| Selenium | mg/L | 0.0060 | 0.0001 | 0.0024 | <0.001 | <0.001 | -- |
| Silicon, soluble | mg/L | 3.3 | 3.3 | 3.2 | 4.6 | 9.5 | -- |
| Silver | mg/L | <0.00005 | <0.00005 | 0.00005 | <0.0005 | <0.0005 | -- |
| Strontium | mg/L | 0.27 | 0.10 | 0.11 | 0.69 | 0.56 | -- |
| Thallium | mg/L | <0.0002 | <0.0002 | <0.0002 | <0.0002 | <0.002 | -- |
| Tin | mg/L | <0.0001 | <0.0001 | <0.0001 | <0.001 | <0.001 | -- |
| Titanium | mg/L | <0.0002 | 0.0004 | 0.0003 | <0.002 | 0.046 | -- |
| Uranium | mg/L | 0.302 | 0.0054 | 0.0078 | 0.002 | <0.001 | -- |
| Vanadium | mg/L | 0.015 | 0.0020 | 0.0017 | 0.001 | 0.012 | -- |
| Zinc | mg/L | 0.0046 | 0.0025 | 0.0022 | <0.005 | 0.051 | -- |
| **Radiunuclides** | | | | | | | |
| Lead-210 | Bq/L | 0.18 | 0.05 | <0.02 | <0.02 | <0.02 | -- |
| Polonium-210 | Bq/L | 0.02 | 0.01 | 0.005 | <0.005 | 0.006 | -- |
| Radium-226 | Bq/L | 0.02 | <0.005 | <0.005 | 0.03 | 0.02 | -- |
| Thorium-230 | Bq/L | <0.01 | <0.01 | <0.01 | <0.01 | 0.02 | -- |

mg/L = milligrams per litre, mg/L as $CaCO_3$ = milligrams per litre as calcium carbonate; µg/L = micrograms per litre; µS/cm = microSiemens per centimetre; N = nitrogen; Bq/L = Becquerels per litre; -- = no data available

### 5.2.3.2 Comparison to Surrogate

A comparison of the average, minimum and maximum surrogate and site groundwater water quality is presented in Table 5.2-4. The percent variance is also shown with a positive variance indicating the surrogate data was more conservative while a negative variance indicates the site groundwater water quality is more conservative. Five trace metals including; arsenic, aluminum, selenium and uranium show a negative variance of greater than 0.5. This suggests the surrogate data for these parameters may not accurately reflect the concentrations of these trace metals in the groundwater at the site.

With the exception of aluminum, iron and uranium, concentrations of the chemical parameters in the groundwater are relatively consistent across the site. Aluminum and iron concentrations are elevated in the drive point piezometer WP13-01 compared to the monitoring wells. This is likely due to the oxidizing conditions in the shallow groundwater compared to the deeper bedrock groundwater resulting in the dissolution of aluminum and iron oxides in the strata. When the concentrations from WP13-01 are not included in the calculated averages, the percent variance is less than 0.5.

Uranium concentrations range between 1 to 7.8 µg/L at all the monitoring wells installed except BH13-01 (302 µg/L). BH13-01 was installed within the Black Lake Shear Zone (mylonitic gneiss) and intersected two major faults (approximately 0.5 m). The fact that known uranium deposits have been identified in the shear zone, the elevated uranium concentrations at this location are likely not indicative of uranium concentrations in groundwater across the site and localized in nature. This is further supported by the low uranium concentrations at BH13-02 and BH13-03, installed along the tunnel alignment to the northwest.

It should be noted that the groundwater water quality results for BH13-05 may not be representative of actually site conditions at this location. The water quality results show a pH of 10.7 at this monitoring well which is typically the result of grout impacts in the monitoring well. The Elevated pH in the monitoring well will result in dissolution/precipitation reactions that would not typically occur under more neutral pH values (e.g., 6.5 – 9). Based on the pH values from the other monitoring wells and drive points, a neutral pH would be expected in the groundwater at this location. Therefore, the water quality from BH13-05 was not considered in any of the statistics presented.

**Table 5.2-4: Percent Variance Between Surrogate and Site Groundwater**

| Parameter | Units | Surrogate Data | | | Site Groundwater Sampling | | | Variance in Average Values |
|---|---|---|---|---|---|---|---|---|
| | | Average | Maximum | Minimum | Average | Maximum | Minimum | |
| Alkalinity | mg/L as $CaCO_3$ | 29.7 | 43 | 7 | 82.0 | 140 | 7.7 | -0.47 |
| Calcium | mg/L | 36.8 | 103 | 0.5 | 11.0 | 16 | 3.9 | 0.54 |
| Chloride | mg/L | 30.8 | 123 | 0.2 | 5.90 | 24 | 0.2 | 0.68 |
| Bicarbonate | mg/L | 176 | 350 | 8 | 91.2 | 146 | 49 | 0.32 |
| Potassium | mg/L | 3.62 | 6.2 | 0.2 | 4.36 | 13.6 | 1.5 | -0.09 |
| Magnesium | mg/L | 91.0 | 476 | 0.2 | 6.16 | 12 | 0.63 | 0.87 |
| Sodium | mg/L | 44.1 | 119 | 1.3 | 19.3 | 57 | 0.41 | 0.39 |
| Sulphate | mg/L | 73.0 | 227 | 0.7 | 6.22 | 12 | 1.3 | 0.84 |
| Hardness | mg/L as $CaCO_3$ | 20.3 | 34 | 2 | 57.2 | 79 | 41 | -0.48 |
| Specific Conductivity | µS/cm | 70.2 | 98.4 | 15 | 177 | 320 | 34 | -0.43 |
| pH | - | 7.1 | 7.5 | 6.65 | 7.14 | 8.95 | 6.43 | -0.05 |
| Total Dissolved Solids | mg/L | 386 | 853 | 20 | 174 | 229 | 130 | 0.38 |
| Ammonium | mg/L | 0.12 | 0.13 | 0.11 | 0.08 | 0.2 | 0.08 | 0.20 |
| Arsenic | µg/L | 0.533 | 0.6 | 0.5 | 33.75 | 92 | 1 | ***-0.97*** |
| Aluminum | mg/L | 0.0225 | 0.07 | 0.004 | 0.2535 | 0.95 | 0.016 | ***-0.84*** |
| Cadmium | mg/L | 0.001 | 0.001 | 0.001 | 0.000 | 0.00001 | 0.00001 | 0.98 |
| Copper | mg/L | 0.00325 | 0.01 | 0.001 | 0.0013 | 0.004 | 0.0002 | 0.43 |
| Iron | mg/L | 0.36 | 1.0 | 0.061 | 1.53 | 5.80 | 0.01 | ***-0.62*** |
| Manganese | mg/L | 0.3935 | 1.38 | 0.02 | 0.033350 | 0.12 | 0.0033 | 0.84 |
| Molybdenum | mg/L | 0.0023 | 0.005 | 0.001 | 0.00635 | 0.013 | 0.002 | -0.46 |
| Nickel | mg/L | 0.02375 | 0.09 | 0.001 | 0.0055 | 0.016 | 0.0009 | 0.62 |
| Lead | mg/L | 0.03225 | 0.12 | 0.002 | 0.00043 | 0.001 | 0.0001 | 0.97 |
| Selenium | mg/L | 0.0001 | 0.0001 | 0.0001 | 0.00238 | 0.006 | 0.0001 | ***-0.92*** |
| Zinc | mg/L | 0.00633 | 0.009 | 0.005 | 0.01508 | 0.051 | 0.0022 | -0.41 |
| Uranium | µg/L | 0.867 | 2.2 | 0.2 | 79.05 | 302 | 1 | ***-0.98*** |

mg/L = milligrams per litre; µS/cm = microSiemens per centimetre; µg/L = micrograms per litre

## 5.3 Quaternary Hydrogeology

In Saskatchewan, Quaternary aquifers are typically composed of well sorted glaciofluvial sand and gravel sediments, whereas the extensive till deposits typically comprise aquitards. The main Quaternary deposits within the RSA and LSA include glaciolacustrine plain, eskers, and glaciolacustrine terraces with estimated thicknesses likely to range from 0 to approximately 20 m. Soils encountered were primarily sand, gravel, cobbles and boulders. The groundwater table within the soil materials is expected to be shallow, and that shallow unconfined groundwater flow will generally parallel surface water drainage patterns reporting to the Fond du Lac River, Black Lake and Middle Lake. During the 2013 field investigation, drive point piezometers were installed at two locations within the soil materials in the Project area to measure hydraulic conductivity and groundwater chemistry parameters (discussed in Section 5.2.3.1) within the Quaternary deposits. Falling head tests were conducted on the drive point piezometers to determine the hydraulic conductivity of the overburden. The results ranged from $5x10^{-4}$ to $4x10^{-3}$ m/s, with a geometric mean of $4x10^{-4}$ m/s. In 2002, one falling head test was completed in an open borehole in the intake area, where a hydraulic conductivity of $2x10^{-5}$ m/s was measured in the soil material (Acres 2002) which is slightly lower than the results of the 2013 investigation however, the results of both investigations are consistent with published values of similar lithologies.

# 6.0 CONCLUSION AND SUMMARY

A baseline study was undertaken to outline the existing geological and hydrogeological conditions of the area encompassing the RSA and LSA. The compilation of historical data across the RSA and LSA comprised the overall study. The geological and hydrogeological conditions are summarized as follows:

- Quartzo-feldspathic gneiss and diabase dykes make up the majority of the bedrock geology. A major structural feature (Black Lake Shear Zone) trends northeast – southwest across the LSA resulting in mylonitic and cataclastic amphibole gneiss and felsic gneiss.
- Quarternary geology in the RSA and LSA consists of glacial landforms such as eskers and terrace deposits consisting of sand, gravel, cobbles and boulders.
- Uranium mineralization is known to occur in the RSA, especially along the Black Lake Shear Zone to the northeast of the Project area in a sequence of paragneisses, meta-gabbro and amphibolite sills.
- Based on information obtained from site investigations, hydraulic conductivities within the crystalline bedrock in the LSA are estimated to range between $6.7x10^{-7}$ to $1.5x10^{-8}$ m/s, while hydraulic conductivity within the Quaternary deposits are predicted to range between $4x10^{-3}$ to $2x10^{-5}$ m/s.
- Groundwater chemistry data collected during the 2013 investigation indicate that with the exception of aluminum, iron and uranium, concentrations of the chemical parameters in the groundwater are relatively consistent across the site. Aluminum and iron concentrations were only elevated in the overburden groundwater, likely as a result of the oxidizing conditions in the shallow groundwater. Uranium concentrations were elevated (302 µg/L) in one monitoring wells which was installed within the Black Lake Shear Zone. The elevated uranium concentrations at this location are likely not indicative of uranium concentrations in groundwater across the site and are considered localized in nature.

## 7.0 LIMITATION

This report has been prepared for the exclusive use of SaskPower. The factual information, descriptions, interpretations, comments, recommendations, and electronic files contained herein are specific to the project described in this report and do not apply to any other project or site. Under no circumstances may this information be used for any other purposes than those specified in the scope of work unless explicitly stipulated in the text of this report or formally authorized by Golder. This report must be read in its entirety as some sections could be falsely interpreted when taken individually or out-of-context. As well, the final version of this report and its content supersedes any other text, opinion or preliminary version produced by Golder.

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References to acts and regulations that may be contained in this report are informally provided on a technical basis. Since acts and regulations are subject to interpretation, Golder recommends SaskPower to consult with legal counsel to obtain suitable advice.

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